bnhcrc.com.au

IMPROVED DECISION SUPPORT FOR NATURAL HAZARD RISK REDUCTION

Annual project report 2016-2017

Holger R. Maier, Hedwig van Delden, Graeme A. Riddell, Jeffrey P. Newman, Aaron C. Zecchin, Graeme C. Dandy, Charles P. Newland
The University of Adelaide

Version	Release history	Date
1.0	Initial release of document	13/09/2017

Publisher:
Bushfire and Natural Hazards CRC

September 2017

Citation: Maier HR, van Delden H, Riddell GA, Newman JP, Zecchin AC, Dandy GC and Newland CP (2017) Improved decision support for natural hazard risk reduction: annual report 2016-17

Cover: South Australia SES

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Decision support systems that contain integrated models for the assessment of natural hazard mitigation options are an important component for robust, transparent, and long-term mitigation planning. Integrated modelling of underlying social, environmental, and economic systems is required to take into account system dynamics, and to explore the implications of future changes, such as changes in demographics, land use, economics and climate. Consequently, a generic decision support system for the long-term planning for natural disaster risk reduction is being developed as part of the Bushfire and Natural Hazards Cooperative Research Centre.

The project consists of implementing an iterative development and use cycle across three different case studies. This development aspect of this cycle focuses on creating a generic framework for the integration of models to answer policy relevant questions, in this case for improved understanding and reduction of disaster risk. The use process tailors this framework to each of the case study regions, Greater Adelaide, Greater & Peri-Urban Melbourne and Tasmania.

The focus of 2016-2017 has been on the completion of the first development cycle for Greater Adelaide, with the prototype software to be delivered to end user organisations shortly. Training was also provided to users within the South Australian government and on-going support will be provided to this user group to enable uptake and use within respective departments.

Work has also continued on the Greater & Peri-urban Melbourne case study with significant process in the data collection and application of the DSS system to the region. Coupled with this has also been the use process of scenario development, with four scenarios for the region currently in draft form prior to follow up sessions in 17-18 to finalise the drafts, quantitatively model the scenarios and look to integrate the exploration of plausible futures to strategy development into organisations.

Similar progress in Tasmania has also been made with the land use model application completed and data collection for the hazard, and exposure modelling ongoing for completion of the first iteration of DSS development by the end of 2017. The participatory use process also saw multiple workshops take place in Tasmania throughout 16/17. These were centred on exploring uncertainties for change in the state, along with collecting data for multiple criteria analysis of risk reduction options, and defining optimisation questions for future analysis.

Other efforts have gone into the publication of journal papers, analysing the current state of literature in the field of decision support for risk reduction planning, and the calibration of land use modelling. Significant effort has also been placed into utilisation activities and exploring future application regions, resulting in a successful NDRP project proposal to apply the DSS in Western Australia.

END USER STATEMENT

Ed Pikusa,

Lead User Representative, Economics and Strategic Decision Making Cluster
Department of Environment, Water & Natural Resources, SA

This project continues to generate new interest from end users, with the six Australian states either expressing interest and seeking a presentation, or committing to an application of the platform.

Follow up workshops from the case studies continue to generate favourable feedback for the platform and its potential utility.

It also has demonstrated the ability to incorporate outcomes from other CRC projects, such as the non-market economic costs project from the University of WA.

The completed case study prototypes from South Australia, Victoria and Tasmania are excellent demonstrations to assist in this future adoption.

I encourage these states and other jurisdictions to see how examples such as these can be utilised by the emergency management sector into the medium and long term. .

INTRODUCTION

The challenges facing policy makers grow increasingly complex and uncertain as more factors that impact on their ability to manage the environment and its risks need to be considered. Due to a large number of influencing environmental and anthropogenic factors, natural hazard risk is difficult to estimate accurately, and exaggerated by large uncertainty in future socio-economic consequences. Furthermore, resources are scarce, and the benefits of risk reduction strategies are often intangible. Consequently, a decision support system assisting managers to understand disaster risk has great advantage for strategic policy assessment and development, and the development and application of such a system is the focus of this project.

The developed decision support system allows for the dynamic understanding and assessment of all three components of risk; exposure, vulnerability and hazard, in line with recent recommendations from the World Bank's Global Facility for Disaster Reduction and Recovery (Fraser et al, 2016). The DSS thus allows policy makers to better understand the drivers of risk and the impact of their policies on the risk profile now and into the future. This enables policy makers to account for climate change, urbanisation, population increases and future environmental conditions in risk assessments.

The overarching framework of the decision support system: (i) is able to deal with complex problems in a systematic and transparent manner; (ii) makes best use of available sources of data and information; (iii) is adaptable/flexible; (iv) deals with multiple, competing objectives: (v) identifies mitigation options that represent the best possible (optimal) trade-offs between objectives; (vi) deals with uncertainty; (vii) caters to a large number of potential solutions; (viii) enhances understanding of the side effects and impacts of different combinations of policy options; and (ix) adopts an interdisciplinary approach across various policy fields.

