Sea-level Rise and Flood Risk Perceptions

of Residents and Businesses

in Port Adelaide, South Australia

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DEDICATION

I dedicate this work to

Professor Graeme John Hugo AO

(5 December 1946 – 20 January 2015),

who had offered extraordinary supervision

with immense knowledge, enthusiasm and vision

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ABSTRACT

The human-environment nexus has yet to be fully understood in the context of natural hazards and climate change. This thesis provides a case study of the issues relating to flood risk perception and response to present and future sea level rise scenarios in Port Adelaide. The study employed a mixed-method approach, using quantitative and qualitative analyses, to include a survey of households in the area to gauge their perceptions of risk and the ways they have experienced, and adapted to, floods that occur frequently. In-depth interviews were also undertaken with local businesses to establish the context for understanding the problems and the ways in which they have adapted to flood situations and the likelihood of future changes.

The resident survey indicated that the risk from storm tides was largely overlooked and the main concern related to local flooding. The property owners mainly wanted to improve drainage capacity to cope with storm water, rather than consider the long-term effects of sea-level rise. The majority of residents did not consider sea-level rise seriously. In general, flood impact was not high on their environmental concerns, as most residents tended to perceive the risks (such as those from king tides) as acceptable. Although storm tides had caused some inconvenience and minor flooding, complaints were mainly about inundation induced by extreme rainfall events. To overcome the impact of floods, government planning was seen to be inadequate to protect properties.

The survey of businesses suggested that overall flood risk was not a major concern. The participants tended to describe their on-site water problems as “unusual weather conditions”, including wave damage to port facilities and tidal inundation to the shipyards and workshops. As a consequence, business activities were temporarily disrupted with concerns about the extra costs of cleaning and repair. Raising the ground level of their site was regarded as too costly by small and medium-scale business owners, as was constructing a breakwater extension. To some large businesses, a potential

hazardous inundation of fuel terminals raised concerns about fire, pollution and the likely impacts on the State's public fuel supply.

Insights into business responses and the risk perceptions of residents for the study area indicate that the stakeholders were more likely to respond when they perceived higher risks from floods. Specifically, businesses with larger adaptive capacity demonstrated proactive adaptation to flood impacts. The statistical modelling results also emphasised a number of influences on risk perception and response related to socio-demographic, spatial and psychological factors. The significant impact on business capital value suggests it is a credible indicator for predicting adaptive response under sea-level rise scenarios.

The study recommends that the State government consider optimising the Sea-level Rise Planning Benchmarks in line with up-to-date predictions. The findings from this research can be used to inform decision-making processes (in particular those relating to land-use planning, coastal infrastructure developments and insurance policies), by providing a means to better determine such things as risk assessment, risk perceptions and the causal factors behind consequential risk adaptation.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Dandong Zheng

May 24th 2017

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ABBREVIATIONS AND ACRONYMS

ABS	Australian Bureau of Statistics
AHD	Australian Height Datum
ARI	Average recurrence intervals (in years)
AR4 (IPCC)	IPCC Fourth Assessment Report (2007)
AR5 (IPCC)	IPCC Fifth Assessment Report (2014)
ASGS	Australian Statistical Geography Standard (2011)
BOM	Bureau of Meteorology, Australian Government
DTM	Digital Terrain Model
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LGA	Local Government Areas, a Non – ABS Structure (structure not defined by the ABS in ASGS, but is approximated using region from the ABS Main Structure)
NCCARF	National Climate Change Adaptation Research Facility (Australia)
PAE(C)	City of Port Adelaide Enfield or the Port Adelaide Enfield City Council
SA2	Statistical Area Level 2 (ASGS)
SLR	Sea-level rise
SRES	IPCC Special Report on Emissions Scenarios (2000)
SREX (IPCC)	IPCC Special Report “Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation” (2012)
TAR (IPCC)	IPCC Third Assessment Report (2001)
WGII AR5	IPCC Fifth Assessment Report: “Climate Change 2014: Impacts, Adaptation and Vulnerability, Working Group II

GLOSSARY OF TERMS

Acceptable risk
'A concept describing that level of risk that is sufficiently low that society is comfortable with it. Society does not generally consider expenditure in further reducing such risks justifiable' (Koob 1998, p. 1).

Adaptation
In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

Adaptive capacity
The combination of the strengths, attributes, and resources available to an individual, community, society, or organisation that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.

Climate extremes (extreme weather/climate events)
The term generally refers to the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes' (IPCC 2012, p. 557).

Exposure
'The presence (location) of people, livelihoods, environmental services and resources; infrastructure, or economic, social, or cultural assets in places that could be adversely affected' (IPCC 2012, p. 559).

Mean sea level
Sea level is measured by a tide gauge with respect to the land upon which it is situated. Mean sea level is normally defined as the average relative sea levels over a period, such as a month or a year, long enough to average out transients such as waves and tides (IPCC 2012, p. 561).

Mental model
'Mental models are personal, internal representations of external reality that people use to interact with the world around them' (Jones et al. 2011, p. 2).

Port Adelaide 2005 Flooding Study
"Port Adelaide Seawater Storm water Flooding Study", a flood risk assessment commissioned by Tonkin Consulting and WBM Oceanics Australia in 2005, in conjunction with funding from the Federal and State government agencies.

Storm surge
The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds); defined as being the excess above the level expected from the tidal variation alone at that time and place (IPCC 2012, p. 563).

Subjective norm
In the theory of planned behaviour (TPB), subjective norm means perceived social pressure arising from one's perception to engage or not to engage in a behaviour (Ajzen and Fishbein 1980, p. 6).

CHAPTER 1. INTRODUCTION

This thesis examines the likely risks from extreme flood events, with particular attention focused on seawater flooding. Two major aspects were examined: (1) the perception of risk from multiple dimensions in terms of both physical and social consequences, and (2) adaptation to floods. Its premise is that an evidence-based, systematic and comprehensive risk assessment can provide a scientifically based strategy of risk reduction for residents and businesses in the study area. The study also explores the complex interaction between human populations and natural phenomena using an interdisciplinary approach (Kates 1971, p. 438).

The first chapter provides an account of the risks from sea-level extremes in Port Adelaide, and addresses crucial questions and objectives. Some important fields of research on the topic of Australian coastal systems and climate change are also briefly reviewed with several research gaps being identified.

1.1 Research Background

1.1.1 Challenges of sea-level extremes

Sea-level change can have profound effects and consequences on coastal settlements. In particular, extreme events such as a tsunami or storm surges that often occur quickly and with limited warning are usually very destructive (Pattiaratchi 2016, p. 3; Pugh 2004, p. 5). Over the past two decades or so, there have been several examples of catastrophic seawater overflow worldwide, causing massive capital losses and emergency responses. Five well known cases are shown in Table 1.1.

Table 1.1 Disasters of sea-level extremes since 2000 (selected)

Time	Disaster of Sea-level Extremes	Trigger Event	Highest Sea Level	Casualties	Loss
26/12/2004	Indian Ocean Boxing Day Tsunami	Earthquake 9.1-9.3 Mw	30 m+	230k-280k	US$11.2b
23-30/8/2005	Hurricane Katrina	Hurricane Category 5	10 m+	1833	US$108b
11/03/2011	Tohoku Tsunami	Earthquake 9 Mw	39 m	19295	US$100b+
29/10/2012	Hurricane Sandy	Hurricane Category 2	3 m+/11 feet+	253	US$65.6b+
11/11/2012	Venice's 6th highest in record	Heavy rain, high tides and waves	1.5 m/5 feet	70% of city inundated	

Source: Author, data assembled from: Munich Re reports (Munich Re 2013b, 2013c), Washington Post at 12 Nov. 2012, and The Atlantic at 12 Nov. 2012.

Flooding in low-lying coastal areas is an issue that requires a fundamental approach to determine the multifaceted way a region can be impacted by such events so that strategies and responses can be made to deal with ongoing and future flooding events (McInnes et al. 2002, p. 217). Some 70 years ago, White (1945, p. 3) argued that numerical simulation be used to determine the forms and extent of engineering work required to adjust to, and confine coastal flood damage. In the areas historically affected by sea-level extremes, records of coastal flood severity and the resulting consequences are now commonly the basis for detailed risk assessments (McCarthy et al. 2006, p. 5).

Through the re-construction of the effects of past extreme events, models of flood dynamics and their impact can be tested (Rogers 2009, p. 14). Taking into account the trends and variations from reliable observations, future risk can be assessed (Hunter 2008, p. 3). For example, sea-level rise projections proposed by Rahmstorf (2007) discovered potential underestimates made by existing flood risk models, resulting in more rigorous methodologies to measure correlations between global temperatures and sea-level fluctuations (Grinsted et al. 2010). These in turn enable better decision making about protection measures.

Although protection measures have paid off to some extent in the majority of cases, the recorded losses from coastal floods are increasing around the world (Haynes et al. 2016, p. 39; Munich Re 2013a). Recent coastal impacts of sea-level extremes (such as those following Hurricane Katrina) have resulted from a combination of individual sea-level extremes, localised land subsidence and long-term fluctuations in mean sea levels (Irish et al. 2014, p. 635; Seed et al. 2006, pp. F-75). However, Birkmann (2006) points out that accumulated small and medium scale threats at the local level can also adversely affect the capacity of communities, societies, or social-ecological systems, to cope with future disasters across a broader regional level. These regional and long-term factors must be modelled alongside the emerging global sea-level trends, so that more comprehensive approaches to future coastal flooding events can be adopted (Church et al. 2010, p. 326).

In addition, social responses have been increasingly viewed as critical to confining flood risk. White (1945) in his study of human adjustment to floods proposed “a geographical approach”, one that included an integrated strategy of social, land use and infrastructure adaptation, rather than exclusively pursuing engineering measures of control and protection. This more ecologically based approach to human adaptation “human ecology”, was highly influential in both academic and government institutions in the 1960’s and 1970’s (Peet and Thrift 1989, p. 62). However, criticisms emerged from disciplines such as political ecology (Bassett 1988; Torry 1979; Watts 1983; Wiener et al. 1977, p. 48), which promoted more sophisticated perspectives on the negative and positive consequences of human impact, exploitation and adjustments to particular geographical and environmental conditions between people and earth.

Since the 1990s, other issues have emerged challenging traditional theoretical and practical approaches to disaster alleviation. Major trends such as globalisation, inequity and financial crises have led to broader consideration of the risk of extreme events and their socio-economic consequences (Barnett and Campbell 2010; Blaikie et al. 1994). On the other hand, increasing acceptance of global climate change (by governments) has added further dimensions to the decision making process, on how to respond and adapt to flood risks (Pelling 2011; Schipper and Burton 2009; Slovic 2000, p. 28).

It is well known that urbanisation and development in flood risk-prone areas increases vulnerability and can result in more severe disasters (Wisner et al. 2012, p. 152). Recovery reports on the aftermath of Hurricane Katrina illustrate this similar development dilemma (Colten et al. 2008; Kates et al. 2006), which has been described as a "long-term pattern" of reducing the effects of relatively high probability events at the expense of increasing vulnerability to larger extremes. Clearly, human responses to the risk of extreme events have long-term effects on sustainability.

These challenges highlight and are exacerbated by the diverging viewpoints held by academia, the residents and business owners in flood prone areas, and the relevant government bodies and decision makers on potential risk and consequences. For example, those developing models based on climate change have transitioned from rudimentary models of impact assessment, to synthesised evaluations of risk and vulnerability, incorporating cross-theme discussions on strategic adaptation and institutional actions (Füssel and Klein 2006; Kates et al. 2012). However, research bodies from both Australia and USA have highlighted significant barriers to effective climate change adaptation, despite the fact that many individuals, businesses and governments are already adapting to climate change (Melillo et al. 2014; Productivity Commission 2012). The divergence in risk perception makes these barriers difficult to overcome and can even result in maladaptive responses (Adger et al. 2009; Barnett and O'Neill 2013; Dang et al. 2014; Koerth et al. 2013; Masud 2015).

Given the extent of these problems, integrated assessments of flood risk from sea-level extremes require both physical and human dimensions, incorporating not only exploratory and descriptive approaches but also explanatory and referential approaches. Within these there is a need to factor in risk perspectives of residents and businesses, including those affecting their perceptions and potential responses to risk, within the present uncertainty of climate change predictions. These are arguably critical criteria for the research design of any case study, one that is able to take into account the complexity of the problems and develop the pertinent research questions, and a sound empirical framework (Creswell 2009, p. 132; Yin 2009, p. 18).

1.1.2 Research “hotspots”

Clearly, one of the foremost challenges for those attempting to model future major coastal flooding events and their associated risk, is factoring in the impact of climate change on sea levels (IPCC 2007, p. 335; 2012, p. 178; 2013b, p. 9). Climate change is expected to significantly change not only the magnitude of extreme weather events, but also their frequency, extent and duration. In places where both exposure and vulnerability are high the consequences can therefore be profoundly compounded (IPCC 2012, pp. 6-7). Therefore, climate change modelling in risk assessments on coastal flooding, while problematic, is critical.

Vulnerability has become a critical concept in hazard research, disaster management, emergency relief and climate change studies (Adger 2006, p. 270; White et al. 2001, p. 81). An adaptation study by O'Brien et al. (2007) found the word ‘vulnerability’ means different things to different researchers and vulnerability could be described as an “end-point” or a “starting-point” in risk assessments, impact analyses, and rural livelihoods and poverty literatures. The two main approaches to vulnerability were detailed as:

> ‘The end-point approach considers vulnerability as ‘the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, and thence to biophysical impact studies and the identification of adaptive options’ … The starting point approach, in contrast, considers vulnerability as a present inability to cope with external pressures or

> changes, which in this case is changing climate conditions' (O'Brien et al. 2007, p. 75).

In addition, Hinkel (2011, p. 200) analysed the concept of vulnerability in the 2007 Fourth Assessment Report (AR4) by IPCC, confirming that it was a central issue, linked to other important concepts like exposure, adaptive capacity, and extreme flooding events.

Like other extreme climatic events, the consequences of flooding depend largely on the level of vulnerability, which can be determined by a range of economic, social, environmental and other factors (IPCC 2012, p. 67). Indeed, a profile of vulnerability can be constructed upon these factors (Wisner et al. 2004, p. 51), using indicator-based regional analyses or other qualitative approaches of risk assessment at the local level (IPCC 2012, p. 90).

Despite the importance of vulnerability as a key determinant of risk, it is difficult to incorporate into risk assessments as it remains a vaguely defined concept (Birkmann 2006, p. 433; Hinkel and Bisaro 2016, p. 7). For example, it is not easy to take into account risk perceptions, which are often based on unscientific yet first-hand experience and observations, and can be influenced by a range of cultural values and psychological factors (Kasperson and Archer 2005). Indeed, the need to incorporate risk perceptions into vulnerability research has been a major challenge, particular as part of a larger strategy to support adaptive action and resilience (Adger 2006, p. 268; Kasperson and Archer 2005).

A feature of research into vulnerability and its importance in risk and impact studies (White et al. 2001, p. 91; Wisner et al. 2004, p. 12), has been the investigation of causal linkages between vulnerability and risk (or risk perception) (Hewitt 1983; IPCC 2012, p. 94). The relationships were identified as 'root causes' of vulnerability found in global economic and political processes (Blaikie et al. 1994; Wisner et al. 2004). This approach argues that social systems create the conditions in which people often perceive of risk in very different ways. This represents a “hotspot” of interacting social factors which become consequential within the context of risk and vulnerability.

In the early stages of studying the root causes of vulnerability, research mainly focused on non-western societies, such as Bangladesh, China and Mozambique, where destructive floods were recorded in the history (Wisner et al. 2004, pp. 225, 208, 363). Since the US was hit by Hurricane Katrina, however, the problems in the western world have been given increasing attention from those exploring vulnerability (Adams et al. 2011; Cutter and Emrich 2006; O'Keefe et al. 1976, p. 566; Oliver-Smith 2009, p. 22). For example, in regard to the problem of levee failure, Bankoff (2006) recognised that the over-dependence on technical protection (such as flood prevention infrastructure) was a form of vulnerability, in that people were more likely to be placed at risk in terms of their proximity to event of unprecedented flooding.

These so called ‘hotspots’ have been the focus of much risk research. However, Kellens et al. (2013, p. 46) point out that future research should aspire to more theoretical and methodological ‘openness’, incorporating integrated frameworks from multiple research fields. The Fifth Assessment Report (AR5) by IPCC also recommended a decision-making approach as a new research domain of disaster risk and adaptation studies in relation to climate change (IPCC 2014, p. 195). The decision-making approach was detailed as:

> ‘The main considerations that inform the decision-making contexts addressed here are knowledge generation and exchange, who makes and implements decisions, and the issues being addressed and how these can be addressed … The overarching theme of the chapter and the AR5 report is managing current and future climate risks, principally through adaptation, but also through resilience and sustainable development informed by an understanding of both impacts and vulnerability’ (IPCC 2014, p. 199).

In the meantime, broader literature relevant to risk, adaptation and vulnerability shows more emphasis has been put on social factors, perceptions of risk exposure, hazard experience and behavioural responses to such events (Becker et al. 2014; Grothmann and Patt 2005; Lindell and Perry 2012). Recently some research has emphasised the local government context such as community practice facilitating adaptive management (Elrick-barr et al. 2015; Nursey-Bray et al. 2016). There have also been important studies on disaster risk reduction (Davidson et al. 2016), and the concept of social resilience has evolved and is interpreted through social ecology (Albrow 1996; Beck 1992, 2006, 2010; Lash et al. 1996).

1.2 Purpose of Research

1.2.1 Objectives and research questions

The overarching aim of this study is to focus on the knowledge contribution to the improved understanding of risk perceptions through systematically investigating and analysing risk and adaptation from a human-environment perspective. To achieve this, it is essential to have a nuanced understanding of the risk itself and the impacts within a specific local community, using risk perceptions and responses given by residents and businesses. It is a challenge to address such broad interdisciplinary issues within one study but in doing so, it is hoped that this study will contribute to the broader understanding of the determinants of risk, including factors affecting risk perception and response. In doing so, it may inform decision making towards more strategic coastal planning and sustainable development.

The more specific objectives of this study are:

- To establish the historical and local contexts around risk
- To incorporate local factors of uncertainty into risk estimates for the future
- To elicit the opinions from residents and the factors affecting their risk perception
- To reveal how businesses perceive and respond to risk, and explain why
- To make policy recommendations relating to risk assessment, perception and adaptation

These objectives together can provide a comprehensive approach to explore the determinants of risk, risk perception and adaptation, in regard to flooding and sea-level rise, as well as enabling a means to explore the influences underlying attitudes towards risk behaviour. By taking this approach the following research questions will be addressed in detail:

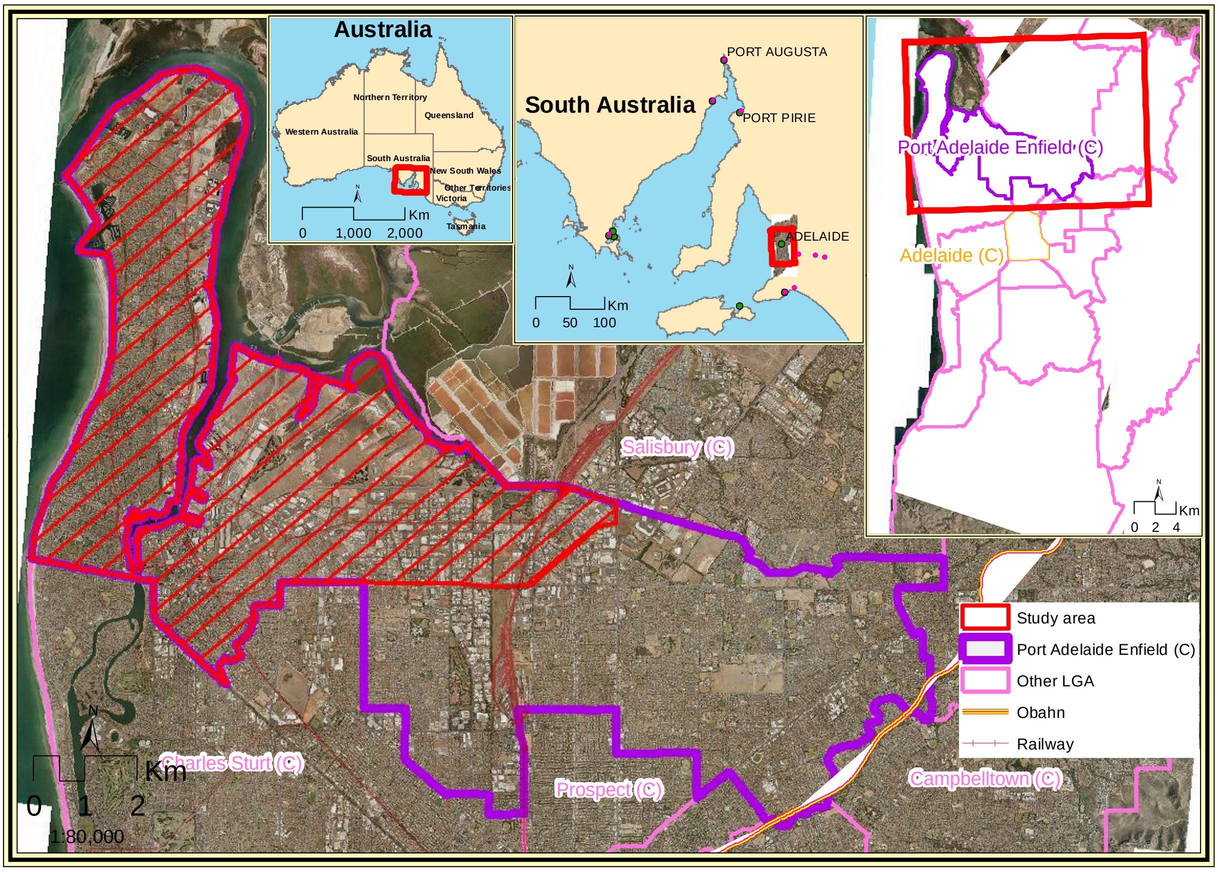
- How can uncertainties be fully considered in estimating local flood risk from sea-level extremes in the future?
- To what extent do residents and businesses understand risk and how they respond?
- What factors influence risk perception?
- What are the businesses' responses to risk?

1.2.2 The study area of Port Adelaide

Port Adelaide is important in terms of its economic role and geographical setting. As the main port of South Australia and a regional hub, it possesses key infrastructure in respect to energy and transportation, providing vital facilities and services to a culturally diverse and growing population of the City of Port Adelaide Enfield (i.e., PAE(C)) and the State. Its strong industrial base and tradition of marine navigation highlight its vital importance to the South Australian economy (ABS 2012; City of Port Adelaide Enfield 2012; City of Port Adelaide Enfield and SGS 2009). The relatively benign weather conditions together with the protection offered by the Port River anchorage has been highly valuable to shipping (Couper-Smartt 2003, p. 148). Key activities include the exportation of grain, wool and, until recently, cars, to the importation of bulk oil, fuel and a range of consumer goods. There is also a clustering of power-generating stations at Port Adelaide. No other hub has such a diverse and important role in South Australia's economy (City of Port Adelaide Enfield 2007; City of Port Adelaide Enfield and SGS 2009).

The study area consists of 22 suburbs and at the time of the 2011 Australian census there was a population of 40,000. Inclusive of Lefevre Peninsula, it covers an area of 49.8 sq km, as shown in Figure 1.1. Identification of the study area took into account governmental jurisdictions, including the 2011 Australian Statistical Geography Standard (ASGS) (ABS 2011, pp. 23-26), experts' advice from the National Tidal Centre, BOM (Rogers 2009, p. 14), and the local city planner's vision (City of Port Adelaide Enfield 2009, p. 489). This resulted in the coverage of the entire area below the level of a 1-in-100-year storm tide (Jacobi and Syme 2005b, pp. Drawing 4-4, 4-5). The area also includes land approximately lower than 4 metres above mean sea level (MSL).

Figure 1.1 Map of Port Adelaide in metropolitan Adelaide, South Australia

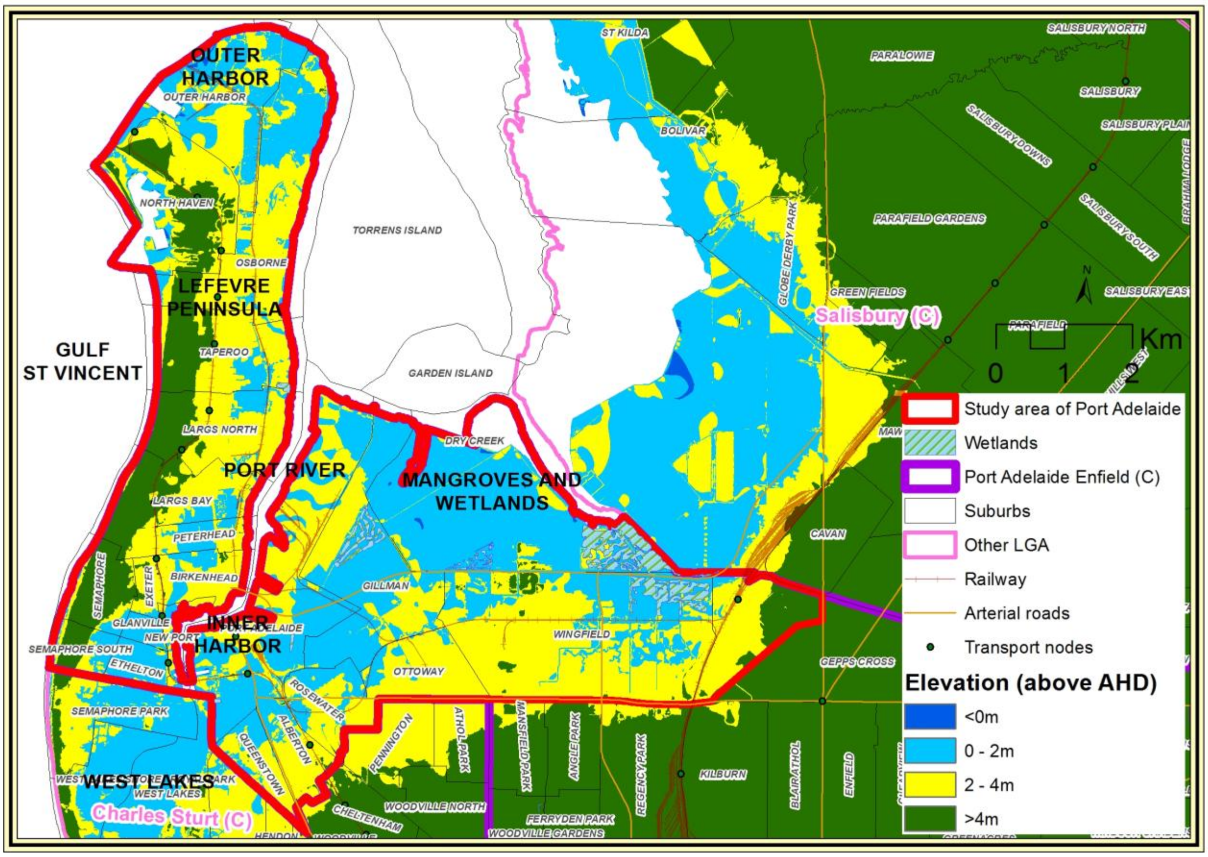


Source: Author, based on ASGS (ABS 2011, p. 25) and data from the governments

A number of geographical and hydrological characteristics are associated with the study area. The Inner Harbor is not geographically exposed to the open sea of Gulf St Vincent; it is sheltered by Lefevre Peninsula on the west. On the eastern side, Gillman and Dry Creek, with large areas of wetlands, mangroves and ponding basins, tend to retain storm water runoff during times of high tides. As the western branch of the largest tidal estuary on the eastern side of Gulf St Vincent, the Port River is marine, receiving limited amounts of locally-derived storm water (GHD 2011, p. 6; Jensen Planning & Design 2009, p. 8).

Figure 1.2 shows a large proportion of the study area is 'low-lying'. In fact, the large area of land (highlighted with blue colour) is below 2 metres AHD, which is under the estimated sea level of a 50yr ARI at Port Adelaide (Davill 2009). This highlights that Port Adelaide is clearly geographically vulnerable to flooding and inundation from extreme sea-level events.

Figure 1.2 Elevation in the study area and suburbs in adjacent regions



Source: Author, based on data from the South Australian government

1.3 Insights into Australian Studies

1.3.1 Studies before 2007

Similar to the rest of the world, studies in Australia on coastal floods, sea-level extremes and climate change have evolved, arguably in two stages, featuring a shift of focus. The majority of Australian research has focussed the biophysical aspects, their variables and impacts, despite there being several calls for broader multi-dimensional studies to inform decision making (Abuodha and Woodroffe 2006). Among the numerous studies on the coastal zone, only some have focused on the uncertainties of future coastal landscapes with increasing global climate change and sea-level rise (Church et al. 2006; Harvey 2006; McInnes et al. 2005; Pittock 2005).

In South Australia, the Port Adelaide 2005 Flooding Study (Jacobi and Syme 2005a) was a locally focused project, producing estimates of floods from hydraulic models, taking into account the factors of land movement and sea-level rise. These early-stage studies analysed and identified knowledge gaps for future research, including data availability, expertise and determining feasible methodology (Voice et al. 2006). It was suggested that a three-pass national vulnerability assessment along the whole of Australian coastal zone was needed, adopting a method used in a Tasmanian study of coastal morphology and vulnerability (Sharples 2006).

Taking into account the human dimension, risk of climate change and flood damage have drawn the interest of researchers, specifically the government on policy such as land use, catchment management and protection of residential property (Betts 2001; Blong 2004; Hawkesbury-Nepean Floodplain Management Steering Committee 2006; McInnes et al. 2003;

Smith and Greenaway 1983; Walsh et al. 2004; Yeo 2003). There were examples among the earliest efforts to use a social survey approach and questionnaire to collect primary data, to assess flood risk perceptions, and to assess community responses in an urban environment (Godber 2005; Godber et al. 2006; McKay 1984).

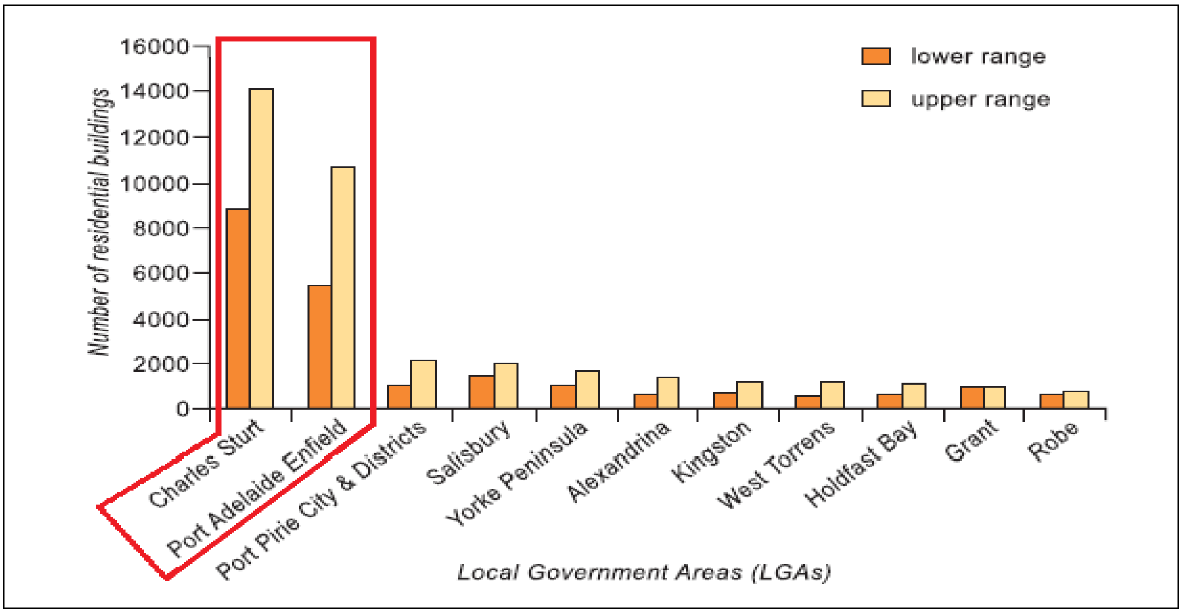
1.3.2 Recent trends in research

The release of 2007 AR4 (IPCC) and the subsequent 2012 SPEX (IPCC) have raised public concerns and prompted increased research into climate change and its contribution to risk from extreme events. For example, following the UK's Stern Review (Stern 2007), the Garnaut Review was undertaken to provide a comprehensive risk assessment from an Australian perspective (Garnaut 2008, 2011). The First Pass National Assessment of the coastal zone vulnerability to climate change and sea-level rise was also conducted at that time (DCC 2009; DCCEE 2011).

Of relevance to the current study, the First Pass National Assessment Report (DCC 2009, p. 110) rated Port Adelaide, together with the adjacent areas of Charles Sturt Council Area, as being the most vulnerable coastal region to sea-level rise in South Australia (Figure 1.3). It was suggested that an indicative 'second pass' site-specific assessment be undertaken across Australia, to identify and evaluate critical local variations in sensitivity and exposure, as to inform the basis for appropriate responses (Sharples et al. 2008).

It is notable that the Port Adelaide 2005 Flooding Study was an example of these 'second pass' assessments. It was arguably the first major effort in Australia to assess flood risks at a local scale. However, some key information is still not available from the study, including: (1) perspectives of floods from local residents and businesses, (2) the consistency between local risk perceptions and the model projections, and (3) potential local responses to floods by residents and businesses, and their coping strategies.

Figure 1.3 Estimated number of existing residential buildings in South Australia at risk of inundation from sea-level rise of 1.1 metres



Source: Adapted from DCC (2009, p. 110)

Australian studies have progressively shown a shift in focus from overall risk and vulnerability assessment at national or regional levels, to more detailed investigations, either sector-oriented or locally focused. One comprehensive study representing local government action to climate change at Clarence Foreshore, Tasmania, investigated multi-dimensional effects of potential hazards in an integrated assessment of coastal risk, socioeconomic impacts, and adaptive responses (Clarence City Council 2009). Another report detailed the multi-dimensional impacts of climate change in the area of Kakadu, Northern Territory, utilising participatory workshops to estimate the acceptability of the current risk level and to develop adaptation options for planning, management and policy responses (Léger et al. 2011).

Emphasising a human dimension, the Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) funded project "Community Attitudes to Climate Change", surveyed 6 major Australian cities in 2009 (Hofmeester et al. 2012; Sweeney Research 2010). Reser et al. (2012) compared the perspectives of risk between UK and Australia in specific areas, after the 2010-11 Queensland floods, known as the 2010-11 Eastern Australian Floods, which had a tremendous impact on public perception of risk from natural hazards and climate change. The occurrence of extreme flood events called for a reconsideration of a broad range of consequences, from building damage and recovery to long-term measures like town planning and insurance coverage (Bird et al. 2012; van den Honert and McAneney 2011).

In the likelihood of increasing natural disasters, Australian research needs to be focused on extreme events in all waterfront areas (riverine, estuary, floodplain, and coasts) potentially under threat, while highlighting issues such as building up resilient communities (Arklay 2012; Hayes and Goonetilleke 2012). Some recent studies have explored community vulnerability in relation to socio-economic or cultural factors (Bell and Blashki 2013; Sevoyan et al. 2013). These have pinpointed vulnerable groups not usually taken into account within immediate response management planning and have revealed knowledge gaps for further investigation.

1.3.3 Limitation of past studies

Australian studies on the risk of extreme weather events and climate change have tended to shift away from a primary focus on the geographical characteristics of regions at risk, toward a broader assessment of social factors and other human dimensions. In addition, as a prerequisite for understanding the decision-making process, social adaptation has drawn intense attention after the 2009 Victoria Black Saturday Bushfires and the 2010-11 Queensland floods (Bird et al. 2014). Since then an overall understanding of the risks from extreme weather events and the impacts of climate change at the national scale has been established, accompanied by state-level risk impact assessments and more than 120 research projects facilitated by NCCARF (Palutikof et al. 2015).

However, a focus on local risk areas and events are urgently needed. A major reason is that even though the mean sea-level trends are basically the same scale within a region, sea levels can exhibit strong local variations. Tidal dynamics and weather conditions are extremely variable even within a small coastal zone and this will impact the scale of wave fluctuations (Mase et al. 2013; Smith and Ward 1998, p. 280; Stockdon et al. 2014).

As national or regional risk assessments of sea-level extremes can only provide more general conditions for an individual local area, the NCCARF Research Plan has called for bottom-up, "stakeholder-driven" and inductive approaches (http://www.nccarf.edu.au/social-economic-and-institutional-dimensions/node/4 - page 21, Accessed 26/04/2013). As a response, the 2009 First Pass National Assessment "Climate Change Risks to Australia's Coast" provided a number of detailed case studies focusing on local areas as "enlarged snapshots". It should be noted the data prerequisites for a local-scaled study of flood risk, including high resolution DTM and high-quality climatic data, are of vital importance (Voice et al. 2006, p. 32). As these local contexts are subject to change, the capacity to update the data over time is critical to risk management in practice (IPCC 2012, p. 91).

Regrettably, research progress in relation to the social and human dimensions has been limited to public awareness and policy at national and regional levels (Sweeney Research 2010). Although there are a few theoretical studies based on sound and context-specific data at sub-regional levels, the majority of empirical studies have been exploratory in nature (Clarence City Council 2009; Raaijmakers et al. 2008). As a result, some important data have been overlooked, due to lack of a viable theoretical framework adopted from social science research

(Becker et al. 2014; Whitmarsh 2008). There are also few methodological standards for the analyses of risk and risk perception, leading to difficulties in validation and comparison among studies (Kellens et al. 2013).

Studies must acknowledge the complexity and multi-dimensional nature of risk scenarios. In doing so they require a theoretical framework based on a interdisciplinary approach, one that can be applied to a local context. To do this a study should adopt an inductive approach, as risk response (like adaptation strategies) needs to ultimately involve all residents, households, businesses and communities at stake. Input from these stakeholders provides a necessary dimension to a sound evidence-based data analysis and risk assessment.

1.4 Structure of the Thesis

This thesis consists of eight chapters, as shown in Table 1.2. Chapter 1 outlines the research background and sets the scene for the multidimensional investigation that is undertaken in the subsequent parts. The aims of the research, key research questions and the study area are introduced.

Table 1.2 Chapter outline of the thesis

Background	Chapter 1	Introduction
Conceptual Framework	Chapter 2	Conceptual and theoretical base of risk adaptation
Methodology	Chapter 3	Methodology
Findings	Chapter 4	Port Adelaide: Flood history and local contexts
	Chapter 5	Risk perception of residents
	Chapter 6	Risk perception and the response of businesses
	Chapter 7	The validity of risk perception and underlying causal influences
Conclusion	Chapter 8	Implications and conclusion

Source: Author

Chapter 2 establishes the conceptual and theoretical framework of the study by: (1) critically reviewing key concepts of risk adaptation that inform the rest of the study; (2) analytically synthesising theoretical models from previous studies and existing research fields addressing coastal flooding, risk perception, adaptation and vulnerability. This chapter outlines factors affecting risk perception and adaptation, including socio-demographic, psychological and geospatial characteristics. It also discusses knowledge gaps in addressing discrete factors unique to localised adaptations. Chapter 3 introduces the methodological approaches and research techniques used in formulating the research design and obtaining and analysing the social survey data.

Chapter 4 defines the local contexts of flooding. The complexity of the flood problems and challenges are illustrated in detail, as well as the options for flood risk mitigation. Chapter 5 summarises the flood and sea-level rise risk perceptions and discusses some of the influencing factors, based on the opinions and past experiences of local property owners. Further analysis examines evidence of associations between the opinions and preferences, in relation to responsibility, planning and development policy, as well as optional strategies for dealing with sea-level rise. Chapter 6 presents the results from the survey with local businesses, illustrating patterns, types of flood risk perception, and identifying problems arising from particular perceptions and some key causal-consequence relationships. After which a case study was used to demonstrate business risk perception, response and potential to adapt to future uncertainty.

Chapter 7 summarises the research findings and proposes several hypotheses in relation to perceived risk, acceptable risk and residency exposure, based on empirical indexing and spatial interpolation of the survey responses. Then influence of risk perception, intention of response and adaptation are examined, utilising structural equation modelling and survey results. The final Chapter 8 presents the major findings in the context of the key research objectives, their policy implications and potential research directions.

CHAPTER 2. CONCEPTUAL AND THEORETICAL BASE OF RISK ADAPTATION

2.1 Introduction

There has been increasing focus on the human dimension in research literature of coastal flooding risk in the context of climate change; however, consensus on a framework for conceptualising the interactions between risk, risk perception and adaptation to risk is lacking (Bubeck et al. 2012; Klöckner 2013; Lindell and Perry 2012). A sound theoretical base for conceptualising such interactions is crucial to systematically investigate the research questions posed here (Ennis 1999, p. 132; Ngulube et al. 2015, p. 49; Udo-Akang 2012, p. 92). This chapter presents an integrated theoretical framework with which these interactions can be empirically examined and analysed.

The framework is based on contemporary research, regarding risk adaptation assessment in the context of extreme events and climate change. While the framework incorporates multiple factors influencing risk perception and adaptive capacity, it highlights the limitations of understanding the interaction among these factors. The framework assumes that risk perception and adaptive response are affected by local contexts. It argues that risk perception does not necessarily lead to actual adaptation action. Rather, some psychological attitudes contribute to the motivation or intentions towards adaptation (Ajzen 2011; Lin et al. 2008; Lindell and Prater 2002; Wheeler et al. 2014). The framework demonstrates that there are two interactive processes when making an adaptive decision: the risk assessment and adaptation assessment respectively.

The chapter is structured as follows. First, it outlines the research approach justified by the ontological and epistemological positions underlying this research. Secondly, a critical review of research literature identifies risk perception as a core contributor to both the processes of risk assessment and adaptation assessment. The influence of risk perception and adaptation are highlighted by emerging empirical studies and theoretical reviews. A number of cognitive and behavioural theories (e.g., PMT and TPB, etc.) are introduced through their applications to the study of risk perception. Thirdly, relevant theories and models are synthesised into an integrated framework with which assumptions and propositions are assessed. Finally, considerations are provided to guide the following chapters. After which the operational approach is briefly illustrated.

2.2 Research Stance and Approach

2.2.1 Ontological position

In order to theoretically address the research questions, it is necessary to clarify the ontological stance in advance. As Minichiello et al. (2008, p. 3) have asserted, philosophical assumptions are critical in bringing ideational concepts into a theoretical framework, and in shaping the approaches, methodologies and techniques used in research and analysis. The writings on risk and hazards, however, have also shown considerable overlap between theoretical considerations, ranging from a predominantly realist approach at one extreme, to a predominantly constructionist's position on the other. Between these, is situated more subjectivist approach which acknowledges a social construction through risk perception and response (Lupton and Tulloch 2002, p. 320; Stallings 1997, pp. 4-6; 2002, p. 300; Wisner et al. 2004, pp. 18-20).

Similar to that described in works by Wisner (2004; 2012; 1993), this study broadly takes a realist approach to risk. That is, the researcher recognises that there is a reality which includes not only sea-level extremes that have occurred in the past, but also risk as an objective hazard that exists. This research position hinges on two important assertions which provide strong support to the methodological design of the study.

Firstly, it does not accept that risk is a characteristic of extreme events whose existence can be physically proved, through technical detection or observation. On the contrary, risks are not observable directly. Instead they can either be perceived through processes of assessment and judgment, or be estimated by utilising techno-scientific, statistical or actuarial means. The “perceived” attribute of risk suggests the following fundamental approaches:

- from a physical dimension, simulating the consequences of extreme events in line with particular scales of risk, and/or
- from a human dimension, assessing whether the interpretations of residents and businesses agree with the simulated results.

Secondly, it accepts that the researcher can never be absolutely certain about the truth of risk, using these approaches. Bryman (2004, pp. 276-277) claims that the approaches are neither “completely incontrovertible”, nor can the reality be assessed directly. This challenge, however, highlights the need for an integrated approach to exploring the truth (of risk) in theoretical and pragmatic terms.

2.2.2 Epistemological consideration

This research adheres closely to a modified objectivist epistemology on the nature of the relationship between people and knowledge. As such, the thesis attempts to highlight risk perception from an observer's point of view, while complying with a phenomenological tradition (Bryman 2004, pp. 13-14), and acknowledging the previously introduced realist's ontological stance. In addition, this research adopts an "open-ended theoretical perspective" (Charmaz 2014, pp. 262,264; Hsieh and Shannon 2005). From an integrated viewpoint, the values of the researcher are minimised at each stage of the investigation.

In this sense the thesis is in agreement with Annells (1996, pp. 386-387) and Charmaz (1990a, pp. 1164,1171), who claim that the above epistemological premise is in line with the assumptions underpinning grounded theory, such as "all is data" (qualitative or quantitative) and discovery at the conceptual level of objectivity (Glaser and Strauss 1967, p. 15). As Charmaz (2014, p. 9) also points out, grounded theory has 'gained acceptance due to its rigor and usefulness'. Therefore, this epistemological position requires the incorporation of grounded theory methodology into the research.

2.2.3 Research approach

This thesis takes a geographic approach toward understanding risk perception and how it contributes to adaptation. Geographers study the human dimensions of risk and climate change in domains of impacts, vulnerability and adaptation, emphasising the scale and human-environment interactions (Halpern et al. 2008; Liverman et al. 2003; McGranahan et al. 2007; Pacione 2003). In addition, geography's scope for determining interactions between the physical and social sciences provides capacity for social and biophysical processes to be analysed (Adger 1999; Adger et al. 2005; Cutter 1996; Smit and Wandel 2006).

As risks are characterised by complexity, scientific uncertainty and socio-political ambiguity (Klinke and Renn 2012, pp. 275-277; Renn 2012), a geographic approach facilitates investigation from an interdisciplinary perspective. Accordingly, the scope of research can be extensive, based on geographic and demographic characteristics, socioeconomic factors, cognitive/behavioural attributes, marginalization, and prejudices (Grothmann and Reusswig 2006; O'Brien et al. 2004; Terpstra 2011; Wachinger et al. 2013). One distinctive and integrating perspective is to understand the dynamics of climate change interacting with human activities through the lenses of place, space and scale (Montello 2009; Pattison 1964; Wilbanks et al. 1997, pp. 24,28,40).

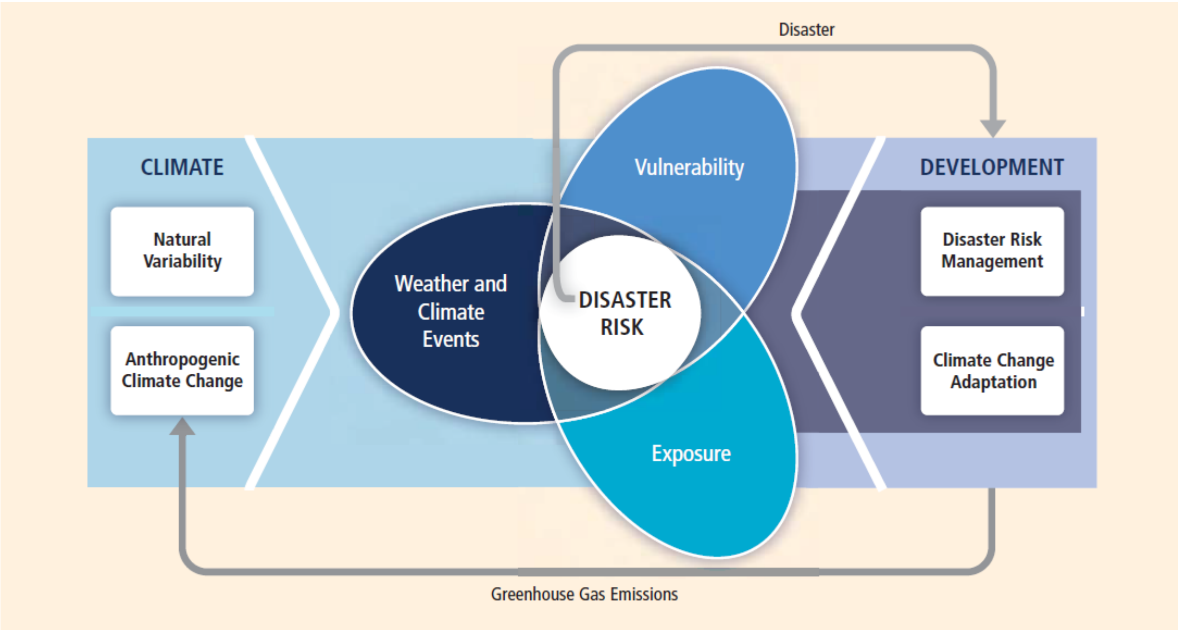
Approaches to risk perception can be summarised according to three commonly used paradigms: axiomatic measurement, socio-cultural, and psychometric (Weber 2001, p. 6). Specifically, attitude-behaviour models from research in psychology have been adapted to explain the cognitive processes of risk perception and adjustment (Bubeck et al. 2012; Ejeta et al. 2015; Grothmann and Patt 2005; Klöckner 2013). These models use psychological scaling and multivariate statistics to produce quantitative representations of risk attitudes and perceptions of protective action (Reser et al. 2014, p. 44; Reser et al. 2012; Slovic and Weber 2002, p. 6).

2.3 Concepts and Models of Risk Adaptation

2.3.1 IPCC's conceptual structure of risk

This thesis adopts key concepts consistent with the core concepts of the IPCC special report on extreme events (SREX), including sea-level extremes, risk perception and adaptation (refer to Glossary of Terms for interpretation), as shown in Figure 2.1. The SREX (IPCC 2012) provides critical insights with respect to risks, distribution of impacts and capacities to adapt to extreme events (IPCC 2014, pp. 1047-1048). Particular efforts include: (1) elaborating on essential concepts to be captured for risk assessment, (2) developing frameworks for following-up conceptual and operational decisions, (3) strengthening the convergence of adaptation with the expertise and knowledge from disaster risk management for a better understanding of the complex interactions between human populations and the environment (IPCC 2014, p. 836; Lavell 2010).

Figure 2.1 Conceptual structure of disaster risk

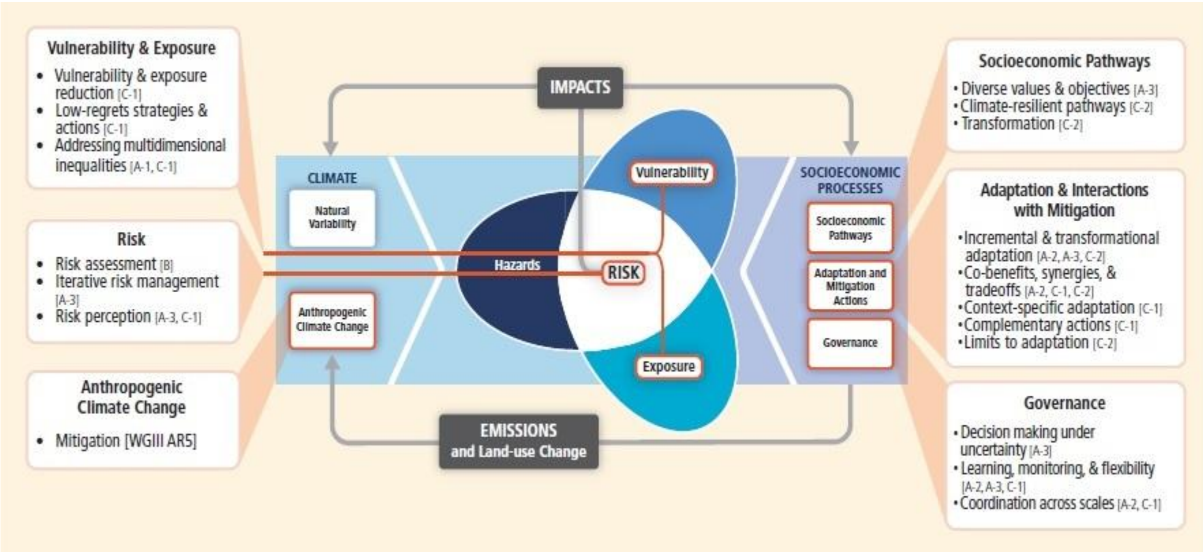


Source: Figure SPM.1 (IPCC 2012, p. 4)

The SREX conceptual structure highlights disaster risk as a sum of extreme events, exposure and vulnerability, indicating a framework of risk assessment which incorporates the socioeconomic context. It provides two starting points for investigation into a case-specific risk in a defined scale. First, determinants of the core components (e.g., extreme events) of risk need to be explored and scientifically estimated under current and future scenarios. Secondly, the interactions between risk components need to be examined, as prerequisites of risk evaluation.

The WGII AR5 (IPCC 2014, p. 3) modifies the conceptual structure with more generalised concepts of risk and hazards (from DISASTER RISK, and Weather and Climate Events), and a new concept of governance. Notably, the core concepts are further demonstrated with solution spaces (Figure 2.2), which reflect the newly emerging research literature on applied studies in climate adaptation, risk perception and decision making (Palutikof and Barnett 2014).

Figure 2.2 The solution space and core concepts of the WGII AR5



Source: Figure SPM.8 (IPCC 2014, p. 26)

This research focuses on risk perception and adaptation largely defined according to the empirical approach which orientates this investigation. There are other important concepts established in the risk structure or emphasised in the AR5, including impacts, vulnerability and resilience (IPCC 2014, pp. 709,1039,1101). Specifically, there are numerous research efforts on vulnerability in the recent literature (Adger 2006; Birkmann 2013; Turner 2010). However, it is beyond the scope of this thesis to cover all aspects of the physical, natural and human dimensions of risk. Rather this research assumes that the empirical data chosen here provides the primary evidence for risk perception and adaptation in a non-disaster scenario at a sub-regional level. It is expected that this will provide an improved understanding of risk, risk perception and adaptation beneficial to further research into adaptation and response to major flood events.

2.3.2 Risk perception in decision-making processes

Either the process of risk assessment or that of adaptation, involves risk perception which is underlying a risk decision (Slovic and Weber 2002, p. 3). On the one hand, risk perception is a critical concept within risk assessment. In fact, risk perceptions are “intuitive risk judgments”, which the majority of people rely on to evaluate risk, and thereby an intellectual discipline of risk assessment is created to meet the needs of rational decision making (Slovic 1987, p. 280). The processing of risk information at both an intuitive and intellectual level, however, leads to an increasing discrepancy of opinions on risk, heuristics and biases that reflect how the brain processes information in different ways (Leiserowitz 2006, p. 48; Sjöberg 2000, p. 6). As risk assessment efforts are likely to be misdirected by biases or faulty subjective judgments, it is important to examine the extent to which cognitive factors predict risk perception (Johnson 2005, p. 631; Slovic et al. 1981, p. 17).

On the other hand, risk perception plays a central role in adaptation planning through influencing the behaviour of people in terms of preparedness and protective actions to risk (IPCC 2012, p. 69; Reynaud et al. 2013, p. 547). In other words, adaptation is the action resulting from behaviours which are themselves predicated on attitudes that are influenced by risk perception. For example, it has been widely assumed that there is a positive correlation between risk perception and the intention of coping (or taking precautionary action), but the effect of how risk perception modifies the adaptation process can only be partially proved (Lindell and Hwang 2008; Lindell and Perry 2000; O'Connor et al. 2005).

Thus the variation of risk perception is crucial for risk decisions, and there are empirical studies continually investigating the effect of cognition on risk perceptions in case-specific contexts (Adger et al. 2007, p. 735; Grothmann and Reusswig 2006).

Therefore, risk perception has increasingly become an important linkage within decision-making processes associated with risk adaptation. WGII AR5 has concluded that the stage has been moving from the traditional risk assessment (or termed as risk management or risk analysis) to a more participant process of decision support (IPCC 2014, p. 195). As introduced earlier (refer to Subsection 1.1.2), the "overarching theme" of WGII AR5 is "managing current and future climate risks principally through adaptation" (IPCC 2014, p. 199).

2.3.3 Psychological models

Although research in natural and technological hazards has a long tradition of accounting for psychological factors in risk perception, impacting consequences, and mitigating responses, it is only recently that modest consideration has been given to examining the underlying functional and mediating roles which cognitive processes play under the context of global climate change (Chang et al. 2010; Slovic et al. 1984; Slovic et al. 1981; Slovic and Weber 2002). Arguably any models examining the risk perception and adaptation to extreme events or the effects of long-term climate change, might be limited without a consideration of cognitive factors, knowledge and values (Blennow and Persson 2009, p. 100; Vedwan and Rhoades 2001, pp. 116-117).

Much literature has emphasised the importance of cognitive processes in the development of conceptual frameworks, regarding threats, hazard and climate change (Lindell and Perry

2004, pp. 32-45; Swim et al. 2011, pp. 242-245). These studies were largely based on behavioural economics, social-cognitive theories and health-risk studies (Dang et al. 2012, p. 49; IPCC 2014, p. 204). Many have mainly focused on the intuitive judgments that comprise an individual's perception, constituting the attitude toward risk. Some have considered the precautionary actions or risk mitigation responses. The most widely used models and applications include Protection-Motivation Theory (PMT) (Floyd et al. 2000; Osberghaus et al. 2010), Theory of Planned Behaviour (TPB) (Ajzen 1991, 2011; Ajzen and Fishbein 1980; Sharifzadeh et al. 2012), Protective Action Decision Model (PADM) (Lindell and Perry 1992, 2004), and Model of Private Protective Adaptation to Climate Change (MPPACC) (Grothmann and Patt 2005).

As one of the major theories in health-protective behaviour research, PMT and its alternative version by Milne et al. (2000) has become a general decision-making model with increasing applications in research on natural hazards, including MPPACC (Grothmann and Reusswig 2006; Rogers 1975; Rogers and Prentice-Dunn 1997). The theory defines three stages: information observation, cognitive mediating processes and coping behaviour, incorporating major concepts of threat appraisal, coping appraisal, protection motivation and maladaptive coping, etc. (Floyd et al. 2000). The theory proposes a positive relationship between protection motivation and behaviour.

