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ECONOMICS OF NATURAL HAZARDS

Annual project report 2016-2017

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ABSTRACT

ABSTRACT: ECONOMICS OF NATURAL HAZARDS PROJECT

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To make natural hazard mitigation efforts efficient and equitable, it is important to understand the full range of costs and benefits and how these costs and benefits are distributed among different segments of the community. However, economic assessments of flood mitigation benefits generally tend to be incomplete and focused on tangible and direct benefits only. Indirect and intangible costs are rarely included in this type of assessments. In reality, intangible values can be large and, in some cases, they can be the most dominant component. The purpose of the Economics of Natural Hazards project is to address this shortcoming by, first, developing a Value Tool that help decision makers estimate intangible values and, second, by undertaking integrated economic modelling of mitigation options in ways that allow for the integration of intangible values. This annual report provides details on the Value Tool developed by the project and the results from the first case study investigating flood mitigation options for the Brown Hill Keswick catchment of Adelaide. The report also summarises the projects engagement activities over the year.

END USER STATEMENT

Ed Pikusa, National Risk Assessment, Measurement and Mitigation Subcommittee (RAMMS), Fire and Emergency Services Commission, SA

This project has generated a lot of interest among Western Australian and South Australian end users.

Integration of non-market costs into the Uni of Adelaide project on planning and optimisation has been discussed, and is a live option for the second stage of the research program

Application of the work to South Australia flood case studies is a useful illustration of the process, which end users can use further.

The register of non-market costs has generated significant interest.

INTRODUCTION

Natural hazards have a number of things in common when it comes to planning, decision making and evaluation of public investments. First, they are complex and, therefore, effective decision making and evaluation requires synthesis and integration of many different types of information within a context of high risk and uncertainty. Second, addressing these issues well requires an inherently multidisciplinary approach, often requiring information from biological sciences, physical sciences, social sciences and economics. Third, data requirements for strong decision making and helpful evaluation are extensive, and existing data sources are usually insufficient for this purpose. Fourth, some of the key impacts of natural hazards are relatively intangible, making them difficult to quantify, especially in a way that can feed into decision making. Finally, research into planning, decision making and evaluation for natural hazards is relatively lacking.

In the case of bushfires, for example, decision making requires combining information on physical, biological, social and economic aspects such as: risks of fire occurrence, risks of fire spread, frequencies of fires of different severities, impacts of weather conditions on these things, losses associated with bushfires of different severities, reductions in those losses under different prescribed burning regimes, and costs of different prescribed burning regimes. Experience in a Bushfire CRC project shows that only a minority of the required information is readily available in existing datasets. Intangible benefits of bushfire management include effects on life, health, feelings of safety, biodiversity, threatened species, and water quality. Integrated economic analysis of strategic bushfire decisions has been undertaken in Australia only for two case studies. The knowledge gaps for other hazards, such as earthquakes, floods, cyclones and tsunamis, are similarly significant.

This project aims to fill key knowledge gaps on issues related to values, risks, and decision making to deliver value for money from public investments in natural hazard management.

This is the third annual report written since the project research activities began in earnest in January 2015. In the next section, we provide a summary of the main components of the project. This is followed by a presentation of the projects key activities over the reporting period. In the third section, we summarise the major results from the research activities in the project.

BACKGROUND

The project has three main components that are outlined below.

ESTIMATE THE NON-FINANCIAL BENEFITS

End-user organisations have indicated the need for a stronger focus on dollar valuation of non-financial benefits from natural hazard policy and management. The challenge here is that there are so many different contexts within which these values may be needed, and it is not practical or affordable to conduct new studies for each context. Environmental economists have developed a technique called "benefit transfer", which involves attempting to extrapolate from existing studies, but even this is not an ideal solution. It requires a high level of economics expertise, and it relies on the existence of relevant studies to extrapolate from, which is often not the case for natural hazards.

This project will develop an innovative tool for efficiently generating estimates of dollar values for non-financial benefits. The aim is to develop a tool that people with only moderate economics knowledge are able to use, and that people with no economics knowledge can learn from.

INTEGRATED ECONOMIC ANALYSIS OF MANAGEMENT AND POLICY

This component of the project involves integration of technical, social, biophysical and policy information within an economics framework with a decision-making focus. Therefore, it is a study that requires high levels of participation by end users. Strengths of the integrated approach to the analysis include that: it provides a mechanism for bringing research results into decision making about policy and management; it combines economic rigour with stakeholder participation; and it provides information in a form that is useful in discussions about resourcing and policy design. Two case studies will be identified in consultation with the CRC and stakeholders. This study differs from other integrated assessment studies or work on decision support systems (DSSs) in that it takes into account the non-financial benefits of mitigation activities. The project is currently collaborating with an end user to conduct its first case study in Western Australia as described in the next section.