PROJECT BACKGROUND

DISASTER LOSSES ARE SIGNIFICANT, AND CAN BE REDUCED

The impacts from natural disasters are staggering in terms of human and economic losses. While the immediate and post-crisis response to disasters is extremely important, mitigation activities before a natural disaster occurs can be extremely effective in reducing potential losses — for every dollar spent on mitigation, a saving of one and a half to five dollars in recovery costs can be expected (Rose et al., 2007). However, developing and implementing mitigation can be extremely difficult in practice, because of the difficulty of convincing decision makers of the advantages of spending money on mitigation works compared with the short-term benefits offered by other potential projects and activities. In addition, because disasters are relatively infrequent, the people influencing mitigation activities may have little personal experiences to guide their evaluation of risk, or the relative benefits of alternative mitigation options. Furthermore, mitigation budgets are generally limited, and given the difficulties mentioned above, the selection of an optimal set of mitigation options is very difficult when many alternative mitigation options are available.

HOW DECISION SUPPORT SYSTEMS HELP SOLVE THE PROBLEM

Because of these difficulties, the use of decision support systems (DSS) is advantageous, as such systems (1) are transparent and can quantify the expected benefits of mitigation investiture across multiple criteria, enabling strong arguments for the selection of particular mitigation options to be made, (2) can be used to assess the likelihood and consequences of natural disasters across multiple criteria, resulting in less bias when assessing the relative benefits of mitigation options, and (3) can make use of formal optimization techniques to find optimal or near-optimal portfolios of mitigation options. However, DSSs for natural disaster mitigation have tended to focus on disaster preparedness and the immediate and post-crisis response to emergencies. Of those DSSs that have focused on mitigation, none have considered, simultaneously, both (1) temporal non-stationarity in climate or land use, and (2) the use of optimization to identify suitable mitigation portfolios. These aspects are important, as natural disasters are likely to become more frequent with climate change, and because consequences of natural disasters are highly sensitive to the land uses at the location of the natural disaster.

OUR APPROACH TO BUILDING DECISION SUPPORT SYSTEMS

Consequently, this project will develop an integrated natural hazard mitigation DSS framework, which will be used to develop prototype DDSs for three case studies. Of these three case studies, the first will consider the Greater Adelaide region, the second will consider Greater Melbourne and its peri-urban fringes, and the third Tasmania. Through a workshop-driven development cycle, this project will deliver prototype DSSs to end users that will optimize the choice of mitigation options, through assessing the performance of various options over the long term using simulation-optimisation approaches. The performance of mitigation options will be evaluated in an integrated way, across a number of natural hazards (bushfire, flooding, coastal surge, earthquake) whilst taking account of land use and climate change.

Consequently, the specific objectives of the project are:

1. To develop a systematic and transparent approach to sifting through, evaluating and ranking disaster and natural hazard mitigation options using analytical processes and tools.
2. To develop prototype decision support software tools that implement the above approach for three end-user defined case studies; Greater Adelaide, Greater & Peri-urban Melbourne and Tasmania.

PROJECT OUTCOMES

1) A systematic and transparent approach to evaluating natural hazard risk reduction options.
2) A framework for making more strategic and less responsive decisions.
3) Building strategic capacity across governments and agencies for considering the future challenges of natural hazard risk in dynamic and growing regions.
4) The ability to sift through, evaluate and rank a large number of risk reductions options.
5) Understanding the trade-offs between economic, environmental and/or social objections for risk reduction options.

RESEARCH QUESTIONS

Methodological questions the project will help answer, include:

1. What tools are helpful for elucidating case study specific information regarding policy options, drivers and uncertainties from domain knowledge experts in workshops?
2. How can we compare all mitigation options available, and identify the mitigation options that give the best possible trade-offs between objectives?
3. How might optimization routines and hazard models be designed to reduce the computational time of finding mitigation options that represent near optimal trade-offs between decision objectives?
4. How significant is the inclusion of land use change when assessing long term mitigation investment strategies?
5. How can uncertainty be better incorporated within natural hazard mitigation assessment?
6. How can metrics be improved for automated land use model calibration?

Questions, relating to the case studies, that the project will help answer, include (for each case study):

1. What are the optimal mitigation options across long-term planning horizons?
2. How will climate and land use change affect natural hazard risk, and what are the implications for this in regard to disaster mitigation budgets?
3. What trade-offs exist between economic, environmental and/or social objectives for different mitigation options?

WHAT THE PROJECT HAS BEEN UP TO

The following sections provide details on progress that has been made across the three case studies within the project, Greater Adelaide, Greater & Peri-urban Melbourne, and the whole of Tasmania. Finally, other aspects of the project and utilisation activities are discussed

DSS APPLICATION CASE STUDIES

Three case study DSS (UNHaRMED) applications are included within the project. The following sections outline the advances in each of these over the previous 12 months.