TPB is a expectancy-valence (EV) psychometric model, predicting people's behaviour (Ajzen 1991; Lindell and Hwang 2008). The model assumes people make decisions based on assessment of the consequences of their options, and thereby the severity of consequence plays a more important role than the probability of the occurrence of hazards (Loewenstein et al. 2001; Sjoberg 2000; Sjöberg et al. 2004). In fact, TPB supplements PMT by additional factors influencing an individuals' intention to response, namely subjective norm, perceived behavioural control and attitude toward the behaviour (Ajzen 1991, p. 182).

PADM attempts to explain personal adaptation to natural hazards by a function of environmental cues, interacting with social cues, information sources and characteristics, as well as receiver's characteristics, etc. (Lindell and Perry 2012). As claimed by Lindell and Perry (2004, p. ix), PADM focused on examining the relationship between communicated information and protective behaviour, containing the most useful features from many attitude-behaviour models for decision making.

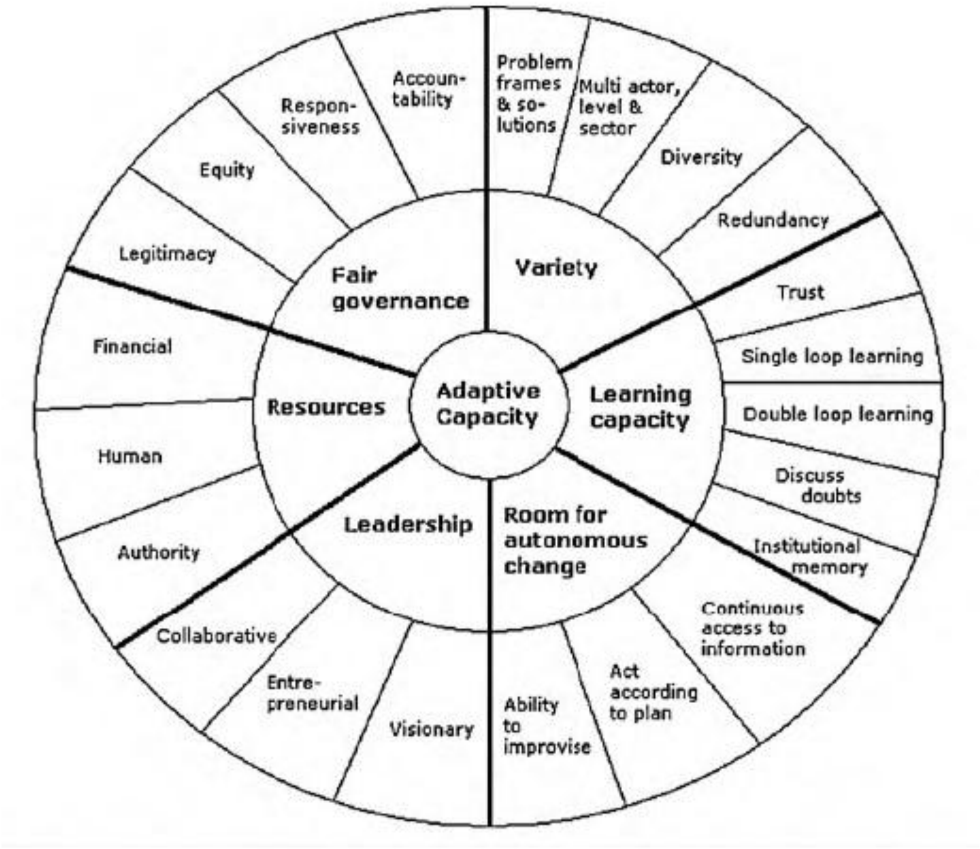
Importantly, PADM explicitly includes situational conditions as factors in the conceptual framework, together with social contexts and personal experience. Although there has been relatively little research about the spatial attributes of natural hazards relating to risk perception, PADM assumes a positive relationship between proximity to hazard and the perceived risk (Lindell and Hwang 2008; Peacock et al. 2005, p. 121). However, previous studies have not thoroughly explored the mechanism by which proximity shapes perceived risk, partially due to the need for finer spatial resolutions (Brody et al. 2008, p. 74). It is also questionable if more suitable spatial indicators are available, instead of simply using the proximity or distance to hazards.

2.3.4 Risk perception and adaptive capacity

Risk perception is associated with adaptation via adaptive capacity, as risk perception affects adaptation options which are a determinant of adaptive capacity. First of all, for adapting successfully to the adverse effects of climate events, people must accurately perceive the risks and options to adapt. However, adaptation options can be either enhanced by human cognition, or be limited by cognitive barriers (Grothmann and Patt 2005, p. 208; Smit and Wandel 2006, p. 288; Yohe and Tol 2002, p. 37). This prompts an approach to understanding adaptation through investigating adaptation options which are influenced by risk perception.

Secondly, adaptation options confine adaptive capacity by multidimensional components, as illustrated in the model ACM, shown in Figure 2.3.

Figure 2.3 The Adaptive Capacity Wheel (ACW)

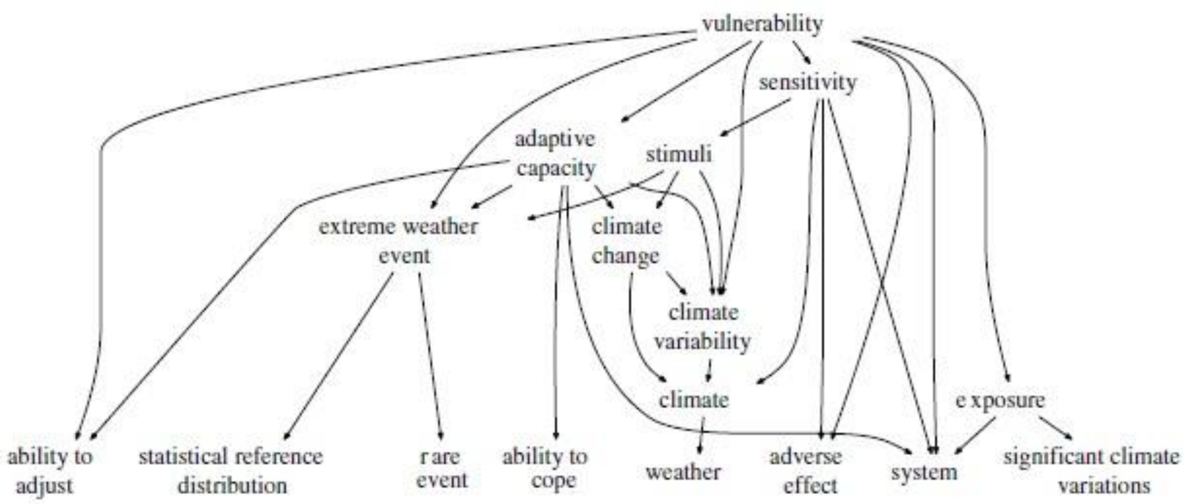


Source: Fig.1(Gupta et al. 2010, p. 464)

These dimensions not only include the objective components (e.g., resources, financial and diversity), but also the subjective norms (e.g., trust, fair governance and equity). But more importantly, these components are in fact possible resources for adaptation options. For example, public trust of fair governance certainly means strong government support would be an option of adaptation. There is room for autonomous change suggesting some self-adjustments would be among considerations to adapt.

It has been further discovered that adaptive capacity plays a central role in risk adaptation. Based on the conceptual space of science-policy interface in IPCC reports, Hinkel (2011) concludes that adaptive capacity is an "operational" concept between the physical world (e.g., extreme weather event) on one side, and the human world (e.g., vulnerability) on the other, as shown in Figure 2.4. Similar to risk perception, which is regarded as a cognitive representation of risk, this result implies adaptive capacity can be used as an indicator of adaptation.

Figure 2.4 Adaptive capacity in a conceptual space of IPCC



Source: Fig.1 (Hinkel 2011, p. 200)

Thus, analysing perceived adaptation options and adaptive capacity provides an important perspective of risk adaptation. In other words, a comprehensive model of risk adaptation must explicitly take risk perception into account, including not only the perceived risk but also the perceived adaptive capacity (Adger 2003; Fletcher et al. 2015).

2.3.5 Business adaptation

Business is a primary social actor, together with people, households and public sector agencies, involved in choosing and enacting organisational responses to the variability of climate impacts (Berkhout 2015, p. 417). Businesses clearly play an important role in regional economies by providing key infrastructures, products and services, employment, and tax revenue (refer to Section 1.2). Consequently, it is vital to understand how businesses perceive risk, and what measures they could take to prepare and adapt to hazards.

However, research in disaster risk and hazards has not focused on business as a distinct unit of analysis. Instead studies have tended to concentrate on aggregating regional or national impacts or post-disaster recovery, from a single perspective (Rose and Lim 2002; Runyan 2006; Tierney 2007). Moreover, most research does not assess business adaptation by explaining risk perceptions of business owners, and there has been only cursory studies exploring the influence of cognitive factors and situational characteristics on adaptive capacity (Botzen et al. 2009b; Chesson and Viscusi 2003; Linnenluecke and Griffiths 2010; Linnenluecke et al. 2013; Zhang et al. 2009).

Under a non-disaster scenario, there has been little systematic research examining adaptation options from a business point of view, leaving an overlooked knowledge gap (Hinkel and Bisaro 2016, pp. 12-13). The intention here is not to inquire in depth into the technical details of business adaptation, but to assess which existing options relate to adaptive capacity. This not only indicates current adaptation, but also informs adaptation strategies which meet case-specific requirements under future uncertainty.

2.4 A New Framework of Understanding Risk Adaptation

A new conceptual framework was developed integrating the Protection Motivation Theory (PMT) and the Theory of Planned Behaviour (TPB) into the IPCC conceptual structure (see Figure 2.1), as shown in Figure 2.5. The wheel-shaped framework Perception-Risk-Adaptive Capacity (PRAC) is a multi-dimensional, multi-layer and open-ended processing model for investigating and analysing risk adaptation.

2.4.1 Major components and structure

Four major components - layers, concepts, processes and models - are structured in the PRAC framework, which can be described as:

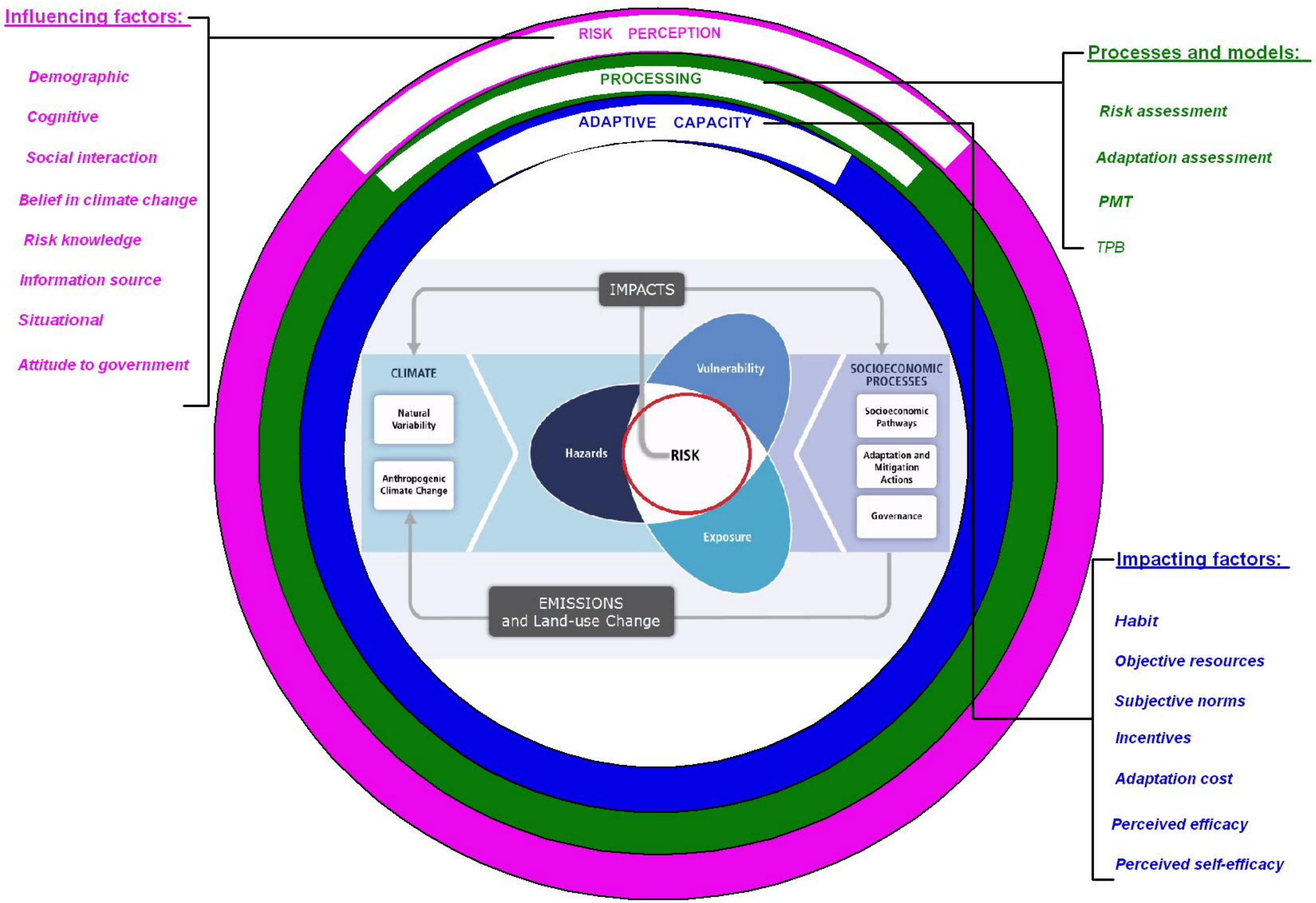
(1) The nomination of two key concepts (risk perception and adaptive capacity) as the representation of two peripheral layers respectively, each incorporates a number of identified influencing factors to be examined.

(2) The allocation of two fundamental processes of risk assessment and adaptation assessment in a peripheral layer of "Processing" provides solution space for justified theories or models to be applied, addressing risk problems from disciplinary or comprehensive perspectives.

(3) The incorporation of PMT to inspect influencing factors (demographic, cognitive, and situational, etc.) for risk perception, indicates how individuals assess the risk to themselves (in terms of perceived causes and consequences for example), without further behavioural change.

(4) The incorporation of TPB to appraise the impacting elements on adaptive intention and protective action, provides insights into adaptive capacity which is critical to decision of adaptation or maladaptation (Barnett and O'Neill 2013). The elements

Figure 2.5 Conceptual framework of Perception-Risk-Adaptive Capacity (PRAC)



Source: Adapted from SPM.8 (IPCC 2014, p. 26) include the micro determinants (habit, adaptation incentives, objective resources and subjective norms, etc.), perceived self-efficacy, and perceived adaptation efficacy which is based on adaptation options and perceived adaptation costs.

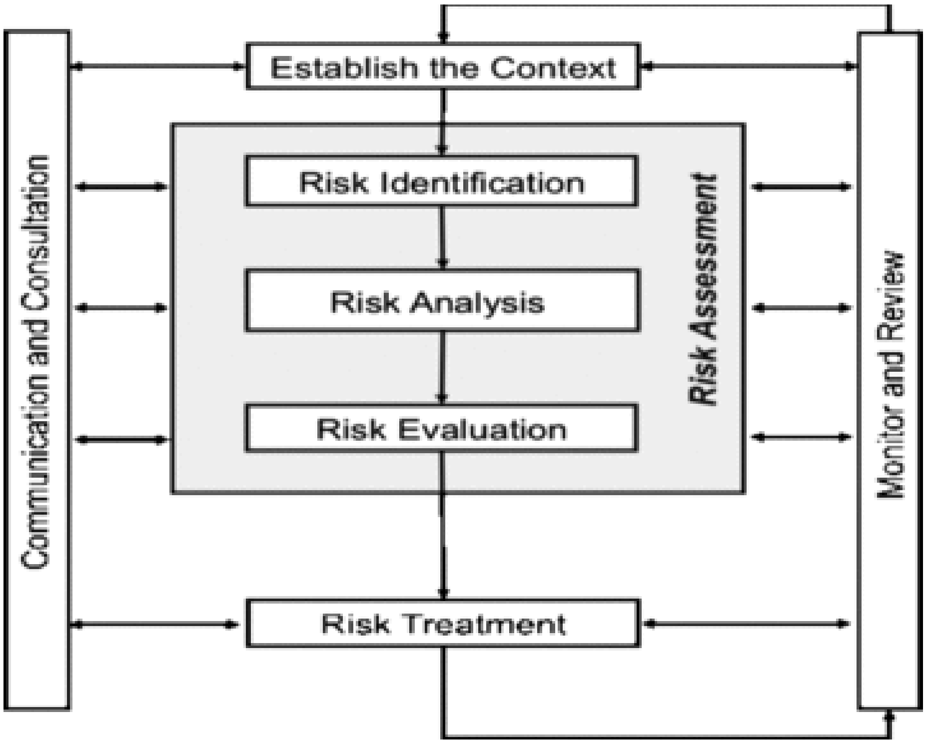
The open-ended structure of the peripheral layers reflects the exploratory nature of the research, enabling future incorporation of new knowledge. The inner core concepts of the PRAC model adapt to case-specific contexts. For instance, “Hazards” and “Risk” correspond to “Sea-level extremes or heavy rainfalls” and “Flood risk” respectively. In addition, the framework is amenable to extension, such as fitting into the layers and processes new models and advanced knowledge. Furthermore, the conceptual layers can include indicators, patterns, statistics, etc. with either spatial or non-spatial formats.

2.4.2 Interrelationships and models

The PRAC framework focuses on dual functions of understanding risk and adaptation. Firstly, elaborate information about risk and adaptation through multi-dimensional investigation, based on which local contexts are established in detail. Secondly, examining and validating the interrelationships among the influencing factors for risk perception and adaptive capacity, based on two assessment processes (risk and adaptation) and justified psychological models (PMT and TPB).

Major components of a standardized risk management path (Leitch 2010) are adapted by the PRAC model for the process of risk assessment. They consist of an iterated process (Cutter 2003, p. 7) shown in Figure 2.6, covering context establishment, risk identification, analysis and evaluation. In particular, this research utilises spatial models in estimating flood risk from both deterministic and probabilistic dimensions (Smith and Ward 1998, p. 200).

Figure 2.6 The process of risk management based on the ISO 31000:2009

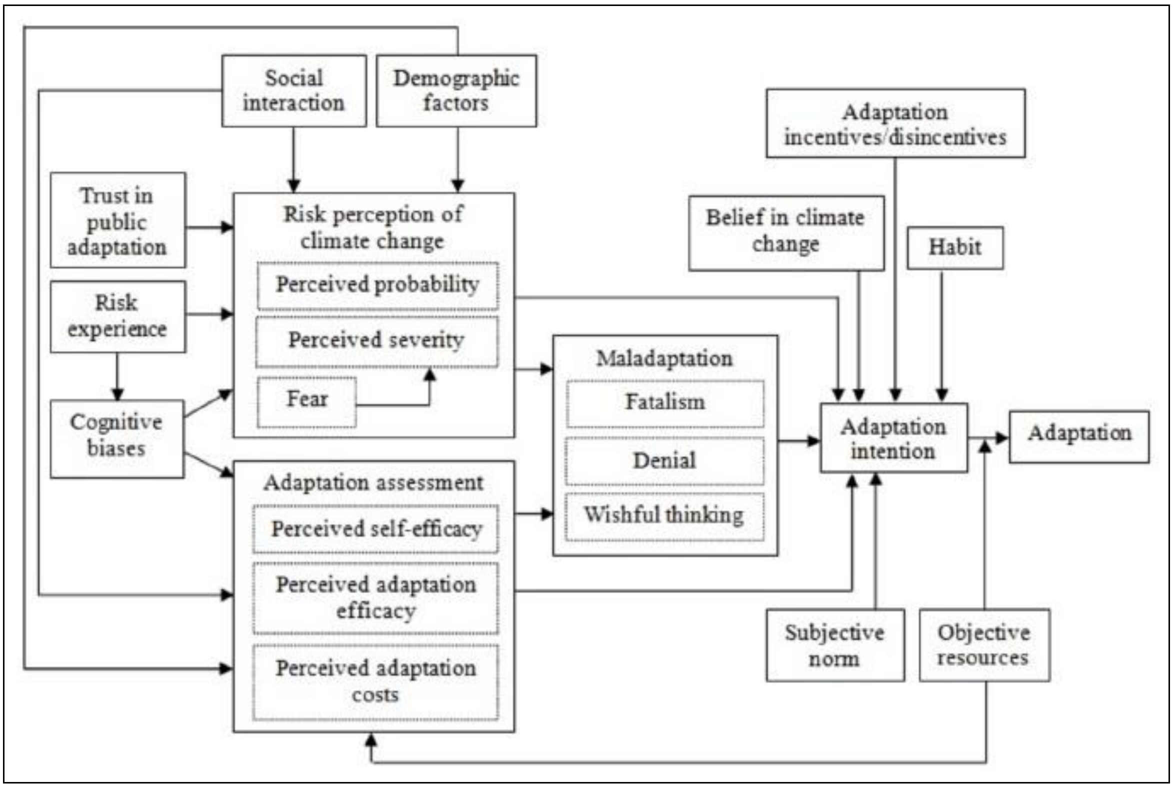


Source: AS/NZS ISO 31000:2009 (Standards Australia 2009, p. vi)

As the second major process of the PRAC framework, the adaptation assessment is based on risk management which is consistent with a risk-based framework described by Dow et al. (2013). The process attempts to assess adaptation opportunities, constraints and limits, through examination of adaptive options, together with other factors influencing adaptation. Importantly, it is supposed that the risk perspective, integrated with informed interaction among case-specific contexts, will provide insights into critical adaptation concerns, such as adaptation barriers and maladaptation. As risk assessment is a prerequisite to adaptation, the key risk dimensions like probability, intensity and uncertainty, are essential in the evaluation of the adaptation pathway. In extreme scenarios, maladaptation may result in deliberate or involuntary system transformation (IPCC 2014, pp. 850,906).

Integrating the PMT and TPB, an alternative presentation by Dang et al. (2012, p. 262) is adopted in the processing layer, as shown in Figure 2.7.

Figure 2.7 Major components of the PMT and TPB in the PRAC model



Source: Adopted from Dang et al. (2012, p. 262)

As similar models incorporating PMT and TPB have been empirically tested for risk perception and precautionary responses to hazards (Ajzen 2011; Grothmann and Reusswig 2006; Reynaud et al. 2013; Sharifzadeh et al. 2012), it is justifiable to apply them in similar contexts with necessary adjustments. However, due to a different focus in the current study, only a number of the model's components (factors) will be examined, including risk perception (attitude toward the behaviour), intention (to response) and trust in public adaptation (trust of the governance structures in the communities at risk). These factors are critical to understand the barriers that limit the mitigation of, and adaptation to, global changes and have substantive implications in legislation and policy making (Craig 2009; Kearney and Merrill 2004; Sax 1970).

2.4.3 Key assumptions and propositions

It is common sense that people's risk perception and adaptation behaviour are generally influenced by personality, culture, and trust in public adaptation, as well as risk experience and cognitive factors. Such propositions are detailed by the incorporated theories (such as the PMT and the TPB). However, some systematic reviews have highlighted the need for the framework of risk adaptation to be supported on both theoretical and empirical grounds.

For example, Bubeck et al. (2012) have challenged the research design of focusing on risk perception and its influencing factors, as the supposed positive relationship between flood risk perceptions and mitigation behaviour is "hardly observed". They claim the reviewed empirical studies "do not find a statistically significant relation at all, or report only a weak relation" (Bubeck et al. 2012, p. 1482). Similar findings further questioned the approach of using risk perception (or influencing factors like socioeconomic characteristics) as a means to predict adaptation behaviour (or risk perception itself) (Botzen et al. 2009a; Kellens et al. 2013).

Considering these critics of the focus of risk perception, it is necessary for this research to test the primary assumptions of risk perception explicitly within the analyses of empirical data, in case-specific contexts.

2.5 Conclusion

Much literature has discussed the impact of socio-economic factors on risk perception as an emphasis of risk studies. However, relatively little research effort has gone into examining the influence of a whole range of socio-cognitive and behavioural factors, situational attributes and adaptive options, for the purpose of understanding the decision-making process of adaptation. Taking a geographic approach, the conceptual framework developed in this chapter incorporates available data into a systematically established model, to provide a comprehensive view of flood risk and adaptation at individual and business levels in case-specific contexts.

This integrated conceptual framework is built on the IPCC core concepts of hazard risk and the identified key concepts of risk perception and adaptive capacity, as well as the influencing factors, forming two processes of risk and adaptation assessments. The risk assessment is initiated from spatial modelling of extreme events, supporting the major assessment process which has incorporated into it an adapted model of major components of protection motivation theory and the theory of planned behaviour. The interaction of risk perception and adaptation is then examined, as well as the relationships between the respective key concepts and their contributing factors. These analyses further contribute to a risk-based approach to adaptation assessment. The conceptual framework and analytical approach can then be applied to empirical case studies similar to the current research.

CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter overviews the methodological bases of the study, specifically the research plan (Creswell 2009). A primary consideration relates to data requirements based on the nature of the problem being addressed, followed by the justification for choosing a mixed methods approach. The structured research design and key procedures are then introduced. The main methods (quantitative and qualitative) employed are explicitly discussed in the subsequent sections, including the primary survey instruments and the analytic choices.

3.2 Methodological Considerations

3.2.1 Data sources

As risk perception has been highlighted as a central concept in the PRAC framework (see Section 2.4), data sources for risk perception are critical in the research design. Perception of risk involves processes of obtaining, analysing and interpreting signals about uncertain impacts of the risk events, such as natural extremes or technological activities (Wachinger et al. 2010, p. 8). These signals may come from direct observation (for example floods witnessed by local residents), or indirect information from others (for example a report about floods in the newspaper).

This study collects multidimensional information about risk perception of floods through surveys, face-to-face interviews and secondary sources. In particular, two primary data sources include the structured questionnaire to property owners who have settled in the study area, and in-depth interviews with local businesses whose major activities are based on the Port precincts. Both the property owners and businesses are in the first order confronting the risk, as local flood safety is critical to their livelihood. Therefore, this study focuses more on their risk perceptions, rather than those of the general public, or government decision makers.

However, primary data are supplemented by secondary data and contextual information collected from multi-level government organisations, such as BOM (Bureau of Meteorology) and the Port authority, to provide a good understanding of the flood-risk problems. This requires key-informant and focus group interviews to be conducted concurrently. These data include storm-tide models, land tenure databases, census, local tidal records, and airborne images in multiple forms. The secondary data also enabled the testing of the representativeness of the survey samples. In particular, data derived from the storm-tide models are fundamental to spatial inundation modelling in this study.

Risk perceptions are essential to understand the flood risk in local contexts. Firstly, it is the locals who have observed and experienced the problems first hand and borne the loss caused by adverse events (Reid 1987, pp. 29-30). Secondly, they 'retain local and traditional knowledge valuable for disaster reduction and adaptation plans' (IPCC 2012, p. 298). Specifically, the role of business as a key stakeholder is highlighted, as their 'internal risk management is critical' to adaptation (Khattri et al. 2010, pp. 3-4). Therefore, risk research has found that the stakeholders' risk perception is 'much richer' than that of the experts who may typically omit 'legitimate concerns' in risk assessments (Slovic 1987, p. 285). As a result, responses 'are destined to fail' unless the stakeholders' insights and intelligence are fully respected and structured into the decision-making process (IPCC 2012, p. 351; Slovic 1987, p. 231).

3.2.2 Context of risk perception

Wachinger et al. (2010, p. 8) suggest that risk perceptions differ depending on the (1) type of risk, (2) the risk context, (3) the personality of the individual and (4) the social context. It has been pointed out that the research context of the current study is differentiated from traditional flood-risk-perception studies (Slovic et al. 1974) undertaken in early 1970, which largely focused on storm-water floods. In more recent years, there have been increasing concerns about frequent storm-tide extremes (see Section 1.1). Such a complex problem requires appropriate data formats for the interpretation of risk estimates, applying Weber's law, using logarithmic rather than numerical scales, or through visualisation tools (Deco et al. 2007).

The risk context is largely defined by future sea-level rise and its quantification is still uncertain. In other words, the risk perceptions in the current study are mixed with perceptions about future risks that are yet to be fully understood scientifically. Discussing this uncertainty which links to climate change, an assumption-laden and debated topic, may result in a "black box" in the perception of risks (Renn 2008; Slovic and Weber 2002, p. 4; Smith 2005). Therefore Kasperson and Kasperson (2001) suggest a format of "interactive dialogue" to reveal what people have really perceived about the potential risk of extremes.

3.2.3 Approaches to risk perception

Constructivist and realist are two main approaches to risk perception (Fischhoff 1989; Jasanoff 1998; Renn 2008, p. 2; Rosa 1998). Constructivists argue that all risks involve some judgment and are perceptual in nature. There are no real risks; they are subjective and socially constructed. That is, they are models which allow people to make sense of things. The realists, on the other hand, assume that there is an outside objective world with risks that can be recognised and understood. Studying risk perception simply means to bring the perception of risk as close as possible to the real risk.

Stemming from the contrast of these two approaches, the discrepancies of risk perception by experts versus lay persons have drawn the interest of many researchers (Bostrom 1997; Hansen et al. 2003; Slovic et al. 1980; Wood et al. 2012). Similarly it has been noticed that the "local (direct) knowledge", personal experiences and circumstances act together to construct the risk perceptions of lay people (Maibach et al. 2008; Weber and Word 2001).

Recent research, however, has observed that the constructivists and realists are in fact using "different languages" to describe the same thing. They argue the perception is subjective, and the expert and lay patterns of reasoning are not that different (Maibach et al. 2008; Morrow 2009, p. 13). This suggests a mixed approach is needed to cope with the challenges (such as risk context, social context, future uncertainty, and the influence of various scales) confronting the current study.

Moreover, a survey approach to risk perception is fundamental if the methodology is justified from a research design point of view. As Creswell (2012, p. 293) describes, the survey approach provides empirical evidence with 'distinguishing features' of collecting, analysing and interpreting data by quantitative and qualitative research. Initially Creswell (2012, p. 26) has suggested 'Six Steps in the process of research': (1) identifying a research problem or issue for study; (2) reviewing the literature; (3) advancing direction through research questions and statements; (4) collecting (5) analysing and (6) reporting data. Following this "process of research", apparently a focus on data, as described in steps (4), (5) and (6), will determine the key component and thereby the research design for the investigation of risk perception.

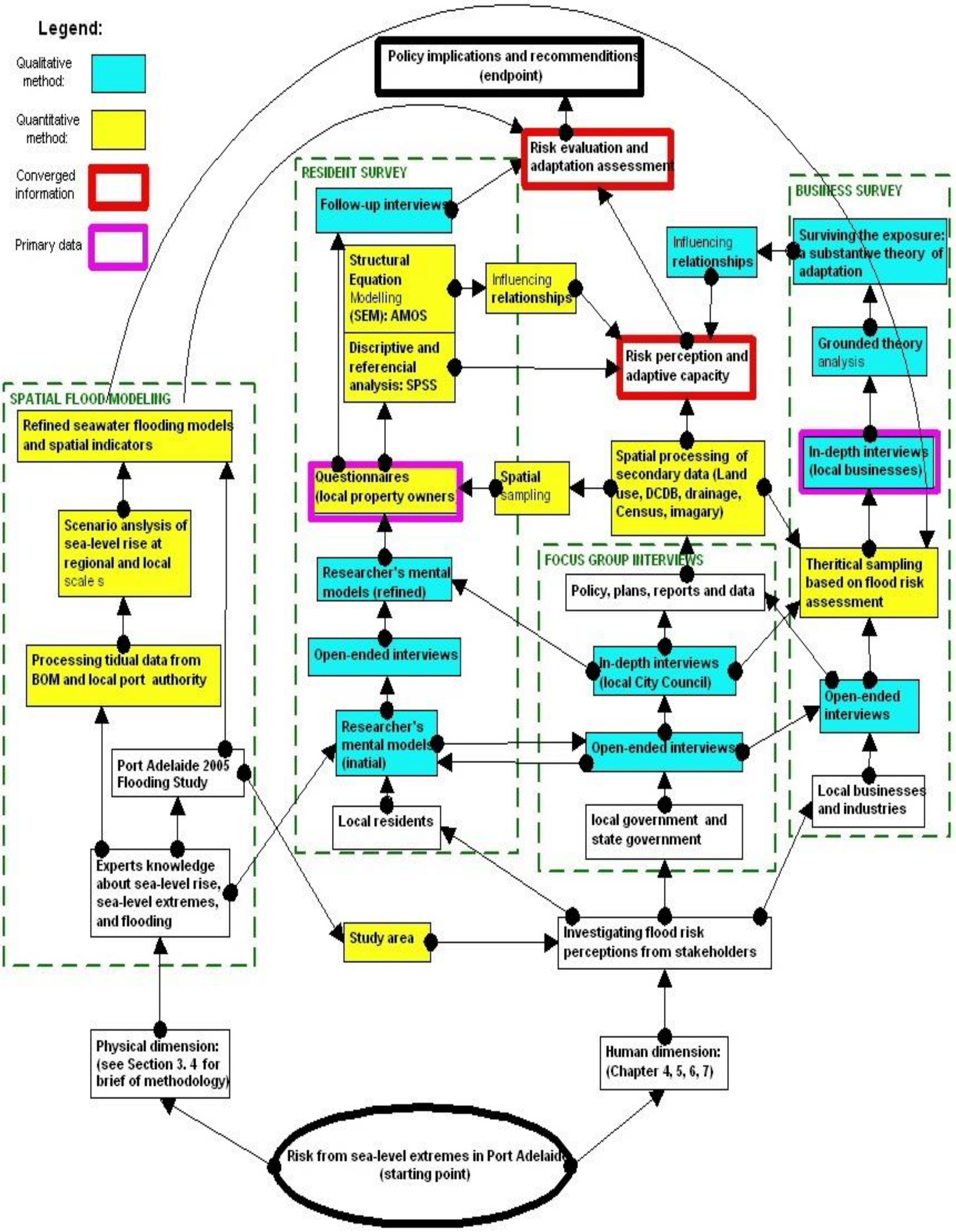
Next, an examination of a number of generalised research designs (Creswell 2012, p. 27) suggests that the survey, ethnographic and mixed methods are relevant to the current study. Firstly, to understand the perceptions from stakeholders requires empirical evidence, primary data that comes directly from property owners and businesses. This, as described by Creswell (2012, p. 376), is the outcome from survey procedures administered to a sample of people about attitudes, opinions and behaviours. The identified aspects and trends can represent that of a larger or entire population, depending on sampling methods.

Secondly, in conjunction with ethnography, case studies focusing on an in-depth exploration of the actual "cases" (Creswell 2012, p. 465; Yin 2009, p. 5) are also needed to elicit risk perception from representative businesses. Finally, the combination of both quantitative and qualitative methods makes a mixed-method research design essential.

3.3 The Research Design

This study employs the 'concurrent mixed methods procedures' of the mixed methods strategies (Buchanan and Bryman 2009; Creswell 2009, p. 14; Teddlie and Tashakkori 2009) to design the research plan, as shown in Figure 3.1. The procedures simultaneously merge qualitative and quantitative data, in order to conduct comprehensive analyses of the research problem, as well as integrate all the information to interpret the overall outcomes. The study collects primary quantitative data from the questionnaire and secondary quantitative data from government databases and hydraulic models. Meanwhile, qualitative data regarding risk perception and adaptation is obtained through in-depth interviews with selected businesses (primary data) in the study area.

Figure 3.1 Research design: concurrent mixed methods and data procedures



Source: Author

In addition to key primary data, follow-up interviews with a broader range of local residents and key informants (e.g. government decision makers) provided valuable information. Relevant flood experience, mitigation measures and comments on government policy also supported the analytical investigation. Quantitative survey data are used in modelling the factors influencing risk perception and response, whereas the analyses of qualitative in-depth interview data gathered from businesses are used in the assessment of adaptive capacity. The quantitative and qualitative data are also used in the integrated risk evaluation with latent variable analyses of risk perception and response.

The methodology structure consists of four major procedures in parallel, but cross-related with each other. Their outcomes contribute to comprehensive risk evaluation and adaptation assessment, based on an understanding of risk perception and adaptation capacity.

These four distinctive procedures are as follows:

- Spatial flood assessment
- Resident survey
- Focus group interviews
- Business survey

For further validation of the research findings of this study, post-survey investigation was undertaken on properties and streets affected by two major flood events:

- At Peterhead and Largs North, after the floods in Peterhead caused by heavy rains during 13-14 February 2014 (refer to Subsection 4.4.3)
- At Peterhead, Birkenhead, Glanville and New Port, after the storm tides and floods in Birkenhead on 9 May 2016 (refer to Subsection 4.6.1)

The post-survey investigation included: (1) follow-up telephone interviews with selected respondents from the resident survey, (2) on-site visits and observations, (3) interviewing residents in flood-affected households and neighbourhoods, and (4) discussions with local community groups and officers of PAE(C). The residents' (changing) risk perceptions were of particular interest, as well as the detailed information about the floods (extent, severity and the exact causes). On-site photos were taken for further reference.

3.4 Spatial Flood Risk Assessment

The IPCC core concept structure of hazard risk has highlighted that extreme sea-level events act as the physical determinant of flood risk from seawater (see Section 2.3). As flood risk 'signify the potential for severe interruption of the normal functioning of the affected society once it materialises as disaster' (IPCC 2012, p. 32), understanding the risk from the physical dimension is critical to further risk investigation in the human dimension. Identified in the PRAC model (Section 2.4), the physical risk becomes one of the situational factors influencing risk perception and adaptation.

Although some earlier studies found that the non-linear effect of changes of mean sea level on the propagation of surges is small (Lowe et al. 2001, p. 187), Arajo and Pugh (2008) reveal that the mean sea-level rise in 20th Century is the main contributing factor to the changes observed in extreme sea levels. Their analysis was based on examining a well-established tide-gauge record in Newlyn (UK), and thereby justified a component method of adding mean sea level changes to existing statistics of tidal and meteorological effects, for an approximation of extreme sea levels. As the 'add-on' mechanism has been successfully applied in developing plausible sea-level scenarios for evaluating coastal impacts, Nicholls et al. (2014) suggest employing both dynamic simulations (model-based) of storm surges and statistical down-scaling approaches comprehensively in risk assessments.

This study estimates flood risk from sea-level extremes through a procedure of spatial flood modelling, composing both probabilistic and deterministic methods (Smith and Ward 1998, pp. 179-202), i.e., scenario analysis of sea-level rise and seawater inundation modelling.

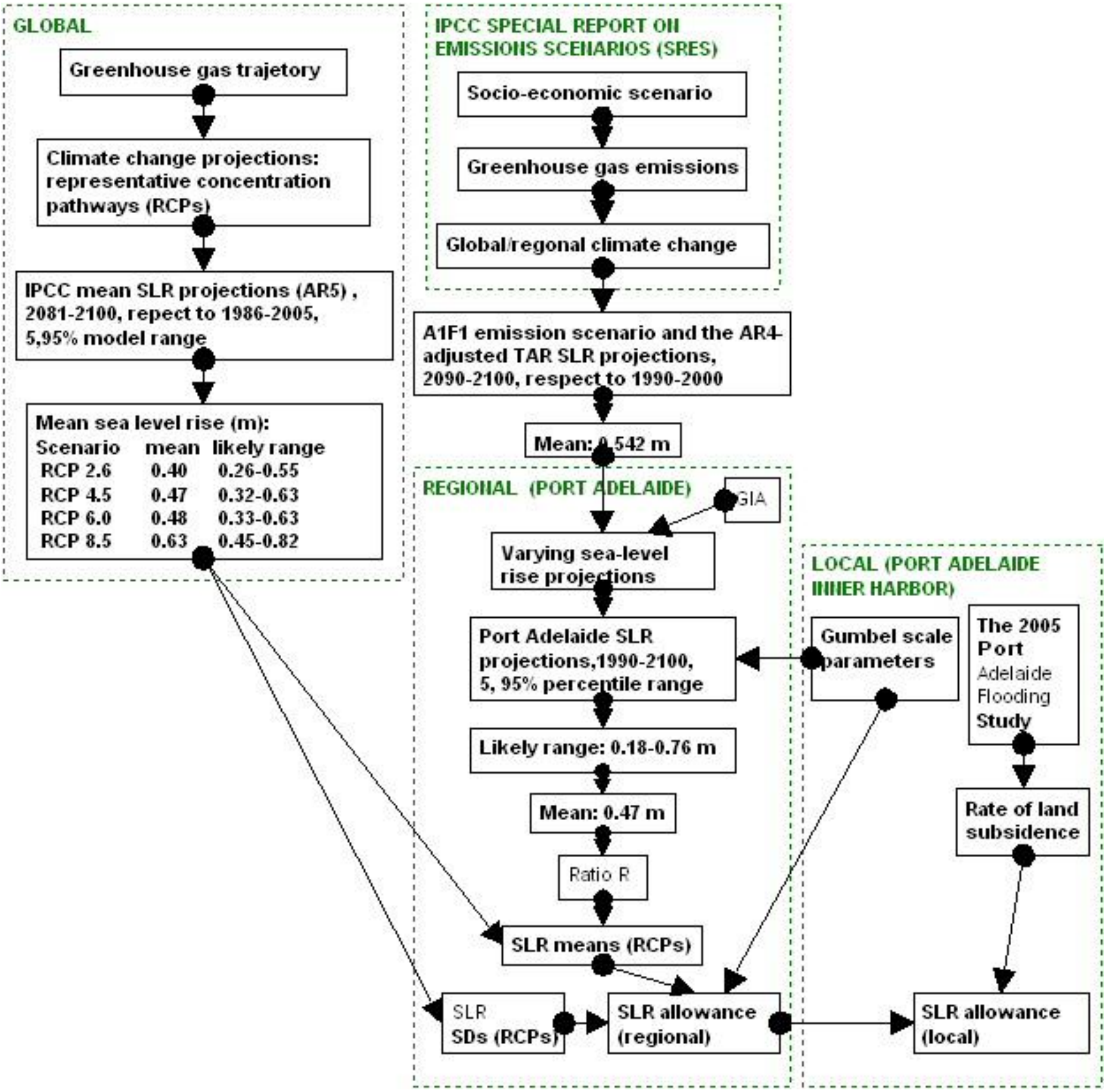
3.4.1 Scenario analysis of sea-level rise

This method is developed to derive the key component of extreme sea levels - the regional and local relative sea-level changes, a long-term effect transformed from global sea-level changes and also a result of regional and local meteorological conditions (Church et al. 2010; Church and White 2011; Woodworth 2010). Figure 3.2 illustrates the main components adapted in an approximation algorithm of the scenario analysis.

3.4.2 Seawater inundation modelling

This method reconstructs the seawater inundation surfaces based on the 2005 Port Adelaide Flooding Study (Jacobi and Syme 2005a), and by applying the updated sea-level allowances (Hunter 2012, 2013a, 2013b; Hunter et al. 2013) derived from the SLR scenario analysis. The modelling involves a number of raster based spatial processes, including hydrological correction, interpolation and extrapolation. A Digital Elevation Model (DEM) with high resolution (vertical 0.2 m/horizontal 2.5 m) is also built into the inundation models. Accordingly the inundation surfaces have been refined to an improved resolution, which is needed in the theoretical sampling of the business survey. Indicators of flood risk can be further developed as situational factors for comprehensive evaluation of risk adaptation.

Figure 3.2 Scenario and allowance for regional and local sea-level changes in Port Adelaide



Source: Author, data derived from Global (IPCC 2013b, p. 21), Regional (Hunter et al. 2013, p. 25), SRES (Hunter 2012, p. 12) and local land subsidence (Jacobi and Syme 2005a, p. 26).

3.4.3 Measuring the inundation: an energy approach

As a generalised measurement of flood risk, a method of creating gravitation-energy surfaces of inundation (GESI) has been developed. The method is based on the Bernoulli Equation (Pozrikidis 2009, pp. 308-337) for fluid flow. Alternatively, the GESI value can be derived by joint-applying Newton's second law of motion and the law of conservation of energy (Ma and Ke 1981, pp. 43,84-100,188-195) to ponded water (inundation). As the GESI value is based on the inundation models representing flood extents and severity (depths), it acts as a comprehensive indicator of seawater inundation.

In fact, the energy components of the inundation can be represented as (1) movement (kinetic) energy, (2) potential (height) energy, (3) molecular (pressure) energy, (4) chemical energy, and (5) heat (caused by thermal effects), plainly based on physical principles. As water is incompressible, the molecular energy is constant. Given that energy loss from heat (due to friction) and chemical change would be too small to be counted, the consequence of inundation is mainly caused by kinetic and potential energy of flooding seawater.

The energy representation can be further simplified to include the potential energy (gravitation energy) solely, at the time when the peak height of the flood is reached. The deluge can be reasonably assumed to be stable for a short period of time (i.e., ~1hr), during which the kinetic energy has transformed totally to the potential energy (Jacobi and Syme 2005a, p. 10; 2005b, pp. Drawing 3-4; Pearce 2010). Based on the potential energy expression $PE = M*g*h$, where both M (the mass of water) and g (gravity acceleration) are constants, the gravitation energy is dependent on inundation depths (h) derived from the inundation models.

Applying the law of conservation of energy, the above interpretation leads to a formulation of the potential energy (i.e. the gravitation energy) of inundation, representing the energy which the flood water brought to the inundated area. Also the value of the potential energy becomes a numerical representation of flood consequences as the energy is generally regarded as the force of nature. Being a standard measurement of work, the energy expression of GESI could be transformed to other formats of energy, force or work in risk related assessments. Taking flood-damage assessment as an example, the potential energy of flood water (reaching its maximum at the peak flood level) can be transformed into a kinetic-energy format, represented by pressure, velocity and depth of the inundation water. Then this derivation can be used in methods of loss functions, stage-damage functions or damage-curves, etc. (Burton and Kates 1964; Jonkman et al. 2008; Merz et al. 2010).

Based on the finite element method (also called micro-element method) in mathematics (Wang et al. 1981, pp. 325-338), the gravitation-energy of inundation can be approximately calculated by summing up the parts, depending on the resolution of the inundation model. As a result, the gravitation-energy of any area under inundation can be simply calculated by adding up the gravitation-energy of each of the micro elements (i.e., the tetragonal prisms) within the area.

It follows that the gravitation-energy surfaces of inundation (GESI) in the study area of Port Adelaide can be created through spatial (raster) processes, for each of the key scenarios/predicted levels: S0 (the current), RCP2.6, RCP4.5/6.0 and RCP8.5 (IPCC 2013b, p. 21). Based on the 2005 Port Adelaide Flooding Study, this study adopts S0 as 2.39m AHD at Outer Harbor and 2.50m AHD at Inner Harbor respectively (Jacobi and Syme 2005a, p. 27). Given that the GESI value is a comprehensive quantification of the flood risk from seawater, it can be incorporated into spatial and temporal analyses for risk evaluation and adaptation assessment, together with findings from examining risk perception.

3.5 Data collection approaches

The study adopts a multi-stage approach for primary data collection. While the quantitative data was mainly collected through structured questionnaires given to a sample of local property owners who live in the study area, preliminary preparations were conducted in advance, including intensive semi-structured interviews with residents to understand the local contexts. In an effort to encourage participation, a major local suburban newspaper (Portside Messenger) published news entitled ‘Flood risk quiz on way’, introducing the research and the mail-out survey (Kennett 2010):

> ‘A RESEARCHER at Adelaide University will survey local residents for their thoughts about the risks of rising sea-levels, flooding and inundation in low-lying areas around Port Adelaide…questionnaires would be posted to randomly selected residents this month, seeking valuable local knowledge…looking into the risk perception…(the researcher said) “I need to learn from both residents and businesses, as I feel it is these people who know the area the best.” He hoped his study would influence state and local government’s decision-making about flood mitigation measures for the area. “I believe the public’s opinion should be the critical prerequisite to any decision-making.”’

Qualitative primary data was mainly collected from in-depth interviews with owners or management staff of the local businesses which were theoretically sampled.

Research ethics were considered for data collection in a number of ways. The preparation for field work began with the process of seeking ethical clearance which was obtained in November 2009 from the Human Research Ethics Committee at the University of Adelaide. The field work (i.e., interviews and questionnaires) was carried out in collaboration with the City Council of Port Adelaide Enfield, the National Tidal Centre (BOM) and local communities (e.g., local community centres, libraries and environment groups).

Stringent measures were taken to ensure the issues of confidentiality, anonymity and informed consent during the research. The tools used to ensure this were the Information Sheet (Appendix 2) and the Introduction Letter (Appendix 6). The former was provided together with each individual questionnaire and the latter was given to each participant of the Business Survey. These contained an outline of the research, the institution, guarantee of confidentiality and other information deemed necessary to ensure the rights of participants. Although generally participants' consent was obtained face-to-face during the semi-structured interviews (Resident Survey), the majority of the participants in the Business Survey provided consent via email prior to the interview. All respondents were given a random identification number and it was clearly indicated that the research would not identify any information provided by an individual and that all information collected would be treated confidentially.

3.5.1 Semi-structured interviews

Semi-structured interviewing, or unstructured interviewing (Morgan et al. 2002, p. 20) is important to find what people know already about the risk. This initial stage of the field work was followed by in-depth and focus group interviews. Unstructured interviews aim to make informants talk as much as possible about how they think about risk while imposing as little as possible of other people's ideas, perspectives and terminology, specifically those of the researcher's (Morgan et al. 2002, pp. 25,63). These beliefs are knowledge-based and risk-relevant, reflecting mental representations (or internal symbols), which have been referred to as the mental models in the research literature (IPCC 2014, pp. 202-204; Johnson-Laird 2004; Tonn et al. 1990).

Slovic (2000, p. xxix) has described the mental models approach and the use of semi-structured interviews to elicit risk perception as:

> '…has used extensive semi-structured interviews to construct influence diagrams and 'mental models' depicting people's knowledge, attitudes, beliefs, values, perceptions and inference mechanisms with regard to specific hazards such as … global climate change'.

Morgan et al. (2002, pp. 25-26) have further detailed the value of semi-structured interviews as 'discovering surprising beliefs and formulations, which helps risk communications and decision making'.

As Slovic (1993) points out, trust is critical for successful social interaction, especially in surveys of risks (Slovic 1999). It is also important for the interviewer to achieve rapport with the respondents (Bryman 2004, pp. 118-119), in line with the aims of personal interviewing. This research has made extensive efforts to reach ordinary people throughout the study area and establish trust, to encourage the respondents to participate and to persist with interviews. A social network for research was also built up by attending workshops, seminars, and meetings organised by Port Adelaide City Council, local environment groups and historical associations.

In order to have a sufficient number of participants, three workshops were organised by the researcher in two community centres (Taperoo and the Junction) and 9 local residents were recruited for interview. A third centre in Osborne secured an additional 4 interviewees, as well as key contacts with the local city council. Other efforts included becoming a volunteer of the SES (State Emergency Services) Flood Safe Project, which provided opportunities to approach locals who had flood complaints, as well as to learn about the State policy on floods.

The semi-structured interviewing approach was useful in developing questionnaires to build up local knowledge of the study area. It also assisted with the consultation with governments, research institutions and the port authority for professional perspectives of the problem. Importantly, the social network and contacts built up during this stage were beneficial to conducting in-depth interviews at later stages of the surveys. Appendix 1 presents a list of 16 questions used frequently in the semi-structured interviews.

3.5.2 Probability sampling for the resident survey

Similar to observational science which originates primary data from field work and sample surveys (Haining 2003, pp. 91-92), the current study relies on sample surveys to property owners as major primary-data sources for investigating risk perception. A major objective for conducting the questionnaire (mail-out survey) was to explore the generalisability in a larger population about key concepts and issues elicited previously in interviews. Therefore, probability sampling was required to identify survey participants (Bostrom et al. 1994; Dillman et al. 2009; Morgan et al. 2002).

A spatial random sampling technique was adopted as both non-spatial and spatial attributes are involved. Based on Haining (2003, p. 94), the non-spatial properties of a population only addresses a 'how much' question, such as the mean level of an attribute in the study area or the proportion of the population that exceeds a certain threshold value. However, the study needs to answer 'where' questions as well, like where the values of an attribute are exceeded or where the extreme values are located. In addition, the 'where' interests need to be extended to constructing maps of population variability, describing quantitative summaries of that variability, or exploring correlation and association (Johnston et al. 2001). Therefore, the spatial random sampling method simply 'borrows strength' from random sampling, but with a spatial focus, ensuring a spatial spread of the samples (Haining 2003, pp. 95,100-103; Stevens Jr and Olsen 2004, p. 262).

The sample frame included all private property (land and house) owners living in the selected study area, given that the property addresses matched with the current mailing address in the study area. The complete list of properties within the study area was selected and compiled from the government property and land use databases, with vacant, government owned, business (corporation) and all other non-residential properties excluded prior to sampling. Owners with multiple properties were identified to prevent them from being sampled more than once. The survey was designed to focus on ownership, partially due to limited information about people who rented in the area, as well as those living within caravan parks, nursing homes and care institutions, including hostels, lodges, and retirement and rest homes provided by Disability Supported Residential Facilities (DSRF) in South Australia.

A list of owners (12052 records) was used as the sample frame, selected from the original records of property ownership (25604), land use (25597) and address (46130) in the government databases. Thus the mail coverage for the questionnaire, as Dillman et al. (2009, pp. 46-49) have described, is represented by the address-list (of the owners) covering the study area. As a result, postal addresses needed for the sample of residents were obtained by cross referencing the attributes of the owner records.

Based on Dillman et al. (2009, pp. 54-62), the sample size necessary for a survey is dependent upon a number of factors, including the size of the population and the margin of error. Under the assumptions of simple random sampling and the confidence of sample representation, generally the greater the variation, the larger the sample size needed for making estimates, and reducing sampling error. However, considering the nature of the current research, a higher confidence level than 95 percent may not be necessary. Therefore, a sample size of 1081 was randomly drawn from the sample frame.

As it was likely that not all questionnaires would be completed and returned prior to the closing date for responses, it was necessary to deal with non-response and missing data upon the completion of the survey (Fink 2003, pp. 18-24). A sample analysis was conducted by comparing the demographic characteristics of respondents against the census population in 2011.

3.5.3 Questionnaire design

A structured questionnaire was used for the resident survey. The prior interviews gave rise to a rich array of risk beliefs (or perceptions), which enabled the questionnaire to be designed to estimate the prevalence of these perceptions in the population being studied. Morgan et al. (2002, p. 84) describe the objectives of the questionnaire as (1) revealing the frequency of key concepts identified and (2) exploring and addressing specific issues emerged from the prior interviews.

The nature of the research and the social status of the study area made it necessary to undertake a mail-out survey using the questionnaire. Firstly the study aimed to gain an unbiased and comprehensive understanding of the risk perception from the whole population living in the study area and therefore required the survey to be answered by all residents living in the area. Other kinds of surveys, such as the CAS (Computer Aided Survey) were likely to rule out those residents who have restricted internet access due to economic status or difficulties using on-line technology. Hence the address-based mail-out questionnaire provided a wider cross-section of the general public with reduced coverage error than would be given by alternative types of surveys (Dillman et al. 2009, pp. 43, 48).

Secondly, the complete address-list of the land and property owners derived from the government property databases made the mail-out questionnaire possible. The sampling frame of stakeholders (in regard to risk) was defined as residential land and property owners, as residents with property ownership would have more credible concerns about risk to their properties than temporary residents such as renters.

The following are some key steps adopted for the design of the questionnaire:

- Begin with constructing a list of concepts to be covered, including thoughts and notes raised in the interviews
- Trim the list by balancing the need for coverage of each concept and the decisions that people are likely to face
- Maintain a consistent style of question formats such as the standard Likert scale to avoid bias from unequal comparisons and evaluation
- Group questions into four main sections, but make sure the closely related concepts (such as the terms for flood and sea-level rise) are not mixed together
- Pilot test (pre-test) the questions and make changes accordingly, as ambiguous wording and unfamiliar terms may result in measurement error by confusing respondents
- Ask multi-choice questions and group them when necessary, as well as re-order the questions, to reduce respondents' cognitive load
- Close with a few demographic questions but avoid asking private and sensitive details, such as personal or family incomes
- Begin with an introductory letter, explaining clearly the purpose of the study
- Attach ethic approval from authorities and reassure respondents that the completed questionnaires will be kept confidential.

The final version of the questionnaire included 22 closed and 26 open-ended questions with options for providing additional information and comments, utilising 37 tick boxes or circling selections for the convenience of completion (see Appendix 3). The four major sections of the questionnaire were: (1) information about general concerns; (2) information about the topic; (3) information about what you may do; and (4) some background information about you. An information sheet about the mail-out survey was also provided, as shown in Appendix 2.

3.5.4 Qualitative approach to the business survey

The current study adopted in-depth interviewing to elicit risk perceptions of businesses, due to a number of distinctive features of the survey, including the mode, data format, and the flexibility requirement for inductive and deductive analyses. First of all, “personal visit” is the most appropriate mode, rather than other regularly used modes (such as mail, fax, CATI, etc.) which are apparently not suitable for surveying businesses and other establishments (Dillman et al. 2009, pp. 414-422), as many businesses will ignore impersonal requests for information (Dillman et al. 2009, p. 406).

Contrary to the resident survey, the 2010 Business Survey adopted an interpretive approach which is qualitative in nature (Minichiello et al. 2008, p. 6). The central concern of the qualitative research is uncovering thoughts, perceptions and feelings experienced by informants at a holistic level (Berry 1999, p. 3; Minichiello et al. 2008, p. 9). A semi-structured in-depth interviewing technique was used to collect the primary sources of data from businesses, which were selected by theoretical sampling (Corbin and Strauss 2008).

As the 2010 Business Survey was exploratory in nature, a qualitative-based approach was essential. There have been some studies about business and industries, focusing on issues like flood damage, adaptation strategies and vulnerability (Davis 1985; Hamilton and Tol 2007), but few looked into the issues from a business perspective. As Minichiello et al. (2008, p. 13) have asserted, however, a qualitative study should ‘strive for a representative sample’, ‘identify purposive cases’ and ‘represent specific types of a given phenomenon’. Risk perceptions were systematically explored among different businesses during the course of survey.