DEVELOP GUIDELINES FOR SOUND ECONOMIC ANALYSIS

This component of the project involves developing an accessible and understandable guide to undertaking economic analysis of natural hazard management and policy. The work will be based on: experience in the research undertaken to address the other project objectives; experience in the Bushfire CRC; relevant research literature and textbooks. The guide aims to be helpful to agencies in:

- formulating its needs for economic analysis,
- knowing what to ask economists (internal or external) to do,
- evaluating the quality of economic analysis that has been conducted,
- understanding the data requirements, and
- supporting economists beginning work on natural hazards.

RESULTS

The major results over the last year include the completion of the first case study on integrated economic modeling and the release of the draft Value Tool. As in previous years, the project has been actively cultivating engagement with end users and research collaborators. Details are presented below.

ENGAGEMENT WITH END USERS AND OTHER RESEARCHERS

As in the previous two years, the project has actively engaged with its end users over year.

SEMC

Project members have had several discussions with members of the State Emergency Management Committee (SEMC) Secretariat, WA (Mal Cronstedt, Andrew Sanders, Heather Taylor and Katherine Clarke). These meetings have helped identify SEMC's research needs and ideas for future projects, and also to identify ways in which economics can be applied to the prioritization of treatment options for natural hazard mitigation. Dates and other details for these meetings have been provided in the quarterly reports for the year.

Collaboration with University of Adelaide BNHCRC Project Team

The project team has continued to interact with the Adelaide Project members, led by Holger Maier, to identify non-market value data needs for the latter's Decision Support Tool. An estimate for the Value of a Statistical life was provided to the Adelaide team to trial the inclusion of non-market values in the Decision Support Tool. Other topics discussed included potential collaboration in publications, help from UWA with the case study in WA and new ideas for research that are highly relevant to fire managers (e.g. optimisation of the distribution of prescribed burns in the landscape to maximise benefits). Further meetings are planned with the Adelaide team.

Collaboration with DEWNR (Adelaide)

UWA Project team members travelled to DEWNR and had two meetings with Mike Wouters and Tim Groves in August 2016 to define the bushfire management options to be evaluated in the second case study and the scope of the study. They also had meetings with the cluster leader, Ed Pikusa (DEWNR), to discuss research focus for the future projects proposals for the 2017-2020 period. Further discussions on the draft project proposal were held between Vernoique Florec and Ed Pikusa in October, where potential custodians for the tools developed at UWA were also discussed. The project has collaborated with DEWNR staff and members of Natural Decisions to plan workshops in relation to the second case study on prescribed burning on private land.

DFES WA (Department of Fire and Emergency Services WA)

In July 2016, Veronique Florec and Atakelty Hailu (UWA) were invited to give a presentation at the DFES Community Engagement Strategic Business Planning Day in Rockingham. The presentation provided the Directorate with an overview of how we apply economic analysis to the management of bushfires, and in particular what type of information would be required to evaluate the costs and benefits of community engagement programs. Further meetings were had between Veronique Florec (UWA) and Suellen Flint (DFES) in September to discuss DFES needs, future project ideas and their input into our economic research. In February, Veronique Florec, Abbie Rogers and Jacob Hawkins (UWA) met with Rachel Armstrong and Tracey Leotta from the Community Engagement Branch of the WA Department of Fire and Emergency Services (DFES). The discussion focused on opportunities for value tool database use in DFES and feedback on the tool.

WA Department of Planning

Project staff met with Department of Planning staff several times in the year. Veronique Florec (UWA) had a meeting with Ben Harvey, Loretta Van Gasselt, Samantha Stokes, Jackie Holm, and Brent Savage (Department of planning) in March 2017 to discuss UWA's research on the economics of bushfire management.

In May, Abbie Rogers, Veronique Florec and Atakelty Hailu met with WA Department of Planning staff (Dale Bastin, Vivienne Panizza, Samantha Stokes, Loretta Van Gasselt) to discuss the relevance of the Value Tool for application to planning policies, particularly those related to coastal hazard management, as well as the possibility of a future workshop on the Value Tool.

Other end users

UWA Project staff have met with other end users and potential collaborators including: Tim McNaught, Samantha Kenedy and Jo Ann Beckwith (OBRM); Office of Emergency Management (OEM); Own Price and Heather Simpson (University of Wollongong); Kevin Ronan (Central Queensland University); Liz Connell (South Australia SES); Dr Geoffrey Donovan (US Forest Service); Tariq Maqsood (Geoscience Australia); and Magnus Oman (City of Swan).

WORKSHOPS ON PRESCRIBED BURNING CASE STUDY

Veronique Florec (UWA) and members of Natural Decisions (Geoff Park and Anna Roberts) organised a workshop in Adelaide with members of DEWNR (including Mike Wouters and Tim Groves) to discuss the scope for and the management options to be evaluated in the second case study on prescribed burning on private land. Synergies and differences between this project and a Natural Decisions project were reviewed and data collection initiated. A subsequent workshop was organized to present the preliminary results from the second case study.