Greater Adelaide

The Greater Adelaide case study has developed a DSS framed on the system diagram shown in Figure 1. The software application has been developed and will be provided to end users within South Australia shortly following a short improvement process based on suggestions gathered during user training at the end of June 2017.

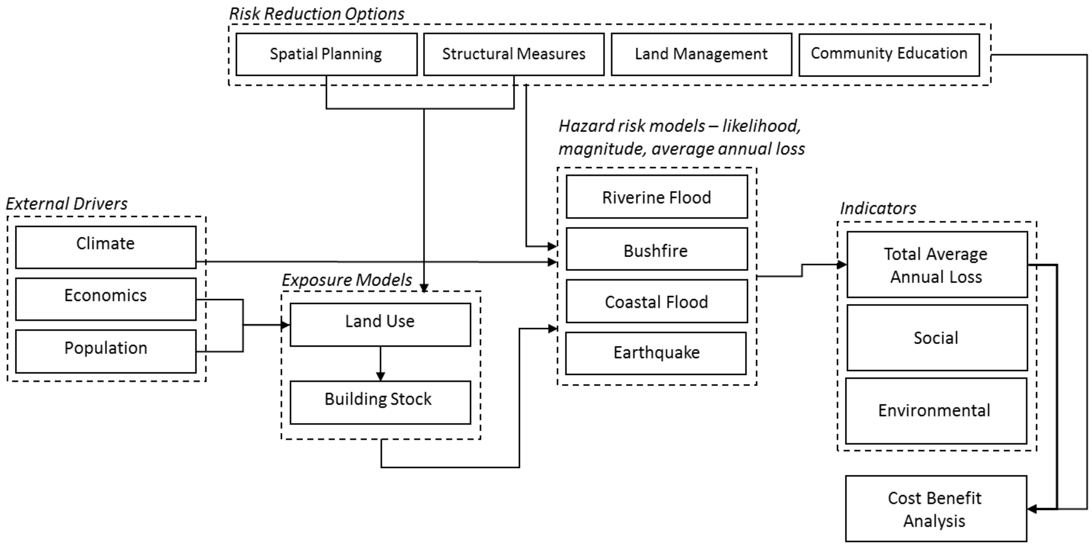

FIGURE 1: SYSTEM DIAGRAM FOR GREATER ADELAIDE

Figure 2 shows the modeler interface of UNHaRMED for Greater Adelaide. This interface allows access to all model parameters for greater system flexibility. The system is also designed with a policy interface, which provides users a simpler way of running policy impact assessments, setting external drivers (climate / population scenarios) and implementing policy options. This allows use of the system without requiring detailed understanding and changes to more specific model parameters, which should only be edited by domain experts. The policy interface and a zoning plan for restricting development in inundation zones are shown in Figure 3.

