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An engagement decision support model to assist the flood risk management cycle

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An Engagement Decision Support Model To Assist The Flood Risk Management Cycle

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by

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Certification

I, Raymond Thomas Laine, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil, Mining and Environmental Engineering, Faculty of Engineering and Information Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Raymond Thomas Laine
29 August 2014

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Abstract

There is a driving societal and legislative shift from citizens having limited tokenistic consultation on matters that affect them, towards directly influencing decision-making processes. Flood risk management is no exception. This research first explores both domestic and international flood risk management processes in a view to identify deficiencies in current practice. It is argued that public participation and evaluation requirements although mandated in many jurisdictions, are not adequately addressed in current processes. In response, a new flood risk management cycle bridging these deficiencies is presented as an alternative.

Secondly, this research presents a new engagement-focused decision support model, which in turn predicates the development of engagement decisions support systems as mechanisms to enhance and assist flood risk management processes and their outcomes. These systems as documented in the thesis combine heuristic, engineering and scientific knowledge with multi criteria, decision support and public participation theory through an online or standalone computer system, to empower the public (i.e everyone including the community, elected representatives, planners, engineers etc.) to derive informed preferred solutions and make collective considered decisions about complex engineering alternatives. Application of the model through an online engagement decision support system for flood risk management options was undertaken for three trial New South Wales catchments on the east coast of Australia to support and validate the thesis. It is argued that this model can be applied to all jurisdictions due to the flexibility in its framework, allowing organisational and/or legislative requirements to be achieved. It was shown that individuals utilising this model were able to overcome narrow uninformed preferences, selecting robust solutions that better reflect preference choices of learned flood managers.

Thirdly, it is argued the engagement-focused decision support model has broader application to other engineering and non-engineering fields that involve social, safety, economic, environmental, political, technological etc. tradeoffs. It is foreseen this model can lead to significant advancement in traditional decision making, as engagement decision support systems could provide a mechanism to enable a truly collaborative, transparent and inclusive participatory process that rightfully empowers the community to make informed decisions about engineering choices that affect them.

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Acronyms

ABI	Association of British Insurers
ACT	Australian Capital Territory
ADSS	Adaptive Decision Support System
AEP	Annual Exceedance Probability
CMAs	Catchment Management Authorities
DAD	Decide-Announce-Defend
DCP	Development Control Plan
DEAD	Decide-Educate-Announce-Defend
DEFRA	Department for Environment, Food and Rural Affairs
DFE	Defined Flood Event
DIP	Department of Infrastructure and Planning
DPEM	Department of Police and Emergency Management
DSS	Decision Support System
EDSS	Engagement Decision Support System
EU	European Union
FEMA	Federal Emergency Management Agency
FIRMs	Flood Insurance Rate Maps
GUI	Graphical User Interface
HMGP	Hazard Mitigation Grant Programs
IDBs	Internal Drainage Boards
LEP	Local Environment Plan
LRFs	Local Resilience Forums
MCDA	Multi-Criteria Decision Analysis
NDMP	Commonwealth National Disaster Management Program
NFIP	National Flood Insurance Program
NFRMP	National Flood Risk Management Program
OECD	Organisations for Economic Co-operation and Development
OEH	NSW Office of Environment and Heritage
PDM	Pre-Disaster Mitigation
PMF	Probable Maximum Flood
RFDCs	Regional flood defence committees
RFMP	Regional Flood Management Planning Initiative
SES	NSW State Emergency Service
SPP	State Planning Policy
USACE	United States Army Corps of Engineers
USMPs	Urban Stormwater Management Plans
WSUD	Water Sensitive Urban Design

Chapter 1

Introduction

1.1 Research significance

Turn on the news………

Flooding has always, and will continue, to have major economic, social and environmental impacts both domestically and internationally. Although these impacts may be beneficial, such as water and nutrient resupply and recharge, floods have the ability to devastate cities and towns. Annually, floods result in 25,000 deaths world-wide with 10 deaths on average occurring in Australia (UNU 2004; NFRAG 2012). Average tangible damages (relating to direct and indirect material losses) resulting from flooding are estimated to total between \$50 and \$60 billion world-wide, with average annual damages of \$314m in Australia, making it Australia's costliest natural disaster (UNU 2004; BTE 2001). Intangible damages (relating to emotional non-monetary losses), including psychological impacts caused by damaged or destroyed homes, loss of personal possessions, financial worries and post-traumatic stress, can cause similar significant economically un-accounted for costs (Green and Penning-Rowsell 1989; Lekuthai and Vongvisessomjai 2001). With projected intensity increases of flood-producing rainfall events, sea level rise, and major population growth in flood-prone areas, these economic, social and environmental consequences are likely to ominously increase in the near future (McLuckie et al. 2010; Zevenbergen et al. 2011).

Considering these portentous consequences, it is critical that an individual, whether they are an engineer, planner, political advisor, politician or community representatives etc, can make informed decisions about flood management options in anticipation of, or in reaction to, inundation events, to reduce the social and economic consequences of flooding. To make informed decisions, the individual must have a robust understanding of the flood risk, the best flood management options available and understand the relative tradeoffs for each option. For many, however, this understanding and heuristic knowledge may be limited or non-existent. Even if this understanding and knowledge does exist, it is recognised that flood risk management can no longer be achieved through purely top-down processes, siloed or one-off projects. Rather, it takes sustained collaborative action at multiple levels involving

those directly or indirectly affected by flooding or the management of flooding working simultaneously to reduce the social and economic consequences of these events (ICE 2013).

This research presents both a new flood risk management cycle and engagement-focused decision support model as a paradigm and approach to empower the public in making collective informed decisions about firstly the current and future residual risk they are willing to accept for utilising the floodplain; secondly the measures available; and thirdly the political, social, environmental, cultural, economic and technological tradeoffs that need to be systematically and equitably balanced to achieve the desired level of residual risk. This research is not the acme of flood risk management but rather a thesis introducing new elements that can be integrated into existing practices to promote inclusive, deliberative, transparent, sustainable decision making in the flood risk management sphere.

1.2 Research questions

The following research questions are examined:

1) What are current flood risk management processes and practices? Are they disparate or analogous? Do opportunities exist for improvement?
2) Could a new engagement-focused decision support model be applied to assist these flood risk management processes and practices in recognition of current legislation, policies, strategies, roles, responsibilities and the increasing requirement for public participation?
3) Can new engagement decision support systems improve the outcomes of flood risk management?
4) Does the engagement-focused decision support model have broader application to other engineering and non-engineering fields?

1.3 Thesis outline

This thesis is divided into six subsequent chapters:

Chapter 2 explores current domestic flood risk management processes and practices including legislation, policies, strategies, roles, and responsibilities to establish a foundation from which the thesis is established. Chapter 3 draws on the findings of the preceding chapter's research, in conjunction with an examination of public participation theory, presents a new flood risk management cycle that addresses identified deficiencies within current best practice. Chapter 4 explores multi-criteria

and decision theory to construct a new innovative engagement decision support model for flood risk management options that can assist the flood risk management cycle. Chapter 5 applies this model, presenting the development, testing and evaluation of an engagement decision support system for floodplain management measures within three trial catchments. Chapter 6 explores the application of the model in further fields and chapter 7 concludes with the thesis arguments and provides insight into further research avenues.

1.4 Research contributions

This thesis:

1) examines flood risk management process and practices both nationally and internationally (which have not been clearly and collectively documented in literature) and proposes a new decision-making cycle for flood risk management that addresses identified deficiencies within current best practice.

2) for the first time, applies public participation, multi-criteria and decision support theory to develop a generic engagement-focused decision support model for flood risk management options. It is demonstrated that this model, supported by a decision support system, can assist with the facilitation of structured objective community flood risk management consultation and rigorous, inclusive, transparent and auditable decision making. The model presented can be organisationally adjusted and fundamentally assists water resource engineers, emergency management personal and institutions responsible for flood risk management.

3) provides a new suite of tools, Engagement Decision Support Systems (EDSS), that can be utilised in both government and private contexts to aid public consultation and participation. It is demonstrated within this thesis, that a well-structured EDSS can provide a mechanism for, and empower stakeholders to, learn about, prioritise and make equitable and balanced decisions about specific engineering solutions rather than passively accepting or not accepting decisions made by engineers. While this thesis provides an applied example within the flood risk management field, it is envisaged that these systems could be utilised in a range of engineering and non- engineering fields (bushfire, mining, coastal, land-use planning etc) that involve tradeoffs in the public sphere. It is foreseen that

tools like these will provide a powerful means to shift informed decision making back to or at least partially back to the community. This will hopefully foster a democratic environment where citizens can participate in making informed decisions in a meaningful way and, in doing so, accept and take partial responsibility for decisions that affect them.

1.5 Thesis publications

Laine, R. and Cook, C. 2014, 'Decision support Aiding Public Participation,' proceedings of the *6th International Conference on Floodplain Management, Sao Paulo, Brazil, September 16–18* pp.1–12.

Laine, R., Cook, C. and Lemass, B. 2012, 'Decision support: Informing flood management,' proceedings of the *52nd Floodplain Management Association Conference, Batemans Bay, Australia, February 21–24* pp.1–10.

Laine, R., Lemass, B. and Cook, C. 2011, 'A Structured Decision Support System for Flood Mitigation,' paper presented at the *ASFPM 35th National Flood Risk Management Conference, Kentucky, United States, May 15–20*.

<u>External thesis presentations:</u>

Floodengage media launch- Cessnock City Council. September 26th 2013. Mayor's Office, Vincent St, Cessnock, Australia.

Flood Steering Committee- Cessnock City Council. September 13th 2013. Council Chambers, Vincent St, Cessnock, Australia.

Amplify Festival- Bright Sparks. June 4th 2013. The Basement, Circular Quay, Sydney, Australia.

Floodengage media launch- Shellharbour City Council. May 30th 2013. SMART Infrastructure Facility, University of Wollongong, Wollongong, Australia.

Flood Steering Committee- Shellharbour City Council. March 27th 2013. Council Chambers, Lamerton Crescent, Shellharbour, Australia.

Chapter 2

Flood risk management process

2.1 Introduction

The notion of flood risk management varies around the world with numerous definitions transitioning from holistic overarching inclusive statements (Sayers et al. 2013; Zevenbergen et al. 2010; European Commission 2007; ADPC 2005) to detailed prescriptive processes (Office of Public Works 2013; DEFRA 2010) all generally aiming to reduce flood losses through the analysis, assessment and mitigation of flood risk.

To understand flood risk management within the context of this research, the following definitions are presented:

<u>Flooding</u> is excess water that temporarily covers land that is normally dry. Excess water sources are generally oceanic, pluvial, fluvial, groundwater, snowmelt, infrastructure failure or a combination of these.

<u>The risk management process</u> as defined by AS/NZS ISO 31000:2009 is the 'systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analyzing, evaluating, treating, monitoring and reviewing risk'.

Therefore, in context, the <u>flood risk management process</u> is the application of legislation and policies, procedures and practices that enable the identification, analysis, evaluation, management, monitoring and review of excess water that temporarily covers land that is normally dry.

This chapter examines international and domestic flood risk management legislation and policies, roles and responsibilities, procedures and practices and compares their similarities and differences. In examining floodplain management and the frameworks in which they exist, this chapter also explores the possibility of a new flood risk management cycle that can be employed within current frameworks to improve domestic and international flood management outcomes.

2.2 United States of America

In the United States it has been ‘concluded that over 9 million households and $390 billion in property are at risk from the 1-percent-annual chance flood’ (FEMA 2013). To address this flood risk, the US government has a comprehensive flood risk management process which comprises federal legislation, federal insurance, and procedures and practices at federal, state, and local level.

2.2.1 Primary legislation, policies and strategy

The primary federal legislation in the United States is the Flood Control Act of 1938. This Act outlines the statutory responsibility of the US federal government to provide and fund flood management, ‘if the benefits to whomsoever they accrue are in excess of the estimated costs,’(US CODE 1938). While this Act remains in force, modifications, by the enactment of other laws governing environment and flood mitigation, have shifted the program from almost full federal funding to one in which states and local sponsors share the costs of both structural and non-structural flood management works (WMO 2004).

Another important piece of US federal flood risk management legislation is the National Flood Insurance Extension Act of 2012. This Act has the primary purposes of: 1) providing for the expeditious identification of, and the dissemination of information concerning, flood-prone areas displayed in flood insurance rate maps (FIRMs); 2) requiring state or local communities, as a condition of future federal financial assistance, to participate in the flood insurance program and to adopt adequate flood plan ordinances with effective enforcement provisions consistent with federal standards to reduce or avoid future flood losses; and 3) requiring the purchase of flood insurance by property owners who are being assisted by federal programs or by federally supervised, regulated, or insured agencies or institutions in the acquisition or improvement of land or facilities located or to be located in identified areas having special flood hazards (U.S Congress 2012).

Thirdly, the Water Resources Development Act 2007 provides a basis for floodplain management works within a federal investment framework that aims to, ‘reflect national priorities, encourage economic development and protect the environment by: 1) seeking to maximize sustainable economic development; 2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used;

and 3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems, (CEQ 2013).

At a federal level the United States has progressed through various specified floodplain management strategies ranging from protect and defend (USWRC 1981), reduce the impact of flooding (FIFMTF 1992), to a risk management approach recognising floodplain function (FIFMTF 1994; CEQ 2013; Rolf Olsen 2006). The latter risk management strategy, principally contained in the Unified National Program for Floodplain Management Water Resources Council report (WRC 1994), details its four primary goals. These goals are to: ‘1) Formalize a national goal-setting and monitoring system. 2) Reduce by at least half the risks to life and property and the risks to the natural resources of the Nation's floodplains. 3) Develop and implement a process to encourage positive attitudes toward flood-plain management and 4) Establish in-house floodplain management capability nationwide’ (FIFMTF 1994).

At a state level, flood risk management has been established through various legislation and programs to meet the objectives of federal legislation and the Unified National Program for Floodplain Management. These varying legislations include, for example, the Flood Hazard Prevention Act 2000 in North Carolina and the Safe Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act 2000 in California.

2.2.2 Roles, responsibilities and programs

The federal government has the primary role of providing technical expertise and financial assistance to both state and local governments, establishing standards and supplying services not otherwise available to state and local floodplain management programs. There are two lead agencies that undertake these federal duties. These agencies are the US Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA).

The role of the US Army Corps of Engineers is to develop comprehensive plans for flood damage reduction and to carry out structural and non-structural flood damage reduction projects as authorised by the Congress and the President (USACE 2010). Their flood risk programs include the National Flood Risk Management Program (NFRMP) involving flood and storm damage reduction projects, operation and management of flood management measures, risk management and communication

including the Levee Safety Program and the Levee Outreach Toolkit (USACE 2014; USACE 2011). The flood risk management process as outlined in the National Flood Risk Management Program Guidance Memorandum is illustrated in Figure 1.

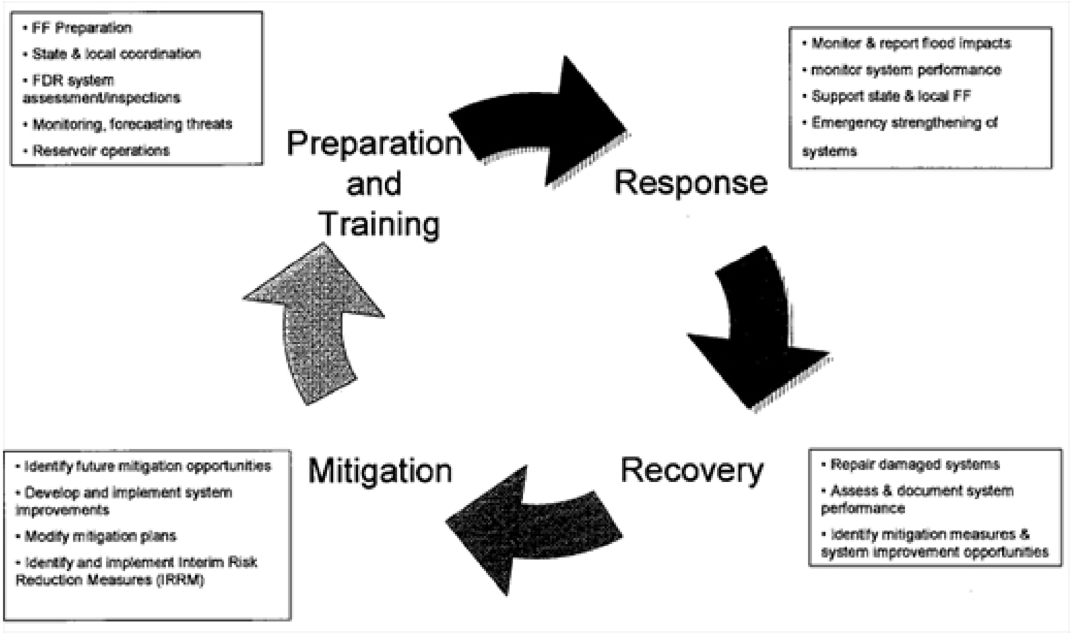

Figure 1: Flood risk management cycle (USACE 2009).

The role of the Federal Emergency Management Agency is to prepare for and respond to all natural disasters, administer the National Flood Insurance Program (NFIP) and provide training opportunities (FEMA 1994). Their flood risk management programs include the risk mapping, assessment and planning (Risk Map) program in which flood maps are being updated and communicated to the affected communities (Figure 2) (FEMA 2011a); the Pre-Disaster Mitigation (PDM) and Hazard Mitigation Grant programs (HMGP) to provide technical and financial assistance to state and local governments to implement flood mitigation measures pre and post disaster declaration (McCarthy 2011); and administer the NFIP (King 2005). The NFIP has a novel mechanism for communities to prepare, adopt and implement floodplain management plans through a specified process. If communities follow the specified 10 step floodplain management process as outlined in Figure 3, the community is 'rewarded' with reduced flood insurance

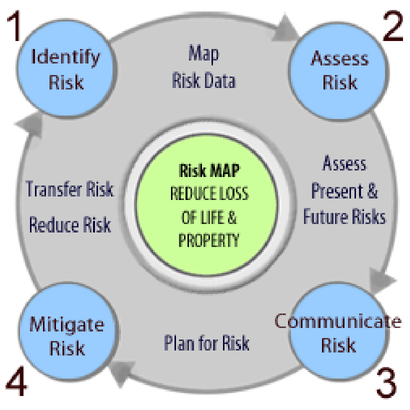

Figure 2: RiskMAP process (FEMA, 2011).

premiums of up to 45% under the NFIP (CRS 2013). As of 2009, over 1,110 communities had undertaken this process. However, flaws have been identified with limited community participation, as 85% of plans only employed one-way flow of information in their engagement techniques and consolation with the 'most socially vulnerable' were identified as underrepresented (Berke et al. 2011).

Table 510-1. Planning steps for mitigation and for the CRS.

Multi-hazard Mitigation Planning	CRS	Maximum
Phase I – Planning process		
§201.6(c)(1)	1. Organize	15
§201.6(b)(1)	2. Involve the public	120
§201.6(b)(2) & (3)	3. Coordinate	35
Phase II – Risk assessment		
§201.6(c)(2)(i)	4. Assess the hazard	35
§201.6(c)(2)(ii) & (iii)	5. Assess the problem	52
Phase III – Mitigation strategy		
§201.6(c)(3)(i)	6. Set goals	2
§201.6(c)(3)(ii)	7. Review possible activities	35
§201.6(c)(3)(iii)	8. Draft an action plan	60
Phase IV – Plan maintenance		
§201.6(c)(5)	9. Adopt the plan	2
§201.6(c)(4)	10. Implement, evaluate,	26
Total		382

Figure 3: Floodplain management planning credit (CRS 2013).

The state government has the primary role of coordinating and guiding local decisions, administering program goals, and determining floodplain management authority. Some states have legislatively derived authorities, funding, and staffing to carry out active and effective floodplain management programs. Other states delegate land-use regulatory authority to local government and in return support them with in-house programs for technical and financial assistance (WRC 1994). One example of a state flood risk management process is California's Regional Flood Planning Process and Basin Wide Feasibility Studies (Figure 4). This process located within the 'Regional Flood Management Planning Initiative' (RFMP) is intended to provide 'the local partners with initial guidance and to promote consistency among RFMPs' (DWR 2012).

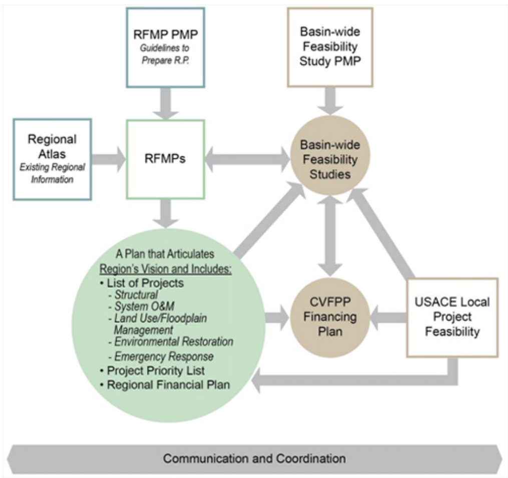

Figure 4: California flood planning process (DWR 2012).

The local government has the primary responsibility of determining and implementing land-use within the floodplain. In some states land-use regulatory authority has been delegated by the state government to local government to ensure the suitable use of the floodplain (Rolf Olsen 2006).

2.3 England

The British government has identified 5.2 million properties, and a significant proportion of public infrastructure across England, at risk of flooding (Environment Agency 2009a). To reduce this risk, the British Government has developed a comprehensive flood plain risk management program which comprises central government legislation, European directives and central and local program delivery.

2.3.1 Primary legislation, policies and strategy

The primary central government flood legislation in England is the Flood and Water Management Act 2010. This Act outlines the statutory roles and responsibilities of various stakeholders, funding arrangements, levies, reporting responsibilities, regulations, and the consultation and consent process. For example it is legislated that the Environment Agency must "develop, maintain, apply and monitor a strategy for flood and coastal erosion risk management in England" (Flood and Water Management Act 2010). This strategy must specify:

> '(a) the English risk management authorities, (b) the flood and coastal erosion risk management functions that may be exercised by those authorities in relation to England, (c) the objectives for managing flood and coastal erosion risk, (d) the measures proposed to achieve those objectives, (e) how and when the measures are to be implemented, (f) the costs and benefits of those measures, and how they are to be paid for, (g) the assessment of flood and coastal erosion risk for the purpose of the strategy, (h) how and when the strategy is to be reviewed, (i) the current and predicted impact of climate change on flood and coastal erosion risk management, and (j) how the strategy contributes towards the achievement of wider environmental objectives' (Flood and Water Management Act, 2010).

The Land Drainage Act 1991 is another piece of central legislation that has relevance for flood management. It documents the functions and responsibilities of flood defence, planning, works and warning systems. This act designates the Environment Agency as a statutory consultee in the town and country planning process. As such, the Environment Agency must make representations to local planning authorities on matters in development plans and certain planning applications that are of concern to its functions (United Kingdom Government 1991).

The Flood Risk Regulations 2009 provide definitions, document the duty to prepare preliminary assessment maps and reports, identify flood risk areas, prepare flood

hazard maps and flood risk maps and stipulate the duty to prepare and publish flood risk management plans (Flood Risk Regulations 2009).

The Planning Policy 25: Development and Flood Risk, is a policy that aims to, 'ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new development is, exceptionally, necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and where possible, reducing flood risk overall' (Crown 2010). Policies to meet this aim include, 'a risk-based approach should be adopted at all levels of planning,' and, 'only permitting development in areas of flood risk when there are no reasonably available sites in areas of lower flood risk and benefits of the development outweigh the risks from flooding" (Crown 2010).

The national flood and coastal erosion risk management strategy as illustrated in Figure 5, encourages stakeholders to:

'1) Know when and where flooding and coastal erosion is likely to happen. Risk management authorities need to improve their understanding of the risks of flooding and coastal erosion. They particularly need to develop a better understanding of surface water and ground water flood risk. 2) Make sure that any flood and coastal risk management plans use the most up-to-date information and raise awareness of these risks among affected communities. 3) Reduce the chance of harm to people and damage to the economy, environment and society by building, maintaining and improving flood and coastal erosion management infrastructure and systems, where it is affordable to do so. 4) Help communities understand the risks and take action to manage them or reduce the consequences - for example, by making their properties more resilient or by adapting to coastal change. 5) Avoid inappropriate development in areas of flood and coastal erosion risk. 6) Improve the detection and forecasting of floods and how warnings are issued, so that people, businesses and public services can take action, plan for and coordinate a rapid response to flood emergencies and promote faster recovery from flooding. 7) Take opportunities to work with and enhance communities, services and the natural environment,' (Environment Agency, 2011b).

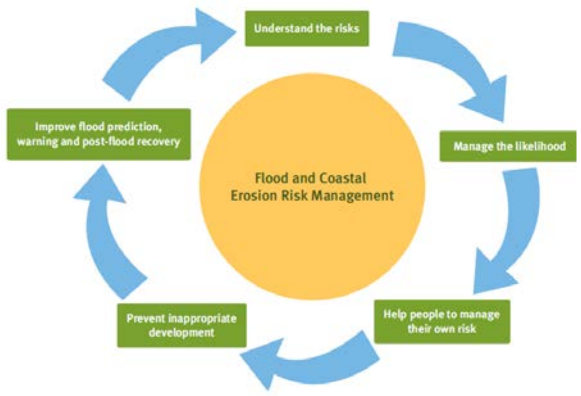

Figure 5: Flood and Coastal Erosion Risk Management Framework (Environment Agency 2011b).

In addition to these central government strategies, policies and legislation, the European Commission adopted legislation for the management and assessment of flood risk which applies to all member states (European Commission 2007). The legislation requires a three stage approach to managing all types of flooding except flooding from sewerage systems which may be excluded. This approach is, '1) A preliminary flood risk assessment to determine where significant flood risks are likely. The assessment must be completed by 2011 and this will feed into further decisions on risk management; 2) Mapping of significant flood risks by 2013; and 3) Preparation of plans to manage the risks by 2015,'(European Commission 2007).

2.3.2 Roles, responsibilities and programs

The primary role and responsibility for floodplain risk management in England is the British government. There are two lead bodies that undertake these central duties. These are the Environment Agency and the Department for Environment, Food and Rural Affairs (Defra) respectively.

The summarised roles and responsibilities of the Department for Environment, Food and Rural Affairs are: 1) Providing national policy for flood and coastal risk management, 2) Administering legislation that enables flood defence works to be carried out, 3) Approval of individual flood defence capital schemes, 4) Providing and administering grant funding to the Environment Agency and Local Authorities(Environment Agency 2009a). Their programs include the Flood and Coastal Resilience Partnership Funding Program, in which local authorities are able to raise a levy from households for flood and coastal protection projects and the Flood Defence Grant-In-Aid Program which primarily administers funds to the Environment Agency for flood warning systems, new and improved coastal defence systems, maintenance and emergency response (Defra 2013).

The primary role and responsibility of the Environment Agency summated are: 1) To be the lead flood risk management authority in England and Wales, 2) To supervise all matters relating to flood defences, 3) To carry out improvements and maintenance works to reduce the risks of flooding from designated main rivers and the sea, 4) To operate pumping stations and control structures, 5) To work with the Met Office to provide flood forecasting and warnings, 6) Advise local authorities on flood risk relating to proposed developments and regulating works affecting main rivers, 7) An obligation to further conservation interests in undertaking its duties, 8) To take part in

emergency planning and response, 9) To manage central government grants for capital projects carried out by local authorities and internal drainage boards, 10) To provide consent and advice as a statutory consultee to local authorities on flood affected planning approvals and development conditions (Environment Agency 2009a). The Environment Agency's flood and coastal erosion risk management programs include the development of catchment flood management plans (as illustrated in Figure 6 and shoreline management plans, construction of flood management measures, flood maintenance, administering the local authority revenue support grants and flood defence grants (Environment Agency 2009a).

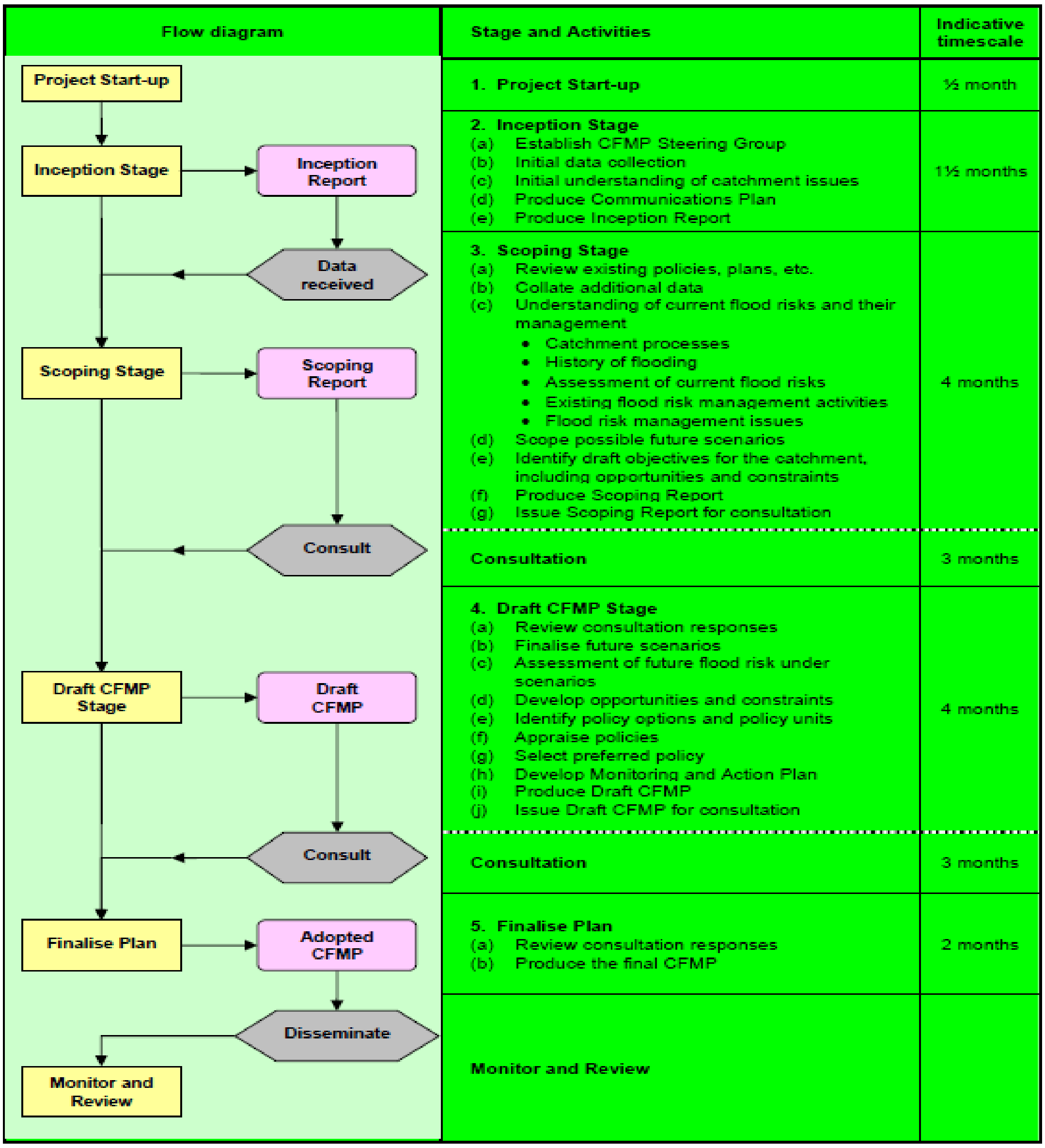

Figure 6: Catchment flood management plan process (Environment Agency 2004).