A VALUE TOOL FOR INFORMED DECISION MAKING INCLUDING INTANGIBEL (NON-MARKET) VALUES

Natural hazards can cause large economic damages and governments recognise the importance of mitigation to avoid these costs (Penman et al. 2011). Limited financial resources make it critical to be able to prioritise mitigation actions efficiently. The use of economic frameworks such as benefit-cost analyses enables the efficient allocation of funds by weighing up the financial benefits and costs of different mitigation programs (Ganewatta and

Handmer 2006). However, economic studies of mitigation tend to focus on financial costs, as opposed to the intangible benefits and costs associated with mitigation which includes the effects on social values, the environment and human health (Milne et al. 2015). This is primarily because the intangible or non-market values are relatively more difficult to quantify than other financial costs and benefits because they are values that cannot be observed in market transactions. But the intangible impacts of natural hazard events (and mitigation benefits) can be significant. For example, in two of Australia's high impact fires the environmental losses accounted for 9% (1983 Ash Wednesday Fires) and 71% (2005/06 Grampians Fires) of the total losses resulting from the fires (Stephenson et al. 2012).

Therefore, understanding both tangible and intangible the costs and benefits of bushfire mitigation is imperative for governments to be able to prioritise the strategies that provide the best value for money. Tangible damages are relatively well documented while intangible costs and benefits (e.g. social and environmental benefits of mitigation effort) have not been well documented. As a result, intangible benefits tend to be neglected in decision making. To address this gap, non-market valuation estimates that show how much people value or are willing to pay (WTP) for the outcomes related to natural hazard mitigation are required.

Ideally, original studies applying non-market valuation would be the preferred approach for providing non-market values for use in policy and decision making, as they offer the most accurate representation of values in a specific context. However, for various reasons, an original study is sometimes not justified or feasible (Rogers et al. 2015). For example, the project or policy timeframe might not allow for the collection of new data, the budget for analysis may be too small, or the decision to be made may be a relatively minor one. In such cases, benefit transfer offers an alternative to conducting an original study.

Benefit transfer is, put simply, the "transfer" or application of data collected from one location to a new location of policy interest. As such benefit transfer relies on the use of non-market valuation results from pre-existing studies at one or more sites or policy contexts (often called study sites) to predict willingness to pay (WTP) estimates or related information for other, typically unstudied sites or policy contexts (Rolfe et al. 2015). The technique is advocated for use in policy making, particularly for non-market values, because usually it is cheaper, takes less time and is more straightforward than conducting original studies.

We have created a look-up database, hereafter called the 'Value Tool', that provides a compilation of intangible values from existing studies that are suitable for use in benefit transfer for bushfire mitigation decision making, as well as for other natural hazards. The database comes with a set of user-friendly guidelines that illustrate how the intangible values can be used to make decisions and prioritise mitigation strategies. For example, a bushfire manager will be able to use the value tool to identify the types of intangible values that might be affected by a prescribed burning plan, such as protecting wildlife and minimising distress to local communities, and find dollar estimates for each of these values. The value tool also provides estimates of intangible values relevant to other types of natural hazards. The tool has been created in order to improve the capacity of bushfire and other natural hazard managers to consider and include non-market benefits and costs in prioritising decisions. Rogers et al. (2017) provides a concise introduction to the economic approaches of non-market valuation and benefit transfer and describes the design of the Value Tool. An example of how to apply the Value Tool is also provided in that paper.

INTEGRATED ECONOMIC MODELLING OF FLOOD MANAGEMENT OPTIONS FOR ADELAIDE

The project has completed its first case study and published the results in two forms, a working paper (Chalak et al. 2017) and later as a forthcoming article with the Australian Journal of Emergency Management (Florec, Chalak and Hailu 2017). The purpose of the case study is to address a shortcoming in a previous evaluation of flood mitigation options for the Brown Hill and Keswick creeks catchment in Adelaide. The catchment includes both rural and urban areas in five local government councils: Adelaide, Burnside, Mitcham, Unley and West Torrens. The earlier analysis done on these options (BHKCP, 2016) indicated that the benefits of mitigation did not exceed the costs (i.e. benefit-cost ratios are below 1). However, that analysis did not include intangible values. Our case study identifies the range of intangible values that need to be recognised, develops a set of estimates for these values based on the published literature and investigate how the inclusion of intangible values changes the results from benefit-cost analyses on the flood mitigation options being considered for the Brown Hill and Keswick creeks catchment.

Table 1 summarises the different cost categories related to natural hazards such as floods. Direct damage costs are the most visible or easily recognisable components. Business interruptions costs occur in areas directly affected by the flood when people are not able to undertake their business activities because of accessibility problems or damages to the workplace (Meyer et al. 2013). They can be similar to 'direct damages' resulting from direct impact on production infrastructure, or to 'indirect damages' resulting from the interruption of economic activity. Indirect costs do not directly result from the physical flood damages but are consequences of direct damages and business interruptions. These costs can occur inside or outside the flooded area but typically involve a time lag and can span over a longer period. They stem from the disruption of public service, transport and supply activities affecting downstream or upstream clients of the companies directly affected by floods.