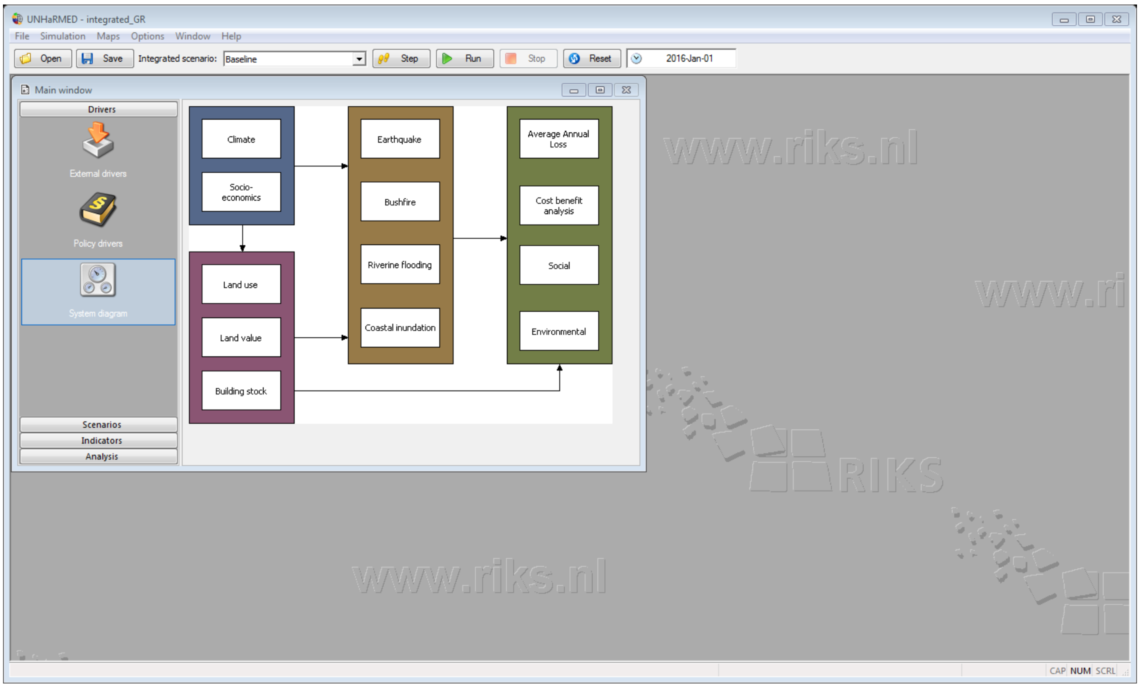

FIGURE 2: MODELLER INTERFACE FOR GREATER ADELAIDE APPLICATION OF UNHARMED

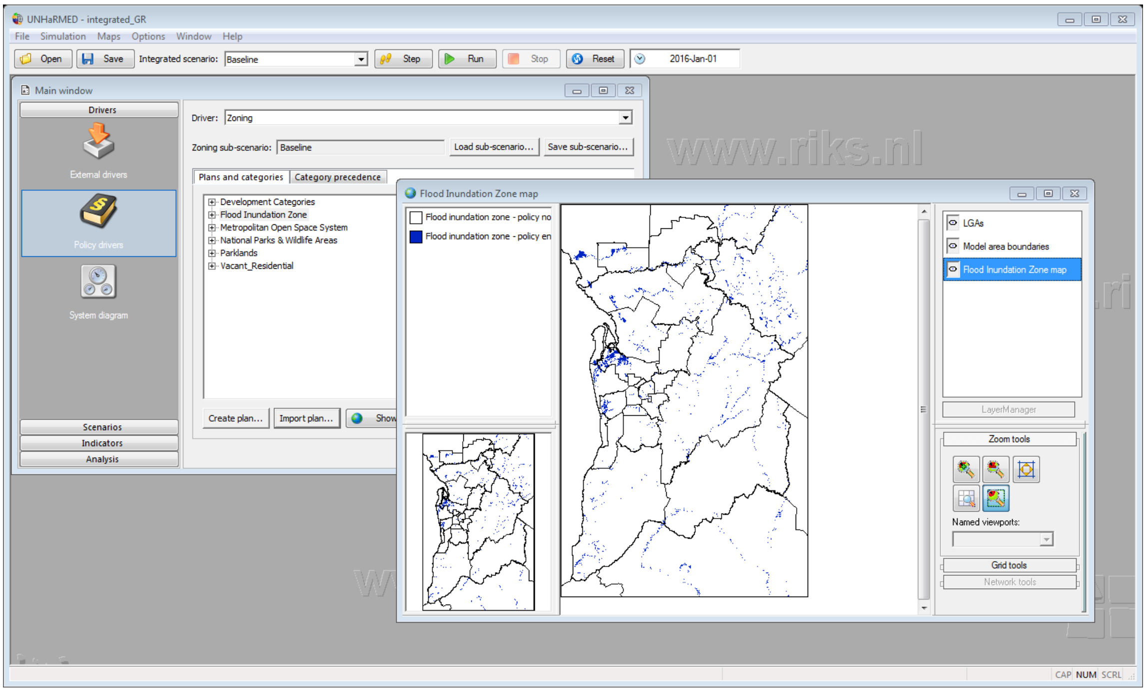

FIGURE 3: POLICY INTERFACE FOR GREATER ADELAIDE APPLICATION OF UNHARMED

Greater & Peri-urban Melbourne

The case-study on Greater & Peri-urban Melbourne continued with the second phase of stakeholder engagement on the use of the system for the region. This process focused on the development of qualitative scenarios for the region considering future challenges for resilience and for government action/intervention.