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Internal Drainage Boards (IDBs) are another centrally appointed operating authority established to deal with land drainage in areas of special drainage need which are

typically smaller watercourses and field drains. Although not a lead authority in floodplain management, their role and responsibilities include: 1) Active land drainage management of lowland areas in England and Wales, 2) Undertaking flood defence works, drainage and water level control of adopted public surface water sewers managed by water companies and certain limited watercourses historically maintained by local authorities (Environment Agency 2009a).

Local government authorities have primary responsibility for development in the floodplain and management of drainage and small watercourses. Other responsibilities include: 1) To prepare and maintain a strategy for floodplain management within their area, 2) Maintain a register of assets and 3) Take the lead role in emergency planning for flooding and handling the recovery of areas that have been effected by flooding (Local Government Association 2012).

Evidently there are identified non-government roles and responsibilities as specified by the Environment Agency (2009a). These include regional flood defence committees (RFDCs), local resilience forums (LRFs), Association of British Insurers (ABI) and the National Flood Forum. The Environment Agency has identified that the RFDCs have a duty to take an interest in all flood matters in their area. They are responsible for decisions about the annual program of improvement and maintenance work carried out by the Environment Agency (Environment Agency 2009b). The LRFs are local planning forums for all emergencies, including flooding. Their responsibilities include bringing together the emergency services, Environment Agency, National Health Service and other bodies like water and energy companies. Together they plan for prevention, control and reducing the impact of floods on the public (Environment Agency 2009b). The ABI and its members have been identified as responsible for providing cover and handling claims for damages caused by flood. Under an agreement with the government, the ABI have committed to continue insurance coverage for most properties, even some at significant risk, in return for action by government to identify and manage risks (Environment Agency 2009b). Lastly, the National Flood Forum, as a registered charity, has been identified as being responsible for providing advice to those at risk and campaigning for better protection from flooding (Environment Agency 2009b).

2.4 Netherlands

The Netherlands has had a long history of being highly vulnerability to flood risk. This high vulnerability stems from 26% of the Netherlands being below mean sea level leaving 9 million people potentially exposed to daily flooding (Ruimtevoorderivier 2007). As a result, the Dutch Government has a long-standing integrated flood plain risk management program which comprises federal legislation, European directives and federal and local program delivery.

2.4.1 Primary legislation, policies and strategy

The primary federal legislation in the Netherlands is the Water Act 2009. This act specifies the objectives and safety standards, roles, responsibilities and procedures regarding water and flood risk management, the legal standards for levees and outlines the procedure of a six yearly safety assessment of all primary flood defences in which the assessment is to be presented to parliament (MTPWWM 2010). Furthermore this legislation documents protection levels for the various rivers ranging from 1/250-year protection upstream to 1/10,000-year protection in the delta area as illustrated in Figure 7 (Alphen 2009).

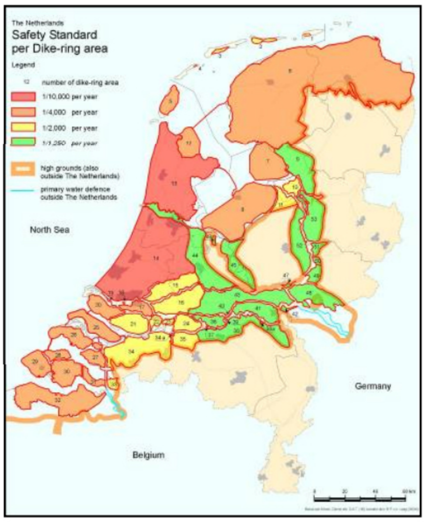

Figure 7: Legal level of flood protection, Water Act 2009 (Alphen 2009).

The Spatial Planning Act 2008, documents roles, responsibilities, consent, compensation, mapping, and other legislative requirements associated with planning and development in the Netherlands (Alphen 2009). It also specifies that water management authorities be informed about activities likely to impact water management (IWR 2011).

The third important federal legislation for floodplain risk management is the Safety Regions Act 2010. This act outlines the roles, responsibilities and procedures in relation to disaster management and stipulates, 'that every region performs a risk analysis, including potential flooding, establishes plans and performs exercises to be prepared,'(IWR 2011).

The Dutch government also has a range of policies and plans as documented in Figure 8. These include both the Room for Rivers Policy (2008), National Water Plan (2009), National floods crisis plan and large-scale evacuations and a national spatial strategy (Alphen 2009). The 'Room for Rivers' policy principally guides with the statement that, 'in giving more room to rivers would substantially lower flood levels and sustain a more attractive environment, both urban and natural,'(Water Information Network 2010). The National Water Plan provides a strategy consisting of, '(1) measures to protect from floods and from droughts, (2) spatial development and water management, (3) a flexible approach starting with "no regret" measures (like spatial reservations), (4) long term funding and a legal basis to guarantee long term implementation,'(Alphen 2009). Flood risk management at the provincially and local levels involves the development of strategies and plans to meet the objectives of federal legislation and the European Water Framework Directive (2000/60/EC).

	Prevention	Protection	Preparation	Response	Recovery
National Legislation	Spatial Planning Act (SPA)	Water Act (WA)	Safety Regions Act (SRA)		
Plans and Policy documents					
State	National Water Plan, TPW&WM– *accent on protection* (WA), *also zoning scheme* (SPA)				
	National Spatial Strategy, HSPE (SPA)				
		National Flood protection programme, TPW&WM (WA)			
			National floods crisis plan and large-scale evacuations, IKR (SRA)		
Province (12)	Provincial Water Plan (WA), also zoning scheme (SPA)				
Waterboard (26)	Water Management Plan (WA)		Flood Disaster Management Plan (WA)		
Safety region (25)			Crisis Coordination Plan (SRA), Disaster Management plan (SRA)		
Municipality (450)	Land use plan (SPA)				

Figure 8: Flood risk management instruments in the Netherlands, grouped by administrative levels and policy fields.(Alphen 2009).

2.4.2 Roles, responsibilities and programs

The federal government has the primary responsibility of legislation, safety standards, financial assistance, establishing guidelines and the management and maintenance of coasts, rivers, lakes and significant structures such as dams and barriers. The primary agency that undertakes these federal duties is the Ministry of Transport, Public Works and Water Management. Specifically, the Rijkswaterstaat, a division of

the Ministry of Transport, Public Works and Water Management has duties to undertake the construction and maintenance of coastal and flood defences. This is in addition to coordinating teams for the implantation of flood risk management plans through the Flood Directive Action Plan process (Figure 9)(Hanne van den Berg 2012). Their programs include the 'Making room for rivers program' which aims to improve safety and protect the land and people living behind dikes from floods, while improving the environmental quality of these environments (Ruimtevoorderiver 2007); and the National Flood protection Programme established to undertake the construction and maintenance of coastal and flood defences (Glas 2010).

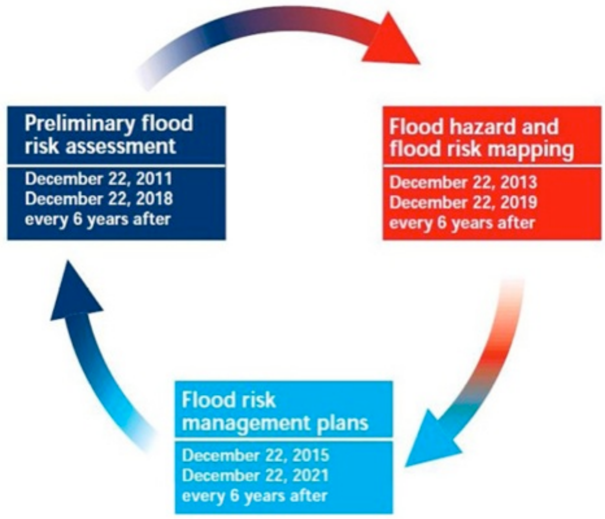

Figure 9: Flood directive action plan process (Hanne van den Berg 2012).

Regional Waterboard Authorities are an independent government body responsible for water management, maintenance of flood defences and disaster management primarily related to dyke ring flood defences at a regional level (Alphen 2009). They have a range of programs primarily focused around the management and maintenance of water barriers: dunes, dikes, quays and levees; the management and maintenance of waterways and water levels; and the maintenance of surface water quality through wastewater treatment (Glas 2010).

At a first-tier local government level, in co-operation with Rijkswaterstaat and Regional Waterboard Authorities, the provinces are responsible for surface and groundwater management, applying federal guidelines to a regional context and guiding land use on a regional scale (Alphen 2009). Municipalities are responsible for implementing national policy and regulating and determining land use at a local scale (Government of Netherlands 2013.

2.5 New Zealand

'In New Zealand, floods are the most costly natural disasters apart from earthquakes and droughts, with total flood damage costs averaged about US$85 million per year from 1968 to 1998,' (IPCC 2007). These damages have resulted as over 100 New Zealand cities and towns are located in the floodplain (Ministry of the Environment 2011). In response to this vulnerability, the New Zealand Government has recently adopted a series of principles for flood risk management supported by varying legislation and a New Zealand Flood Risk Standard (NZS 9401:2008).

2.5.1 Primary legislation, policies and strategy

The primary pieces of central government legislation managing flood risk in New Zealand are the Resource Management Act 1991 and the Civil Defence and Emergency Management Act 2002.

The Resource Management Act 1991 outlines the roles and responsibilities for regional and local councils in dealing with flood risk, primarily through proactive planning. Under this Act, regional councils are required to control the use of land for the avoidance or mitigation of natural hazards, including flood. Authorities are required to control the actual or potential impacts of the use, development or protection of land, including for the purpose of avoiding or remedying natural hazards (Ministry of the Environment 2011). The Resource Management (Energy and Climate Change) Amendment Act 2004 further requires local authorities to have particular regard to the impacts of climate change (Ministry of the Environment 2011).

The Civil Defence and Emergency Management Act is another key piece of legislation for flood risk management. The Act primarily 'focuses on the sustainable management of hazards, resilient communities and on ensuring the safety of people, property and infrastructure in an emergency. The Act recommends an approach based on risk reduction, readiness, response and recovery,' (Ministry of the Environment 2011). The Act also documents the roles and responsibilities of central government agencies, local authorities and emergency services in relation to disaster management (DIA 2007).

Other New Zealand legislation that relates to flood risk management includes The Drainage Act 1908, the Soil Conservation and Rivers Control Act 1941, the Local Government Act 2002, the Local Government (Rating) Act 2002, and the Building Act

2004. The Building Act 2004 and Building Code, for example, currently require residential buildings and community care facilities to be built at a higher elevation than the flood level of a 1-in-50-year event and does not yet require a flood protection standard for commercial buildings (PCO 2014).

The New Zealand government has also adopted a series of principles for flood risk management decision making. Summarised, these principles are to: 1) Take a precautionary approach, as there is a social responsibility to minimise the exposure of a community to harm as much as possible when scientific investigation has found a plausible risk, 2) Use flexible or adaptive management options, 3) Use no-regrets options that will deliver benefits that exceed their costs whatever the extent of climate change, 4) Use low-regrets options that have relatively low costs when certainty of the associated risks is low, 5) Avoid making decisions that will make it more difficult for you or others to manage climate change flood risks in the future, 6) Use progressive risk reduction that is, 'new developments should not be exposed to, nor increase, flood risk over their intended lifetime. For existing developments the level of risk should be progressively reduced', and 7) Adopt an integrated, sustainable approach to the management of flood risk (Ministry of the Environment 2011).

New Zealand, through a centrally appointed technical committee, has developed a New Zealand standard for flood risk management NZS 9401:2008 Managing Flood Risk – A Process Standard) (Figure 10). This standard sets out a high-level decision-making framework, based closely on the international standard ISO 31000:2009 Risk Management − Principles and Guidelines. In summation, the standard provides an explanation of hazard risk management, highlighting the importance of shared responsibilities. It defines flood risk and provides an overview of the significant factors affecting flood risk management. It establishes the key management perspectives, assessment principles, and implementation criteria through which decisions can be best developed and promotes six steps in the risk assessment being, 1) establish the context, 2) identify hazards and describe the risks, 3) analyse the risks, 4) evaluate the risks, 5) assess appropriate responses based on the risks, and 6) communicate, consult, monitor and evaluate (New Zealand Standards 2008).

Local councils have varying flood policies based on addressing the central government principles and legislation requirements. One example is the Greater Wellington Regional Councils flood policy which states, 'Our policy is that new development is avoided in areas of flood risk. Where development does take place in

these areas (including infill development), we recommend that residual risk is recognised,' (Greater Wellington Regional Council 2011a).

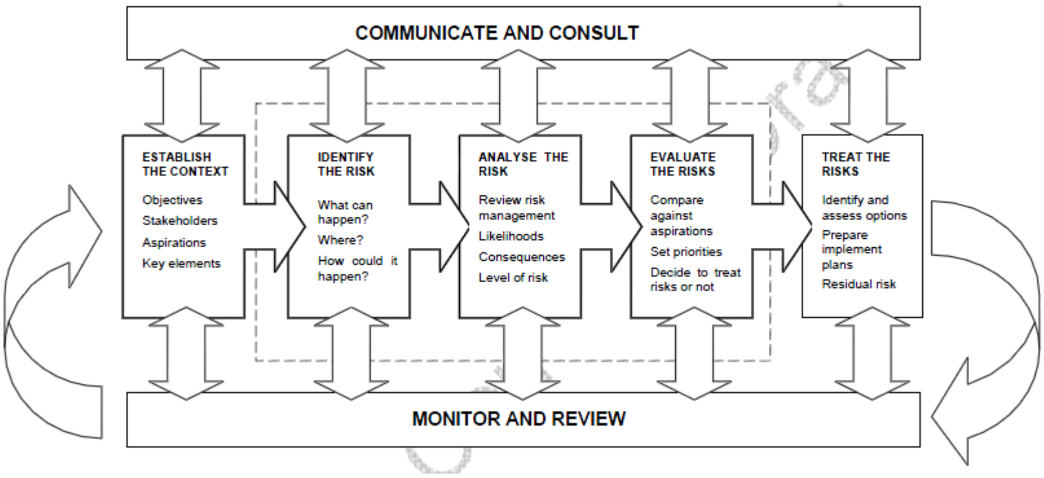

Figure 10: NZS 9401:2008. managing flood risk – a process standard (New Zealand Standards 2008).

2.5.2 Roles, responsibilities and programs

The New Zealand Government, through the Ministry for the Environment and Ministry of Civil Defence and Emergencies, has the role of establishing legislation, providing, 'local government necessary powers to manage flood risk, providing guidance, maintaining forecast and warning systems and emergency management preparation and recovery,' (Ministry for the Environment 2008b).

At a second level, regional councils have the primary role and responsibility of managing rivers and catchments, setting policies, generating funding, undertaking floodplain management plans, operating and maintaining flood defence systems, and regulating dams. Regional councils are also responsible for issuing flood warnings, maintaining records of river flows, lake levels, rainfall and past floods (Ministry for the Environment 2008a; Ministry for the Environment 2008b). Their programs include flood protection, maintenance, and management. These are primarily funded by regionally-generated rates and capital loans from the central government (Greater Wellington Regional Council 2010; West Coast Regional Council 2010). The floodplain management process, as facilitated through the regional councils flood management program, consists of three phases. These phases are illustrated in Figure 11:

Phase 1: establish the context

This involves, 'studying rainfall and runoff, and identifying catchment conditions that may lead to increased run-off and possible flooding; Assessing the flood and erosion hazard (describing the hazard); Reviewing existing flood and erosion hazard management; Considering present and future uses of the floodplain, such as housing, recreational, commercial, or agricultural development; Considering the impact on environmental factors such as the habitats and ecosystems that exist on the floodplain and in the corresponding river systems; Identifying landscape, recreational and community values; Identifying potential damages on the floodplain,'(Greater Wellington Regional Council 2011b).

Phase 2: understand the risk and treatment options

This involves, 'identifying all possible practical solutions to help control the flood hazard. Once a number of options have been identified, combinations of non-structural and structural measures for managing the flood risk are usually possible. These should look at managing the risk over the full flood risk spectrum i.e. from an annual event to an extreme event,' (Greater Wellington Regional Council 2011b).

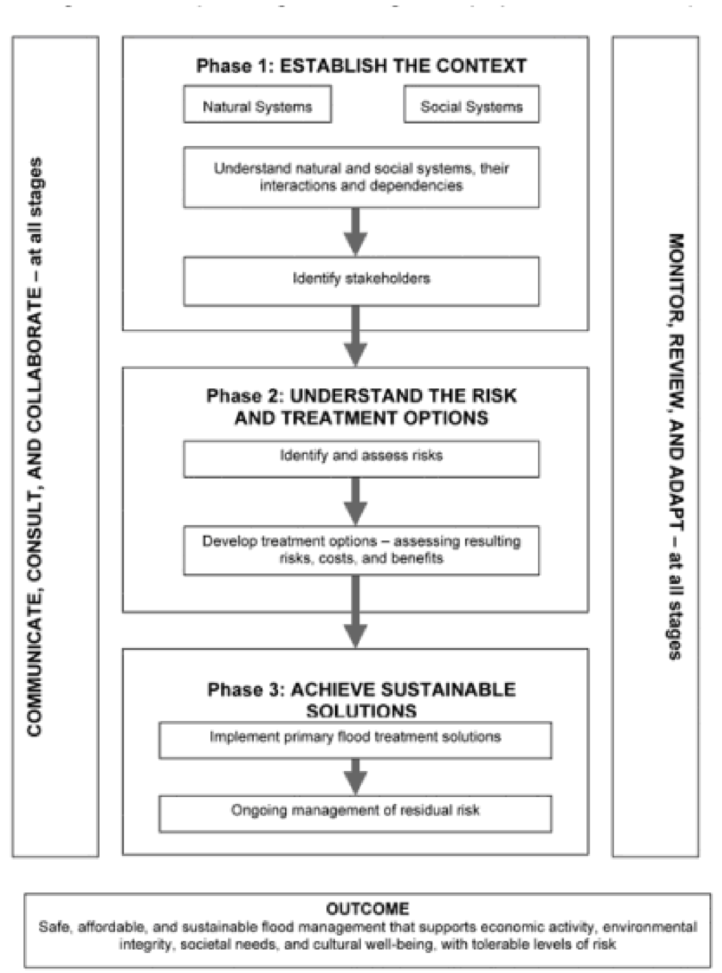

Figure 11: New Zealand floodplain management planning process (Greater Wellington Regional Council 2011b).

Phase 3: achieve sustainable solutions

This involves selecting, 'a preferred option after looking at non-structural options, the cost of any construction work, the level of flood risk that results, and the social and environmental effects. This forms the basis of the final floodplain management plan. These plans are then either endorsed and carried forward or not, depending on the degree of support from the local and wider community,' (Greater Wellington Regional Council 2011b).

At a local level, district councils are responsible for land-use planning, determining and regulating building controls, and informing their communities of flood risk (Ministry for the Environment 2008b).

2.6 Australia

Flooding in Australia poses a significant risk with over 122,300 properties prone to mainstream flooding and average annual damages totalling an estimated $314m annually (BTE 2001). To address this flood risk, the Australian government has guidelines, state legislation and program delivery on a federal, state and local level.

2.6.1 Primary legislation, policies and strategy

There is no federal legislation that deals with, or addresses, floodplain risk management in Australia. The federal government has instead developed broad guidelines on appropriate land use, floodplain management and warning systems. These national guidelines are largely contained in Managing the Floodplain: A guide to best practice in flood risk management in Australia (AEMI 2013b), and the predecessor guidelines Floodplain Management in Australia: Best Practices and Guidelines (SCARM 2000). Managing the Floodplain (2013) aims, 'to encourage practice that works towards the following vision flood risk management in Australia: Floodplains are strategically managed for the sustainable long-term benefit of the community and the environment and to improve community resilience for floods,' (AEMI 2013b). The Floodplain Management in Australia: Best Practices and Guidelines, 'aims to provide a set of best practice principles and guidelines for the management of the risks associated with flooding across the floodplains of Australia,' (SCARM 2000).

Managing the Floodplain: A guide to best practice in flood risk management in Australia (2013) establishes a list of key best practice flood risk management principles from which a framework is explored (Figure 12)(AEMI 2013b). The presented principles are: 1) A cooperative approach to manage flood risk; 2) A risk management approach; 3) A pro-active approach; 4) A consultative approach; 5) An informed approach; 6) Supporting informed decisions; 7) recognition that all flood risk cannot be eliminated; 8) Recognition of individual responsibility. The document then provides, 'broad advice on all important aspects in managing flood risk in Australia,' including establishing the roles and responsibilities and guidance on understanding flood behaviour, flood risk and treatment (AEMI, 2013b).

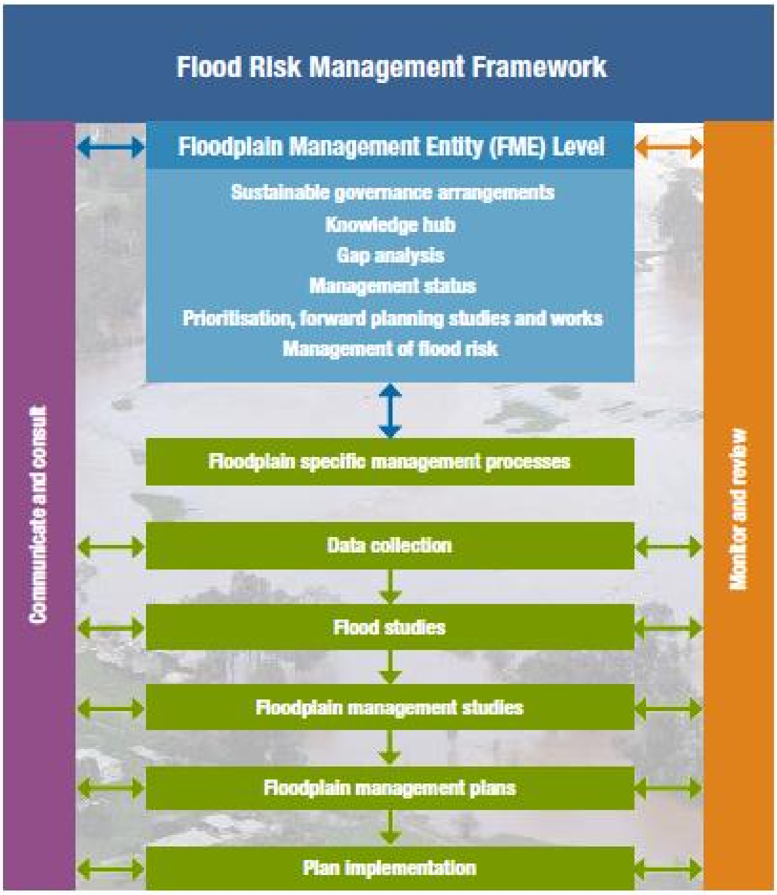

Figure 12: Australia's best practice flood risk management framework (AEMI 2013b).

Floodplain Management in Australia: Best practice and Guidelines (2000), similarly provides a range of floodplain management principals. These principles slightly different to principles contained in Managing the Floodplain (2013) are;

1) A *pro-active response,* i.e. floodplain management needs to be a proactive approach rather than a reactive approach;

2) *Community expectations*, i.e. 'the community can expect that floodplains will be developed and used in an ecologically, economically and socially sustainable fashion in accord with the broader principles of sustainable natural resource and environment management and of integrated or total catchment management';

3) *Policy integration and implementation*, i.e. effective policy and legislation provides a 'reliable social and legal foundation for floodplain management';

4) *The flood problem*, i.e. recognise that there are three distinct flood problems: Existing, Future and Residual.

5) *Risk awareness*, i.e. 'the local community needs to understand and appreciate the concept of flood risk and exposure to flood hazard';

6) *The floodplain management plan*, i.e the development of, ‘a comprehensive planning process to develop a floodplain management plan is the most effective and equitable way to realise the multiple objectives of floodplain management’;

7) *The flood emergency plan*, i.e. the, ‘preparation of a flood emergency plan encompassing flood warning, defence, evacuation, clean-up and recovery arrangements is the most effective way to address the residual risks associated with floods’;

8) *Appropriate land uses*, i.e. ‘land use needs to be matched carefully to flood hazard to both minimise the risks and consequences of flooding’;

9) *Flood maps*, i.e. ‘flood maps that show the extent, depth, velocity and hazard of flooding for nominated flood events are an important tools for the preparation of floodplain management plans and emergency management plans’;

10) *Floodplain management measures*, i.e. ‘an integrated and appropriate mix of measures needs to be developed for each specific floodplain area including land use planning, structural measures, development and building controls and flood emergency plans’;

11) *Urban infrastructure*, i.e. ‘urban infrastructure needs to be designed to minimise the effects of flooding on their operation and to facilitate clean-up and recovery, essential facilities… be sited in flood free locations or above PMF level, or failing this be protected with permanent or temporary banks’;

12) *Performance indicators and data collection*, i.e ‘collecting appropriate data concerning flood behaviour and flood hazard to provide an objective basis for the design and assessment of floodplain management programs,’(SCARM 2000).

In order to achieve these principles, a floodplain management framework is presented (Figure 13). The formulation of the framework in conjunction with the planning system and emergency management system entails: 1) Establishing a floodplain management advisory committee; 2) Carrying out a flood study; 3) Carrying outing a floodplain management study and plan; 4) Adopting a management plan; and 5) Implementing the system (SCARM 2000).

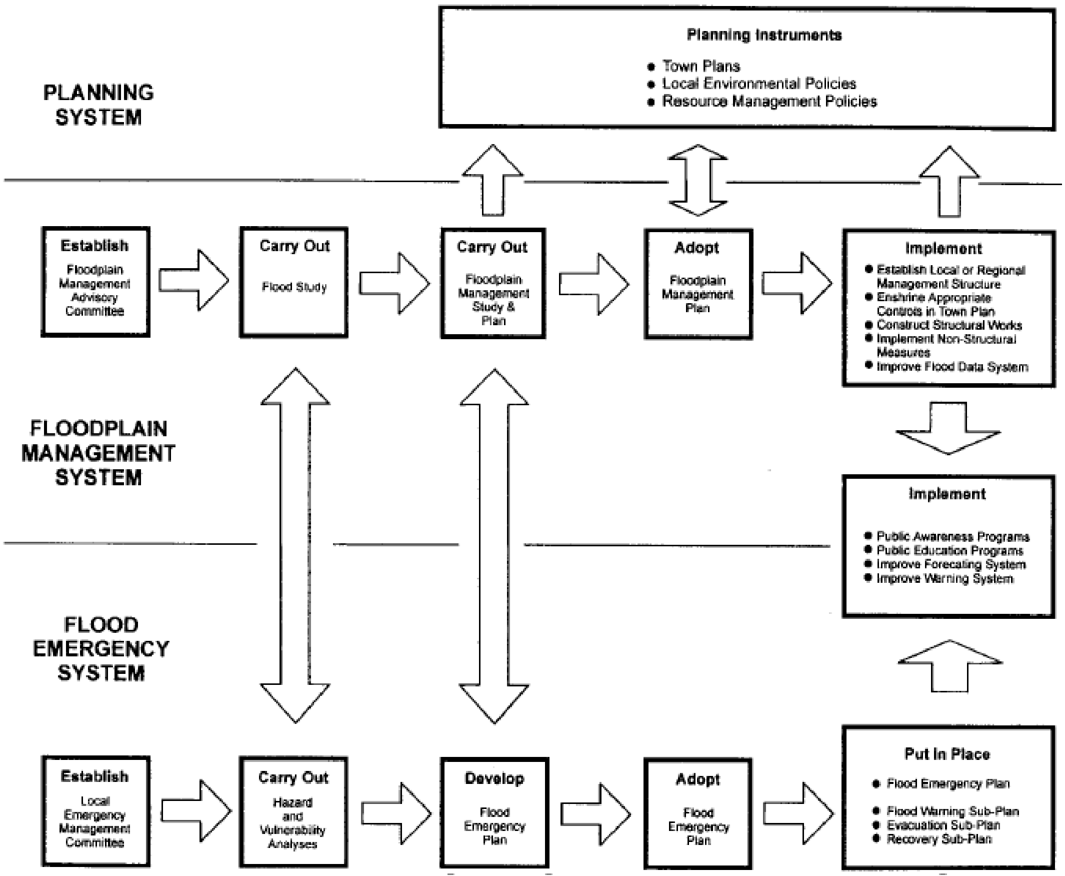

Figure 13: Relationship between the statutory planning, floodplain management and flood emergency management process (SCARM 2000).