The mitigation effort itself (e.g. structural works) can be the source of costs both direct and indirect. Direct costs are the expenditure on research, design, construction and maintenance of mitigation infrastructure (Meyer et al. 2013). Indirect costs relate to the externality effects on other sectors of the economy that result from mitigation expenses (e.g. through competition for resources or labour). Depending on whether the costs are observable in market values or not, flood damage and mitigation costs can be classified as tangible or intangible.

Type of damage or cost		Tangible	Intangible
Damage costs	Direct	(Inside the flooded area) Damage to buildings, infrastructure and other property, evacuation and rescue expenses, clean-up costs	Loss of life, injuries, psychological distress & other health effects, loss of memorabilia, water quality problems and loss of environmental goods
	Business interruption	(Inside the flooded area) Losses due to damaged production assets or accessibility problems	Nonmarket losses (e.g. ecosystem services) due to interruption
	Indirect	(Outside the flooded area) Losses imposed on consumers and producers, upstream and downstream of directly affected companies; (market) cost of traffic disruption	Nonmarket aspects of traffic and other disruption suffered, inconvenience of post-flood recovery, trauma, loss of trust and increased sense of vulnerability
Mitigation costs	Direct	Direct setup or capital costs of infrastructure and running and maintenance costs	Cultural heritage and environmental damage resulting from flood infrastructure (e.g. dams) and other changes
	Indirect	Costs imposed on other economic sectors	Loss of recreational values because of mitigation investment or structure

TABLE 1. FLOOD DAMAGE AND MITIGATION COSTS CATEGORIES (SOURCE: ADAPTED FROM MEYER ET AL. (2013))

Intangible values

Intangible values affected by floods may include environmental assets, health impacts and social values such as cultural heritage (see Table 2). Health effects range from loss of life (or mortality), to physical injuries and psychological distress, all of which are direct intangible impacts. There is research evidence showing that floods cause numerous psychological effects that are adverse to health. For instance, a study conducted by the UK Environmental Agency and the Department of Environment, Food and Rural Affairs (EA-DEFRA 2005) indicates that a large proportion of flood-affected people (about 80%) suffer from anxiety when it rains, about two thirds (65%) report increased levels of stress, and more than half report sleeping problems (EA-DEFRA 2005). Other health effects include morbidity, trauma and loss of trust in authorities (Merz 2010).

Floods can also affect natural assets and ecosystem services, negatively or positively. These effects depend on the speed of flooding and whether wildlife has had the chance to escape. For example, the Queensland floods of 2011 had adverse impacts on marine and terrestrial biodiversity, including some threatened species such as the cassowary, but had positive effects on freshwater systems such as those on the Murray River (Reid 2011). Other environmental impacts include water quality problems generated by floods such as water contamination and hypoxic blackwater, which are detrimental to fish (Whitworth et al. 2012).

Health	Environment	Social
Mortality, morbidity, injury, stress/anxiety, pain, trauma, grief, increased vulnerability among flood survivors	Wildlife loss, ecosystem degradation, water quality problems, invasive species	Recreation values, amenity values, safety, social disruption, cultural heritage, animal welfare, loss of memorabilia

TABLE 2. NON-MARKET VALUES IMPACTED BY NATURAL HAZARDS (SOURCE: ADAPTED FROM GIBSON ET AL. (2016))

Even small floods can cause disruptions to traffic in urban environments, and these disruptions can add up to significant damages especially if the floods occur regularly (ted Veldhuis and Clemens 2010). Larger floods can cause substantial population displacements causing prolonged social disruption. Other social intangible flood damages include: loss of recreational opportunities and amenity values; increased risk of loss of life; loss of cultural heritage and memorabilia; and harm to animals.

Methods

Study Area

The Brown Hill and Keswick creeks catchment is comprised of four creeks: Brown Hill, Keswick, Glen Osmond and Parklands creeks, which are important drainage watercourses in metropolitan Adelaide (see map of the creeks in Figure 1). The risk of flooding from the creeks in the surrounding urban areas is relatively high with a long history of flooding issues in the area (Hydro Tasmania, 2006, WorleyParsons, 2012). The creeks have a low standard of flood protection and, up until recently, there were no clear plans for mitigation due to lack of an agreement between the councils affected on the extent of the problem, the mitigation works needed and the cost-sharing arrangements (Hydro Tasmania, 2006, BHKCP 2016). In 2006, a Flood Management Master Plan was developed and conditionally approved by the Stormwater Management Authority. However, community concerns in relation to some of the proposed works, such as the proposed flood control dams in the upper reaches of Brown Hill Creek, prompted the Stormwater Management Authority to revise and update the plan in 2012 and 2016 (BHKCP 2016). BCAs were conducted at each step taking into account only tangible flood losses, although it was recognised that intangible losses could constitute a significant component (WorleyParsons 2012; BHKCP 2016).