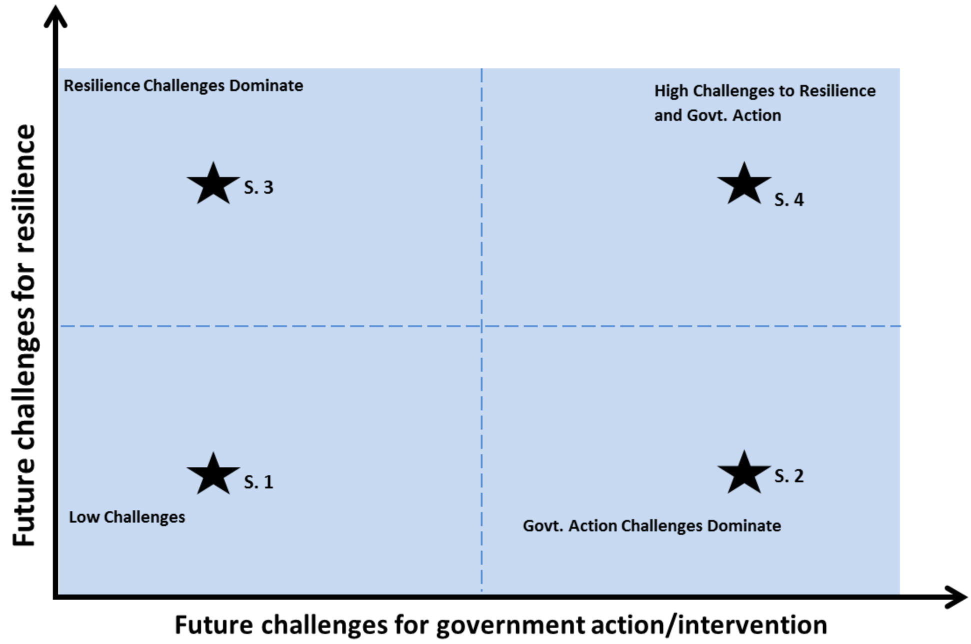

FIGURE 4: SCENARIO FRAMING FOR THE GREATER AND PERI-URBAN MELBOURNE FRAMEWORK

This process saw the development of four draft scenarios that will subsequently be modelled using the DSS for the Greater and Peri-urban Melbourne region. The draft scenarios were also critiqued in a follow up workshop on 29/11/2016 with the same stakeholder group who developed the storylines and the text has subsequently been updated in response to this feedback. Future steps in the scenario process will look to quantify specific model parameters using stakeholder knowledge, and then model the socio-economic futures, along with their associated risk profiles, to consider a variety of risk futures. This will be coupled with a process to consider the strategic strengths, weaknesses, opportunities and threats that arise across different scenarios for different organisations as they position themselves into the future.

Table 2 outlines the next steps in the region's development and use process. In late 2017, the first prototype of the system will be completed, with all models populated and integrated. This will be followed by the quantitative scenario processes, system training, and policy support exercises.

Purpose	Description	Indicative completion date
Prototype 1 completion	Data collected, processed and used to populate the DSS system. Models calibrated and validated.	Dec 2017

Quantification of Scenarios	Participatory quantification of exploratory scenarios using simple models and historical trends.	Dec 2017
Socio-economic & Risk Scenarios	Presentation of modelled scenarios highlighting plausible socio-economic developments and risk profiles. Critical feedback on their development, extremity, plausibility, consistency and representativeness.	Apr 2018
UNHaRMED Training	Training provided to users across multiple organisations who have been involved in the system's development. Trained users will also be supported in the short term with further meetings and online support.	Jun 2018
Policy Support	Presentation and discussion on policy support mechanisms and results from modelling of risk reduction portfolios and consideration of robust and adaptive approaches for dealing with future uncertainty.	Jun 2018

TABLE 1: NEXT STAGES FOR GREATER & PERI-URBAN MELBOURNE CASE STUDY

Tasmania

The case-study on Tasmania similarly has continued with data collection and model development for the region. The land use model is developed and has undergone preliminary calibration – Figure ## shows a screenshot of the land use component for Tasmania. Modelling for coastal inundation has also been completed for inclusion within the DSS.