A further set of guidelines published at a federal level that deal with broad hazard management are the National Emergency Risk Assessment Guidelines (Australian Emergency Management Committee 2009). These guidelines aim to, ‘improve the consistency and rigour of emergency risk assessments, increase the quality and comparability of information on risk and improve the national evidence-base on emergency risks in Australia’. The documented stages by which this is achieved are: 1) Establish the context, 2) Identify risks, 3) Analyse risks, 4) Evaluate risks, and 5) Treat risks. At each stage, a range of tools and outcomes are recommended. The summated recommended outcomes are:

Stage 1: Objectives, scope, stakeholders, criteria, key elements; Ensure there is enough time required for the risk assessment; A sufficient pool of expertise involved in the risk assessment; Sufficient information collected for the risk assessment;

Stage 2: Develop impact potentials from which a bow-tie diagram can be established for example figure 14; A summary of risks associated with the

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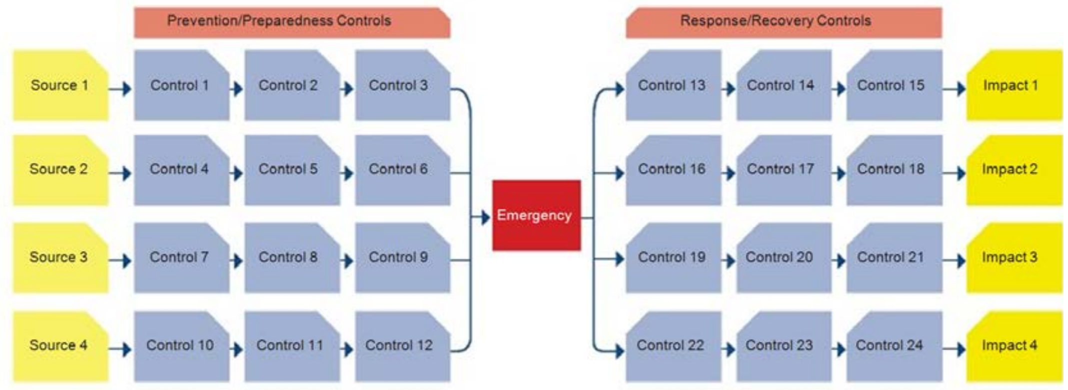


Figure 14: Example of bow-tie diagram (Australian Emergency Management Committee 2009).

light of the relevant events; A summary of existing prevention and preparedness factors; A summary of existing response and recovery factors; Feeding the information into the risk register.

Stage 3: Rate existing controls; Assign consequence and likelihood ratings to each risk and determine the risk level; Determine risk curves, for example figure 15; Summary of confidence conclusions for events; Integrate the determined information into the risk register.

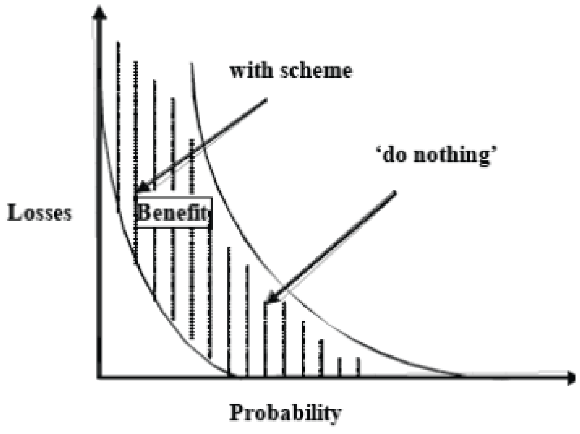


Figure 15: Example of risk curve with and without flood management scheme (Scotland Government 2009).

Stage 4: Apply ALARP to determine tolerability; Examine objectives which support risk assessment and treatment; Summary fed into risk register; Stage 5 outcomes recommended are: Analysis of risk treatment options, completed risk register, establish monitor and review procedures (Australian Emergency Management Committee 2009).

Flood risk management legislation, policies and programs vary between state and territory jurisdictions. A detailed analysis of Australian state and territory legislation and strategies is documented in the preceding subchapters 2.7 to 2.13.

Correspondingly, local authorities have varying flood policies based on addressing their respective state legislation and policy requirements.

2.6.2 Roles, responsibilities and programs

The federal government has the primary responsibility of developing guidelines and strategies for floodplain and emergency management, providing financial assistance under the Natural Disaster Resilience Program and Natural Disaster Relief and Recovery Arrangements, providing defence force personnel and equipment to assist in evacuation operations, providing weather forecasting services, and collecting imagery, topography, and national flood exposure data (AEMI 2013b; SCARM 2000).

The Australian Attorney-General's Department is responsible for coordinating central policies and systems for law and justice, national security, emergency management, disaster resilience and relief (AAGD 2014a). Their programs include the Natural Disaster Resilience Program and the Natural Disaster Relief and Recovery Arrangements. The Natural Resilience Program is established to provide funding to States and Territories for disaster mitigation works and support for emergency management across all natural hazards including flood (AAGD 2011a). The Natural Disaster Relief and Recovery Arrangements provides financial assistance to states and territories for disaster recovery costs (AAGD 2014a).

The Bureau of Meteorology is responsible for monitoring weather systems likely to develop flood producing rainfall, providing flood level forecasts, and issuing flood warnings (AAGD 2011a). Their programs include establishing national weather instrumentation, some rainfall gauges and river gauging networks and maintaining and managing weather and climate data (BOM 2014).

The state government has the principal role, 'to develop appropriate standards and strategic approaches for floodplain management and to ensure they are applied in a coordinated and integrated fashion across the state,' this includes having a, 'lead-role in fostering and assisting with the development and implementation of floodplain management plans,' (SCARM 2000). The state also has a role and responsibility in funding damage reduction measures and flood relief, providing technical advice to local agencies via water resources authorities, state planning agencies or counter disaster and welfare services, as well as, 'recording flood data and damage data on a

state-wide basis to facilitate their use for management purposes,' (Australian Department of Primary Industries 1992). Furthermore, it is recommended that each state and territory support effective land-use planning; development and building controls; lead flood emergency management planning and response; and develop and maintain information systems to support decision making (AEMI 2013b).

Local government or direct management agencies in some jurisdictions (that is Catchment Management Authorities) have the role of implementing floodplain management strategies, promoting flood awareness, incorporating the planning provisions of floodplain management plans into statutory planning instruments, collecting flood data after a flood event, maintaining floodplain management measures such as structural mitigation measures, planning measures, flood plans etc. and assisting in flood warning, evacuation and flood recovery (AEMI 2013b; SCARM 2000).

2.7 Australia – New South Wales

More than 110,000 properties are prone to flooding in New South Wales with average annual damages totalling $128.4 million (BTE 2001). To address the risk and losses associated with flooding, the NSW Government has a comprehensive flood risk management process which comprises state legislation, policies, guidelines, local policies and controls and state and local programs.

2.7.1 Primary legislation, policies and strategy

The primary pieces of legislation managing flood risk in New South Wales are the Environmental, Planning and Assessment Act 1979, and the Water Act 1912. The Environmental, Planning and Assessment Act specifies the roles and responsibilities of the three levels of government and sets out the controls and assessments determining development in NSW (DIPNR 2005). Under part 6, section 117, the Act allows the, 'Minister for Planning to issue directions that relevant planning authorities such as local councils must follow when preparing planning proposals,' (DIPNR 2005). Of relevance to flood management is the ministers' flood prone land direction No.15. This directive sets out to, '1) ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual, 2005. 2) ensure that the provisions of a Local Environment Plan (LEP) on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land,'

(NSW DoP 2007). Another important aspect of the Environmental, Planning and Assessment Act is the issuance of Planning Certificates under Section 149 for potential purchasers of property sold in NSW. Under this Act, in conjunction with the Environmental Planning and Assessment Regulation 2000 Schedule 4, Councils are to provide information detailing flood related development controls imposed by policies adopted by council on these planning certificates for land subject to flooding. This provides a, 'supplementary means of informing prospective purchasers of the nature and extent of flood risk for a property,' (DIPNR 2005).

The Water Act 1912 is of significance for rural floodplain management. This Act allows for the preparation and adoption of strategic floodplain management plans (section 166A of part 8), determines responsibility for assessing complying and non-complying floodplain structures (section 171 of part 8) and provides authority for the state government to issue stop work and rehabilitation notices (section 180B of part 8)(New South Wales Government 1912).

Another important piece of NSW legislation is the Local Government Act 1993. This Act clarifies the role of local governments in floodplain management, providing general statutory functions and powers to, 'take measures to protect its area from hazards,' however local government, 'have regard for and give due weight to policies, plans and objectives of the other spheres of government,' (NSW Government 1993). Other relevant legislation includes the Fisheries Management Act 1994, the State Emergency Services Act 1989 and the State Emergency and Rescue Management Act 1989.

The defining floodplain management state policy is the NSW Flood Prone Land Policy 2005. This policy aims to, 'reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible,' (DIPNR 2005). This policy states:

> 'a merit approach shall be adopted for all development decisions in the floodplain to take into account social, economic and ecological factors, as well as flooding considerations; both mainstream and overland flooding shall be addressed, using the merit based approach, in preparation and implementation by councils of strategically generated floodplain risk management plans; the impact of flooding and flood liability on existing developed areas identified in floodplain risk management plans shall be

reduced by flood mitigation works and measures, including in-going emergency management measure, the raising of houses where appropriate and by development controls and the potential for flood losses in all areas proposed for development or redevelopment shall be contained by the application of ecologically sensitive planning and development controls,' (DIPNR 2005).

To support the Flood Prone Land Policy 2005, the state has produced the Floodplain Development Manual: the management of flood liable land (DIPNR 2005). This manual provides, 'a process for floodplain risk management to enable councils and their floodplain risk management committees to understand flood behaviour and impacts'. This process closely follows the national best practice process being undertaken via: 1) data collection; 2) flood study; 3) floodplain risk management study; 4) floodplain risk management plan; 5) plan implementation and overseen by a Floodplain Risk Management Committee. The manual also highlights the importance of analysing flood events up to the Possible Maximum Flood (PMF), as it, 'provides an upper bound of flood behaviour and consequences for emergency response planning. It can identify critical factors, such as key levels for loss of evacuation routes and inundation of entire areas, so that appropriate emergency response and recovery planning and community education programs can be developed,' (DIPNR 2005). The manual further provides advice on flood planning levels, hydraulic and hazard categorisation, and flood damage calculations (DIPNR 2005).

Supplementary to the Floodplain Development Manual, the state has produced a range of supporting guidelines. These include: Temporary or relocatable flood barriers; Rainwater tanks – limitations as floodplain risk management devices; Drainage behind and through levees; Flood emergency response planning classification of communities; SES requirements from the floodplain risk management process; Residential Flood Damage and supporting calculation spreadsheet; and Practical consideration of climate change guidelines (NSW Office of Environment and Heritage 2011).

Local governments currently (although under review) have Local Environmental Plans (LEP) as statutory instruments to manage flood risk in their communities though identified flood overlays. These plans are intended to establish the requirements for the use and development of land within their Local Government Area (NSW Government 2008). In addition, local councils have varying non-statutory Development Control Plans (DCPs) with incorporated flood policy statements and

endorsed floodplain management plans as mechanisms to manage flood risk in their LGA. For example, the Wollongong Local Governments LEP prescribes that flood planning areas are:

> ‘(a) to maintain the existing flood regime and flow conveyance capacity,
> (b) to enable evacuation from land to which this clause applies,
> (c) to avoid significant adverse impacts on flood behaviour,
> (d) to avoid significant effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses,
> (e) to limit uses to those compatible with flow conveyance function and flood hazard.
> This clause applies to land at or below the flood planning level.
>
> Development consent must not be granted for development on land to which this clause applies unless the consent authority is satisfied in relation to all the following matters:
> (a) all habitable floor levels of the development will be above the flood planning level,
> (b) the development will not adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties,
> (c) the development will not significantly alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain,
> (d) the development will not affect evacuation from the land,
> (e) the development will not significantly detrimentally affect the floodplain environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses,
> (f) the development will not result in unsustainable social and economic costs to the community as a consequence of flooding,
> (g) if located in a floodway area-the development will not be incompatible with the flow conveyance function of, or increase a flood hazard in, the floodway area,’ (NSW Government 2009).

The Wollongong Local Governments flood related Development Control Plan (DCP) Chapter E13 for example, provides objectives and a comprehensive guideline for the design of structures within floodplains. This includes the establishing flood precincts and building and evacuation standards that apply to these precincts. For example, Figure 16 documents the standards that apply to development within the Towradgi Creek Floodplain (Wollongong City Council 2009).

SCHEDULE 1: PRESCRIPTIVE CONTROLS – TOWRADGI CREEK FLOOPLAIN

	Flood Risk Precincts (FRP's)																							
	Low Flood Risk								Medium Flood Risk								High Flood Risk (& Interim Riverine Corridor)							
Planning Consideration	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3										2,6 or 7	2 or 5	2	1	2,4 6							1	2,4 6
Building Components		2										1	1	1	1	1							1	1
Structural Soundness		3		2		3						2	2	3	2	2							1	1
Flood Affectation		2	2		2	2					1	1 or 2	1	1	1	2							1	1
Evacuation		2, 4	5	3, 4	4	3, 4					5	3,4	1,4	3,4	1	1 or 3							1	1 or 3
Management & Design		4, 5	1								1		2,3 5	2,3 5	2,3 5	2,3 5							2,3 5	2,3 5

	Not Relevant		Unsuitable Land Use

Figure 16: Example of Wollongong Councils flood related development controls applying to flood risk precincts (Wollongong City Council 2009).

2.7.2 Roles, responsibilities and programs

The primary role and responsibilities of the New South Wales government in relation to floodplain management are to: 1) develop legislation and strategy; 2) provide broad policy direction; 3) provide specialised technical advice; 4) provide financial assistance; 5) undertake emergency management services; and 6) assist in flood warning and communication (DIPNR 2005). The primary state government agencies that undertake these roles and responsibilities are the NSW Office of Environment and Heritage, NSW Office of Water, NSW State Emergency Service and the NSW Department of Planning and Environment.

The role of the Office of Environment and Heritage (OEH) in floodplain risk management varies across the state. In areas not designated under part 8 of the Water Act 1912, the flood related roles and responsibilities of OEH are to: 1) provide a lead role in setting and supporting best practice in the management of flood risk at a state level; 2) collect and maintain flood data; 2) assist local government with the

preparation and implementation of floodplain management studies and plans; 3) assist local government with the implementation of mitigation measures; 4) advise and assist local government on the evaluation of significant development proposals; 5) provide technical advice to other agencies and other OEH areas on flood risk management to assist in meeting their responsibilities in areas that overlap such as land-use planning processes, flood data collection, flood warning, public infrastructure and emergency management; 6) provide flood-gauging data for coastal areas via the Manly Hydraulics Laboratory; and 7) administer floodplain management programs including financial assistance provided by the NSW Ministry of Police and Emergency Services under the Commonwealth Natural Disaster Resilience Program (NSW OEH 2011). In areas designated under part 8 of the Water Act 1912, the OEH has the delegated statutory role and responsibility to: 1) prepare flood management plans that form the basis for assessing controlled works; 2) collect and maintain flood data; 3) provide technical floodplain management advice; and 4) assist the Office of Water in assessing and deterring floodplain management works under Part 8 of the Water Act 1912 (DIPNR 2005). OEH's primary floodplain management program provides local government financial and technical support to prepare and implement flood risk management plans. The program generally contributes $2 for every $1 provided by local government as long as studies, works and plans are prepared in accordance with the NSW Floodplain Development Manual (2005) and the floodplain management process contained in Figure 17.

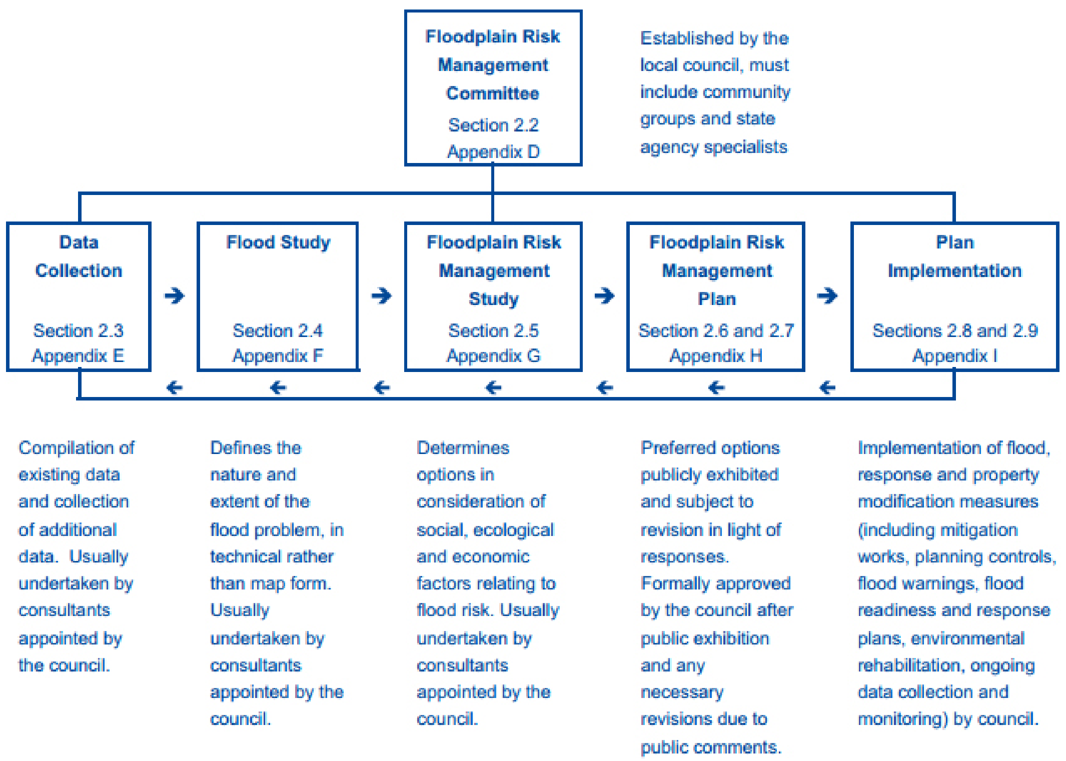


Figure 17: NSW floodplain management process (DIPNR 2005).

The Office of Water floodplain management roles and responsibilities are associated to rural areas designated under part 8 of the Water Act (NSW NOW 2011). These roles and responsibilities are to: 1) assess complying and non-complying floodplain structures; 2) issue stop work and rehabilitation notices; and 3) develop legislation and strategy (NSW NOW 2011).

The Ministry of Police and Emergency Services floodplain management roles and responsibilities are associated with emergency management policy, financial assistance and flood recovery (NSW SES 2011). The NSW State Emergency Services (SES), under the Ministry, is the designated combat agency for dealing with floods. As a result the flood related roles and responsibilities of the SES are to: 1) facilitate emergency planning; 2) coordinate the development of local disaster plans and state disaster plans; 3) develop flood warning procedures, establish flood warning systems and undertake flood warning communication; and 4) carry out emergency management response and recovery (NSW SES 2011). Financial assistance provided through the Commonwealth Natural Disaster Resilience Program is delegated to the OEH for administration through the NSW Floodplain Management Program.

The Department of Planning and Environments' flood related roles and responsibilities are to: 1) develop legislation, state planning policies and planning directives including flood prone land directives and policies 2) Assess and provide guidance to local councils with the development of LEPs, and 3) develop regional planning strategies (NSW DoP 2011).

Local government councils hold the primary responsibility of floodplain management in New South Wales under the Local Government Act 1993 and Environmental and Assessment Act 1979. Councils' role and responsibilities are to: 1) implement floodplain management strategies through Local Environmental Plans, and Development Control Plans; 2) facilitate flood management studies and plans; 3) raise funding; 4) investigate, design, construct and maintain flood mitigation works; 5) assist in emergency management and community education; and 6) undertake post flood appraisals (DIPNR 2005).

2.8 Australia – Northern Territory

It is estimated that around 3,000 properties are prone to flooding in the Northern Territory, with average annual damages totalling $8.1 million (BTE 2001). As a result, the territory has legislation and programs to reduce the impacts of flooding.

2.8.1 Primary legislation, policies and strategy

The primary piece of legislation applying to floodplain management is the Water Act 1992. This Act provides for the, 'declaration of Water Control Districts in areas where there is a need for enhanced management to avoid stressing of groundwater reserves, river flows or wetlands,' (Northern Territory Government 1992). Under section 34 of this Act, 'to enable effective planning for water resource development and environmental protection, it is the duty of the Controller to ensure as far as possible that a continuous program for the assessment of water resources of the Territory is carried out, including the investigation collection, collation and analysis of data concerning the occurrence, volume, flow, characteristics, quality, flood potential and use of water resources,' (Northern Territory Government 1992). This includes undertaking floodplain management plans and assessments (DNREAS 2010).

The Planning Act 2009 also has a role in floodplain management throughout the Territory by providing for the establishment of Northern Territory Planning Scheme (NT Department of Lands and Planning 2011). Under the General Performance Criteria of the Northern Territory Planning Scheme, flood management is addressed to a planning degree via the 'Land subject to Flooding and Storm Surge' clause 6.14. This clause as it states, aims, 'to reduce risk to people, damage to property and costs to the general community caused by flooding and storm surge'. It does this by defining the minimum habitable floor level as 300mm above the design flood area and the, 'use of fill to achieve required floor levels should be avoided'. Under this clause, the design flood area is, 'i) in an area subject to a floodplain management plan that defines a flood event, is as specified in that plan; or ii) if there is no floodplain management plan that defines a flood event for an area, is the 1% Annual Exceedance Probability (AEP) flood event,' (NT Department of Lands and Planning 2011).

The local government has no floodplain management related legislative powers in the territory, but is required to both assist with emergency management and recovery post flooding (LGANT 2014). This is a unique approach considering the local

government’s powers and functions in relation to services and maintenance such as storm water infrastructure.

2.8.2 Roles, responsibilities and programs

The territory government has the primary responsibility of floodplain risk management. There are four lead bodies that undertake these duties. These are the Department of Lands and Planning, the Development Consent Authority, the Northern Territory Emergency Services, and the Department of Natural Resources, Environment and The Arts (NRETA) respectively.

The Northern Territory Department of Lands and Planning’s primary flood related roles and responsibilities are to: 1) develop legislation, guidelines and legislative arrangements regarding land development in floodplain areas; 2) provide strategic planning and growth frameworks; 3) provide floodplain mapping programs related to developments in floodplains; and 4) provide technical support to the Development Consent Authority (Rajaratnam 2009).

The primary flood related role and responsibility of the Development Consent Authority is to determine development applications with respect to the Planning Act 2009 and Northern Territory Planning Scheme (Northern Territory Government 2011).

The Northern Territory Emergency Services’ primary flood related roles and responsibilities are to: 1) Develop flood warning procedures and undertake flood warning communication; 2) Undertake flood risk mapping with technical assistance provided by NT Department of Natural Resources, Environment and The Arts (NRETA); 3) Implement flood public awareness and education programs; 4) Review and refine emergency preparedness and post-flood recovery planning; and 5) Administer the NT Natural Disaster Resilience Program (Northern Territory Emergency Services 2011; Rajaratnam 2009). This program provides monies from the Territory and Commonwealth for the construction of mitigation works and emergency management (Rajaratnam 2009).

The primary flood related roles and responsibilities of Land and Water Division of the NRETA are to: 1) Administrator and regulate the NT Water Act 1992 involving commissioning flood management studies and assessments; 2) Operate and maintain flood warning monitoring sites (river height and rainfall recorders) in selected

catchments; 3) Provide flood forecasting with the support of the Bureau of Meteorology 3) Develop flood forecast models 4) Provide flood related technical assistance (NRETA 2011).

2.9 Australia – Queensland

As recently witnessed with widespread flooding in both 2011 and 2013 (claiming 33 lives, 15.7 billion in economic losses and 10 billion in reconstruction costs), Queensland has a significant exposure to flood risk (Queensland Floods Commission 2012; World Bank 2011; IBISWorld 2011). It has been identified that more than 65,000 properties are prone to flooding in Queensland during a 1 % AEP flood event, with annual average damages totalling $111.7M (Jayasinghe 2009; BTE 2001). The flood risk management process comprises state legislation, guidelines and programs, and local schemes and practices.

2.9.1 Primary legislation, policies and strategy

The primary state legislation applying to floodplain management is the Sustainable Planning Act 2009 (SPA 2009). The SPA 2009 is Queensland's principal planning legislation that coordinates planning at the local, regional and state levels. Under this Act numerous plans are to be developed including regional plans, master drainage plans, and infrastructure plans under varying circumstances. In reference to floodplain management priority infrastructure plans, master drainage plans and floodplain management plans are to be developed in consideration of major drainage and flood mitigation elements (Queensland Government 2009). The SPA 2009 requires local government to ensure floodplain management matters are reflected in planning schemes and that natural hazard management areas (flood) are mapped (Queensland Government 2009).

To achieve this, the State Planning Policy (SPP) 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide was developed (Queensland SPP 2003). This SPP aims to ensure that natural hazards including flood are adequately considered when making decisions about certain development. Under this policy the SPP sets out the state's position that 'generally, the appropriate flood event for determining a natural hazard management area (flood) is the 1 % AEP (Queensland SPP 2003). However, the SPP recognises that the adoption of a lower DFE may be appropriate depending on the circumstances of individual localities, 'The adoption of a lower Defined Flood Event (DFE) would require the local government to demonstrate by thorough analysis

that the proposed level of flood protection is appropriate to the circumstances of the locality,' (Queensland SPP 2003).

Other Queensland legislation that relates to flood risk management include: the Queensland Reconstruction Authority Bill 2011, the Local Government Act 2009, Plumbing and Drainage Act 2002, the Building Act 1975, the Disaster Management Act 2003, the Environmental Protection Act 1994 the Water Act 2000, and statutory regional plans. Besides the Queensland Reconstruction Authority Bill 2011, these Acts, in reference to floodplain management, primarily relate to local governments' roles and responsibilities detailed subsequently. Of interesting note, under section 577 of the Water Act 2000, a water authority has power to take any land to which the Acquisition of Land Act or Land Act apply for drainage purposes (Queensland DERM 2010).

Following the 2011 floods, the Queensland reconstruction Authority was formed to 'reconnect. rebuild and improve Queensland communities and its economy,' (Queensland Government 2014a). Since formation they have released a number of guidelines and plans in relation to floodplain management, land use planning and reconstruction. Two important floodplain management documents are 'Planning for stronger, more resilient floodplains Part 1: Interim measures to support floodplain management in existing planning schemes' and 'Planning for stronger, more resilient floodplains Part 2: Measures to support floodplain management in future planning schemes,' (Queensland Government 2014b). These documents outline a floodplain management process as illustrated in Figure 18 in involving: '1) Flood study – a technical document to determine the nature and extent of flooding; 2) Floodplain Risk Management Study – an options assessment which evaluates management measures and options for the floodplain in respect to both existing and future

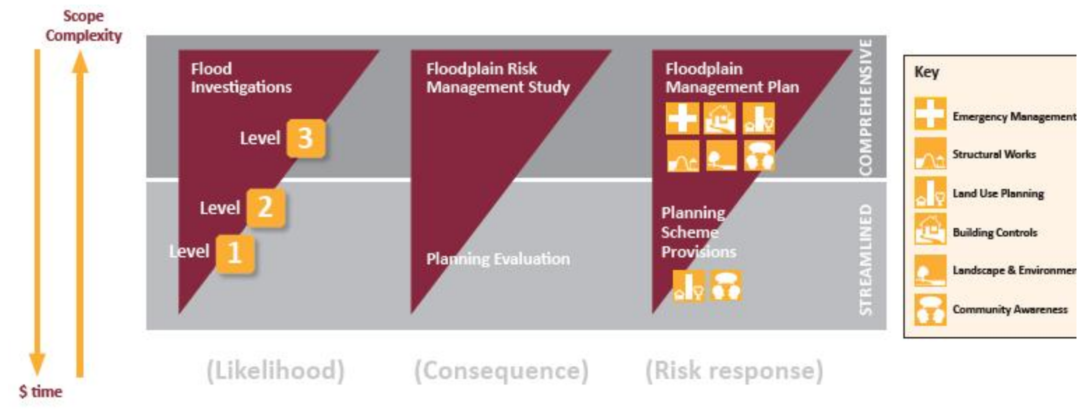


Figure 18: Queensland flood risk management process (QRA 2012a).

development; and 3) Floodplain Management Plan – formal adoption of a plan of management for the floodplain,' (QRA 2012a).

A further state guideline for floodplain management in Queensland, is the Queensland Urban Drainage Manual 2007. This document: outlines the objectives of urban stormwater management; highlights the planning tasks local governments should undertake to develop a stormwater strategy for their area including how they co-exist (Figure 19); lists the latest legislative requirements and legal issues applicable to stormwater management; expanding the discussion on planning considerations for stormwater projects; provides discussion on environmental considerations; provides recognition and guidance on 'soft' engineering approaches including the use and design of vegetated drainage channels; provides broad guidance on the application of stormwater quality measures on small projects where it is impractical to conduct detailed water quality modelling; and provides a rational approach to the management of the public safety risk associated with stormwater stormwater systems (Queensland DNWR 2007).