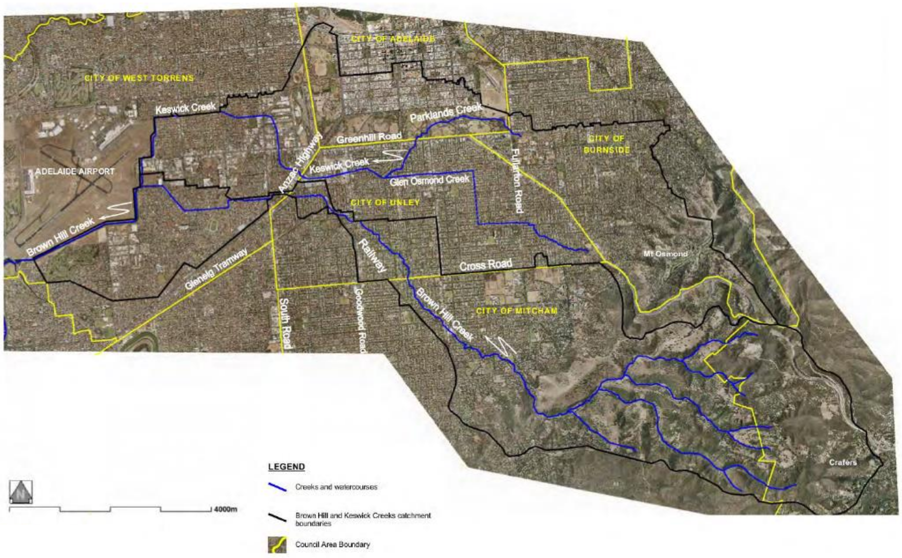

FIGURE 1. BROWN HILL AND KESWICK CREEKS CATCHMENT, ADELAIDE, SOUTH AUSTRALIA (SOURCE: BHKCP, 2016)

Mitigation options evaluated

The main purpose of the planned works is to mitigate the risk and impact of major flooding in the catchment, up to and including a 100 year average recurrence interval (ARI) flood. The mitigation works are divided into two parts. Part A works are designed to mitigate flooding in urban areas in the lower parts of the Brown Hill and Keswick creeks through a combination of detention basins, diversion of high flows and watercourse upgrading for greater flow capacity. Part B works are intended to mitigate flooding from the upper Brown Hill creek and combine three components: a detention dam (at one of two alternative sites); high flow bypass culverts; and creek capacity upgrade works (including bridge upgrade works). There are eight different ways in which these components may be combined but all options are expected to achieve a similar level of protection for the catchment.

We evaluate part A works (as one option), two part B works options that have generated community opposition (i.e. those involving the construction of dams, options B1 and B2) and a third part B option that has been identified as a preferred option by the community (option D). It is important to note here that options B1, B2, and D, which belong to part B works, are to be implemented only after part A works are completed. The options are:

- **Part A works:** this option involves the construction of detention basins, a flood control dam in Glen Osmond creek, capacity upgrade for the lower Brown Hill creek, flow diversions from Keswick creek to Brown Hill creek, a diversion culvert and modifications to an existing dam. They are all combined as one option because this part of the Storm Management Plan has already been approved.

- **Option B1:** this option involves the construction of a flood control dam in the Brown Hill Creek Recreation Park (see location of the dam in Figure 2).

- **Option B2:** this option involves the construction of a flood control dam in the Ellisons Gully.

- **Option D:** this option involves upgrading critical sections of upper Brown Hill creek over 1.9 km, including critical bridges, to give the creek sufficient capacity to contain the peak flow of the 100 year ARI storm.

FIGURE 2. LOCATION OF FLOOD-CONTROL DAMS FOR OPTIONS B1 AND B2 (SOURCE: BHKCP, 2016)

The economic attractiveness of each option is evaluated against a baseline scenario of doing nothing (i.e. no mitigation works at all). The benefits correspond to the reduction in average annual damage (AAD) that can be expected from the implementation of each management option. Benefit-cost ratios are calculated for each option by dividing the present value of benefits by the present value of the costs. Details of the mitigation options in Part B works are presented in Table 3.