Analytical induction as a feature of the qualitative approach has been beneficial to the 2010 Business Survey. The initial research questions were revised during the process, to suit the situation of interviewing, as described by Minichiello et al. (2008, p. 12). This flexibility enabled the qualitative research to be conducted along with taking photographs and making on-site observations, as well as obtaining relevant documents. Data and the field notes of the interviews were analysed afterwards. Identified significance and themes were incorporated into case studies, forming an integrated multi-method approach.

3.5.5 Theoretical sampling for the business survey

As Minichiello et al. (2008, pp. 168-173) point out, a rigorous systematic sampling procedure is critical to obtain reliable information in a qualitative study. The 2010 Business Survey selected industrial organisations from the contacts obtained in previous stages of the survey. Then theoretical sampling, a particular kind of purposive sampling (Charmaz 2014, pp. 197-200; Glaser and Strauss 1967, p. 45; Ritchie and Lewis 2003, pp. 80-81) was applied to businesses in the study area.

There were three steps to the sampling procedure. The first was to sample the shipping industry and port facilities. As the immediate analysis suggested large businesses might bear less risk, Small and Medium-sized Businesses (SMBs) became a focus. With the support from a premier business hub in Port Adelaide, the second stage of interviews included a number of SMBs. However, SMBs generally operate for 10-20 years, a time period not sufficient for many to experience extreme flood events. Therefore, the third step was to sample businesses in a broader category utilising ANZSIC (Australian and New Zealand Standard Industrial Classification) (ABS 2006) and the results of flood risk assessment on business premises. This provided a short-list of 43 businesses (see Appendix 7), based on which a number of key contacts were obtained from the local city council. A total of 34 businesses took part in the in-depth interviews, as shown in Table 3.1.

Table 3.1 Summary of business participants of the in-depth interviews

Category/classification	Number	Notes
Automotive Repair	2	1 wholesaler
Business Storage and Wholesale	4	2 Oil terminals, 1 Chemical, 1 Grain
Construction	1	Workshop
Gas and electricity	2	Power station
Home industry	2	Care and training (SMBs)
Hotels	4	3 SMBs
Housing	2	1 SMBs
Manufacturing	4	1 SMBs, 3 large size/scale
Recreation	1	Marina and yacht club
Retail Trade	3	2 Fishing markets, 1 Deli Café
Supermarket	2	
Wholesale Trade	2	Fertilizer (SMBs)
Business Consulting	2	
Port Facility	1	
Aquaculture	1	
Financial Service	1	Bookkeeping (SMBs)
Total	34	

Source: Author

Each interview lasted between 15 minutes to about 2 hours. Interview participants were either business owners or their managers (directors) of the operation. Otherwise the representatives of the selected organisations were employees responsible for emergency, environment or safety. Most of the interviews were conducted in the office of the business participants, with the exception of three interviews with SMBs were organised at a local business hub.

3.6 Data Management, Analyses and Synthesis

3.6.1 Data coding and management

The current study applies coding and database techniques to the management of the survey data. This approach enables systematic maintenance of the data for both spatial and non-spatial attributes collected from survey respondents. In addition, data cleaning was continually carried out, through detection of outliers (Fink 2003, p. 22), and necessary correction of respondents' misspelling and typos, based on cross-checking with the government land and property datasets.

Establishing reliable coding (codebook) is critical to the analysis of the data (Creswell 2012, p. 176). Codes or values were assigned to closed questions in advance of data collection. For the open-ended questions, however, they were decided after inspection of the survey data. In order to set up a high-quality codebook, a flexible and manageable storage scheme of relational databases was developed.

3.6.2 Quantitative data analysis

The study used three approaches to analyse the quantitative data: descriptive analysis, inferential statistics and structural equation modelling (SEM). Descriptive analysis was used to delineate risk perceptions of property owners through summarising and comparing the answers from the survey respondents. A number of variables were derived and the inter-relationships were explored, including demographic characteristics, general concerns about environmental issues, knowledge of floods and sea-level extremes, and experience of floods, as well as perspectives on risk related responsibility, policy options on sea-level rise and so forth. Also the primary data provides insights into adaptive capacity and adaptation means. Standard statistical procedures were performed by software SPSS (Norusis 2004).

Whenever a relationship indicating statistical significance was found between two distinct variables, inferential statistics was applied to explore relationships associated with the situational contexts of flood risk, concerns of sea-level rise and local responses. As most of the variables are measured on a nominal scale, analyses for statistical significance ($p < 0.05$) were conducted, utilising Pearson's Chi-Square ($\chi 2$) statistic and Fisher's exact test to examine independence between variables (Moore et al. 2012, pp. T-20; Wagner 1992, p. 274). The procedure consists of comparing observed and expected counts to the Chi-Square distribution (Wagner 1992, p. 358) to see how unlikely the observed value is if the null hypothesis is true.

Structural equation modelling (SEM) is employed to explore the influences related to risk perception and intention to respond (Byrne 2010, pp. 5-6; Carvalho and Chima 2014, p. 6; Zaalberg and Midden 2010, p. 162). SEM is a second generation of multivariate analysis (Fornell and Larcker 1987; Gefen et al. 2000, p. 3) and is a combination of both factor and multiple regression analyses, providing comprehensive means for testing and improving theoretical models (Anderson and Gerbing 1988, p. 411; Hair et al. 2010, p. 617). Specifically, this study aims to identify factors influencing residents' perceived risk of flooding (including the risk from sea-level rise), residents' assessment of private and public responses, adaptive measures, intention to adapt, and the significance of these influences. Hence, SEM helps confirming the integrated research framework (refer to Section 2.4), including the socio-psychological theories (i.e., PMT and TBP) under the local context of risk adaptation.

SEM was carried out by using statistical software Amos (Hsu 2010) to address an overall picture of the research for mainly two reasons. Firstly, Amos is a combination of both interdependence and dependence multivariate techniques with capacity to represent unobserved concepts (the hypothesised constructs or latent variables) in the relationships, accounting for measurement error in the estimation process (Hair et al. 2010, p. 617). Secondly, it aims at defining a model to reflect the entire set of relationships by measurable indicators (observed variables) (Hair et al. 2010, p. 617). Thereby, in the conceptual research framework of PRAC (refer to Section 2.4), all the causal influences can be estimated simultaneously by SEM.

Both confirmatory and exploratory factor analyses (Byrne 2010, pp. 5-6) were undertaken in the study, guided by a "six-stage decision process" (Hair et al. 2010, pp. 635-659). The process included defining constructs, developing and assessing measurement models, research design, and specifying and assessing the structure model. Due to the characteristics of the model, the maximum likelihood (ML) estimates (Byrne 2010, p. 141) were adopted for model evaluation. As the majority of the observed variables were categorical, parameter estimates derived from a Bayesian approach (Byrne 2010, p. 152) were also utilised to test the goodness-of-fit of the posited model.

The characteristics of the SEM model (e.g., sample size, the number of observable variables and model complexity, etc.) are critical to decide the selection of validity criteria (Byrne 2010, p. 81). For instance, with Chi-square test in SEM, the null hypothesis is that the observed and estimated covariance matrices are equal, or there is no statistically significant difference between them. As a result, insignificance is expected (i.e. p-value >0.05). However, if the number of observations is higher than a typical 200 cases, and the number of observable variables is larger than 10, the significance value is normally expected (Kline 2010, pp. 12,101). Thereby numerous practical indices of fit (such as the goodness-of-fit statistics) were developed in research literature for the evaluation process of SEM (Byrne 2010, p. 73).

The study adopted the criteria of overall goodness-of-fit, suggested by Brown (2006, p. 145), reporting: (1) model $\chi 2$ along with its *df* and *p* value (<0.05); (2) multiple fit indices (e.g., SRMR, RMSEA, CFI) and cut-offs used (e.g., RMSEA <= 0.06); and (3) confidence intervals, if applicable (e.g., RMSEA). Similarly, Lei and Wu (2007, pp. 36-37) gave a summary of common fit indices for their example analyses, using the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), the likelihood ratio chi-square goodness of fit statistic, and sometimes the confirmatory fit index (CFI). Among a number of Bayesian estimation Fit Measures, a posterior predictive *p*-value (close to 0.5) is typical of a correct model (Gelman et al. 1996; Lee and Song 2003).

In order to reflect the full extent to which the model is plausible, however, researchers need to assess model adequacy based on multiple criteria. As a complete validation requires taking into account theoretical, statistical, and practical considerations (Byrne 2010, p. 84), it is obviously beyond the scope of the study. This means the above criteria of overall goodness-of-fit for validating the SEM model are adequate.

3.6.3 Qualitative data analysis

In addition to content analysis (Hsieh and Shannon 2005), the study employed grounded theory methodology (GTM) to analyse the in-depth interviews of the 2010 Business Survey. GTM is being recognised as a valuable approach to research into management and organisational behaviour (Carrero et al. 2000; Gummesson 2002; Partington 2002). In particular, GTM's unique ability provides a conceptual overview of the phenomenon under study – what is actually going on. Through reflecting on the participants' thoughts about issues they consider important, GTM helps to gain understanding and acquire new insights about the issues of concern.

The exploratory nature of GTM is particularly suitable to the 2010 Business Survey, which is for discovery of new patterns of behaviour (i.e., perception and response) that are relevant and problematic for those involved, rather than verification of existing theory. Literature showed that neither a solid theoretical framework, nor an applicable methodological procedure were available for conducting such an investigation (as that of the 2010 Business Survey) in the agenda of social science research (Kellens et al. 2013). Many studies only reach fragmented conclusions or provide only thematic descriptions due to the challenges of applying strict procedures for analysing qualitative data. But GTM fills this methodology gap by providing a range of iterative strategies for data collection, analysis and inductive theoretical conceptualisation (Bryant and Charmaz 2007; Glaser 2008a; Glaser and Holton 2007).

GTM is process-focused, not limited to a particular organisation under investigation (Bigus et al. 1994, p. 41; Locke 2001, p. 33). This makes it an ideal choice for analysing in-depth interviews. As a qualitative research approach, in-depth interviewing traditionally relies on describing and developing themes from the data, in order to address the research questions and to improve understanding of the central points (Creswell 2012, p. 619). Applying GTM, however, basic social processes (BSPs) can be explored and conceptualised, providing additional insights into the research topic (Glaser and Holton 2007, p. 54). Two types of BSPs include basic social structural processes (BSSPs) and basic social psychological processes (BSPPs), to which GTM has been extensively applied in eliciting information from in-depth interviews (Charmaz 1990b; Charmaz and Belgrave 2002; Eaves 2001; Minichiello et al. 2008).

While the tenets, process and techniques of classic grounded theory methodology were outlined by Glaser (1978, 1998, 2005) and Charmaz (2006, 2012, 2014), a brief description of the methodology has been provided by Holton (2006) as follows:

> 'Grounded theory, developed in the mid-1960s, is an extensively used and well-documented methodology (Glaser, 1978, 1992, 1998, 2001, 2003, 2005; Glaser & Strauss, 1967). It is a general methodology of analysis linked with data collection and uses a systematically applied set of procedures to generate an inductive theory about a substantive area. With roots in the positivist paradigm and quantitative sociology's concept indicator model, grounded theory utilises the interchangeability of indicators through a process of constant comparison to enable the emergence of conceptual theory that is empirically grounded in data. The methodology is emergent, with the researcher entering the field open to exploring a substantive area and allowing the chief concerns of those actively engaged therein to guide the emergence of a core issue or problem to be resolved. The conceptualisation of the core problem becomes the basis for the articulation of a grounded theory that explains the problem and its resolution.' (Holton 2006, pp. 6,7).

GTM's interactive procedures were applied to the business in-depth interviewing process to generate conceptualised patterns of adaptive responses, based on which adaptive capacity can be elaborated. Typical GTM procedure includes theoretical sampling, open coding, and theoretical coding (Charmaz 2006; Glaser 2005, 2008a). The discovered patterns compose a substantive theory of business surviving flood risk, integrating attitudes, process, intention to respond, actions and adaptive options. The outcomes of the 2010 Business Survey were not only summarised themes of risk perceptions, but also an overview of time, place and people, as how the risk was perceived and responded to by businesses.

The 2010 Business Survey was arguably the first attempt to apply GTM in disaster risk research. The risk perspective from business (rather than social/psychological behaviour in general) transformed the aforementioned basic social process (BSP) to basic business process (BBP). Based on Glaser and Holton (2007, p. 54), the basic social process (BSP) represents one type of core category (or variable). Thereby the BSP (or BBP as in the case of the current study) enables the researcher to "transcend the descriptive detail of the data and abstract the incidents within as indicators of the latent patterns of social behaviour that would eventually emerge as a conceptual theory" (Holton 2006, p. 67). Accordingly, the BBP indicates the patterns of business response in the context of flood risk.

This study adopted the influence diagrams to represent the findings from the analysis of the 2010 Business Survey by implementation of GTM. The influence diagrams are common devices in many technical fields (e.g., information systems, management studies and organisational research, etc.) to link with a rigorous decision-making process via transformation and integration of entities, relational structures and workflows (Howard and Matheson 2005; Morgan et al. 2002, pp. 35, 44-45), as well as in applications of probabilistic inference (Shachter 1988). Similarly, GTM theoretically reflects and summarises the patterns and systematic uniformity flows captured in analytical procedures of coding (i.e., open, focused and theoretical coding) (Charmaz 2014, p. 151; Glaser 2005, p. 74). The influence diagrams proved to be an appropriate means for demonstrating the major outcomes of the 2010 Business Survey.

3.6.4 Integrated evaluation of risk adaptation

This research seeks to provide a comprehensive evaluation of flood risk and adaptation in the study area as a whole, synthesising the outcomes from both quantitative and qualitative analyses of the survey data. An indexing approach (Glaser 2008b, pp. 41-46; Ritchie and Lewis 2003, pp. 220-222) was used for abstracting and analysing core concepts of perceived risk, as well as testing hypotheses of risk perception, occupancy exposure and adaptation. The questionnaire responses and business interviews were then utilised to demonstrate typical problems of risk adaptation in the research context. Integrated pictures of the risk from either sea-level rise or flooding were also established by spatial interpolation of the questionnaire responses. These provided insights into the local risk perceptions, including perceived flooding hotspots, awareness of flood causes and future risk concerns.

3.7 Conclusion

This chapter detailed the overall strategy of methodological design and justified the choice of specific research methods used in the study. Based on a mixed methods approach, both primary and secondary data sources were utilised to collect quantitative and qualitative data for spatial flood modelling, descriptive and inferential analyses, and structural equation modelling (SEM), to address the research questions around risk adaptation. The SEM was used to explore and specify influencing factors, assessing relationships between variables and indicators.

The study has adopted a number of approaches and research methods, including an energy approach to seawater inundation which was developed to provide a comprehensive indicator of flooding risk. The grounded theory methodology was applied to the 2010 Business Survey of flood risk perception, for sampling, analysing and conceptualising qualitative data. Constructing indices was originated as a synthesising approach to risk evaluation and adaptation assessment.

CHAPTER 4. PORT ADELAIDE: FLOOD HISTORY AND LOCAL CONTEXTS

4.1 Introduction

Port Adelaide is a major Australian port and the gateway to South Australia, playing a critical role in the regional economy (see Subsection 1.2.2). 1841 to 1970 was seen as Port Adelaide's heyday and it was ranked as the 3rd busiest port in Australia in 1950 by shipping volume (Couper-Smartt 2003, p. 79). However, this is an area where threats from floods and opportunities for development overlap. Although flood hazard mitigation has become the Port's vital adaptation strategy, the interaction with uncertain climate change has not been adequately understood, due to the complexity of flood issues and different perspectives.

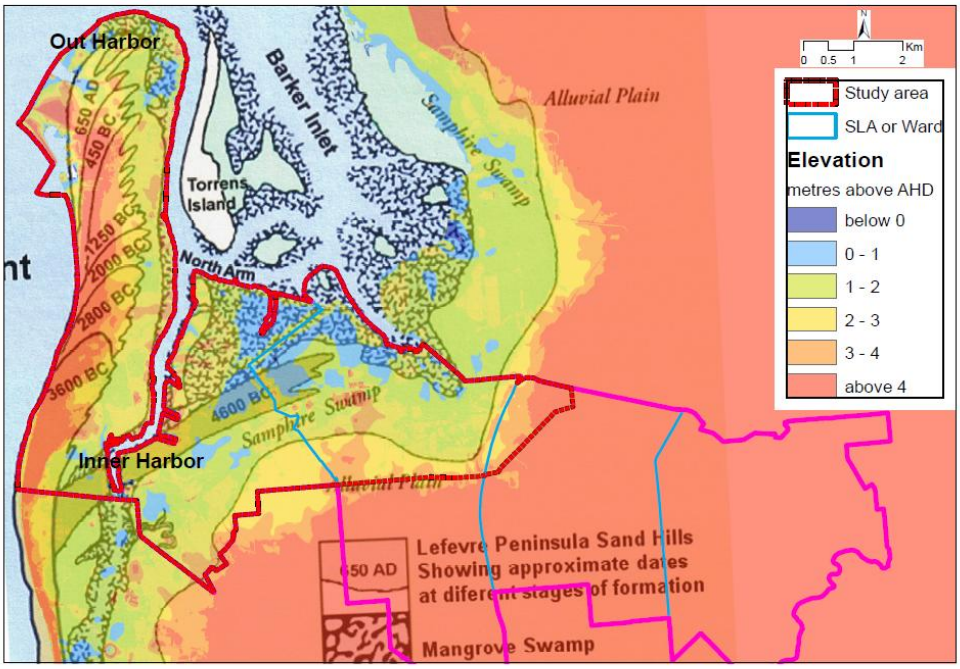
This chapter provides an overview of the flood problems in Port Adelaide from a historical point of view. It begins with the history of settlement, emphasising that the flood problems arise from the Port being built upon a low-lying swamp. This is followed by an examination of flooding and tidal data, demonstrating a worst case scenario of disaster and some local patterns associated with the nature of floods. Then the persistent drainage problems are explored in detail. Finally, public feedback on government responses to floods is reviewed, reflecting the serious concerns from residents and the complicated issues involved. The reporting materials are based on governmental and institutional publications, spatial and remote sensing processes, and consultation with authorities.

4.2 The History of Settlement

4.2.1 A "Commodious Harbour" on swamps

Safety and accessibility were the major concerns during Port Adelaide's establishment as the first and major harbour in South Australia, from European settlement in the 1830s at Inner Harbor, to the containerisation at Outer Harbor in the 1960s (Stuart 1998). In fact, these criteria made up the first of the ten requirements and the first of the six of primary importance for the "commodious harbour" Instructions for choosing a site for the new capital, Adelaide, carried out by Colonel Light, Surveyor-General of the new Colony of South Australia in November 1836. For Port Adelaide, these requirements were crucial as it was eventually built up on samphire and mangrove swamps of an estuary, and the sandy ridges of Lefevre Peninsula (Couper-Smartt 2003, p. 13). Figure 4.1 shows the character of the landscape dated back to the time before European settlement.

Figure 4.1 Port Adelaide: land development by the time of European settlement



Source: Author, overlaid map (Couper-Smartt 2003, p. 23)

Located in Gulf St Vincent, Port Adelaide has experienced the shifting of sands for thousands of years due to tidal movement, which has formed the sand dunes (or sand hills) of the western side of Lefevere Peninsula. On the eastern side, however, a tidal pattern dominates the Port River estuary, which is subject to storm surges resulting from a combination of strong north-west winds and low atmospheric pressure systems over the Southern Ocean. These form "King Tides", though rare, which are much higher than the predicted tides and have been responsible for inundations in the low-lying areas of the Port (McCarthy et al. 2006, p. 56; Reid 1987, p. 29). It has been documented that 'in the early days in the port, even a moderate spring tide was sufficient to swamp the inhabited areas' (Couper-Smartt 2003, p. 26).

The authorities and developers were aware of the high-water threat from the inception of Port Adelaide, and therefore, flood hazard mitigation has been practised for many years. In 1840, the port was officially sited at "New Port", i.e., the current Inner Harbor, away from the "Old landing place", the muddy and dusty Port Misery (Figure 4.2). Efforts to protect the settlement have continued over generations, accompanied by improvements in access to the port. Largely based on the current suburb of Port Adelaide, the flood-relief measures have been documented as follows (Hartshorne 2001; Reid 1987; Ritter 1996):

- dredging the Port River to facilitate navigation;
- using the dredged silt to raise land levels;
- using the dredged silt to construct embankments or levees;
- land-filling creeks; and
- dredging canals

Due to these flood-relief efforts, confidence increased, documented in a number of historical studies:

Figure 4.2 Old Landing Place and the New Port in 1840

Source: Potter (1999, p. 5)

- ‘By 22 June (1865) the bank along The Minories had reached the height of seven feet and was able to withstand any tide… Despite this, minor flooding continued at the Port well into the twentieth century.’ (Reid 1987, p. 36)

- ‘Virtually all of Port Adelaide is now well above sea-level, although the Birkenhead Tavern occasionally has to resort to sandbags’ (Couper-Smartt 2003, p. 26)

- ‘Every boundary of Port Adelaide had been secured by a mud seawall a century earlier,…The continual raising of the soil level eventually meant the last embankment was no longer necessary’ (Hartshorne 2001, p. 11)

During this time, the Port continued to grow steadily and through the boom years (1860 to 1890) population increased almost five-fold (to about 5000 in the 1891 Census) (Reid 1987, p. 36). In addition to the construction of port facilities, at least 18 bridges had been built in the study area by the 1990s (Ritter 1996). The history of the “commodious harbour” (till the 1960s) recorded booms in infrastructure and industry as a decisive force in stabilizing the economy of South Australia. A number of other achievements as milestones in the development of Port Adelaide are as follows (Couper-Smartt 2003, pp. 87-102,183-196,211-234; Hartshorne 2001, pp. 84-85; 2005, pp. 30-54):

- Rail line from Adelaide reached the Port in 1856
- Port Adelaide Institute opened in 1859
- First major long-distance telephone call in Australia was made from Semaphore to Port Augusta in 1878
- The Port’s first tram line started in 1879
- Gas street lighting started in 1881
- Telephone exchange started operation in 1883
- South Australia’s first power station was built in 1898 in Nile Street
- Outer Harbor railway stations built in 1908
- Outer Harbor’s deep-water berths came into service in 1908
- Osborne power station started production in 1923
- Wharf reconstruction during the 1920s and 1930s
- The “Greater Port Adelaide Plan” was released in 1949, outlining further expansion of the Port, including the West Lakes and North Haven projects
- Basic infrastructure (i.e., domestic services of water mains, deep drainage and sewer mains, bus services, libraries and post offices) was extended to the Lefevre Peninsula (Outer Harbor and Taperoo) during the 1950s
- In the 1960s, containerisation in Outer Harbor, new methods of large-scale handling cargo and the trend of preferring road transport rather than railways shifted the centre of port activities from Inner Harbor to Outer Harbor

In summary, Port Adelaide experienced continual harbour growth from its inception to the 1960s. Flood hazard mitigation in the early stages fundamentally secured its prosperity. In the Inner Harbor in 1959, approximately the time of its peak prosperity in the 20th Century, the waterfront was almost fully occupied with wharves, shipyards and storages, as well as large-size factories as shown in Figure 4.3.

Figure 4.3 Inner Harbor, Port Adelaide in 1959

Source: Author, photo imagery from the South Australian Government

4.2.2 "Rejuvenating the Port"

Since the 1960s, the Inner Harbor's commercial activities have steadily moved downstream and consequently most of the traditional industries along the Port River banks were forced to close or relocate interstates/overseas, leaving behind seriously polluted lands and large buildings vacant with an uncertain future. The biggest impact was upon the local workforce with year by year unskilled jobs vanishing on the wharves. The lack of jobs inevitably led to declined population growth, with widespread social repercussions. At the end of last century, Port Adelaide was eventually described as “little more than a social welfare dispensary with hotels and a few supermarkets appended” (Couper-Smartt 2003, p. 422; Hartshorne 2001, p. 53). Comparing Figure 4.3 with Figure 4.4, the latter shows many big enterprises had disappeared and there are now large areas of vacant land at the same sites where the swamps prone to tidal flooding were found at initial settlement.

Figure 4.4 Inner Harbor, Port Adelaide in 1997

Source: Author, photo imagery from the South Australian Government

The idea of rejuvenating the port was first publicly discussed in the mid 1970s, followed by numerous plans for redevelopment. Some proved to be controversial among stakeholders, such as the land zoning policy in the 1962 Adelaide Metropolitan Development Plan (Town Planning Committee 1963, p. 291). More recent milestone projects have also not been very successful, such as the retail expansion in the 1980s and the Newport Quays waterfront development in 2000s. It appears that after three decades, Port Adelaide is still struggling to find its orientation in a changed world, and many of the renewal plans were considered not to be thought through or workable in practice (Couper-Smartt 2003, p. 421; Hartshorne 2001, p. 53).

4.3 Flood Problems: a Glimpse

Port Adelaide prospered from its establishment until its modernisation in the 20^{th} century, largely owing to the effective strategies for mitigating flood problems. This section examines the historical records of floods and provides an overview of the problems. Specifically, the consequences of seawater flooding (caused by king tides) were illustrated by the disastrous floods in 1865. Modern impacts of king tides were represented by photo images of recent minor floods at the waterfront of the Inner Harbor, as well as the inundation of the low-lying area in Birkenhead.

4.3.1 The "Great Floods"

The inundation and deaths at Port Adelaide on 12 May 1865, was probably the most destructive in the Port's history, as shown in Figure 4.5. Unlike the inrush of sea through the levees which previously happened in 1851 and 1859, a break in the sandbag wall in 1865 was the main cause, which was a combination of a high tide, storm surge and heavy rainfall. Most of the Port was flooded with water depth up to 2m within some of the inundated houses. Although the Portland embankments held firmly on that occasion, the Portland Estate was inundated by rain to a depth of 1.5m (Hartshorne 2001, p. 9).

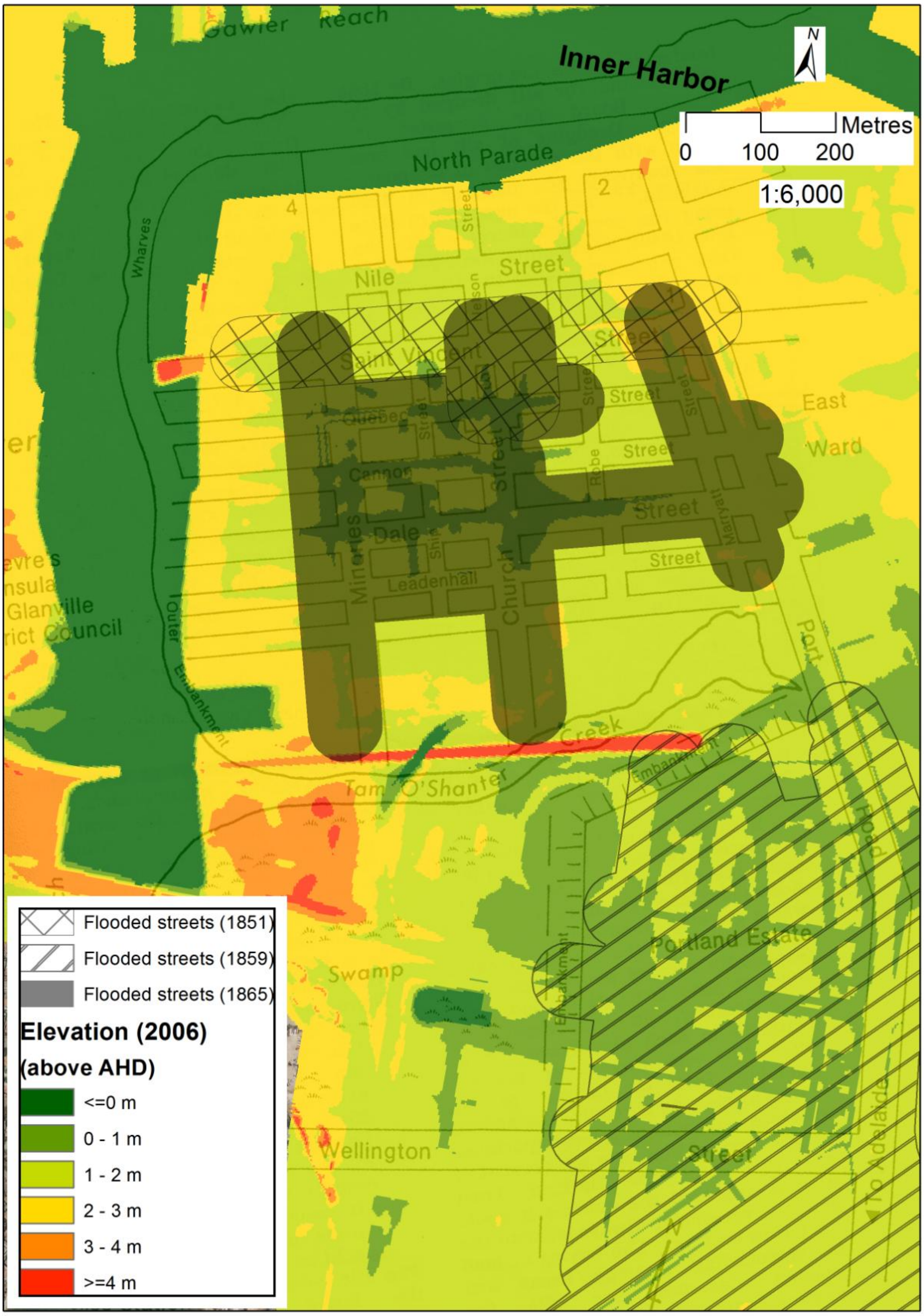
Figure 4.5 The inundation at Port Adelaide on 12 May 1865

Source: Imagery from McCarthy et al. (2006, p. 52)

Figure 4.6 illustrates the inundation based on a number of data sources, including a map of the 1865 flood by Reid (1987), a 2010 photo image from the State government and the recent elevation (2006) of Port Adelaide. The streets flooded were also marked up on the overlaid maps. Those three flood events were termed “the Great Floods”, which occurred within a 15 year period, demonstrating a number of features as follows:

- The 1859 flood overflowed most of the area of the old Portland Estate, extending further south to Queenstown and east to Port Road (Couper-Smartt 2003, p. 59; Hartshorne 2001, p. 5)
- Central areas of the Inner Harbor along Saint Vincent Street were inundated in the 1851 flood (McCarthy et al. 2006, pp. 50-56; Rogers 2009, pp. 5-15).

Figure 4.6 "the great floods" and elevation (2006) in Port Adelaide



Source: Author, data from PAE(C), the State government and Reid (1987, p. 31)

- Low-lying areas behind the elevated high grounds (wharfs and embankments) were flooded during the Great Floods.
- A strong correlation exists between these inundated areas and their elevation, emphasising that ground level is critical to flood risk mitigation.

4.3.2 Records and statistics

Table 4.1 shows the floods within the study area, assembled from a number of relevant studies (Couper-Smartt 2003; Hartshorne 2001; McCarthy et al. 2006; Reid 1987; Rogers 2009). These studies, based on text reviews of newspapers and other historical publications, have revealed that floods occurred every few years. In particular, they identify a number of causes of floods: a combination of tides, wind and storm surges (43.5%); concurrent drainage problems; and rainfall (67.4%). Rainfall was responsible for more than 2/3 of the floods recorded. The few figures for flood depth indicate the consequences of those flood events.

Since the 1930s, records from tidal gauges in Port Adelaide have been available for most of the following years as scientific observations for analysing determinants of sea-level extremes and impacts on the study area. Based on the data and consultant information provided by the National Tidal Centre (BOM), the following summary presented in Table 4.2 shows the highest ten sea levels that occurred at Inner Harbor and Outer Harbor till the end of 2012 (BOM 2013; Chittleborough 2011; Davill 2009, 2013).

Table 4.1 Summary of floods within the study area before 2005

Date	Suburbs	Causes	Flood depth
17/06/1851	ALBERTON	Tides, storm surge	
17/06/1851	PORT ADELAIDE	Tides, storm surge	
16/05/1859	PORT ADELAIDE	Tides, storm surge	
12/05/1865	PORT ADELAIDE	Tides, storm surge, heavy rain	2 m
13/05/1865	PORT ADELAIDE	Tides, storm surge	1 m
19-31/07/1872	PORT ADELAIDE	Heavy rain	
8-14/05/1875	PORT ADELAIDE	Heavy rain	
12/05/1875	DRY CREEK	Heavy rain	
11-12/06/1878	ALBERTON	Heavy rain	
26/07/1883	SEMAPHORE	Rain, gale	
12/05/1888	PORT ADELAIDE	Tides, storm surge	
01/01/1889	PORT ADELAIDE	Rain	
17/04/1889	GLANVILLE	Heavy rain	
05/02/1890	DRY CREEK	Heavy rain	
25/03/1899	GLANVILLE	Heavy rain	
10/07/1904	PORT ADELAIDE	Heavy rain	
17/11/1907	PORT ADELAIDE	Rainfall	
17/11/1907	SEMAPHORE	Rainfall	
26/08/1909	DRY CREEK	Heavy rain	
13/02/1913	PORT ADELAIDE	Heavy rain	
13/02/1913	SEMAPHORE	Heavy rain	
15/05/1915	SEMAPHORE	Tides, storm surge	
15/05/1915	BIRKENHEAD	Tides, storm surge	0.75 m
21/06/1916	PORT ADELAIDE	Heavy rain	
29/06/1916	PORT ADELAIDE	Tides, storm surge, backflow of drains	
02/08/1923	DRY CREEK	Heavy rain	
22/09/1923	PORT ADELAIDE	Heavy rain	
22/09/1923	ROSEWATER	Heavy rain	
1933	PORT ADELAIDE	Heavy rain	
12/12/1938	ETHELTON	Tides, storm surge	
12/12/1938	PORT ADELAIDE	Tides, storm surge	
13/12/1938	PORT ADELAIDE	Tides, storm surge	
11/04/1948	GLANVILLE, CENTRAL PORT ADELAIDE, PORT ROAD	Backflow of storm tides via drains, heavy rain	
02/06/1965	PORT ADELAIDE	Tides, storm surge	
19/03/1967	ETHELTON	Water from the Port River	0.6 m
26/06/1981	DRY CREEK	Heavy rain	
15/10/1985	PORT ADELAIDE	Sudden rainfall	
25/05/1994	PORT ADELAIDE	Tides, storm surge, heavy rain	
25/05/1994	SEMAPHORE	Tides, storm surge, heavy rain	
23/06/1994	BIRKENHEAD	Tides, storm surge, rain	
12/01/1998	SEMAPHORE	Heavy rain	
07/02/1998	PETERHEAD	Heavy rain	
27/07/1998	PORT ADELAIDE	Tides, storm surge	
28/07/1998	PORT ADELAIDE	Tides, storm surge	
06/08/1998	PORT ADELAIDE	Heavy rain	
22/03/2000	OTTOWAY	Heavy rain	
21/06/2000	PORT ADELAIDE	Tides, wind, heavy rain	
09/12/2004	LARGS BAY	Heavy rain	

Source: Author, based on McCarthy et al. (2006) and other cited documents

Table 4.2 Highest sea levels in Port Adelaide

Inner Harbor					Outer Harbor				
No.	year	month	metre (AHD)	ARI	No.	year	month	metre (AHD)	ARI
1	1981	7	2.327	1/50	1	2007	7	2.255	1/50
2	1995	7	2.307	1/50	2	1981	7	2.227	1/50
3	2009	4	2.3	1/20	3	2009	4	2.202	1/50
4	2011	5	2.272	1/20	4	1981	6	2.127	1/20
5	1994	5	2.227	1/20	5	1995	7	2.117	1/10
6	1999	6	2.211	1/20	6	1960	5	2.097	1/10
7	1981	6	2.207	1/20	7	1999	6	2.096	1/10
8	1972	6	2.177	1/10	8	2000	6	2.062	1/10
9	2000	6	2.151	1/10	9	2011	5	2.06	1/10
10	1945	6	2.137	1/10	10	1953	5	2.037	1/10

Source: Author, aggregated data based on Davill (2009, 2013)

Despite some data limitations (such as absent data in some years) (Davill 2008), these tidal records show a number of characteristics associated with high sea levels and the specific local variations between Inner Harbor and Outer Harbor:

- 1-in-50-year high sea levels occurred 2-3 times in the past 50 years
- 1-in-20-year high sea levels occurred 5 times at Inner Harbor in the past 20 years, compared to 1 time at Outer Harbor
- The difference of ARI sea levels at Inner Harbor and Outer Harbor
- During each event, sea levels at Inner Harbor were generally higher than those at Outer Harbor
- High ARI sea level occurred at Outer Harbor that did not necessarily correspond to a high ARI sea level at the Inner Harbor (such as in July 2007 and June 1981)

4.3.3 Floods by "King Tides"

Low-lying areas in Port Adelaide are subject to inundation due to high tides, which are generally termed "King Tides", if protective structures (like levees or sea walls) are ineffective. One of those well known sites is the Birkenhead Tavern as shown in Figure 4.7, which has consistently experienced seawater flooding over time.

Figure 4.7 Birkenhead Tavern (left) and Cruickshank's Corner, looking toward North

Source: Author

The photo images displayed as follows depict the consequences of seawater flooding in areas of Port Adelaide, during high sea-level events in 1995, 2011, 2009 and 2007 respectively. The B&W photo (Figure 4.8) shows Port River (seawater) breaking its banks and inundating Birkenhead Tavern and the surrounding area in July 1995, looking towards the south. This storm-induced king tide was a 1-in-50-year event at Inner Harbor, due to low atmospheric pressure and strong westerly winds. This storm surge event in 1995 was substantial, as it was only a 1-in-10-year event at Outer Harbor. The colour photo at the lower proportion of Figure 4.8 was taken during a normal tide in 2012 for comparison.

In July 1981, another 1-in-50-year event occurred not only at Inner Harbor, but also at Outer Harbor. A water level of 1.5 metres above the forecast tide was recorded (Harvey and Caton 2010, p. 30).

Figure 4.8 Flooding at Birkenhead Tavern in July 1995 (top photo)

Source: Photographs by Martin Lewicki
(https://www.facebook.com/martin.lewicki.3/posts/10151676168999508#_=_)

On 22 May 2011, strong winds and high tides hit the Inner Harbor and caused a 1-in-20-year water level rise of the Port River. Figure 4.9 (right photo) depicts inundation in Jenkins Street, while looking from the opposite bank of the Port River, the left photo shows the extended reach of the captured seawater and the nearby houses on the edge of flooding, given that the high water was 1.25 metres above the predicted tide level (Denny 2011).

Figure 4.9 High water and inundation at Inner Harbor on 22 May 2011

Source: Photographs by Sue Lawrie (http://blogs.abc.net.au/sa/2011/05/the-king-tide-of-may-2011.html)

On 25 April 2009, storm and king tides caused a 1-in-20-year event in Inner Harbor and induced wide-spread inundation due to seawater either directly flooding from the Port River or flowing back from the drainage systems. Figure 4.10 (left) displays the high water level, compared with a normal tide level (right) at Harbour-side Quay, looking from the opposite river bank at Newport Quays. Just a few hundred metres away on the south bank of the Port River, Figure 4.11 (left) shows Queens Wharf was inundated. The intersection of Nelson St and St Vincent St (facing south to St Paul's Anglican Church) was flooded by seawater from drainage systems (right).

Figure 4.10 Water levels at Harbour-side Quay on 25 April 2009

Source: Photographs by Des Neville (http://www.dailytelegraph.com.au/gallery-e6freuy9-1225705408089?page=13)

Figure 4.11 Queens Wharf and Nelson St on 25 April 2009

Source: Photographs from PAE(C)

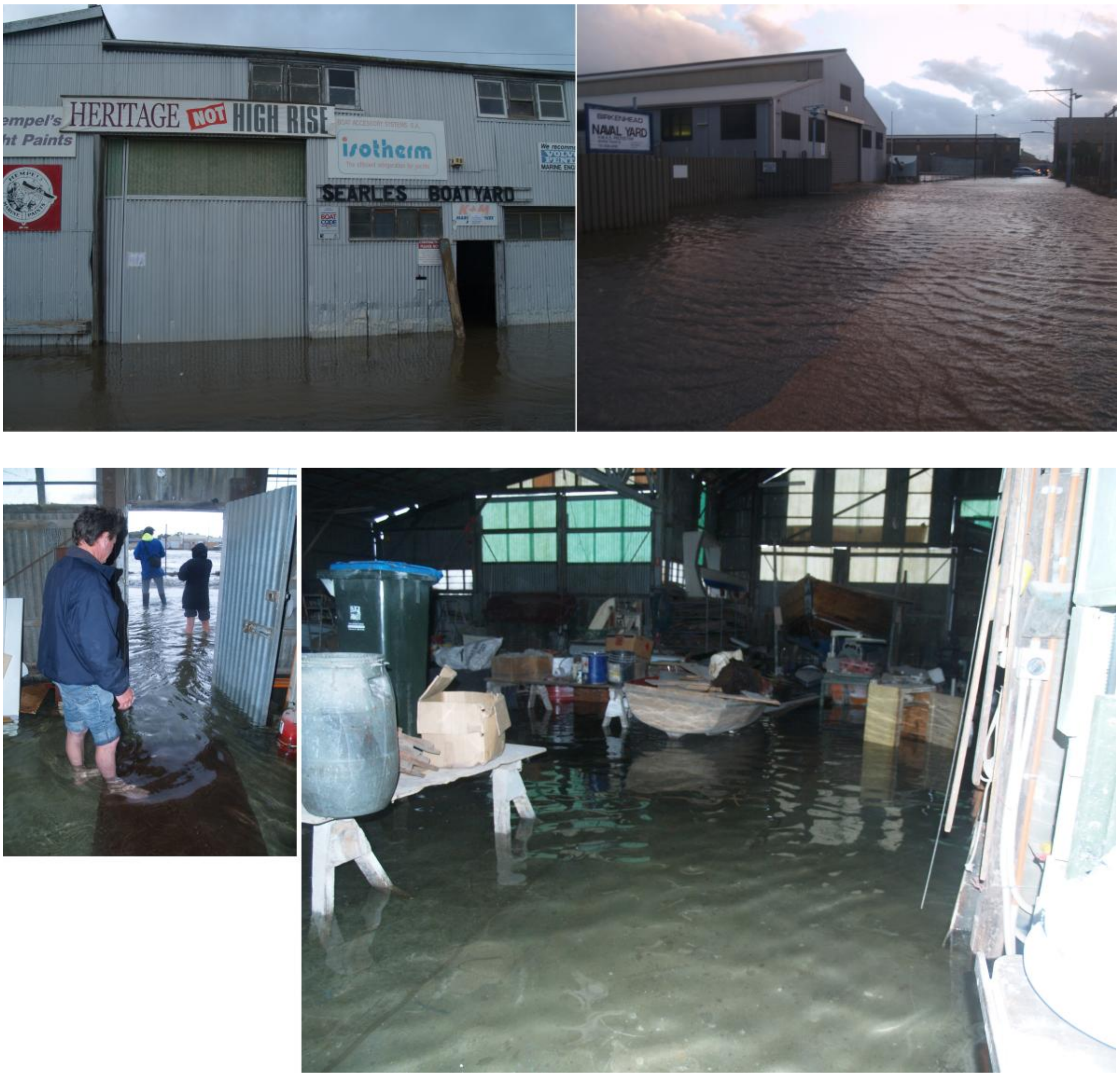
Figure 4.12 shows the General Motors Holden site (left top) and Fletcher's Slip (right top) were flooded, together with a contaminated stockpile removed from the nearby Newport Quays development. The flood went further up to Jenkins Street as shown in Figure 4.12 (bottom).

Figure 4.12 Jenkins Street and adjacent areas were flooded on 25 April 2009

Source: photographs from Tony Kearney

Figure 4.13 shows boatyards Searles (left top) and Naval (right top) were surrounded by flood, while inside Searles (bottom) was inundated throughout, impeding business activity.

Figure 4.13 Seawater inundation at Searles and Naval on 25 April 2009



Source: Photographs from Tony Kearney

Figure 4.14 illustrates the proximity of the contaminated stockpiles, Fletcher's Slip and Newport Quays (left, the cluster of multi-story residential properties), highlighting complex issues in Port Adelaide, such as the wide concerns of environment contamination, loss of heritage sites and heightened flood risk in new developments.

Figure 4.14 Photo taken after the flood on 25 April 2009 at Fletcher's Slip

Source: Photograph from Tony Kearney

4.4 The Problematic Drains

In Port Adelaide the flood problems are complex for a number of reasons, specifically the interaction of seawater and storm water in the drainage systems. This section highlights the main issues of the problematic drainage systems, including their performance during high tides and heavy rains respectively.

4.4.1 Seawater back flow

In Port Adelaide, seawater back flow happens in areas behind wharfs during high tides. Figure 4.15 (left) shows Hughes St (near Fletcher Rd) in Birkenhead was flooded by seawater back flow from storm water drainage systems in 2009, while the photo (right) shows flooded May St in the same area.

Figure 4.15 Seawater back flows in Birkenhead on 25 April 2009

Source: Photographs by Breton Coppick (http://www.heraldsun.com.au/news/photos-e6frf7jo-1225705408089?page=7)

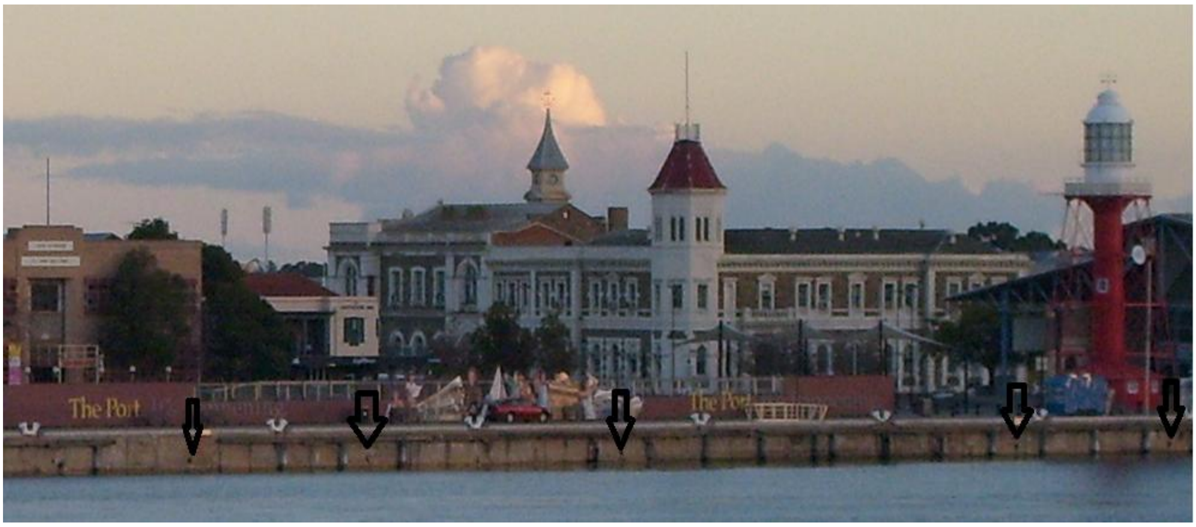
Even more frequent sea-level events can cause inundation due to the drainage problems, as much of the area in Port Adelaide is below high-tide levels, and the performance of old drains is dependent on the tidal levels. The Advertiser (the Australian daily newspaper) released a photo of Inner Harbor, as shown in Figure 4.16, indicating that flooding at Torrens Place, around the intersection of Nelson Rd and St Vincent St (facing) was caused by a 1-in-5-year king tide, which resulted in traffic restriction.

Figure 4.16 Torrens Place on 28 October 2007

Source: Photograph from Mike Burton (http://www.adelaidenow.com.au/news/south-australia/port-hit-by-king-tide/story-e6frea83-1111114747798)

Figure 4.17 pinpoints the outlets of the drainage systems on the side of McLaren Wharf. These outlets are exposed during low tides for releasing storm water. But they are submerged by the river during high tides, causing floods in the adjacent streets because of the back flow of seawater from the elevated river.

Figure 4.17 McLaren Wharf: outlets of storm water drainage network



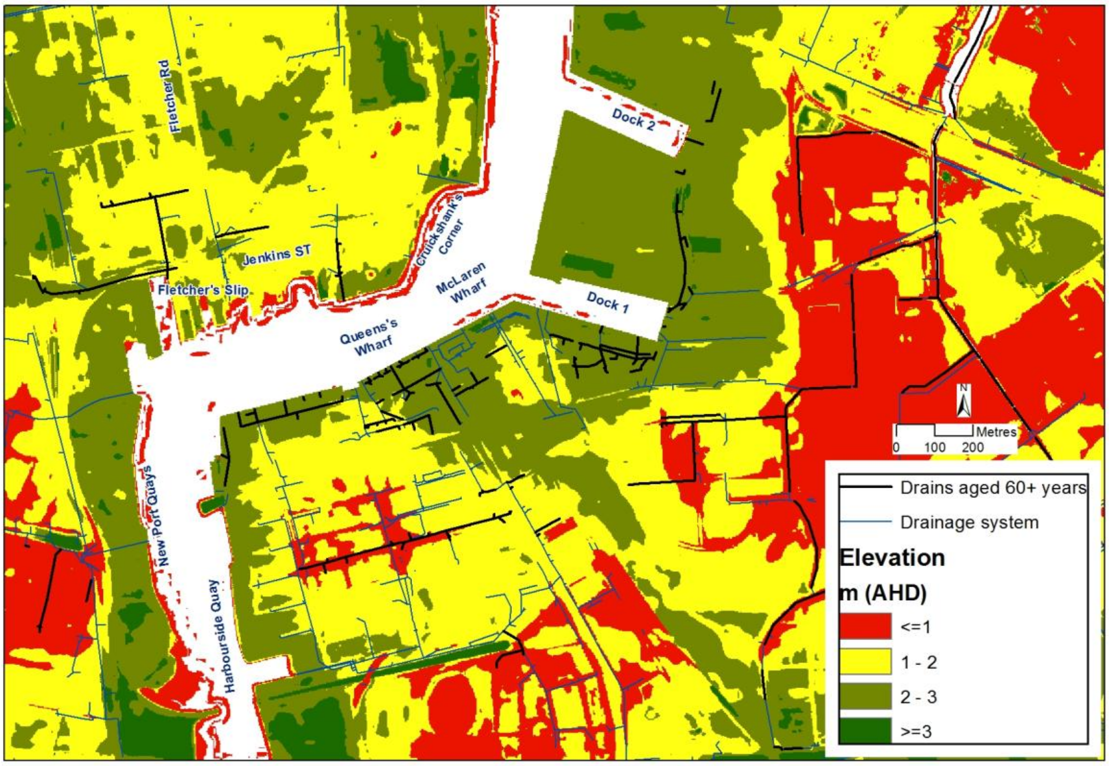
Source: Author

4.4.2 Outdated drains, elevation and sea level

As demonstrated in Table 4.1 and Figure 4.16, the old drainage systems in some areas of Port Adelaide have failed to protect against floods during heavy rains and high tides. According to Dearman (2010) and Iasiello (2013), Port Adelaide's drains were based on a gravity system down to the Port River. As some networks were constructed before the 1950s, they had capacity below contemporary standards for handling excessive storm water run-off during torrential rainfall, and regularly some parts of the drainage systems are overloaded. Some of the old drainage systems are shown in Figure 4.18.

It is argued that back-flow problems increase during high tides. If land subsidence within the study area is taken into account, the overflow of water (seawater mixed with storm water) could be even worse (Belperio 1993; Jacobi and Syme 2005a).

Figure 4.18 Inner Harbor: old drainage systems and elevation



Source: Author, based on data from PAE(C) and the South Australian Government

4.4.3 Storm water flooding in Feb 2014

The floods of 13-14 Feb 2014 in Peterhead have drawn attention to issues of storm water flooding, low-lying areas and the capacity of local drainage facilities. In this wettest 24-hour period in Adelaide since 1969, Port Adelaide had 84 millimetres of rain. ‘It was estimated to be a 1 in 20 year event and obviously the system could not cope …’ (PAREPG 2014). About a dozen of houses were flooded in Mary, Alfred and Walton streets, despite sandbags being put around many properties to keep out the rising water.

The impacts were reported by the media as follows.

> 'PETERHEAD residents could have been forgiven for thinking they had woken up on a house boat on Friday morning as torrential rain flooded their homes and streets. Many houses on Mary St, Alfred St and Walton St were flooded inside and out, while the streets resembled a river by 6am this morning… Many parked cars on the streets were submerged in flood water up to 1m deep… Walton St resident … said it was the second time in 20 years it had happened… <u>It took about six months to dry out and everything had to be gutted and it took about a year to get it right again… Now we're starting that all over again</u>… another downpour later today would create more flooding inside the house… We can't do anything until it subsides… We've lived here for 20 years and it happens when it rains a lot, but not this bad… A lot of the walls will be ruined… <u>Fire crews were on scene for most of the morning at Peterhead pumping water out from the streets, while police closed the roads to traffic</u>… Some homes in nearby Semaphore also experienced flooding …' (Harris 2014).
>
> '… (4 residents) have only just returned to their home in Alfred St after the flooding in February… the lower half of their split-level house has to be rebuilt after water cracked the walls and ruined the floorboards… concerned it would happen again between now and 2017 … <u>If this is an ongoing thing, what's the point of fixing the place?</u> …' (Boisvert 2014a).
>
> (A resident) 'whose home was flooded, said her <u>insurance company was considering demolishing the house</u>…' (Boisvert 2014b).