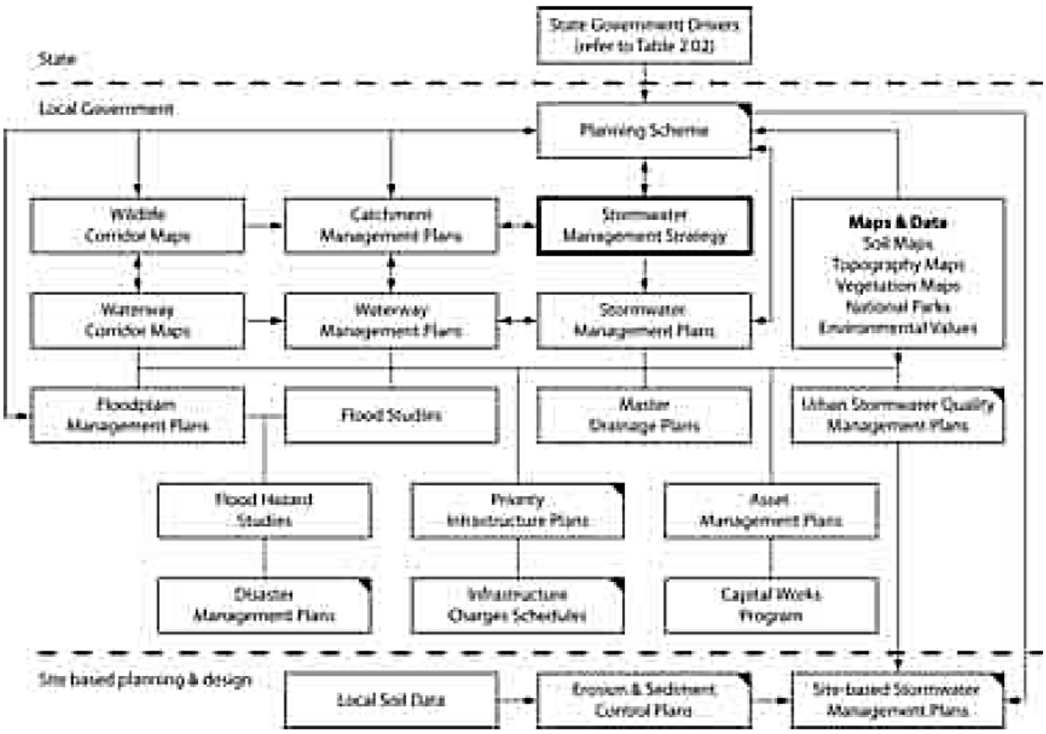


Figure 19: Linkage between plans (Queensland DNRW 2007)

Local government has local planning schemes as statutory instruments to manage flood risk in their communities (Queensland DERM 2010). These schemes involve codes that are applicable to the subject development. The model code for development located within the floodplain is documented in the Planning for stronger,

more resilient floodplains Part 2: Measures to support floodplain management in future planning schemes' guidelines with the codes' purpose being, 'to manage development outcomes in the floodplain so that the risk to life, property, community and the environment during future flood events is minimised and to ensure that development does not increase the potential for flood damage on site or to other property,' (QRA 2014b).

2.9.2 Roles, responsibilities and programs

The Queensland government has the primary responsibility of developing state land-use planning legislation, providing funding for flood studies and mitigation works, approving certain works in watercourses, developing state and district counter-disaster plans, and undertaking emergency services such as responding to and recovering from natural disasters. The primary agencies that undertake these responsibilities are the Department of Communities, Department of Community Safety, Department of Infrastructure and Planning, Department of Environment and Resource Management and the Queensland Reconstruction Authority.

The roles and responsibilities of the Department of Communities in relation to floodplain management are to: 1) Coordinate community recovery efforts after disasters, this includes the provision of short, medium and longer term recovery strategies and services. 2) Coordinate media communication during flood events 3) Conduct disaster management training and exercises; 4) Facilitate flood event mapping during an event to assist in response planning 4) Coordinate deployment of temporary flood barriers and 5) Administer the Commonwealth National Disaster management Program (NDMP) for Queensland (Queensland DERM 2010).

The roles and responsibilities of the Department of Community Safety in relation to floodplain management are to: 1) Administer flood mitigation funding available to local governments; 2) Coordinate through Emergency Management Queensland Natural Disaster Relief and Recovery Arrangements including the South West Queensland Flood Mitigation Fund 3) Compile and manage the state and local hazard profile; 4) Review state and national flood related guidelines and 5) Administer the Disaster Management Act involving ensuring local government have prepared local disaster management plans for their communities (Queensland Government 2013; Queensland DERM 2010).

The Department of Infrastructure and Planning's (DIP) primary responsibility in flood management is to develop and maintain legislation and regulatory frameworks through the Sustainable Planning Act (2009), the Building Act, the Local Government Act and associated statutory instruments and plans including SPP 1/03. This legislation obligates local council to prepare planning schemes in consideration of SPP 1/03 which precludes development from flood proven areas; sets habitable floor levels in designated natural hazard management areas; and allows local government the ability to construct and levy charges for infrastructure including flood mitigation works. The DIP also administer the Natural Disaster Relief and Recovery Arrangements, the floodplain security scheme and the Regional Flood Mitigation Program (Queensland Government 2013; Queensland DERM 2010).

The roles and responsibilities of the Department of Environment and Resource Management in relation to floodplain management are to: 1) Maintain the physical integrity of watercourses and lakes, 2) Collect data and operate a network flow gauging and rainfall stations, 3) Provide technical agency advice to the SPP 1/03 and the Urban Drainage Manual (Queensland DERM 2010).

The Queensland Reconstruction Authority's roles and responsibilities in relation to floodplain management are to: 1) coordinate and implement the state plan across government agencies including overseeing the reconstruction of essential public assets within disaster affected communities; undertake state-wide floodplain mapping to support local government planning schemes; review river in rainfall gauging networks in partnership with key stakeholders (QRA 2014a). Moreover, the Queensland Flood Commission of Inquiry recommended that the authority lead flood studies for urban areas, model flood planning controls and lead publication of flood information (Queensland Floods Commission 2012; QRA 2014b).

Although the state has a significant role in floodplain management after 2011, the local government still retains the primary responsibility for flood risk management in Queensland (Queensland Floods Commission 2012). The roles and responsibilities ultimately include: 1) assessing flood risk; 2) determining local investment priorities; 3) determining land-use planning: 4) undertaking development approvals: 5) planning, joint-funding and implementing flood mitigation measures; and 6) developing stormwater management programs (Jayasinghe 2009).

2.10 Australia – South Australia

More than 8,500 properties are prone to flooding in South Australia with average annual damages totalling $18.1 million (Pikusa 2013; BTE 2001). To address the risk and losses associated with flooding, the state has a stormwater/flood risk management process which comprises state legislation, policies and guidelines, as well as local policies and controls and programs on a state and local level.

2.10.1 Primary legislation, policies and strategy

The primary legislation managing flood risk in South Australia is the Water Resources Act 1997. This legislation sets out the statutory responsibilities of Catchment Water Management Boards and Local Government. Under this Act, Catchment Water Management Plans (CWMPs) are to be prepared by Catchment Water Management Boards addressing a range of water management issues including flood risk. These plans on competition have the statutory ability to effect changes in land-use policies through amendments to the relevant councils' development plans. The Act also details local governments responsible for providing flood protection and mitigation during flood emergencies (South Australian Government 1997).

The Development Act 1993 is a secondary piece of legislation that addresses flood risk. Flood risk management is achieved through this Act via enabling local government to develop policies that control development, including the adoption of flood risk management development policies. The key responsibility for the administration of the Development Act 1993 lies with the relevant council and as a result, councils have the power to amend the policies in its development plan. Under this Act, local government is the relevant authority for issuing approval for development activities (South Australian Government 1993).

The Local Government Act 1999 further clarifies local governments' role in floodplain management providing general statutory functions and powers to, 'take measures to protect its area from hazards,' however local government, 'have regard for and give due weight to policies, plans and objectives of the other spheres of government,' (South Australian Government 1999).

Other relevant legislation includes the South Western Suburbs Drainage Act 1959, the Natural Resources Management Act 2004, and the Fire and Emergency Services Act 2005.

The Urban Stormwater Management Policy (2005) is a South Australian state government policy that provides a multi-objective framework for the management of stormwater in the urban areas of the state including flood management. Under this policy, Urban Stormwater Management Plans (USMPs) are to be developed with the floodplain management objectives of: 1) Providing an appropriate level of affordable flood protection to community expectations; and 2) Minimising damage to property and risk to life due to flood waters. This policy states that, 'stormwater management plans are to be mandatory for councils seeking funding support from the state and are to be linked with councils' statutory planning responsibilities and local strategic and infrastructure plans,' (South Australian Government 2005). This policy goes on to say that, 'the state is to assist in the production of floodplain mapping in known flood prone catchments where sections of natural or "improved" watercourses pass through urban areas to allow local councils to quantify the extent of flooding risk and to aid future planning for both land use and emergency response in managing stormwater,' (South Australian Government 2005).

The state has also produced a Stormwater Strategy (2011) that details nine actions towards developing a, 'blueprint for urban water'. Two actions of relevance are: '1) By 2012, evaluate options for management of urban watercourses on public and private land to further minimise flooding risk; and 2) By 2015, further improve the management of flood risk by prioritising flood mitigation scheme proposals and by evaluating the possibility of ensuring information about flood risk is available at the time of property purchase adequate insurance cover investing in flood preparedness, and ensuring the State's planning system includes minimum risk standards for all types of developments,' (South Australian Department of Water 2011).

Another important document relating to floodplain management is the Guidelines for Urban Stormwater Management 2002. These guidelines detail the USMP process and state that, 'Where development on or adjacent to land liable to inundation by drainage or flood waters is permitted, the works should be designed to ensure the floor level of buildings or storage areas are above the 1 in 100 year flood level and that the development does not adversely impact on flood levels,' 'A design AEP of 1 in 500 years should be adopted for development category Strategic I: Floors of Hospitals, Civil Defence Headquarters,' and 'A design AEP of 1 in 200 years should be adopted for development category Strategic II: Police, Fire, Ambulance, water and wastewater treatment plants, power stations, gas stations etc,' (South Australian Government 2002).

Local government have development plans as statutory instruments under the Development Act 1993 as a mechanism to manage flood risk in their communities. These plans are key documents in the South Australian planning and development system and contain zones, maps and written policies (including flood policies) to guide land-use development (South Australian Government 2002).

2.10.2 Roles, responsibilities and programs

The key floodplain management roles and responsibilities of the Government of South Australia are to: 1) develop legislation and strategy; 2) assist local government in stormwater management through plan development and funding; 3) undertake emergency management services; 4) develop emergency management plans; and 5) assist in flood warning and communication. The primary agencies to achieve these responsibilities are the Department of Water, Department of Planning and Local Government, South Australian Fire and Emergency Services Commission, Catchment Management Boards and Stormwater Management Authorities.

The South Australian Department of Waters' flood related roles and responsibilities are to: 1) develop water management strategies and legislation; 2) coordinate and evaluate options for the management of urban watercourses on public and private land to further minimise flooding risk; 3) help councils to develop and implement stormwater management plans and; 4) provide flood related technical assistance to state and local government agencies (South Australian Department of Water 2011).

The flood related roles and responsibilities of the South Australian Department of Planning and Local Government are to: 1) ensure information about flood risk is available at the time of property purchase: 2) ensure the states planning system includes minimum risk standards for all types of developments; 3) to set priorities and standards for stormwater planning and infrastructure investment and; 4) develop policy and legislation that minimise the impacts of natural hazards (South Australian Government 2002).

The South Australian Fire and Emergency Services Commission's flood related roles and responsibilities are to: invest in flood preparedness including 1) undertaking emergency management plans; 2) developing flood warning procedures and undertake flood warning communication; 3) communicating flood risk and; 4)

administering the Natural Disaster Resilience Program (South Australian Fire and Emergency Services Commission 2011).

The statutory flood related roles and responsibilities of the Catchment Water Management Board are to: 1) administer the Catchment Management Subsidy Scheme; 2) 'prepare and implement a Catchment Water Management Plan in accordance with the Water Resources Act; 3) provide advice to the Minister and the constituent councils within the board's area in relation to the management of water resources; 4) promote public awareness of the importance of the proper management of water resources in the board's area and the sustainable use of those resources,' (South Australian Government 1997).

The primary flood related roles and responsibilities of the Stormwater Management Authorities are to prioritise stormwater planning and infrastructure projects on a catchment-wide basis and administer the Catchment Management Subsidy Scheme (South Australian Government 2007). The Catchment Management Subsidy Scheme is a program established for delivering stormwater management and flood mitigation projects whereby if the catchment exceeds 40ha, 50% of the coasts may be met by the State Government (South Australian Government 2007).

Councils hold the primary responsibility of floodplain management in South Australia under the Local Government Act 1999. Councils' roles and responsibilities are to: 1) implement floodplain management strategies through development plans; 2) develop flood management policies; 3) raise funding; 4) undertake mitigation works; 5) assist in developing catchment and urban stormwater management plans and; 6) assist in emergency management and community education (South Australian Government 2002).

2.11 Australia – Victoria

More than 25,700 properties are prone to flooding in Victoria with annual average damages totalling $38.5m (BTE 2001). Recent flooding in early 2011 is testament to this, with more than 3,500 properties having been damaged and losses totalling around $1.3 billion (Edwards 2013). To address the risk and losses associated with flooding, the state has a risk management process which comprises state legislation, strategies and guidelines, local schemes and programs at a state and local level.

2.11.1 Primary legislation, policies and strategy

The primary legislation managing flood risk in Victoria is the Water Act 1989. This legislation sets out the statutory responsibilities of state agencies and their functions in floodplain management. These functions include: 1) find out how far floodwaters are likely to extend and how high they are likely to rise; 2) declare flood levels and flood fringe areas; 3) declare building lines; 4) control developments that have occurred or that may be proposed for land adjoining waterways; 5) develop and implement plans and take any action necessary to minimise flooding and flood damage and; 6) provide advice about flooding and controls on development to local councils, the Secretary to the department and the community (Victorian Government 1989).

Other Victorian legislation that relates to flood risk management include the Planning and Environment Act 1987, the Local Government Act 1989, the Building Act 1993 and the Emergency Management Act 1986. These Acts, in reference to floodplain management ,primarily relate to local governments' roles and responsibilities detailed subsequently.

Another important state document for floodplain management in Victoria is the Victorian Flood Management Strategy. This document: provides a consistent state-wide framework for the management of flood related issues (Figure 20); documents responsible authorities, agencies and groups; sets out objectives, provides a state-wide policy framework for best practice principles and guidelines, establishes priorities for state-wide action, and identifies roles and responsibilities of key stakeholders; provides the state-wide context for the development of regional floodplain management strategies, floodplain management plans and specific guidelines; and provides a process of continual assessment and improvement for flood management in Victoria (Victorian DNRE 1998).

As a requirement of the Victorian Flood Management Strategy, a series of Regional Floodplain Management Strategies have been created by regional Catchment Management Authorities (CMAs). These strategies detail roles, responsibilities, cost-sharing arrangements and key programs for floodplain management stakeholders within the respective CMA regions. These regional floodplain management strategies are, 'project based and set out tasks, priorities, timeframes, costs and lead

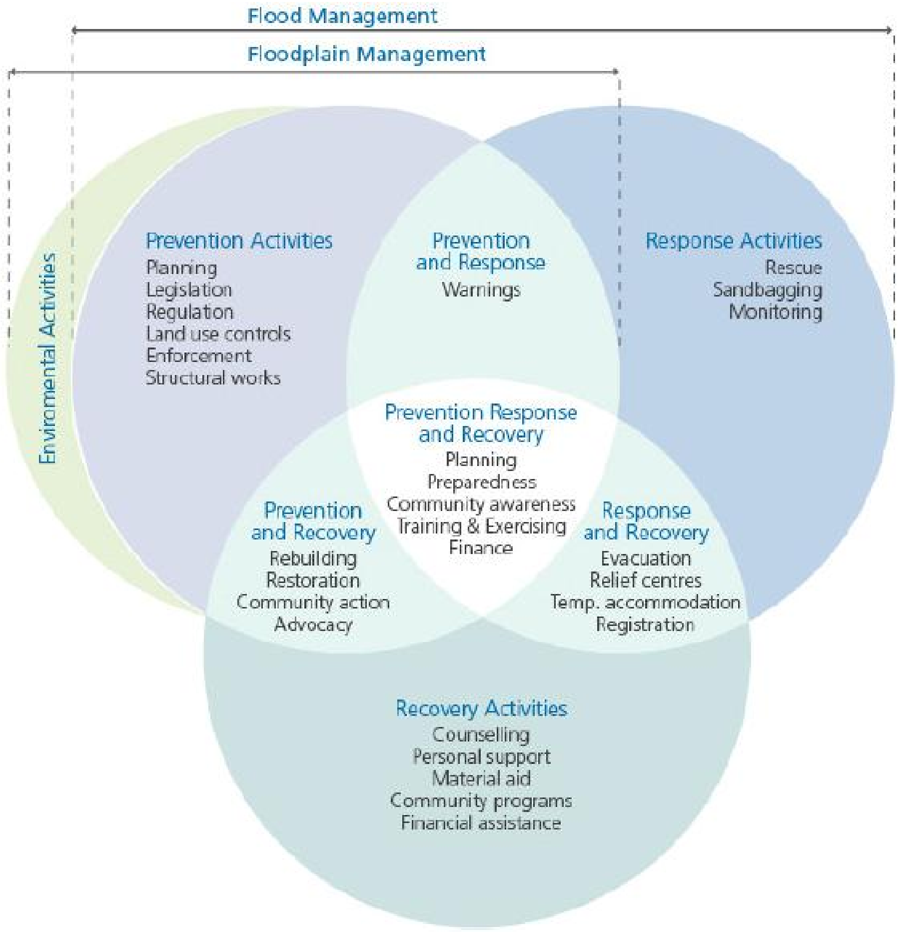


Figure 20: Victorian flood risk management framework (Victorian DSE 2012).

agency/support agency roles,' for the CMA programs (Victorian Office of Water 2011).

There are also a range of flood related state guidelines. These include guidelines on the Rapid Appraisal Method for Estimating Flood Damage, Levee Design Construction and Maintenance, Economic Benefits of Land-use Planning in Flood Management, Declaring Flood Levels, and Preparing Technical Briefs (Office of Water, 2011).

Local government have local planning schemes as statutory instruments to manage flood risk in their communities, although they do not have any specified floodplain management function (Edwards, 2013)(Office of Water, 2011).

2.11.2 Roles, responsibilities and programs

The Victorian government has the primary responsibility of: developing state legislation, policy and standards for flood management; providing financial assistance; encouraging and facilitating flood warning systems; developing emergency management programs and promoting best practice, such as flood studies and floodplain management plans, flood mitigation measures; ensuring flood information is collected and made available; and conserving natural resources and environmental values of state significance.

The role and responsibilities of the Department of Sustainability and Environment's Floodplain Management Unit are to: 1) Develop state legislation, policy and standards for flood management and provide input to national flood management policy; 2) Provide inter-governmental, state-wide and regional liaison; 3) Provide quality assurance of regional programs; 4) Oversee proper investment of Government resources; 5) Coordinate and maintain the state-wide flood database; 6) Contribute to the collection of flood data for major floods of state significance; 7) Support and assist communities to implement flood mitigation works to reduce the risk of flooding to existing development, where the works are cost effective and address a significant flood risk; 8) Facilitate management arrangements for levee systems across the state; 9) Encourage and facilitate the implementation of flood warning systems and provide real time access to stream flow data collection networks for flood warning purposes; 10) Provide timely flood advice to emergency management agencies; 11) Support community education and knowledge; and 12) Assist in the assessment of natural disaster relief claims for the restoration of flood damage to public assets (Victorian DSE 2012; Victorian Office of Water 2011).

The Victoria State Emergency Services' roles and responsibilities in relation to floodplain management are to: 1) Coordinate flood response activities; 2) Provide advice, information, education, training and assistance in emergency management; 3) Assist municipal councils develop emergency management plans; 4) Control agency for storm and floods; 5) Rescue persons from, or endangered by, emergency or dangerous situations; and 6) Disseminate flood warnings to municipal councils and other bodies identified in the municipal emergency management plan (Victorian Office of Water 2011).

The roles and responsibilities of CMAs and Melbourne Water in relation to floodplain management are to: 1) Develop, oversee and, where appropriate, implement regional floodplain management strategies, which integrate local floodplain management issues and prioritise the development of urban and rural floodplain management plans within the region; 2) Support and facilitate the implementation of regional land-use planning measures to reduce the future growth of flood risk and flood damages and, in particular, to provide input to planning schemes, respond to planning referrals, provide flood advice and help resolve planning issues; 3) Support and facilitate the implementation of regional flood warning systems; 4) Maintain and enhance regional flood information and coordinate monitoring of significant flood events; 5) Monitor and report on regional flood management performance; and 6) Advise Government on regional flood management priorities (Victorian DSE 2012; Victorian Office of Water 2011).

The role and responsibilities of the Department of Planning and Community Development are to: 1) Develop land-use planning and environmental assessment guidelines and policies; 2) Provide planning advice; 3) Administer legislation and regulations; 4) Develop local government planning schemes and associated standards and codes; 5) Develop long-term plans for Victoria's regions and cities; and 6) Provide funding for infrastructure and services to support the development of local communities (Victorian DCPD 2011).

Local government has the roles and responsibilities in relation to floodplain management to: 1) Oversee and implement local floodplain management plans through a process similar to Figure 20, to reduce the adverse effects of flooding to acceptable levels agreed to in consultation with their local communities; 2) Incorporate flood provisions into their local planning schemes allowing them to control development and works on floodplain land; 3) Ensure that regulations concerning building on land liable to flooding are enforced; 4) Provide, own and manage local community infrastructure within their boundaries in accordance with agreed levels of service; 5) Implement and maintain local flood warning systems, including systems for flash flooding; 6) Maintain and enhance local flood information and monitor significant local flood events; and 7) Develop and resource the implementation of flood response plans, as part of their municipal emergency management plans (Victorian Office of Water 2011).

2.12 Australia – Western Australia

More than 9,500 properties are prone to flooding in Western Australia with average annual damages totalling $17 million (BTE 2001; Water and Rivers Commission 2000). To address the risk and losses associated with flooding, the state has a flood risk management process which comprises state legislation, flood risk management principles and guidelines, local policies and schemes and programs on a state and local level.

2.12.1 Primary legislation, policies and strategy

The primary legislation managing flood risk in Western Australia is the Water Resources Legislation Amendment Act 2007. This legislation sets out the statutory responsibilities of the Minister for Water and Department of Water and their functions in floodplain management. These functions include: 1) Declaring drainage courses; 2) Developing plans for and providing advice on flood management; 3) Carrying out, collaborating in or procuring research or investigations relating to water resources; and 4) undertaking, co-ordinating, managing, and providing practical and financial assistance to, activities and projects for the conservation, management or use of water resources (Western Australian Government 2007).

Other Western Australian legislation that relates to flood risk management include:the Waterways Conservation Act 1976, Local Government Act 1995, Emergency Management Act 2005 and the Planning and Development Act 2005. The Planning and Development Act 2005 in particular establishes provisions for the creation of state planning policies ad regional and local planning schemes.

A planning instrument prescribed under the Planning Development Act 2005 for addressing flood management is the State Planning Policy No.3.4 Natural Hazards and Disasters. This policy aims to encourage local governments to adopt a systematic approach to the consideration of natural hazards and disasters when performing their statutory or advisory functions (WAPC 2006). Under this policy, 'Proposed development on a floodplain is considered acceptable with regard to major flooding as long as it does not produce an adverse impact on surrounding development and it has an adequate level of flood protection (WAPC 2006). Land uses in flood prone areas should not allow development that will obstruct floodways'. The policy goes on to say that, 'All habitable, commercial and industrial buildings should have their floor levels above the level of the defined flood event’, with the '100-

year average recurrence interval flood should be used as the defined flood event,' (WAPC 2006).

The Department of Water also actively promotes six principles for sound floodplain management. These principles are: '1) ensure land use minimises flood risk and damage costs; 2) ensure all three levels of government and the local community accept their responsibilities in floodplain management; 3) ensure appropriate floodplain mitigation measures minimise damage and are acceptable to the local community; 4) promote the use of non-structural rather than structural mitigation measures where possible; 5) ensure floodplain management measures have beneficial economic, social and environmental outcomes; and 6) provide flood forecasting and warning systems and emergency management arrangements to help minimise the impact of flooding,' (Water and Rivers Commission 2000).

Local governments have local planning schemes and building regulations as statutory instruments to manage flood risk in their communities. Local councils also have varying flood policy statements. One such example is the Town of Bassendean Council Local Planning Policy No 4. Floodplain Management & Development Policy. An excerpt from this comprehensive policy details that, 'habitable floor levels and all electrical installations should be a minimum of 0.50 metre above the 100 year ARI flood level,’ and that, 'planning consent will not be granted for the construction of a dwelling within a floodway unless it is to replace an existing dwelling and the applicant can demonstrate that the dwelling can be constructed to be protected from a 100 year ARI flood,' (Town of Bassendean Council 2008).

2.12.2 Roles, responsibilities and programs

The primary role of the Government of Western Australia is, 'to develop appropriate standards and strategic approaches for floodplain management and to ensure that they are applied in a co-ordinated and integrated fashion across the State,' (Waters and River Commission, 2000). This role is undertaken by the Department of Water, the Fire and Emergency Services Authority of Western Australia, the Department of planning and the Western Australian Planning Commission.

The Department of Water provides guidance on floodplain management in Western Australia and is the State’s lead floodplain management institution. The department’s primary flood related roles and responsibilities are to; 1) Undertake flood mapping; 2)

Develop floodplain management plans as documented in Figure 21; 3) Collect and analyse flood data; 4) Provide advice to the Planning Commission, Local Government and other agencies on flooding and recommend guidelines for sound development on floodplains; 5) Provide development application advice to Local Government; and 6) Assist in flood forecasting in association with the Bureau of Meteorology for the issuing of flood warnings (Western Australian Department of Water 2009).

The flood related role and responsibilities of the Fire and Emergency Services Authority of Western Australia (FESA) are to: 1) Coordinate emergency services 2) Implement flood public awareness and education programs; 3) Develop, review and implement emergency management plans; 4) Develop mitigation initiatives; and 5) Administer the Western Australian Natural Disaster Resilience Program (Rodgers 2013; FESA 2011).

The Department of Planning and the Western Australian Planning Commission are responsible for developing, reviewing, and implementing the Western Australian land-use planning system. The Department of Planning's primary flood related role and responsibility is to advise the Western Australian Planning Commission on land-use planning and policy matters through the preparation and review of Region Schemes, Corridor Plans, Town Planning Schemes and Scheme amendments and the development of planning policies. The Western Australian Planning Commission's

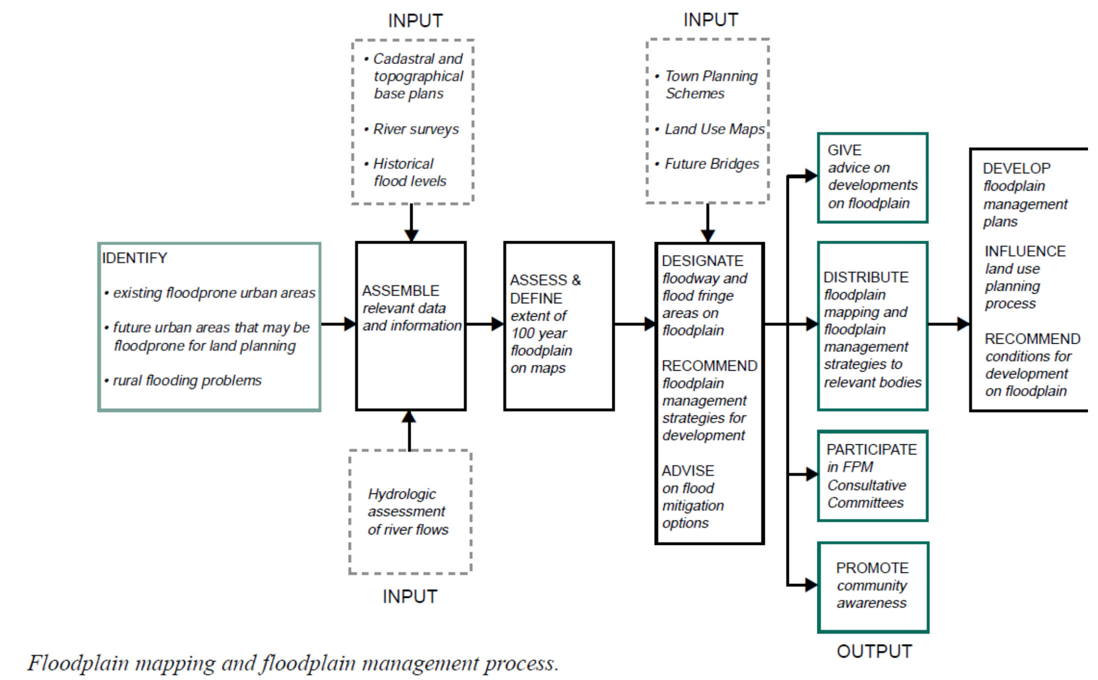


Figure 21: Western Australian floodplain management process (Water and Rivers Commission 2000).

flood related roles and responsibilities are to determine as the statutory authority under the Planning and Development Act 2005, region planning schemes and strategies, local planning strategies, town planning schemes and amendments to town planning schemes, structure plans and outline development plans, planning guidelines and non-statutory plans and policies, subdivision applications, and development applications (Planning Western Australia 2011).

Local governments have the primary responsibility to: '1) Implement floodplain management strategies through land-use planning and development controls – statutory planning & building regulations; 2) Incorporate floodplain management strategies into Town Planning Schemes or Council Policy Statements; 3) Promote flood awareness at the community level and contribute to emergency response planning,' (Rodgers 2013).

2.13 Australia – Australian Capital Territory

'Canberra is a planned city and is well designed to deal with flooding, largely due to the early adoption of appropriate planning, development and engineering standards,' (ACT Government 2011). However, Canberra has still experienced flooding, with the most notable 1971 event causing seven casualties within the Woden Valley (ACT Government 2011). As a result, the Australian Capital Territory (ACT) has legislation and programs to reduce the impacts of flooding.