Component Options	B1	B2	D
Detention dam location[1]	Brown Hill Creek Recreation Park	Ellison's Gully	Not required
Estimated number of properties requiring creek capacity upgrade works; requiring an agreement or easement	29	22	66
Number of properties where land acquisition is required	0	2	0
Number of properties requiring an easement for Dam Site 2	0	3	0
Number of public bridge upgrades	4	4	10
Creek rehabilitation works	Full length of creek	Full length of creek	Full length of creek
Capital costs	AU$ 40.9 M	AU$ 44.1 M	AU$ 35.5 M

TABLE 3. DETAILS OF EVALUATED FLOOD MITIGATION WORKS (SOURCE: BHKCP (2016))

These options were presented for public consultation. Among the three, option D has been identified as the preferred option by the councils and the community because it satisfies the following factors: 1) it has the lowest capital and maintenance costs; 2) it does not require the construction of culverts; 3) it provides better than 100-year ARI protection for short duration storms; and 4) it satisfies community preferences for 'no dam' solution. The option involves upgrading the capacity of the creek at critical sections, including some specific creek choke points such as bridges (BHKCP 2016). It is designed to mitigate flooding at a catchment scale. However, the option would involve upgrade works on 66 private properties, 36 in the Unley Council area and 30 in the Mitcham Council area (BHKCP 2016). By comparison, the number of private properties that would need to be involved in the case of options B1 and B2 are, respectively, 26 and 19. Therefore, while the cost estimates are slightly lower for option D, it is likely to involve very high transaction costs, which are currently not included in the total costs for the option. Hence, evaluating options B1 and B2 as possible alternatives is of interest to the stakeholders.

Results

Intangible cost and benefit estimates

A detailed discussion of the values estimated is presented in Chalak et al. (2017) and Florec, Chalak and Hailu (2017). Here we present only a summary of the values for eight intangible values which correspond to damage caused by flood events (or the risk of flooding) or by the implementation of the mitigation options. Five of these values belong to the first category (i.e. they are the direct result of flood events): mortality; electricity outage; road traffic annoyance; road traffic delays; and inability to return home. These values are presented by type of flood event in Table 4.

[1] The detention dam on the Brown Hill Creek Recreation Park would be 12 meters high with a capacity of 11 megalitres, while the dam on Ellisons Gully, a tributary to the Brown Hill Creek, would have a height of 19.5 meters with a capacity of 355 megalitres.

Type of event	Intangible value	Base case	Part A works	Part A + Part B works
10 year ARI	Mortality	2	0	0
	Electricity outage	4,123	0	0
	Road traffic annoyance	3,226	0	0
	Road traffic delays	661,200	0	0
	Inability to return home	15,155	0	0
20 year ARI	Mortality	6	0	0
	Electricity outage	11,230	0	0
	Road traffic annoyance	4,384	0	0
	Road traffic delays	2,519,400	0	0
	Inability to return home	41,285	0	0
50 year ARI	Mortality	32	3	0.1
	Electricity outage	39,093	7,819	213
	Road traffic annoyance	6,204	2,283	16
	Road traffic delays	6,094,440	0	0
	Inability to return home	143,715	28,743	784
100 year ARI	Mortality	145	11	0.3
	Electricity outage	83,304	18,551	426
	Road traffic annoyance	19,108	7,031	50
	Road traffic delays	9,341,160	5,093,520	0
	Inability to return home	306,243	68,199	1,568
500 year ARI[2]	Mortality	515	216	216
	Electricity outage	296,054	123,861	123,861
	Road traffic annoyance	67,908	28,411	28,411
	Road traffic delays	33,197,575	13,888,995	13,888,995
	Inability to return home	1,088,358	455,340	455,340
PMF (Probable Maximum Flood)	Mortality	1,186	1,186	1,186
	Electricity outage	681,591	681,591	681,591
	Road traffic annoyance	156,341	156,341	156,341
	Road traffic delays	76,429,062	76,429,062	76,429,062
	Inability to return home	2,505,670	2,505,670	2,505,670

TABLE 4. INTANGIBLE DAMAGES DIRECTLY CAUSED BY A FLOOD EVENT (AU$)

The most significant intangible damage directly caused by flood events is road traffic delays. This is because a large number of people would be affected by the delays caused by road closures if a flood occurs. The second most significant intangible damage is the inability to return home when the house is flooded, but it is substantially smaller than road traffic delays (between 30 to 60 times smaller). The smallest intangible damage corresponds to mortality, which is explained by the very low number of fatalities expected from flooding in the catchment.

The damage estimates for different flood events can be converted into average annual damages (AAD) using the probability values for each event, as shown in Table 5.

Intangible value	Base case	Part A works	Part A + Part B works
Mortality	5	2	2
Electricity outage	3,862	1,507	909
Road traffic annoyance	1,149	373	208
Road traffic delays	550,215	166,248	101,421
Inability to return home	14,199	5,540	3,343

TABLE 5. AVERAGE ANNUAL DAMAGE FOR INTANGIBLE VALUES (AU$)

Other intangible values were calculated on an annual basis rather than per flood event, either because they are affected by the implementation of a mitigation option (i.e. recreation and cultural heritage) or because they arise

2 Intangible damages for a 500 year ARI flood and for the PMF were estimated using the proportional increase in tangible damages reported in BHKCP (2016) from a 100 year ARI to a 500 year ARI flood and to the PMF for the base case scenario. The reduction in intangible damages due to the implementation of each strategy was estimated using the proportional decrease in tangible damages reported in BHKCP (2016).

from the risk of flooding instead of being the result of a flood event (i.e. morbidity). These values are presented in Table 6. In the absence of mitigation, the losses from flood risk related to morbidity are the most important intangible values (AU$1,077,047 per annum), followed by road traffic delays (AU$550,215).