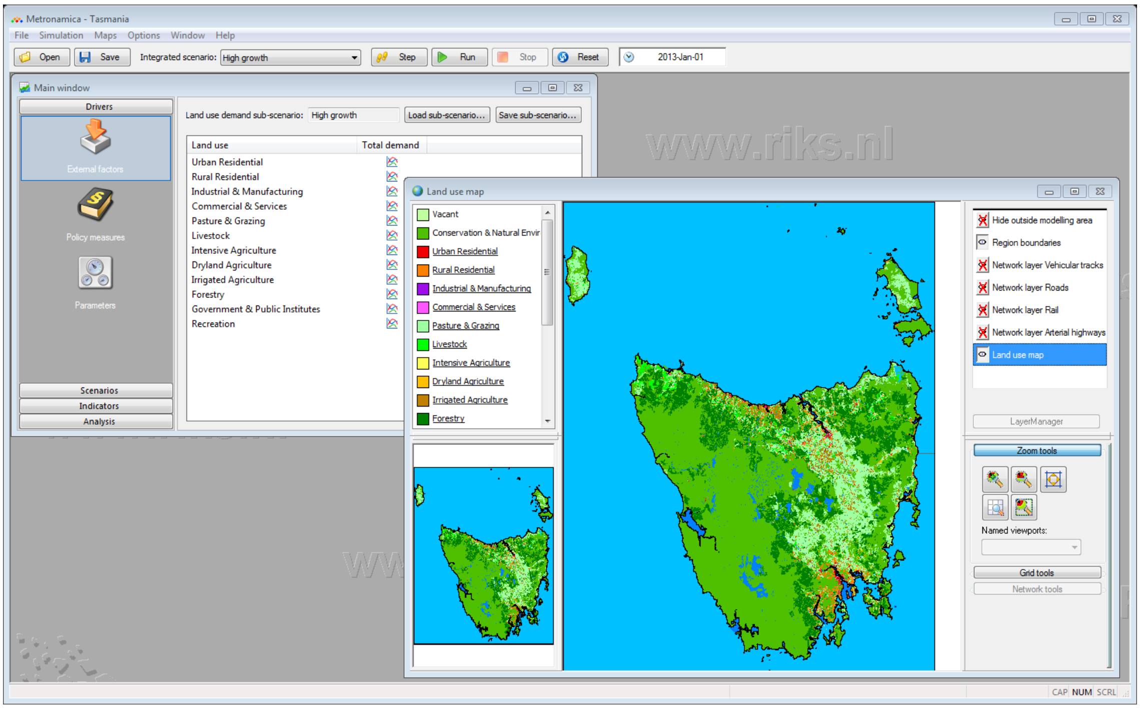

FIGURE 5: LAND USE MODEL FOR TASMANIAN APPLICATION

The participatory use process was also progressed with a workshop on 8/11/2016. This workshop showed a preview of the DSS and commenced the stakeholder problem formulation of several optimization problems that will be considered in the next year. This involved considering different scenarios for change across Tasmania (best / worst case, and most likely), along with the consideration of the group's vison and objectives, different hazard problems, and risk reduction options. This has been collated in *Tasmanian multi-hazard mitigation planning: Stakeholder problem formulation* (February 2017). The qualitative problem formulation as collated in this report has then been translated into quantitative parameters to enable multi-objective optimisation of mitigation strategies for different hazard contexts.

Table 3 outlines the next steps in region's development and use process. In late 2017, the first prototype of the system will be completed, with all models populated and integrated. This will be followed by training of users.

Purpose	Description	Indicative completion date
Prototype 1 completion	Data collected, processed and used to populate the DSS system. Models calibrated and validated.	Dec 2017
UNHaRMED Training	Training provided to users across multiple organisations who have been involved in the system's	Dec 2017

	development. Trained users will also be supported in the short term with further meetings and online support.	
Optimisation - risk reduction planning	Using participatory input for problem formulation, optimisation runs considering different hazards and risk reduction options will be performed to consider the trade-offs between risk reduction and cost.	Jun 2018
Socio-economic & Risk Scenarios	Presentation of modelled scenarios highlight plausible socio-economic developments and risk profiles. Critical feedback on their development, extremity, plausibility, consistency and representativeness.	Jun 2018
Policy Support	Presentation and discussion on policy support mechanisms and results from modelling of risk reduction portfolios and consideration of robust and adaptive approaches for future uncertainty.	Jun 2018

TABLE 2: NEXT STAGES FOR TASMANIA CASE STUDY

UTILISATION ACTIVITES & PROJECT HIGHLIGHTS

Multiple utilization activities have also been undertaken in 2016/2017 to support the use of the system within different organisations. The current focus of utilization activities has been in South Australia, with this case-study the furthest progressed in terms of software development.

Technical specifications for UNHaRMED have been produced and will be released with the software to South Australian end users. These specifications provide all technical details regarding the modelling processes, inputs, parameters, equations and algorithms used, as well as the outputs. They also provide information on the input and default data / values used, where these were sourced and what processing was applied to them. This will enable expert users to gain greater insight into the modeling processes and also highlight areas for future improvements / developments.

See: *UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, Technical Specification Version 1.0 (Van Delden et. al. 2017)*

Training exercises for the Greater Adelaide application have also been developed. These exercises were used as the basis of training provided to users on 20, 21, 22 June 2017. The exercise introduces users to the different aspects of the software's interface, and takes them through setting external drivers, implementing risk reduction options, and analysing impacts. There is also a guided exploration of model parameters considering separately hazard, exposure and vulnerability components.

See: *UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, User Training Version 1.0 (Van Delden et. al. 2017)*

A report is currently being completed considering the link between urbanisation and flood risk. This report will consider the rate and probability of urbanisation and how this may affect flood risk due to increased run-off, loss of natural retardation areas, and accelerated stream responses etc. Probabilistic land use modelling has been completed and this will then be compared against historical and modelled flood events provided by the South Australian Department of Environment, Water & Natural Resources. Data on these flooding extents are still being collected.

A new application of the UNHaRMED development and use process has also successfully been funded for a region within Western Australia. This is funded jointly by a National Disaster Resilience Program grant, multiple departments within WA State Government and the CRC. The system will consider the risk from bushfire, earthquake and coastal hazards. The model extent includes 47 local government areas, and is shown below in Figure XX.