2.13.1 Primary legislation, policies and strategy

The primary pieces of legislation applying to floodplain management are the Planning and Development Act 2007 and Emergencies Act 2004. The Planning and Development Act 2007, has the primary role in floodplain management within the territory as it gives authority to the Territory Plan as the key statutory planning document, in which the plan requires, 'the pattern of development to reflect land capability constraints' including natural hazard (ACT Government 2014a). The Emergencies Act 2004, establishes the requirement for an emergency plan 'for an emergency if there is a responsible possibility of the emergency happening in the ACT' such as flood (ACT Government 2004).

The Floodplain Protection Guideline (1995) is another important document that specifies the objectives and standards for floodplain management in the ACT. These guidelines state that the, 'planning and management of floodplains should be based

on the key objectives'. These key objectives being, 'to preserve the flow capacity of the floodplains of the ACT and to protect the functioning of these floodplains as ecological systems,' (ACT DUS 1995). This document also establishes guidelines for development within the floodplain. These guidelines are that:

> ‘1) Residential areas: All habitable floors are to be above 1:100 ARI flood level. Basements for car parking may be permitted below the 1:100 ARI flood level providing that permanent, internal vertical access is provided for escape in the event of flooding.
> 2) Commercial areas: Walkways, service areas, basements are to be above the 1:100 ARI flood level.
> 3) Institutional areas: Walkways, service areas, basement carparks are to be above the 1:100 ARI flood level.
> 4) Archives, reference collections, etc are to be above the 1:500 ARI flood level with the establishment of emergency measures to safeguard collections in the event of a more extreme flood,’ (ACT DUS 1995).

The guideline however, does not state or recommend a flood risk management process or framework by which these standards or objectives should be met.

There is no local government in the ACT and as such there is no floodplain management function at this level. These typical local government services are performed by The Territory and Municipal Service Directorate (ACT Government 2014c).

2.13.2 Roles, responsibilities and programs

The territory government has the responsibility of floodplain risk management within its jurisdictional boundaries. There are three lead bodies that undertake these duties. These are the Environment and Sustainable Development Directorate, Territory and Municipal Services Directorate, and the Justice and Community Safety Directorate respectively.

The Environment and Sustainable Development Directorate’s primary flood related roles and responsibilities are to: 1) develop legislation, guidelines and legislative arrangements regarding land development in floodplain areas; 2) provide strategic planning and growth frameworks and; 3) determine development applications (ACT Government 2014b).

The primary flood related role and responsibility of the Territory and Municipal Services Directorate is to construct and maintain stormwater and floodplain management infrastructure (ACT Government 2014c; Paynter 2011).

The Justice and Community Safety Directorate's primary flood related roles and responsibilities, through primarily the ACT Emergency Services Agency, are to: 1) Develop flood warning procedures and undertake flood warning communication; 2) Undertake flood risk mapping and planning 3) Implement flood public awareness and education programs; and 4) Review and refine emergency preparedness and post-flood recovery planning; and 5) Administer the Natural Disaster Resilience Program (ACT Emergency Services Agency 2012; Paynter 2011).

2.14 Australia – Tasmania

More than 2,000 properties are prone to flooding in Tasmania with average annual damages totalling $2.4 million (BTE 2001). To address the risk and losses associated with flooding, the state has a risk management process which comprises of state legislation, strategies and codes, local policies and planning schemes and programs at a state and local level.

2.14.1 Primary legislation, policies and strategy

The primary pieces of legislation managing flood risk in Tasmania are the Building Act 2000 and Building Regulations 2004. The Building Act in relation to managing flood sets out the responsibilities of 'persons' and designates under section 159 that, 'A person must not erect or place a building containing habitable rooms on land subject to flooding unless the floor level of each habitable room in the building is 300 millimetres or more above the prescribed designated flood level for that land,' (Tasmanian Government 2000). Under the Building Regulations 2004 for the purposes of section 159 of the Building Act, the designated flood level is:

> '(a) 600 millimetres above ground level or the highest known flood level, whichever is the highest, for land known to be subject to flooding other than as provided in paragraph (b) or (c); (b) the level which has a 1% probability of being exceeded in any year for the following watercourse floodplains: (i) the Derwent River through New Norfolk; (ii) the upper reaches of the Tamar River and the lower reaches of the North Esk River; (iii) the Huon River at Huonville and Mountain River; (iv) the South Esk River through Perth and Longford to the Tamar River; (v) the Jordan River below Pontville; (vi) the Mersey River through Latrobe; (vii) the Bagdad Rivulet; (viii) the Elizabeth River through Campbell

Town; (ix) the Meander River through Deloraine; (x) the Macquarie River through Ross; (c) 600 millimetres above the ordinary high-water mark of the spring tide for land on which flooding is affected by the rise and fall of the tide,'(Tasmanian Government 2004).

The Land Use Planning and Approvals Act 1993 is the primary planning legislation in Tasmania. Under this Act, planning schemes are to be developed with mandatory common provisions to be addressed. One provision of relevance is the flood prone land code. Although currently in draft 'the purpose of this provision is to ensure that the development of flood prone land provides for (a) limits to acceptable levels the potential effect of flooding on the well-being, health and safety of occupants, and (b) limits to acceptable levels the potential damage caused by flooding to private and public property, and (c) is compatible with its periodic inundation; and (d) maintains the natural function of a floodplain to convey and store floodwaters during a flood, and (e) maintains existing floodways and, where appropriate, provides opportunities for the creation of new floodways,' (Planning Commission 2011).

Other relevant legislation includes the Local Government Act (1993), Natural Resource Management Act (2002), Emergency Management Act (2006) and the Water Management Act (1999)..

2.14.2 Roles, responsibilities and programs

The primary roles and responsibilities of the Government of Tasmania in relation to floodplain management are to: 1) develop legislation and strategy; 2) assist local government; 3) undertake emergency management services; 4) develop emergency management plans; 5) assist in flood warning and communication; and 6) provide flood management funding. The primary agencies responsible for these functions are: the Planning Commission; Department of Primary industries; Parks, Water and Environment, and the Department of Police and Emergency Management.

The Planning Commission's flood related roles and responsibilities are to: 1) assess draft planning schemes, draft planning directives and dispensation projects of regional significance; 2) assist local government in developing local planning schemes; and 3) develop legislation and planning directives including flood prone land provisions (Planning Commission 2010).

The Department of Primary Industries, Parks, Water and Environment's flood related roles and responsibilities are to: 1) assist in floodplain mapping; 2) provide flood

related technical assistance to state and local government agencies; 3) assist in the development of floodplain mitigation studies and management plans; 4) collect and analyse flood data; and 5) assist in flood forecasting (Tasmanian DPIPWE 2011).

The Department of Police and Emergency Management's flood related roles and responsibilities are to: 1) facilitate emergency planning; 2) coordinate the development of municipal emergency management plans, regional emergency management plans and the Tasmanian Emergency Management Plan; 3) develop flood warning procedures and undertake flood warning communication; and 4) administer the Tasmanian Natural Disaster Resilience Program (Tasmanian SES 2011).

Local government have the primary responsibility to: 1) Implement floodplain management strategies through land-use planning schemes, flood prone land codes, State building regulations and development controls; 2) Incorporate floodplain management strategies into Local Planning Schemes and Council Policy Statements; 3) undertake and fund flood management works; 4) develop floodplain management and emergency management plans 5) Liaise and inform the community about flood risk (Local Government Association Tasmania 2011).

2.15 Flood risk management process synopsis

For the purposes of this research, four international nations which are part of the Organisations for Economic Co-operation and Development (OECD) and seven national flood risk management process were explored, yet it is acknowledged that numerous flood risk management practices exist internationally. Although not explicitly explored, the researcher has studied many of these practices and limited his discussion to the four selected international flood risk management case studies based on the jurisdictions flood risk, complexity and/or their exemplary practices. In doing so, it is intended that the exploration undertaken provides a good foundation for the following flood risk management synopsis to be drawn.

2.15.1 Legislation, policy and strategy

From the floodplain management processes examined internationally, it is evident that best practice flood risk management has a specific legislative framework with supporting policies as undertaken in Britain, the United States and the Netherlands. This legislative framework (and associated policies) ensures a consistent and

integrated approach to flood risk management throughout national, state and local authorities. It is clear that such a framework provides for well-functioning authorities with clear statutory roles and documented institutional coordination. Such legislative frameworks also specify resources required, allocating mechanisms for funding and technical capacity to manage flood risks.

The Flood and Water Management Act 2010 in England for example, specifies that the Environment Agency must, 'develop, maintain, apply and monitor a strategy for flood and coastal erosion risk management,' detailing the benchmarks the strategy must achieve (Flood and Water Management Act 2010). This legalisation was established following the outcomes of the Pitt Review (2008) concluding, 'we must be much clearer about who does what,' regarding the roles and responsibilities of all institutions (both government and non-government) in flood risk management (Cabinet Office 2008).

Both in New Zealand and Australia, no national legislation specific to flood risk is present. With the exception of Victoria, Western Australia, the Northern Territory and Tasmania, this has resulted in the remaining states and territories implementing piecemeal legislation mainly through land-use planning, natural resource and emergency management acts to address flooding. Of the states and territories with flood risk management legislation, none clearly articulate the floodplain management objectives nor process. Although federal legislation is not necessarily required to achieve best practice flood risk management, states and territories should be able to satisfy themselves that there is a well-documented flood risk management process, that flood risk management responsibilities under this process have been clearly allocated, and that the allocated institutions (both government and private) have the technical capacity and resources to implement and follow the process.

New Zealand for example in a recent review, documented that, 'a national policy statement could strengthen planning provisions in regional policy statements and district plans that manage development in flood-prone areas, making councils' approaches better able to withstand challenge,' (Ministry for the Environment 2008).

2.15.2 Strategy and processes

All countries examined have similar strategies to flood management involving a multi-faceted approach of predominately land-use planning (i.e. development controls,

planning restrictions etc.) engineered solutions (i.e. house raising, levees, storage basins, stream rehabilitation etc.), emergency management (community awareness, flood prediction, evacuation plans etc.) and disaster recovery (government support, insurance etc.). All have strategic documents to some degree to manage floods and political directives such as the EU Directive 2007/60/EC (Assessment and Management of Flood Risk), which has established a unified European approach to identify and assess risks and hazard and prepare plans to manage such risks (European Commission 2007).

All jurisdictions undertake a risk assessment for flooding beyond the 1% AEP i.e. United States predominantly to the 0.2% AEP, England typically to the 0.1% AEP, Netherlands greater than the 0.01% AEP, Australia and New Zealand to the probable maximum flood and all besides New Zealand adopt a minimum floor height of predominantly the 1% AEP design flood for residential development with or without freeboard. New Zealand interestingly only requires residential and community care facilities to have floor levels higher than the 2% AEP design flood in its federal legislation and building codes but provides the ability for individual local governments to implement policies at higher level of protection i.e. the 1% AEP design flood (PCO 2014).

It is also evident that all jurisdictions examined follow a similar simplistic flood risk management process. This flood risk management process typically involves, as illustrated in Figure 22: 1) Identifying the risk; 2) Identifying the risk management measures; 3) Making a decision; and 4) Adopting and implementing the decision, while communicating and consulting, and monitoring and reviewing being a fundamental part of the strategy.

Figure 22: Generic flood risk management process.

Despite communication and consultation being identified as a fundamental requirement, and all having some form of two-way communication, it is evident a traditional, 'decide, inform the client community, and then justify our decision, or decide, announce and defend,' model takes precedent (Delli Priscoli 2004). Further public participation and citizen involvement are extensively referred to however, no

jurisdictions actually provide guidance on integrating public participation into their process nor reflect this in their framework.

Spatial and/or temporal scale is rarely included in jurisdictions flood risk management process, although recognisably evident in practice. Further uncertainty associated with all steps for example data collection, model assumptions, future socio-economic, climatic change, decision making, implementation etc. is seldom documented in frameworks.

Moreover, performance evaluation is consistently documented as a key requirement, yet guidance is either not provided or is contained in separate processes (New Zealand, United Kingdom) or alluded to (Australia). A new flood risk management cycle with public participation and performance evaluation underpinning the process will be discussed in the proceeding chapter, effectively bridging these identified inconsistencies between flood risk management requirements and their process or framework.

2.15.3 Responsibility and programs

Of the countries examined, the roles and responsibilities for flood management and the programs these institutions implement are split primarily between specialist water resource engineering institutions (USACE, Rjkswaterstaat, Regional Waterboard Authorities, and emergency management institutions (FEMA, MCDEM) or umbrella of both (Environment Agency). In Australia the roles and responsibilities are primarily undertaken by local government with varying levels of technical assistance provided by the state (New South Wales, Queensland, South Australia, Tasmania and partially Victoria), directly through state water entities such as catchment management authorities (Victoria) or emergency management institutions with a broader focus on disaster management i.e. disaster preparation, response and recovery (Northern Territory and Australian Capital Territory).

Flood risk management programs although significantly vary in budget, are split between flood risk management measures and recovery arrangements. Although most countries actively disclosed floodplain risk management programs and their expenditure (England, United States and Netherlands), information on both Australian and New Zealand's programs and investment was seldom available. Exemplar public disclosure of floodplain management programs is demonstrated in England, with

effective documents that clearly quantify the benefits of government flood expenditure to its citizens. For example, in England the Environment Agency has quantified that their flood programs can produce outcomes that, 'reduce expected damage by at least £8 for every £1 spent,' (Environment Agency 2009b).

2.16 Conclusion

It is evident that although the driving mechanisms of flooding (oceanic, pluvial, fluvial, groundwater, snowmelt, infrastructure failure etc.) differ between countries, regions and communities, with varying socioeconomic, cultural and intuitional pressures resulting in hazard disparities, flood risk management processes are generally analogous. This analogous process typically involves: 1) Identifying the risk; 2) Identifying the risk management measures; 3) Making a decision; and 4) Adopting and implementing the decision, while communicating and consulting, and monitoring and review being a fundamental part of the strategy.

Similarly, the roles, responsibilities and programs in which these institutions implement are comparable, although with varying budgets and levels of public disclosure, as summarised in Appendix A. All programs tend to be implemented through a strategic planning basis such as flood management plans, with floodplain management measures being a fundamental component of these strategic documents. Therefore, it is conceivable that a new flood risk management cycle could be successfully employed and implemented within existing legislation and policies, to advance identified deficiencies in the current analogous process (i.e. integrating public participation and performance monitoring into the process), improving domestic and international flood management outcomes.

Chapter 3

New flood risk management cycle

3.1 Introduction

Flood risk management processes are generally analogous typically involving 1) Identifying the risk, 2) Identifying the risk management measures, 3) Making a decision, and 4) Adopting and implementing the decision, while communicating and consulting, and monitoring and review being a fundamental parts of the strategy. Although this process is typical, there are numerous deficiencies in the outcomes being achieved through the process. These deficiencies primarily relate to performance monitoring and community engagement. This chapter firstly explores the theory of public participation and the institutional requirements and then progressively outlines a new decision-making cycle for flood risk management building upon this theory that can be employed within exiting frameworks to improve domestic and international flood management outcomes. It is not the intent of this chapter to mandate a new framework nor interfere with long established existing processes, rather to introduce and justify new elements of a proposed flood risk management cycle that can integrate identified deficiencies in current flood risk management best practice.

3.2 Public participation

Public participation has long been recognised as an essential element of democratic governance, as it moves beyond paternalistic institution decision making to inclusive pluralistic civic-focused deliberative decisions. This is a significant transitional approach from the changing but still entrenched DAD (Decide-Announce-Defend) or DEAD (Decide-Educate-Announce-Defend) decision-making mentality that is intrinsically evident in many engineering practices worldwide with floodplain risk management being no exception. Yet in adopting such an approach, as advocated by numerous researchers and institutions (Delli Priscoli 2004; EC 2007; Firus et al. 2011; ICE 2014; Jha et al. 2012; Sayers et al. 2013; USACE 2009; US Government 2013; Walsh 1999; WMO 2004) public participation in engineering decision making inclusive of flood risk management has and will continue to transition to allow those who are directly or indirectly affected by decisions to be involved in the decision-making process.

3.2.1 What is public participation

Public participation is nothing new, and in essence is rooted to the ancient Greek governance system demokratia (democracy) i.e 'kratos' (rule or power) by the 'demos' (people)(Blackwell 2003). Numerous definitions of public participation exist in literature (e.g, Beierle et al 2002; EU Water Directors 2002; IAPP 2006; Smith 1983) but all revolve around the notion of a process that allows the public (i.e. everybody) to participate in, inform and influence decisions made that affect them. As identified by Lucus (1976)(cited in Stokes 2012, p. 4), it is the identification of process rather than outcome that characterises its definition. Yet it is the ideology that defines and drives the process.

This process in the context of flood risk management could include identifying and defining the problem or opportunity, obtaining and gathering information, identifying and evaluating the risks and solutions, making and implementing the decisions, monitoring and reviewing the process and decisions made through mechanisms including questionnaires, workshops, focus groups, citizen juries, advisory groups, referenda (for a full list of mechanisms and their descriptors see Firus et al. 2011; IAPP 2006c; Rowe and Frewer 2000). The ideology, as recently categorised by Renn and Schweizer (2009), derived from the culmination of numerous theorists and commentators (Cohen 1997; Dewey 1927; Ethridge 1987; Fisher and Ury 1981; Foucault 2003; Habermas 1984; Lenski 2005; Malinowski 1944; Pierce 1867; Radcliffe-Brown 1935) generally falls within six distinct 'prototypes'. These are the:

1) Functionalist prototype, 'where participation aims to improve quality of decision output, and follows a rationale that argues for representation of all knowledge carriers, integrating systematic, experiential and local knowledge';

2) Neo-liberal prototype, 'which aims to represent all values and preferences in proportion to their share in the affected population, thus focusing primarily in the collection and representation of (well-informed) public preferences';

3) Deliberative prototype, 'where competition between participants,' arguments are promoted with respect to criteria of truth and normative validity, reaching consensus through argumentation';

4) Anthropological prototype, 'which is based on the belief that common sense is the best judge in reconciling competing knowledge and value claims, thus promoting the inclusion of non-interested laypersons representing social categories such as gender, income and locality';

5) Emancipatory prototype, 'where the goal is to empower less privileged groups and individuals, by strengthening the resources of those who are more negatively affected and challenging traditional power structures in society'; and

6) Post-modern prototype, 'whereby participation aims to demonstrate variability, plurality and legitimacy of dissent, thus leaning towards acknowledgement of plural rationalities. Within this concept, mutually acceptable arrangements are sufficient and there is no need to reach a final product or joint statement (i.e. reaching closure),' (Renn and Schweizer 2009, cited in CEEC 2012, para. 2).

Therefore, the ideological diversity identified by Renn and Schweizers 'prototypes' (2009), warrants the need for ideologies to be recognised and accounted for throughout the process, both internally and externally. This includes selecting mechanisms that effectively instil the level of participation, and hence define the role and influence of the public to achieve the desired ideological goals throughout the decision-making process. This may include a combination of mechanisms such as citizen advisory committees to appease the priorities of the functionalist, mediation for the neo-liberal, world cafes for the deliberative, citizen juries for the anthropological, symposia for the emancipatory and open space conferences for the post-modern actors (IAP2 2006c; Renn and Schweizer 2009). Due to this identified ideological complexity and their resulting goals, Laine et al. (2014, p. 2) drawn from the IAP2 principles of practice for participation (2006a p. 25-28), three key commitments have been identified that are required prior to seeking participation or selecting mechanisms. These commitments being:

1) 'Decision-makers will clearly define and articulate the level of influence the public will have at each stage of the decision making process and will implement the defined level of commitment when decisions are made.

2) The process will be equitable, inclusive, transparent, accountable and provide mechanisms to seek out and facilitate appropriate participation from those that are affected by the decision.

3) Clear communication and documentation will be provided on how the above commitments were decided and achieved."

These three commitments, although unlikely to be the highest priority for emancipatory actors, generally encompass the goals of the various ideologies. Once established they provide the basis for selecting the right mechanisms, or combination of mechanisms, at the right stage in the process to achieve the desired public participation goals and decision-making outcomes as illustrated in Figure 23.

TO:	Inform	Consult	Involve	Collaborate	Empower
GOAL:	Share balanced and objective information to achieve mutual undertstanding of the problem, alternatives, trade-offs, opportunities and/ or solutions	Ask questions, listen and gain ideas, feedback, information and knowledge that will be considered and responded to during decision- making	Build networks, relationships and strong two-way communication with outcomes integral to decision-making	Build capacity to partner in decision-making with shared responsibility	Build capacity to pass full decision-making and responsibility to others
TOOLS: (mechanisms)	Fact sheets Brochures Web Sites Presentations Reports	Public comment Public meetings Public exhibitions Focus Groups Surveys	Workshops Deliberative-polling Social networks Online chat	Committees Consensus-building Participatory decision-making	Citizen juries Referenda Citizen panels DSS

Figure 23: The building blocks of public participation adapted from the IAPP public participation spectrum and AEMI community engagement model (IAP2 2006a; AEMI 2013a).

3.2.2 Pros and contras of public participation

The advantages and disadvantages of public participation are emerging with increased quantified application and systemic research (see Day 1997; Rosenburg, Innes and Booher 2004; Irvin and Stansbury 2004). Advantages are broadly aggregated into three viewpoint categories: normative, substantive and instrumental (Fiorino 1989; Moynihan 2003; Stirling 2008).

Normative inclined advantages relate to the process being able to encourage, empower and enrich 'social learning' (Wynne 1992) of both society and individual citizens, particularly for minority or typically excluded groups (Sterling 2008). Resultantly, social learning through participation allows individuals to see and explore the differences and similarities between their own values and interests and those of their fellow citizens. This, in turn, leads to a socially enlightened, healthier democratic community that is capable of developing broader, more inclusive, consensual, rational and just policies that better reflect common interests focused on a mutual recognition

of the public good (Cohen 1996; Dryzek 2002; Singleton 2002). In doing so, public participation in a normative view opens up representative democracies with weak cultural commonalities, limited public involvement, distrust and social fragmentation to a deliberative environment that as Ran asserts, 'increases the connection among citizens, increases buy-in, and produces a society capable to confront their problems,' (Ran 2012 p. 409; Habermas 1987; Rosenberg 2007).

Substantive inclined advantages relate to encouraging and accommodating multiple perspectives in order to gain local knowledge (Singleton 2002; Wittmer et al. 2006) that generate new ideas and/or refine existing ideas (Ananda and Herath 2003), enabling the development of more inclusive representative outcomes and solutions unavailable to decision-makers (Beierle 2002). Further substantive benefits of public participation include socially innovative and robust solutions that actually meet the needs of those affected (Grove-White et al. 2000) and enhanced social capital and resulting economic benefits (CNPPAM 2002).

Instrumental inclined advantages, although intrinsically linked to the latter, relate to successful outcomes of collaborative relationships. These include legitimised decisions (Surowitzky 2004), improved accountability, credibility and trust (Desai 1989; Rauschmayer & Risse 2005; Fung 2003), increased ownership and responsibility not only for the decisions made but also for the, 'implementation and realisation,' of the solutions (Evers 2012 p.13; Moore 1994; McCool and Guthrie 2001) and less conflict, litigation and delays leading to more cost efficient results (Davis and Franks 2014; Thomas 1995, Randolph and Bauer 1999).

While the advantages for public participation are apparent, the process has weaknesses, although seldom in comparison and largely manageable through the selection of suitable mechanisms (see Rowe and Frewer 2000). Commonly reported weaknesses of public participation include the process being costly and time consuming (Til and Meyer 2001, Lawrence and Deagen 2001; Echeverria 2001); leading to group-think (Janis and Mann 1977; Hart 1994; Webber 1998), potential skewed representation (Feldman and Quick 2009; Nutt 2002), public dissatisfaction with over-promises (Bickerstaff et al. 2002; Smith and McDonough 2001; Ananda and Herath 2003; Julian et al. 1997), loss of technical balance resulting in inferior results (Coglianese 2001), and uncertainty (World Bank 1996).

To provide a short rebuttal to the above common disadvantages, costs and time in addition to group-think, loss of technical balance and uncertainty can be managed with appropriate planning (refer IAP2 2006; Involve 2005, Rowe and Frewer 2000). Representativeness can be achieved through appropriate sampling and selection techniques such as random stratified samples with appropriate power imbalance and marginalising (financial/geographic/cultural etc.) factors addressed (refer Firus 2011; Fung 2007). Thus, public participation can address a number of traditional decision-making shortfalls provided users recognise that a diverse range of mechanisms and approaches to address the range of ideological outcomes will be required to achieve sustainable inclusive decision outcomes.

3.2.3 Requirement for public participation in the flood risk management process

Flood risk managers in public, private and voluntary sectors are increasingly required to be more transparent, collaborative and participatory as governance shifts from 'hierarchical' to 'markets' to 'networks' (Bevir and Rhodes 2006). With this transition and associated complexity comes responsibility to identify and adapt to the public's needs as 'customers' requiring a service, 'partners' helping to produce services, and 'citizens' to deliberate and decide on future directions (Thomas 2013). It is recognised that flood risk management can no longer be achieved by top-down processes. Changing public and institutional desires to devolve power and resources towards local democratic structures and communities in a bid to curb democratic malaise and unsustainable flood management measures need to be accommodated (ICE 2014; Aulich 2009).

Multiple countries and organisations have embraced these shifting desires developing laws, strategies, plans, policies, and standards to incorporate public participation in daily work practices, particularly with regards to open information and collaboration on service delivery (OECD, 2014). Flood risk management institutions are no exception with many requiring public involvement to varying degrees within their flood risk management process (e.g Environment Agency, FEMA, Rjkswaterstaat, USACE).

Significant initiatives shaping public participation implementation include the Rio Declaration (UN 1992) and Aarhus Convention (UNECE 1998). The Rio Declaration on Environment and Development provided a set of 27 principles on which, 'nations can base their future decisions and policies,' which gained census from 108

governments representing over 98% of the world population (UN 1992, p.6). Of these principles, principle 10 identified, 'environmental issues are best handled with the participation of all concerned citizens,' placing a non-legally binding requirement that, 'states shall facilitate and encourage public awareness and participation,' (UN 1992 p.2). In implementing the Rio Convention, the Aarhus Convention on Access to Information, Public Participation and Access to Justice in Environmental Matters (1998) was developed and signed by 26 European Union (EU) countries as a legally binding EU law transposed into Directive 2003/35/EC. The role and importance of public participation within this convention and subsequent directive include provisions such as:

> 'Each Party shall endeavour to ensure that officials and authorities assist and provide guidance to the public in seeking access to information, in facilitating participation in decision-making and in seeking access to justice in environmental matters'; 'Each Party shall provide for early public participation, when all options are open and effective public participation can take place'; 'Each party shall ensure that in the decision due account is taken of the outcome of the public participation' and 'Each Party shall make accessible to the public the text of the decision along with the reasons and considerations on which the decision is based,'(UNECE 1998).

Resultantly, all EU directives are fundamentally linked to public participation inclusive of EU 2007/60/EC (Assessment and Management of Flood Risk). EU 2007/60/EC establishes a unified requirement for its member states to, 'encourage the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the river basin management plans,' (EC 2007). This includes 'Member States' making, 'available to the public the preliminary flood risk assessment, the flood hazard maps, the flood risk maps and the flood risk management plans,' (EC 2007).

Similarly, public participation features prominently in the United States markedly onwards from 1964, with the Economic Opportunity Act requiring, 'maximum feasible participation,' (Callies 1981, p. 290). In recent times, the US Government for federal investment in water resources including flood risk management, states, 'federal agencies should collaborate fully on water activities with Tribal, regional, state. local and non-government entities, as well as community groups, academia and private land holders to realize more comprehensive problem resolution and better informed decision making (US Government, 2013). Further institutions such as the USACE and

FEMA have released strategic plans, engineer circulars (e.g 105-2-409 Planning in a Collaborative Environment) and guidance, focusing heavily on the need to build collaborative capacity (USACE 2014; FEMA 2002).

In England, the Civil Contingencies Act 2004, 'encourages those delivering front line services to consider the need of the community and engage community members when developing and delivering services to them,' (Cabinet Office 2011). The Sustainable Communities Act 2007, 'provides for the opportunity for all people resident in any area to play an equal role in the economic, social and civic life of the area,' (Crown 2007). Additionally, the cabinet-endorsed Communities in Control: Real People, Real Power 2008 white paper requires local people to be involved in making decisions on the spending priorities for a defined public budget (DCLC 2011). In context to flood risk management, as an EU member, meeting the requirements of EU 2007/60/EC, the Flood Risk Regulations 2009 state, 'the Environment Agency and each lead local flood authority must consult the following about the proposed content of a flood risk management plan: (a) authorities listed in regulation 36(3) that may be affected by the plan, and (b) the public,' (Crown 2009). Further, the National Flood and coastal erosion risk management strategy for England 2011 declares:

> ‘risk management authorities should work with in partnership with communities to understand the community perspective of flooding and coastal erosion, help communities understand and actively prepare for the risks, and encourage them to have direct involvement in decision making and risk management actions,’ (Environment Agency 2011b, p.14).

In Australia, the federal government has also embraced this shift supporting in principle 12 of the 13 recommendations from the recent Government 2.0 Taskforce 2010. The central supported recommendations of this report are:

- ‘using technology to increase citizen engagement and collaboration in making policy and providing service will help achieve a more consultative, participatory and transparent government
- public sector information is a national resource and that releasing as much of it on as permissive terms as possible will maximise its economic and social value to Australians and reinforce its contribution to a healthy democracy
- online engagement by public servants, involving robust professional discussion as part of their duties or as private citizens, benefits their agencies, their professional

development, those with whom they are engaged and the Australian public. This engagement should be enabled and encouraged,'(DFAD 2010, p.3).