	Base case	Part A works	Part A + Part B works		
			B1	B2	D
Values affected by the implementation of a mitigation option					
Annual loss in recreation	0	0	32,313	32,313	0
Annual loss in cultural heritage	0	0	9,853	0	0
Values arising from the risk of flooding					
Annual morbidity costs	1,077,047	311,411	15,983	15,983	15,983

TABLE 6. INTAGIBLE VALUES ESTIMATED ON AN ANNUAL BASIS (AU$)

Table 7 summarises the tangible and intangible flood damage value estimates for the different mitigation scenarios: base case (no mitigation); Part A works only; and Part A plus Part B works. Tangible damages were extracted from BHKCP (2016) while intangible values are based on the calculations done by this case study. The table shows how the combined tangible and intangible flood damages decline under the different mitigation options.

In some cases, mitigation has a relatively bigger effect on tangible than on intangible damages; and in other cases, the opposite is the case. For instance, for a 100 year ARI flood, which is the target of the mitigation works currently under consideration, tangible flood damages under the base case scenario were estimated around AU$122 million and intangible flood damages around AU$9.7 million. With the implementation of Part A works, tangible damages would be reduced to AU$31 million (i.e. a reduction of about 75%) and intangible damages would be reduced to AU$5 million (i.e. a reduction of 47%). In contrast, for a 50 year ARI flood, the implementation of Part A works would reduce tangible damages from AU$45 million to AU$9 million (a reduction of 80%), while intangible damages are reduced from AU$6 million to AU$40,000 (a much larger reduction of 99.4%). However, it is important to remember that the values estimated per event correspond to the potential damages that would be caused by the floods directly and do not include recreation, cultural heritage and morbidity (which are estimated on an annual basis and do not depend on the severity of the flood).

ARI in years	Type of values	Base case scenario	Part A works	Part A + Part B works
10	Tangible	4,800	0	0
	Intangible	700	0	0
	Total	5,500	0	0
20	Tangible	10,600	0	0
	Intangible	2,600	0	0
	Total	13,200	0	0
50	Tangible	45,000	9,000	400
	Intangible	6,300	40	1.0
	Total	51,200	9,000	400
100	Tangible	122,200	30,500	810
	Intangible	9,700	5,200	0
	Total	132,000	35,700	820
500	Tangible	434,400	181,700	181,700
	Intangible	34,700	14,500	14,500
	Total	469,000	196,200	196,200
PMF	Tangible	1,000,000	1,000,000	1,000,000
	Intangible	79,800	79,800	79,800
	Total	1,079,800	1,079,800	1,079,800

TABLE 7. COMBINED TANGIBLE AND INTANGIBLE FLOOD DAMAGE ESTIMATES PER FLOOD EVENT (AU$'000)3

Converting damage values into AAD makes it easier to appreciate the differences between tangible and intangible values. Table 8 shows the AAD for tangible and intangible values for different mitigation scenarios. Intangible damages are substantially smaller than tangible damages across all scenarios. Intangibles represent 21% of total damages for the base case scenario, about 18% for Part A works, and between 6 and 8% for Part A + Part B. In the case of options B1 and B2, there are intangible costs related to the construction of dams. These costs are AU$42,166 per year for option B1 (consisting of AU$32,313 for recreation and AU$9,853 for cultural heritage value losses) and AU$32,313 per year for option B2 (recreation only). These construction related value losses have the effect of reducing the total benefits for these options compared to options D. As a result, the damage reduction benefits obtained with B1 and B2 are lower than those obtained with D (AU$5.56 million).

Type of damage	Base case	Part A works	Part A + Part B works		
			Part A + B1	Part A + B2	Part A + D
Tangible	5.96	2.23	1.92	1.92	1.92
Intangible	1.65	0.49	0.16	0.15	0.12
Total	7.61	2.71	2.08	2.07	2.04
Reduction in AAD		4.89	5.52	5.53	5.56

TABLE 8. TANGIBLE AND INTANGIBLE AVERAGE ANNUAL DAMAGES FOR DIFFERENT SCENARIOS (AU$ MILLION)4 (SOURCE: BHKCP (2016))

The economic attractiveness of an option is evaluated against the base case scenario by considering the reduction in AAD. In our case, the base case scenario is the one without any of the mitigation works (parts A or B). The costs of options B1, B2 and D are AU$41, AU$44 and AU$36 million, respectively, while the costs of Part A works are AU$111 million. These options (Part B works) are considered only as an add-on to Part A works. Therefore, the total costs considered are those for Part A alone and the costs of the combined implementation of Parts A and an option from Part B works. Besides the size of the capital costs, the trajectory of the costs has an effect on present value calculations and benefit-cost ratios. We follow the approach in BHKCP (2016) to define the stream of costs for each option and assume that outlays are spread over a period of seven years. We also adopt their discount rate of 6% and 30

[3] Includes only those intangible items that can be quantified per event; that is, mortality, electricity outage, road traffic annoyance, road traffic delays, and inability to return home. Values in this table have been rounded to facilitate the readability of the results.