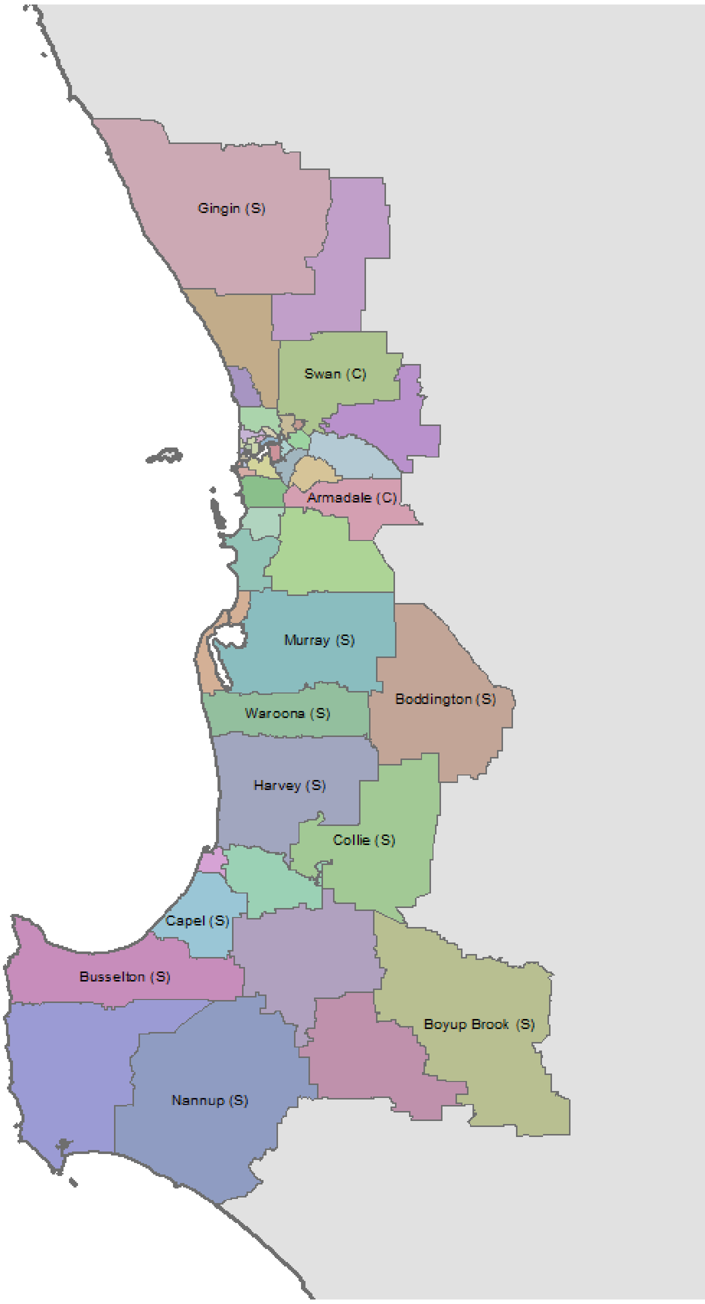

FIGURE 6: PROPOSED MODEL EXTENT FOR WESTERN AUSTRALIAN APPLICATION

PUBLICATIONS LIST

JOURNAL PUBLICATIONS

Newman, J. P., Maier, H. R., Riddell, G. A., Zecchin, A. C., Daniell, J. Schaefer, A. M. van Delden, H., Khazai, B., O'Flaherty, M. J., Newland, C. P. (2017) Review of Literature on Decisions Support Systems for Natural Hazard Risk Reduction: Current Status and Future Research Directions, *Environmental Modelling and Software* (in press)

Newland, C. P., van Delden, H., Neman, J., Zecchin, A., Maier, H. R. (2017) Multiple Objective Optimisation Framework for Automatic Parameter Tuning of Cellular Automata Land-Use Models with Multiple Dynamic Land-Use Classes, *Environmental Modelling and Software* (submitted)

REPORTS

Van Delden H., Vanhout R., Riddell G.A., Maier H.R., Newman J.P., Zecchin A.C., Dandy G.C., (July 2016) "Mock-up DSS Software Interface" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Riddell, G.A., Van Delden, H., Dandy, G.C., Maier, H.R., Zecchin, A.C., Newman, J.P., (February 2017) "Greater Adelaide Multi-hazard Mitigation Planning" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Riddell, G.A., Van Delden, H., Dandy, G.C., Maier, H.R., Zecchin, A.C., Newman, J.P., (February 2017) "Tasmania Multi-hazard Mitigation Planning" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Van Delden H., Riddell G.A., Vanhout R., Newman J.P., Maier H.R., Zecchin A.C., Dandy G.C., Daniell J., Schaeffer A., (June 2017) "UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, Technical Specification Version 1.0" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Van Delden H., Riddell G.A., Vanhout R., Newman J.P., Maier H.R., Zecchin A.C., Dandy G.C., Daniell J., Schaeffer A., (June 2017) "UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, User Manual Version 1.0" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Van Delden H., Riddell G.A., Vanhout R., Newman J.P., Maier H.R., Zecchin A.C., Dandy G.C., Daniell J., Schaeffer A., (June 2017) "UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, User Training Version 1.0" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