State, territory and local governments throughout Australia are no exception, with all moving towards public participation and citizen engagement as part of achieving a more consultative, participatory and transparent government (for discussion see Cavaye 2004). With relevance to floodplain management, the Australian Emergency Management Handbook 7 Managing the Floodplain- a guide to best practice in flood risk management in Australia 2013 states, 'Consultation is fundamental to the successful delivery of flood risk management to the community. It should be undertaken with internal and external stakeholders during all stages of the floodplain-specific management process,' (AEMI 2013b). This is further supported by Handbook 6 National Strategy for Disaster Resilience – Community Engagement Framework recognising, 'community engagement should be part of day-today-business in the prevention, preparedness, response and recovery phases of emergency management. Communities need to be engaged before, during and after major emergency events,' (AEMI 2013a).

Therefore, it is evident public participation is no longer disjunctive from government nor flood risk management, but an integral requirement supported by international declarations. Yet, from the literature examined, guidance on integrating public participation in the flood risk management process is not forthcoming.

3.2.4 Application of public participation mechanisms in flood risk management

Public participation mechanisms are extensively used throughout numerous jurisdictions highly dependent on their processes, practices, roles and responsibilities. Although these mechanisms typically fall on the inform and consult side of the engagement building blocks (Figure 23), there is evidently an increasing application of involve, empower, collaborate mechanisms in current flood risk management best practice largely due to the identified increased institutional and citizen requirement to engage the public in the decisions that affect them. Examples of mechanisms typically utilised in flood risk management include (adapted from IAP2 2006c; Firus et al. 2011):

- <u>Newsletters and brochures:</u> Used to convey information about the flood risk management process including the risk and opportunities for input. Advantages include simplicity and ability to reach a large target audience.

Disadvantages include only having a limited capacity to communicate information particularly on complicated concepts such as flood risk management.

- Questionnaires and surveys: Mainly paper based however, moving to online, telephone and in-person delivery. Provides both qualitative and quantitative data, and gathers perspectives from a diverse range of people if well distributed and publicised. Advantages include easily conducted, understood, repeatable, with 'useable' results. Disadvantages include restricted information if purely quantitative and expensive, particularly in urban areas when conducted through paper based, telephone or in-person modes of delivery.

- Technical reports: Predominately highly complex technical documents that convey information on the objectives, methodology and results of a range of topics including flood risk and flood risk management measures. Advantages include providing detail through explanations of the topic, analysis and results. Disadvantages include too much information and/or not written in clear accessible information for the public to utilise.

- Public information sessions and meetings: A forum that allows the community to hear about the flood risk management process, its complexities, listen and respond to other peoples comments, experiences, questions, and an ability for the conveners to receive input and build rapport. Disadvantages include potentially skewed representation particularly when contentious, limiting input from the broader public and difficult to document outcomes. Often the loudest rather than collective views dominate the sessions and meetings.

- Tours and field trips: An organised event to share information and gain a firsthand experience about flooding and/or management measures to reduce flooding. Advantages include dispelling myths, deliberation, rapport and consensus building. Disadvantages include resource intensive and limited representation.

- Public exhibition: The meaning and outcomes of public exhibition vary around the world in flood risk management. In NSW Australia, public

exhibition generally entails placing a document on public display from which submissions and feedback are sought prior to decisions being made and the document finalised and adopted. In Europe, as identified by Firus et al (2011), public exhibition is more literal comprising organised information panels, interactive displays and talks to exhibit and raise awareness of flooding and its management. Therefore, the advantages and disadvantages range significantly between the two meanings and outcomes from simple, inexpensive with limited deliberation to complex, relatively expensive with a significant opportunity to build consensus and awareness of the risks and potential solutions.

- Open houses: Are spaces with multiple displays or stations where people can walk around, seek information and discuss flood risk management topics with committee representatives. Advantages include a less formal environment promoting dialogue and thorough explanations. Disadvantages include being resource intensive and difficult to report.

- Workshops and world cafes: Are public forums where participants conduct simultaneous conversations or work together on exercises to provide specific input into the process. Advantages include fostering discussion to find common values and expectations, provoking discussions about new ideas and solutions and getting participants engaged. Disadvantages include having an active and willing representative group willing to invest time and knowledge into the mechanism.

- Deliberative polling and citizen juries: Are structured processes that allow a group of selected demographically diverse representatives an ability to discuss and explore options after hearing evidence to decide or provide recommendations. Advantages include equal opportunity to be heard, building trust and consensus. Disadvantages include skewed evidence leading to uninformed decisions and recommendations and significant resources required.

3.3 The cycle

The cycle pieces together the generally analogous floodplain risk management process and builds upon the identified deficiencies to improve domestic and international flood management outcomes. The cycle as illustrated in Figure 24, breaks down into seven stages with the formation of a flood risk management committee or working group and public participation at its fundamental core. These seven stages are 1) Identify the risk; 2) Identify risk management measures; 3) Performance criteria; 4) Make decision; 5) Adopt and implement decision; 6) Monitor and evaluate and, 7) Review. To reiterate, it is not the intent of this cycle to mandate a new framework nor interfere with long established processes, rather introduce and justify new elements building a contemporary flood risk management cycle. In doing so, it is hoped elements can be routinely integrated into revised flood risk management practices recognising the value of allowing those who are directly or indirectly affected by flooding or the management of flooding to be involved in the decision-making process through different mechanisms at various stages.

Figure 24: Flood risk management cycle (Laine et al. 2011)

Further, although the processes are generally analogous, the jurisdictions needs are often unique due to the social, economic, cultural, political contexts. As a result consideration must be given to ensure the process meets the real needs and priorities of those affected.

3.3.1 Committee or working group

The formation of a committee or working group establishes the foundation of the flood risk management cycle. It is the role of the committee to guide and facilitate the activities within the flood risk management cycle. This may entail an advisory or directive relationship depending on the social, economic, cultural, political context in which the cycle is operating. As flood risk management is a collective effort requiring the involvement and support of multiple stakeholders, it is recommended the committee broadly reflect the public. These stakeholders therefore may include national government, state or regional governments, local governments, development institutions, utilities, non-governmental organisations, community-based organisations, private businesses, educational institutions, community groups, insurance and individuals both directly and indirectly affected. At a minimum it is vital the committee include decision makers and those with direct legislative government and non-government roles and responsibilities to foster accountability, trust, sustainable outcomes and ownership. Without these members, the cycle may be at risk of producing technically, politically and/or financially unsustainable solutions.

For example, the Netherlands vital committee members would include, as a minimum, representatives from the Rijkswaterstaat, Regional Water Authority, Safety Regions, municipality, municipality elected representatives, local community, private businesses and educational institutions i.e. TU Delft. In New South Wales Australia, the vital committee members would include representatives from the local government, local government elected representatives, NSW OEH, SES, Department of Planning, Transport NSW, the BOM, local community, and private businesses.

Thus, the primary reasons for establishing a committee are to:

1) Develop a lead group to guide, facilitate and be accountable for the cycle;
2) Provide a routine mechanism to collaborate and deliberate;
3) Ensure continuous representation throughout the cycle and;
4) Foster ownership and implantation of the solutions identified.

3.3.2 Public participation

Public participation, in its absolute essence, is the core of the new flood risk management process. Transcending the belief that those who are directly or indirectly affected by flooding, or the management of flooding, have the right and responsibility to be involved in the decision-making process. The success of public participation in

flood risk management relies on the selection of the right mechanisms, or combination of mechanisms, at the right stage in the process to achieve the desired public participation goals and decision-making outcomes. To assist with this selection, the following paradigm illustrated in Figure 25 is offered, recognising the inherit limits in doing so such as governance, context. Reasoning for the level of public participation and hence, role and influence of the public through the public participation mechanisms, is subsequently discussed at each stage in the cycle.

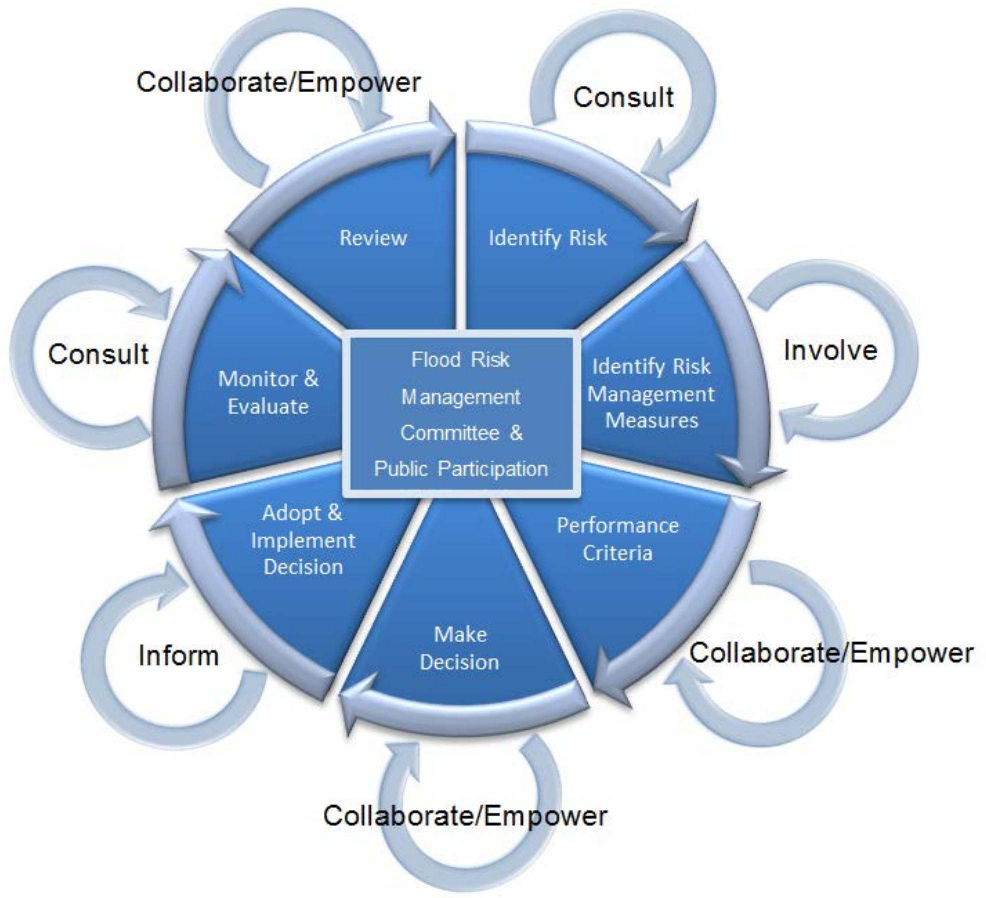


Figure 25: Application of public participation to the flood risk management cycle (Laine et al. 2014)

As public participation builds from inform, to consult to involve, diverging between collaboration and empowerment, it needs to be recognised that empowerment should not be viewed as the acme of public participation but rather an approach, no more legitimate than the next, to achieve the desired public participation at each stage in the decision-making process. This view, supported by Dorecy et al (1994), and diverges from Arnsteins original 'ladder of citizen participation' where citizen control was the only legitimate objective (1969). Hence, this approach allows mechanisms to be recognised and utilised as a means to address and reflect the real needs,

priorities, concerns and values of the community in which the cycle is operating, rather than a tokenistic zenith.

Further, it is vital to select mechanisms that cater for everyone including the vulnerable or marginalised such as the economically disadvantaged, elderly, people with disability, ethnic minorities or geographically dispersed. If these groups cannot be represented through the public participation tools selected, targeted mechanisms such as internet-based tools or one-on-one or group interviews, should be explored to ensure input from these individuals is incorporated and they too are part of the decision-making process.

Thus, the primary reasons for public participation are to:

1) Ensure the outcomes sustainably reflect the needs, values, knowledge and priorities of those directly or indirectly affected by flooding and its management including institutions, businesses, marginal community groups etc. (Jha et al. 2012; Singleton 2002; ICE 2014);
2) Develop new, robust and innovative outcomes integrating all kinds of knowledge unseen through traditional flood risk management consultative approaches (Beierle 2002; Grove-White et al. 2000; Ren 2009);
3) Promote broad awareness, education and dialogue about the flood risk and its collective management, developing collaborative relationships, enhancing social cohesion, and strengthening community resilience (Cohen 1996; Dryzek 2002);
4) Gather support, commitment and ownership from a range of stakeholders inclusive of the directly affected community members, to guarantee long-term sustainability of the outcomes and their delivery through a more cooperative empowered public (Evers 2012; Moore 1994; McCool and Guthrie 2001) and;
5) Increase trust, accountability, credibility, legitimacy and acceptance in the process and decisions made, reducing conflict, litigation and delays (Desai 1989; Rauschmayer & Risse 2005; Fung 2003; Davis and Franks 2014; Thomas 1995, Randolph and Bauer 1999).

3.3.3 Review

This stage involves assessing whether the current and future residual risk of utilising the floodplain is acceptable by the public. Ultimately this is a vexed question among risk managers as the perception of risk among the public, as identified by Wachinger et al., depends, ‘on the type of risk, the risk context, the personality of the individual,

and the social context,' which is influenced by various factors such as, 'knowledge, experience, values, attitudes and emotions,' (2013, pp. 1049). Hence, the driver for review is precisely these identified factors. Therefore, a review is likely required if the consequence and/or likelihood of flooding is unknown or insufficient and/or the desirability of the current and future residual risk has changed due to environmental, technological, political, cultural, economic changes i.e. a recent flood event, climate change, model and technological advancements, budget constraints, emergency management shifts, political decisions, or when applied to the Source-Pathway-Receptor-Consequence model (Sayers et al. 2002), when one variable changes significantly.

In the proposed flood risk management cycle, it is put forth in a normative view due to the inherit nature of this stage (decisions representing the public's interests where the public can meaningfully contribute), that those affected by flooding or the management of flooding should actively be involved, deliberate and decide whether the residual risk of utilising the floodplain is acceptable. Mechanisms that could be utilised at this stage to achieve the above collaboration/empowerment goal include surveys, public meetings, workshops, citizen advisory committees, citizen juries, decision support systems etc. This could also include minimum government standards (for example the 1% AEP flood minimum residential floor level) as a basis for understanding and consensus building particularly with public authorities.

It is not the intent at this stage to determine a specified acceptable level of risk, rather to share and discuss information and experiences to achieve a mutual understanding of past, present and future flooding, empowering the public to make informed inclusive decisions around whether the residual risk is either acceptable or not. If the latter is the outcome, then deliberation on how this might be achieved should be undertaken i.e quantifying the sources, pathways, receptors, consequences; analysing options and implementing these options as described in the preceding stages. During deliberation, different flood study data collection, modelling techniques and assumptions that could be utilised, and their relative advantages and disadvantages including their respective costs, levels of uncertainty, requirements etc. (see Babister et al. 2014) should be presented so congruence on an approach forward can be sustained, which may include referring the decision to the flood committee at some stages of the cycle. It is important at this stage, that uncertainty, whether it be uncertainty in future catchment characteristics (population, land use, rainfall, sea levels) uncertainty in current data, and uncertainty in model outputs and

their application, be clearly presented and communicated to support informed decision of whether to review.

Thus, the review stage, due to the public's ability to meaningfully contribute and make decisions that affect them, should:

1) Utilise a range of collaborate/empowerment mechanisms including those that include minorities, to share balanced and objective information to gain a mutual understanding of the residual risks and the assumptions/uncertainties, decide whether the residual risk is acceptable and an approach forward if not acceptable.

3.3.4 Identify risk

Risk identification is a well-understood stage of the flood risk management process with all domestic and international practices examined adequately addressing this requirement. Flood risk is a product of the likelihood or chance of a given flood event occurring, multiplied by the consequences or damages resulting from that event for a given area (Knight 1921; AEMI 2013b). Flood risk is not the favouring of likelihood over consequence or vice versa as stressed by Bernstein:

> 'any decision relating to risk involves two distinct yet inseparable elements: the objective facts and a substantive view about the desirability of what is to be gained, or lost by the decision… the risk-adverse make choices based on the consequences without regard to the probability involved… the foolhardy make choices based on the probability on an outcome and without regard to its consequences,'(1998, pp 383; cited in Woodruff 2005).

To understand the likelihood, a range of processes are undertaken. These processes involve: 1) Hydrologic analysis estimating design flow hydrographs or design peak flows for flood events typically through flood frequency analysis (if flow data is available) and/or rainfall runoff routing modelling utilising probabilistic design rainfall (spatial and temporal) for fluvial systems; and 2) Undertaking hydraulic analysis for the design events or failure analysis estimating the water depth, velocities, flood extent typically through steady state or dynamic one-dimensional (1D), dynamic quasi 1D/2D, dynamic 2D and 3D calibrated and validated numerical models and/or scaled physical models.

Hydrologic and hydraulic analysis can be undertaken for past, present and future conditions. This provides an insight into flood behaviour in consideration of changes

such as landform modification, imperviousness, increased rainfall intensity, higher ocean boundary conditions due to sea level rise etc. Further hydraulic analysis with expert interpretation can additionally provide an understanding of flood function, such as flow conveyance, flood storage areas and flood fringe, which can assist multiple realms such as strategic land-use planning and emergency management planning (AEMI 2013). For example, strategic land-use planning outcomes through understanding function may include not permitting development in flow conveyance areas for the full range of floods up to and including the possible maximum flood, and placing development controls reducing infill in flood storage areas and/or these flood storage occupying developments requiring adequate offsets, such as detention basins.

To understand consequence, the hydraulic outputs for the design events are analysed with consideration of exposure and vulnerability assessment data i.e. socio-economic impact, environmental condition, asset susceptibility to damage, evacuation modelling, warning systems, depth/velocity/duration/harm functions, failure analysis etc. (see Jha et al. 2012). This combination produces risk-based information such as: flood risk maps; rate of rise scenarios; infrastructure; private and public property annual average damage curves as exemplified in Figure 26; expected annual damage; crop damage; evacuation timing and routes; number or people isolated; risk to life and numerous other direct and indirect, tangible and intangible impacts for each of the modelled design events of interest i.e. 20%, 10%, 2%, 1%, 0.5% AEP and; PMF with varying boundary and blockage assumptions.

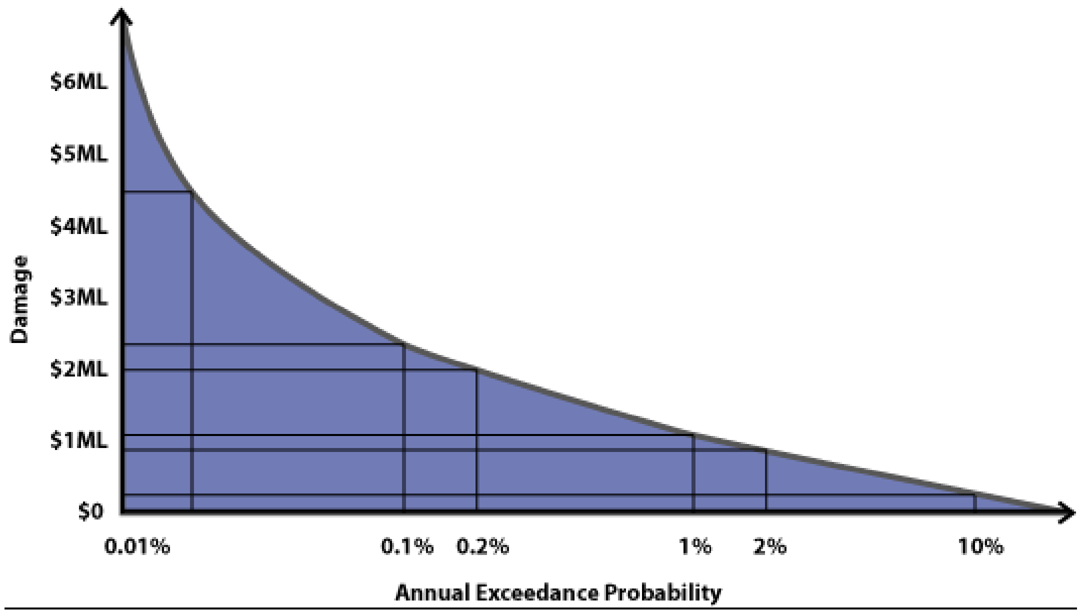


Figure 26: Annual average flood damage curve

As stated by the Environment Agency (2013), and supported by scholars (Slovic 1986; Rowan 1991; Carey 2005; Griffin et al. 2008), risk information and their uncertainties should be explicit where possible e.g. critical infrastructure at risk: No. electricity sub stations, No. water pumping stations, No. sewage treatment works, No. telephone exchanges, No. major arterial roads cut, No. sections of railway including stations overtopped, No. hospitals, No. schools, No. council chambers etc. effected by a 1% AEP flood and supported by maps and simulations. Further risk needs to be considered for the full range of flood events up to and including the Possible Maximum Flood (PMF or Qmax).

Due to the technical complexity, impartially and continuity required at this stage, it is unlikely or even detrimental (due to bias or personal agendas) to move beyond the consult level of participation. For this stage, it is therefore recommended that mechanisms such as fact sheets, presentations, questionnaires, interviews, public meetings, public exhibitions and reports be utilised to collect and present local knowledge about the flood behaviour, such as the effects of flooding on resident's property or nearby areas, timing, depth and vulnerability analysis data such as previous damages, isolation, resilience, deprivation, demographics. In utilising these mechanisms to collect local knowledge, modellers are able to calibrate and validate their flood models, parties are able to improve consequence data and, in doing so, flood practitioners are able to generate more accurate risk profiles for the full range of floods. In doing so, can build mutual understanding and trust between flood practitioners and the public about the risks flooding presents.

As the public is generally forced to trust the risk results, as individuals are unable to undertake the modelling themselves and can potentially introduce bias, it is vital the results and uncertainties are communicated effectively. This may include the way the message is framed and formatted (Joslyn et al. 2009; Faulkner et al. 2007), the implicit assumptions and uncertainty of flood risks and its implications communicated (AEMI 2013, Engineers Australia 2012), and the perception of roles and responsibilities including false beliefs, particularly what public agencies can undertake and do, expressed (Wachinger et al. 2013; Huber and Rothstein 2013; Demeritt and Nobert 2014).

Thus, the identify risk stage due to the technical complexity, impartially and continuity required should:

1) Develop risk analysis profiles for the full range of floods for a given area both current and future which may include: maps and simulations for displaying flood heights, depths, velocities, duration, provisional hazards (velocity x depth); flood function; timing of inundation or overtopping of critical structures, access roads, properties; flood isolation; flood damage curves; and harm (incorporating warning time, awareness, evacuation, duration, rate of rise, type of development, demographics, velocity x depth. etc) for the various design events; risk matrices; uncertainty curves etc.
2) Utilise consultative mechanisms to share balanced and objective information to gain a mutual understanding of the risks flooding presents for the full range of floods.
3) Be completed in under a year in order to maintain continuity throughout the cycle.

3.3.5 Identify risk management measures

The identification of risk management measures is also a well-understood process. This stage involves identifying appropriate and technically feasible flood management measures to address residual risks for the full range of floods up to and including the PMF. As identified by Laine et al. (2012), these risk management measures generally fall within four categories: 1) Flood management measures; 2) Building management measures; 3) Land-use planning management measures and, 4) Response management measures. Flood management measures and building management measures can then be further categorised for comparative purposes. Flood management measures can be sub-categorised as 1) Exclusion of flood water; 2) Conveyance of flood water; and 3) Containment of floodwater. Building management measures can be sub-categorised as 1) Existing buildings and 2) Future buildings. Examples of management measures associated with each category in conjunction with land-use planning and response management measures are represented in Table 1.

Table 1: Flood risk management measures (Laine et al. 2012)

Flood Management Measures		
Exclusion of Floodwater eg:	Containment of Floodwater eg:	Conveyance of Floodwater eg:
Earthen Levee	New Flood Mitigation Dam	Widen Existing Channel
Concrete Levee	Raising Existing Dam Wall	Deepen Existing Channel
Pop-Up Levee	Detention/ Retardation Basins	Realign Existing Channel
Drop In Boards	Enhanced Floodplain	New High Flow and/or Low

	Storage	Flow By-Pass Channels
Flood Gates	Increased Permeable Surface	Culvert Upgrades
One-Way Flow Valves		Realign Culverts
Sand Bags		Redesign/ Realign Bridge
Automatic Barriers		Underground Tunnels
Manual Barriers		River/Stream Rehabilitation
		Blockage barriers
Building Management Measures		**Land Use Planning Management Measures**
Existing Buildings eg:	Future Buildings eg:	Land-Use Planning Management Measures eg:
Wet Flood Proofing	Flood Smart Housing	State Environmental Planning Policies
Dry Flood Proofing	Flood Smart Sub-divisions	Local Environment Plans
House Raising	Flood Design Standards	Development Control Plans
Upper Story Flood Free Refuge	Flood Free Access	Local Flood Policies
Raise Electrical & Fixed Assets	Upper Story Flood Free Refuge	Incentives For Residential Zone Changes
Flood Resilient Materials And Design	Property Fill	Incentives For Residential Relocation
Strengthen Foundations	Relocatable Construction	
Improved Drainage	Modifiable Construction	
Housing Relocation		
House Removal		
Response Management Measures		
Flood Education Packages	Community Awareness	Drills and Exercises
Flood Intelligence	Response/ Evacuation Plans	Recovery Plans
Flood Prediction	Flood Warning	

In order to identify appropriate and technically feasible flood management measures, each measure should be appraised against a range of constraints such as social, safety, environmental/ ecological, economic, political and flood behaviour based on heuristic, engineering and scientific knowledge. This typically involves undertaking additional flood modelling, environmental assessments, socio-economic assessments, vulnerability and adaptation assessments etc. For example, investigating a management measure such as an earthen levee that provides protection up to the 1% AEP design flood event, at this stage in the cycle requires an initial safety assessment such as overtopping analysis, defence reliability and fragility curves, environmental assessment, flood behaviour assessment i.e. increased conveyance resulting in adverse downstream impact, political and social assessment

and economic assessment such as benefit and cost illustrated through an annual average damage curve in Figure 27.

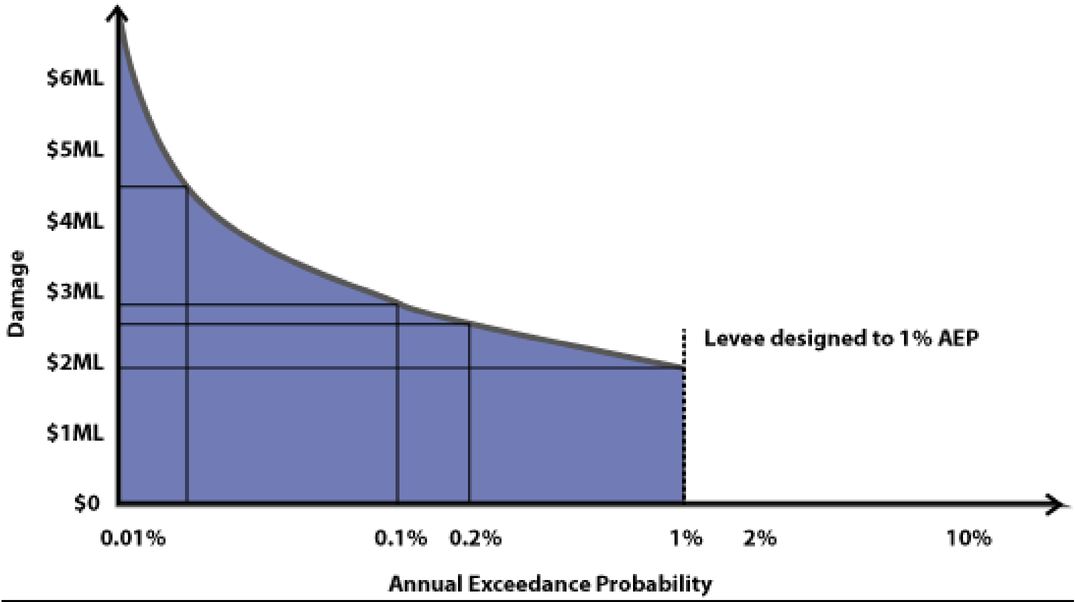


Figure 27: Annual average flood damage curve with levee

From a substantive view the goal of this stage is to build networks and derive socially innovative, adaptive and robust solutions, typically a portfolio of measures that meet the need of those affected. Therefore, mechanisms such as public meetings, decision support systems, public workshops, focus groups, technical steering committees could be employed to find measures that reduce risk-to-life and property. As management measure assessment can be a time-consuming exercise, particularly for works, it is recommended that limitations such as time and availability of scientific information be communicated to the public to establish analysis prioritisation of the various management measures. This may include focusing on management measures that can reduce high risk in flood matrices i.e. frequent events with significant damage, but should not exclude measures that deal with extreme events. Hence, analysis should be prioritised on a merit based risk assessment. Further management measures need to be analysed for the full range of floods including potential residual risks if the measures are implemented i.e. risk post flood exceedance of a levee/ flood detention basin's design height, failure modes etc.

Thus, the identify risk management stage due the technical complexity of modelling and assessments, should:

1) Analyse a range and typically a portfolio of management measures (flood management measures; building management measures; land use planning management measures and response management measures) including those

identified by the community, providing economic, social, environmental, political/legislative, and technical advantages and disadvantages for each measure. This will include undertaking flood behaviour modelling, uncertainty analysis, fragility, socio-economic and environmental assessment forming the basis of informed public decision making;

2) Utilise involve mechanisms to attract new, robust and innovative management measures from the public and develop balanced and objective information to support informed decision making;
3) Be completed in six months as to maintain continuity throughout the cycle.

3.3.6 Performance criteria

Establishing performance criteria is limited in many current flood risk management processes with notable exceptions, such as England. This stage involves establishing robust, specific, measurable, accountable and result-orientated performance criteria against which flood risk management process, decisions, progress and outcomes can be evaluated. In order to achieve, this as identified by numerous scholars (i.e. Innes and Booher 1999; Milward and Provan 2000; Margerum 2002; Schively 2007; Mandarano 2008; Laurian and Shaw 2009; Deyle and Slotterback 2009), performance criteria need to reflect the goals of the cycle whether they be: individual, group and or community level outcomes; process-oriented outcomes; content-oriented outcomes; or user-oriented outcomes (see Bryson et al. 2013).