[4] The values have been rounded to facilitate the readability of the results.

years as the relevant time horizon in our calculation of present values. Finally, the benefits of mitigation are assumed to occur starting from year 3 as in BHKCP (2016). More precisely, we assume that 10% of the benefits from mitigation will be delivered in years 3 and 4, 20% in years 5 and 6, 40% in year 7, 50% in year 8, 70% in year 9, 80% in year 10 with the full benefits of mitigation delivered in year 11 and beyond.

Summary of benefit-cost estimates

The results from the benefit-cost analysis are summarised in Table 9. Part A works are estimated to generate benefits of about AU$38.5 million over a 30 year horizon. The present value of the costs for Part A works is about AU$88.5 million. As a result, Part A works has a benefit-cost ratio of about 0.4. This means that every dollar invested in Part A generates only AU$0.4 in benefits.

Among Part B works, the option that generates the highest incremental benefits is option D. The present value of benefits from Part A + option D are AU$44.3 million. The cost, however, is much higher (AU$116.8 million), leading to a benefit-cost ratio of 0.38, which is smaller than the ratio for Part A works alone. Options B1 or B2 generate slightly smaller benefit-cost ratios. In summary, for the baseline analysis, none of the options considered pass the benefit-cost ratio test.

Values	Part A works	Part A + Part B works		
		Part A + B1	Part A + B2	Part A + D
Present value of benefits	38.5	44.0	44.0	44.3
Present value of costs	88.5	121.1	123.7	116.8
Net present value	-50.0	-77.2	-79.7	-72.5
Benefit cost ratios	0.44	0.36	0.36	0.38

TABLE 8. PRESENT VALUES OF TANGIBLE AND INTANGIBLE COSTS AND BENEFITS FOR ALTERNATIVE MITIGATION OPTIONS ($AU MILLION)

In the report from the case study, these estimates are subjected to sensitivity analysis to determine how significant intangible values have to be before any of the mitigation options pass the benefit-cost ratio test. This was necessary partly because we believe the intangible value estimates we have used are conservative (lower-bound) values. And since no survey has been conducted in the case study area to assess people's willingness to pay for intangible mitigation benefits, there is a high level of uncertainty attached to the figures employed above. The results from the sensitivity analysis show that intangible values have to be much bigger than they are currently estimated to be to change the outcomes of the analysis (Chalak et al. 2017).

CONCLUSION

Over the course of the year, the project has concluded its work on the draft version of the non-market valuation tool (Value Tool) and its integrated economic modeling case study. The Value Tool provides a practical means of finding non-market values for inclusion in natural hazard decision making, through the use of benefit transfer. The Value Tool and its guidelines can be used to improve decision making through a number of ways. Tool will be publicly available for decision makers to utilise by the end of 2017. A custodian will maintain the tool to ensure its currency for decision making in the future. The Value Tool guidelines identify key gaps in the non-market valuation literature with respect to provision of WTP estimates suited for natural hazard decision making, particularly for the value types of mental health, ecosystems, cultural heritage and memorabilia. A future research focus will be to address these gaps by conducting original non-market valuation studies to provide suitable estimates for inclusion in the database.

The case study on integrated economic modelling has focused on flood mitigation options for the Brown Hill Keswick catchment of Adelaide. It identified some of the intangible values that need to be considered in the assessment of mitigation options and integrated them into an economic analysis. The results show that the most substantial intangible values in terms of AAD are morbidity (i.e. WTP to reduce flood-related health effects) and road traffic delays (i.e. WTP to avoid road traffic delays caused by flood events). However, intangible values remain relatively small compared to the potential tangible damages that floods may cause in the area; they represent only between 6 and 21% of total damages.

The analysis shows that all options generate benefit-cost ratios smaller than 1, even when intangible values are included in the analysis. A sensitivity analysis showed that intangibles would have to be substantially higher than our current estimates for any of the flood mitigation options to generate a benefit-cost ratio equal or larger than 1. However, it is unlikely that such high intangible values would be consistent with the reality in the catchment, given that in most of the published literature average WTP estimates to avoid flood (intangible) impacts are usually smaller. But it is possible that the significance of intangible values could change going forward into the future. For example, intangible values are likely to increase over time with increases in income and/or improvements in living standards. They are also likely to increase if households in the catchment are subjected to more frequent flooding, which could be a result of climate change as it has been the case in other parts of Australia and the world. Finally, to better understand the trade-offs that households are willing to make and their WTP to avoid the flood damages in the area, additional information could be obtained by conducting a non-market valuation survey in the Brown Hill and Keswick creeks catchment.

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