A number of issues have been highlighted:

- The consequences of floods that affected victims' adversely
- The duration of the impact and recovering
- Victims doubted the government response, given that floods had occurred before
- Some victims placed hope on flood insurance

4.5 Local Understanding of Flood Risk

As introduced earlier (Section 1.3), the Port Adelaide 2005 Flooding Study was a joint State and local government initiative in assessing flood risks from both seawater and storm water in Port Adelaide, based on the best data available in 2005, as well as the SLR scenarios from the TAR (IPCC) released in year 2001 (DCC 2009; Renewal SA 2012). Its hydraulic models (Jacobi and Syme 2005a, pp. 17-27) were transformed for creating inundation surfaces in the current study using updated sea-level-rise projections. PAE(C) has committed to improve the public drainage systems to mitigate the urgent threat from storm-water floods (Iasiello 2013). A summary of recent efforts include:

- Increasing the capacity of drainage systems to help discharge storm water to the Port River during rainfall events, by constructing new pumping stations and holding basins;
- In coalition with the State Emergency Service (SES), supplying sandbags to residents if notified prior to a storm event, to minimise the impact of floods;
- Western Adelaide Region Climate Change Adaptation Plan (Hancock 2013);
- With funding support from the Adelaide and Mt Loft Ranges Natural Resource Management Board, developing storm-water management plans (e.g., Lefevre Peninsula Stormwater Management Plan) for catchments in the Council area and shared with other City Councils

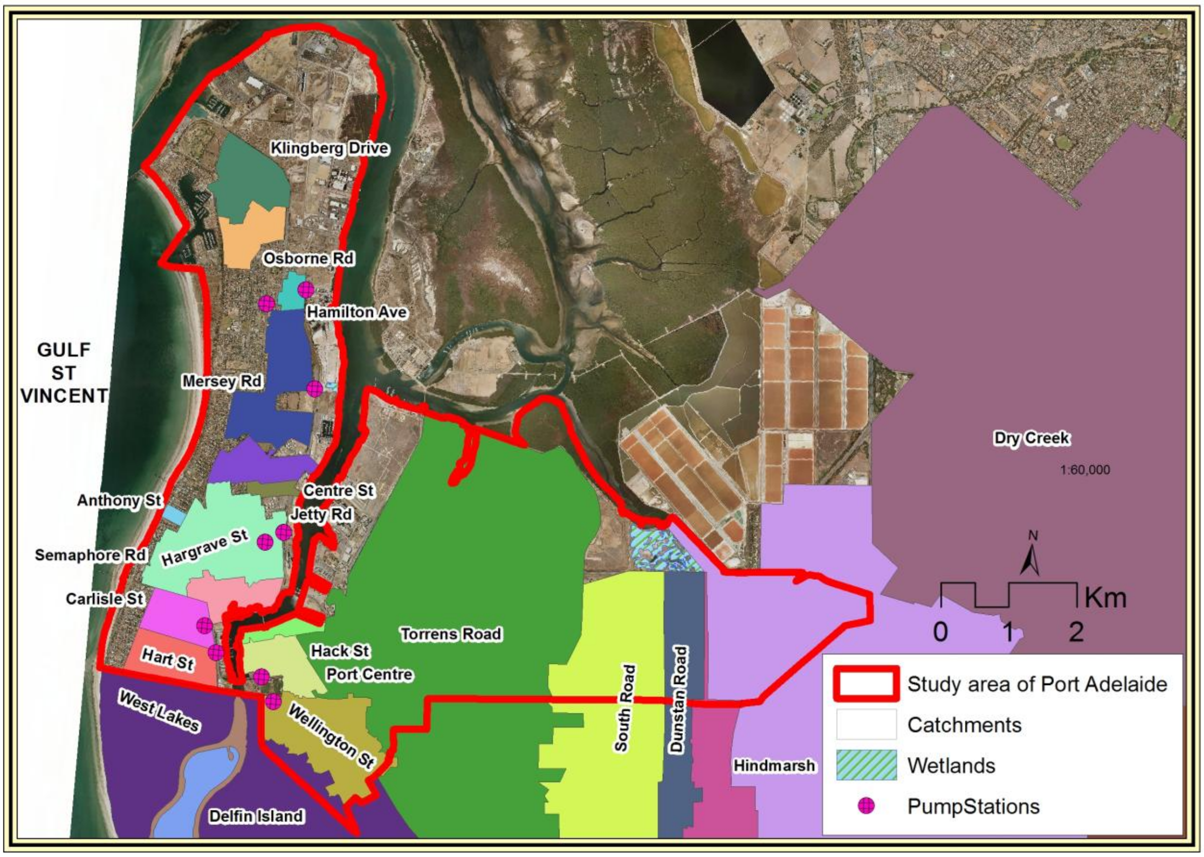
4.5.1 Storm-water catchments

There are five kinds of stormwater management strategies in this region (Iasiello 2013): gravity, pumped, private, soakage, and dune discharge. Privately owned catchments are those that belong to large industrial enterprises along the western bank of the Port River. PAE(C)'s storm-water management has focused on the gravity and pumped catchments, which include the following 21 catchments within the study area, as shown in Figure 4.19:

- Anthony Street catchment
- Carlisle Street catchment
- Centre Street catchment
- Dunstan Road catchment (part of)

- Hack Street (Port Adelaide Pump Station) catchment
- Hart Street (Ethelton Pump Station) catchment
- Hargrave Street (Peterhead Pump Station) catchment
- Hamilton Avenue catchment
- Hindmarsh catchment (part of)
- Jetty Road catchment
- Klingberg Drive catchment
- Lulu Terrace catchment
- Mersey Road catchment
- North Arm East catchment (part of)
- Osborne Road catchment
- Port Centre catchment
- Semaphore Road catchment
- South Road catchment (part of)
- Torrens Road catchment (part of)
- West Lakes catchment (part of)
- Willington Street (Pump Station) catchment

Figure 4.19 Major storm-water catchments in the study area



Source: Author, data from PAE(C)

These storm water catchments, together with wetlands, environmental preserves (parks, ponding basins and open spaces) and soakage areas, are critical to storm water management and flood risk mitigation. The key points of PAE(C)'s storm-water management (Elliott 2015; Elliott and Wood 2015; Iasiello 2013) in the study area include, but are not limited to, the following:

- Storm water is generally discharged to the sea, the Port River or West Lakes
- There are a number of large pumping stations and holding basins for helping in the discharge of storm water to the Port River during rain fall events
- Storm water run-off is increasing due to urban consolidation, rising building densities, more paved areas and reduced open space
- The quality of water entering the storm-water system is decreasing
- PAE(C) is committed to mitigating flood risks to the public and private properties from storm water and seawater
- PAE(C) is committed to reducing the amount of pollution passing through the storm water system and into the natural waterways

4.5.2 Flooding hotspots

Major flooding (or ponding) of storm water is known to occur throughout the study area. Streets, roads or properties/homes have been adversely affected, depending on the on-site circumstances when the floods occur. The most troublesome flooding hotspots include, but are not limited to the following (City of Port Adelaide Enfield 2014b; Elliott 2015; Elliott and Wood 2015; Iasiello 2013):

- **Carlisle Street catchment:** Swan Terrace, Bucknall Road, Exmouth Road, Mellor Road and Stewart Street in <u>Glanville</u>
- **Hack Street (Port Adelaide Pump Station) catchment:** Old Port Road and Church Street underpass in <u>Port Adelaide</u>
- **Hart Street (Ethelton Pump Station) catchment:** Emu Street, Freer Road, Hanson Street and Robin Road in <u>Semaphore</u>; Graham, Victoria and Rosetta Street in <u>Glanville</u>; Mary Street, Swan Terrace and Carlisle Street in <u>Ethelton</u>; Nazar Reserve in <u>Semaphore South</u>
- **Hargrave Street (Peterhead Pump Station) catchment:** Hargave Street in <u>Peterhead</u>; Woolnaugh Road and *Hall Street* in <u>Semaphore</u>
- **Hamilton Avenue catchment:** Hamilton and Bridges Avenue in <u>Osborne</u>
- **Lulu Terrace catchment:** *Adelaide* and Olive Street in <u>Largs Bay</u>; *Wills*, Mary, Alfred and Walton Street in <u>Peterhead</u>
- **South Road catchment (part of):** Millers Road in <u>Winfield</u>
- **West Lakes catchment (part of):** Jervois Road in <u>Semaphore South</u>

The flooding hotspots were assembled from PAE(C) reports of past flooding events, largely depending on the scale of rainfall events, mitigation measures undertaken and the performance of local drainage systems. For instance, it is reported that the drainage improvement works completed by PAE(C) proved to be very successful in mitigating flooding in the following streets, "which would have flooded" with the heavy rainfall on 13-14 February 2014 (City of Port Adelaide Enfield 2014a, p. 109):

- Coppin and Hall Street, Semaphore
- Magarey and Carnavon Street, Largs North
- Wills and Adelaide Street, Largs Bay
- Lipson Street, Port Adelaide
- Jennifer Street and Gray Terrace, Rosewater

The report further details the intensity of the rainfall event, as well as the functioning of pump stations which were critical to eliminating flooding hotspots:

> '… 35 mm of rain fell on the afternoon of Thursday 13 February and all pump stations adjacent the Port River were operational and only minor street flooding was reported. Approximately 85 to 90 mm of rain fell on Friday 14 February with a more intense fall in the early hours of Friday morning (City of Port Adelaide Enfield 2014b, p. 117).
>
> Friday 14 February 2014: approximately 109 mm of rain, 90 mm between 2.35am and 2.35pm, 63 mm between 2.45am and 8.45am (City of Port Adelaide Enfield 2014a, p. 51).
>
> … The intense rain in the early hours of Friday 14 February exceeded the capacity of the Hart Street, Elder Road, Hack Street and Mersey Road pump stations hence street and property flooding began to occur around 5am …' (City of Port Adelaide Enfield 2014a, p. 108).
>
> '… Flooding of properties and homes occurred in Hanson Street, various streets in Peterhead and Winfield …'(City of Port Adelaide Enfield 2014a, p. 109).

Importantly, the "Rainfall intensity frequency duration analysis" shows records of "period ponding" exceeded an ARI of 50-100 (years) at some pump stations during the rainfall events on 14 February 2014 (City of Port Adelaide Enfield 2014a, p. 52).

4.6 Challenge and Response

Clearly any future change in weather patterns would be a challenge for Port Adelaide residents. However, the history of addressing flood problems has also raised challenges from two fundamental and interrelated perspectives, one practical the other strategic. The former is mainly in relation to feedback from the public, focusing on calls for an effective and integrated approach to reduce or eliminate flood risks. The latter is based on the government planning scheme to minimise the risk of flooding and improve environmental management. This section discusses challenges and innovative options arising from local response to flood risk.

4.6.1 "Freak King Tide" and flood in Birkenhead

The storm tide event on 9 May 2016 was perceived to be "Freak" in Port Adelaide and indeed, it has had exceptional implications. Such a high storm surge and abnormal tides have only been witnessed previously in 2007. But in 2016, the inundation of houses in Birkenhead was first reported by the media, and then validated in the post-survey investigation of this study (refer to Section 3.3). It was found that the incident was not only a surprise, but also deserved a rethink of the causes and consequences.

Some notable impacts across the flood-affected area are as follows:

- Waves crashed over jetties, seawater blocked up roads/streets and the Birkenhead Bridge was closed to traffic due to flooding (Jones and Robertson 2016)
- In Birkenhead, high tides and surges overflowed the Port River bank and under-standard levee, and then filled up the car park of Birkenhead Tavern, crossing over Semaphore Rd and down the road opposite. The floods finally arrived at Walker St

and left 17 properties inundated, as indicated in photos shown in Figure 4.20. The water marks were visible, as highlighted by red arrows.

- In Outer Harbor, the Port River breached a levee bank at Mutton Cove conservation reserve (FMC 2016).
- The issue of inundation due to seawater back-flow (refer to Subsection 4.4.1) reoccurred and started to draw public attention, as indicated by an announcement from the local environment group:

> ‘We reckon the broken flap valve on this drain allows water to flood Hughes St, Birkenhead every king tide’ (PAREPG 2016a).

Figure 4.20 Buildings flooded, Semaphore Rd, Birkenhead on 9 May 2016

Source: Author

Key weather conditions relating to the incident were:

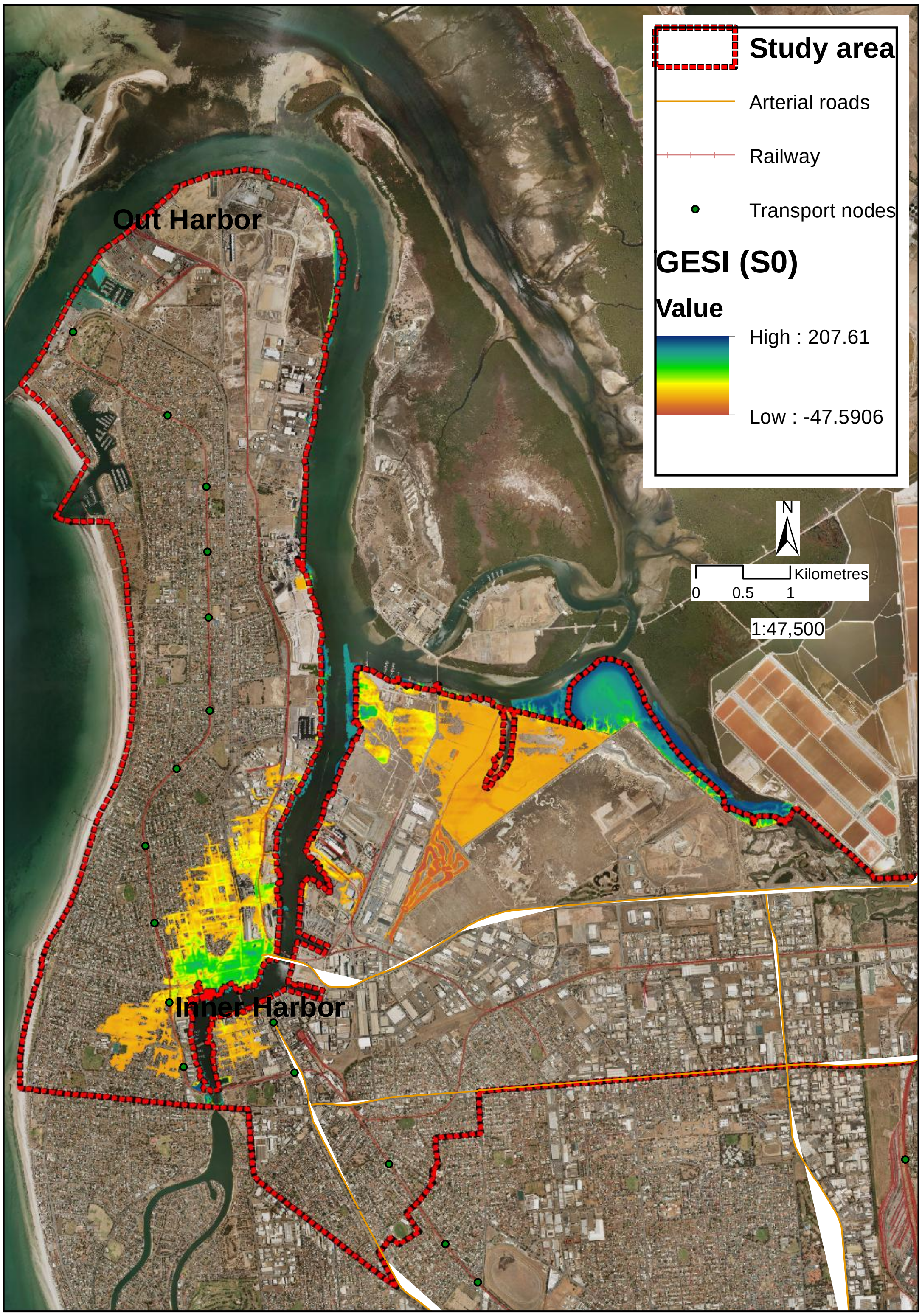
- Intense low pressure system with north-westerly winds up to 100km/h (Jones and Robertson 2016)
- Heavy showers with up to 20 mm rain on western suburbs of Adelaide (Robertson 2016)
- Sea level reached 2.375m (AHD) at Outer Harbor – the highest record with a storm surge peaked at about 1.2m (Davill 2016)
- Water level (Port River) peaked at 2.458m (AHD) at Inner Harbor (Pearce 2016)

Clearly the flooding in Birkenhead was predominantly due to high tides and storm surges, as Walton St and May St in Peterhead, as well as the houses in New Port did not flood and they had storm-water flooding problems before. Peterhead had suffered storm water flooding in 2014 (refer to Subsection 4.4.3) but this time, residents asserted that “the problem was fixed by the Council”. Similarly, the residents in New Port were confident as they were assured that ground levels had been built up.

Therefore this flooding incident was a warning that flood risk from storm tides, were different to the floods caused by heavy rains and storm water. In fact, since then the risk perception of the stakeholders (residents and businesses) were observed to change, calling for urgent flood works around the waterfront in Port Adelaide, specifically in the low-lying areas of Birkenhead (Baseley 2016; Eichler 2016).

As the highest recorded sea levels during the flood event of 9/5/2016 were close to those of the current scenario S0 (refer to Subsection 3.4.3), it is supposed S0 would be a reasonable approximation of the flood. As shown in Figure 4.21, indeed the GESI values (under S0) for the waterfront areas of Birkenhead are highlighted, in consistent with the results from the post-survey investigation.

Figure 4.21 Risk indicator (GESI values) under the current scenario base S0



Source: Author, photo image from the South Australian Government.

An additional issue also arose from the on-site validation of the extent of the flood event. As the sea level record was close to that of the predicted level under scenario S0 (Jacobi and Syme 2005a, p. 27), this storm event provided valuable records for a review of the current ARI (tide) estimates which were based on tidal records at Port Adelaide from 1942 to 1989 (Davill 2009). This work will be critical to understand some uncertainties around the ARI standards, specifically the affect of sea-level rise. Accordingly, a re-calibration of the inundation model under scenario S0 would be beneficial to coastal protection practice.

4.6.2 Seeking effective and adaptive response

Despite the local Council's continuing efforts to reduce flood risks in Port Adelaide, the public is demanding more effective and adaptive solutions (Boisvert 2014a; Boisvert 2014b; Harris 2014). In particular, the pressure comes from the households affected by past flooding events:

> '(A government official) said the pump, set to be in place by January, would not work until those pipes were installed, which would not be until the end of 2016 or start of 2017… "This pump station is designed for a one-in-five-year event so any rain above that, there will be flooding in the street and possibly in a one-in-50-year event there may be flooding in houses"… He said the council had already started some works to reduce the risk of flooding, such as extending the walls of a storm water drainage basin in Mary St and supplying residents with sandbags … the pipes and the pump would substantially reduce flooding in the area.' (Boisvert 2014a, pp. 4,5)
>
> '(A resident whose house was flooded) said … having to wait three years for action was "ridiculous" and residents were worried about a wet winter ahead. "We're going to be in the exact position we were in five weeks ago" ... "They just don't get it."… The flood works project should be put out to tender for businesses to suggest quicker and more effective answers ... the council could do simple things like sweeping streets more often and installing larger stormwater pits to take away excess water… (The resident) … preferred an idea … to buy houses in Peterhead and offer their owners land at Birkenhead Reserve, as reported by the Portside Messenger earlier this month … but (the City Council) had expressed concerns about the loss of open space in Birkenhead' (Boisvert 2014a, p. 3).

The “planned retreat” from flood-prone areas (by an option of “buy-out”) is a controversial proposal with potential for increasing storm-water flows, which in turn off-sets its merits. Other innovative ideas emphasised adaptation to environmental changes, rather than a traditional engineering approach focusing on drainage and pumping. For example, the Living Shoreline approach and the methods of WSUD (Water Sensitive Urban Design) suggesting wetlands and detention basins, as shown in Figure 4.22, need to play an increasing role in storm water management (City of Port Adelaide Enfield 2015; URPS 2015).

Figure 4.22 Detention basins in Peterhead

Source: Images from City of Port Adelaide Enfield (2014a, p. 54)

Despite the response to the flood problems, as reported by the media, inevitably there are complicated issues, including conflicting land uses, taking short- or long-term views, and competing priorities. The challenges require a more sustainable, strategic and comprehensive resolution, as well as joint efforts from both the authorities and the community.

4.6.3 The "buy out" option for Peterhead

As GESI (gravitation-energy surfaces of inundation) (Subsection 3.4.3) provides measuring criteria in high resolution for decision making on flood hazard mitigation at the local scale, the "buy out" option can be quantitatively evaluated by applying the GESI under the current scenario of S0 from the Port Adelaide 2005 Flooding Study, as shown in Figure 4.23.

Figure 4.23 Assessment of the "Buy out" option in Peterhead

Source: Author, photo image from the South Australian Government

Clearly the alternative lands in Birkenhead Reserve (owned by the local government) are exposed to the risk of flooding caused by an event of 1-20-year ARI (tide). For comparison purposes, about 40 houses were selected in Mary, Walton and Alfred streets in Peterhead (top left, Figure 4.22), including those flooded on 13-14 February 2014 (about 6-8 houses). In fact, the values of GESI (S0) for these houses were in the range of 0 to 67 (means of 9 to 51 for each property). On the contrary, the values of GESI (S0) for the Council's lands in the reserve were in the range of 1 to 141 (mean: 89). The increased values of means imply the exposure to risk from sea-level extremes would increase as well.

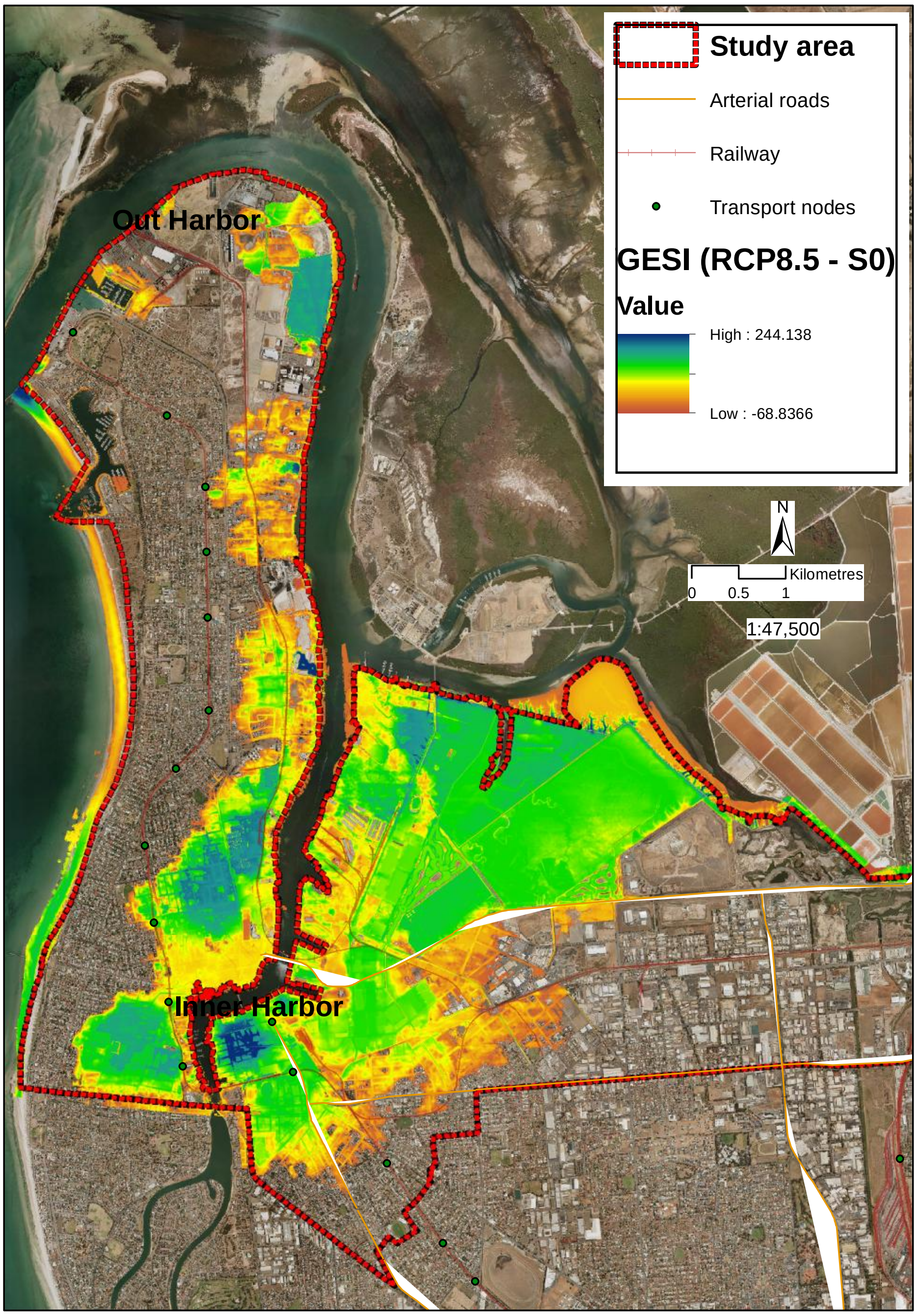
In other words, the suggestion was not optimal, as it meant moving from an area prone to storm-water flooding (1-in-20-year), to another area prone to seawater flooding (either 1-in-20-year or 1-in-100-year). Further, the part of the Council land free of seawater inundation in the reserve (highlighted in green), is limited.

Given that the local land subsidence and sea-level rise are likely to impact simultaneously, the room for the "buy out" option will be further restricted under future scenarios like RCP2.6, RCP 4.5 or RCP 6.0 (Section 3.4). On the other hand, the storm-water flooding problems (which initiated the "buy out" suggestion) need to be modelled and transformed into GESI format. Then an index of occupancy exposure can be formulated, providing support to decision-making in relation to the "planned retreat" or "buy out" option for flood risk mitigation.

4.6.4 Perspectives on sea-level rise

It is surprising that sea-level rise as a potential challenge was not a major concern in the focus-group discussion with local residents. Council officials, too, indicated that sea-level rise was a long-term concern, compared with the much more urgent need to mitigate flood risk from heavy rains. However, the risk can be examined by comparing GESI values (refer to Subsection 3.4.3), i.e., subtracting a current scenario S0 from the worst sea-level rise scenario RCP 8.5 in AR5 (IPCC 2013b, p. 21), as shown in Figure 4.24. It is indicated that Inner Harbor and Peterhead would expect the biggest increase of storm-tide flooding.

Figure 4.24 Increase of risk/GESI values from S0 to RCP 8.5 (late 21st Century)



Source: Author. The underlying photo image is from the State Government.

4.6.5 Planning the future of Port Adelaide

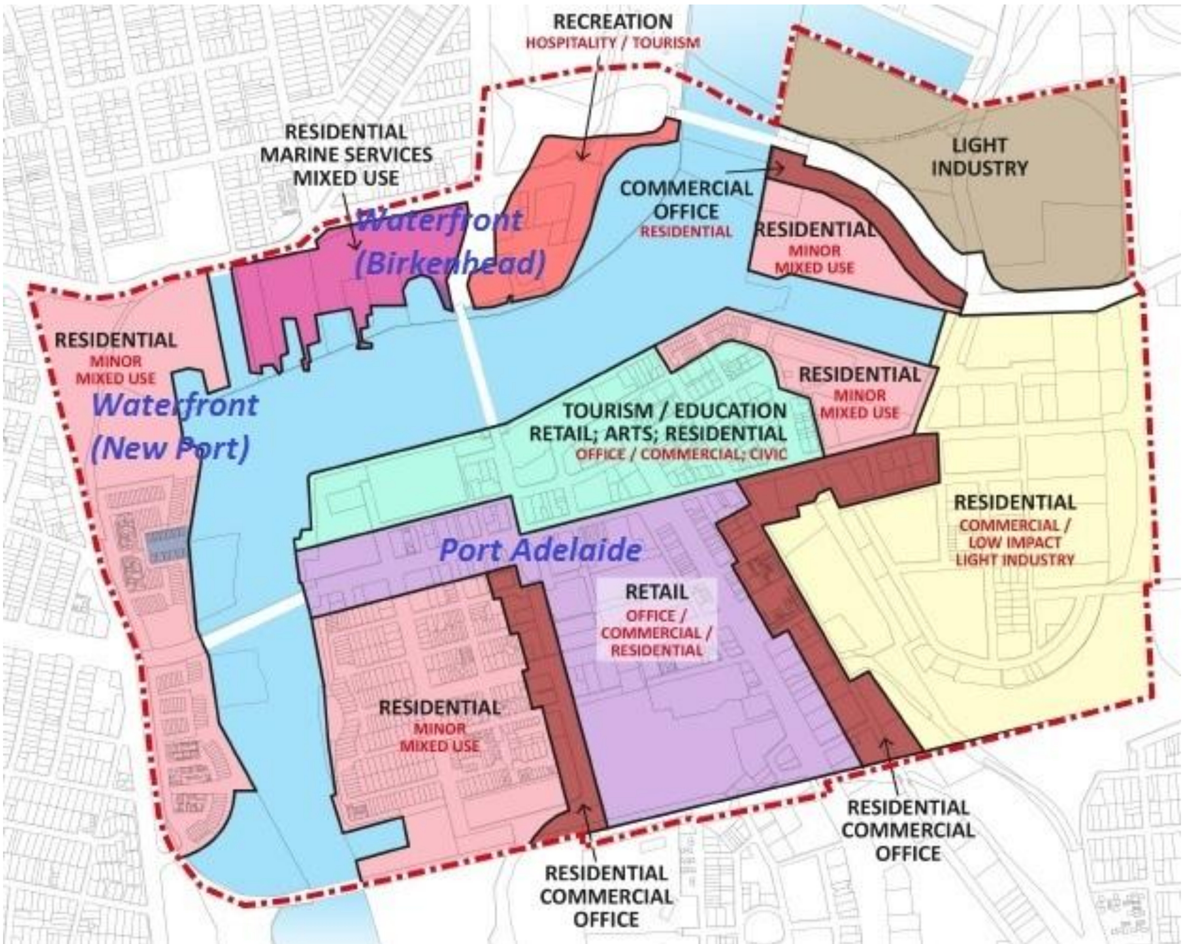
Urban planning is an important response to the flood risk problems. Released in April 2012, the "*Port Adelaide Master Plan: the Review of Background Documents*" provided an insight into the State government's perspective on the revitalization of the Port Adelaide Centre and Waterfront. As a first initiative of the governments' Port Renewal Project, from a broad stakeholders' point of view, the Review summed up the issues which should be considered in the planning stage (Renewal SA 2012).

The review showed that the risk of flooding was beyond the major concerns of the renewal project, though a knowledge gap was identified in relation to understanding the implications of flood risks and sea level rise. Neither the 11 Core Priorities nor the 18 Additional Priorities included any reference to flood risks. The flood issue only appeared in the second last page as the final of 5 "potential constraints to implementation – other constraints".

Although the review adopted the concepts from the Port Adelaide 2005 Flooding Study with regard to the potential sea-level rise impacts on floods, flooding is only the 4^{th} of the "issues to be addressed in (the) master plan (gap analysis)" with a piece of suggestion: 'a further investigation into the implications of the study is needed'. Despite that the review reflected an awareness of a similar level of concern at the same site (the Inner Harbor) where Colonel Light was commissioned to investigate 177 years ago, however, the world has changed since then and a question is yet to be answered: has the flood risk been adequately considered in the planning and development of the area?

As key components in urban planning, land uses in Inner Port were defined in the Port Adelaide Precinct Plan, as shown in Figure 4.25. The plan listed a number of environmental constraints but none related to the risk from flooding (Renewal SA 2014b, p. 23). There was no acknowledgement of any flood issues, including those raised in the surveys of this study which was confirmed by PAE(C) (e.g., the inundation on the waterfront of Birkenhead and storm water concerns in Newport). The plan discussed the waterfront Newport Quays development, but failed to acknowledge any concerns of flooding in the section "Lessons from waterfront renewal projects".

Figure 4.25 Land use in the Port Adelaide Precinct Plan



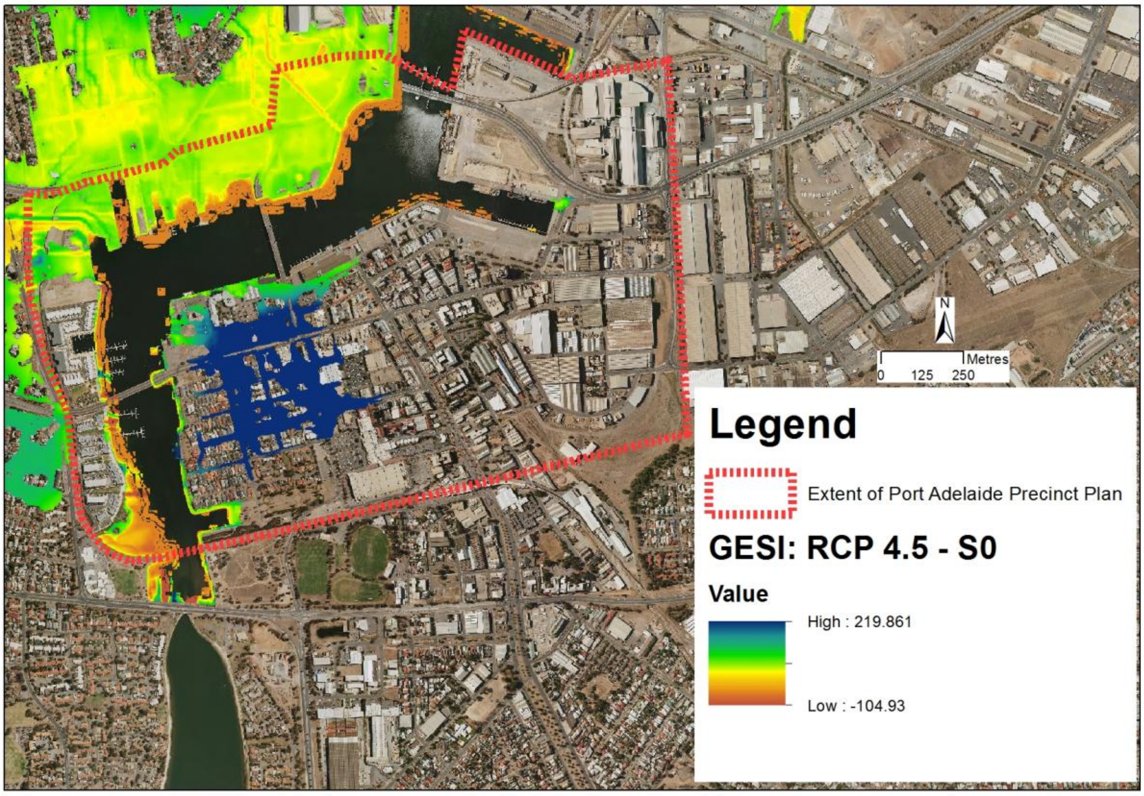
Source: Adapted from Figure 5.2 (Renewal SA 2014b, p. 32)

It should be highlighted that in Port Adelaide, either storm tides or heavy rain can cause flood problems, as shown by the surveys and post-survey investigation. For example, there were witnessed inundations from storm water in New Port, despite the State government flood benchmarks (for high sea levels) were applied in the “Newport Quays development”.

The spatial inundation modelling (refer to Subsection 3.4.2) revealed risks from storm-tides in the areas of the precinct plan as follows:

- Under S0, most of the waterfront (mainly for residential use) in Birkenhead is at risk of inundation, as well as many streets in the historical central area of Port Adelaide.
- Under RCP8.5, flooding would extend to almost all the areas of the waterfront and the central area (mainly for commercial use) of Port Adelaide.
- As indicated by the increasing GESI values, central Port Adelaide would experience severe flooding in future decades, as shown in Figure 4.26. As RCP 4.5 is only a moderate scenario (IPCC 2014, p. 129), mitigation measures and adaptation should not be overlooked in central Port Adelaide.

Figure 4.26 Increase of risk/GESI values from S0 to RCP 4.5 (late 21st Century)



Source: Author. The underlying photo image is from the State Government.

4.7 Conclusion

Port Adelaide is vitally important to South Australia from both economic and environmental perspectives. Over time, it has sought protection against floods through continued efforts, including building up the ground level and embankments. Other strategies of flood mitigation included changing water ways and controlling and redirecting upstream storm water. Recent capital works have focused on new pipes and pumping stations. Fortunately, high sea-level events scaled at 1-in-50-years have been rare and only minor floods from storm tides have been recorded. Thus to date sea-level rise has not been a real concern in the study area.

Floods caused by heavy rainfall have become a more urgent concern and the Council's storm water management is currently the focus. However, residents' demands for a higher level of flood safety have not been met by the drainage-improvement measures. Public debates on the response to floods tend to be mixed with other concerns, such as pollution, responsibility and land policy. There is no doubt that both the public and the local authorities are seeking more effective and adaptive approaches. These call for systematic investigation into the complex problem of flooding to assist with a comprehensive decision-making process.

CHAPTER 5. RISK PERCEPTION OF RESIDENTS

5.1 Introduction

This chapter overviews the survey of resident property owners and discusses the results of the mail-out questionnaire, eliciting risk perceptions in relation to floods from local residents in general, and the property owners in particular. First, it briefly outlines the implementation of the survey, including summaries of survey stages, questionnaire responses and issues raised in follow-up interviews. Then the demographic profile of the survey respondents is introduced by presenting their age-sex structure, level of education and occupation. A comparison with the 2011 Census indicates that the questionnaire responses were representative of the survey population, at the Statistical Area Level 2 (SA2) of the Australian Statistical Geography Standard (ABS 2011).

The questionnaire responses were analysed, utilising both quantitative (e.g., descriptive and inferential statistics) and qualitative (e.g., content analysis) methods introduced in Chapter 3. The respondents' perspectives were summarised as a number of issues and themes, including general concerns, knowledge of floods, and opinions on responsibility, planning policy and risk mitigation options. The associations between risk perception and perspectives on urban development and sea-level rise policy are explored. The barriers to adaptation are also discussed from the point of view of respondents.

The questionnaire was designed to collect information to answer the following questions from property owners:

- How do respondents perceive the risk from sea-level extremes, in the context of environmental concerns?
- Respondent's knowledge of local floods, storm tides and sea-level rise
- What is considered to be an acceptable risk perceived by respondents?
- What are their opinions and expectations about governmental and institutional efforts related to flood risk mitigation?
- What are the possible actions of individuals in response to the risks?
- What are the opinions of respondents on flood risk mitigation and adaptation? Are there any obstacles to adaptation from their perspective?

5.2 Overview of the Resident Survey

5.2.1 Survey implementation

The field work included semi-structured interviews, mail-out questionnaires and follow-up interviews. Key points and main stages in the implementation of the survey can be summarised as follows:

- A pilot survey of 28 semi-structured interviews was conducted in the study area of Port Adelaide, plus additional 11 topic-specific talks with local residents focusing on their risk perception of floods. These interviews helped to develop the mail-out questionnaire and established the local context of floods which also substantially benefited the 2010 Business Survey carried out in the next stage.
- The mail-out questionnaire entitled *The* "*Residents' Opinions on Sea-level Rise and Flooding" Survey in Port Adelaide* went through significant drafting stages (5 revisions) prior to the pilot-test with a number of professionals involved, including

11 research graduates from the University of Adelaide (5 in the School of Social Sciences and 6 in the Faculty of Science). The Port Adelaide Enfield City Council provided advice and comments on the questions, key terms and wording, based on staff experience in doing surveys. These revisions to the questions were important to ensure local coverage.

- 13 completed responses to the pilot-test of 26 local residents suggested that some minor changes in style and format of the questionnaire were required.
- The majority of the 1081 questionnaire packs were posted to the sampled recipients in the study area. Reminder letters were sent out to the addresses if no response was received within 4 weeks and again in about 2 months. Copies of the reminder letter are attached as Appendix 4.
- 7 follow-up interviews were conducted based on requests from the returned questionnaires.

5.2.2 Summary of survey responses

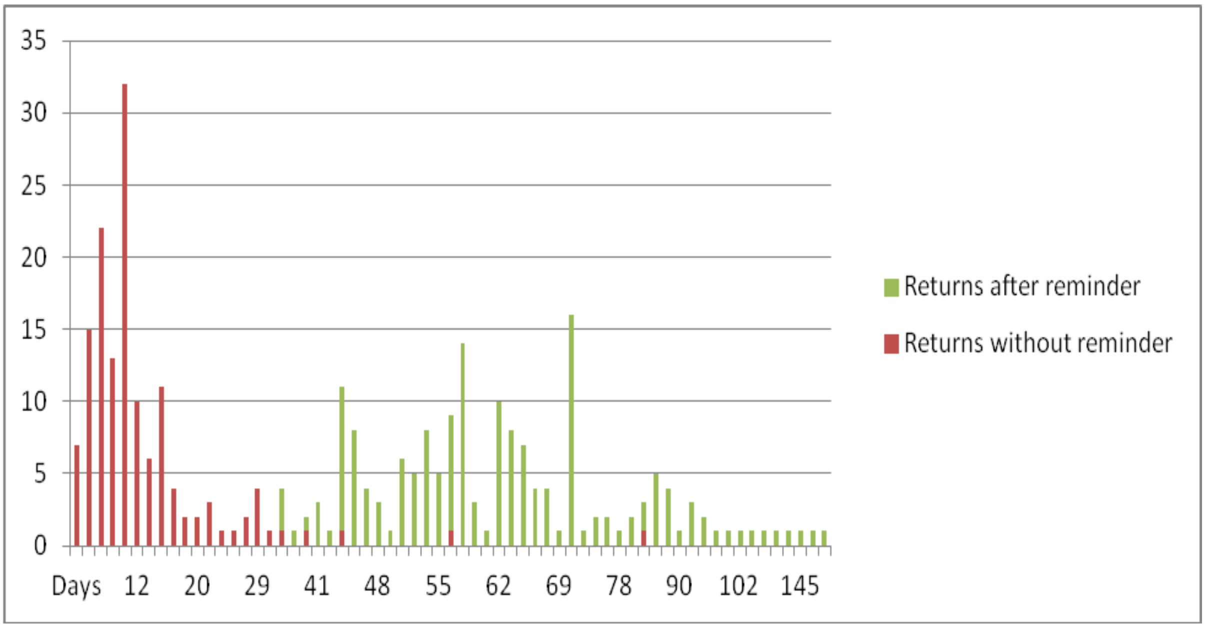
Questionnaire returns: Figure 5.1 shows the responses of the mail-out survey, and indicates that the majority were returned within 3 months. The highest response was clustered in the first month, with 30 returned in one day after the first week. The follow-up reminder letters promoted noticeable waves of responses, lasting about 2 months.

Statistics of the mail-out responses are as follows:

- The sample frame of property owners numbered 12052 (Subsection 3.5.2).
- Questionnaires were sent out to 1081 random sample units (9 percent of 12052).
- Overall 317 responses, including 297 initial returns from the random samples (about 28 percent of 1081), 7 from personal interviews, and 13 from the pilot test.

- 296 written questionnaires were returned from the 1081 sample units, including 2 partially completed questionnaires. This generates an actual response rate of about 27.4 percent (296/1081), and a margin of error (sampling error) 0.056, i.e., 5.6% at the 95% confidence interval, based on a formula by Dillman et al. (2009, p. 56).
- About 55 percent had returned the questionnaires after receiving a reminder letter.
- Some 57 percent of respondents expressed interest in a follow-up interview.
- Only fifth of respondents registered for DVD shows which were organised later at local community centres for the respondents as appreciation for their participation.

Figure 5.1 Number of questionnaire returns received in days after the mail-out



Source: 2010 Resident Survey

Follow-up interviews: A number of issues contributed to the comprehensive understanding of the risk contexts and were addressed in follow-up interviews:

- Issues around the current flood-insurance policy, such as its coverage and conditions
- Drainage problems at particular sites, and health problems caused by releasing storm water directly into the sea (or through the Port River)
- Photos of high tides, floods and inundation in streets

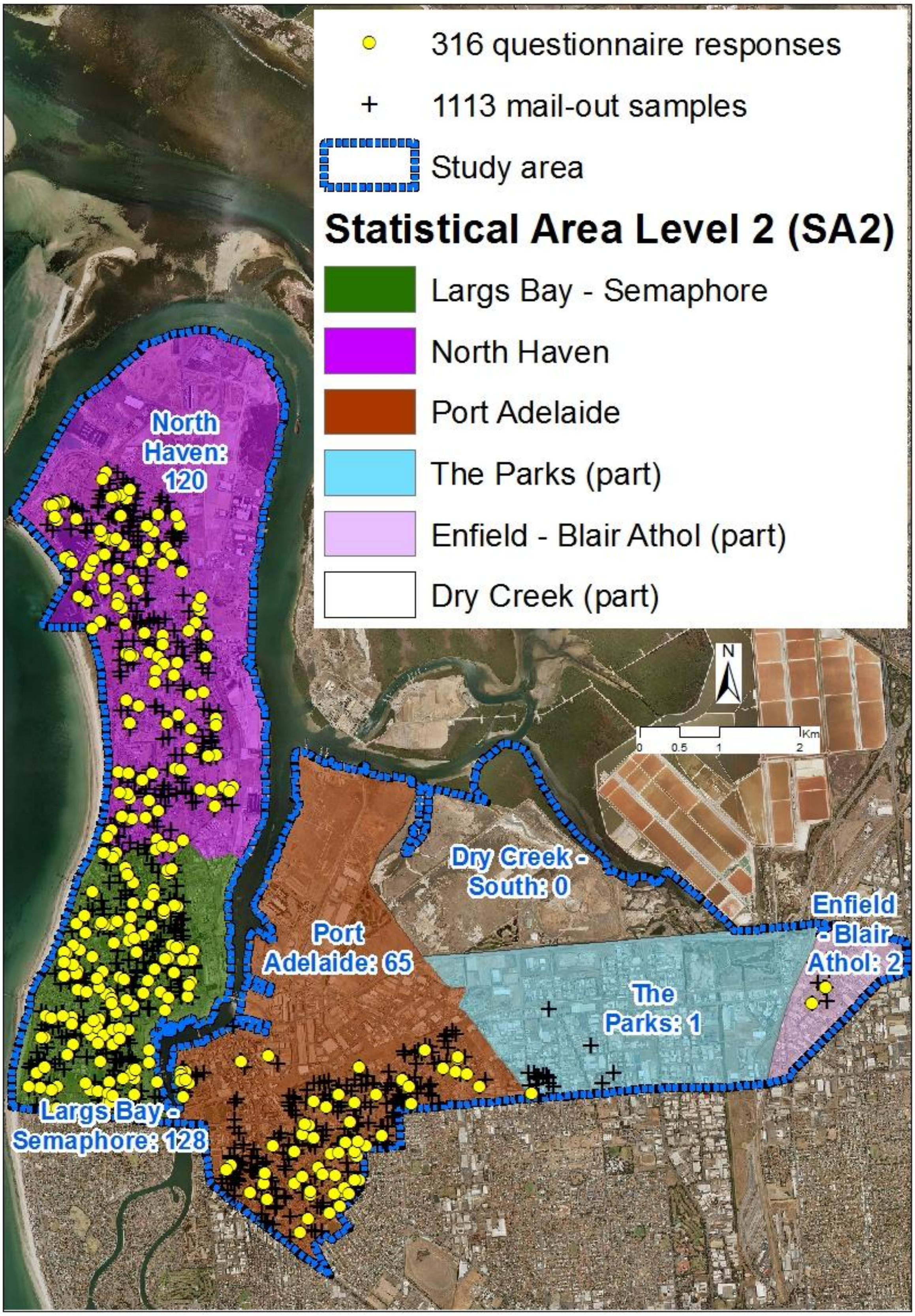
- Residents mark-up of vulnerable sites on the street directory provided
- Contacts for the 2010 Business Survey
- Concerns about environment conservation due to declining open space, marine vegetation and animals, and as a result of pollution, urban expansion and industrial development
- Other policy problems such as land use and restricted public access to beaches and waterfronts
- Heavy rain induced flood events at Peterhead (refer to Subsection 4.4.3)
- A storm tide induced flood event at Birkenhead (refer to Subsection 4.6.1)

5.2.3 Distribution of responses

As appropriate spatial units are important to census-based survey analysis (Hugo 2007, p. 335), the distribution of questionnaire responses (mail-out returns) was examined at both the scale of the study area as a whole, and the lower sub-regional level of Statistical Area Level 2 (SA2) (ABS 2011). As the smallest area for the release of ABS non Census and Intercensal statistics, the SA2 unit is stable between Censuses. In addition, it is a key level at which data on business demographics are available, as well as estimated residential population (ABS 2016, p. 2). The SA2 also identifies functional regions or sub-regions, providing "a relatively good sub-LGA geography" (Bamber and Walter 2009, pp. 608,610).

The number and distribution of questionnaire responses are shown in Figure 5.2, indicating the SA2 unit of analysis is an appropriate sub-regional scale due to the following reasons:

Figure 5.2 Number and distribution of the questionnaire responses



Source: 2010 Resident Survey and ASGS (ABS 2011)

- It covers most of the flooding hotspots detailed earlier (Subsection 4.5.2).
- The SA2 captures most responses, given that it is the largest geographic unit in the study area. For instance, Port Adelaide, Largs Bay – Semaphore and North Haven minimise the effect of the non-random-sampling responses (from either the pilot survey or consultants) by a much larger amount of overall responses.
- Suburbs of Parks, Enfield – Blair Athol and Dry Creek were excluded in sub-regional analysis, as only parts of them fall into the study area. The ability to define the characteristics of the study population is also limited, due to few responses from those areas.

5.3 Demographic Characteristics

Research literature shows that demographic attributes (like age, sex, income and education, etc.) are among factors that influence the perception of risk. For instance, although there is some debate over explanations for gender differences, males and females appear to perceive risks differently (Enarson et al. 2007; Fothergill 1998; Gustafsod 1998; Lindell and Perry 2004). It has also been shown that there is a significant negative correlation between strong feelings of risk and higher income and educational level (Slovic 2000, p. 12). In addition, a "white male effect" has also been widely discussed under risk and climate change contexts (Finucane et al. 2000; Kahan et al. 2007; McCright and Dunlap 2011; Satterfield et al. 2004). White males consistently rate the risks of hazards lower than other groups, in specific marginalised populations that perceive themselves to be subject to injustices (Kahan et al. 2005, p. 1; Olofsson and Rashid 2011, p. 6).

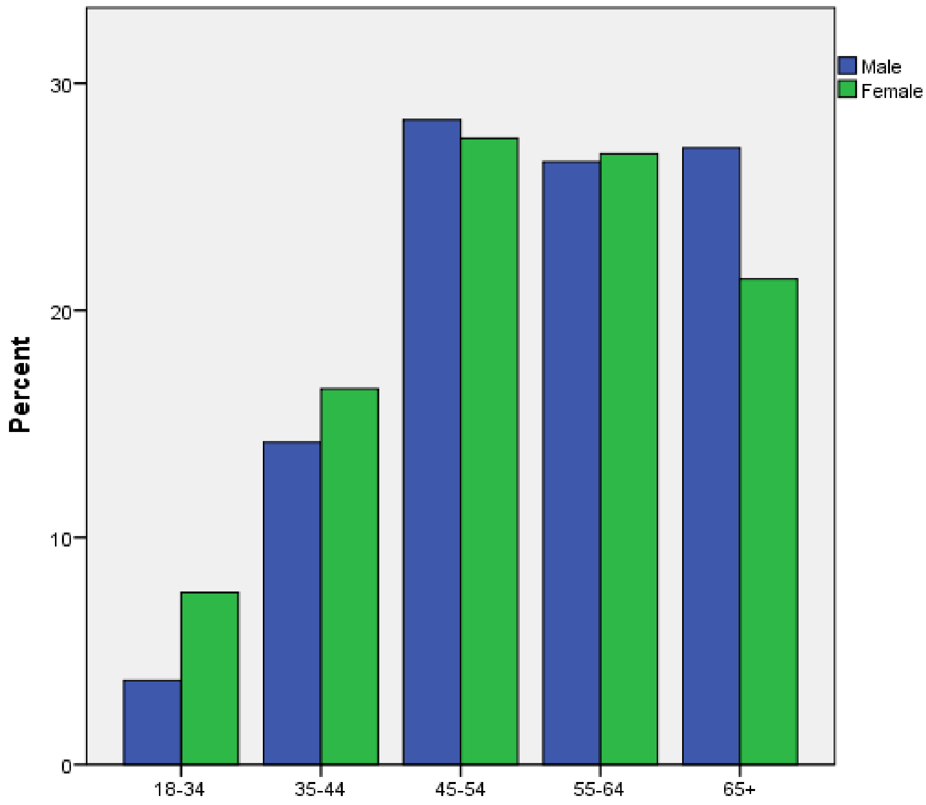
This section summarises population characteristics of the survey respondents. It provides a snapshot of the demographics at two spatial levels, the study area as a whole and Statistical

Area Level 2 (SA2), facilitating the discussion of risk perceptions in the following sections. The demographics include age and sex structure, and an economic profile (occupation and level of education). Australian 2011 census data are used to evaluate the representativeness and diversity of the survey results, as well as validate the geographical units adopted for the quantitative analyses of the study.

5.3.1 Age, sex and family structure

Age and sex: Overall, most respondents were over 45 years old, with the youngest age group (under 35) substantially smaller than the others, as shown in Figure 5.3. Males dominated at older ages, specifically aged 65 and above. By contrast, females under the age of 45 appeared more likely to be respondents of the questionnaire than males.

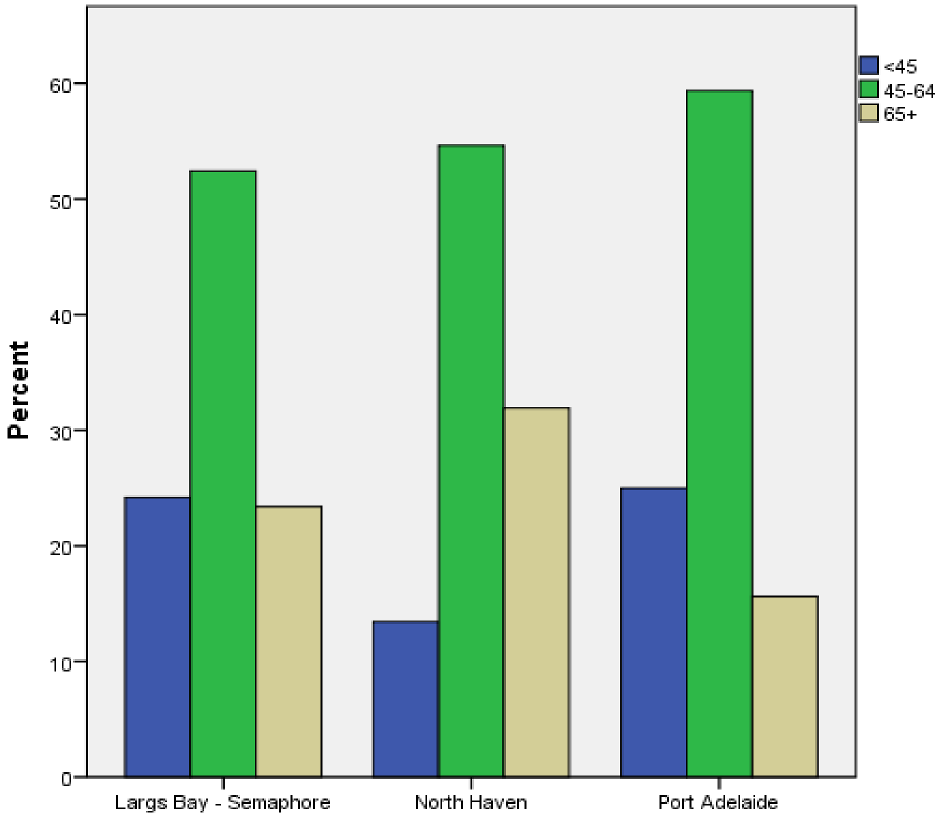
Figure 5.3 Respondents by age and sex



Source: 2010 Resident Survey

At SA2 level, the respondents varied by area, with North Haven (65+, 32%) having the oldest representation, Largs Bay – Semaphore (65+, 23%), while Port Adelaide had 16 percent, as shown in Figure 5.4. By contrast, about a quarter of the respondents were younger than 45 in Port Adelaide and Largs Bay – Semaphore, however the youngest group only represented about 13 percent in North Haven.

Figure 5.4 Respondents by age group by SA2 (Suburb)

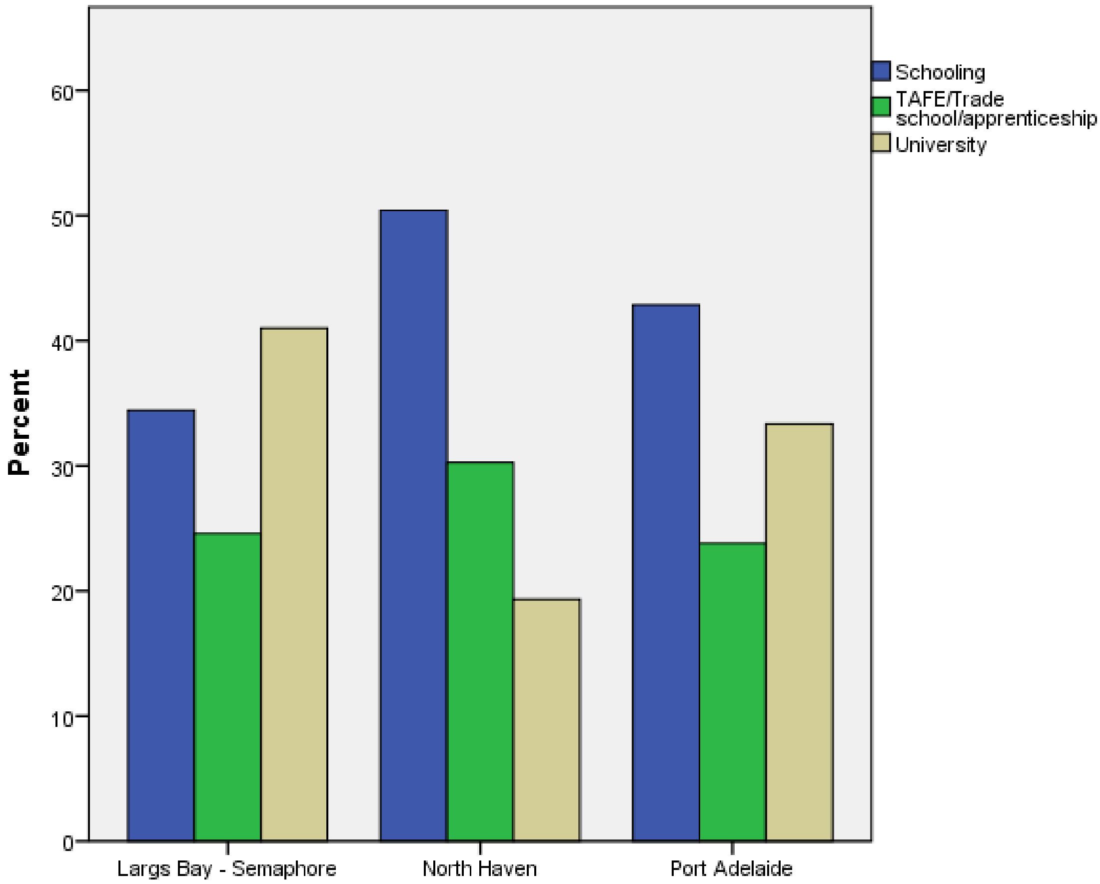


Source: 2010 Resident Survey

5.3.2 Level of education and occupation

The survey shows that slightly more than half (55%) of the respondents achieved some post school qualifications (either from university or from TAFE/Trade school/Apprenticeship), while about 41 percent had recorded either primary or secondary as the highest qualification attained. A larger proportion of respondents from Largs Bay - Semaphore tended to have a university level of education, while North Haven had the lowest, as shown in Figure 5.5.

Figure 5.5 Highest level of completed education by SA2 (Suburb)



Source: 2010 Resident Survey

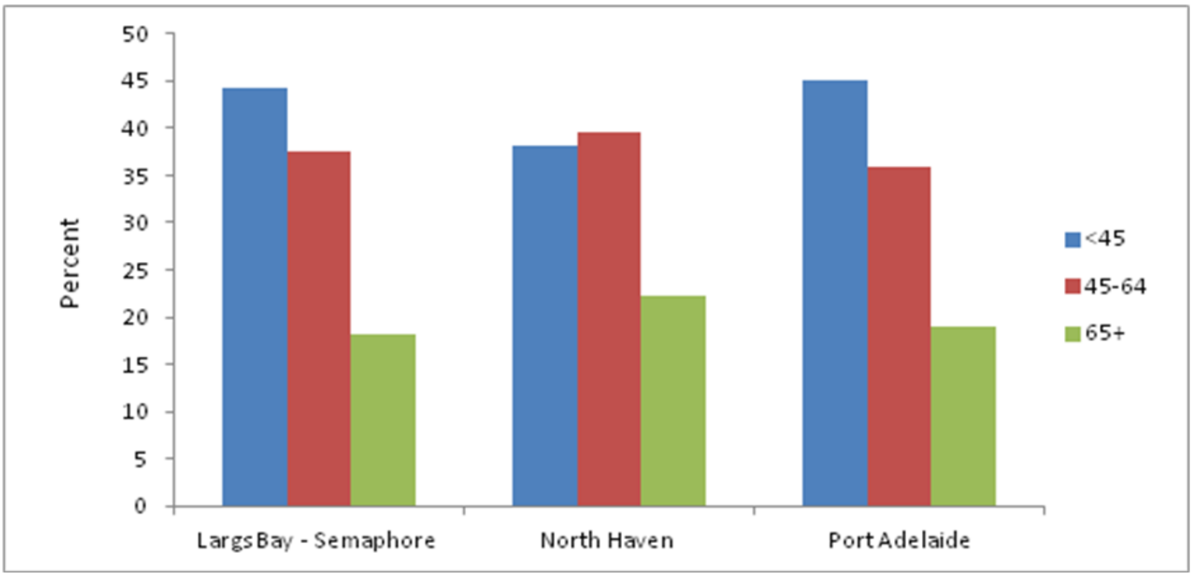
Overall nearly one third of respondents are retirees (32%), which account for the lower educational attainment in North Haven than from other suburbs. Those employed were defined as the main income earners in the household, and their main occupations listed in the questionnaire were professional (25.3%) and manager/administrator (12.7%). This was particular the case with the respondents living in Largs Bay and Semaphore, where it was also indicated to have higher educational levels.

5.3.3 A comparison with Australian 2011 Census

The 2011 Australian census enables some comparisons to be made regarding the demographics in the study area. As the census was conducted about 6 months after the survey, it provides some clarification of the representativeness of the respondents. It should be noted that census data are not particularly relevant in this instance, because the adopted sample frame (property owners) was only a proportion of the people counted at the Census night, i.e., the residents in occupied private dwellings recorded in the Basic Community Profile) (ABS 2011).