In recognition of the public's role in determining the goals and outcomes and given the performance criteria, it is suggested that collaborative empowerment mechanisms be utilised at this stage, such as public workshops, surveys, decision support systems, taskforces, forums, committees, citizen juries and panels. These mechanisms can include both conventional and participatory performance criteria (see Campilan 2000), allowing the public to balance locally relevant criteria with those that can be applied more broadly. This forms the basis of informed decision making and subsequent evaluation.

Conventional performance criteria for floodplain management may include:

- percentage of population covered by flood risk analysis;
- percentage of population covered by warning systems;
- percentage of population covered by emergency response plans;
- number of residents with above-floor flooding in design flood event;

- number of future residents with above-floor flooding in design flood event;
- number of residents with property flooding in design flood event;
- number of residents isolated in design flood event;
- number of future residents isolated in design flood event,
- number of residents with significant risk to life during design flood event;
- number of non-functioning critical utilities and services for design flood event;
- number of future non-functioning critical utilities and services for design flood event;
- number of properties with flood-related development controls;
- number of future properties with flood-related development controls;
- current expected annual damages;
- future expected annual damages;
- present value benefit;
- present value cost;
- number of measures that are adaptable;
- number of measures that are sustainable;
- number of measures that are resilient;
- percentage of authorities aware of their responsibilities.

Participatory performance criteria for floodplain management may include:

- whether the individuals involved reflect the demographics of the broader public;
- the number of new alternatives;
- the individuals’ satisfaction with the process;
- and the percentage of individuals;
- involved in the decision-making process;
- percentage of individuals with increased knowledge of the communities risk and their vulnerabilities;
- percentage of individuals with increased knowledge of the floodplain management measures;
- percentage of individuals that changed their attitude towards certain management measures;
- percentage of individuals with increased awareness of their responsibilities;
- percentage of individuals satisfied with the processes transparency;
- percentage of individuals with increased confidence in public authorities technical abilities;

- percentage of individuals that thought the decisions equitably balanced tradeoffs;
- percentage of individuals that thought they had sufficient information to make informed decisions;
- percentage of individuals that thought decisions were made in a reasonable period of time;
- percentage of individuals willing to discuss and defend the process to others;
- percentage of individuals that believe they have benefited from being involved in the cycle.

Thus the performance criteria stage, due to the public's ability to identify locally relevant criteria, improve results, meaningfully contribute, and develop ownership, should:

1) Utilise a range of collaborate/empowerment mechanisms, to deliberate on selecting appropriate performance criteria for which decisions are made and subsequently evaluated.
2) Be conducted in a matter of weeks and possibly linked to commencement of the decision making stage of the flood risk management cycle.

3.3.7 Make decision

This stage involves making informed balanced accountable decisions about the use, relevant risks, and management of floodplains in light of the information presented. This is an extremely complex task that requires a robust understanding of flood behaviour, the risks, uncertainties, options and tradeoffs involved in flood risk management. Although a daunting task, as identified by numerous practitioners and scholars (Delli Priscoli 2004, EC 2007, Firus et al 2011, ICE 2014, Jha et al 2012, Sayers et al 2013, USACE 2009, US Government 2013, Walsh 1999 and WMO 2004) these decisions are best made by those who are directly or indirectly affected by flooding or the management of flooding if decision- makers support this approach. If decision-makers concur with the level of influence, then decision making at this stage should be facilitated through empowerment/collaborate mechanisms such as public workshops, decision support systems, committees and citizen juries.

This stage firstly involves establishing objectives based on assessment of risk, the management measure analysis and performance criteria. Resultant objectives could

include: as a minimum 2% of the population should be involved in the decision making and these individuals should reflect demographics of the community inclusive of minorities; average annual average damage reduction of 10% should be achieved by year X; the highest priority measures selected will be implemented by year X subject to funding; future critical utility services will be designed to withstand the PMF; all affected residents will have warning disseminated to them etc.

Establishing these objectives is a highly iterative and adaptable process as they will change with deliberation, confidence assessments and analysis of social, safety, economic, environmental/ecological, flood behaviour and political tradeoffs. Hence, it is not the intent of this stage to set unrealistic objectives as risks can rarely be removed entirely, but to offer an environment where individuals are empowered to make informed decisions through inclusive deliberative exchanges of acceptable risk, values and ideas to foster and reach balanced outcomes that instil civility, legitimacy and consensus in the decisions made.

Once the objectives and underpinning management measures have been established, all decisions should be clearly communicated and documented providing the unengaged public a further opportunity to be involved prior to final adoption of decisions made. Documentation will usually take form as a flood risk management plan for catchment X in which the following are clearly communicated: 1) a list of objectives; 2) the acceptable levels of both current and future residual risks for different areas and land-uses including number of properties with above floor flooding, critical utilities services affected etc. and how these decisions were made; 3) a list of prioritised management measures specifying their objective, ranking, benefit/cost, funding source, and short justification; 4) maps and/or simulations of both current and future residual risks for the full range both pre and post management measures, and the locality of all management measures and 5) a clear outline of roles and responsibilities of everyone not only for the implementation of the measures, and evaluation of the decisions but for emergency management preparation, response and recovery. This includes clearly demarcating roles and responsibilities if they are shared.

Thus, the make decision stage should:

1) Utilise a range of collaborate/empowerment mechanisms including those that include minorities, to empower the public to make informed balanced decisions about flood risk management objectives, performance criteria, current and future

residual risk, uncertainties, management measures and resultant roles and responsibilities.

2) Clearly document and communicate the decisions made.
3) Be completed in under a year as to maintain continuity throughout the cycle.

3.3.8 Adopt and implement decision

This stage involves implementing the decisions made which could include spin-off public participation cycles particularly in the investigation, design and construction of works. However, as the decisions have already been made this stage primarily revolves around keeping the public informed about implementation. Public participation mechanisms to achieve this stage include fact sheets, reports, websites, information portals, advice centres etc.

3.3.9 Monitor and evaluate

This stage involves both monitoring and evaluating the desired outcomes and decisions made via performance criteria through time. This important milestone allows the committee, external independent experts and/or increasingly with participatory evaluation and local stakeholders, the ability to document and reflect on whether the outcomes were or were not achieved, why and why not. This could be undertaken through involve, collaborate or empower mechanisms; however, for efficiency consult and inform mechanisms (such as public comment, meetings, surveys, facts sheets and reports) can adequately address this stage. By utilising collaborate/empower mechanisms, as identified by numerous authors (Narayan 1993; Cousins and Whitmore 1998; Fawcett et al. 2003) monitoring and evaluation can collectively build trust and resilience through endowing individuals to recognise specific tasks they can assist with to achieve goals and undertake corrective action.

The outcomes of this evaluation stage, in conjunction with flood events, flood behaviour changes, technological advancements and shifts in environmental, social, political attitudes, time-lapsed etc. can then re-prompt the review stage of flood risk management cycle. It should be recognised that the flood risk management cycle is a continual process, and is required to be, due to the continual shifts identified.

Thus, the monitor and evaluation stage should:

1) Utilise a range of mechanisms to assess the objectives and decisions made via performance criteria to establish if these were achieved and if not, why not and what corrective actions are required and justified.
2) Be continually undertaken throughout the implementation stage with major evaluations occurring at defined time stages for example every year, 10 years, 50 years etc. or as determined via outcomes or assessment points in the collaborative/ empowerment decision-making stage.
3) Clearly document, report and communicate results and findings of the monitoring and evaluation, inclusive of assessment points, corrective action and subsequent decisions made.

3.4 Limitations and risks

'Even the best needles are not sharp at both ends,' Chinese proverb

There are significant risks if decision-makers do not define and articulate the level of influence the public will have at each stage of the decision-making process or implement the defined level of commitment when decisions are made. This can be extremely disenfranchising for all involved and substantive benefits may not be realised. Hence, commitment must be sought by decision-makers prior to undertaking the cycle and selecting mechanisms, as these mechanisms effectively instil the level of participation, and hence define the role and influence of the public throughout the decision-making process.

Skewed representation risks diverting decisions back to paternalistic DAD or DEAD mechanisms manipulated by vested parties. Further, if balanced contributions from all individuals including experts is not achieved, then decisions made can be unsustainable. They could be technically unfeasible or have insufficient resources to implement decisions for example. Hence, the flood risk management cycle requires the active participation of public and private, both expert and lay individuals (if there is such a distinction) from broad demographic backgrounds including the marginal. This can be achieved through both the mechanisms utilised and clear communication of the normative, substantive and instrumental benefits of implementing the cycle.

Information biases is an additional risk however, as Renn establishes 'information and education process is always biased in one or the other direction regardless of the

effort to provide comprehensive, complete and objective information,' and one needs to recognise that this as an endemic problem to all decision making (1993 p.188).

Further the flood risk management cycle needs to be cognisant, receptive, draw upon and feed into other cycles. These other cycles may include land-use planning, emergency management, infrastructure renewal, political cycles. This is vital for not only the successful implementation of the flood risk management outcomes but for civic society, to reduce flood related economic, social, environmental and political risk. Like every decision, tradeoffs are required but due diligence of the flood risk management cycle should be afforded as its contribution can be significant.

3.5 Conclusion

The incorporation of public participation and performance monitoring into the generally analogous flood risk management processes not only addresses increasing statutory, institution and citizen public participation requirements but facilitates a dialogue about the application and selection of mechanisms and hence, the role and influence of the public at various stages throughout the flood risk management cycle. In doing so, flood risk management practices can continue to advance beyond the incumbent technocratic decisions of the past towards a more inclusive, deliberative environment where those affected by flooding and the management of flooding can make informed decisions about the current and future residual risks of utilising the floodplain, and the tradeoffs they are willing to make to achieve this level of risk.

Again it was not the intent of this chapter to mandate a new framework nor interfere with long-established existing processes, but rather introduce, define and justify new elements of the proposed flood risk management cycle as documented in sections 3.3.1 to 3.3.9 that can build upon identified deficiencies in current flood risk management best practice.

Chapter 4

Decision making and a new engagement decision support model for floodplain management options

4.1 Introduction

Decisions can be relatively simple to inherently complex. Flood risk management decisions as illustrated in the flood risk management cycle, are positioned towards the complex side of the spectrum. This complexity arises as there are multiple stakeholders (i.e everybody affected by flooding or the management of flooding), there are varying responsibilities, incongruent objectives and multiple outcomes. This chapter explores decision making, systems available to assist complex decision making, and applications of previous support systems in the water resources field establishing the foundation for a new engagement decision support model. It is envisaged this new engagement decision support model with application to the selection of floodplain management options, can assist the flood risk management cycle to improve domestic and international flood management outcomes by supporting informed, inclusive, transparent, sustainable decision making.

4.2 Decisions

Every day we make decisions, sometimes explicitly and sometimes with little conscious thought at all. A decision, as simply defined by the Oxford Dictionary, is the 'action of deciding' (OED 2014). This action of deciding may be through conscious or unconscious cognitive or affective thought, resulting in the selection of a belief or course of action among several finite alternatives, (Dijksterhuis and Nordgren 2006). To achieve the selection, a decision-making process is generally undertaken. Brim et al. (1962 p.9) proposed six sequentially linked phases to this process, these being: '(1) identification of the problem; (2) obtaining necessary information; (3) production of possible solutions; (4) evaluation of such solutions; (5) selection of a strategy for performance; and (6) actual performance of an action or actions, and subsequent learning and revision'. Others, like Halpern (1997), propose this process involves determining goals, generating alternatives to attain these goals, evaluating whether the alternatives meet the specified goals, and selecting an alternative or set of alternatives that best meet the goal. However, as highlighted by numerous scholars, (Lavington 1921; Kalecki 1937; Stigler 1939; Tinter 1941; Markshack and Nelson

1962; Benjaafar et al. 2014), not all decisions are sequential and linear thus flexibility with potentially circular feedback is required to reflect realistic and robust decisions.

Further, as highlighted by many scholars (e.g. Knight 1921, Ellsber 1961; Raiffa 1968; Kahneman and Tversky 1979; Bell 1982; Peterson 2009) unpinning classical decision theory, decisions generally take place under three conditions. These conditions are certainty (outcome probability is known), risk (outcome probability is known but uncertain), and uncertainty (outcome probability is unknown) (Swayer and Ellis 2008). As both risk and uncertainty are common when choosing alternatives, four general rules/theories summated by Krajewski et al. (2013) can be applied. These rules are:

- Maximin: Choose the alternative that is the “best of the worst.” This is achieved by selecting the alternative that performs best under the worst scenario.
- Maximax: Choose the alternative that is the “best of the best.” This is achieved by selecting the alternative that performs the best under the best scenario.
- Laplace: Choose the alternative with the best-weighted payoff. This is achieved by selecting the alternative with the highest performing average over the full range scenarios.
- Minimax: Choose the alternative that gives the best “worst regret.” This is achieved by selecting the alternative that minimises the maximum ‘regret’/loss for the full range of scenarios.

More recent theories building upon the above rules to deal with risk and uncertainty when choosing alternatives include: Robust Decision Making, introducing a maximin or minimax rule to quantify robustness based on the theory that “if a solution is robust against the worst case scenario it should perform reasonably well regardless of the outcome”(Ranger et al. 2010; Woodward 2012); Info-Gap decision theory, building upon robustness, tests alternatives against a range of current and future scenarios to ensure the worst case scenario is catered for (Ben-Haim 2001); Robust Optimisation, building upon Laplace, strives to find alternatives that perform optimally (e.g. minimax) to a range of functions or objectives, both under certain and uncertain constraints (Beyer and Sendhoff 2007; Ghaoui 2014); and Real options, building upon Bayesian decision analysis theory to provide alternative courses of action at multiple steps in time to deal with uncertainty and new information (Meyers 1977; Woodward 2012).

4.2.1 Complex decision making

Belton and Stewart (2002) define decisions in two categories: 1) 'the decision that does not matter that much' as the consequences are not substantial, are short term and can be easily rectified such as deciding what to eat for breakfast and 2) 'the decisions that do matter' as their consequences are substantial, the impacts are longer term, may affect many people and poor decisions may be difficult to rectify, such as federal budgets (Belton and Stewart 2002). It is these 'do matter' typically complex decisions that a disciplined and transparent decision-making process is required to provide: 'Structure; Rationale for decisions; Consistency in the decision making process; Objectivity; Documented assumptions, criteria, and values used to make decisions; and Decisions that are repeatable, reviewable, revisable, and easy to understand,' (Baker et al. 2001).

To elaborate on a typical decision making process for complex decisions the following steps are presented (adapted from Fulop 2014; Umass 2014; Baker 2001):

<u>Step 1: Identify the decision to be made.</u> This step involves clearly defining the problems, needs and goals of the decisions to be made.
<u>Step 2: Gather relevant information.</u> Complex decisions require information. This step involves gathering data about the problems, the constraints, criteria, alternatives, decision-making tools, evaluation methodologies and validation techniques.
<u>Step 3: Identify alternatives.</u> Through collecting information several possible alternatives may be initially identified. This step involves individual and/or group consultative mechanisms such as brainstorming to generate a list of alternatives. These alternatives can be broad or refined, as alternatives can be screened for feasibility at this point or culled at a later stage through a decision making tool.
<u>Step 4: Define criteria.</u> This step involves generating criteria which will be used to discriminate and separate alternatives to support comparison between them.
<u>Step 5: Weigh evidence.</u> This involves weighting alternatives against criterion via the information gathered.
<u>Step 6: Choose among alternatives.</u> This is typically conducted through a decision-making tool such as simulation and prediction models, expert systems, multi-criteria decision analysis and decision support systems. The alternative that best addresses the problem is selected which may involve a combination of alternatives.

Step 7: Validate alternatives against problem or decision to be made. This step involves what the title implies, ensuring the selected alternatives address the problems and meet the requirements, needs and goals of the decision.

Step 8: Take action. This step involves implementing the decision made in step 6.

Step 9: Review decision and consequences. The decision post implementation should be evaluated to see if the selected alternatives address the problems and meet the requirements, needs and goals of the decision. If these have not been achieved by the decision, then previous steps should be repeated in order to make a new decision. This could involve refining the problem, gathering more detailed or somewhat different information, developing additional alternatives, modifying criterion, utilising a different decision-making tool etc.

4.2.2 Decision making in flood risk management

As identified in chapter 2, flood risk management decision-making is typically undertaken by the principal authorities whose responsibility or shared responsibility it is to manage flood risk. For example in England this is the Environment Agency, in the Netherlands this is the Rijkswaterstaat, in the United States this is predominately FEMA and USACE, in New Zealand this is the Ministry of Civil Defence and Emergency Management in conjunction with regional councils, and in Australia it is a combination of state, territory and local governments depending on the jurisdiction. The decision-making ingrained in this flood risk management process is generally a traditional paternalistic top-down approach with limited tokenistic citizen ‘consultation’. However, shifts are underway with increased institutional requirement to devolve power and resources towards local democratic structures and communities as identified in subchapter 3.2.3. Yet there is a perplexing gap between the complexity in flood risk management and the average citizen’s ability to make informed decisions in the field. This gap arises as flood risk management decisions are inherently complex, requiring a sound understanding of floodwater behaviour, its interactions, uncertainties, assumptions and associated risk through to making informed balanced accountable decisions based on variable social, safety, economic, environmental/ecological, flood behaviour, organisational and political tradeoffs. Further, there is clear evidence in behavioural decision research that, 'humans are quite bad at making complex, unaided decisions,' (Slovic et at. 1977) 'as they mis-process important information,’ (Kahneman et al, 1982); ‘they seem to have little instinctive ability to clarify objectives,' (March, 1978), ‘create a wide variety of

alternatives,'(Keeney, 1992), or ‘structure decision tasks,' (Simon,1990)'(McDaniels et al, 1999). As a result it is understandable why traditional institutions and, 'most engineers regard the public as insufficiently informed about engineering intuition – and lacking the will to become so informed,' (Broom 1986), and thus take it upon themselves to sprout the unachievable line, 'I will take care of everything for you,’ limiting citizen responsibility and sustainable decisions (Delli Priscoli 2004). Decision-making systems as one mechanism in the new flood risk management cycle may offer assistance to close this gap, providing an opportunity for citizens to quickly delineate competing options or scenarios, and make balanced informed decisions building a degree of collective responsibility.

4.3 Decision-making systems

There are numerous decision-making systems available to assist with complex decision making. These systems include simulation and prediction models, expert systems, multi-criteria decision analysis and decision support systems. A brief summation is provided below to demonstrate the foundation of decision making systems however, extensive literature is available on each (see Robinson 2004; Giarratano and Riley 2004; Belton and Stewart 2002; Burstein and Holsapple 2008).

4.3.1 Simulation and prediction models

Simulation and prediction models are tools utilised to predict and/or simulate real world systems. These are tools developed to test scenarios and alternatives through typically scaled physical and/or mathematical models that are more costly, risky or not possible in the real world (Shinde 2000). The results and model outputs can be utilised to inform decision-makers. Particular advantages of simulation and prediction models particularly computer-based systems include providing the opportunity to quickly test base conditions, alternative approaches and/or assumptions, to verify, test designs, alter conditions, examine responses and decide on potential avenues or forecasts (Silverman 2013). However, the systems are only as good as the data entered and the assumptions and theories they are based on. As such, Sargent (2005) states that verification and validation should occur including system testing, accuracy derivation and system documentation with clear limitations and constraints, in order to assist decision making.

4.3.2 Expert systems

An expert system is a computer program that attempts to store all task-specific information in relation to a particular domain. This is so that users can call upon that information as required to provide expert answers mimicking human experts (Liao 2004). Expert systems consist of two principal components: 1) the knowledge base which contains the domain-specific expert knowledge attained through experts in the field which may have confidence factors or weights and; 2) a reasoning, inference or engine that through encoded rules supplies information to the user to recommend one or more course of action (Engelmore and Feigenbaum 1993). Advantages of expert systems include providing a platform for the sharing of expert knowledge at all times, the capturing of staff knowledge creating permanent knowledge repositories, the efficient retrieval of information and providing an automated process based on rational decisions (Hansen 2004). Typical disadvantages of these systems include a narrow supply of information and knowledge, significant establishment costs and maintenance effort, and the inability to deal with ambiguous problems and generate creative solutions (Hansen 2004).

4.3.3 Multi-criteria decision analysis

Multi-criteria Decision Analysis (MCDA) as defined by Belton and Stewart (2002), 'is an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter,' (2002 p.2). These approaches include, for example, the Weighted sum approach (Fishburn 1967) Goal Programming (Charnes et al. 1955; Charnes and Cooper 1977), the Analytical Hierarchy Process (Saaty 1980; 2004; 2009) and Outranking (Brans et al. 1986). All MCDA approaches solicit and synthesise input from stakeholders and arrive at a collective decision or recommendation (DCLG 2009). This is typically achieved by identifying a set of alternatives or options, deriving a set of weighted evaluation criteria, and assessing the performance of each option against the weighted criterion scores to derive preferred solutions (Geng and Wardlaw 2013). The primary advantages of the MCDA approaches over other systems include being able to account and compare objectives and criteria that are multi-objective, conflicting, incomparable and incommensurable (Omann 2000). Disdavantages of MCDA approaches include its complexity, it produces deterministic outcomes and it limits parametric measurement in some cases (Fenton and Neil 2000).

4.3.4 Decision support systems

A Decision Support System (DSS) is simply, 'an interactive computer based system that utilises a model to identify and draw upon relevant data in order to aid decision making,' (Lemass, 2004) although numerous definitions exist (see Keen and Scott-Morton 1978; Brennan and Elam 1986; Mallach 1994; Srinivasan et al. 2000; Turban 2001). The primary role of a DSS is to assist a decision-maker through a series of procedures, while supplying and delineating quantitative and/or qualitative data to enable the decision-maker to make informed choices amongst competing options to solve a problem or meet an objective. The DSS architecture is typically structured with a user-friendly front-end graphical user interface (GUI), following a model drawing upon a back-end database or knowledge-base containing quantitative and/or qualitative data (Power 2002). As raised throughout literature (Simonovic 1996; Srinivasan et al. 2000; Lemass 2004), a DSS is not designed to make decisions but to act as a tool to support and aid the decision-making process.

4.4 Multi criteria decision making methods

Embedded within the decision-making systems, most prominently in the multi-criteria decision analysis and decision support systems, are decision-making methods. Widely utilised methods in current practice include value measurement, outranking and goal programming, and have been developed and refined over the past half-century. Numerous scholars and practitioners have developed variant approaches to these methods each with their advantages and disadvantages. The following multi-criteria decision-making methods and approaches are examined for potential application in the engagement decision support mode.

4.4.1 Value measurement methods

Value measurement methods are based on defining a numerical score (or value) for each alternative based on criterion in order to preference the alternatives i.e. alternative A is preferenced to alternative B if $V(a) > V(b)$ where $V(a)$ and $V(b)$ are the overall scores of alternatives A and B respectively (Loken 2007). If $V(a) = V(b)$ then alternatives are deemed indifferently preferenced (Thokala 2011). There are numerous approaches to value measurement methods including the weighted summation (Wsum) approach (Fishburn 1967) and Analytic Hierarchy Process (AHP)(Saaty 1980; 2004; 2009).

The Wsum approach is undertaken via the following steps:

1. Definition of alternatives: identify the policy alternatives which are to be compared with each other.
2. Selection and definition of criteria: identify the effects or indicators relevant for the decision.
3. Assessment of scores for each alternative: assign values to each effect or indicator for all alternatives.
4. Standardization of the scores in order to make the criteria comparable with each other.
5. Weighting of criteria, in order to assign priorities to them (Herwijnen 2014a).

The following equation is then applied to calculate the total score of each alternative:

$$V(a) = \sum_{i=1}^{m} w_i v_i(a)$$

where $V(a)$ is the overall value, w_i represents the relative importance weight and $v_i(a)$ represents alternative a's performance score on criterion i. The alternative with the highest overall score is preferred when conducted for each alternative.

Advantages of the Wsum approach include being relatively simple, transparent, easy to explain, providing a structured approach and can accommodate both quantitative and qualitative information (Keeney and Raiffa 1976; Belton et al. 2002; Herwijnen 2014a). Disadvantages relate to alternatives and criterion requiring preferential independence and difficulty in deriving parametric measurement scales (Belton et al 2002).

The AHP approach is undertaken via the following steps:

1. Develop the AHP hierarchy i.e. goal, objectives, sub objectives, attributes, criterion and alternatives.
2. Computing the vector of criteria weights. This is completed by pairwise comparison, requiring the decision-maker to answer ‘How important is criterion C_1 to C_2 ?’. Rating the importance between the two criterion according to a numerical scale between 1 (equally important) and 9 (absolutely more important).

$$Cr = \begin{bmatrix} C_1/C_1 & \cdots & C_1/C_n \\ \vdots & \ddots & \vdots \\ C_n/C_1 & \cdots & C_n/C_n \end{bmatrix}$$

3. Pairwise comparison of alternative for each criterion (scoring). Again this is achieved by asking the decision maker "How important is alternative a_1 to a_2?". Rating the importance between the two criterion according to the same numerical scale 1 to 9.

$$Ar = \begin{bmatrix} a_1/a_1 & \cdots & a_1/a_n \\ \vdots & \ddots & \vdots \\ a_n/a_1 & \cdots & a_n/a_n \end{bmatrix}$$

4. Obtaining an overall score by combining the alternative rating (Ar) with the criterion rating (Cr) and then ordering the alternatives based on their overall scores in decreasing order (Saaty 1990; Herwijnen 2014b).

Advantages of the AHP approach include being relatively straightforward, include both subjective and objective evaluation measures, parametric tests can be conducted and bias in decision-makers is reduced (Belton et al. 2002; Herwijnen 2014b). Disadvantages relate to ranking irregularities such as rank reversal, the onerous process of pairwise analyses if many criteria and alternatives exist, and as noted by some scholars the limitation of having an artificial scale of 1 to 9 highlighted by the scenario: alternative A being 25 times more important than option B (Belton et al. 2002; Herwijnen 2014b).

4.4.2 Outranking methods:

Outranking methods like value measurement methods use a preference relationship called outranking relation, to establish 'dominance' of one over the other for that criterion (Roy and Bouyssou 1993; Thokala 2011). This approach is usually achieved by the 'concordance-discordance' principle declaring that alternative A outranks alternative B if 'a majority of the attributes supports this assertion (concordance condition) and if the opposition of the other attribute -the minority- is not too strong (non-discordance condition),'(Bouyssou 2014). To achieve this two models are generally utilised ELECTRE (ELimination Et Choix Traduisant la REalité) (Roy 1968) and PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations)(Brans 1982).

The ELECTRE approach is undertaken via the following steps:

1. Deriving alternatives and criteria through the computer system which is usually facilitated.
2. Define the concordance index c_{jk} which is achieved by calculating for every pair of alternatives (aj, ak) the sum of all weights for those criterion i where alternative j scores at least as high as alternative k i.e.

$$c_{jk} = \sum_{i:a_{ij} \geq a_{ik}} w_i, \quad j, k = 1, \ldots\ldots, n, \qquad j \neq k.$$

2. Define the discordance index (d_{jk}). If aj performs better than ak on all criteria then the discordance index is zero. If not then for each criterion where ak performs better than aj, the ratio is calculated between the performance level between ak and aj and the maximum difference in score on the criterion concerned between any pair of alternatives i.e.

$$d_{jk} = \max_{i=1,\ldots\ldots,m} \frac{a_{ik} - a_{ij}}{\max\limits_{j=1,\ldots\ldots,n} a_{ij} - \min\limits_{j=1,\ldots\ldots,n} a_{ij}}, \quad j, k = 1, \ldots\ldots, n, \qquad j \neq k$$

3. Define the concordance threshold $c*$ and discordance threshold $d*$ such that $0 < d* < c* < 1$.
4. Combine the concordance and discordance indices to determine that aj outranks ak if $c_{jk} > c*$ and $d_{jk} > d*$. The concordance and discordance thresholds can be adjusted to change the number of alternatives considered (Fulop 2013; DCLG 2009).

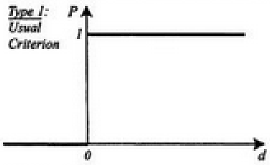
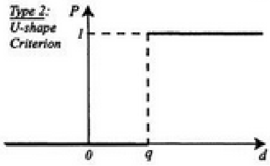
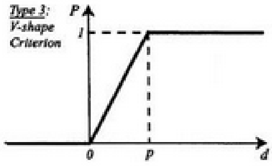
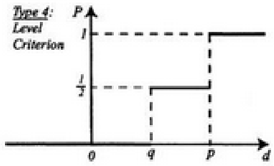
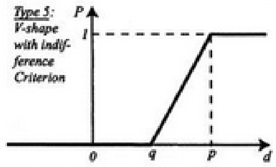
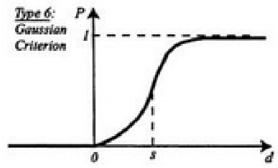
The alternatives that outrank others are seen as strong preferences and ultimately categorise alternatives into acceptable and unacceptable (Greening 2004). This approach is then combined with alternative MCDA methods to get a ranking among alternatives (Loken 2007; DCLG 2009).

Advantages of the ELECTRE approach, like AHP, are it can utilise parametric analysis techniques, refine alternatives and provide acceptable alternatives to the decision-maker to then assess. Disadvantages primarily relate to its complexity with requiring a ‘black box’ computer program (Loken 2007).

The PROMETHEE approach is undertaken by the following steps:

1. Criterion weights and alternatives are determined prior to input into the PROMETHEE computer system.

2. Preference functions $P_i(a_j a_k)$ are defined from the following six typical functions representing the degree of preference between individual alternatives a_j and a_k.