CONFERENCES

Van Delden, H., Riddell, G.A., Vanhout, R., Newman, J.P., Zecchin, A.C., Maier, H.R., Dandy, G.C., 2016. Integrating participation and modelling to support natural hazard mitigation planning, iEMSs 2016, Toulouse, France.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., Dandy, G.C., 2016. Futures of resilience and mitigation: Combining stakeholder knowledge, statistical analysis and integrated modelling to better understand and reduce disaster risk, iEMSs 2016, Toulouse, France.

Van Delden, H., Riddell, G.A., Vanhout, R., Maier, H.R., Zecchin, A.C., Newman, J.P., Daniell, J.E., Dandy, G.C., 2016. A Spatial Decision Support System (SDSS) for understanding and reducing long-term disaster risk, 6th International Disaster and Risk Conference IDRC Davos 2016, Davos, Switzerland. 6th International Disaster and Risk Conference IDRC Davos 2016, Davos, Switzerland.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., Newman, J.P., Dandy, G.C., 2016. Exploring the future of resilience and mitigation to better plan for disaster risk reduction. 6th International Disaster and Risk Conference IDRC Davos 2016.

Maier, H.R., Riddell, G.A., Van Delden, H., Newman, J.P., Zecchin, A.C., Vanhout, R., Daniell J., Schaeffer A., Dandy, G., Newland, C., 2015. A spatial decision support system for natural hazard risk reduction policy assessment and planning. Paper presented at AFAC Conference, September 2016, Brisbane, Australia.

Van Delden, H., Riddell, G.A., Maier, H.R., Vanhout, R., Newman, J.P., Zecchin, A.C., Dandy, G.C., Newland, C.P., 2016. Transforming risk analysis and mitigation planning in Australia. Poster presented at AFAC Conference, September 2016, Brisbane, Australia.

Newland, C.P., Van Delden, H., Maier, H.R., Newman, J.P., Zecchin, A.C. 2015. Enhancing exposure modelling through automative calibration of land use models, Poster presented at AFAC Conference, September 2016, Brisbane, Australia.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., Dandy, G.C., Newman, J.P., 2016. Futures of Greater Adelaide 2050: An exploration of disaster risk and the future, Poster presented at AFAC Conference, September 2016, Brisbane, Australia.

CURRENT TEAM MEMBERS

Prof. Holger Maier (University of Adelaide)

Project Lead Researcher, responsible for ensuring that the project delivers to contractually agreed scope and budget, and also responsible for the project communication between end-users and the project team, and communication with the cluster Lead User Representative and Lead Researcher. Also responsible for supervision of post-doctoral fellow and PhD students.

Dr Aaron Zecchin (University of Adelaide)

Deputy project leader, co-supervision of post-doctoral fellow and PhD students, oversight of optimisation and development of overall process and decision support system.

A/Prof Hedwig van Delden (Research Institute for Knowledge Systems (RIKS) / University of Adelaide)

Key researcher, responsible for running participatory workshops with end-users, data/information/model integration, application and calibration of the Metronamica land use modelling framework for those cases it will be applied to, and development of DSS software. Also responsible for supervision of post-doctoral fellow and PhD students. Accountable to the Project Lead Researcher for delivery of the prototype DSSs.

Emeritus Prof Graeme Dandy (University of Adelaide)

High level oversight on optimization and development of overall process. Workshop facilitator and co-supervision of the post-doctoral fellow.

Jeffrey Newman (University of Adelaide)

Responsible for literature review, collection of available data, information and models, development of overall framework, development and implementation of optimisation component of the project, day-to-day running of the project.

	Graeme Riddell (University of Adelaide) Responsible for day-to-day running of the project, data and model collection and conceptualization, and stakeholder engagement processes. PhD project looks to develop a framework to handle *knowledge uncertainty* (an uncertain future state of the world) for decision making with a focus on natural risk reduction planning.
	Charles Newland (University of Adelaide) Spatially distributed models are an effective means for the assessment of policy and planning investment options for optimal natural hazard mitigation. To broaden the applicability of spatially distributed models and allow more effective and efficient usage by decision makers, Charles' research aims to improve their calibration procedure.

REFERENCES

1. Fraser, S., Jongman, B., Balog, S., Simpson, A., Saito, K., Himmelfarb, A., *The making of a riskier future: How our decisions are shaping future disaster risk.* Global Facility for Disaster Reduction and Recovery, The World Bank, Washington DC, USA, 2016.
2. Rose, A., et al., *Benefit-cost analysis of FEMA hazard mitigation grants.* Natural Hazards Review, 2007. 8(4): p. 97-111.