A comparison with census data, however can evaluate if the survey collected information from a diversity of population, via cross-checking some characteristics such as age structure. Figure 5.6 shows the percent of population by age groups in the census for Port Adelaide, Largs Bay – Semaphore and North Haven (at SA2 level), and there tends to be an over representation of older age groups in North Haven with younger age structures in Port Adelaide and Largs Bay – Semaphore, as found in the survey.

Figure 5.6 Persons by age group in 2011 Australian Census



Source: ABS (2012)

Compared with Figure 5.4, the census appears to have recorded higher percentages of persons in young age groups, who were not the most likely to property owners. The survey responses demonstrated approximately similar pattern of age distribution from the census, given that the questionnaire respondents represented more particularly the sample frame of property owners who were generally older than the total population from the census.

5.4 The Content of Risk Perception

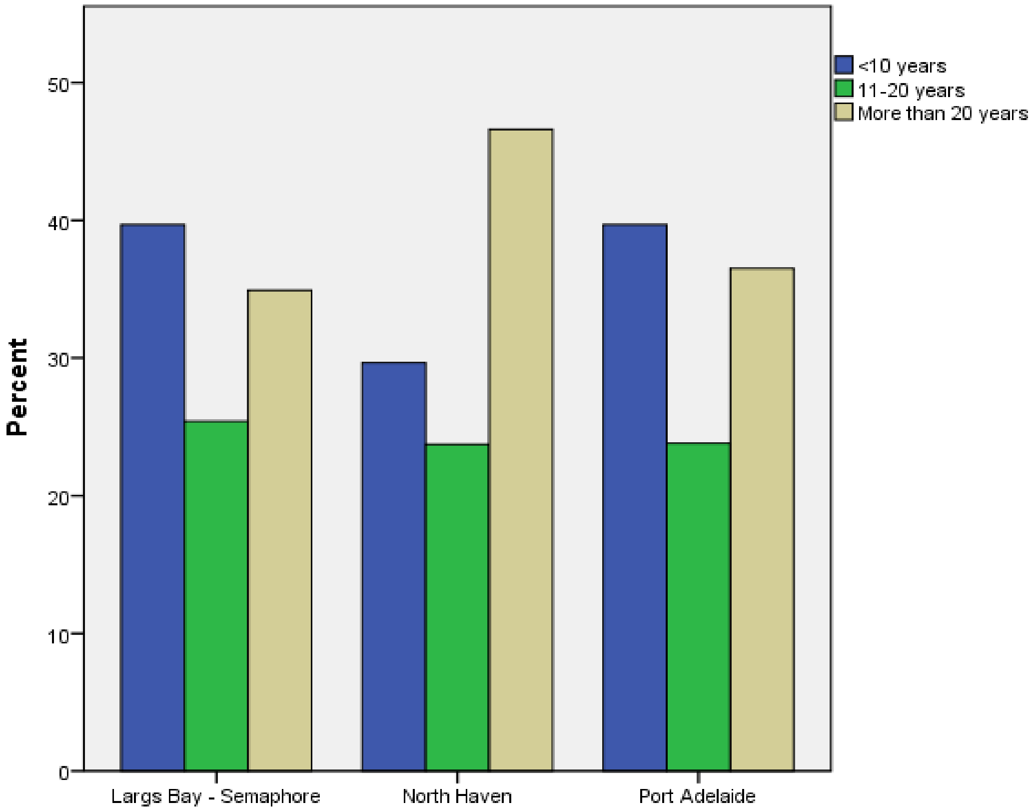
This section represents the results of the resident survey in five major parts: general concerns around environmental issues, local knowledge and perspectives of risks from floods and sea-level rise, opinions on responsibilities and policy, preferences on risk mitigation, and adaptive capacity.

5.4.1 Issues of living at Port Adelaide

It is important to explore if personal values, beliefs and science literacy interact with flood risk perceptions (Kahan et al. 2012; Slimak and Dietz 2006; Whitmarsh 2008). The mail-out questionnaire elicits the relevant personal attributes by collecting local contexts of duration of residency, main reasons for living at the current address, and major information resources about the environment. In particular, property owners were asked about concerns around a number of environmental issues in relation to pollution, as well as reservations about the environment and climate change. Concerns over floods and sea-level rise were examined, as well as how environmental issues impact on the quality of the life.

Duration of residence: On average, respondents had lived in the area for 11 to 20 years, with a high percentage of them living there more than 20 years, particularly in North Haven which corresponded with the older age structure identified in that area. A relative balance between males and females is also shown among the respondents in the study area as a whole. However, in Largs Bay – Semaphore and Port Adelaide, more respondents had been there for less than 10 years, as shown in Figure 5.7.

Figure 5.7 Duration of residency by SA2 (suburb)

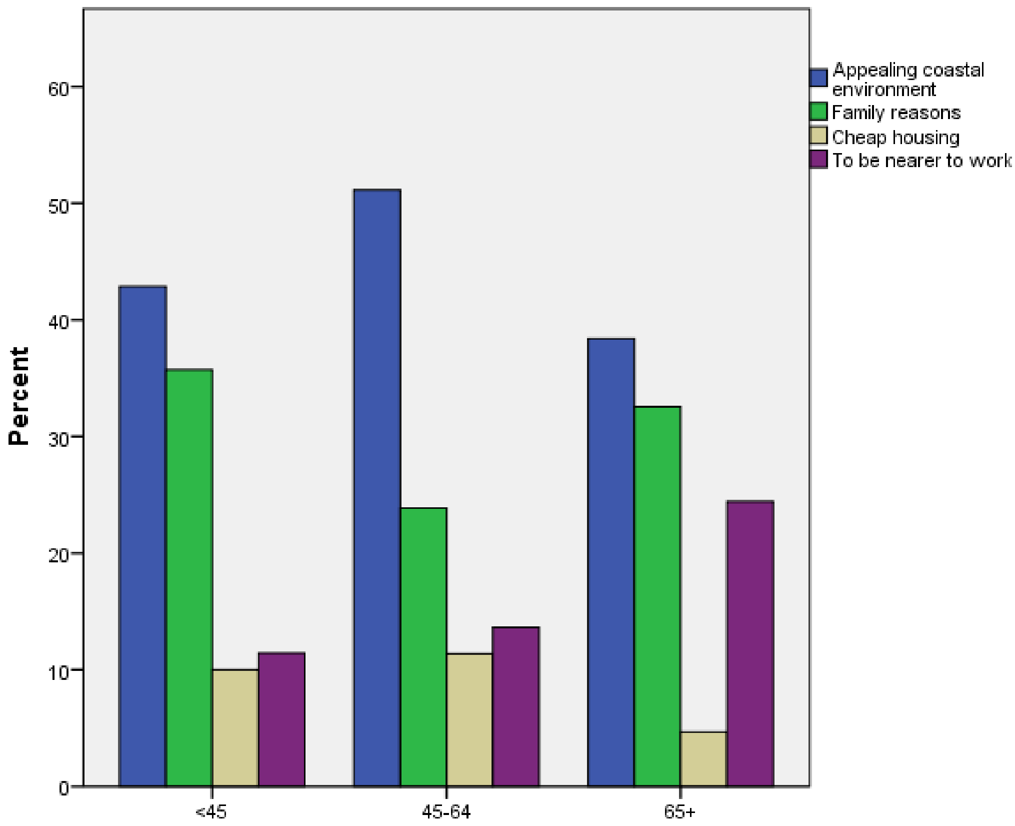


Source: 2010 Resident Survey

Main reasons for living at the current address: Respondents overwhelmingly chose the area for reasons connected to the sea and coast (45.9%), and for family reasons (28.7%), suggesting a settled community with a strong preference for living close to the natural environment. Minor reasons included being nearer to work (about 1 in 6 people) and cheap housing (about 1 in 10). Survey data also showed the differences between males and females were generally small (less than 10%), in terms of each of the reasons.

In addition, respondents' reasons for living in the area varied across age groups, as shown in Figure 5.8. Compared to younger age groups, a higher percentage of the retirees chose the reason of work commitment, implying why they moved to the area a long time ago. However, respondents under the age of 45 were least likely to move there for a job, but most likely because of family reasons. On the other hand, most of the respondents from the 45-64 age group showed a strong preference for the coastal environment. They were also least likely to indicate family reasons, suggesting changed concerns, interests and values between generations.

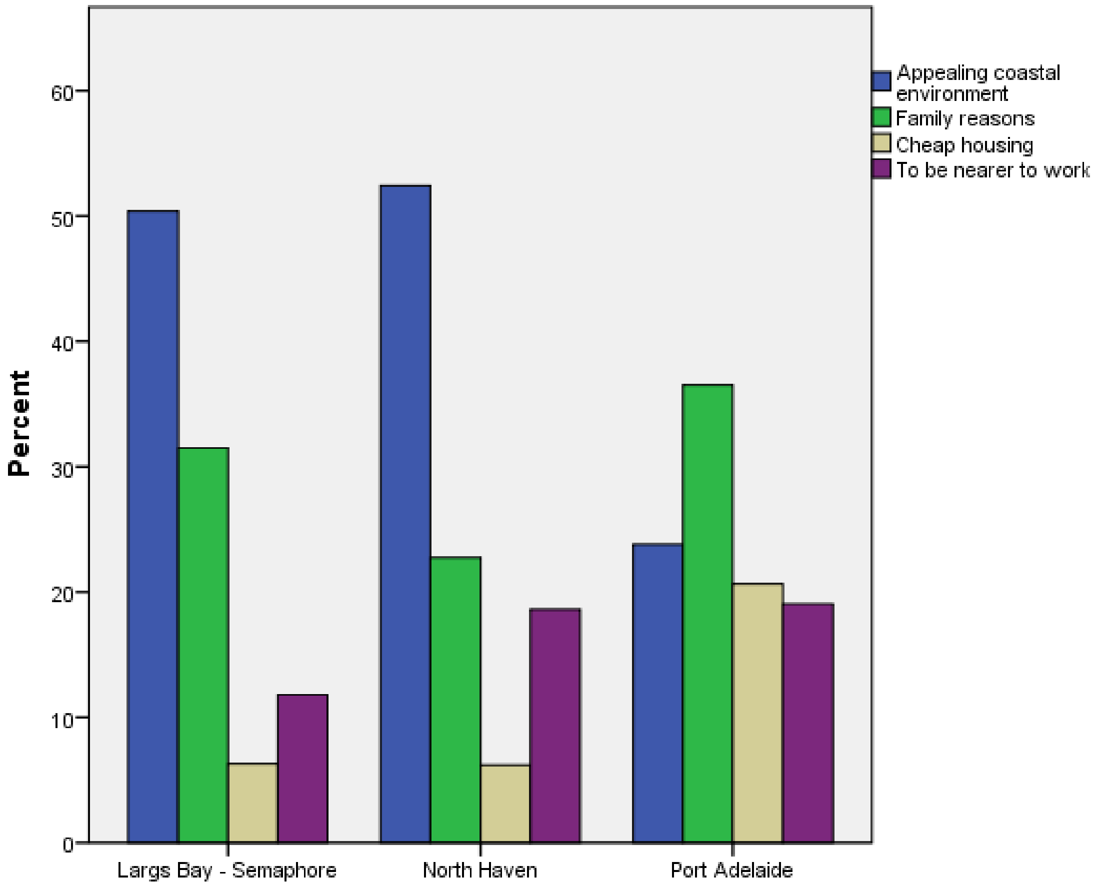
Figure 5.8 Main reasons for living at current address by age group



Source: 2010 Resident Survey

Furthermore, the reasons for living in the area varied across suburbs, as shown in Figure 5.9. Obviously respondents chose North Haven and Largs Bay – Semaphore overwhelmingly due to the “Appealing coastal environment”. For those living in Port Adelaide, the Inner Harbor, however, “family reasons” were more prominent.

Figure 5.9 Main reasons for living at current address by SA2 (suburb)



Source: 2010 Resident Survey

Concerns around environmental issues: It is noted that a number of pollution-related problems were of most concern (about 89%), as shown in Table 5.1. These problems include “Pollution of air”, “Pollution of sea”, and “Pollution of the Port River”. By contrast, adverse impacts of some well-known weather events were of lesser concern, such as “Heat waves” (65.5%), Strong winds (60.5%) and Heavy rainfall (48.5%). In between this spectrum, concerns about floods (66.1%) and future sea-level rise (69.2%) were only slightly above the three least concerns. Less than 70 percent were concerned about “Less access to beaches or river banks” and “Coastal erosion”. Most of the other environmental issues are rated higher than 70 percent.

Table 5.1 Environmental issues that would impact on quality of life

Environmental issues	Disagree	Unsure	Agree
Pollution of air	2.9%	7.8%	89.3%
Pollution of sea	2.6%	8.4%	89.0%
Pollution of the Port River	3.3%	8.1%	88.6%
Reduce number of animal and plants	4.8%	10.9%	84.2%
Loss of green space	7.5%	11.4%	81.0%
Long-term drought	7.7%	11.6%	80.6%
Oil spill from nearby storages	7.7%	14.7%	77.6%
Contamination of groundwater	6.4%	16.0%	77.6%
Loss of seagrass	8.5%	19.0%	72.5%
Coastal erosion	12.5%	18.3%	69.2%
Future sea-level rise	**12.2%**	**18.6%**	**69.2%**
Less access to beaches or river banks	14.2%	19.0%	66.8%
Floods	**16.8%**	**17.1%**	**66.1%**
Heat waves	12.9%	21.6%	65.5%
Strong winds	**15.1%**	**24.4%**	**60.5%**
Heavy rainfall	**22.7%**	**28.8%**	**48.5%**

Source: 2010 Resident Survey

Major information resources about environment: The respondents rated “TV or radio” (82.3%) and “Books, newspapers and magazines” (65.6%) as the main sources of information about the environment, indicating the key role of the media in shaping the perception of risk. Data also indicated that respondents kept face-to-face contact with each other about environmental issues (38.2%), as well as accessing the “Internet” (37.5%). Notably, about 1 in 6 respondents did their own study or research on environmental issues, suggesting that many property owners were considering the environment seriously.

5.4.2 Local knowledge: when, where and why did floods occur?

The questionnaire explored the property owners' knowledge of local floods in 3 aspects: the times and sites of past floods, as well as the causes of floods. It was designed initially to differentiate floods caused by storm tides. However, it was discovered that the respondents tended to mix all floods together, no matter what the exact causes. It was also not surprising that the respondents were more likely to recall recent floods than those that had occurred a long time ago. However, the details of past floods provided insights into the current problems, including the locations of flood hot-spots.

Timing of past floods: Property owners were asked about when floods happened in Port Adelaide as a whole (Category I in this section), or occurred close to their premises in particular (Category II in this section). About 25 percent of respondents provided details about past flood events (45 in Category I and 21 in Category II), including when they occurred and where. The majority of flood events recalled were in 2009 and 2010 (the two years immediately before the survey), i.e., about 56 percent recalled the floods in Category I and about 84 percent in Category II. Residents were more likely to recall recent flood events close to their premises.

There appeared to be more flood events in winter than in summer and autumn, specifically in July, August or September which accounted for about 63 percent of the floods in Category I, and about 70 percent of those in Category II. By contrast, however, the local tidal record indicates that storm tides were mainly between April and July (autumn), as shown previously in Table 4.2. Respondents tended to recall floods due to heavy rains in winter rather than to storm tides that occurred earlier. Table 4.1 (Summary of floods within the study area before 2005) displayed a similar concentration in winter, as all floods are included.

Notably two floods in July 2007 and April 2009 were among those recalled by the respondents, which were attributed to the highest sea levels due to storm tides (each was an event of 1/50 ARI in Outer Harbor, as shown earlier in Table 4.2). The latter was also rated as a 1-in-20-year event at the Inner Harbor, causing wide-spread inundation (depicted earlier in Figures 4.10-13 and Figure 4.15). Surprisingly the rest of the eight highest sea-level events (refer Table 4.2) could not be linked with other floods reported by the survey. This implies that heavy rain rather than a high sea-level event was perceived as the major threat to properties by respondents at the time of the survey.

Sites flooded in the past: Respondents said that Port Adelaide, Birkenhead and Peterhead were among the most frequently affected suburbs by flood events; and St Vincent St, Mary St (Peterhead) and Jenkins St were among the most frequently-named streets. The nominated flooded streets were listed under Category I and Category II. Within each category, the streets were further grouped and ordered by the percentages they were nominated.

(1) Category I (flooded streets in the study area):

- St Vincent St (13.5%)
- Port Rd (12.5%)
- Mary St (Peterhead), Nelson St and Victoria Rd (7.3% for each)
- Nile St and Jenkins St (6.3% for each)
- Semaphore Rd (4.2%)
- Lady Gowrie Dr, Alfred St and Osborne Rd (3.1% for each)
- Old Pelham St, Close St, Hanson St and Fletcher Rd (2.1% for each)
- Commercial Rd, May St, Newcastle St, Mellor Rd, Wilson St, Teakle St, Swan Tce, Chad St, Moorhouse Rd, Roberts St, Maud St, Lipson St, Jervois Rd, Harvey St, Eastern Pde, Dale St and Robe St (1% for each).

(2) Category II (flooded streets close to property):

- Victoria Rd (6.9%)
- Mary St and Jenkins St (5.6% for each)
- Close St, Fletcher Rd, Military Rd, Railway Tce and Semaphore Rd (4.2% for each)
- Alfred St, Constellation Crt, Hall St, Hanson St, Hughes St, Lady Gowrie Dr, Mary St (Ethelton) and Walker St (2.8% for each)
- Albert St, Causeway Rd, Charnock St, Commercial Rd, Eastern Pde, Esplanade, Kyarra St, Maud St, Moldavia Walk, Montpelier St, Old Pelham St, Osborne Rd,

Osborne St, Port Rd, Robin Rd, Russell St, Sir Keith Smith Dr, Swan Tce, Teakle St, Union St, Wills St, Company St, Mellor Rd, Roberts St, Strathfield Tce, Woolnough Rd, Graham St and Olive St (1.4% for each)

Category I included fewer streets than Category II, which was more representative of local floods close to the respondents' homes. Figure 5.10 shows that the majority of the flooded streets were in Largs Bay – Semaphore and Port Adelaide at SA2 level.

Figure 5.10 Main streets flooded in the past

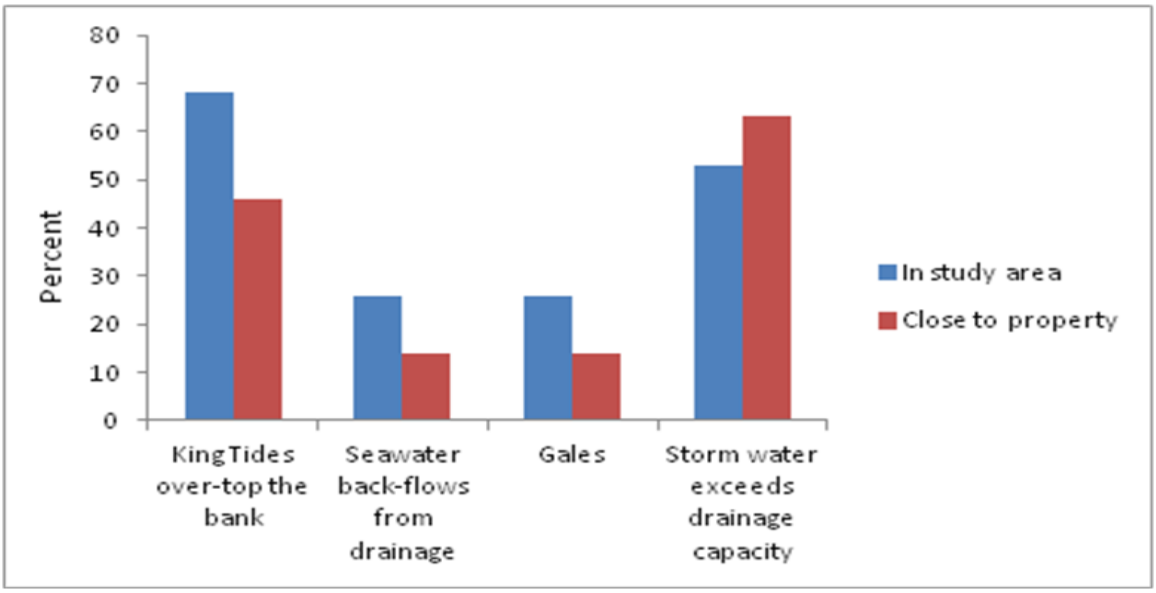
Source: 2010 Resident Survey

Five locations frequently flooded in the past are as follows, including three located in Birkenhead:

- Birkenhead Tavern
- North Haven marina
- Old GMH Factory (located at Birkenhead water-front near Jenkins St)
- Taperoo Beach and
- Port Adelaide Yacht Club (located at Birkenhead water-front near Jenkins St)

Causes of floods: The questionnaire was designed to test four major causes for floods in Port Adelaide, as shown in Figure 5.11. The multiple responses confirmed that these causes were fundamental to local floods. However, a range of causes linked to management and city planning were also shown to be relevant, including failure to clear drains before extreme weather events, increased stormwater runoff from infill housing, and reduced green field for absorbing excess rainwater due to profit-driven urban development projects. These four causes were further examined as defined by the survey.

Figure 5.11 Major causes of floods given by respondents



Source: 2010 Resident Survey

Despite the dominance of King Tides as a single cause (68.1%), floods in the study area were mainly due to a mix of drainage problems, including seawater back-flows from drains (25.5%) and poor drainage (52.9%). In terms of the causes of floods near the respondents' properties, drainage problems were highlighted even further. In fact, drainage inefficiency (63.2%) was seen to be the major cause of floods replacing King Tides (45.9%).

Assembling the local knowledge of floods, nine areas (along the banks of the Port River) appeared to be frequently flooded in the past, as shown as "Hotspots" in Figure 5.12. Obviously, they are among the areas with a high risk of flooding, and therefore flood mitigation and adaptation should focus on them.

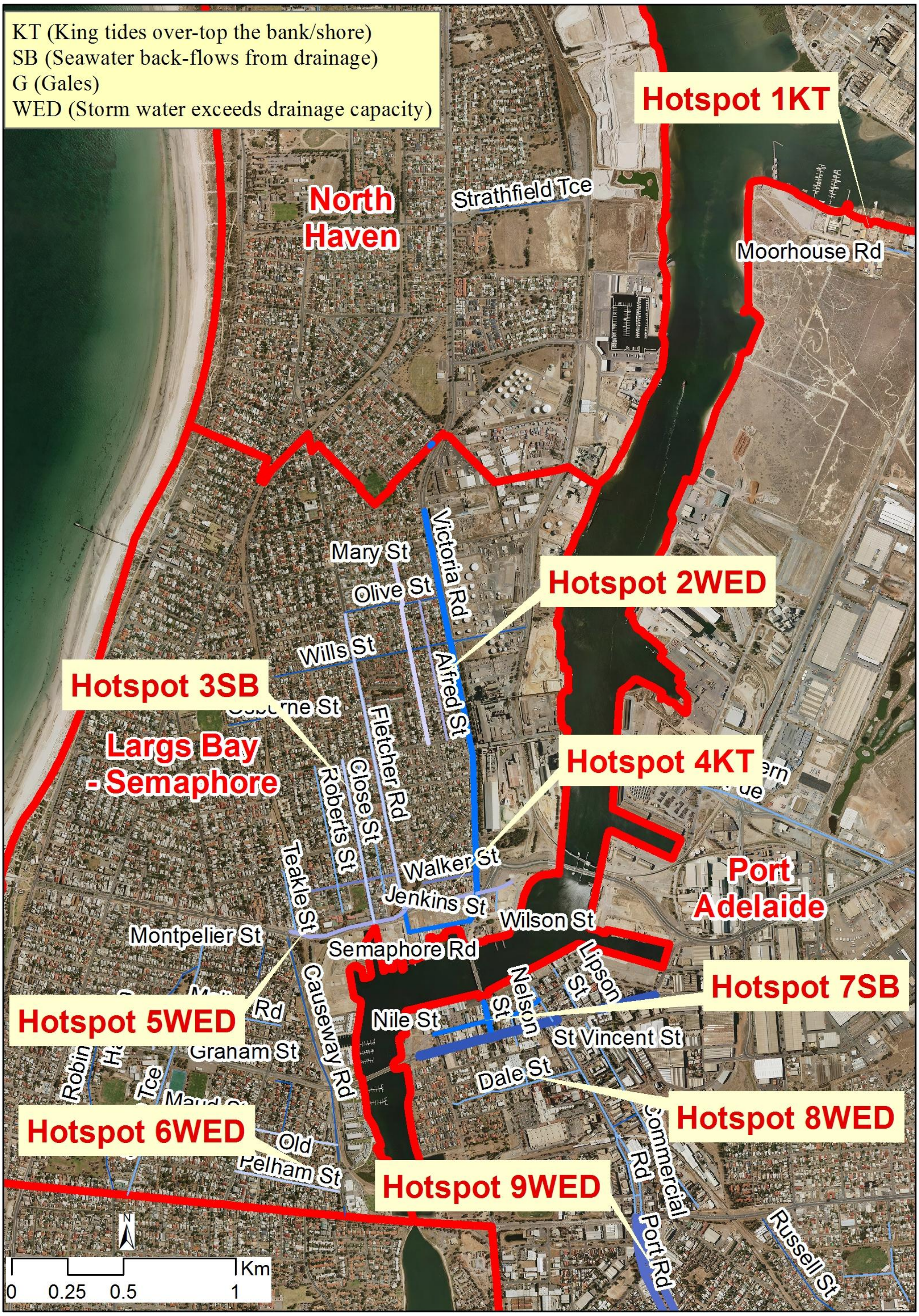
The following sources of information were utilised for establishing the flood hotspots:

- Local storm-water catchments as introduced earlier (Subsection 4.5.1)
- Local pumping stations as shown earlier (Figure 4.19)
- Known flooding hotspots as described earlier (Subsection 4.5.2)
- Local land elevation as shown earlier (Figure 1.2)
- Predicted Outer Harbor and Inner Harbor sea levels in Table 4-5 (Jacobi and Syme 2005a, p. 27) and
- Sea defence assessments in Drawings 4-6, 4-7 and 4-8 (Jacobi and Syme 2005b)

Finally, it should be noted that some respondents highlighted "bad planning" as another major cause of floods, as implied in the comments as follows:

'… Sea level rises have not occurred in any different pattern for the past 50 years in this area and the town planning hasn't improved either. King tides are the only cause of flooding along with wind direction.' (Source: 2010 Resident Survey – No.2006)

Figure 5.12 Major flood hotspots given by respondents



Source: 2010 Resident Survey

5.4.3 Personal experience of floods

When asked about their experience with floods, slightly more than a quarter of respondents (26.7%) had personal experience of floods; while about 10 percent had experienced floods locally and 31 percent had experienced floods elsewhere in South Australia, interstate or overseas.

5.4.4 Risk perception of sea-level rise and floods

The questions about risk perception of sea-level rise and floods were grouped to 2W (what and when) respectively, eliciting "what" they were thinking about the risk (possibility), and "when" the property owners expect their properties might be affected. Two questions followed, inquiring whether moving away was an option, and if they had insurance coverage for flooding.

About the possibility of properties being affected: There were more concerns over sea-level rise than floods, showing that property owners were generally looking at the long-term effects of sea-level rise. Nearly 47 percent of respondents expected their properties would be affected by sea-level rise in the future, while only about 37 percent expected they would be flooded.

About the time when there would be risk: Most respondents considered that sea-level rise would be a problem in the long-term future, while flooding would be a more urgent and immediate concern. The majority of respondents said that they would be affected by sea-level rise in "21-40 years" (18.8%) or in "more than 40 years" (18.7%). Only 3.6 percent of respondents expected sea-level rise "within 10 years", compared to about 13 percent believed they were at risk from floods within 10 years.

About whether moving away would be a response to flood risk: Among those who perceived risk from floods, about 41 percent responded positively to the option of "moving away". Overwhelmingly these respondents expressed a desire that they would move to "higher ground", "up in the hills", "nearer the city" and "further inland", etc., reflecting an awareness of land elevation as a key factor defining flood risk. About two thirds of them said that they would move within metropolitan Adelaide, while others would move to other parts of South Australia or interstate.

About flood insurance: Flood concern may not be the only reason to have flood insurance, as among those who had purchased insurance coverage for flooding (159/317, 50%), only about 36 percent perceived their properties might be affected by floods. There were three main reasons given by respondents who did not have flood insurance: (1) flood was not included in the insurance policy (51%), (2) it was not needed (13%), and (3) it was too expensive (9%).

5.4.5 Opinions on responsibility and planning policy

Researchers have found that opinions on responsibility are an important part of risk perception, as sharing responsibility plays a critical role in risk management (Box et al. 2013; Haynes et al. 2008). The questionnaire grouped opinions on responsibility into either protecting properties from flood damage or mitigation of sea-level rise impacts. Specifically, the questions focused on government, strategic planning, and development projects, highlighting the distinct local contexts which are associated with risk, occupancy and responsibility.

Responsibility: Respondents believed that "government planners" and "developers and builders" should shoulder most of the responsibility (67.5% and 46.9% respectively) for protecting properties from flood risks, compared to occupants or property owners (21.2%) doing so, as shown in Table 5.2. It is also interesting that the occupants or property owners thought that they should take even less responsibility than the SES (35.8%).

Table 5.2 Rating of responsibility for protecting properties against flooding

	Little	Neutral	Very much
Occupants or property owners	20.9%	51.0%	21.2%
Hazard and emergency (SES)	11.0%	45.1%	35.8%
Developers and builders	15.0%	30.9%	46.9%
Government planners	10.1%	16.8%	67.5%

Source: 2010 Resident Survey

Planning: As cases directly relevant to planning and development in Port Adelaide, the Newport Quays residential project (Cox Architects 2003) and proposed industry expansion (South Australian Government 2010, p. 83), were asked for property owners' to comment. Apparently, more respondents were against industry development (72.4%) than against the residential project (46.9%). Open-ended questions revealed that people disliked the water-front residential project because of its bad design and style, destroying heritage and landscape (25%), flood risk (8%), environmental impacts (4%), not well planned for a balance of land, buildings and infrastructure (4%), and reducing public access to the shore (3%).

The main reasons for lack of support for developing the near-shore vacant land for industry, included concerns about pollution to air and water (34.3%), broader adverse environmental impacts (12%), better to be reserved for people, parks, tourism with public access (8.3%), all the adverse impacts combined (5.1%) and concerns about floods and sea-level rise (4.2%). Clearly, the respondents were more concerned about pollution than floods.

Policy options: Responses to Likert-scale questions about government policy options dealing with sea-level rise provided insights into a number of important issues, as shown in Table 5.3. The highest level of support was given to "publishing maps and other information of projected SLR" (92%), followed by "Taking action to cut greenhouse gas emission" (85.9%). In contrast, the highest disagreement to responses was "Continuing the development of key infrastructure in areas at risk" (58.2%). Although the second highest disagreement was "Owners bear risk of SLR", property owners had mixed views on planned retreat ("Plan for removing houses at high risk of SLR") and compensation ("Compensating for property damage/loss due to SLR" or "Compensating for lowered property values due to SLR). For example, planned retreat was both the lowest percent in "Agree" and in "Disagree" among the three options, indicating a high degree of uncertainty among respondents.

Table 5.3 Responses to government policy options on sea-level rise

Policy options	Disagree	Unsure	Agree
Taking action to cut greenhouse gas emission	4.8%	9.3%	85.9%
Limiting housing development in areas at risk from SLR	6.4%	11.6%	81.9%
Protecting properties from the effects of SLR	14.4%	10.5%	75.2%
Owners' bear risk of SLR	36.8%	21.2%	42.0%
Plan for removing houses at high risk of SLR	21.4%	37.0%	41.5%
Publishing maps and other information of projected SLR	4.5%	3.5%	92.0%
Compensating for property damage/loss due to SLR	21.8%	29.5%	48.6%
Compensating for lowered property values due to SLR	29.0%	28.0%	43.0%
Continuing the development of key infrastructure in areas at risk of SLR	58.2%	22.7%	19.1%

Source: 2010 Resident Survey

5.4.6 Options for risk mitigation

Table 5.4 shows the main options to reduce risk, given that two major problems existed in the current storm-water drainage systems: the blockages during heavy rains, and the inadequate capacity for overflow of storm water. Flood water control involved establishing wetlands for holding flood water, using parks and gardens for harvesting rainwater, and recharging underground aquifers. “Using water tanks” was suggested by most respondents for domestic storage of rain water. Building sea walls was the third highest rated option (18.1%).

Table 5.4 Options to reduce the risk of flooding (multiple responses)

Nomination	Options
41.7%	Maintaining and upgrading storm water drainage systems
20.1%	Better flood water control, retaining and storage
18.1%	Building sea walls, retaining walls, dykes or barriers
7.6%	Addressing climate change
5.6%	Building up areas for new housing and staying a safe distance to the sea
2.8%	Sand bagging in emergency
1.4%	Planting mangroves or other coastal vegetation along the shore and bank
1.4%	Sharing flood predictions and maps with the public
1.4%	Limiting land subdivisions and hard-surface expansion

Source: 2010 Resident Survey

Except for the traditional option of building up the land for housing, some respondents strongly suggested regulations for limiting landfill housing, which were seen to substantially increase storm water overflow through enlarging hard and impermeable land surfaces. There was advice about planting mangroves and vegetation along the Port River (and the sea shore) to moderate the effects of sea-level extremes and long-term sea-level fluctuations. Some respondents also suggested to stop storm-water flowing into the sea/river directly (via drainage systems), to improve the quality of water bodies. About 68 percent were for and 32 percent were against “building sea walls”.

5.4.7 Adaptive capacity

Risk perception involves an understanding of adaptive capacity, which is a combination of factors and resources attached to individuals and the community that can be used to deal with risk and reduce adverse impacts (IPCC 2012, p. 556). Apparently, preparedness is one of the key factors indicating adaptive capacity. As discussed in the previous subsection, water tanks were suggested by property owners as rain water storage for mitigating flood risks. The size of the water tank is potentially a measure of adaptive capacity as well. Other resources of adaptive capacity include the availability of vehicles and use of bore (well) water in households.

Preparedness: Most respondents (98%) were not aware of an emergency plan or evacuation plan; about two thirds of respondents did not think that flood risk has been adequately considered in regional planning and development. Only one respondent was able to name a plan, i.e., the on-going “Flood safe” program by the SES (State Emergency Service) at the time of survey.

Water tanks in households: About half of the respondents had water tanks in use at home with the median of the total volume (size) 3000 litres. But a respondent who had lived at the Inner Port for 50 years commented as follows:

‘… too few people have rainwater tanks. They are compulsory in new houses, but they are too small (I think 1000 litres, mostly) … My house has 15000 litres … Uncollected rainwater runs into the streets, collects pollutants towards the sea …’ (Source: 2010 Resident Survey - No. 2003).

Domestic use of vehicle(s) and bore water: Most respondents would use vehicle(s) (94.5%) to evacuate from extreme water events. Surprisingly, about a quarter of the respondents (25.9%) had water pumps/bores for watering purposes. Small percentages of them had observed that salinity was increasing (7.1%) and that the water table was decreasing (9.7%).

5.5 Influencing Factors and Themes of Risk Perception

A number of themes on risk perception are examined here, based on the variables derived for the descriptive statistics reported earlier (Section 5.3). These themes include relationships between key independent variables (demographics characteristics, flood experience and length of residence of the respondents) and dependent variables associated with concerns about sea-level rise and floods. Interactions among causes to floods, options of risk mitigation, and attitudes toward planning and development are tested, in relation to public acceptance of the risk. Other facets of risk perception are explored with respect to instances from the associations among satisfaction with flood policy, development projects and planning. Two policy options, “limiting housing development in areas at risk” and “planned retreat” on sea-level rise, were tested against the characteristics of respondents and their responses to flood policy.

5.5.1 Factors influencing risk perception

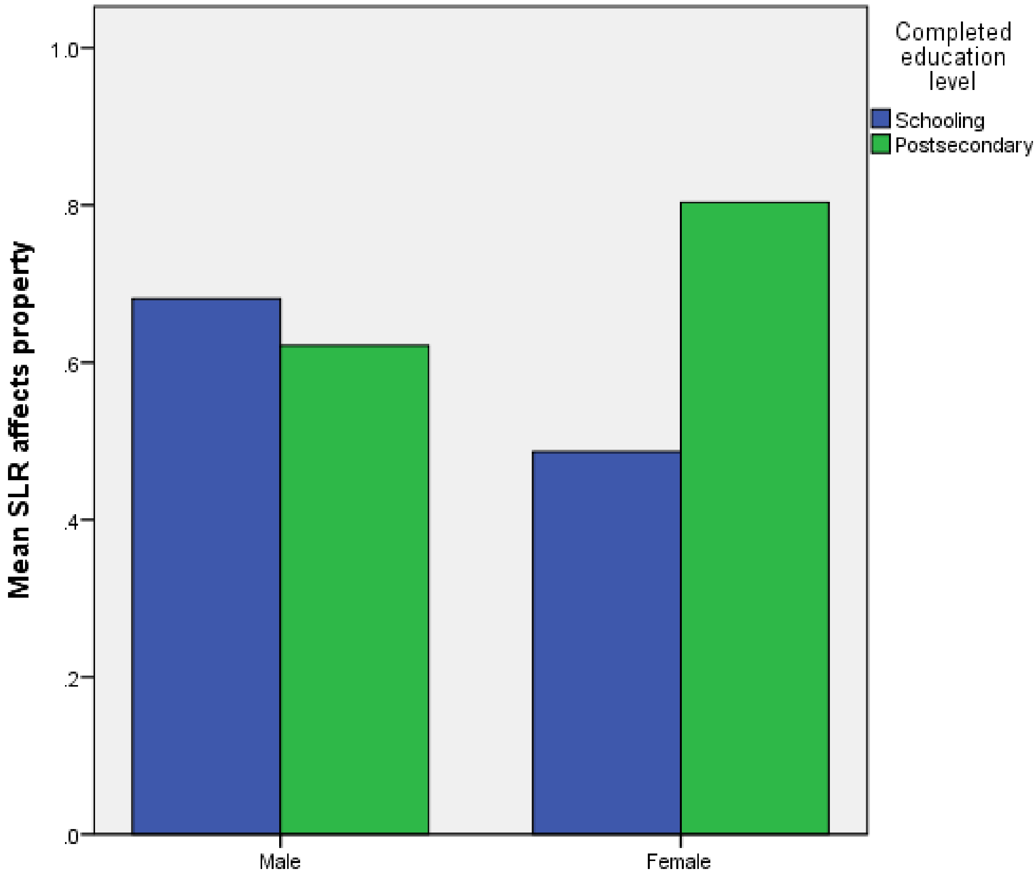
(1). Age and completed education level

Respondents’ concerns about sea-level rise decreased with age, but increased with higher levels of education. A similar influence of age and education levels was also found concerning risk of floods.

(2). Completed education levels of males and females

It was found that males with high levels of education were less concerned about sea-level rise than females, as shown in Figure 5.13. This implies males may perceive themselves to posses greater capacity than females to adapt to sea-level rise as a long-term problem.

Figure 5.13 Expectation of SLR affecting property, by sex and completed education level of respondent



Source: 2010 Resident Survey

(3). Duration of residence, flood experience and sex

Respondents who had lived in the area the longest (i.e., more than 20 years) were those who perceived the lowest future effects of potential sea-level rise. This was particularly the case for the oldest males. A similar pattern for the effects of duration of residence on flood expectation was identified. Although flood experience was found to have a positive effect on risk perception from either sea-level rise or floods, there was generally no difference of the effects between males and females.

5.5.2 Urban development and planning

Urban planning can contribute to risk reduction, which represents a shifting focus of disaster response from solely rescue and recovery to integrated coastal management (Harvey and Caton 2003, p. 45; Wisner et al. 2012, p. 641). Applied to Port Adelaide, a major port of South Australia under great pressure of renaissance (Subsection 4.2.2), associations between the evaluation of contemporary planning and risk perception are examined here.

The relationship between the questions "*Do you think the risk of flooding has been adequately considered in the planning and development of the Port Adelaide area?*", and variables of age, sex, completed educational level, occupation, and duration of residence, were examined using the Chi-Square test to establish statistical difference. Some key attributes representing risk perception did provide adequate evidence ($p < 0.05$) to reject the null hypotheses that "there is no association to the responses of the question in relation to planning and development". The identified associations can be described with the variables highlighted as follows.

(1). Concerns of floods or sea-level rise: Some two thirds of respondents, who were positive about planning and development in Port Adelaide, did not perceive flooding to be a risk to their properties. On the contrary, those who responded negatively to local planning and development did perceive flood risks. Not surprisingly, a similar association was also evidenced between the answers to "*Do you think your property might be affected at some time in the future by <u>sea-level rise?</u>*" and responses to the question about planning and development in Port Adelaide. In fact, more than half of the respondents (54%) also positively commented on planing and development, and did not yet perceive a risk from sea-level rise. In comparison, about three-quarter (74%) of those respondents who were dissatisfied with local planning and development, perceived risks from sea-level rise in the future.

(2). Flood experience: It was also found that the residents' comments on local planning and development were not independent of their flood experience (p = 0.001). That is, there was a statistically significant relationship between their flood experience and their attitudes toward planning and development.

(3). Responsibility of government planners: An association was found between the comments on planning and development, and the level of responsibility the respondents believed the government planners were for protecting properties against flooding (p = 0.01). In other words, those who were positive about local planning and development, tended to think that the government planners were responsible for protecting properties against flooding, while those not tended to answer negatively. This implies that sharing the responsibility of flood protection among individuals and groups ("*Occupants or property owners*", "*Developers and builders*", "*Hazard and emergency*", and "*Government planners*"), would be a complex and controversial issue. The issue could become more complicated if the attitude towards local planning and development was taken into account.

(4). Attitudes to water-front residential development: The responses to the question about the Newport Quays project were also related to the comments on local planning issues (p = 0.000). Respondents who took a positive view of the project were more likely to be satisfied with local planning, while those who did not favour things like the Newport Quays project were critical of the planning issues.

(5). Attitudes to near-shore land development for industry: The majority of respondents did not want such development which also appeared to be related to their comments on local planning (p = 0.000). It appeared that those responding negatively to flooding risk did not agree with further development of near-shore land for industry. This was reinforced by answers to open-ended questions: that concerns about pollution, rather than floods or sea-level rise, contributed to dissatisfaction with urban planning and development.

Overall more than 60 percent of respondents were negative about local planning and development (refer to subsection 5.4.5), highlighting the important role of public trust, which strongly links with risk perception and actions for reducing risks (Slovic 1993, p. 676). In particular, the association between attitudes to water-front residential development and planning issues was evidenced by nearly half responses being negative to the Newport Quays project. As Slovic (1993, p. 679) has emphasised, a typical trust-destroying event is "carrying much greater weight than positive events". The case of the Newport Quays project may represent exactly such a situation.

5.5.3 Preferences for policy on sea-level rise

Government policy is critical to mitigating flood risks and adapting the impacts of sea-level rise in the future (IPCC 2014, p. 210; Pontee and Parsons 2012, pp. 5,10). As a policy option, limiting development in areas of risk from sea-level rise has drawn much attention (Hallegatte 2009, p. 244; Nicholls and Cazenave 2010, p. 1519). This option was examined by the survey responses, whereby most respondents (84%) who were not satisfied with the current flood policy, expressed agreement with the proposal of regulating development in areas under threat of sea-level rise. The Chi-Square statistics showed that the option was associated with the views on planning and development as well (p = 0.004). Respondents who criticised planning and development in Port Adelaide were more likely to want to limit housing development in areas at risk from sea-level rise, compared to those who were satisfied with government planning.

Another increasingly debated policy option is “planned retreat” (Abel et al. 2011; Niven and Bardsley 2013). In contrast to the previous option, however, there appeared to be no relationship between preferences for “planned retreat” and comments on local planning and development. This implies that there would be other factors (beyond the scope of planning and development) that influenced the respondents’ opinions on this policy option.

5.6 Conclusion

This chapter outlined the responses to the resident survey into risks from floods and sea-level rise in Port Adelaide. The demographics showed that the respondents were generally represented by age and sex, and were also well distributed across the general education levels and occupational categories. Respondents tended to be concentrated over the age of 45, which is understandable, given that they were property owners. The majority of respondents had lived in the area for more than 10 years and had chosen the area mainly for either environmental or family reasons. Interestingly, floods and sea-level rise were ranked among low-level concerns, in contrast to those about pollution (to air, sea or the Port River), suggesting risk perceptions tended to be diverse and complicated issues.

It was found that the respondents’ knowledge of floods was largely based on recent observations of flood problems caused by storm water or seawater. The scale of floods observed by respondents did not exceed a 50-year water event but they did provide details about past floods, including when they occurred, the sites flooded and areas or streets inundated, as well as the major causes of flooding. Taking into account that the majority of respondents did not have a personal experience of floods, it can be asserted that the local risk perception is basically heuristic.

In general, respondents viewed floods were a more urgent risk than sea-level rise, although they appeared to be well aware that location/elevation was a deciding factor determining the level of risk. Flood hotspots could then be identified from local knowledge. It was interesting that most respondents did not want to move from the area. Similarly, purchasing insurance with flood coverage was also not seen as a practical way to address the problem. On the other hand, respondents believed that government and planners should take the responsibility for flood risk mitigation. Interestingly however, more than half of the respondents didn't think that the risk of flooding had been adequately considered in the planning and development of Port Adelaide. They suggested a number of options for flood hazard mitigation, ranging from comprehensive adaptation actions to an engineering fix like "building sea walls".

A number of themes have been identified:

- The expectations of sea-level rise tended to decrease by age while they increased by completed education levels.
- Generally fewer males with higher levels of completed education expected to be affected by sea-level rise; while the number of females, particularly those who had a tertiary level of education, increased substantially expecting that their properties would be affected by either sea-level rise or floods in the future.
- Respondents who had lived in the area the longest were the least likely to be concerned about future sea-level rise or floods.

- Flood experience positively influenced the risk perception of respondents to sea-level rise and floods
- While both “King tides over-top the bank/shore” and “Storm water exceeds drainage capacity” were nominated as major single causes for floods, in flooded areas close to property, drainage problems were highlighted as the dominate cause

The survey found that the evaluation of attitudes to planning and development tended to be related to property owners’ perceptions of risk from floods and sea-level rise. A similar association was shown with their personal experience of floods, as well as with their view of government planners’ responsibility to flood risk mitigation. In addition, property owners’ preferences to the Newport Quays project, or to the plan of developing near-shore vacant land for industry, were also found to be related to their attitudes towards planning and development. Policy options such as to “limit housing development in areas at risk from sea-level rise” was related to the evaluation of planning and development, in relation to addressing the risk of flooding, while “planned retreat” was appeared to be not an option in risk planning. This implies “planned retreat” may be a more controversial option which should be assessed in a broader political scope than that merely of planning and development.

CHAPTER 6. RISK PERCEPTION AND THE RESPONSE OF BUSINESSES

6.1 Introduction

This chapter presents analysis of the 2010 Business Survey on risk perception about floods in Port Adelaide. Firstly, the themes of risk perception from businesses are analysed, and then their risk response is addressed. This is also compared to the risk perceptions of residents in the previous chapter. The core category of business survival is discussed from the analysis of the in-depth interviews. By close examination of the causal-consequence relationship between the risk and response, the results indicated a number of characteristic patterns of business survival. Two fundamental types of survival are then discussed in detail, as well as the problems relating to the basic business process (BBP) (refer to Subsection 3.6.3). Using survey data, the chapter also highlights the business adaptive capacity and how that was influenced by factors such as the classification of industry, locality, scale and capital value.

6.2 Themes and Conceptualisation

6.2.1 Themes of business risk perception

In the 2010 Business Survey, notes and transcripts collected from the interviews were the major source of content analysis, supported by auxiliary documents including notes of field work, business introductions, guides to operating functions and products, annual reports, technical references, historical maps, etc. On-site photos and inundation maps were used for clarification purposes, in regard to the causes and consequences of past flooding events. A proto-type basic business process was abstracted, applying the qualitative methods introduced earlier (Subsection 3.6.3). In a narrative style, the basic business process consists of four stages and themes in consequential order, representing the local risk perceptions of businesses: (1) Tracking down the threat, (2) Detailing the risk exposure, (3) Problem, impact and concern, and (4) Mitigating action.

The basic business process and its relevant attributes (or categories) are as follows:

1) Tracking down the threat: Three kinds of events were identified as risk to businesses in the context of flooding, including strong waves/swells, high tides, and heavy rains. These **causes** were identified as events that led to either damage (by strong wave/swell) or inundation (caused by high tides, heavy rains or a mix of the two).

2) Detailing the risk exposure: a key property (or attribute) of this category represents the **condition**/situation of a business' presence confronting the extreme events, including the business' locality and elevation (either absolute or relative height of the ground level). There were three kinds of locality: (1) on the beach of the open sea, (2) on the waterfront of river/channel, or (3) in a residential area behind the wharf.

   Elevation is critical in identifying the risk exposure. In fact, it is noticeable that the businesses on the beach or on the waterfront of the river, were generally at low ground level. For example, a few marinas and sailing clubs that were interviewed were located on the beach or on the waterfront of the Port River. They were prone to inundation and the elevation showed an obvious causal-consequence association. However, some businesses interviewed with water-front infrastructure had raised building foundations, and thereby were now free from inundation.

3) Problem, consequence and concern: this stage/theme has an attribute of “suffering as extra business loss”, which was conceptualised based on interview transcripts of “repairing cost”, “losing productivity”, and “loss of time”, etc. These indicate a **consequence** (or impact) of exposure to extreme events.

4) Mitigating action (or **response/adaptation**): This is a stage/theme of the actions taken by businesses in response to perceived risk. These actions are dependent on the condition of risk exposure which is differentiated business by business. For example, “Upgrade breakwaters” was proposed by a major sailing club in North Haven. To mitigate flood risk, a manufacturing company (fabrication) took action by “land filling”. In a residential area behind the wharf, the inundation problems of a small business (automotive repair) responded with “Fix: remove blockage, add sumps” (conducted by local authorities).

The category of “Concerning future trends” was also identified from those businesses which had been adversely affected by sea-level extremes, specifically those located at the waterfront. They were keen to be informative and actually some had already initiated their own study on the impacts of sea-level rise.

6.2.2 Business survival: risk response and exposure

The stages and themes of business risk perception were distinct from the risk perception of residents in the previous chapter, because it was more focused on risk response rather than attitudes and perspectives. As asserted by Elrick-Barr et al. (2016, p. 177), knowledge regarding action (to climate risks) occurring at the household level is limited, specifically about the impact orientated adaptive actions, responses and related behaviour. In terms of business response and adaptation, in-depth studies are rare or only focus on one specific industry (Eberlein and Matten 2009; Kolk and Pinkse 2005; Levy and Kolk 2002).

The business survey undertaken here produces a capacity for a better understanding of the risk response and adaptation at a small scale based on in-depth interviews. More importantly, the response in detail (as represented by the characteristics of the basic business process) provides an insight into the extensive uncertainties that exist in future response to the risks, as well as "the use of scenarios of the future to explore the potential consequences of different response options" (Moss et al. 2010, p. 747). Therefore, it is necessary to conduct a systematic examination on what actions were taken by those local businesses to mitigate the risks, and why they behaved in that way, and the implications under current and future scenarios.

Constant grounded theory procedures (refer to Subsection 3.6.3) were applied to the categories/attributes/properties identified in conceptualising the basic business process (BBP). As a highly conceptualised abstraction, business survival (or termed as "surviving the risk exposure") was eventually designed to be a core category (or core variable), representing the basic business process. Based on Glaser and Holton (2007, p. 60), the core category has met the criteria in a number of ways. Firstly it accounts for a large variation in the pattern of behaviour that frequently appeared in the interviews, such as the businesses acted differently facing similar threats. Secondly it is related to the majority of other categories, such as "suffering business loss", "mitigating response" and "concerning future trends", providing relevance and explanatory power for the detailed examination of these relevant categories.

The core category highlights risk exposure which is a critical condition to business survival. In fact, the business interviews show a clear relationship between business location and business activities. For instance, the risk exposure of water-front infrastructure turned out to be different to that of shipping facilities (such as a slipway or a launch ramp), due to their distinct business functions. In other words, the core category is highly dependent on risk exposure which relates to either the location or a specific business function. This indicates that the exposure is a key property due to its decisive role in shaping the core category.

6.3 Characteristics of Business Survival

According to Glaser and Holton (2007, p. 58), theoretical coding conceptualises how the variables may be associated with each other and how they can be integrated into hypotheses about the problems under consideration. In applying the analytical procedure of theoretical coding of the concepts associated with the core category of business survival, a causal-consequence relationship emerged. The characteristics of recurring processes and break points were also identified to being crucial to risk response. Furthermore, a nested and structural order was recognised from the process of resolving the problem. The order reflects an underlying mechanism of business response to risk exposure.

These concepts, characteristics and patterns make up the conceptual framework for the core category of business survival which consists of a number of key categories (variables), including the cause, consequence, contingency, covariance and condition. The status of business survival can be differentiated by the cause (the independent variable) and consequence (the dependent variable) respectively. For example, the recurring process demonstrates repeat responses to a cause. A break point then directs the business process in a nested and structural order of “resolving the problem”, in respect to a number of outcomes/consequences, such as “no problems”, “damage”, or “inundation”. These multi-facet interactions between the cause and consequence within the process of business survival are detailed as follows.

6.3.1 Causal-consequence relationship

The causal-consequence relationship can be represented from three perspectives - exhibiting the overall risk perception, and the variables representing the cause and consequence. First of all, data from the 2010 Business Survey indicated that flooding risk was NOT a major concern among the businesses in Port Adelaide: 17 businesses (50%) stated that they did not perceive a flood problem or risk to their businesses. They also could not name a flood incident in the study area. An additional 12 businesses (35%) observed inundation in streets and roads (beyond the business sites), and the inconvenience was seen as a major consequence of these minor flood problems.

Only 5 businesses reported in detail about adverse flood events, 2 were large businesses, and 3 were small and medium-sized businesses. These businesses representing 15 percent of those interviewed, termed their on-site problems as “water problem”, “flood” or simply “unusual conditions”. Although not included in the interview samples, two extra small businesses (Port Adelaide Dental Service and a nearby Indian Restaurant) were frequently sand-bagged during high tides or heavy rains.

Secondly, the causes of the “water problem”, “flood” or “unusual” weather conditions, etc. can be grouped into two categories: storm tides and heavy rains. The storm tides were the major source of threat to businesses located on the water-front and in low-lying areas, resulting in seawater inundation. In particular, those facing the open sea highlighted wave damage to be a serious consequence of strong waves/swells, often exacerbated by storm tides as well. Heavy rains were responsible for wide-spread inundation in inland areas across the Port Adelaide region. Notably storm water flooding had increasingly become a major concern for businesses situated beyond embankments.

Thirdly, the consequences to businesses' "surviving the exposure" varied, ranging from a temporal disturbance to business activities, to extra costs (precaution, repairing and cleaning), and to "losing productivity". There were also continued inputs of research and corporative efforts. Notably, major costs in lifting-up the ground level on the business sites had substantial financial consequences, specifically to those medium-small size businesses that had employed this strategy. Most importantly, at the time of survey moving away was NOT a seriously considered option of those businesses which were interviewed.

Notably, flood risk mitigation measures were undertaken largely by local authorities and the State Emergency Service. The actions included sand-bagging (for temporary response) and using pumping stations in cases of flooding. Besides, breakwaters provided effective protection against wave damage to the marina and port facilities, although an impending upgrade project may have financial consequences. Finally, an upgraded drainage system was widely considered to be the ultimate solution to heavy-rain induced flood problems by providing an adequate capacity for storm water run off.

6.3.2 Recurring process

The first feature of business survival is recurring process, which means a business is likely to experience and respond to flooding risks in a periodic way. That is, when a similar risk experience repeats, the response is likely to be undertaken again, given that the same cause of strong waves/swells, high tides or heavy rains occurs again. The risk experience includes either "no problems" or "having a problem". The risk response includes "resolving the problem", which a business is under pressure to do, in order to mitigate the risks. Those businesses previously affected by flood problems adversely may expect to have a transformed risk experience of "no problems", if the responsive actions have been taken in time and have proved effective. Alternatively, once again those businesses might confront similar water problems they had experienced before.

In the 2010 Business Survey, the recurring risk experience of "no problems" was typically demonstrated by Flinders Port, a large-scale port owner/operator which had expressed high confidence on flood risks (refer to Subsection 6.4.2 for details). However, a yachting marina in North Haven was suffering wave-damage problems and was seriously considering an upgrade of the breakwater for better protection of its infrastructure and facilities during storm-tide events. This yachting business was at a stage of "resolving the problem", as it had started a study program on the water problems, as well as lobbying for government funding. Apparently, the yachting business expected its responsive measures would take effect, and the next time "unusual weather conditions" occurred, its risk experience would turn out to be "no problems", rather than suffering wave damage again.

Most of the interviewed businesses had a recurring risk experience of "no problems", and therefore they were not likely to respond to the risks anyway. However, for those that did have "water problems", they were under pressure to respond and to convert their risk experience to "no problems" in the future. Some responses were meant to address mixed causes. Examples include widely-used sandbags in the event of potential flooding. In addition to protecting properties from storm water flooding (due to heavy rains), the sandbagging was also used to prevent seawater backflows from the drain during high tides, as seen at the Dental Service and a nearby Indian Restaurant in Port Adelaide.

Furthermore, the recurring process tends to be consistent with the frequently reoccurring nature of extreme flood events. This implies that a change of frequency in flood events would affect the way in which business would respond.

6.3.3 Break point

Although the recurring processes display the transformable processes/status of "surviving exposure", including "no problems", "having a problem" and "resolving the problem", break points represent a number of significant criteria that differentiate the recurring status. The identification of these break points is critical to understanding how the businesses respond to the flood risks, as these break points act as "tipping points", from which the recurring status can be transformed. In addition, the break points highlight the conditions under which the interviewed businesses undertook their responsive measures.

Survey data demonstrated that the business responses focused on break points. Based on the interviews, typical business responses were linked with the causes and consequences of flood risks, as shown in Table 6.1 (the break points are underlined). The business responses to flood risks are summarised as follows:

- Upgrade breakwater protection
- Lift ground level/building foundation
- Upgrade drainage systems
- Keep the drains maintained
- Keep sufficient capacity of storm-water retention

- Implement effective sand bagging
- Make sure the pumping capacity is sufficient and capable

Table 6.1 Causes, consequences and break points from business interviews

Cause	Break point	Consequence	Response
strong wave	Is there sufficient breakwater protection?	wave damage to facilities on the water-front	Seeking protection
high tide	Has building foundation built up to safety level?	Inundation of infrastructure &buildings on the water-front	Lifting ground level
high tide	Has ground level built up?	Inundation to workshops on the water-front	Lifting ground level
heavy rain	Has building foundation built up to safety level?	Inundation of streets and business sites	Lifting ground level
heavy rain	Has the drain blocked?	Inundation of streets and business sites	Maintenance of drain
heavy rain	Is the drainage system sufficient?	Inundation of streets and business sites	Upgrading drainage
heavy rain	Can storm water retaining, storage & wetland cope with?	Inundation of streets and business sites	Improving capacity
heavy rain	Has sandbagging been implemented (at business sites)?	Inundation of streets and business sites	Taking precaution
heavy rain & high tide	Has building foundation built up to safety level?	Inundation of seawater backflow to streets and business sites	lifting ground level
heavy rain & high tide	Has a capable pumping station been built?	Inundation of seawater backflow to streets and business sites	Improving adaptive capacity
heavy rain & high tide	Has sandbagging been implemented (at business sites and drain inlets)?	Inundation of seawater backflow to streets and business sites	Taking precaution

Source: 2010 Business Survey

As Moss et al. (2010, p. 754) have highlighted, the projected sea-level rise would also have a critical impact on the break points and thereby the consequences. Some businesses were seriously evaluating the consequences and responses in the context of future scenarios, such as the yachting business which had considered a breakwater (as the break point) crucial in protecting its marina:

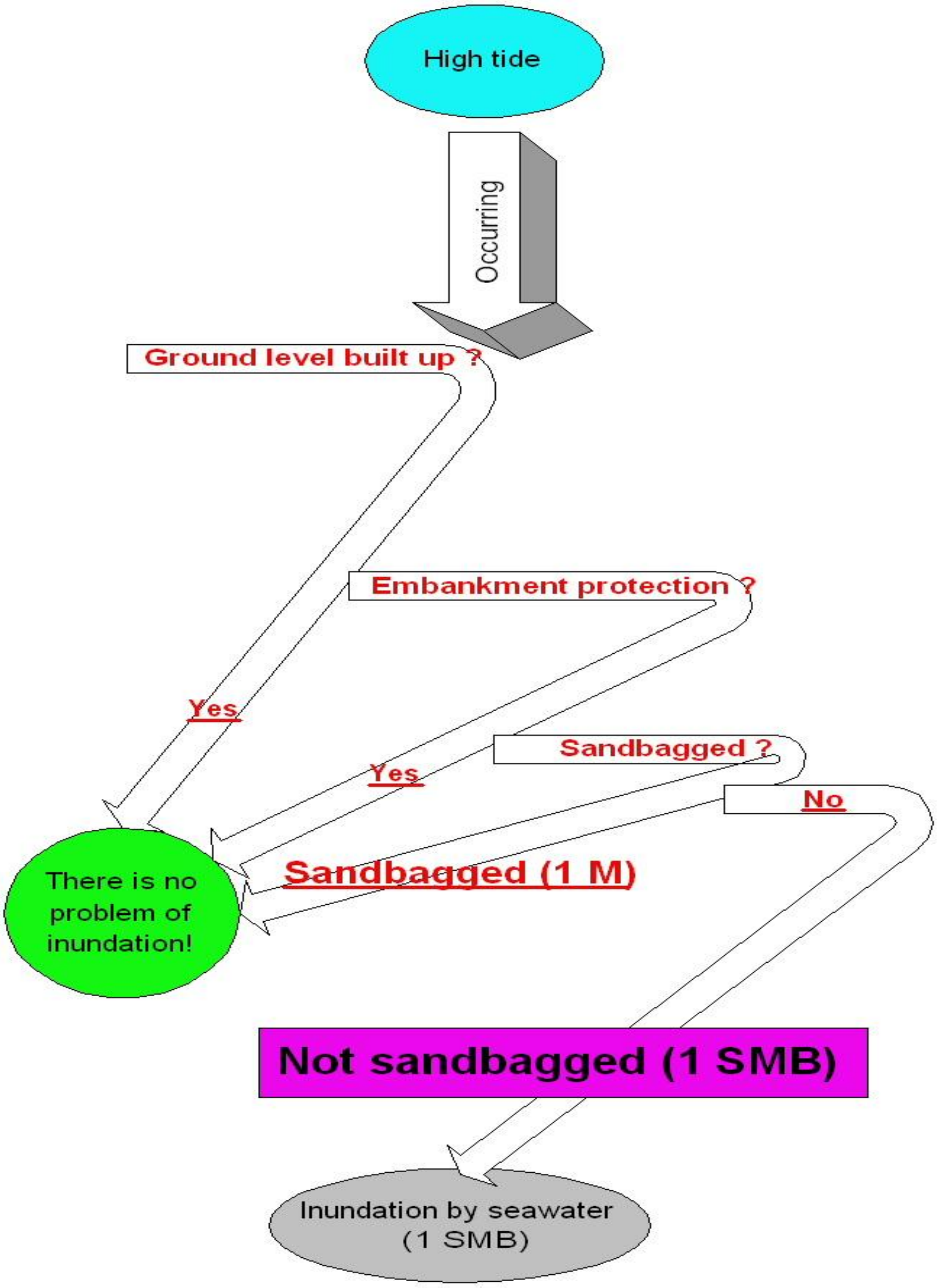
"… During the year we probably have had 10 or 12 days roughly, considered to be significant. I don't know if it would get worse over 30 years or not, a period was too short to be able to say like 'ok, we've got as twice like those as 30 years ago', I don't think it is right to say like that…but we were certain to have probably considered it more now, because we have … and also because this one (marina) here is more exposed, than this one here…what happened is during storm conditions and high tides, you get swells build up, rolling into the marina, basically penetrating it. The marina here is somewhat protected by the peninsula and the breakwater. But this one is more exposed unfortunately …" (source: in-depth interviews in the 2010 Business Survey, no. 2).

6.3.4 Nested and structural order

The processes of "resolving the problem" show nested and structural orders which reflect a unique character of the causal-consequence relationship. A nested and structural order highlights a distinct sequence of responses to flood risk, from a cause/threat, through to a break point, and then to a particular consequence such as "No problems", "damage" or "inundation". For example, facing the threat of high tides, the majority of businesses located at sites where the ground level had been built up, would end up with "no problems". If some business sites were not high enough, embankment protection was needed or sandbagging should be implemented in an emergency. Although sandbagging was not regarded as a permanent protection, it was cost-effective, and in fact, a final option/bottom line (based on business interviews). If a business was unsuccessful in these responses, it would end up with "inundation by seawater", as shown in Figure 6.1.

Birkenhead Tavern has basically followed the order demonstrated in Figure 6.1, in a recurring process to mitigate flood risk from high tides. It had been relying on sandbags for business survival, given its low-lying locality and the sub-standard embankment in Birkenhead. The shipyard of a SMB (Small-Medium Business) in the water-front of Gilman had suffered inundation during the "Anzac Day" King Tide in 2009. Its response was to build up the ground level, an “expensive” option (compared to sandbagging) but it aimed to permanently eliminate the threat from high tides.

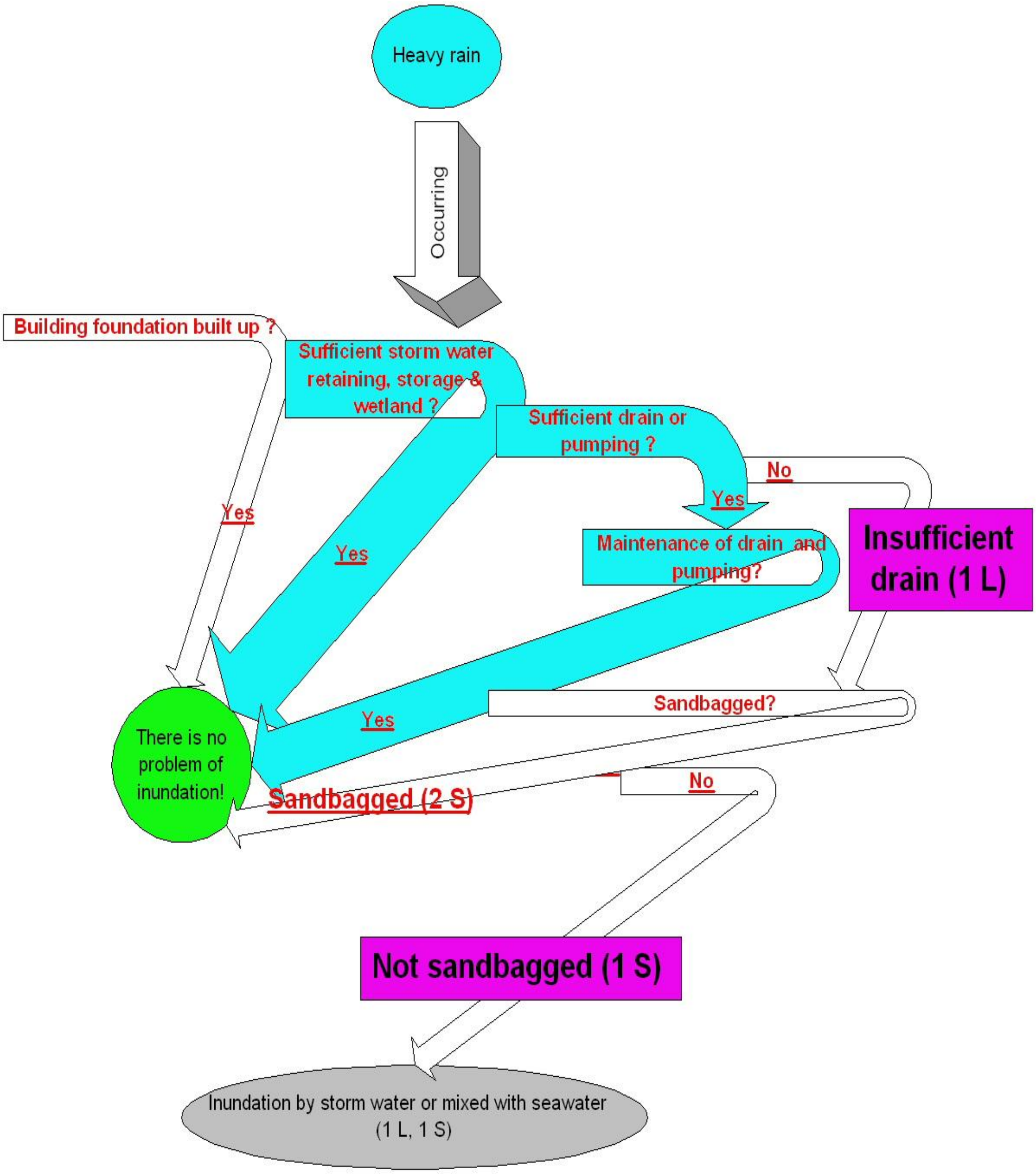
Figure 6.1 Response to high tide in nested and structural order



Source: 2010 Business Survey

It should be stressed that the stages of response are “structural”, representing a latent pattern of risk responses. These logic/patterns display a number of sequential criteria/interaction between causes and consequences, based on the nature of flooding. The order is also shared by the majority of interviewed businesses as common sense, rather than simply related to a single business attribute, such as the size/scale, industrial classification or the length of time the business had been established. Figure 6.2 shows the nested and structural order exhibited as responses to the risk from heavy rain.

Figure 6.2 Response to heavy rain in nested and structural order



Source: 2010 Business Survey

A number of attributes associated with the responsive options in the nested and structural order are as follows:

- Generally the lower in the order (closer to the bottom), the less the cost of an option.
- The higher in the order (closer to the top), the longer term of the effect (protection)
- The lower in the order, the easier to put into practice
- Generally the lower in the order, more frequently human involvement/action is required

6.4 Types of Business Survival

As detailed earlier (Subsection 6.2.1), the interviewed businesses can be classified into two groups: (1) seven businesses did have flood problems, and (2) the rest had no problems at the time of survey. This section firstly focuses on those that did have water problems, discussing the causal conditions and consequences, as well as the responsive options taken by the businesses for surviving the exposure to flood risks. Then, an enterprise-sized business with "no problems" is examined in detail, by scrutinizing the typical attitudes to risks and the recurring process/experience of survival.

6.4.1 "Having a problem" on site

As highlighted in the previous section, businesses on the water-front exhibited different break points and structural orders from those located further inland. Thereby they presented two categories of businesses having on-site flood problems. The first is featured by industries of recreation, ship-building, and port facilities. The nature of the water-front locality makes wave protection critical to the facilities like launch ramps, slipways and concrete surfaces, etc. In addition, seawater inundation is also threatening their infrastructure and buildings. As a result, their offices and workshops need to be above water as well. This was also the situation for water-front hospitality in the case of the Birkenhead Tavern. Thereby the structural orders highlight the critical responsive option for these businesses to survive: (1) wave protection (i.e., breakwater), (2) if the ground level is not high enough and embankment protection is not sufficient, sandbagging would be the bottom line.

The second category includes businesses inland (not necessarily on the water-front). A car service business interviewed in Glanville had been flooded due to a drain blockage which was fixed by local authorities. If the problem recurs, low cost options would include sandbagging or water pumping, as demonstrated in the structural orders in Figure 6.2. More complex problems were encountered by the Port Adelaide Dental Service and a nearby Indian Restaurant, where sandbagging had been implemented around the business sites to prevent inundation from heavy rain. In addition, the inlets of public drainage systems were also sandbagged to hold seawater back flows during high tides.

Exxon Mobil, an oil/fuel/petrol wholesaler (Large-scale) was in the second category. It had experienced "floods in the terminal" when there was unusual weather conditions described as "high tide and bad storm". Like other petrol terminals in Port Adelaide, Exxon Mobil operates on a large area of concrete ground, storing fuel products in large-sized oil tanks. As the business site is prone to hydrocarbon hazards, large amounts of storm water cannot be simply sandbagged or pumped out. This was a complicated situation which will be discussed in detail later (refer to Subsection 6.5.2).

6.4.2 "No problems": a case on the waterfront

Although flood problems were ruled out by the majority of businesses that participated in the survey (38/43 = 88.4%), it is necessary to examine the attitudes and experiences of these "lucky" businesses more in detail, to provide a broader perspective of the issues. Although a few were concerned about future uncertainties (e.g., sea-level rise), many businesses were confident that they had "no problems". This was particularly the case of large-sized businesses, as they believed that everything was under control. Aiming to gain insights into this type of business, a case-study methodology was applied to the analysis of Flinders Ports, a typical water-front enterprise.

Flinders Ports is South Australia's premier port facility provider, with its main service point at Port Adelaide as a gateway to overseas. Based on the Guide to the Ports (Flinders Ports 2010), the Port of Adelaide consists of an Inner and an Outer Harbor with over 20 wharves including the container port, as shown in Figure 6.3. A number of commercial berths are distributed along the study area, including the loading and exporting berths for businesses operated on the banks of Port River. The berths handle a range of principal commodities of bulk and break bulk cargoes, including grains, minerals, fertilizers, livestock, motor vehicles and other products for wide use in the State economy.

The interviews were centred on marine operations (everyday) and the safety of port infrastructure, including wharf facilities, bulk loading infrastructure, storages, and shipping channels, etc. The operational services and infrastructure are major components addressed in a flood emergency plan (Flinders Ports 2008, p. 100). In terms of causal conditions, the interviews focused on storm tides, consistent with the emergency plan and the Port User Guide (Flinders Ports 2015, p. 2).

A number of key points around the issues of flooding were covered in the interviews. These points were described as follows:

Figure 6.3 Berths in Port Adelaide

Source: Flinders Ports (2015, p. 2.4)

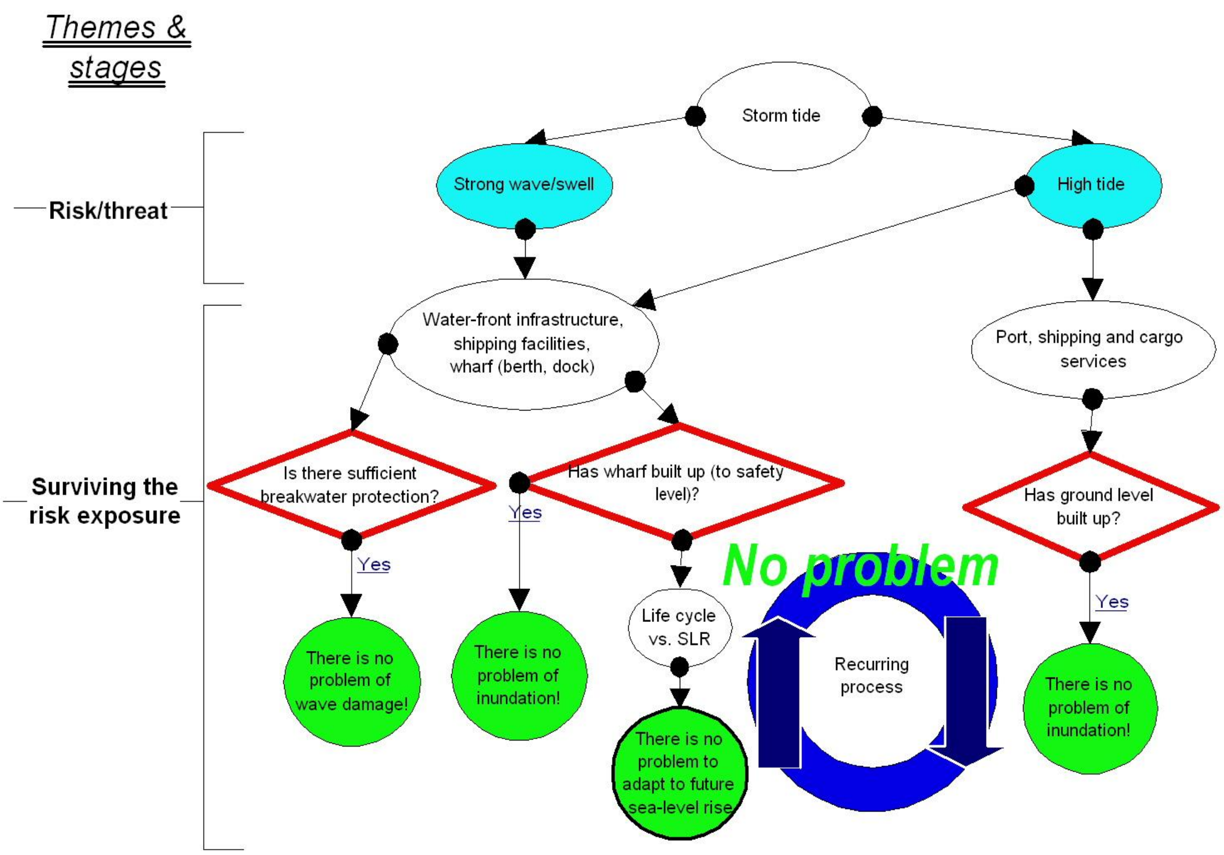
- The danger during periods of severe weather conditions
- Options to handle the situation and mitigate the adverse affects
- The impacts of future changes of tides and sea levels
- How can the ports and industries cope with the changes?
- Critical points for "surviving the exposure" and the responses
- Advice and suggestions

Firstly, there are a wide range of precautions for storm tides hitting the ports, but this response is not taken as an emergency. Very strong winds and waves can damage wharfs and beacons along the channel. Consequently it is necessary to fix the damage quickly. Shipping operations on berths can be affected as well. Thereby traffic control is practised when necessary. For instance, tugs should be looked-after during storm conditions, ensuring height clearance and similarly for container cranes. When tides are high (for about 1 hour), ships must be stopped from getting into the ports (i.e., stop operation in times of extreme conditions). Generally, bad weather conditions happen 4-5 times a year but only last for about 6-8 hours maximum a day.

Secondly, factors such as planning, proper operation, timely repairs and maintenance, and protection by breakwaters contribute to "surviving the exposure" of flood risk. The height of wharfs is a critical standard in designing the ports. Maintenance includes dredging sands to keep the depth and width of the channel (Port River) against the side-way effect of currents. It was believed that all these requirements had been met at Flinders Ports and apparently there were no recurring problems. Two break points were identified as (1) sufficient breakwater protection, and (2) the wharf (ground) had been built up (to a safe level), as shown in Figure 6.4.

Clearly the wharf heights were fundamentally important as break points. Based on data obtained in the interviews, the changes to wharf heights demonstrate the adaptation of Flinders Ports to not only bigger ships, but also to sea-level changes in more than a century. In fact, the heights of old wharves on Doc 1 and Doc 2 (Inner Harbor) were built up to approximate 4.5 metres (LAT) in the 1890s. New wharves nearby were consistent with this height, like Berths 18 to 20 (4.6m). Later in the 1950s, OH 1 to 4 in the Outer Harbor were built up to 5.4 – 5.7m, increasing the height of the berth by about 0.7m in a period of 60 years. It is noted that the height of OH 6 to 8 dropped down slightly to 5.3m for special considerations of container terminals (Flinders Ports 2015, p. 2.5).

Figure 6.4 Flinders Ports' risk perception: "no problems"



Source: 2010 Business Survey

Importantly there was an optimistic attitude towards the effects of sea-level rise and tidal changes in the future, as Flinders Ports were taking a long-term view of the impacts. In fact, they perceived it would take longer than their life cycles to confront the challenge of a substantial sea-level rise in the future. Here life cycle means the lifetime of a port to build up for the use of shipping, which may mean ??? are demolished for new ports???. In that way there would be no problems to adapt. In other words, it would be better to rebuild a port ("start from scratch") than upgrading an old one beyond its life cycle. Alternatively, ships generally have a shorter life cycle (20-30 years) than ports and thereby, it is easier for the shipping community to adapt to ports by building a new generation of ships, rather than ports to adapt to ships (i.e., adapt to tides and sea-level rise).

Moreover, it was argued that there were many more changes than just sea-level rise that happened during the Ports' life cycle and therefore continued efforts to address the new requirements. The following introduction provides an insight into the Ports' capacity of adaptation (e.g. the stage development project, as underlined):

> 'Flinders Ports is committed to improving port services to the benefit of existing trades and assisting in the development of new business. The Company continues to expand its port facilities to meet the demands of its customers….With the development and growth of the mining sector in South Australia, Flinders Ports is looking to develop all its ports to offer a competitive supply chain solution to the industry….One of the projects has been a stage development of a bulk precinct located at the Inner Harbor in Port Adelaide. The development has incorporated upgrades to wharf drainage systems; construction of a bulk ship loader; construction of storage facilities; proposed construction of rail directly into the precinct and a weighbridge and wash down facilities' (Flinders Ports 2015, p. 1.1)

From Flinders Ports' point of view, smaller ports (fishing or recreational ports) might be more affected than the big ports by tides or sea-level rise. They may block up and need dredging every year due to generally less protection and maintenance than big ports. In sum, the case of Flinders Ports clarifies three critical criteria for a water-front business to "survive the exposure” of risks from high tides: (1) ground level, (2) wave protection, and (3) adaptation, taking into account the business (infrastructure)’s life cycle.

6.5 Local Issues of Business Survival

The in-depth interviews showed a number of complicated situations of businesses “surviving the exposure”. Although some businesses did not have a current problem at the time of interview, they were worrying about adverse effects in the future. Others raised site-specific problems, which made more sense than the consequences of wave damage and inundation. In other circumstances, multiple causes were evident. As some problems might potentially result in adverse consequences and uncertainty of business survival, this section will examine these issues in more detail.

6.5.1 “Concerns of adverse effects” in the future

Reflecting the uncertainty of the basic business process “surviving the exposure”, five (3 large-sized, 2 SMB) interviewed businesses expressed concerns about flood risk in the future when storm tides occur. Some of them already had experienced on-site problems, but others were worrying about the possibility. Thereby the discussion here focuses on a number of aspects as follows.

- What conditions were these businesses concerned about?
- Why were they concerned? and
- Contexts of changing causes, conditions and processes

The future concerns from businesses were largely based on past experience of water problems but a general knowledge of future sea-level rise was likely contributing to the risk perceptions.

A marina that suffered wave damage and tidal inundation in 2010, expressed concerns about an increase in storm-tide events, such as a 50-year event that potentially might occur sooner in the next 30 years. A shipyard was considering whether its on-going mitigating effort of raising the ground level could guarantee it would be flood free at least for 40 years. It should be noted that both these businesses had initiated efforts to mitigate the flood risks on site. In fact, their responses were focusing on exactly the break points identified earlier, including extending the breakwater and building-up ground level. Both of these options had substantial financial impacts on the businesses themselves. However, these responses were aimed at providing long-term protection and were seen to be the most cost-effective way of resolving the problems.

As an umbrella of Small and Medium-sized Businesses (SMBs), the local business chamber centre at Todd St. expressed concerns about the uncertainty in relation to the low-frequency but high-impact sea-level extremes, largely due to its obligations to assist businesses prepare for an emergency. Although there were no on-site flood problems, the centre needed to make sure the SMBs had insurances and the means to carry on business after they had been adversely affected by an extreme event. There was evidence that the relatively short life cycle (10-20 years) of typical SMBs, would affect their risk perceptions adversely.

The final group included the Pelican Point Power Station and the ASC (Australian Submarine Corporation). As the key utility/energy infrastructure of the State, the former was considering a review of the building flood levels/standards set in its initial environmental impact assessment report (Swinbourne 1998, p. 14), in the context of updated scenarios (storm tide, wave effects, land subsidence, standard sea-flood risk level, and sea-level rise). A proposed standard sea-flood risk level (as an extreme sea level) was set to a 200 year ARI, instead of a 100 year ARI in the 1998 report.

As the largest Australian-owned navy defence company, ASC's Osborne site consists of two parts, one of which has yet to further build up ground to a safe ground level. Given that the seawall/levee banks in this area were out-of-date, there were concerns of the impacts on infrastructure, particularly in relation to storm tides and projected sea-level rise. Seeking informed decision-making, ASC called for a dedicated modelling of seawater flooding for this area based on high-resolution elevation data.

Overall, the businesses with concerns were more likely to be large-sized enterprises which were taking a long-term view of the future, in respect to the possibility of changing causes, conditions and potential adverse consequences. These concerns reflect the uncertainty among the variables of the causal-consequence relationship, as discussed earlier (Section 6.3).

6.5.2 Potential hazardous inundation of fuel terminals

The consequence of inundation can have serious side effects, such as potential hydrocarbons hazards, including catching fire and contamination to soil and groundwater. This is particularly the case in respect to the fuel terminals, located on the Port River bank on then Lefevre Peninsula, storing and loading liquid products of petrol, aviation fuel, diesel and bitumen. ExxonMobil's Birkenhead Terminal was one of these businesses, which had been operating on a property of 15 hectare land since 1920's. Figure 6.5 (left) highlights its operation sites.

Unlike Flinders Ports sitting on the waterfront, the terminal is located behind its importing berth, and therefore the flood problem was said to be caused by "bad storm" (i.e., heavy rain), rather than high tides. The berth was assumed to be higher than the highest tides and it was also noticed that the protection banks (walls) were built up high enough around the fuel tanks at the terminal sites, as shown in Figure 6.5 (right). Based on interviews, however, the protection was "for tank failure, not for flooding – they stop spills of oil but not floods".

Figure 6.5 ExxonMobil Birkenhead Terminal sites

Source: Photo imagery (left) from the South Australian Government

Importantly, "The sewer is the main area to be concerned" due to the large paved ground, which has been extended several times to support the rail siding and other facilities for loading tank trucks/cars simultaneously (Figure 6.6). In the meantime, the sewer system has also been built up to a maximum capacity to treat 22-million-litres of storm water per year, depending on a 5-million-litre tank storage. The storm water is a thick mixture of hydrocarbons, collected from a dozen sumps and pumps across the large paved area during wet seasons.

When an extreme event of heavy rain occurs, however, the great volume of contaminated storm water overflows the sewer system and quickly floods the nearby roads and streets. The floating hydrocarbons are hazardous, causing pollution, and a fire risk, which are more serious than the consequence of storm-water inundation. It was claimed that incidents of "overflowing sewers" had occurred every 5-6 years on the sites of ExxonMobil's Birkenhead Terminal. Each time measures of hazard precaution were taken at the terminal for an emergency and yet no permanent solution has been considered.

Figure 6.6 Loading tank trucks at the Birkenhead Terminal

Source: Photo from ExxonMobil and Birkenhead Terminal (2014)

Although the "hazard" problems of spills of liquid fuel have been focussed on human safety issues and the environment (ExxonMobil 2011; ExxonMobil and Birkenhead Terminal 2014), the potential hazardous impacts accompanying heavy rain/sewers have been overlooked. In addition, interviewees highlighted that there were similar issues with other fuel terminals (e.g., BP) in Port Adelaide, and therefore there was a need for a serious resolution.

6.5.3 Conflicts of responsibility on public fuel supply

Who is responsible for the State's fuel security, the oil company or the government? This crucial question was raised in the interviews with representatives of the ExxonMobil's Birkenhead Terminal, when there was a discussion around the impacts of flooding on business activities:

"(In the case of floods)…function will be affected. Government may see it is the oil company's responsibility to maintain the supply (of fuel). As a business, we don't see our responsibility to continue to supply to the State. If we were destroyed, it'll affect the State! … We'll do the best we can …' (Source: in-depth interviews in the 2010 Business Survey, No.11).

This is a particularly worrying statement as in 2010, ExxonMobil was critical to the fuel supply of South Australia, as about 70 percent of petrol was imported from the Birkenhead Terminal. If the other two biggest suppliers were taken into account, the proportion rose to 95 percent. The terminal received “all of its product by ship from refineries in Victoria, Western Australia and Singapore” (ExxonMobil 2013). Figure 6.7 shows the big tanks of petrol storage at the terminal by ExxonMobil at the Birkenhead Terminal.

Figure 6.7 Large-sized petrol tanks at Birkenhead Terminal

Source: Photo from ExxonMobil and Birkenhead Terminal (2014)

Despite the fact that the terminal played an important role in the State’s economy, apparently the issues of responsibility were controversal. The terminal’s business point of view was explained further by the interviewees as:

‘… There is no public drain in this area – only Mobil built drains and we treat the sewers … we own the land and use the Berth of Flinders Ports. If ships can’t come, then it is our problem as well … We have no emergency plan to the supply. Our emergency plan is for the safety of our staff, protecting people and the environment, but not for the public and the State …’ (Source: in-depth interviews in the 2010 Business Survey, No.11).

As highlighted in the interview transcripts above (underlined), there were multiple stakeholders involved in the issues of public fuel safety (i.e., security of supply). The stakeholders' response to an emergency is dependent on their answers to the question of responsibility. The response, like the emergency plan, will obviously have critical impacts on fuel security and public welfare. In other words, conflicts of responsibility on public fuel security need to be addressed to avoid any adverse consequences, particularly relate to fuel supply that has already been affected by storms or potentially sea-level rise.

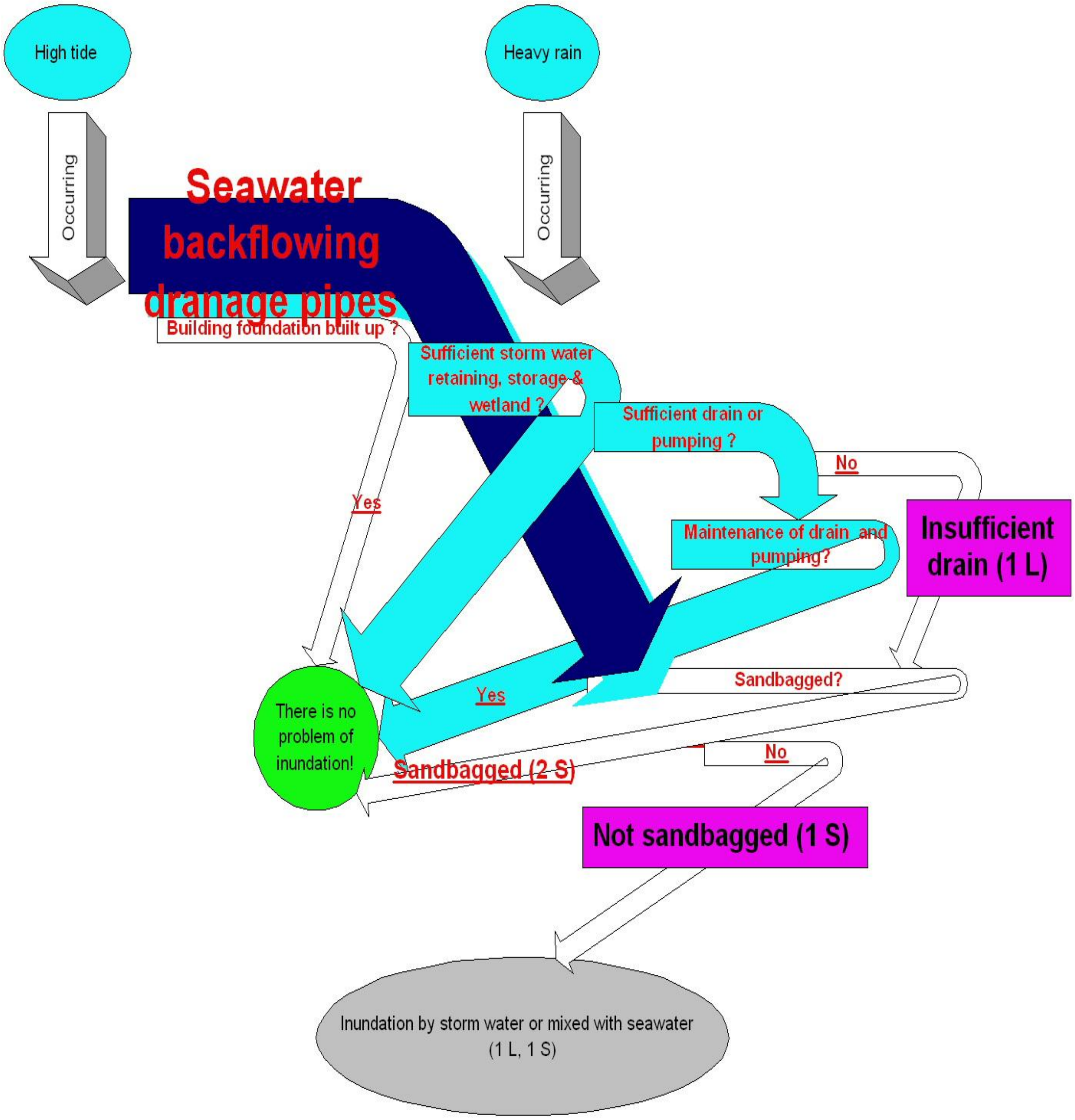
6.5.4 Covariance of causes and consequences

A covariance of the concurrent causes of high tides and heavy rain, as well as their consequent inundations was noticed in the "surviving" process, as shown in Figure 6.8. It highlights seawater back flowing along out-of-date drains under old streets of Port Adelaide during high tides. In times of heavy rain, the problematic drains restrict the flow of storm water and consequently inundations are unavoidable. The responses to flood risk include pumping out the flood water, and sand bagging drain inlets at business sites.

The consequence of high tides is seawater back-flowing in the drains, largely reducing the drainage systems' capacity. In the meantime, the consequence of heavy rain is a large volume of storm water flowing into the drains as well. As a result of concurrent high tides and heavy rain, water levels (of both seawater and storm water) will back up even higher and eventually cause inundation.

As the covariance between the causes and consequences has potential to change adversely at an elevated level (given that the local sea-level is rising), the out-of-date drainage systems deserve serious consideration in the business process of surviving flood risk.

Figure 6.8 A covariance of high tides and heavy rain



Source: 2010 Business Survey

6.6 Some Insights into Business Response

In order to have an in-depth understanding of the underlying principles for local businesses responding to flood risks, the question of "*Why did the businesses respond to water problems* *like those described in Section 6.3?*" was explored, not only focused on the businesses which had "water problems", but also included those that did not perceive a risk. This section details some important results of the study.

6.6.1 Critical factors influencing the response

A number of points appear to be critical to businesses' adaptive behaviour, when comparing the interviews. The context in which they were discussed varied little, and the underlying logic did not differ substantially. In addition to the business location (i.e., if located in the waterfront or low-lying areas) and functionality discussed earlier (Section 6.4), the important factors include:

- The scale/size of the business
- The length of time the business has been established
- The view on responsibility/who should be responsible for flood mitigation
- Business plan/long-term view

For example, big enterprises generally did not perceive a risk from floods, as demonstrated earlier by Flinders Ports (Subsection 6.4.2), large storage companies, and two electricity plants. By contrast, small/medium sized businesses were more likely to perceive flood problems, like those experienced at the marinas at North Haven. The underlying reason is that a big company usually has greater adaptive capacity than smaller ones. Also the longer the business has been established, the more likely it has already mitigated flood risks on site.

It was noticed that smaller businesses were more likely to say the government should take responsibility for floods. They saw it as unfair for a new business to take full responsibility for water problems. As an example, a fabrication business with workshops on the waterfront at

Gilman was obviously stuck in this situation. Finally, it was forced to raise the business site as a dedicated response to the flood problem. It is important to note that the fabrication company was different to many other small businesses, as it had a long-term plan for development on site which was "rare to find on the waterfront of Port Adelaide" (Source: in-depth interviews in the 2010 Business Survey, No.7). Obviously, its ambition of further business expansion made it difficult to relocate somewhere else.

On the contrary, a small car service business at Exeter that had suffered frequent flooding relocated away from Port Adelaide. While the exact reason for moving was unclear, the manager commented:

"We have been here for about 20 years, … now 8 people working here, our business includes wholesale, parts distribution, and selling car parts, computers and pumps, etc… We do have flood problem and it had happened a few times a year. The worst one was about 8 months ago, because of heavy rain (and last long). This corner of the block was flooded, through this door to that door. … It was fresh water (not salty). There maybe a king tide that day and storm water has trouble to get away…That day stopped business, plus damage and one-day payment for cleaning (preparing the next day). It costs at least a couple of thousand dollars. If we haven't been here during the day, it will be a lot worse (the cost could reach $20K) … and emotional stress… The Council won't pay … It was very hard to get the right person … When they (the Council) fixed the storm water, they found a blockage down further. They put extra sumps, but have not yet convinced that they had solved the problem … The Semaphore pipe project was to bring water to here even faster, but the problem is that water will have no way to go! Each time road works are built on top and make the road taller and taller (that means the storm water in the street will flow into the residential lands which are lower). We punk holes on the road to get the water off faster, but (that response was) not very successful. Ideally, (we should) put our building higher. … Big business has just to leave, but it is not easy for us (to move away)". (Source: in-depth interviews in the 2010 Business Survey, No.17)

As discussed earlier (Section 6.3), the businesses at risk typically have to respond in the nested and structural orders. Over a long period of time (e.g., 30 years), the responding processes will recur many times (e.g., a few times each year). If the problem could not be fixed at the break points, there will be higher costs for the problem to be resolved later in the following stages. For example, maintenance costs for pumping stations would be much higher in the years to come (note: a number of survey respondents pointed out that potentially there would be higher costs for flood damage due to power failures in running the pumps).

It was also noted that a business with long-term prospects would be likely to invest more than those businesses that take a short-term view, on measures to address fundamental problems (i.e., problems at the break points). The fabrication company had to raise the "ground level", despite costing much more than other measures, such as sandbagging. However, in the long term, fixing the problems at the break points is more secure and cost-effective.

The above discussion highlights a number of factors likely to impact on a business decision to take responsive actions. Some of these factors are:

- Adaptive capacity (e.g., property/capital value)
- Subject norms (i.e. the perceived social pressure such as the impacts of other people in family or community, to perform or not to perform the behaviour)
- Public trust/sharing responsibility
- Locality (relevant to spatial attributes)
- Business functionality

6.6.2 Nexus between the business response patterns

A number of characteristics (i.e., recurring process, break point and nested/structural order, etc.) are responsible for business survival (i.e., surviving the risk exposure of flooding), which was conceptualised as a basic business process (BBP). As the BBP consists of actual business responsive actions on, and adaptation to, the perceived risk of flooding, those characteristics are in fact patterns of the business response under the risk of flooding.

A number of business response patterns were identified by examining the risk perception and response under local contexts, indicating some interactions and criteria underlying the business decisions to respond. These critical issues are as follows:

- The bottom line of business survival was to avoid the adverse consequence of wave damage or inundation, based on the type of responsive options that were taken. This means the focus of business response was to ensure that the "break points" (as tipping points) should NOT be crossed.

- It appeared that the majority of the interviewed businesses responded to flooding risks in a most cost-effective way. As the 2010 Business Survey showed, most businesses experiencing the recurring process of response ended up with "no problems".

- A key criterion for business risk response was costs. This means that businesses need to make sure their choices of responsive options are cost effective, whether they estimated the costs in the short-term or in the long-term. In fact, each responsive option needs to be evaluated in the specific situation of a business. This evaluation involves comparing the costs associated with the specific recurring process of resolving water problems and those costs that may eliminate future problems.

- The business concerns about future uncertainty reflected the potential impacts of sea-level rise on those patterns of business survival. First of all, the interviews showed that businesses were more likely to worry about the increasing frequency of flood events or the strength of wave/swell. These trends would result in an adverse consequence of wave damage or floods, due to worsening the causes of high tides and heavy rain. The current responsive measures would be insufficient to keep the tipping points (i.e., break points) from being crossed.

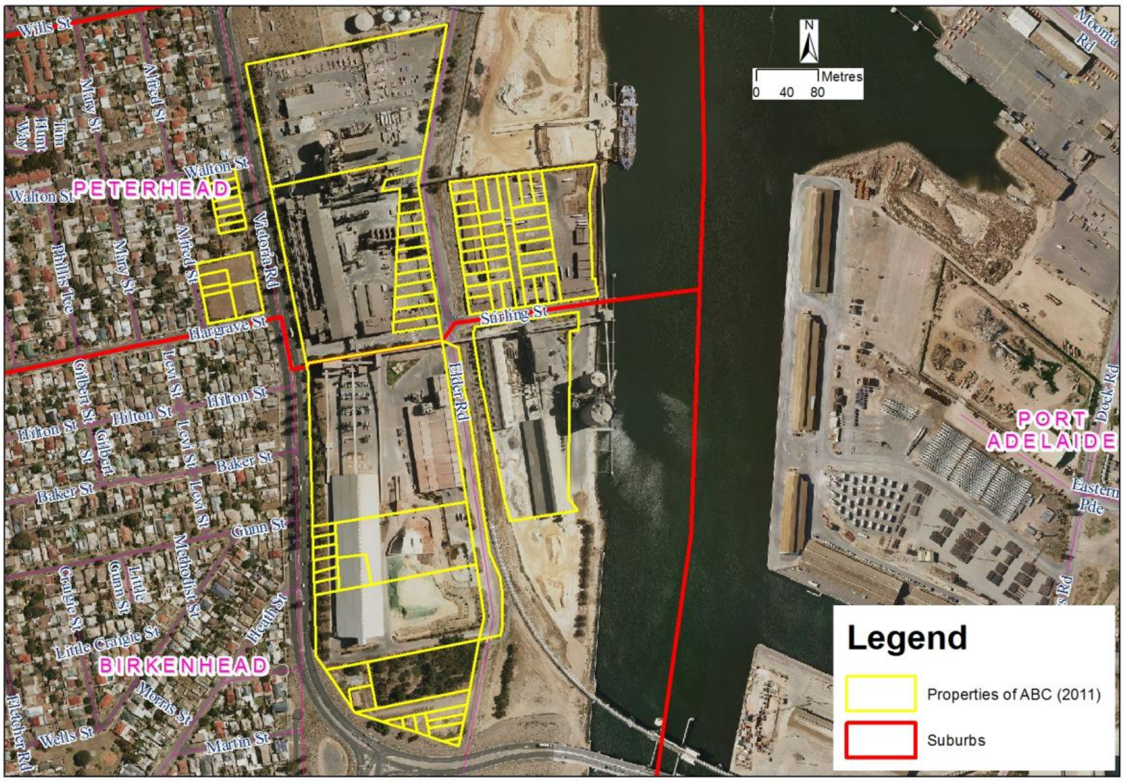
In addition, the current patterns of response would be under increasing pressure to change, which adds more uncertainty to future response and adaptation. For example, under future changed weather conditions, the current break points would be adjusted accordingly. The recurring process and structured order of response may change as well. These changes will certainly impact on the costs of response and thereby, the business risk response and adaptation will change accordingly. This would be likely to have mixed results for business survival and in a worst scenario, some businesses may not be able to adapt to these series of changes and close.

6.7 Risk Perception, Response and adaptation at Adelaide Brighton Cement

6.7.1 Introduction

Adelaide Brighton Cement (ABC) contributed to the 2010 Business Survey providing practical experience and an effective strategy in mitigating flooding risk, at its Birkenhead/Peterhead business sites on the west bank of Port River, as shown in Figure 6.9. This section reviews this business case based on examining risk perception, mitigation response, and reflected adaptive capacity. Then the risk from potential inundation by sea-level extremes was modelled under future conditions of projected sea-level rise, based on which the possible outlook, influencing factors the process of business survival were discussed.

Figure 6.9 Adelaide Brighton Cement (sites) in Birkenhead and Peterhead



Source: Author, data and underlying photo image from the State Government.

6.7.2 "Come to see why we don't have flooding"

A senior manager responsible for site security at ABC, said: "*I have not seen a flood for 23 years … there is no need of a policy on flooding*". Despite the notion "*got much flooding in the Peninsula*", he expressed high confidence of flood safety at ABC sites. Given the large area of concrete/bitumen grounds on site, apparently they "*need a lot of drainage systems for storm water*" (Source: in-depth interviews in the 2010 Business Survey, No.10).

However, ABC achieved "remarkable" flood safety by taking comprehensive measures of adaptation, featuring two "gravity feed storm water capturing systems" with a number of key components (Figure 6.10):

- Two large-size underground water tanks

- Parks
- Ponds
- Wetlands
- Pumps as a precaution to deliver excess water to the parks

Figure 6.10 ABC's storm-water capturing systems

Source: Author

The storm water capturing systems kept "clean" water in tanks during winter, and in summer it was used for watering trees, as an environmental barrier between Adelaide Brighton Cement and the adjacent residential areas (left side, Figure 6.11). The tank water was also used to wash trucks (right side, Figure 6.11) to meet EPA's requirements, ending up with "dirty" water which was treated by the ponds and parks (as pollution filters), before it entered into the public storm water systems.

Apparently these water capturing systems have ensured ABC's business functions run at capacity during both high tides and large volumes of storm water runoff. At the time of storm tides, the wharf was high enough to restrain the rising sea and keep away damaging waves. During heavy rain, water was directed to the water tanks, ponds, and parks in turn, before passing into the storm water drainage systems.

This was a typical reflection of the business recurring processes introduced earlier (Section 6.3), demonstrating successful survival against exposure to flooding risks from high tides, strong wave/swell and heavy ran, respectively. Importantly, at each "break point", the protection (e.g., wharf) and adaptive measures were adequate and effectively directed the process to "No problems" or "Resolving the problems". ABC's ground level, as a core "break point" was a fundamental determinant of the protection/ mitigation measures.

Figure 6.11 Tank water usage in Adelaide Brighton Cement: watering and washing

Source: Author

Unlike property owners who reported little adaptive behaviour in the questionnaire, the ABC displayed a complete business process of risk perception, intention and response. A strong perceived behavioural control influenced intention by balancing costs (e.g., constructing storm capturing systems) and benefits (keeping business processes going) (Cyert and March 1992, p. 17), and making the most of available resources.

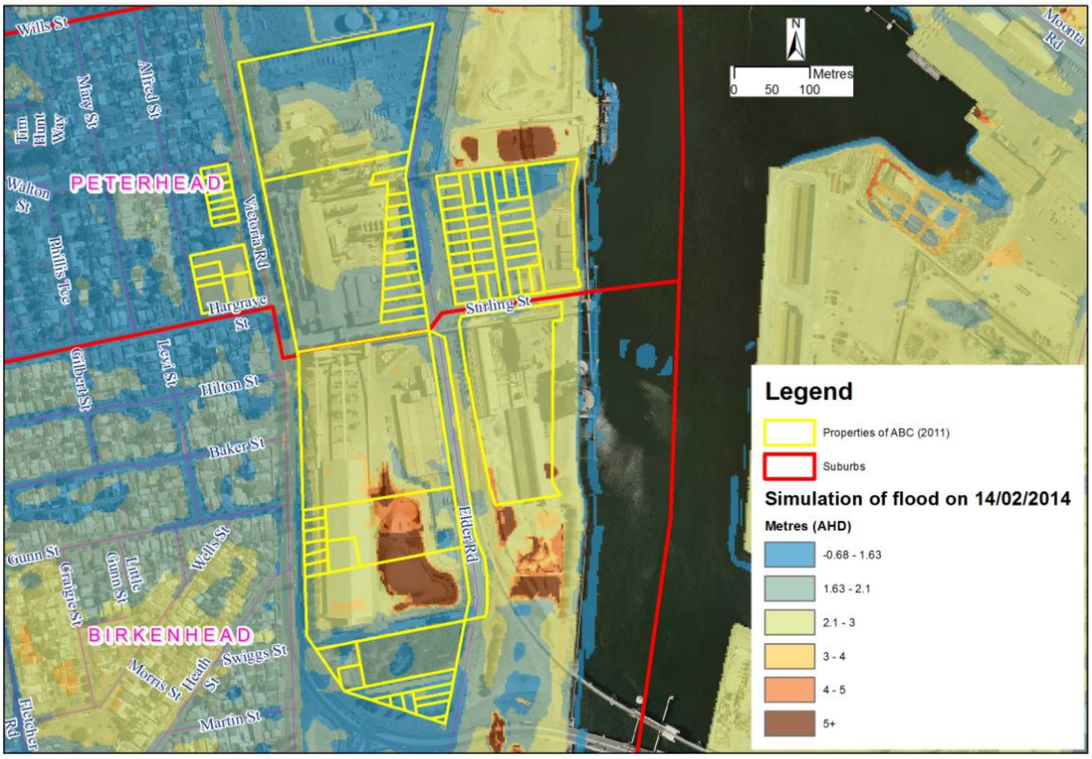
6.7.3 Reflected adaptive capacity

ABC's success in flood risk mitigation demonstrated a well-established adaptive capacity, which was advantaged by its location, including the following conditions:

- The business sites were higher than the nearby residential areas
- Low-lying parks and wetlands were valuable resources for retaining excess storm water
- Large areas of vacant land outside the northern boundary could be used for extended flood detention. This provided even greater potential to adapt to extreme weather events.

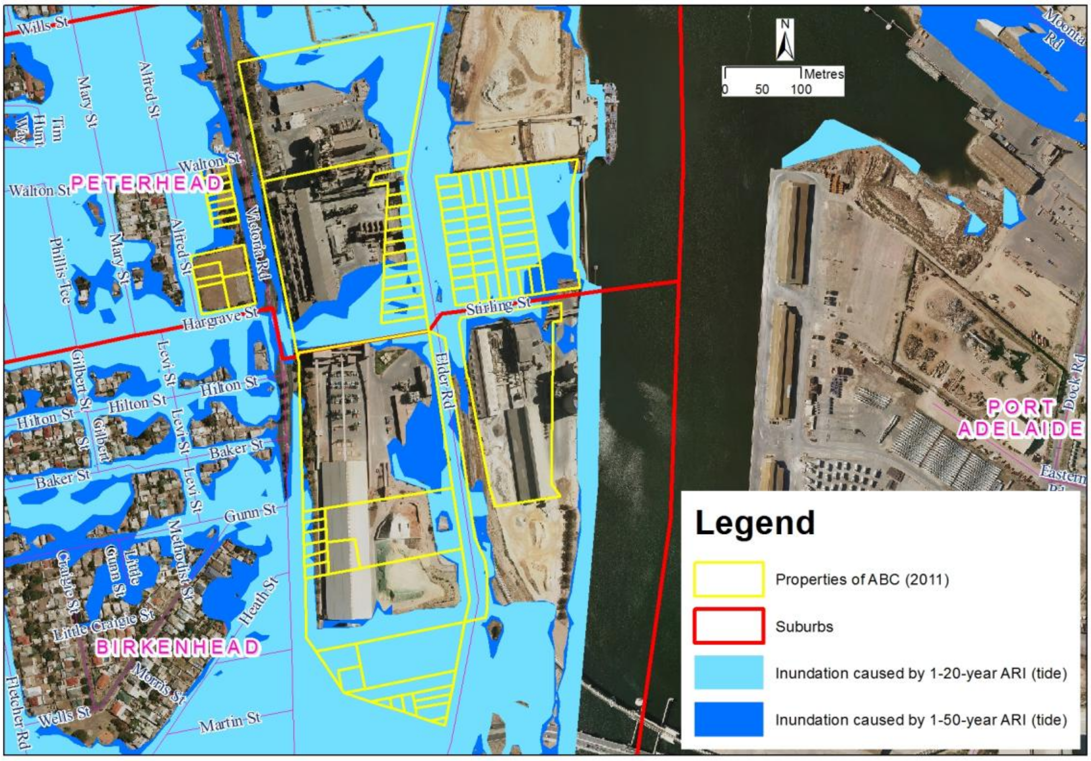
Although the low-lying lands were prone to flooding, they were utilised to increase adaptive capacity for risk mitigation. A simulation of the floods (14/2/2014) in Peterhead revealed that the impact on ABC sites was limited, as shown in Figure 6.12. The excess water was captured and storm tides of 20-year or 50-year ARI (tide) did not cause disastrous inundation due to the protection of the wharf, as the models show in Figure 6.13. The extent of inundation was confirmed by the storm tide induced flood event (9/5/2016) in Birkenhead (refer to Subsection 4.6.1).

Figure 6.12 Simulated storm-water Flooding on 14 February 2014



Source: Author, data and underlying photo image from the State Government.

Figure 6.13 Modelled seawater inundation at ABC sites at current conditions

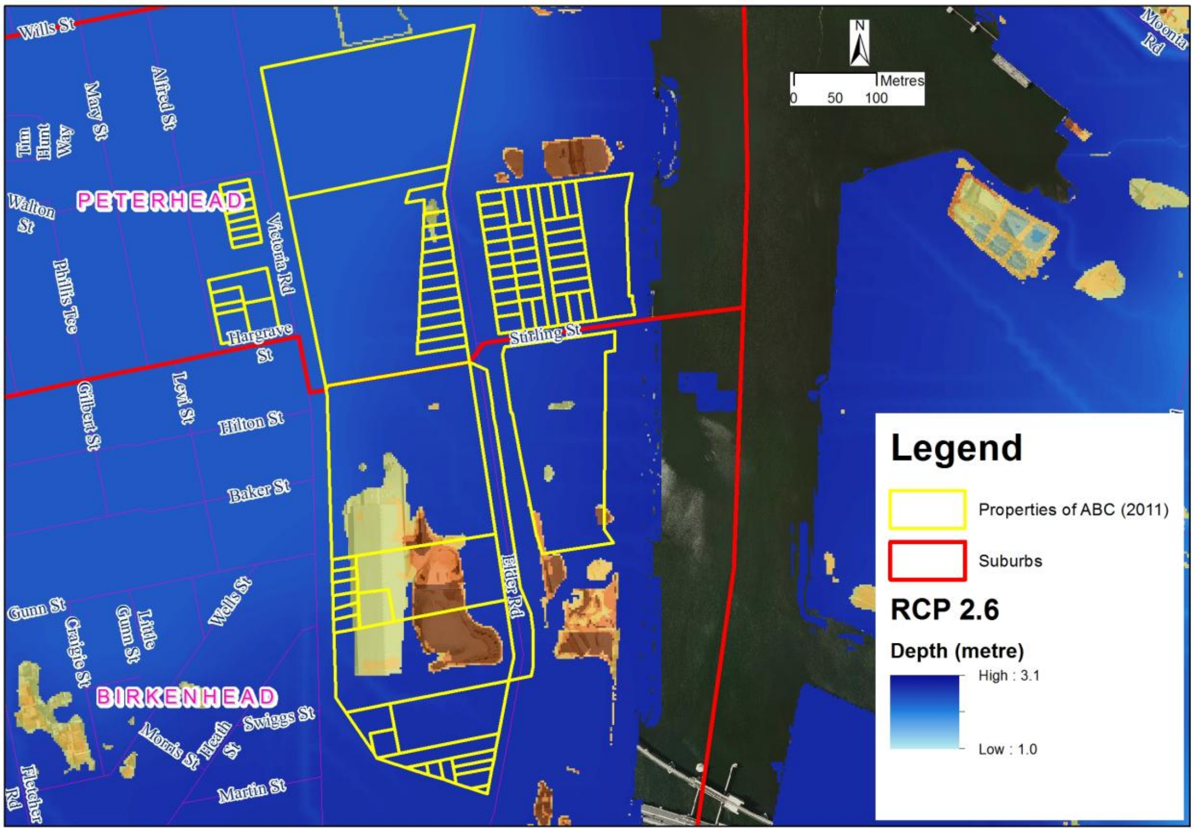


Source: Author, data and underlying photo image from the State Government.

6.7.4 Potential flooding risk in the future

ABC staff expressed concerns that sea-level rise may put pressure on ABC's present water systems and mitigation measures. Based on RCP 2.6 (IPCC 2013a, p. 21), a refined inundation model (refer to Subsection 3.4.2) was used to predict the flooding risk at the end of 21st Century, as shown in Figure 6.14.

Figure 6.14 Predicted inundation at ABC sites under RCP 2.6 in 2100



Source: Author, data and underlying photo image from the State Government.

While RCP 2.6 was a low scenario in IPCC (AR5), the inundation model of an extreme sea-level event was at the scale of 1-100-year ARI (tide). Also the local land subsidence was incorporated into the modelling as well. As a result, wide-spread flooding across ABC's sites in Port Adelaide was indicated. The sites in Peterhead were almost totally inundated and in Birkenhead, only the workshop and material pile would survive due to high ground levels.

Local flood water would be well above one metre. Unlike the floods caused by heavy rain/storm water, which could be contained in wetlands or pumped into the Port River, the extended seawater inundation would not be preventable because the river would also be high. If heavy rain should occur at the same time, there would be an even worse case of flooding, as the low-lying lands would lose capacity to contain floods due to seawater inundation. Therefore, the risk of flooding from storm tides to ABC in future decades should not be overlooked.

6.8 Conclusion

This chapter presented the analysis of the Business Survey on risk perception of floods. The analysis was initially based on data from in-depth interviews with 34 businesses. A basic business process (BBP) of business survival (or surviving the exposure) was conceptualised as a core category integrating the contexts of business risk perception. The second phase of the survey analysis focused on examining the latent patterns of the BBP and a causal-consequence relationship, revealing characteristics of recurring processes, break points, and structural orders, etc. The break points have been emphasised, as the significant breaks leading to distinct critical causes, consequences and options of response to risk exposure, as well as interactions among the key categories.

Based on the conceptual patterns, the survey results showed interactions among key concepts of the basic business process, along two dimensions: the types of business survival and the problems of surviving the risk exposure. Flood risk and threats, business conditions of exposure and options of response are interrelated accordingly, as well as the risk mitigation actions taken by businesses. Following that, a water-front business was chosen as a case study to demonstrate the insights relating to its risk perception. Focusing on the problems of business survival, the empirical survey data were reviewed in broader contexts, including the temporal dimension of risk and exposure, potential side effects upon adverse consequences and conflicts of responsibility between businesses and government. Also revealed was an interactive covariance between the key causal variables underlying the business survival process, indicating that an adverse consequence would increase under the context of sea-level rise.

The business survey also indicated some factors influencing risk perception and response, including the size of business, how long it had been in business and if there was a long-term view of business development. A discussion focusing on the relationships between the disclosed business-response patterns, found that the break points (as tipping point of response) and business value (such as the view on costs) affected business responses, as well as the attitudes toward future risk uncertainties such as sea-level rise. As a large enterprise, Adelaide Brighton Cement demonstrated how flood risks were perceived and responded to, as well the potential limitation of its adaptive capacity. The findings from the Business Survey provide a useful start to understand local contexts for making decisions on risk mitigation and adaptation.

CHAPTER 7. THE VALIDITY OF RISK PERCEPTION AND CAUSAL INFLUENCES

7.1 Introduction

This chapter explores the relationships between flood risk and risk perception, specifically the factors influencing risk perception and response. Firstly, the concepts of risk perception and occupancy exposure are established through data acquired from the resident and business surveys (Chapter 5 and Chapter 6), under the local contexts (Chapter 4). These concepts are transformed into empirical indices for quantitative representation through examining the survey responses. Spatial references to occupancy exposure are also constructed. Then hypotheses are developed by comparing the indices and related variables from the survey analyses. The hypotheses provide an integrated picture of flood risk perception across the study area.

Second, the Chapter explores the causal influences underlying risk perception and related factors (i.e., risk, response and adaptive capacity, etc.) through Structured Equation Modelling (SEM), a multivariate technique composing latent structure and factor analysis (refer to Subsection 3.6.2). The analytical procedures of SEM specify the constructs of a structural model of risk perception based on the theoretical framework (refer to Section 2.4). Then the estimates of the measurement model are statistically tested by survey data, using model fitting criteria. Finally, the postulated causal influences among the risk, risk perception and response are demonstrated by the responses from the resident and business surveys, including socio-demographic attributes, psychological/cognitive factors and geographical variables. Specifically, capital value is discovered as an indicator impacting on business adaptive capacity.

7.2 Empirical Concepts

The analyses of the resident and business surveys have emphasised two empirical concepts critical to the validity of risk perception: (1) **perceived risk** directly relates to the items of the questionnaire (Appendix 3), and (2) **occupancy exposure** (of the risk) derived from the core category of “surviving risk exposure” (refer to the business survey). These concepts are important as they represent a human (subjective) and a physical (objective) dimension of the core concept of risk respectively. The former concept stands for risk perception and the latter can be transformed from exposure, a key component of the conceptual structure of risk (i.e., disaster risk, extreme event and exposure). This section details the specification of these two empirical concepts, specifically the conceptualisation of occupancy exposure, and its relationship to “place” (location).

7.2.1 Perceived risk

The perceived risk by property owners’ was designed to be elicited by two sets of questions: (1) perceived risk about sea-level rise (Question 5 and 5a), and (2) perceived risk about flooding (Question 8 and 8a). The first question was about the awareness of risk and the second question was about how soon the risk would eventuate. Based on the rules of concept specification (Glaser 2008b, pp. 41,42; Lazarsfeld 1958, p. 102), perceived risk therefore consists of two components ***(concern about sea-level rise*** and ***concern about flooding)***. These components were further indicated by a set of predefined temporal dimensions (i.e., the answers to Question 5a or Question 8a, the time period “Within 10 years”, “10-20 years”, “21-40 years” and “More than 40 years”, etc.).

7.2.2 Risk exposure and "place"

Despite a key role in the structure of risk (IPCC 2012, p. 32), exposure has not been fully represented in risk research, including risk evaluation and risk perception (Kellens et al. 2013, pp. 43,46). Firstly, the majority of exposure studies have been generally exploratory to gain an indication of the potential damage or loss when risk becomes disaster. Typically, questions addressing exposure assessment have been about the number of people, structures, or economic sectors at risk in a region (Birkmann 2013, p. 46; Vojinovic and Abbott 2012, p. 452 and 505). It is often assumed that risk exposure remains the same within the flooding boundary of a hazard map. Therefore, local variation of exposure to risk is often easily overlooked, and it is difficult to evaluate the risk at sub-regional and local scales.

Secondly, few studies have evaluated the exposure from a risk perception point of view. Instead, the analyses are likely to be purely logical deductions from flooding models, displaying a weak empirical background of risk perception. A study by Zhang et al. (2010) asserted that risk perception was partially a mediation factor between hazard proximity and housing value. They considered the hazard proximity as an indication of the risk to the "place. But in their concept model, risk exposure has neither been a focus nor explicitly represented by hazard proximity as a key dimension. In addition, exposure was "cross-sectional" in their study, as different sources of hazards (floods, hurricanes and toxic chemicals) were treated in the same way. This means the significance of the outcomes may have also been mediated.

In this study, the indication of "place" has dual implications: (1) emphasising "place" as a spatial attribute of exposure deserves appropriate examination and presentation, and (2) shedding light on using an index as a measurement for exposure. Although "the literature and common usage often mistakenly conflate exposure and vulnerability" (IPCC 2012, p. 69), exposure plays a fundamental role in considering location, land and places, as the interaction between these components can be articulated under the context of risk as:

> 'Population dynamics, diverse demands for location, and the gradual decrease in the availability of safer lands, mean it is almost inevitable that humans and human endeavour will be located in potentially dangerous places. Where exposure to events is impossible to avoid, land use planning and location decisions can be accompanied by other structural or non-structural methods for preventing or mitigating risk' (IPCC 2012, p. 69)

The indicator/index approach has been widely adopted in studies of risk, vulnerability and exposure (Balica et al. 2012; Birkmann 2013, pp. 87-95). Some have explicitly assigned location indices (Vojinovic and Abbott 2012, p. 505). However, the criteria for the indices varied from study to study. As a consequence, this heterogeneity leads to difficulties in evaluating and sharing results among studies. Therefore, it is necessary for risk exposure and "place" to be conceptualised on an empirical base.

7.2.3 Occupancy exposure

The 2010 Business Survey undertaken here provided a major source of data to demonstrate flood risk exposure in Port Adelaide, and thereby the formation of the concept of occupancy exposure. The terminology of occupancy adopted here was about the characteristics of "surviving the exposure" (i.e., break points, nested and structural orders), which were clearly determined by "place", or the business-location related situations (refer to Section 6.3). For example, the "break points" displayed a number of location-related conditions of risk exposure, ranging from "protection", "ground level", "drainage system", "storm water storage", "precaution", to "pumping" respectively. The components of occupancy exposure can then be further developed to include local conditions, such as engineering protection, function of the drainage system and capacity of storm water storage, as well as the surrounding landscape of the location, etc. Obviously, occupancy exposure consists of multiple dimensions, rather than simple and directly observable variables.

Occupancy exposure means that the risk exposure is related to human settlement and determined by the presence of residential properties, business settings and infrastructures. Based on Glaser and Strauss (1967, p. 193), a category suggested by qualitative data can be used for quantitative analysis, given that it is "another slice of data" for resolving the main concern in the same area of interest. Therefore the current study utilises the qualitatively conceptualised occupancy exposure to complement the quantitative analyses of the questionnaire responses. Research literature provides additional reference for this mix-method approach which has become increasingly important (Coyle and Williams 2000; Graneheim and Lundman 2004; Hsieh and Shannon 2005; Walsh 2015).

7.2.4 Spatial dimension

The above delineation of occupancy exposure has substantially reduced its dimensions to location-related attributes, including ***elevation, hazard proximity*** and ***surrounding landscape,*** etc. Unlike articulated answers to survey questions, these geographical attributes are spatially referenced and built up on the mail-out address of survey respondents across the study area. It must be noted that the representation of some spatial attributes are still challengeable, such as the surrounding landscape which represents the overall territorial characteristics around the location. For instance, a business interview revealed the occupancy exposure was due to "the road level which is getting higher and higher in road projects". Clearly this means that the occupancy exposure is closely associated with a number of attributes, including the ground level/elevation and other landscape characteristics which may need further reference.

7.3 Analytical Indices

This section outlines the adoption of a social indexing methodology in setting up and validating crude indices for the concepts of perceived risk and occupancy exposure. Statistical and spatial techniques were incorporated in selecting and constructing indicators. The purpose of scientific indexing in social research has been clarified as:

> 'No science deals with its objects of study in their full concreteness. It selects certain of their properties and attempts to establish relations among them. The finding of such laws is the ultimate goal of all scientific inquiries' (Lazarsfeld 1958, p. 100).

7.3.1 Crude index

Based on Glaser (2008b, pp. 41-46), an indexing procedure termed as "Crude" or "general duty" indexing was adopted to indicate concepts and explore relationships between variables. The indices are based on individual items, attributes or simple summations of them. The test of core indices is simply to see if they work for the concepts, and are consistently related to other items or variables, before the most sensitive index can be chosen.

The crude indices suffice in generating relationships of theory but relax the requirement of pursuing the "best set of indicators" due to the rule of "interchangeable indices". Because some indicators may only be weakly related to the concept, more indicators need to be considered for choosing an appropriate set. The formation of indices can be described as:

> '… as with the problem of projective indices, knowing the laws which relate indicators to one another is of great importance … The aim always is to study how these indicators are interrelated with each other, and to derive from these interrelations some general mathematical ideas of what one might call the power of one indicator, as compared with another, to contribute to the specific measurement one wants to make … In the formation of indices of broad social and psychological concepts, we typically select a relatively small number of items from a large number of possible ones suggested by the concept and its attendant imagery' (Lazarsfeld 1958, pp. 103-105).

7.3.2 Choosing indicators

The time dimension of "**Within 10 years**" is chosen as the indicator for the concept of perceived risk. Given that only the respondents who perceived a risk from floods or sea-level rise (SLR) were considered in the crude indexing, the time frame provides information on SLR and concerns about flooding, the two components of the concept of perceived risk. It is clear that "Within 10 years" is the most important dimension, as it represents a perceived immediate threat. Other periods of time (i.e. "10-20 years", "21-40 years", "In more than 40 years", etc.) are longer and therefore likely to be less reliable in estimation due to the uncertainty of a future risk.

On the other hand, **Elevation** is selected as the main indicator to occupancy exposure. It is fundamental as other attributes of spatial dimension like hazard proximity or surrounding landscape are largely determined by elevation which is measurable. In fact, elevation is generally easier to be quantified than other attributes. In the current analysis, the elevation of a particular property owned by a respondent of the questionnaire has been selected, which also makes the elevation a major indicator for exposure in the context of flooding risk.

7.3.3 Index construction

Based on Glaser (2008b, p. 43), the first step of constructing the index for core concepts is to dichotomize the value of the indicator. In other words, the elevation data (the location of each questionnaire respondent) needs to be categorized as either "low elevation" or "high elevation" to obtain comparative groups. The critical elevation value used to separate the responses is utilised as a "break point", from which a lower elevation is generally perceived to be risky by the questionnaire respondents, while a higher elevation value tends to be considered safer than those located at a "low elevation".

The median of the elevation values, as a better measure of central tendency than the arithmetic mean of the data set (Wagner 1992, p. 45), is chosen as the preferable "break point" for dividing "low elevation" and "high elevation". Table 7.1 indicates the medians of the elevation values for the various time periods and the value of about 2.32m is related to the perceived risks of flooding within 10 years. The medians of the elevation data for the locations of those respondents who had concerns about sea-level rise produced a value of 2.29m, and therefore 2.32m was adopted as the single "break point" value of elevation in the following discussion.

Table 7.1 Medians of elevation vs. temporal dimensions of perceived risk

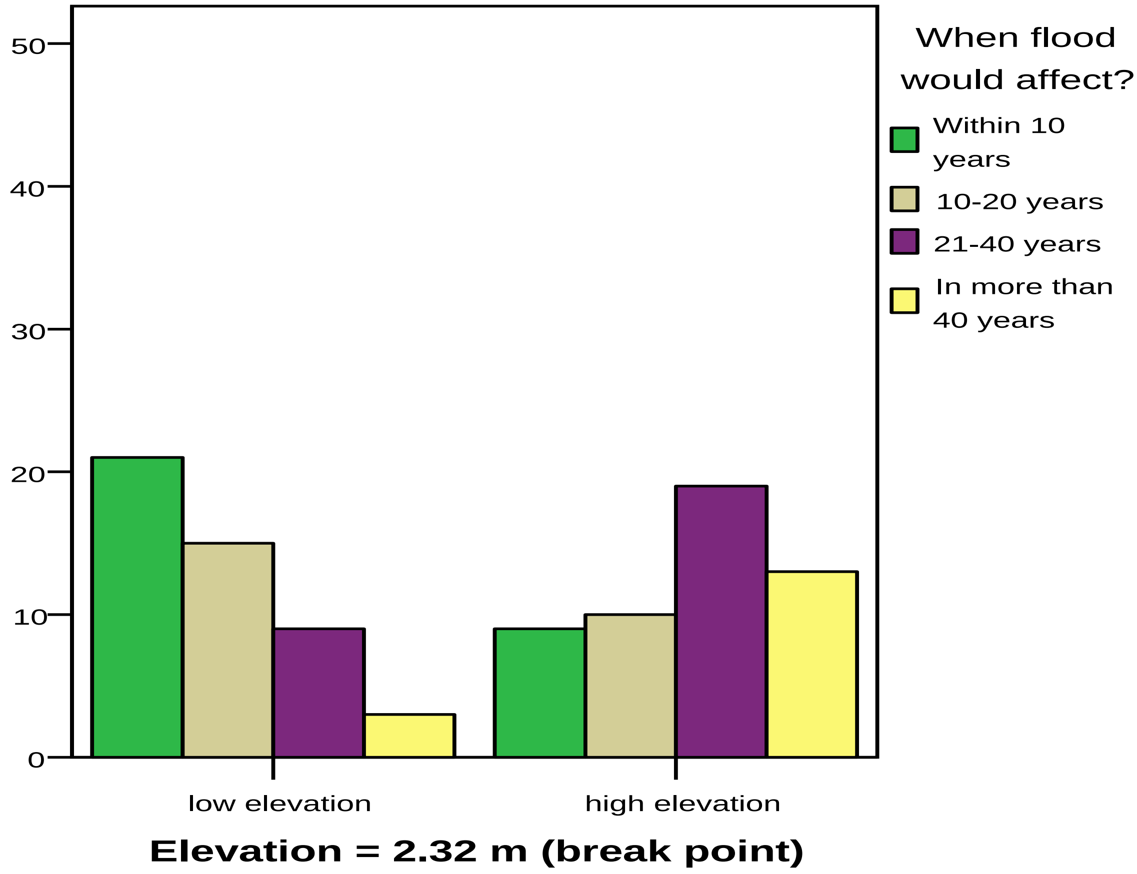
Respondents	When flood would affect?	Median
Elevation	**Within 10 years**	**2.32**
	10-20 years	3.07
	21-40 years	3.84
	In more than 40 years	3.73

Respondents	When SLR would affect?	Median
Elevation	**Within 10 years**	**2.29**
	10-20 years	2.84
	21-40 years	3.73
	In more than 40 years	3.47

Source: 2010 Resident Survey

The significance of the elevation value of 2.32m (used to differentiate the two groups) can be further examined by cross-tabulations supported by Chi-Square Tests (Glaser 2008b, pp. 44,50), as shown in Figure 7.1. It confirms clearly that the "break point" affects the perception of risk to flooding. The number of respondents at "low elevation" steadily decreased as the time scale increased. At "high elevation", however, the trend was more varied as the number of respondents first increased, then decreased at longer time scales. The significance of the "break point" confirms that the choice of indicators was appropriate.

Figure 7.1 Relationship between low and high elevations of respondents' properties and their concerns about flooding in the time periods specified

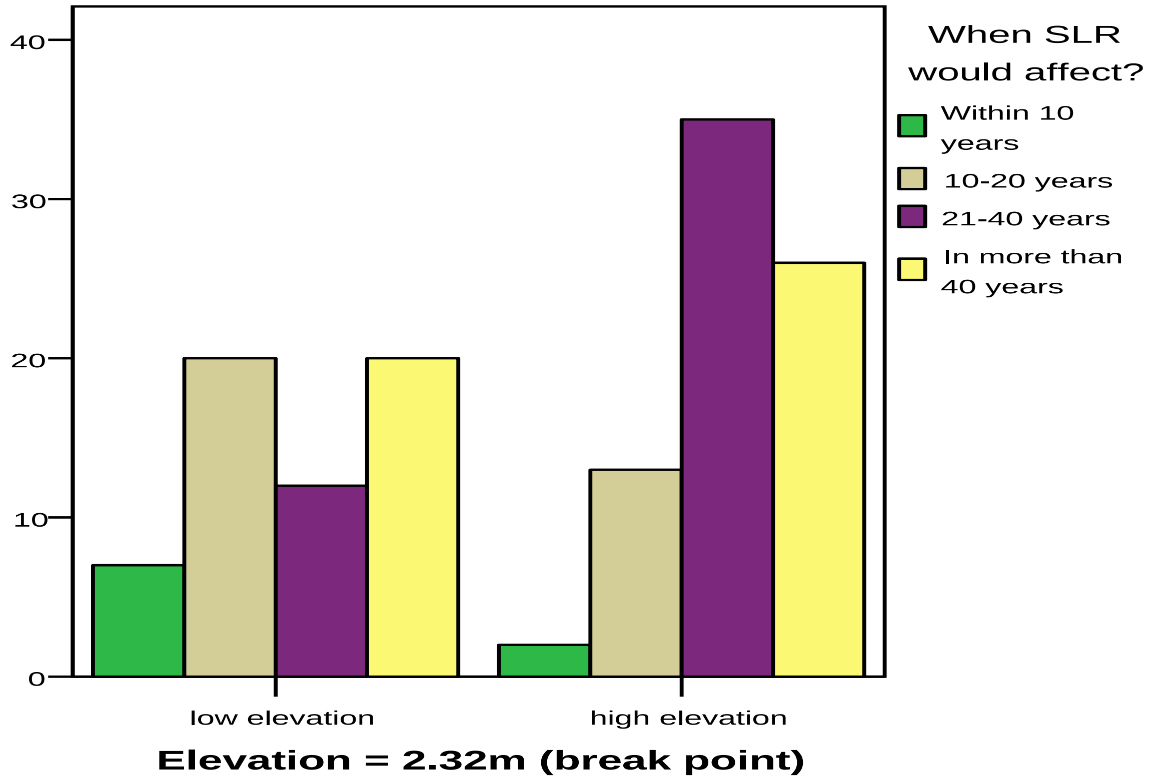


($\chi 2$ = 16.910, df = 5, p = 0.005)

Source: 2010 Resident Survey

The effect of the "break point" on perceived risk of sea-level rise was less distinct than from the perceived risk of flooding, displaying an overall increase of respondents when the time scale shifted to longer terms at either low or high elevation, as shown in Figure 7.2. The break point is thereby statistically established as a threshold, demonstrating the theoretical relevance of the core index to perceived risks of either flooding or sea-level rise. In fact, the core index reflects a critical interface between the perceived risk from a human dimension and the risk from a physical dimension, specifically the perspective of occupancy exposure.

Figure 7.2 Relationship between low and high elevations of respondents' properties and their concerns about sea-level rise in the specified time periods



($\chi 2$ = 22.627, df = 5, *p* = 0.000)

Source: 2010 Resident Survey

7.4 Hypotheses of Risk Perception

This section details the rationale and process of constructing hypotheses validating risk perception, based on concepts of perceived risk, occupancy exposure, and sea-level estimates. The main analytical methods include comparison of indices and variables, theoretical sampling (refer to Subsection 3.5.5) and spatial transformation and interpretation. The suggested hypotheses include matching up the perceived flood risk to local sea levels across subregional areas, and validating risk perceptions on complex flood problems and responses in local contexts. Finally, integrated pictures of the perceived risk were demonstrated for each of the two components (i.e., concern about flooding and concern about sea-level rise).

7.4.1 Perceived flood risk and local sea levels

Compared with the local high sea levels, the elevation threshold (2.32m) is actually between the 50-year and 100-year ARI (tide) levels at Outer Harbor. Although a higher flooding standard is adopted at the Inner Harbor (Davill 2009; Jacobi and Syme 2005a, p. 66), the elevation threshold (2.32m) falls just below the level of 20-year ARI. Overall, the crude index of occupancy exposure reveals that areas at the Inner Harbor are perceived to be much more at risk from sea-level events than areas at Outer Harbor. Therefore, a 100-year sea-level extreme is more likely to be a concern at Outer Harbor, than at the Inner Harbor where a 20-year event would be problematic. Perceived risk by location of respondent to household survey (Statistical Area Level 2) was examined according to the median value of elevation calculated for each of the areas, as shown in Table 7.2.

Table 7.2 Relationship between property elevation and local sea levels by location of respondents (SA2)

SA2	Total respondents	Answer (Within 10 years)	Percent	Elevation (median) above AHD (m)	Tide gauge (Harbor)	ARI (tide) (years)
Largs Bay - Semaphore	128	18	14.1	2.10	Inner	10
North Haven	120	9	7.5	2.92	Outer	200
Port Adelaide	65	3	4.6	1.90	Inner	5

Source: 2010 Resident Survey

In Largs Bay – Semaphore (SA2), even a 10-year storm-tide event may cause concern about flooding, as the median value of elevation (taken from the properties where the owner responded to perceived risk of flooding "Within 10 years") decreased to as low as 2.1 m. Interestingly, this water level was approximately consistent with the local 10-year ARI (tide). Table 7.2 also shows a similar situation in Port Adelaide (SA2), but a reversed trend was apparent in North Haven (SA2), as the respondents' properties were generally located at a much higher elevation. This implies the perceived risk of flooding in North Haven was likely due to storm water rather than seawater.

Some local flood problems were elucidated by the crude index as well. For instance, the median value of elevation (1.9m above AHD) in Port Adelaide (SA2) was low, approximately equivalent to the 5-year ARI (tide). However, only a few respondents perceived flood risks "Within 10 years". Given that these respondents were not located on the waterfront, where the wharf had been built up higher than the tide levels, their concerns were more likely related to storm water rather than seawater, or they had concerns of seawater back-flowing through the local drainage system.

7.4.2 Variation in flood problems in Largs Bay – Semaphore

Risk perception and response were examined in the suburbs of Ethelton - Glanville, Birkenhead and Peterhead within the Largs Bay – Semaphore (SA2), because flooding problems in these areas were complex due to the fact that they were low-lying and had out-of-date drains and water-defence infrastructure. Specifically, Birkenhead and Peterhead were well-known as "flooding hotspots" (refer to Section 4.5 and Section 4.6). The historical floods were the result of multiple causes: local heavy rain/storm-water, high tides and low-lying land.

The local flood context together with the residents' risk perception provides insights into the complexity of the problem and practical response.

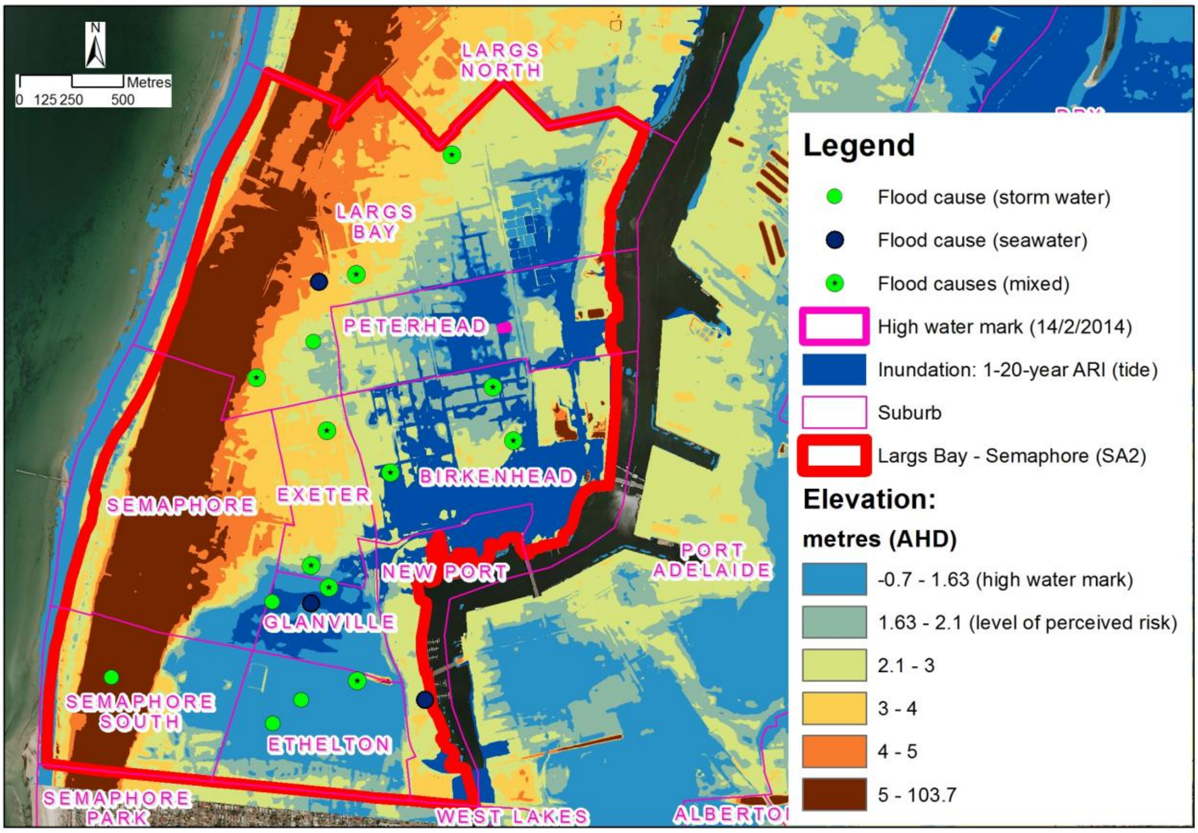
First, it appeared that the more immediate problems came from storm-water flooding caused by heavy rain, rather than tides overtopping the levee. The majority of respondents, as well as the local government, took the view that fixing the problematic drainage systems should be a priority (refer to Subsection 4.4.2, Subsection 4.6.2 and Subsection 5.4.2). This perception assumes that the storm-water floods were generally more frequent than a comparable level of inundation caused by storm tides. In other words, within a similar time scale, extreme events of rainfall were more likely to cause more severe damage than high tides.

Local risk perception can be examined by a number of data sources as follows:

- The surveyed high-water mark of 1.63m (AHD) in Peterhead (Nobbs 2014, p. 6) was used to simulate the storm-water flood on 14 February 2014, a rated 1-in-20-year heavy rain/storm-water event (Subsection 4.4.3)
- The core index of perceived flood risk identified for the subregion, i.e., the threshold value of elevation 2.1m (AHD) (refer to Table 7.2)
- Modelled inundation caused by a 1-in-20-year ARI (tide) under the scenario S0 (refer to Subsection 3.4.2), and
- Geo-referenced responses to the question of flood cause (i.e., refer Q7a in Appendix 3)

Apparently, respondents at higher elevation levels were more likely to perceive a risk from storm-water rather than seawater or a mix of the two causes, as shown in Figure 7.3. By contrast, two respondents chose high tides as the single cause of flood risk, as one was located on the waterfront (in New Port), and the other in the lowest area of Glanville, which was termed as a "big pond" by local residents from the survey.

Figure 7.3 Estimated inundation: 1-20-year ARI (tide) vs. floods (14/2/2014)



Source: 2010 Resident Survey

In addition, a 20-year ARI (storm-water) event, like that of 14/2/2014, can cause more inundation than that of a 20-year tidal event, as demonstrated by the overlapping boundaries in Figure 7.3. In fact, the high water mark for the storm-water event was about 1.63m above AHD in Peterhead. It was much higher than the estimated seawater level of a 20-year ARI (tide), which is about 1.49m above AHD. The high water mark was actually just above the estimated seawater level (about 1.61m above AHD) of a 50-year ARI (tide) event by simulation (refer to Subsection 3.4.2). Therefore, the major concerns of flooding would be heavy rain/storm-water events in the short-term.

Secondly, the large low-lying residential area in Peterhead and the relatively high waterfront (industrial lands, wharves and levees) to the east, made it difficult to discharge storm water into the Port River, as evidenced by the flood event of 14/2/2014. This was the result of a failure to adequately address both types of flood causes. Mitigating flood risk to residential properties from heavy rain requires the efficient discharge of storm water into the Port River. On the other hand, the wharves and levees (embankments) need to be built up to hold high tides coming in from the Port River. This means that the ground level of the waterfront needs to be higher than the local ARI (tide) levels.

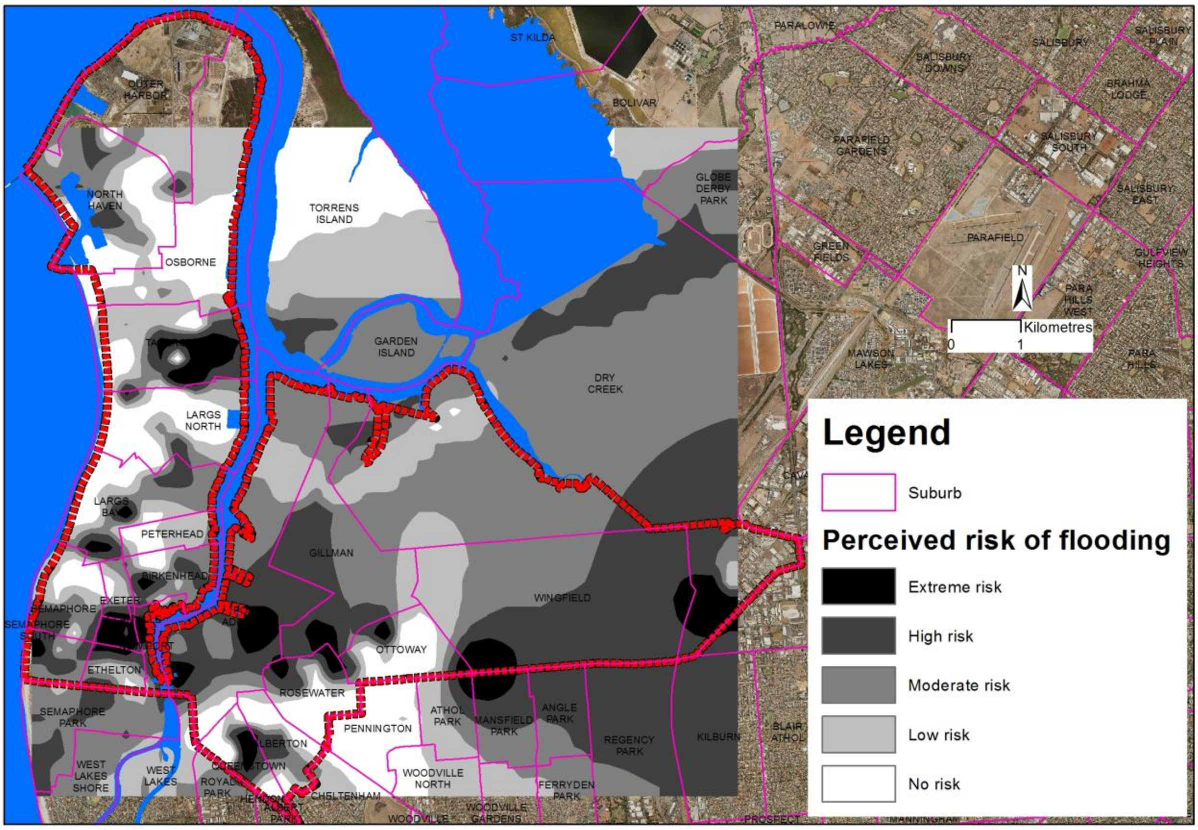
The dilemma is that the waterfront area holds back tides but at the same time makes the discharge of stormwater difficult. Given that the local land subsidence is a contributing factor to flood problems (Jacobi and Syme 2005a, p. 2), the traditional responses to flooding (draining stormwater and building sea defences) have created additional problems of seawater back-flow along the drains (refer to Subsection 4.4.1).

Finally, large areas of Birkenhead have been under threat of storm-tide flooding due to its unprotected waterfront (Jacobi and Syme 2005b, Drawing 4-7). Historical flood events had the potential adverse effects as demonstrated through modelling a 20-year tidal event inundation (Figure 7.3). The recent flood event (9/5/2016) clearly demonstrates the risk of seawater inundation in Birkenhead, which must not be overlooked.

7.4.3 Integrated pictures of perceived risk

Integrated pictures of the perceived risk from survey respondents were created for the whole study area based on spatial interpolation of responses to concerns about flooding and sea-level rise. Figure 7.4 shows geographically highlighted hotspots of the perceived risk from either flooding or sea-level rise as matched with the survey responses.

Figure 7.4 Interpolation: perceived risk of flooding by households (10 year time frame)



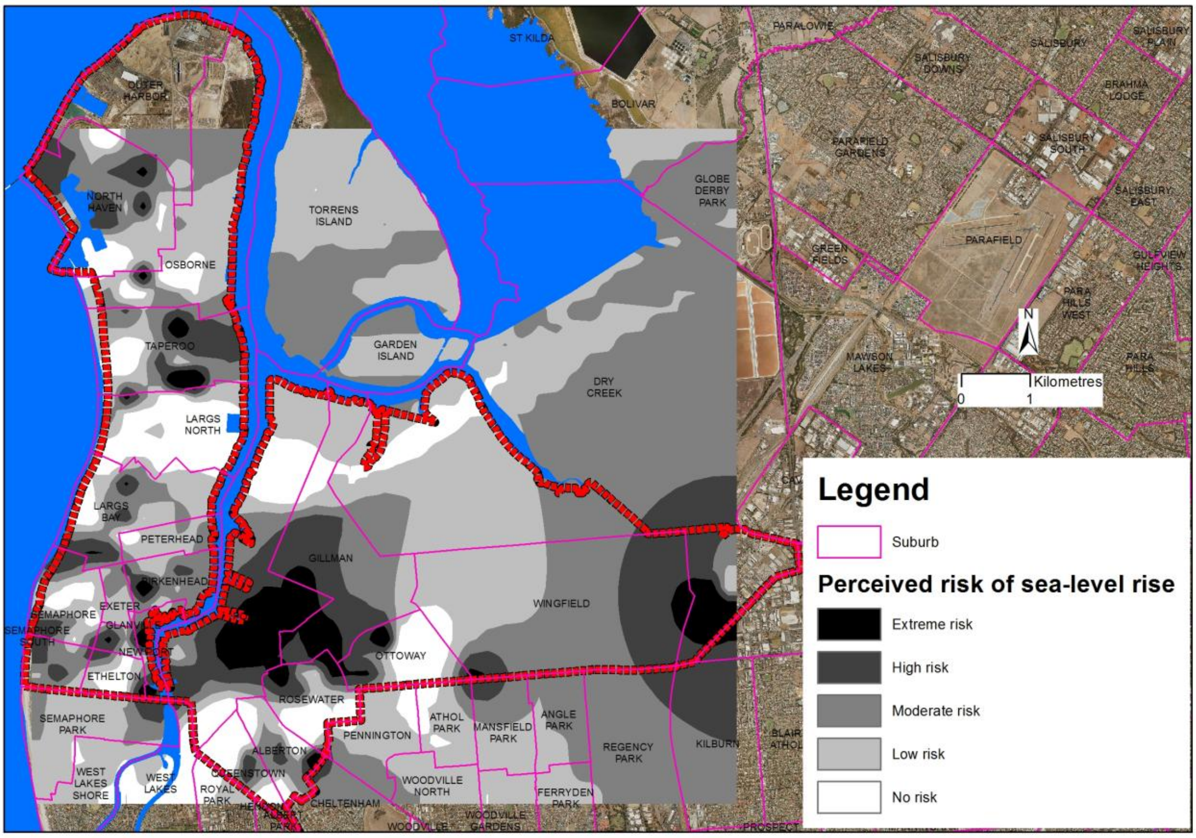
Source: 2010 Resident Survey

The perceived risk of flooding demonstrated a number of important points as follows:

- Comparison with seawater inundation models (refer to Subsection 3.4.2) reveals some discrepancies which potentially reflect the hotspots of storm-water flooding. This contributes to a more comprehensive understanding of the flooding issues, which include both seawater and storm-water flooding problems.
- It is interesting that the flooding event of 14/2/2014 did not show up as a flooding "hotspot" in Figure 7.4. This may reflect a shift in the "hotspots" in the years since the questionnaire was undertaken, and the difficulties associated with perceiving the changing dynamics of risk.
- The perceived risk is generally lower than that demonstrated by flood models and estimates, highlighting the importance of the communication of risk among stakeholders.

Figure 7.5 shows that perceived risk of sea-level rise appeared less realistic than that of flooding, partially because sea-level rise was unlikely to be noticed in the short-term and as yet unpredictable.

Figure 7.5 Interpolation: perceived risk of sea-level rise by households (10 year time frame)



Source: 2010 Resident Survey

Therefore, some of the perceived risk of sea-level rise by respondents at higher elevations was likely a speculative guess. Both Figures 7.4 and 7.5 show a similar relationship of perceived risk of flooding and sea-level rise. Given that accurate gauges of sea-level rise were generally unavailable, it would be reasonable to assume that the perceived risk of flooding was likely affecting the expectation of sea-level rise.

7.5 *Influencing Factors and Constructs*

This section investigates the causal relationships underlying flood risk perception through structural equation modelling (SEM). First, influencing factors of risk perception are examined and specified as endogenous and exogenous variables, building on the resident survey data. Then the causal constructs of risk perception are developed, based on the theoretical framework and survey findings. As an empirical indicator, the on-site GESI value is introduced to comprehensively quantify the risk of flooding. The proposed causal structure is evaluated by goodness-of-fit tests and then the parameters are estimated, indicating a number of interrelationships among the observed variables and latent factors surrounding the core concept of risk perception.

7.5.1 Overview of influencing factors

Socio-economic factors, psychological-cognitive-behavioural elements and situational conditions are commonly found to affect risk perception and the intention to respond. In addition, many interconnected factors contribute to the process of risk perception, including the features of risk, resource availability, social cues, personality, and speculative judgments (Botterill and Mazur 2004; Ulleberg and Rundmo 2003).

Research has grouped those factors into a number of endogenous (dependent) and exogenous (independent) variables (Byrne 2010, p. 5; Hair et al. 2010, p. 617). In total, 40 observed variables were indicated by the survey questionnaire responses, including demographic characteristics, attitudes and behavioural intentions which are shown in Table 7.3. There were an additional four attributes derived from the seawater inundation models (refer to Section 3.4) and the State Government land/property databases.

Table 7.3 Indicators and constructs used in measuring the model based on survey responses to household questionnaire

Indicator	Description	Measurement	Construct
Q3a	Rating erosion among environment concerns	5 scales (1-5)	Concern of SLR
Q3d	Rating SLR among environment concerns	5 scales (1-5)	
Q5	Concern of SLR	Yes/No	
Q5a	Concern of SLR in temporal dimensions	5 terms of time	
Q3c	Rating floods among environment concerns	5 scales (1-5)	Concern of flooding
Q3f	Rating heavy rain among environment concerns	5 scales (1-5)	
Q3p	Rating strong winds among environment concerns	5 scales (1-5)	
Q8	Concern of flooding	Yes/No	
Q8a	Concern of flooding in temporal dimensions	5 terms of time	
Q9	Flood experience	Yes/No	
Elevation	Elevation of the properties of respondents	-0.59 to 10.73m	Exposure
GESI(0)	Value of GESI based on S0	0-86	Risk (flooding)
Q17	Age	5 age groups	Risk perception
Q18	Sex	Male/Female	
Q20	Dependent children	Yes/No	
Q24	Highest level of completed formal education	4 categories	
Q23	Occupation of the main income earner	11 categories	
Q1	Time of residence	4 terms of time	
Q2	Main reason for living at the current address	4 categories	
Q20a	Children aged under 18 living at home	Yes/No	
Q8b	Moving away	Yes/No	Intention
Q8d	Building sea walls	yes/No	
Q16a	Cutting greenhouse gas emissions	yes/No	
Q16b	Limiting housing development in areas	yes/No	
Q16c	Protecting properties	Yes/No	
Q16d	Owners bearing the risk	Yes/No	
Q16e	Planned retreat	Yes/No	
Q16f	Publishing projections of SLR	Yes/No	
Q16g	Compensating property damage	Yes/No	
Q16h	Compensating property devaluation	Yes/No	
Q16i	Developing infrastructure in areas of risk	Yes/No	
Q19	Having vehicle(s)	Yes/No	Perceived behavioural Control (response to floods)
Q12o	Occupants or property owners' responsibility	1-5 Likert scales (unsure-very much)	
Q12d	Developers and builders' responsibility		
Q12p	Government planners' responsibility		
Q12es	Hazard and emergency' responsibility		
Q4a	Speaking to people in the community	Yes/No	Subjective norm
Q4d	Meetings and presentations	Yes/No	
Q13	Risks have been addressed in public	Yes/No	Public trust
Q14	In favour of water-front development	Yes/No	
Q15	Agree with developing land for industry	Yes/No	
Q22a	Volume of domestic water tank	Litres	Adaptive capacity
Area	Land area of property	m²	
CapV	Capital value of property	$	

Note: (1) GESI refers to gravitation-energy surfaces of inundation (see Subsection 3.4.3);
(3) S0 refers to the existing case, no sea-level rise or land subsidence (Jacobi and Syme 2005a, p. 26).

Source: 2010 Resident Survey and the State Government land and property databases

7.5.2 GESI: a comprehensive indicator to flooding risk

GESI (gravitation-energy surfaces of inundation) (refer to Subsection 3.4.3) can be used as a comprehensive spatial indicator to flooding risk, incorporating the situational attributes of occupancy exposure and the characteristics of sea-level extremes. Specifically here GESI is the on-site value for each of the properties owned by the questionnaire respondents, based on the scenario condition S0 (existing case, no sea level rise or land subsidence) of the Port Adelaide flooding study (Jacobi and Syme 2005a, p. 26). The advantages of using GESI rather than a crude index (such as site elevation or water level) are identified as follows:

- Other spatial dimensions like hazard proximity and surrounding landscape can be represented by a single GESI value as it is comprehensive. A crude index approach, however, may result in multiple indices for representing these dimensions, calculated from 2D or 3D elevation models (ESRI 2001; Johnston et al. 2001; Lane 1999).
- GESI represents both risk exposure and extreme events. As occupancy exposure is related to local ARI and therefore, exposure should be defined by extreme events, in particular the consequences of flooding as well (e.g., water depth and the extent).
- Obviously the spatial unit of elevation (e.g., metre) is insufficient in representing exposure to flood risks. Also this single measurement makes it difficult to compare between results of exposure.
- GESI also represents the characteristics and spatial attributes which are components of exposure, as it was originally stemmed from the hydraulic models of the Port Adelaide 2005 Flooding Study, incorporating parameters into the modelling process, including climatic, hydraulic and torrential factors, and local condition of levee banks.

7.5.3 Hypothesised model of causal structure

The influencing structure of risk perception was initially derived from the theoretical base and survey responses discussed earlier (Section 2.4 and Chapter 5/Section 7.2/Section 7.3 respectively). The constructs are transformed from the IPCC's conceptual structure of disaster risk (refer to Figure 2.1) and core elements in the cognitive mediating processes of MPT (Protection-Motivation Theory) and TPB (Theory of Planned Behaviour).

According to Rogers and Prentice-Dunn (1997), MPT consists of attitude, threat appraisal and coping appraisal, which can be interpreted as social interaction, demographic factors and vulnerability, etc. (Grothmann and Reusswig 2006, p. 105; Poussin et al. 2014, p. 70).

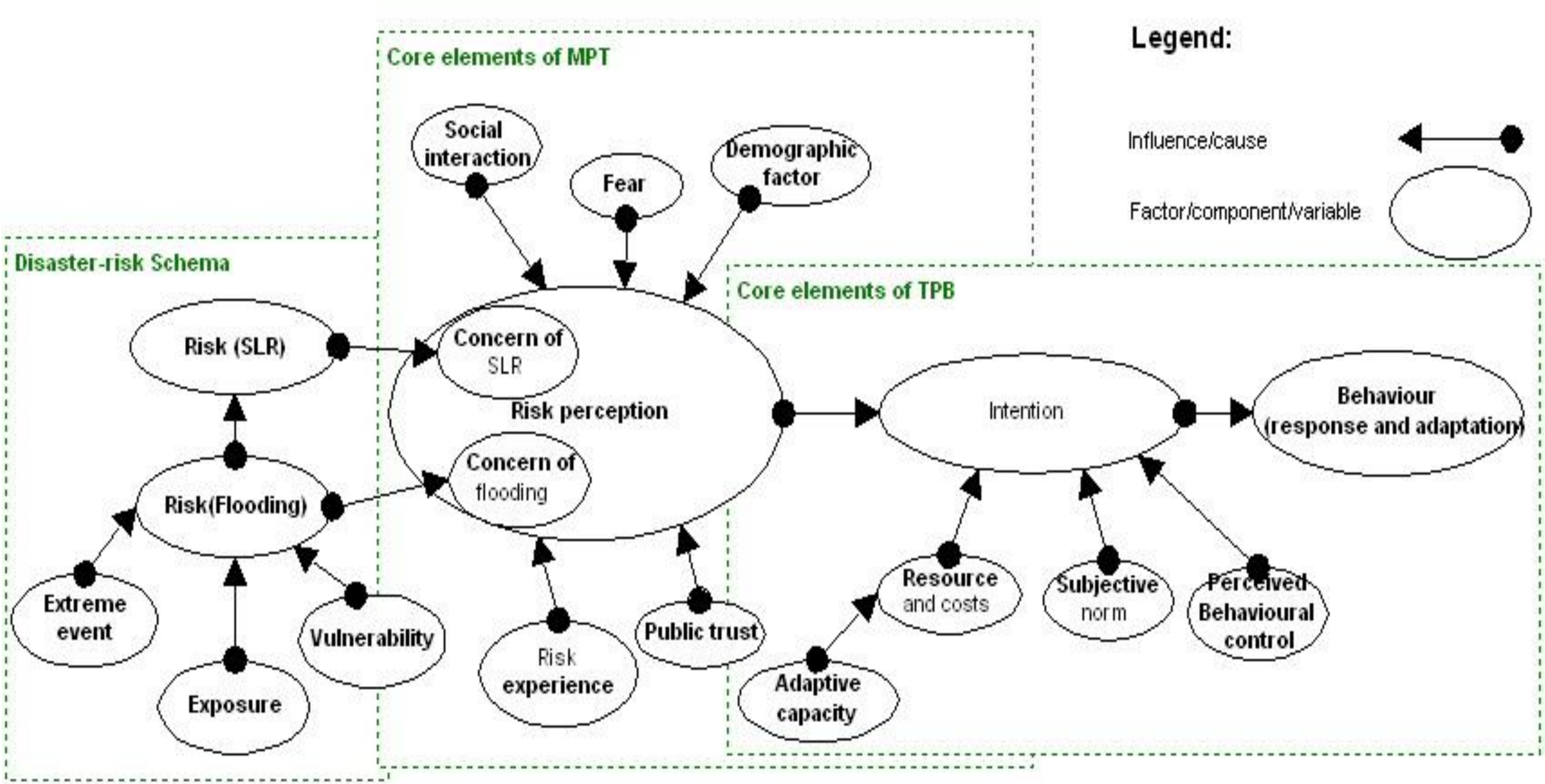
TPB is the cognitive foundation, including attitude/risk perception, subjective norm, perceived behavioural control, intention and ultimately behaviour, which is assumed to be underlying a reasonable and consistent action (Ajzen and Fishbein 2005, p. 194).

A disaster-risk schema of sea-level rise and flooding, which are exogenous variables for the core factor of risk perception, adds an empirical base, as it was identified that the perceived risk consists of two components, concern about sea-level rise and concern about flooding. The core elements (some are overlapped across the schema and theories) are illustrated in a causal structure, as shown in Figure 7.6.

7.5.4 Measurement model and validation

A measurement model with indicators (i.e., elements) from the questionnaire was developed for parameter estimates and model fitting (Kline 2010, p. 95), as illustrated in the path diagram

Figure 7.6 Causal structure of risk perception, intention and behaviour



Source: Author

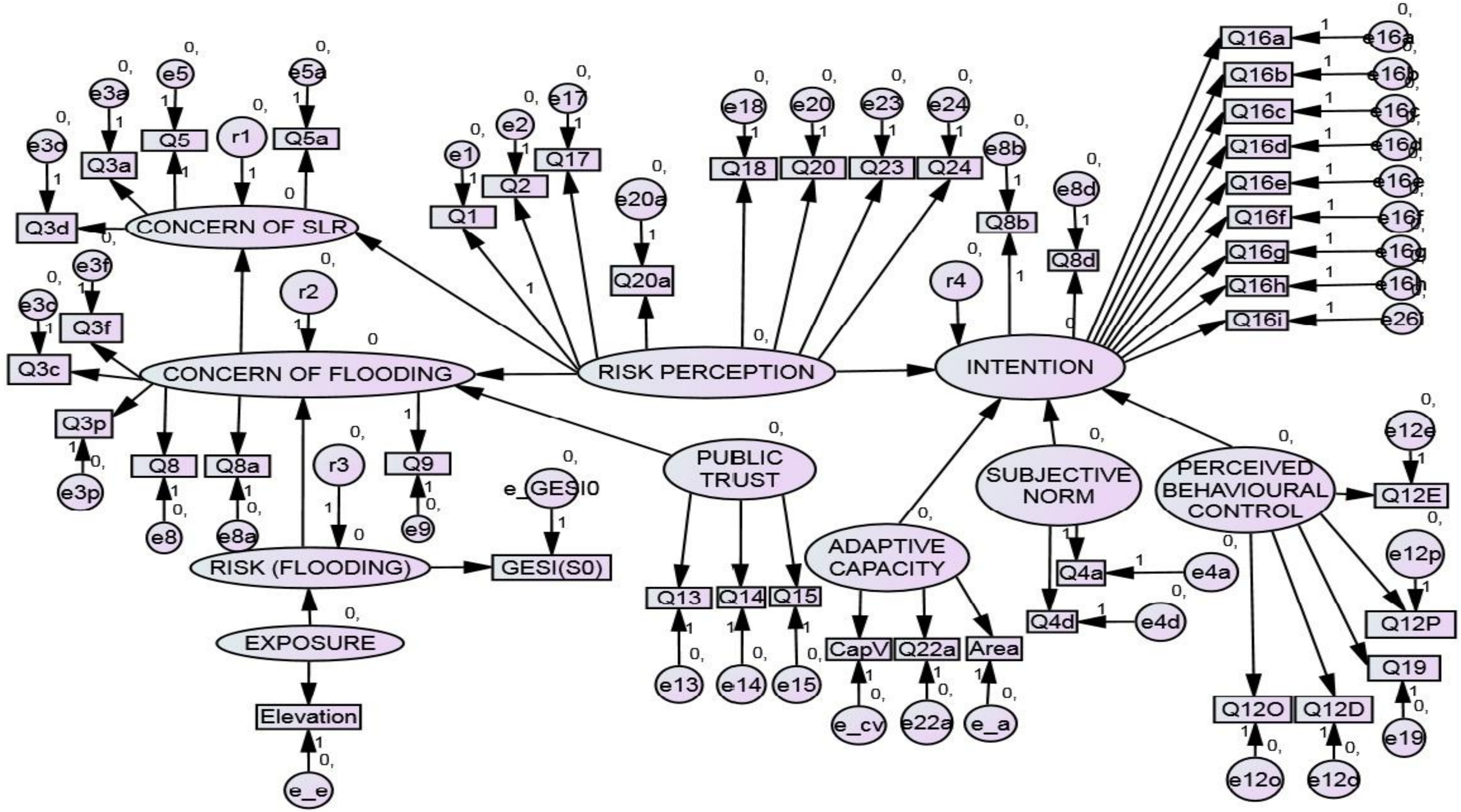
in Figure 7.7. The hypothesised structure was then transformed into a CFA structural model (Byrne 2010, p. 129) through exploratory analysis, focusing on core constructs of risk perception and intention. Some 44 observed (measurable) variables (outlined in Table 7.3) were used to estimate risk perception (which was hypothesised as accounting for concerns about sea-level rise and flooding) and intention to respond.

Four constructs were specified in the measurement model: public trust, adaptive capacity, subjective norm and perceived behavioural control. No further improvement of the model fit was conducted, because it is argued that (MacCallum and Austin 2000; MacCallum et al. 1992) any radical model modification should be strongly supported by the literature, as data-driven qualification may capture sample characteristics which tend to reduce the likelihood of model generalisation.

The results of SEM generally reflect an acceptable fit, given the size of the samples, the large number of observed variables and the complex structure. The model uses 316 valid observations elicited from the questionnaire responses. The factor structure is subjected to second-order CFA. The goodness-of-fit indices for the measurement model are $\chi 2$ = 1665.606, df = 872, p = 0.000, CFI = 0.693, RMSEA = 0.054 (90% confidence for RMSEA = 0.050 – 0.058) and CMIN/DF = 1.910.

In addition, the fit measures of Bayesian SEM (Posterior Predictive p = 0.52, Deviance Information Criterion = 24238.32, effective number of parameters = 80.80) indicated that the model was correct. It was confirmed that the instrument had a valid construct, as well as a good model fit to the questionnaire data.

Figure 7.7 Measurement model for flood risk perception and intention to response:

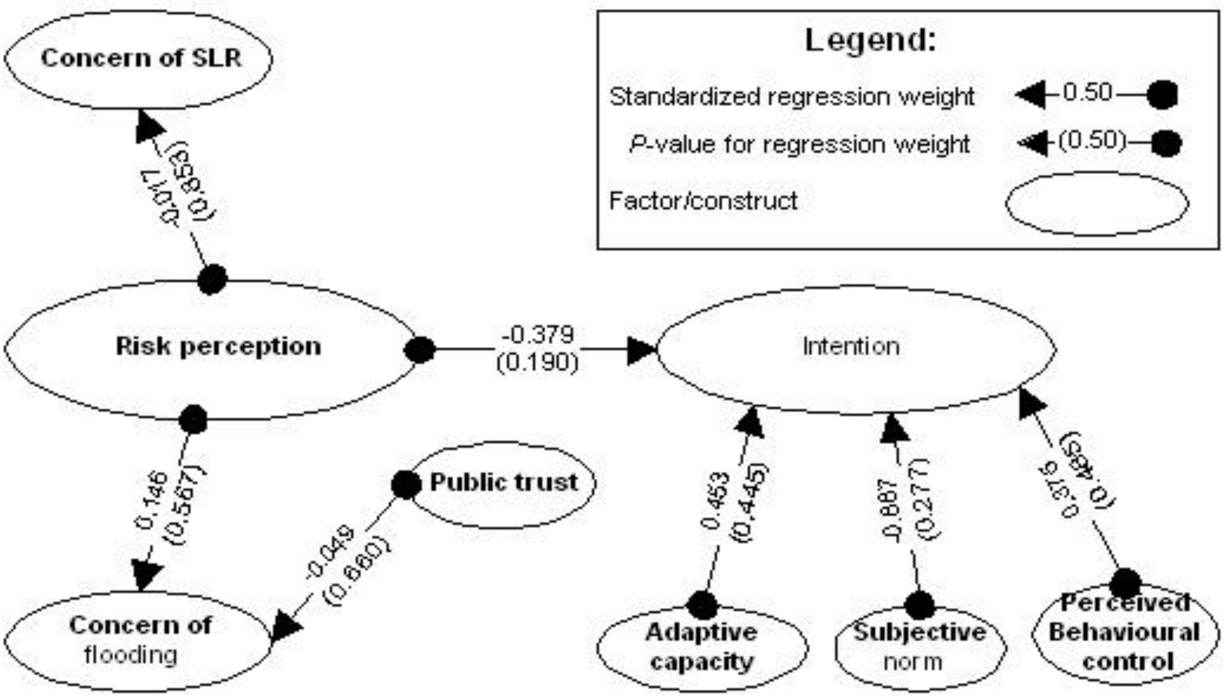


Source: Author

7.5.5 Influences on constructs

The estimated influences generally support the conceptual model illustrated in Figure 7.6, because no statistical significance was found in the parameters (path coefficients and *p* values) for the eight constructs. This means that the estimated factor loadings fit the data reflected by their indicators, as shown in Figure 7.8. Here a limitation of this study should be noted, as for the purpose of model identification, two original constructs, risk (flooding) and exposure, needed more constraints. However, this information was not available in the survey. Hence the two constructs, risk and exposure, were not adopted in the final measurement model to be estimated.

Figure 7.8 Structural model for flood risk perception and intention



Source: Author

Compared with concerns about sea-level rise, property owners' concerns of flooding were more likely to be influenced by their risk perception, a core construct which was affected by social interaction and demographic attributes. The loading parameters, however were all small (i.e., β = -0.017 and 0.146 respectively), indicating weak influences on these specific concerns from general risk perception. It was the same situation with public trust, which had a weak impact on concerns about flooding. This was further supported by a correlation value r = 0.037 between risk perception and public trust. Further, as expected risk perception shows a moderate impact (β = -0.379) on intention, the second core construct.

Focusing on intention, perceived behavioural control shows a reversed, but similar level of influence (β = 0.375), as that from risk perception. However, the impacts on intention from adaptive capacity increased (β = 0.453). In particular, the subjective norm shows a remarkable influence on intention (β = 0.887). Based on the squared multiple correlation (R^2) for the targeted construct intention, these constructs can explain over 31 percent of variation in response intention (or adaptation).

The reflected associations between constructs can be explained by the estimates of correlations (r), among which the relationships between subjective norm and each of public trust, perceived behaviour control, and adaptive capacity are strong. In addition, risk perception has a moderate association with perceived behaviour control, subjective norm, and adaptive capacity respectively, as highlighted (in bold font) in Table 7.4.

The results of the structural equation model indicate that property owners are more likely to respond to adaptation when they perceive higher risks from floods (i.e., higher risk perception), higher levels of behaviour control and larger capacity for adaptation. Specifically, subjective norm strongly influences both risk perception and response. Those constructs (risk perception, intention, public trust, subjective norm, adaptive capacity and perceived behaviour control) are among major elements of cognitive-behavioural theories, specifically TPB (Theory of Planned

Behaviour). Therefore they emphasise the importance of socio-psychological factors to be incorporated into the framework to investigate the risk perceptions and behaviour intentions of stakeholders.

Table 7.4 Correlations between constructs (Default model):

CONSTRUCTS			ESTIMATE
Risk perception	<-->	Perceived behaviour control	-.175
Risk perception	<-->	Subjective norm	-.308
Risk perception	<-->	Public trust	.037
Perceived behaviour control	**<-->**	**Subjective norm**	**.718**
Perceived behaviour control	<-->	Public trust	-.089
Subjective norm	**<-->**	**Public trust**	**-.572**
Adaptive capacity	<-->	Risk perception	-.147
Adaptive capacity	<-->	Perceived behaviour control	.054
Adaptive capacity	**<-->**	**Subjective norm**	**.495**
Adaptive capacity	<-->	Public trust	-.196

Source: Author

7.5.6 Influences of observed variables

The path coefficient for regression of an observed variable onto a latent variable can be presented by the standard regression weight, reflecting the influence to a construct as factor loading (Byrne 2010, pp. 9,123), also providing a value of comparison to other influences. As a result, those strong influences on constructs are highlighted (in bold font) by standardised regression weights, as shown in Table 7.5.

Table 7.5 Standardized regression weights (Default model):

OBSERVED VARIABLE/INDICATOR		CONSTRUCT	ESTIMATE
Q5: SLR would affect property	**<---**	**Concern of SLR**	**.730**
Q5a: when SLR would affect	<---	Concern of SLR	.126
Q3a: concern of erosion	**<---**	**Concern of SLR**	**.536**
Q3d: concern of SLR	**<---**	**Concern of SLR**	**.768**
Q8: flooding would affect property	**<---**	**Concern of flooding**	**.714**
Q8a: when flooding would affect	<---	Concern of flooding	.425
Q3c: concern of flooding	**<---**	**Concern of flooding**	**.701**
Q3f: concern of heavy rain	**<---**	**Concern of flooding**	**.590**
Q3p: concern of strong winds	**<---**	**Concern of flooding**	**.619**
Q9: has flood experience	<---	Concern of flooding	.043
Elevation	<---	Concern of flooding	-.069
GESI(0)	<---	Concern of flooding	.138
Q1: time of residence	**<---**	**Risk perception**	**.539**
Q2: reason of living on the address	<---	Risk perception	-.003
Q17: age group	**<---**	**Risk perception**	**.732**
Q18: gender	<---	Risk perception	-.043
Q20: having children under 18 at home	<---	Risk perception	-.292
Q20a: age of the youngest dependent child	**<---**	**Risk perception**	**.531**
Q23: occupation	<---	Risk perception	.187
Q24: level of completed formal education	<---	Risk perception	-.479
Q8b: should move away to response	<---	Intention	.300
Q8d: should build up seawall to response	<---	Intention	-.228
Q16a: should cut greenhouse emission	**<---**	**Intention**	**-.508**
Q16b: should limit housing development	**<---**	**Intention**	**-.519**
Q16c: should funding support to housing	<---	Intention	-.415
Q16d: should owners bear the risk	<---	Intention	-.001
Q16e: should remove house at risk area	**<---**	**Intention**	**-.578**
Q16f: should publish projections of SLR	<---	Intention	-.485
Q16h: should compensate for losing house value	<---	Intention	-.336
Q16g: should compensate for house damage	<---	Intention	-.349
Q16i: should develop infrastructure in area at risk	<---	Intention	.109
Q13: risk has been considered in planning	**<---**	**Public trust**	**.685**
Q14: in favour of water-front development	<---	Public trust	.421
Q15: should developing near-shore land for industry	<---	Public trust	.363
Q4: talk to people	<---	Subjective norm	.184
Q4: get information from meetings and presentations	<---	Subjective norm	.206
Q12: responsibility on occupants and property owners	<---	Perceived behavioural control	.474
Q12: responsibility on developers and builders	**<---**	**Perceived behavioural**	**.860**
Q12: responsibility on government planner	**<---**	**Perceived behavioural**	**.915**
Q12: responsibility on hazard and emergency	**<---**	**Perceived behavioural**	**.552**
Q19: having vehicle	<---	Perceived behavioural control	-.036
Q22a: volume of domestic water tank	<---	Adaptive capacity	.140
Area of property	<---	Adaptive capacity	.335
Capital value of property	**<---**	**Adaptive capacity**	**.748**

Source: Author

In addition to the displayed effects of socio-demographic factors, spatial variables are of particular importance from both theoretical and practical perspectives. Firstly, GESI's potential to be a comprehensive indicator to exposure, risk of flooding, and risk perception, has been confirmed. While the derived elevation of property shows a very small effect on concern of flooding (β = -0.069), a stronger association between the GESI (0) value and risk perception of flooding (β = 0.138) was discovered. In fact, the influence of GESI on risk perception is assumed to be underestimated because residents' risk perception was based on smaller floods with water levels lower than that of an estimated 100-year extreme event (refer to Subsection 7.4.1). Therefore, GESI (0) only represents the risk perception approximately, as it was based on the 100-year ARI. Also this suggests that GESI values based on 20-year ARI (tide) could demonstrate better results of influence on risk perception.

Secondly, the capital value of property shows a much stronger impact (β = 0.748) on adaptive capacity than the area (β = 0.335), suggesting TPB (theory of planned behaviour) can be applied in case studies of response and adaptation, as demonstrated in the next section.

7.5.7 The vital influence of capital value

Based on the structure model in Figure 7.8, the core construct intention is largely dependent on capital value and this is the case for Adelaide Brighton Cement, a big business in manufacture as discussed from the 2010 Business Survey earlier (refer to Section 6.7). Firstly, the company's flood mitigation practice demonstrated strong perceived behavioural control. Second, another influence of intention, subjective norm, is more relevant to a residential property owner than to a large organisation, as adaptive capacity and its key indicator capital value account for the difference. In fact, the capital value of property shows a strong effect (75%) on adaptive capacity which had an influence (45%) on intention. Overall, over 55 percent variation of capital value can be explained by the variables in the measurement model (R^2=56%). Hence ABC's capital value is critical to the intention of response.

As an enterprise with capital value (property) over $40 million (based on calculation of the State Digital Cadastral Databases), there is a qualitative match between the structure model and Adelaide Brighton Cement's adaptive behaviour. This means the possibility is small for the company's adaptive capacity to be overwhelmed by increasing risk of floods, given that all the influences on intention are present and risk perception reflects the risk correctly. Therefore, the causal structure of Figure 7.6 proved to be useful to explain the current risk perception and mitigation practice, as well as to forecast adaptive response.

The capital value of property shows the strong impact on adaptive capacity and supports the theory of planned behaviour (TPB) to be applied in a business case like Adelaide Brighton Cement. At current conditions, their risk perception, effective mitigation and adaptation demonstrated a strong match with TPB, as well as the causal structure hypothesised in the structured equation model. Under a future sea-level rise scenario, the potential increasing risk of inundation caused by storm tides can be modelled. However, Adelaide Brighton Cement's strong behaviour control and in particular, large adaptive capacity (indicated by a large capital value), which were evidenced as critical to its successful risk mitigation in the past, imply strong intentions of responding to flood risk in future years. This means the company's adaptive capacity is unlikely to be overwhelmed by increasing risk of flooding in the future of which they are fully aware.

7.6 Conclusion

Socio-economic elements have been commonly discussed in past studies as influencing factors of risk perception. However, risk determinants, cognitive-behavioural facets and situational conditions have not been fully studied, particularly in local contexts. This chapter, therefore, incorporates some of these important factors and takes a two-stage approach to risk evaluation and validation of risk perception, interactively utilising crude indexing, structural equation models and spatial techniques to form integrated pictures of risk adaptation. The empirically derived concepts and spatial factors support hypotheses of risk perception in Port Adelaide, as well as the relationships between variables and indicators utilised in the analysis. Cognitive-behavioural theories are also applied in the contexts of risk perception, response intention and adaptive behaviour for an in-depth understanding of the risk issues.

Indexing analysis of questionnaire responses shows the perceived flooding risk is approximately equivalent to the level of a 20-year ARI (tide), varying from about 100-year ARI (tide) in North Haven and Outer Harbor, to below 20-year ARI (tide) in Largs Bay - Semaphore, and Inner Harbor. The major causes of flooding were also varied crossing sub-regional areas. Overall, flood problems caused by heavy rain (storm water) were an urgent concern rather than inundation due to storm tides. The integrated picture of risk perception also reveals flood hotspots, in particular those caused by storm water and drainage problems.

The results of the structural equation model indicate that property owners are more likely to have an intention to respond when they perceive higher risks from floods, and exhibit higher levels of behaviour control and larger capacity for adaptation. Specifically the subjective norm has a strong influence on both risk perception and intention to respond. The influencing factors of intention show strong correlations with public trust. The results emphasise the influence of socio-psychological factors on risk perception and behaviour intentions. In addition to the effects of demographic attributes and motivation factors, spatial variables are important. GESI, a comprehensive indicator for risk of flooding, shows a stronger association with risk perception than elevation. Capital value is also found to be a critical indicator of adaptive capacity which can be demonstrated by cases from the business survey, such as that of Adelaide Brighton Cement.

CHAPTER 8. IMPLICATIONS AND CONCLUSION

8.1 Introduction

This thesis examined one of the most significant but least studied relationship between humans and the environment that impinge on the lives of residents and the survival of businesses in Port Adelaide. It has focused on the risk of flooding, not only under present conditions, but also under future uncertainties, in particular changes associated with sea-level rise. Inevitably such an undertaking in the context of climate change is seriously limited by the range, coverage and quality of available statistics. Challenges also come from the lack of a theoretical framework and systematic methodology. However, analysis provided here on a range of information sources in conjunction with knowledge gained from field investigation of residents and businesses contributes to an understanding of flood risk for Australian coastal settlements and, in particular, for Port Adelaide.

This chapter summarises the major findings and assesses the extent to which they have broader significance for Australian coastal settlements. Some of the implications for disaster research, urban planning and policy making are indicated, by reviewing relevant land-use and development plans and regional climate change strategies. The possibility of making a generalisation of this research to larger-scale studies is considered, along with any limitations. Finally some suggestions regarding future research needs and approaches are put forward.

8.2 Findings and Implications Regarding Risk Perception

The household/resident survey on risk perception was integral to this study, as it achieved a comprehensive and in-depth understanding of the stakeholders' positions and perspectives. The present body of knowledge regarding risk perception has been somewhat limited in relation to the local contexts, or insights into the interaction of the causes, consequences and responses. By using questionnaire data, for example, it was possible to estimate the representativeness of general opinions on the topic and associations between some actions. However, the resource constraints meant that the questionnaire was insufficient to elicit some critical issues relating to the topic. To overcome this, some semi-structured interviews were undertaken initially to provide guidance to the design of the resident and the business surveys.

8.2.1 Risk perception of residents

The resident survey showed that flood risk from storm tides was largely overlooked, as local concerns focused mainly on improving the drainage capacity to cope with floods caused by heavy rain, rather than the long-term effects of sea-level rise. Flood impacts on local life did not appear to be as important as broad environmental issues. In general, property owners perceived flood risk to be acceptable. However, the main complaints about flooding came from the inundation of houses induced by 1-in-20-year rainfall that had occurred relatively recently. It was found that the survey respondents perceived a 1-in-50-year storm-tide event to be inconvenient, as roads, streets and bridges were blocked. There were signs of change in this perception, as a recent storm tide had flooded 17 properties.

In addition, the responsibility to protect properties was perceived to be mainly due to a lack of government planning and lack of awareness by the building industry. Respondents considered limiting residential development in flood-prone areas appeared to be a less controversial option than proposing “planned retreat”. On the other hand, the majority of residents did not consider the risk of sea-level rise seriously. Generally, the concerns decreased by the length of time respondents had lived in the area and as the age of them increased, but increased among those who had higher completed education levels. In particular, there was an increasing number of young females with tertiary education who expected an adverse affect of sea-level rise on their properties in the future.

8.2.2 Risk Perception of Businesses

The survey of local businesses found that overall flood risk was not a major concern in Port Adelaide. Only about 15 percent of participants had any on-site water problems, which were described as due to “unusual weather conditions”, including wave damage to port facilities, tidal inundation to shipyards or workshops, and storm-water flooding. Concerns about sea-level rise were mainly limited to those situated on the waterfront which were the most likely to be affected by high tides. Some other enterprises simply had concerns on the topic, including a large utility supplier on the river bank and a State owned industry which was expecting to expand at the site.

It was found that smaller scale businesses were more likely to be affected by water problems than larger ones. In Birkenhead, it was shown that a restaurant on unprotected low-lying land was periodically inundated by 1-in-20-year storm tides. A few businesses behind the wharf were also affected by either storm-water flooding or seawater backflow due to problems with the drainage systems. As a consequence, business activities were temporally disrupted with extra costs of cleaning up and repairs. Raising site levels or constructing breakwater/seawall extensions would be substantial costs for small to medium businesses. In addition, a potentially hazardous inundation of the fuel terminals in Peterhead was raised relating to floating hydrocarbons (fire and pollution) which posed a potential health risk. This highlighted issues of conflicting responsibilities about public fuel supply between the government and the utility companies. Potentially this could impact on the State's fuel safety in the future, with consequences for the state economy.

8.2.3 Influencing factors to risk perception

From the perspective of a greater understanding of risk perception, this study has empirically examined socio-economic factors, psychological elements and situational conditions. The results indicate that the age of property owners had a strong influence on risk perception. Interestingly, the effect of gender was not confirmed in the structural equation modelling. Among social factors, the length of residence was also a major factor. Surprisingly, flood experience showed a weak effect on risk perception. These results imply that the relationships between risk perception and influencing factors are complicated and very much associated with local contexts.

A significant finding was the causal influence from risk perception to intention to respond. It was confirmed that a number of cognitive-behavioural factors (perceived behavioural control, subjective norm and adaptive capacity) would strongly affect the intention of respondents to respond or adapt to perceived flood risk. In addition, the capital value of property was found to be a strong indicator for adaptive capacity. This implies that the intention to respond (e.g., taking adaptive actions) was potentially predictable by adaptive capacity or capital value, given the circumstances of the property owners and businesses.

8.3 Findings and Implications for Theory and Methods

8.3.1 Addressing uncertainty in estimating sea-level extremes

Coastal risk assessment has been the major means to determine flooding risk however the use of state-of-the-art technology to obtain optimal results was limited in practice due to resources. As an example, the Port Adelaide 2005 Flooding Study conducted hydraulic modelling of storm tides, providing estimates of flooding risk under the global sea-level rise predictions released in 2001 from the TAR (IPCC) (Jacobi and Syme 2005a, p. 41). However, for optimal urban planning purposes, flood models need to be upgraded regularly whenever new data area available. Specifically up-to-date sea-level rise scenarios need to be taken into account (URPS 2016).

In Chapter 3, an approach was outlined, incorporating scenario analysis with spatial and statistical techniques to refine the prediction models of the Port Adelaide 2005 Flooding Study. The most significant components of this method were:

(1) An upgraded digital terrain model with superior vertical and horizontal resolutions

(2) Up-to-date global projections of sea-level rise based on AR5 (IPCC)

(3) Local and regional sea-level rise scenarios were developed to upgrade methodology, compared to previous work of simply using the global sea-level rise projections, as adopted in the Port Adelaide 2005 Flooding Study (Jacobi and Syme 2005a, p. 26).

(4) Adapted an "allowance" methodology to construct local and regional allowances for sea-level rise based on statistical modelling of extreme values, rather than a "rule-of-thumb" arithmetic estimate of extreme sea levels.

The method can be used to update the models whenever new parameters are available. This has important implications for risk assessment. For example, the inundation caused by 1-in-50-year storm tides can be estimated from a typical model of 1-in-100-year ARI (tide) to derive flood boundaries for evaluation of the perceived risks by survey respondents.

An “allowance” method has recently been highlighted by Church et al. (2016), proposing a broader utilisation in establishing and improving sea-level rise benchmarks for coastal planning and management in Australia. Policy implication of the “allowance” method adopted in the current study will be detailed in Subsection 8.4.1.

8.3.2 Process of risk response: a theoretical perspective

A significant finding from the business survey was the basic business process (BBP) of surviving the risk exposure and the causal-consequence relationships. This conceptual knowledge of business survival provides a theoretical framework featured by recurring processes, break points, nested and structural orders, delineating how risk exposure was perceived by businesses, and how the causes and consequences of the exposure were overcome, as well as the number of sequential responses that were undertaken. These characteristics of the BBP reflect patterns of adaptive behaviour (intention and response) to flooding risk. A latent covariance of causes and consequences was also identified, indicating that seawater backflow is likely to worsen with sea-level rise.

The business process was fundamentally important as it highlights exposure to underlying risk related concepts. In this study, both the resident survey and the business survey showed that exposure acted as a causal nexus between the perceived risk from stakeholders and the actual risk they were confronting. On the one hand, risk evaluation was able to be conducted in local contexts, focusing on the actual risk/exposure. On the other, the intention to respond and responsive actions could then be elicited, from the risk perception (or perceived risk) point of view. Thus, the current study has demonstrated a comprehensive but practical approach to risk through examining risk exposure and risk perception, to achieve an understanding of risk response and adaptation.

In addition, the demonstrated process of risk response shows the contemporary adaptation management to "unusual conditions" (i.e., extreme flood events), specifically coping mechanisms and co-evolution characteristics (Pelling 2011, pp. 25-47). The "break points" are a close representation of thresholds/tipping points in the anatomy of adaptation theory (Lisa et al. 2009, pp. 36,54). The structured order of responses reflects the logic underlying business decision making on flood risk mitigation. Thereby, the interactive causes and consequences, the patterns of responsive behaviour and the nexus between them, form a substantive theory of "surviving the exposure". This then provides an empirical prototype for business adaptation to climate variation in Port Adelaide.

8.3.3 GESI: an innovative method of quantifying flood risk

GESI (Gravitation-Energy Surfaces of Inundation) provides a powerful representation of flooding risk. The method was initially developed to measure the impact of inundation, due to its uniform quantification of the flooding risk from a specific extreme event. For example, GESI predicts that Birkenhead would be hit the hardest by storm tides under the current scenario base S0 (Subsection 4.6.1). This result was also indicated by the storm-tide induced flood event of 9/5/2016.

In addition to indicating inundation risks, GESI has demonstrated an increased capacity for risk assessment, including the evaluation of mitigation options. Subsection 4.6.3 provides a comparative analysis of the “buy out” options based on GESI value. Furthermore, GESI can take into account uncertainties. For example by comparing a current scenario to an up-to-date projection of future sea-level rise, it is predicted that the heart of Inner Port and Peterhead would be mostly affected by storm tides in future decades, as discussed earlier (Subsection 4.6.4).

GESI was also utilised in this study as a comprehensive indicator to flooding risk, in the measurement and test of a hypothesised structural equation model for causes influencing risk perception (refer to Subsection 7.5.2).

8.4 Policy Implications

Clearly, land and property are the most affected by flood problems. In South Australia, a large proportion of lands is owned and managed by State and local government. Therefore this section focuses on the implications for State government policy, in respect to future sea-level rise and mitigating flood risk in urban development plans. Some more general policy issues are also discussed, including support for small businesses coping with flood risks, as well as the problems associated with flood insurance policy.

8.4.1 Optimising sea-level-rise planning allowance

The scenario and allowance approach proposed here (Section 3.4) enables a timely updating of the height specifications necessary in the protection of coastal settlements in the context of sea-level rise (SLR). In Australia, government has attempted to mitigate flood risk to settlements (in the six states and territory along the coast) through establishing Sea-level Rise Planning Benchmarks (Good 2011, p. 5). South Australia was the first State to develop specific coastal climate change adaptation strategies and the recent policy of SLR provisions required an allowance for 1m (0.3m + 0.7m) of SLR by 2100, applying to new developments (Coast Protection Board 2015; Harvey et al. 2012).

Applying the extreme value statistics, down-scaling considerations were taken into account in the research methodology adopted here, as well as local contexts. For example, the SLR allowance for regional Port Adelaide was differentiated from that for Inner Port, where land subsidence has been occurring. This enables the approach to sea-level rise planning to be statistically based, making it more applicable and more manageable to meet the needs of strategic policy. In cases where flooding cannot be tolerated, which results in building critical infrastructure, a precautionary approach should choose a higher allowance based on estimates of the maximum possible sea-level rise (Hunter et al. 2013, p. 22).

8.4.2 Land-use in coastal planning

The study highlights the importance of land-use strategies for mitigating flood risk in State and regional planning. Land use and territorial planning were identified as critical factors in risk reduction in flood prone areas (IPCC 2012, p. 69). In Queensland, robust land-use planning for mitigating flood risk has been an essential component of hazard management in development plans and frameworks (Symes et al. 2009, p. 123). As discussed in chapter 6, many stakeholders tended to overlook risk exposure to an extreme event severer than 1-in-50-year storm tides. However, some large businesses such as the Adelaide Brighton Cement (ABC), successfully transformed its low-lying land to increase the adaptive capacity for mitigating flood risks (refer to Subsection 6.7.2).

The consequences of ignoring a worst scenario flood risk assessment would be significant for a development project if the problems are recognised too late. This would incur increased costs due to increasing the ground level or building sea walls. Based on comments made by survey respondents, a flood disaster could occur in the future because of profit-driven developments. Riddell et al. (2017, pp. 18,28) recently explored scenarios of future risk in Adelaide. In the case of Hurricane Katrina in the United States, developers had been "reducing consequences to relatively frequent events, and increasing vulnerability to very large and rare events" (Kates et al. 2006). Thus the bottom line should be not putting new settlements at risk. Bearing the cost of reducing exposure to an acceptable level is the only alternative. Further, development should not make adjacent areas more exposed to flood risk.

8.4.3 "Surviving" and "thriving": small businesses need support

From the survey responses it was clear that both the property owners and the local businesses perceived the responsibility of flood risk mitigation to fall with government authorities. It was expected that the government could provide assistance to the Small and Medium-sized Businesses (SMBs) when adverse flood events occurred. In addition, a number of issues arising from the survey and the interviews were as follows:

- Risk assessments and knowledge of local flood problems appeared not to be shared, and it was likely only the businesses had to bear the consequences. There were small businesses that rented/purchased land from the government but were not informed about the existing exposure to floods. This had resulted in unexpected costs for repairing damage and cleaning up after floods. Some even had to build up the ground level of the business site.
- People were losing trust in the authorities. This would have profound implications for risk communication and response (Few et al. 2007; Gifford 2011).

- Some small businesses perceived the authorities to be ineffective, with comments such as "*they were just not available*", "*they do not want to listen*" or "*they are hopeless*".
- Some businesses criticised the authorities as being "*short-sighted*", "*just for money*", or "*they only care about election*".

Strong and effective government support is critical for small businesses and the local economy, not only for surviving but also thriving in an environment which is exposed to flood risks. This is of particular importance in Port Adelaide which has experienced economic and social problems due to decreasing productivity, reduced port activity and population ageing (refer to Section 4.2). It was discovered that an interviewed auto-motive service had relocated out of Port Adelaide after the 2010 Business Survey. It had survived in Port Adelaide for about 20 years, hiring eight employees at the time of interview. The business manager had complained about the inefficacy of maintaining public drains, but had denied the option of "moving away" due to financial concerns. Compared with the case of ABC (Adelaide Brighton Cement) which was discussed earlier (Subsection 6.7.2), the small-scale business was in a much more vulnerable position due to its small adaptive capacity. Nevertheless, it moved away!

8.4.4 Flood insurance

The findings of this study can provide key information to improve the efficacy of flood insurance policy. The survey found that property owners perceived taking flood insurance as an option for flood risk mitigation. Small and Medium-sized Businesses (SMBs) were strongly advised by the local Business Chamber to have flood insurance cover. However, the association between risk perception and taking flood insurance was not statistically confirmed. A follow-up interview in Peterhead highlighted the potential problems in relation to this discrepancy as follows:

- Flood (by high tides) was not included in the policy of most popular insurances.
- Some residents were not aware if floods were covered in their property insurances.
- If the insurance did cover floods, it was perceived to be too expensive.
- Some owners underestimated the flood risk to their properties, and therefore did not consider insurance.

There has been an urgent need in Australia for insurance to cover floods from seawater, as indicated by increasing insurance claims for storm surge damages (Killalea 2016; Sundstrom 2016; Tilbury 2009). Improved flood risk estimates, like the refined flood models proposed here can help both the insurance organisations and the stakeholders to better understand the actual risks they face. In addition, the patterns of business response to flooding risk provide information for cost-efficiency analyses for the development of fair insurance pricing and policy. In the meantime, the governance issues with sea-level rise and seawater floods need to be explored and proposing a new set of laws would be of assistance to supportive insurance schemes.

8.5 Limitations of the Study and Future Research

8.5.1 Is generalisation possible?

First of all, it is necessary to acknowledge that risk perceptions from those non-owner residents were not represented in the Resident Survey, as the study focused on property owners. This limitation was partially remedied by semi-structured interviews at Harbour-side Quay, where some participants were tenants of Housing SA (a major public housing provider in South Australia). Interviews were also conducted with AnglicareSA (a private disability & mental health service) and Supported Residential Facilities (SRF) Project – Western Region (jointly funded by City of Port Adelaide Enfield, State and Federal Governments). It was suggested that the mobility of population with disability might undermine their adaptive capacity, as well as evacuation plans were likely needed for an extreme flood event. Although these issues were reflected in the questionnaire (i.e., collecting information about vehicle ownership and the awareness of emergency plans), further investigation under the context of non-owner residents was not a part of this research.

Clearly it is not possible to generalise from the findings of this study to other coastal regions of Australia, or indeed other South Australian locations. Port Adelaide is the "last undeveloped port waterfront in Australia" (Renewal SA 2015) with distinctive economic, social and environmental features. Flood problems have to be addressed in an era of global climate change and economic down turns, as well as profound demographic changes in Australia and must take into account local contexts.

This study has probed the integrated dimensions of the flood problems in Port Adelaide. A suitable data set for a representative sample of stakeholders of other Australian ports was not available. However, the problems are widespread and significant in Port Adelaide and probably in other coastal towns of Australia. Understanding the issues in a few localities can suggest hypotheses that could be tested and questions that could be asked in larger-scale studies. The intensive methods of investigation employed in this small scale survey provide a greater depth of understanding of the processes, which are so profoundly influenced by variables operating at the level of the individual resident and the local business, as compared with larger-scale investigations.

8.5.2 Dimensions of risk assessment

Much remains to be done in Port Adelaide flood risk assessment. A fundamental need is to incorporate storm-water flooding into the inundation models. The surveys found that heavy rain was identified as a major cause of flood for current scenarios and accordingly was set as a priority by local authorities (southFront 2016). However, seawater flooding has been highlighted in research literature in the context of global sea-level rise. The storm-tide induced flood event (9/5/2016) at Birkenhead was a good example of the issue. Although the Port Adelaide 2005 Flooding Study concluded that there was “no reliable correlation between rainfall event probability and storm tide probability” (Jacobi and Syme 2005a, p. 15), responses from the resident survey (and the post-survey investigation) called for a reassessment of the “coincidence of high rainfall and high sea levels” in Port Adelaide (PAREPG 2016b, p. 5). The current study proposes to undertake a joint-probability analysis (Coles 2001, p. 22; Hawkes 2008; Lian et al. 2013) to address the problem.

The complex interaction of the two major flood causes (i.e., storm tides and heavy rains) deserves dedicated analysis. This would include a worst-case scenario thoroughly addressing the drainage problems (identified in the surveys and post-survey investigation), such as the efficacy of the old drains and the potential back flow of seawater. This approach should take into account new information, as well as future uncertainties. Accordingly the GESI method may be able to be developed into a universal quantification of flooding risk, incorporating extreme events of both storm tides and heavy rains. This would be a useful step toward the establishment of “manageable” and “adaptable” indices to be used for decision making.

Additional investigations into broader influences on flooding risks in Port Adelaide are needed. Questions posted by survey respondents included, for example: *what would be the* *role of West Lakes Seawater Scheme in defining the water levels at Inner Harbor? What would be the best way for West Lakes to contribute to regional flood risk mitigation?* When the flood problems in Port Adelaide were considered in a broader policy agenda, there would be more knowledge gaps to fill.

8.5.3 Dimensions of risk perception

Although considerable effort was put into the research of risk perceptions in Port Adelaide, some shortcomings were unavoidable due to limited resources. First, despite that subregional differences of risk perception were identified (refer to Section 7.4), further examination was not possible. Second, the model of causal structure is still at a stage of infancy. It was also evidenced in the survey that risk perceptions were subjected to change in the years to come. Therefore dedicated efforts are needed to extend the study for better understanding of risk perception and future changes.

Further research is necessary to improve and develop the measurement of current constructs of the conceptual model for better prediction of business intentions and behaviour. The constructs of risk and exposure need to be identified in the structure model (refer to Figure 7.8), so that the important influences of risk and exposure on risk perception could be represented quantitatively. The measurement model (refer to Figure 7.7) may be further refined or generalised, given that cognitive-behavioural theories (such as the Protection-Motivation Theory) could be applied in different contexts of the 2010 Business Survey, in addition to the case of Adelaide Brighton Cement discussed in this study.

It may be useful to use a multi-group structural equation model to investigate how the subregions at SA2 (i.e., Largs Bay-Semaphore, Port Adelaide CBD and Outer Harbour, etc.)

differ from one another in factors influencing risk perceptions and response to the threats of flooding. If adaptation intentions are found to significantly differ across subregions, underlying causal factors could be further explored. Local authorities could then pay attention to the characteristics of each subregion, or the corresponding critical factors for each specific area, to design appropriate adaptation strategies.

Focusing on the adaptation behaviour of residents or businesses, additional constructs need to be incorporated into structural equation modelling, according to the concepts and interactions defined in relevant cognitive-behavioural theories, such as PMT (Protection Motivation Theory) or TPB (Theory of Planned Behaviour). This study goes some way to better understand the drivers to adaptive behaviour. For example, what are the influences of the characteristics and patterns of business survival on response as maladaptation or adaptation? The outcome may help identify tipping points of adaptation which have profound policy implications.

It would be beneficial to incorporate new surveys providing information for the changing contexts of risk perception, for a better understanding of the nexus among risk, risk perception and response, as well as their causal influences. Examining these interactions would provide insights about how risk perceptions are changing. This knowledge can be used to improve public trust which was found to hinder risk communication between the stakeholders and decision makers.

8.5.4 Dimensions of risk adaptation strategy

An important research field to which the theory of business response (i.e., business survival or surviving the exposure) could make a substantive contribution, would be risk mitigation/adaptation strategy, based on robust cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA) (Boardman et al. 2006; Garber and Phelps 1997; Mishan and Quah 2007; Siegel et al. 1996). Traditionally, CBA has been required as an effective tool for decision-making worldwide, for proposed waterway infrastructures, flood control strategy and environment policy (Dunham 1959; Hanley and Spash 1993; Pearce 1998). In Australia, CBA was established as a Federal policy for regulation and finance, demanding that the benefits be in excess of the estimated costs (Australian Government 2006, p. 4; Chalak et al. 2016).

The mechanics of business flood response are particularly relevant, in regard to the evaluation of mitigation measures between benefits and costs which are directly confined by the "causal-consequence" relationship. In fact, the existing business survival patterns (i.e., recurring process, break point and nested and structural order) represent the results of CBA from a majority of the local businesses at Port Adelaide, in response to flood risks and exposure during their business life cycles. Although under the current scenario, many of those adaptive actions (e.g., those undertaken in the structural order) turned out to be feasible and cost-effective in the first place, there were concerns about the uncertainties upon future conditions, in specific those related to sea-level rise.

As an example of a responsive action in the structured order, flood reduction through wetland restoration (Hey and Philippi 1995) was requested by local residents. This calls for quantification of the mitigation option and incorporation into a CBA for developing adaptation strategy. The CBA results are also increasingly important to the studies of flood damage and vulnerability in regions suffering natural disasters (Messner and Meyer 2005). In order to estimate the impacts of future scenarios on the patterns of response, however, the CBA needs to be upgraded utilising flood probability modelling (Apel et al. 2006). Notably, the methodology of "addressing uncertainty" (refer to Subsection 8.4.1), has met this demand and provided a practical approach.

8.5.5 Integration of business response into land developments

One area of future research that is of crucial importance for the study area is the controversial release of "employment land" in Gillman for development of a major industrial hub. The South Australian government aimed at creating up to 6000 jobs in 25 years in Gillman (Renewal SA 2014a). However, Gillman has been used as a critical buffer to storm tides and retention to seawater flooding for inlands areas (Jacobi and Syme 2005a, p. 57). Also recognised for its ecological significance are its water bodies (the Port Adelaide River and the Barker Inlet system), which are vital parts of Adelaide International Bird Sanctuary National Park and Adelaide Dolphin Sanctuary (Filby et al. 2010; SA Governor 2016). Already these marine ecosystems are under increasing pressure from the impacts of industrial and coastal developments in close proximity, such as heavy metal pollution, beachfront damage, and stormwater/waste water discharge to the sea (Bryars 2003; Townsend 2005; Wilkinson et al. 2005).

These indicate an urgent need for an incorporated analysis of the inter-relationships between the development and the risk of flooding, as well as the impact on the environment. *To what extent are the development-induced environmental changes related to the vitally important ecosystems (e.g., marine species, mangroves and wetlands, etc.) in adjacent areas? What impact will land-use change have on flooding risk and exposure under future uncertainties? What would be the implications of the identified patterns of business risk response for the development of the industry hub?*

8.6 Conclusion

There can be no doubt that governments' efforts to rejuvenate Port Adelaide have mainly focused on population growth and increasing employment opportunities. A typical approach is through redevelopment of the vacant waterfront areas along the banks of the Port River, as well as establishing businesses on the large low-lying lands in Gillman. However, the flood experiences of some residential areas, including those within the development plans, indicate potential risks of flooding from either seawater or storm water. Discrepancies exist between the perceived and the actual risks, depending on factors of physical or human dimensions. The predicted sea-level rise makes the concerns even more complex. The task of Port Adelaide's planners to revive economic prospects, while simultaneously mitigating flooding risk, is a massive one and will require a good understanding of the local contexts, specifically risk perceptions and estimates from upgraded risk assessments. This research has potential to assist a successful transformation of Port Adelaide to a sustainable flood-safe future and it is imperative that research efforts are directed towards understanding the consequences of not taking immediate action.

APPENDICES

Appendix 1: Open-ended Questions for the 2010 Resident Survey

1. How long have you been living in this area (Port Adelaide)? What do you like about this area?
2. When I bring up the word flood, what kinds of thoughts does that bring to mind?
3. Some of the effects of flood are that it can make inundate houses?
4. Can you please name a few areas (or streets) in Port Adelaide which have been flooded before?
5. Can you remember when these floods occurred?
6. Can you tell me about how the sea rises?
7. It's great that you've taken photos of the flood, may I have a look?
8. If you have noticed water backflows from the drain, was that salty water?
9. Can you give me an idea how the locals cope with the flood problem?
10. Do you have insurance for floods on your property?
11. I heard about the levee would provide protection, do you think so?
12. Talking about flood losses, who would be responsible for that?
13. You have reminded me of the problem of pollution, are there other concerns you think would be important?
14. Have you heard about sea-level rise (SLR)?
15. How do you think SLR would affect this region?
16. How would you like the apartments built up in the Newport Quay project?

Appendix 2: Information Sheet for the 2010 Resident Survey

Information for Survey Participants

This survey is designed for listening to your perceptions and ideas on the potential effects of projected sea-level rises and flooding risk in Port Adelaide. We would like to have your opinions as your unique knowledge and experience will improve our understanding of the issues. **It is important to hear the opinions of people from all backgrounds.** We hope the findings will be of benefit to decision-making processes and eventually to our participants.

How you can help?

You can contribute to this study by filling out the **enclosed survey** and doing this should only take about 15 minutes of your time. Participation in this project is completely voluntary. While there will be opportunities to participate in other phases of this project filling out this survey does not obligate you to be involved in further research activities.
Please keep this **information sheet** for your records, and feel free to contact **Dandong Zheng** on **(08) 8303 5899** regarding any aspect of the project at any time.

How to complete this survey:

- Most of the questions can be answered by either **crossing or ticking a box**
- **Circling a number** of ratings
- Some columns can be filled with one word or a few words

Please complete the survey as soon as possible, and return it to us **using the envelope supplied**. No stamp is required on this envelope.

Confidentiality

All information you provide is completely confidential will only be used in aggregated form and will not be shared with anyone. The number on the top-right corner of the survey's first page is only used for administration purpose, ensuring your address will not be used again for sending a reminder letter after you have returned the survey. The survey information comes directly to the University where it is de-identified, coded and kept securely. Any results that are released in reports will not contain any information about individuals. All the survey material will be destroyed when the project is complete.

We would like to award you:

- Blue-ray/DVD **Disc show of "The Forbidden City",** a new documentary of China.

A DVD Disc show of the documentary has been warmly welcomed in Taperoo Community Centre last month. Please **complete the survey as soon as possible** and include an email address or a telephone number for quick contacts. We will advise you of the venue/time after you return the survey to ensure you are included in the show.

For information about the University ethics process please see the information on the back of this sheet.

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The Human Research Ethics Committee is obliged to monitor approved research projects. In conjunction with other forms of monitoring it is necessary to provide an independent and confidential reporting mechanism to assure quality assurance of the institutional ethics committee system. This is done by providing research participants with an additional avenue for raising concerns regarding the conduct of any research in which they are involved.

The following study has been reviewed and approved by the Human Research Ethics Committee (**Ethics approval number: H-161-2009**):

STAKEHOLDERS' SURVEY ON PERCEPTIONS OF POTENTIAL SEA-LEVEL RISE AND FLOODING IN PORT ADELAIDE

1. If you have questions or problems associated with the practical aspects of your participation in the project, or with to raise a concern or complaint about the project, then you should consult the PhD researcher:

   Name: *Dandong Zheng*
   Address: *Department of Geographical & Environmental Studies,*
   The University of Adelaide
   Room 820, Napier Building, North Terrace Campus
   Adelaide 5005
   Telephone: *(08) 8303 5899*

2. If you wish to discuss with an independent person matters related to
   - Making a complaint, or
   - Raising concerns on the conduct of the project, or
   - The University policy on research involving human participants, or
   - You rights as a participant

Please contact the University **Human Research Ethics Committee's Secretary on phone (08) 8303 6028**, or website: http://www.adelaide.edu.au/ethics/human/.

Reward to Survey Participants

The Forbidden City

Multi-language DVD/Blue-ray Disc Show

China’s history, culture, arts, architecture and sightseeing

Note: Time/venue will be advised after you return the survey.

Appendix 3: Questionnaire (2010 Resident Survey)

The "Residents' Opinions on Sea-level Rise and Flooding" Survey in Port Adelaide

No. ___________

This section will ask for information about general concerns…

1. **How long have you lived at your current residence?**
   ☐ Less than 2 years ☐ 2-10 years ☐ 11-20 years ☐ More than 20 years
2. **What was the MAIN reason for living at your current address?**
   ☐ Close to the sea ☐ To be nearer to work ☐ Family reasons
   ☐ Others (please specify) ____

3. The following environmental issues may or may not be of concern to you as a resident in the Port Adelaide area. **Using the scale below, please circle one of the numbers to evaluate your level of agreement about how each issue would impact on your quality of life.** If there are any other concerns, please list as well.

Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	2	3	4	5

	ENVIRONMENTAL ISSUES	*RATE*					*COMMENTS*
a	**Coastal erosion**	**1**	**2**	**3**	**4**	**5**	
b	**Contamination of groundwater**	**1**	**2**	**3**	**4**	**5**	
c	**Floods**	**1**	**2**	**3**	**4**	**5**	
d	**Future sea-level rise**	**1**	**2**	**3**	**4**	**5**	
e	**Heat waves**	**1**	**2**	**3**	**4**	**5**	
f	**Heavy rainfall**	**1**	**2**	**3**	**4**	**5**	
g	**Less access to beaches or river banks**	**1**	**2**	**3**	**4**	**5**	
h	**Long-term drought**	**1**	**2**	**3**	**4**	**5**	
i	**Loss of green space**	**1**	**2**	**3**	**4**	**5**	
j	**Loss of seagrass**	**1**	**2**	**3**	**4**	**5**	
k	**Oil spill from nearby storages**	**1**	**2**	**3**	**4**	**5**	
l	**Pollution of air**	**1**	**2**	**3**	**4**	**5**	
m	**Pollution of sea**	**1**	**2**	**3**	**4**	**5**	
n	**Pollution of the Port River**	**1**	**2**	**3**	**4**	**5**	
o	**Reduced number of animal and plant species**	**1**	**2**	**3**	**4**	**5**	
p	**Strong winds**	**1**	**2**	**3**	**4**	**5**	
q	(other issue)	**1**	**2**	**3**	**4**	**5**	
r	(other issue)	**1**	**2**	**3**	**4**	**5**	
s	(other issue)	**1**	**2**	**3**	**4**	**5**	
t	(more comments)						

4. **Where do you currently get information about the environment?**
   ☐ Speaking to people in the community ☐ TV or radio ☐ DVD documentaries
   ☐ Meetings and presentations ☐ Technical literature ☐ Government publications
   ☐ Internet ☐ Books, newspapers and magazines ☐ Own study or research
   ☐ Others (Please specify) ____

This section will ask for information about the topic…

5. **Do you think your property might be affected at some time in the future by <u>sea-level rise</u>?**
☐ No ☐ Yes ☐ I don't know

5a. If yes, how soon do you expect <u>sea-level rise</u> to be a problem?
☐ Within 10 years ☐ 10-20 years ☐ 21-40 years ☐ In more than 40 years ☐ Unsure

6. **If you are aware of any flood that occurred <u>within the City of Port Adelaide Enfield</u>, please indicate its time: ___________** (month)/____________ (year) **and the street(s) affected ________________________________. Otherwise, please skip the next question 6a.**

6a. What do you think were the major causes of <u>this</u> flood from the following?
☐ King tides over-top the bank/shore ☐ Seawater back-flows from drainage ☐ Gales ☐ Storm water exceeds drainage capacity ☐ Others (please specify): _________________

7. **In <u>areas close to your property</u>, if you are aware of any flood that occurred, please indicate its time: _____**(month) / _______ (year) **and the street(s) affected ____________________.**
Otherwise, please skip the next question 7a.

7a. Please select the possible major causes of <u>this</u> flood from the following?
☐ King tides over-top the bank/shore ☐ Seawater back-flows from drainage ☐ Gales ☐ Storm water exceeds drainage capacity ☐ Others (please specify): _________________

8. **Do you think flooding might affect your property or land some time in the future?**
☐ No, please skip the next 4 questions: 8a, 8b, 8c and 8d ☐ Yes ☐ I don't know

8a. If yes, how soon do you expect that your property might be affected by flooding?
☐ Within 10 years ☐ 10-20 years ☐ 21-40 years
☐ In more than 40 years ☐ Unsure

8b. Do you think moving away would be an option to reduce the risks of flooding?
☐ No ☐ Yes. If yes, please indicate where you'd like to move to___________________

8c. What are other options you consider practical to reduce the risks of flooding?
____

8d. Do you agree with the option of building sea walls to protect the area from flooding?
☐ Yes ☐ No. If no, please indicate why_______________________________________

9. **Have you ever personally experienced a flood anywhere?**
☐ No ☐ Yes. If yes, please indicate when ____________ and where________________

10. **Do you have insurance coverage for flooding?** ☐ Yes ☐ No
If no, please indicate the reason as below
☐ Not necessary ☐ Not covered in the policy ☐ Expensive
☐ Others (Please specify) ____

This section will ask for information about what you may do…

11. **Are you aware of any emergency plan or evacuation plan for major flooding events in your area?**
☐ No ☐ Yes. If yes, please indicate what the plan is called________________________

12. **How responsible do you believe the following individuals and groups are for protecting properties and lands against flooding?**
(Please circle <u>one</u> number for each row below).

INDIVIDIALS AND GROUPS	**RESPONSIBILITY**				
	Unsure	**Little**	**Some**	**Medium**	**Very much**
Occupants or property owners	**1**	**2**	**3**	**4**	**5**
Developers and builders	**1**	**2**	**3**	**4**	**5**
Government planners	**1**	**2**	**3**	**4**	**5**
Hazard and emergency managements	**1**	**2**	**3**	**4**	**5**

13. Do you think the risk of flooding has been adequately considered in the planning and development of the Port Adelaide area?

☐ Yes ☐ No. If no, please give an example____

14. Are you in favour of water-front developments (such as the Newport Quays Project)?

☐ Yes ☐ No. If no, please explain ____

____

15. Do you agree with the opinion of developing the near-shore vacant land for industry?

☐ Yes ☐ No ☐ I don't know

Please indicate why you think so ____

____

16. How do you think government should deal with the following issues? (Please rate your opinion using the scales below)

Strongly disagree	Disagree	Unsure	Agree	Strongly agree
1	2	3	4	5

	ISSUES	RATE					COMMENTS
a	**Should government be taking further actions to cut greenhouse gas emissions?**	1	2	3	4	5	
b	**Should government limit housing development in areas at risk from <u>sea-level rise</u>?**	1	2	3	4	5	
c	**If government do allow development in these areas, should there be available support financially to protect properties from the effects of <u>sea-level rise</u>?**	1	2	3	4	5	
d	**Should development in areas at risk from <u>sea-level rise</u> be at the owner's risk – with limited community liability?**	1	2	3	4	5	
e	**Should there be a plan for removing existing housing in 'high risk' areas from <u>sea-level rise</u> in Australia?**	1	2	3	4	5	
f	**Should maps and other information that show areas at risk from projected <u>sea-level rise</u> be published?**	1	2	3	4	5	
g	**Should home owners be compensated for property damage or loss due to <u>sea-level rise</u>?**	1	2	3	4	5	
h	**Should home owners be compensated for lowered property values in risk areas of projected <u>sea-level rise</u>?**	1	2	3	4	5	
i	**Should government continue to develop key infrastructure, such as power stations, major electricity transmission and gas pipelines in areas that are at risk of <u>sea-level rise</u>?**	1	2	3	4	5	

Any more comments: ____

This section will ask for some background information about you…

17. Which of the following age groups are you in?

☐ 18 – 24 ☐ 25 – 34 ☐ 35 – 44 ☐ 45 – 54 ☐ 55 – 64 ☐ 65 – 74 ☐ 75 +

18. And your gender? ☐ Male ☐ Female

19. Do you have vehicle(s)? ☐ Yes ☐ No

20. Do you have children aged under 18 living at home? ☐ Yes ☐ No

20a. If yes, how old is your youngest child at home? _____________ years old

21. Do you ever use a bore (well) at your property for watering purposes? ☐ Yes ☐ No

21a. If Yes, have you observed the following:

☐ Rising water table ☐ Falling water table ☐ Increased salinity
☐ Decreased salinity ☐ Others (please specify) ____________________________

22. Do you use rainwater tank(s) at your property? ☐ Yes ☐ No

22a. If yes, what is the total volume (size) of the tank (s): ______________________ litres

23. What is the occupation of the <u>main income earner</u> in your household?

☐ Clerical ☐ Construction worker ☐ Home duties ☐ Manager/administrator ☐ Plant and machine operator ☐ Professional ☐ Retired ☐ Sales and services ☐ Seafarer ☐ Student ☐ Trades ☐ Other (please specify): ______________

24. What is your highest level of completed formal education?

☐ Primary ☐ Secondary ☐ TAFE/Trade school/apprenticeship
☐ University ☐ Other (please specify): ___________________________________

This section will ask for your follow-up information and comments…

25. Would you agree to participate in a follow-up survey/discussion within 3 months?

☐ Yes ☐ No

25a. If yes, please provide a telephone number __________________________ or an email address _________________________@________________________ for contact.

26. If you have additional comments or suggestions that you feel may be of use to this study, please provide them below.

____
____
____
____

Thank you for taking the time to complete this survey, we appreciate your efforts.

To finish up the survey, please **post this survey back** using the self-addressed, postage paid envelope provided.

Thank you again for your help with the study!

Appendix 4: Two reminder Letters for the 2010 Resident Survey

THE UNIVERSITY
OF ADELAIDE
AUSTRALIA

The "Residents' Opinions on Sea-level Rise and Flooding" Survey

DEPT. OF GEOGRAPHICAL & ENVIRONMENTAL STUDIES
PROFESSOR GRAEME HUGO
DIRECTOR, NATIONAL KEY CENTRE FOR SOCIAL APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS (GISCA)
LEVEL 8, NAPIER BUILDING
ADELAIDE UNIVERSITY SA 5005, AUSTRALIA

CRICOS Provider Number 00123M

30 September 2010

Dear Port Adelaide area resident(s),

Three weeks ago a questionnaire was mailed to you because your household was randomly selected to help in a study about the opinions on sea-level rise and flooding in the City of Port Adelaide and Enfield.

If someone at your address has already completed and returned the questionnaire, please accept our sincere thanks. If not, we would be extremely appreciative if you could complete it and send it to us. We are especially grateful for your help with this important study.

We have included another copy of the questionnaire. The questions should only take about 15 minutes to complete but your participation is of vital importance as we need a high response rate to validate the survey outcomes. We are very keen for our results to be fully representative of the whole community.

The completed questionnaire can be returned to us using the pre-paid envelope supplied in the mail. No stamp is required on this envelope. If you have questions regarding the questionnaire please contact us at mobile 0432 071 525 or email address Dandong.zheng@adelaide.edu.au.

Also please feel free to contact me if you have any further questions (Tel: 8303 5646).

Yours sincerely,

Professor Graeme Hugo
ARC Australian Professorial Fellow

This project is funded by the Faculty of Sciences and the Faculty of Humanities & Social Sciences, the University of Adelaide

THE UNIVERSITY OF ADELAIDE
AUSTRALIA

DEPT. OF GEOGRAPHICAL & ENVIRONMENTAL STUDIES
PROFESSOR GRAEME HUGO
DIRECTOR, NATIONAL KEY CENTRE FOR SOCIAL APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS (GISCA)
LEVEL 8, NAPIER BUILDING
ADELAIDE UNIVERSITY SA 5005, AUSTRALIA

CRICOS Provider Number 00123M

The "Residents' Opinions on Sea-level Rise and Flooding" Survey

19 November 2010

Dear Port Adelaide area resident(s),

About two months ago a questionnaire was mailed to you because your household was randomly selected to help in a study about opinions on sea-level rise and flooding in the City of Port Adelaide and Enfield.

If someone at your address has already completed and returned the questionnaire, please accept our sincere thanks. If not, we would be extremely appreciative if you could complete it and send it to us. We are especially grateful for your help with this important study.

We have included another copy of the questionnaire. The questions should only take about 15 minutes to complete but your participation is of vital importance as we need a high response rate to validate the survey outcomes. We are very keen for our results to be fully representative of the whole community.

The completed questionnaire can be returned to us using the pre-addressed and stamped envelope supplied in the mail. If you have questions regarding the questionnaire please contact us at mobile 0432 071 525 or email address Dandong.zheng@adelaide.edu.au.

Also please feel free to contact me if you have any further questions (Tel: 8303 5646).

Yours sincerely,

Professor Graeme Hugo
ARC Australian Professorial Fellow

This project is funded by the Faculty of Sciences and the Faculty of Humanities & Social Sciences, the University of Adelaide

Appendix 5: Guided Questions for the 2010 Business Survey

1. How long has you business been in Port Adelaide?
2. Why did you choose the current business site?
3. Has there been any concern about weather events?
4. Has there been any water problem, either coming from the sky, or from the sea?
5. What has been exactly the situation when that (weather event) happen?
6. What was exactly the cause (or reason) for that? Could you show me that in detail?
7. What were exactly the effects to the business when that happens?
8. How did that affect infrastructures/buildings/devices? Did that really bad?
9. Do you have any records or photos showing that?
10. Did that affect business activity in any way?
11. Was that called an emergency?
12. Did employees have any particular concern about that?
13. Were there any side effects in relation to the problem?
14. How did the business response to that? Did the business have any plan for that?
15. How can the business get rid of the problem? Or how can those could be mitigated? Is there a particular measure to stop that happen?
16. Does the business need any help to address the problem? What do you think that I can give a hand?
17. Do you expect in the future that could happen again? Is there any other concerns?
18. Do you know any water problem in the adjacent area?
19. About other businesses like yours, do they have the similar view?
20. May I have a look around and understand where had happened?

Appendix 6: Introduction to the 2010 Business Survey

THE UNIVERSITY
OF ADELAIDE
AUSTRALIA

The "Business View on Flooding and Sea-level Rise" Survey

DEPT. OF GEOGRAPHICAL & ENVIRONMENTAL STUDIES
PROFESSOR GRAEME HUGO
DIRECTOR, NATIONAL KEY CENTRE FOR SOCIAL APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS (GISCA)
LEVEL 8, NAPIER BUILDING
ADELAIDE UNIVERSITY SA 5005, AUSTRALIA

CRICOS Provider Number 00123M

10 November 2010

Dear Sir/Madam,

This is to introduce Mr Dandong Zheng who is a PhD student in the Department of Geographical and Environmental Studies at the University of Adelaide. He is preparing a thesis on impacts of flooding and sea-level rise in the areas of Port Adelaide.

As part of his study he is collecting some information from businesses which may have concerns regarding this issue. I would be most grateful if you are able to help him with his work. I can give you a complete undertaking that no names or personal identification will be attached to the information which you give him. All information will be treated in the strictest confidence and only aggregated statistics will be used in the study.

His thesis is concerned with reflecting the impacts and adaptation options in regard to possible flood-water problems, and the information you give him will be invaluable in achieving his aims. We hope our findings will contribute to improved adaptation strategies. If you have any question about the study, please have no hesitation in contacting me by phone (8303 5646) or email <Graeme.hugo@adelaide.edu.au>.

I would really appreciate your participation in the study.

Yours sincerely,

Professor Graeme Hugo
ARC Australian Professorial Fellow
Director, The National Centre for Social Applications of GIS

This project is funded by the Faculty of Sciences and the Faculty of Humanities & Social Sciences, the University of Adelaide

Appendix 7: Short-listed businesses with estimated flood risk

Business	Classification	Risk_i	Size
(Name not exposed)	Automotive Repair	100%	S_size
(Name not exposed)	Automotive Repair	32%	M_size
(Name not exposed)	Business Storage	71%	S_size
(Name not exposed)	Business Storage	57%	S_size
(Name not exposed)	Business Storage	52%	M_size
(Name not exposed)	Business Storage	44%	L_size
(Name not exposed)	Business Storage	40%	L_size
(Name not exposed)	Construction	100%	S_size
(Name not exposed)	Construction	85%	M_size
(Name not exposed)	Gas and electricity	30%	M_size
(Name not exposed)	Gas and electricity	6%	S_size
(Name not exposed)	Home industry	99%	M_size
(Name not exposed)	Home industry	44%	S_size
(Name not exposed)	Hotels	100%	M_size
(Name not exposed)	Hotels	98%	S_size
(Name not exposed)	Hotels	72%	M_size
(Name not exposed)	Hotels	54%	S_size
(Name not exposed)	Hotels	39%	L_size
(Name not exposed)	Hotels	32%	L_size
(Name not exposed)	Manufacturing	100%	S_size
(Name not exposed)	Manufacturing	100%	S_size
(Name not exposed)	Manufacturing	86%	S_size
(Name not exposed)	Manufacturing	81%	L_size
(Name not exposed)	Manufacturing	64%	S_size
(Name not exposed)	Manufacturing	56%	L_size
(Name not exposed)	Manufacturing	50%	M_size
(Name not exposed)	Manufacturing	4%	L_size
(Name not exposed)	Manufacturing	0%	L_size
(Name not exposed)	Recreation	88%	L_size
(Name not exposed)	Recreation	65%	M_size
(Name not exposed)	Retail Trade	100%	S_size
(Name not exposed)	Retail Trade	92%	M_size
(Name not exposed)	Retail Trade	28%	M_size
(Name not exposed)	Road Freight Transport	81%	L_size
(Name not exposed)	Road Freight Transport	22%	M_size
(Name not exposed)	Supermarket	18%	M_size
(Name not exposed)	Telecommunications	70%	L_size
(Name not exposed)	Telecommunications	50%	M_size
(Name not exposed)	Telecommunications	43%	S_size
(Name not exposed)	Wholesale Trade	100%	S_size
(Name not exposed)	Wholesale Trade	90%	M_size
(Name not exposed)	Wholesale Trade	81%	L_size
(Name not exposed)	Housing		L_size

Note: Risk_i is the ratio of the business premises predicted to be inundated, under the current scenario against the worst scenario in year 2100, during extreme events of 100 - year ARI (tide) in Port Adelaide, based on the refined inundation models developed in the current study (refer to Section 3.4).

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