Generalised criterion	Definition	Parameters to fix
Type 1: Usual Criterion 	$P(d)=\begin{cases}0 & d\le 0\\ 1 & d>0\end{cases}$	–
Type 2: U-shape Criterion 	$P(d)=\begin{cases}0 & d\le q\\ 1 & d>q\end{cases}$	q
Type 3: V-shape Criterion 	$P(d)=\begin{cases}0 & d\le 0\\ \frac{d}{p} & 0\le d\le p\\ 1 & d>p\end{cases}$	p
Type 4: Level Criterion 	$P(d)=\begin{cases}0 & d\le q\\ \frac{1}{2} & q<d\le p\\ 1 & d>p\end{cases}$	p, q
Type 5: V-shape with indifference Criterion 	$P(d)=\begin{cases}0 & d\le q\\ \frac{d-q}{p-q} & q<d\le p\\ 1 & d>p\end{cases}$	p, q
Type 6: Gaussian Criterion 	$P(d)=\begin{cases}0 & d\le 0\\ 1-e^{-\frac{d^2}{2s^2}} & d>0\end{cases}$	s

3. Multi-criteria preference indexes from the above preference functions are then defined using the following summation formula:

$$\pi\,(a_j a_k) = \sum_{i=1}^{m} w_i P_i(a_j a_k)$$

4. In order to rank alternatives the following equations are then undertaken:

Positive ranking flow:

$$\Phi^{+}(a_j) = \frac{1}{n-1}\sum_{k=1}^{n} \pi(a_j a_k)$$

Negative ranking flow:

$$\Phi^{-}(a_j) = \frac{1}{n-1}\sum_{k=1}^{n} \pi(a_k a_j)$$

with a_j being preferred to a_k when $\Phi^+(a_j) \geq \Phi^+(a_k)$ and $\Phi^-(a_j) \leq \Phi^-(a_k)$, a_j being indifferent to a_k when $\Phi^+(a_j) = \Phi^+(a_k)$ and $\Phi^-(a_j) \leq \Phi^-(a_k)$, else they are incompatible (Brans 1982; AGH 2014; Fulop 2013).

Advantages of the PROMETHEE approach is the ability to utilise parametric analysis techniques, it is a transparent calculation, and the software is easy to use (Velasquez and Hester 2013). Disadvantages, like ELECTRE, relate to its complexity, as it would be difficult to explain the process to decision makers.

4.4.3 Goal, aspiration or reference level methods:

These methods are based on the satisficing model suggested by Simon (1976), which focus on eliminating alternatives until attaining satisfactory level of performance for each criteria. Goal programming (Charnes et al. 1955) as one approach is generally undertaken by the following steps:

1. The goals are determined and given a priority level (i.e. priorities $P_1 \geq P_2 \geq \cdots \geq P_n$)
2. Goals are assigned a deviational variable. The variables can be either positive d^+ or negative d^- with positive representing an overachievement of the goal and negative representing an underachievement of the goal. Noting the objective of goal programming is to minimise deviations from desired goals.
3. The following equation is then typically applied:

$$Minimize\ z = \sum_{i=1} P_i({d_i}^+ + {d_i}^-)\,, \qquad where\ i = 1,2,3, \ldots\ldots, n \quad (1)$$

Subject to:

$$\sum_{j=1} a_{ij}x_j \leq b_i\,, \qquad where\ j = 1,2,3, \ldots\ldots, m \ (2)$$

$$\sum_{j=1} a_{ij}x_j - {d_i}^+ + {d_i}^- = b_i\,, \qquad (3)$$

$$with\ x_j, {d_i}^+, {d_i}^- \geq 0 \quad (4)$$

where a_{ij} represents the coefficient, b_i the right-hand side value, ${d_i}^+$ the over-achievement of goal i, ${d_i}^-$ the under-achievement of goal i, P_i the priority level of the ith goal, and x_j the decision variable. Function (1) aims to minimise deviations from the goal, while subjecting to constraints (2) and goal equations (3), with (4) the goal programming model (Ho et al. 2006).

Advantages of goal programming include its ability to handle a large number of alternatives in a relatively simple pragmatic way to find 'satisficing' alternatives (Ahmad et al. 2005). Disadvantages include its inability to subjectively weight criterion, resulting in the utilisation of other methods such as AHP to fulfil this role (Velasquez and Hester 2013).

4.5 Application of support systems in water resources

Numerous support systems have been developed in the water resource realm over the past few decades due to their inherit advantages to assist with critical decision making. These systems include applications in flood hazard mapping (FLOOD DSS, HAZUS, ANFAS etc.); flood response routing and emergency management (Gold Coast City Council, River Thames, EFAS, FLIWAS etc.) a combination of both including option investigation (REDES, The Planning Kit, MDSF2, EUROTAS, RASP, PAMS); flood education games (FloodRanger, FloodManager, WaterManager); water quality prediction (WATERCAST etc.); aquatic ecological models (CAEDYM etc.); urban stormwater improvement models (MUSIC etc.); and, soil and water models (SWIM etc.)(CWCD 2010; FEMA 2011c; Mirfenderesk 2009; Sanders and Tabuchi 2000; Simonovic 1999; Cook et al. 2009; Van Schijndel 2005; McGahey et al. 2006; Gouldby et al. 2008; ASFPM 2013; CWR 2006; Wong et al. 2001; CSIRO 1992). The following support systems are presented as a snapshot of the endless possibilities these systems can provide in the water resources field.

4.5.1 Hazus

Hazus is a risk-based decision support system for multi-hazard loss estimation resulting from earthquake, riverine and coastal floods, and hurricanes initiated by the Federal Emergency Management Agency (FEMA) and developed via the National Institute of Building Sciences in the United States (Seligson 2008). It is generally designed for 'government planners, GIS specialists and emergency managers' by combining science, engineering, and mathematical modelling with geographic information systems to estimate physical damage, economic and social losses (Nastev and Todorov 2013; FEMA 2014). The backend consists of geographic information, infrastructure asset data, economic damage functions, various hazard models with a front end rule based GUI which allows the user through a modelling and decision support framework to: 1) identify the hazard i.e. flood, tornado etc.; 2) profile the hazard i.e. for flood this includes frequency, depth, and velocity; 3) develop an inventory of assets affected i.e. buildings, infrastructure, agriculture, population

etc. and, 4) estimate losses i.e. cost of repairs, replacements, income loss, shelter and recovery needs, opportunity costs etc.(Croope 2009). Hazus has been successfully applied in the United States and continues to evolve with increased functionality including rapid impact assessment and disaster response (FEMA 2014).

4.5.2 DayWater

DayWater is an Adaptive Decision Support System ADSS for urban stormwater pollution source control funded through the European Commission Framework 5 (Thevenot et al. 2008). The ADSS has been developed as a web-based client server database application that guides technologically inclined users through a chain of activities and questionnaires. Users select relevant measures and criteria/indicators, for input into a matrix from which multi-criteria approaches can be selected and weightings agreed upon through group consensus to compare proposed measures to be implemented (Thevenot et al. 2008). The system is developed as a set of database tables, software tools, and feedback system logics (relations, functions, procedures, etc.) with a relatively easy-to-use GUI front-end interface. The system has been utilised with success in Europe, facilitating stormwater alternatives and scenario testing at a number of locations generating both acceptable and unacceptable alternatives (Ellis et al. 2006; Thevenot et al. 2008).

4.5.3 MDSF2

The Modelling and Decision Support Framework 2 (MDSF2) provides a platform for users to interrogate flood risk information such as the probability and consequences of inundation and coastal erosion, allows future scenario simulation and supports users to investigate different flood response options (Environment Agency 2014). The decision support toolset has been principally designed for staff at the UK Environment Agency allowing them to work through source/ pathway/ receptor/ management response modules. For example the user can alter the source i.e. flood flow, the pathway i.e. the terrain/flowpath, the receptor i.e. population, agricultural land to evaluate multiple cases, develop economic metrics and uncertainty information. The system architecture is developed to be platform independent, containing a set of database tables and GUI frontend interface with the ability to utilise ArcGIS and/or proprietary flood model feedback (McGahey et al. 2010). The platform has been successfully applied in the United Kingdom for,'long-term strategic planning; catchment studies; national, strategic or local flood risk assessments; asset management etc.'(Environment Agency 2014).

4.5.4 User-friendly support systems

Although many support systems exist for the water resources field, they are often designed for specialised targeted technical end users. This is evident in numerous flood risk management decision support systems, as the graphical user interface is limited (REDES; Gold Coast City Council Flood Response Routing; EFAS) or reliant on specialised software to run (MDSF2; HAZUS). Table 2 adapted from McGahey et al 2006 and Schanze 2007 summarises the user-friendliness for a range of flood risk management related decision support software tools.

Table 2: Flood management DSS user-friendliness

DSS	Average citizen user-friendliness
MDSF2	Limited
REDES	Limited
HAZUS	Limited
FloodManager	Good
FloodRanger	Good
Daywater	Limited
EUROTAS	Limited
RASP	Limited
PAMS	Good
ANFAS	Limited
EFAS	Limited
WaterManager	Good
Planning Kit	Good

It clear from the DSSs examined, that although many have limited user friendliness, there are exceptions, such as Planning Kit and the flood education games FloodManager, FloodRanger and WaterManager. These tools effectively bridge the flood risk information gap in a easy-to-use robust web based architecture, allowing the average citizen the opportunity to run scenario tests. However, all five DSS systems identified on the binary user-friendliness scale as good, still operate at the inform level of engagement of the public participation spectrum (figure 23). As a result significant opportunity exists for tools that build upon these information sharing foundations, aiding and empowering citizens to make informed choices about complex decisions such as flood risk management.

4.6 New engagement decision support model

The new engagement decision support model this research presents is fundamentally a fusion of multi-criteria, decision support and public participation theory. It is a hybrid approach that provides flexibility in application and recognises the need for organisational, political, cultural and technical requirements to be addressed including legislation, policies, strategies, roles and responsibilities as examined in chapter 2. Delivery of the model is intended through EDSS. These systems are structured, accessible, interactive, tailored computer-based tools that seek to engage and assist the public to make informed decisions about complex issues. They do so by guiding the user through a series of questions and steps, delineating user inputs and supplying unbiased quantitative and/or qualitative data in plain accessible language and/or pictures to enable the user to make informed choices between competing options or scenarios. It is not the intent of this model, nor the EDSS, to make decisions, but rather to support and aid the decision making process through a transparent, inclusive, deliberative and auditable process. The model can be employed at any stage in the decision-making process, with any community i.e small town with isolated issues to multi-jurisdictional areas with complex issues and is based on the Wsum value measurement approach. This approach was selected above other methods noting its limitations, as user comprehension and simplicity was viewed as a key foundation to providing a transparent, inclusive, flexible model that truly supports informed decision making by everyone. However, other multi-criteria approaches such as AHP can substitute the Wsum approach within the model if deemed apt provided they are commutated clearly and are understandable to non-technical users.

4.6.1 Model

The generic engagement decision support model is underpinned by the following framework (Figure 28):

1) A complex decision involving multiple stakeholders, incongruent objectives and multiple outcomes.

2) Development of a quick-to-run, easy-to-use, digestible, flexible, transparent computer based system with multiple databases collecting and providing information and a single matrix appraising options at the back end. This system

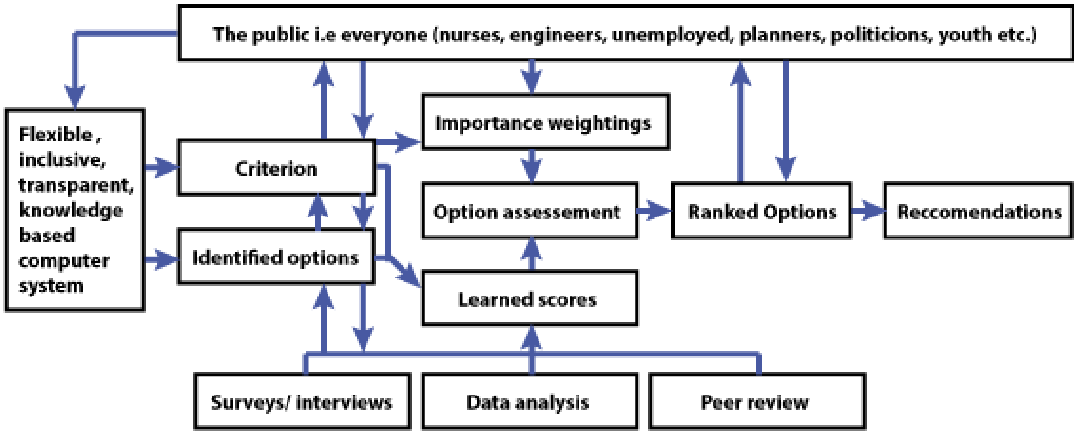


Figure 28: The engagement decision support model.

has to be supported and potentially designed by the decision-maker/s and the broader community.

3) The identification and selection of criterion questions (cq_i) where $i = 1, \ldots\ldots, m$ to which options are appraised. This can be achieved through public participation mechanisms such as surveys, forums, technical working groups, committees, workshops, decision support systems etc. and typically comprise social, safety, environmental/ecological, economic, organisational/ political, and technological criteria. This is an iterative process with the identification and selection of options step below, as both are interdependent and require involvement from decision-makers, specialist experts and the broader community.

4) The identification and selection of options to be appraised (O_j) where $j = 1, \ldots\ldots, n$. This can also be achieved through public participation mechanisms as listed above involving the community, specialist experts and decision makers. This will typically utilise model outputs and again is an iterative process with the identification and selection of criterion questions step above.

5) The scoring of the options (O_j) against the selected criterion questions (cq_i) to generate learned scores (ls_{ij}). This involves utilising expert judgment, interviews, case studies, literature reviews and research queries to derive justifiable, transparent and consistent leaned scores for each option. These learned scores are then entered into a matrix (see below for example) and sensitivity analysis conducted.

Options (O_j)	Criterion guestions (cq_i)								
	cq_1	cq_2	cq_3	.	.	.	.	.	cq_m
O_1	ls_{11}	ls_{12}	ls_{13}	.	.	.	.	.	ls_{1m}
O_2	ls_{21}	ls_{22}	ls_{23}	.	.	.	.	.	ls_{2m}
O_3	ls_{31}	ls_{32}	ls_{33}	.	.	.	.	.	ls_{3m}
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
$O_{\boldsymbol{n}}$	ls_{n1}	ls_{n2}	ls_{n3}	.	.	.	.	.	ls_{nm}

6) The user assigning importance weightings $(w_{\boldsymbol{i}})$ for each criterion question based on their values via the system to which the equation 1 is applied and option assessment conducted:

$$O = (O_1, O_2, \dots\dots O_n)$$
$$where\ O_j = \sum_{i=1}^{m} w_i ls_{ij} \qquad [1]$$
$$O_j > O_{j+1}$$

w_i represents the user defined importance weight for m criterion question, and ls_{ij} represents the learned score for m criterion question and n option

7) The user being presented with the list of equitably ranked preferences based on equation 1. The user is then encouraged to investigate and understand why options ranked the way they did, learn about their specific advantages/ disadvantages and constraints. This includes conducting ‘What If’ sensitivity analysis i.e. **What** will happen to the ranking **If** the importance input is changed, enabling a greater appreciation of alternate views and tradeoffs that have to be made. The user is then presented with the opportunity to re-rank the options (hopefully now better informed about the decisions they are making).

8) The user submitting their preferred management option recommendations and providing additional demographic information for dissemination and aggregation.

9) Decisions are informed by or made from the aggregation of all response recommendations collected. This decision is then communicated and reported to the public, including how the user input contributed to the decision made.

The step sequence is important to ensure efficiency and coherence in the approach with the exception of steps 3 and 4 which should be generated interdependently. Presenting the user in step 6 with the criterion questions without understanding the link to the options initially, is seen as a significant advantage limiting typical emotive predisposition option bias in a hope to bring rational judgements about their values to the preferencing of options. It is foreseen that in doing so users can truly be empowered to make enlightened balanced decisions about complex engineering and non-engineering choices, allowing them to align their values with options through a transparent framework. As such the model is particularly powerful in the decision-making cycle when involve, collaborate and engage levels of influence are selected by the decision-makers.

4.7 New engagement decision support model for flood risk management options

The generic nature, flexibility and scalability of the model enable it to be applied at numerous stages in the flood risk management cycle. The prominent stages for inclusion are: 1) identify risk management measures; and 2) make decision. These stages lend themselves to the model, as their intent is to share balanced and objective information, achieve a mutual understanding of the risks, alternatives, tradeoffs, opportunities and solutions while building strong two way communication and potential decision making responsibility. The following subchapter explores the processes and considerations of the model via the development of an EDSS for flood risk management options as a mechanism to assist at the identify risk management measures stage of the flood risk management cycle as shown in Figure 29.

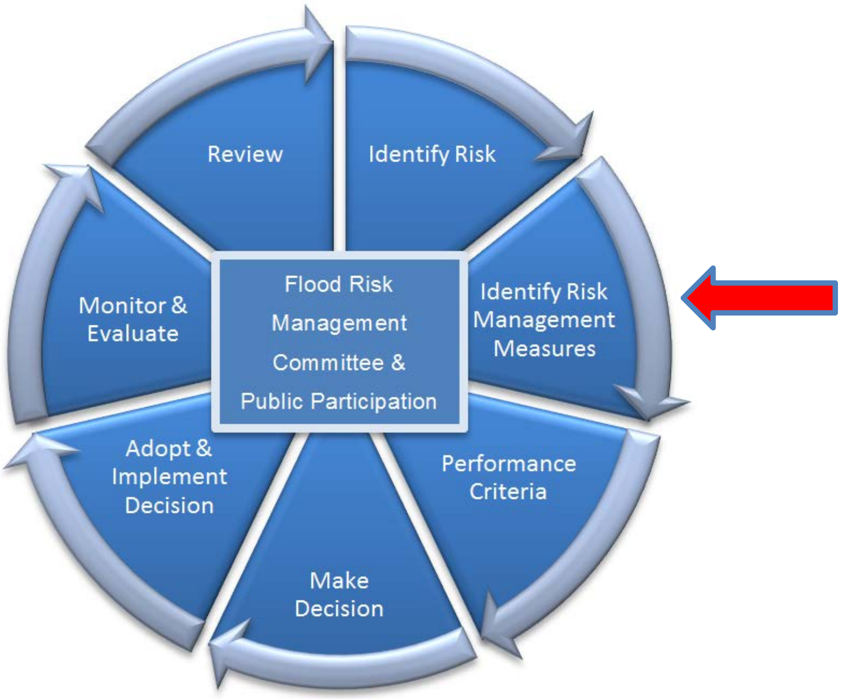


Figure 29: Flood risk management option EDSS application in the flood risk management cycle.

4.7.1 System design

System design is fundamental to an engagement decision support system for floodplain management options. As the intent of the system is to provide a structured, accessible, interactive, transparent program that seeks to engage and assist the public to make informed decisions about complex issues, a number of criteria are viewed necessary to achieve this goal. These criteria include:

1) Currency: The system should contain the best available information. This would include up-to-date information on the various flood risk management options' specific advantages and disadvantages inclusive of social, safety, economic, environmental, political, technological constraints, as well as case studies documenting past successes and lessons learned.

2) Defendable: The system requires a structured methodology, as provided by the model, that is repeatable, transparent and justifiable. The results from the EDSS should be auditable and able to withstand challenges.

3) Accessible with equal opportunity: The system should be available to all. This may include developing a standalone and online EDSS, providing the opportunity

for users with no, limited or full internet access the ability to participate. Further, the standalone and online system should be designed in accordance with the Web Content Accessibility Guidelines 2.0 and be free to access.

4) Interactive and comprehensible: The system, information contained within, and frontend GUI should be quick-to-run, digestible, non-restrictive and engaging, facilitating users discovery of floodplain management options and allowing them to make informed decisions. One aspect of achieving this requirement is breaking down technical engineering information into relevant understandable packets of information without jargon, potentially assisted by pictures where possible. This is also achieved by allowing users the opportunity to proceed back and reassign importance weights (w_i) to the value based criterion questions (cq_i) thus prompting interactive user exploration and understanding.

Software architecture of both the front-end GUI and backend database are not explicit provided the above criteria can be achieved. For example the system for the standalone version could be developed through an Microsoft excel spreadsheet with a visual basic programmed 'macro' frontend, or for the online version through a MySQL, Microsoft Access or MSSQL backend, with a PHP, Java or ASP.NET programmed frontend.

4.7.2 Selection of flood risk management criteria:

Flood risk management is an integrated cycle of negotiating tradeoffs among varying values and constraints. These values and constraints are generally encompassed within social, safety, environmental/ecological, economic, flood behaviour, political/ organisational spheres and formed through varying psychological and physical constructs (Laine et al. 2012; Rosenburg 2007). Values and constraints are as identified by von Winterfeldt and Edwards (1987), abstractions that help organise and guide preferences. Consequently, in application to the engagement decision support system for floodplain management options, it is from these values and constraints that criterion are derived to assist decision making.

Criterion as defined by the Oxford English Dictionary is 'a principle or standard by which something may be judged or decided,'(OED 2014). It is the term 'judge' which is an important distinction, as it is the role of criteria in the engagement decision support model to rank preferred to non-preferred management options based on user

defined weightings and learned scores. As there are millions of criterion that could be used to judge alternatives, Renn (1993) and more recently Munda (2004), Madlener and Stagl (2005) and Johnson (2006), demonstrate that the selection of criteria are best accomplished by asking all relevant stakeholders and decision-makers what values and constraints they would use to judge alternatives. This includes selecting criteria that reflect the whole community, their values and concerns. In doing so, a sustainable approach is derived, as those who are likely to criticise the objectivity are part of the decision-making environment in which the criteria are derived and options assessed.

In developing criteria Belton and Stewart (2002) establish a list of considerations. These summated being:

1) 'Value reference': All criteria can be linked to objectives and values.
2) 'Understandability': All users can interpret and understand the criterion.
3) 'Measurability': All options must be able to be measured against the criteria qualitatively or quantitatively, with the data source specified where possible.
4) 'Non-Redundancy': Criteria should not measure the same objective and value. As highlighted by Keeney (1992) this can lead to 'double counting' or redundant criteria (redundant in context, meaning that all measures will score the same and cannot be differentiated by the criteria). Rather similar criteria should be grouped, with methods such as criteria correlation coefficient method available to assist (see Wooler 1982; Eden and Jones 1984).
5) 'Completeness': As noted by Keeney and Raiffa (1976) all important objectives are to be covered by the criteria. This includes utilising all criteria necessary to compare differences between the options to arrive at options that satisfy the objectives goals.
6) 'Operationally': All criteria must be able to be used in the selected model to produce a comparison between options. This includes reducing the number of criteria to the essential minimum and providing concise information as to not place extensive demands on deriving supporting information.

Further Keeney and Raiffa (1976) suggest criterion and sub criterion or in their terms 'objective' and 'sub objectives' be provided as hierarchical structures illustrated in Figure 30, as to serve as a completeness checklist for decision-makers. In this hierarchical structure criterion are defined as X_1, X_2,….,X_n and sub criterion Z_1, Z_2,….,Z_n were n is the maximum number of criterion.

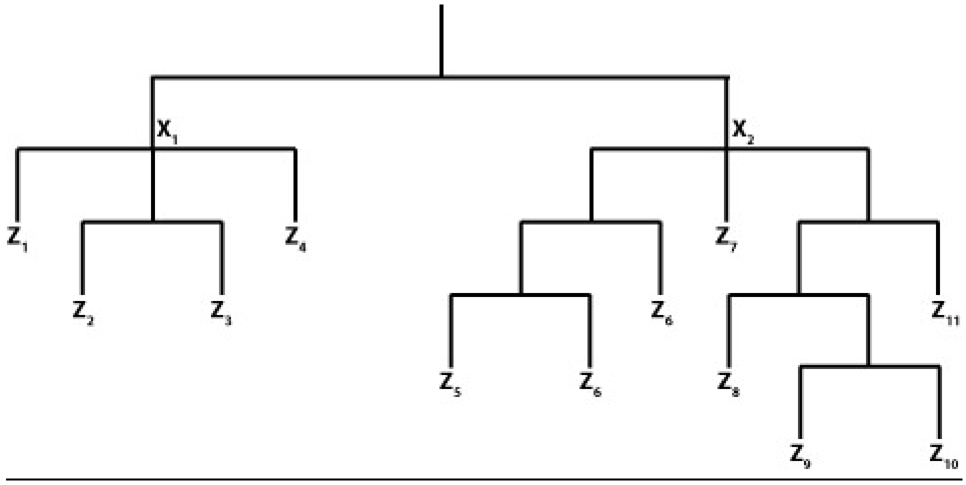


Figure 30: Criteria hierarchy (Keeney and Raiffa 1976).

Criterion and sub criterion within context of the engagement decision support system for flood risk management options should cover the concerns of all affected citizens. The identification of criterion and sub criterion could ideally be facilitated through public participation mechanisms such as surveys, forums, committees, workshops. For example, during the public meetings and exhibition of the identify risk stage of the cycle, a short questionnaire or quick feedback register asking community members to document and submit important values and criterion they would use to evaluate options could be undertaken. Another methodology might be to examine literature or policy documents. These values could then be utilised by the committee to select core representative values from which criterion questions can be derived. It is vital that criterion questions do not favour one particular value segment, but rather encompass a range of locally relevant social, safety, environmental/ecological, economic, organisational/political, and technological criterion. Further criterion should be unambiguous and concise reflecting a core value.

As noted in the engagement decision support model, the selection of criterion is an iterative process with the identification and selection of options step, as both are interdependent. This is an essential consideration as highlighted by Keeney and Raiffa (1976), as criterion are redundant if all options score the same and/or perform poorly against all criteria, with the latter less important particularly if an options performance is incommensurate to reducing flood risk but desired by the public.

Example criterion for a flood risk management option EDSS could include: aesthetics; amenity; impacts on the social environment, social acceptability, equity, equality, safety, awareness, impact on aboriginal heritage, impact on flora, impact on

fauna, impact on geomorphology, water quality impacts, volumetric changes, adverse impact, initial costs, ongoing cost, payback period, reliability, reduced damages, compatibility with existing system, compatibility with legislation, policies and regulation etc.

4.7.3 Selection of flood risk management options

As identified in sub chapter 3.3.5, there are four predominant flood risk management measurement categories. These categories being: 1) Flood management measures; 2) Building management measures; 3) Land-use planning management measures and 4) Response management measures. Within each category there are numerous options (Table 2) or variants of options from which to choose. The selection of options for inclusion in the flood risk management options EDSS at the identify risk management measures stage of the flood risk management cycle should be decided through public participation mechanisms involving the community, specialist experts and decision-makers based on flood risk information from the identify risk stage. One approach to achieving this utilised by Bowden and Preheim (2014), is the use of an online portal where users can post ideas for the public to view. These ideas can then be critiqued, built upon, and polled by the community (Bowden and Preheim 2014). It is not the intent of the floodplain risk management option EDSS at this stage to identify site specific options, but rather generate a semi-generic list suitable options, to gain public support and prioritise options for site specific analysis. In doing so, flood behaviour analysis and assessment is optimised for each option recognising the time and cost involved in undertaking the analysis and assessment.

4.7.4 Learned-score matrix

The development of a learned-score matrix is the fundamental backbone of the system. The learned scores (ls_{ij}) are generated through expert judgment, interviews, case studies, literature reviews and research queries to derive justifiable, transparent and consistent scores for each option. As flood management constraints are a combination of qualitative and quantitative variables across different scales exceptional care is required to achieve relative option comparison.

Firstly, the measurement scale needs to be selected. As numerous scales of measurement exist, all must be examined for best fit to each criterion. Scales of measurement include: Nominal, assigning a number to an object with no ranking; Ordinal, ranking an object and assigning a number without distance; Interval scale,

ranking an object at consistent intervals with the distance between objects important; Ratio, assigning a number based on a ratio unit fixed to an absolute zero; and Absolute, assigning a probability based on a relative ratio scale without units or an absolute zero (Saaty 2009).

Within the system, parametric measurements such as interval, ratio and absolute scales should be utilised where possible however, in reality it is acknowledged this is not always achievable. If parametric measurements are not achievable, as the relative distance between alternatives for criterion is impracticable, then limitations of the approach should be documented. As all criterion and alternatives are exposed to the same measurement relationships by virtue of the weighted sum method within the model, ordinal preferences among alternatives can be determined in absence of parametric measurements yet relative distance should be treated provisionally.

A popular parametric measurement approach is the use of a 'preference scale'. This is simply a 'scale anchored at their ends by the most and least preferred options on a criterion. The most preferred option is assigned a preference score of 100, and the least preferred a score of 0…Scores are assigned to the remaining options so that differences in the numbers represent differences in strength of preference'(DCLG 2009). Another approach is a rating scale where the user selects a statement or numeric value that corresponds with their criterion preference on the given scale (Dillman et al. 2009). If rating scales are not numeric in nature then Friedman and Amoo (1999) highlight the importance of selecting category descriptors that are truly equal interval and can be interpreted in that manner, if parametric data analysis is required. The latter is generally applicable to many criterion likely selected in flood risk management option preferencing. Therefore, bipolar rating scales such as 1= strongly disagree; 2= disagree; 3= neutral or N/A; 4= agree; 5= strongly agree can be utilised with categorical descriptors to limit non equidistant skew.

Secondly, the options need to be scored against criterion to derive the learned scores. To derive learned scores a range of mechanisms can be employed including case studies, literature review, research queries, interviews and expert judgement. Interviews are excellent mechanisms to elicit learned scores. Recruitment of interviewees can be based on or a combination of (adapted from Diamantopoulos and Schlegelmilch 2000):

1) Convenience: Interviewees are selected as they are convenient to interview i.e. available, accessible etc.
2) Judgemental: Interviewees are selected based on the interviewers judgment of whether they meet the requirements of the task at hand i.e. experience, representativeness etc.
3) Quota: Interviewees are selected on the basis of satisfying some specified criteria i.e. number, percentage female etc.
4) Multiplicity (snowball): Interviewees are selected based on the referrals of others. These interviewees then refer another person to be interviewed.
5) Random: Interviewees are select randomly based on a number of methodologies i.e. lotteries, computer generated random samples etc.
6) Systematic: Interviewees are selected in systematic order from a list after a random start.
7) Stratified: Interviewees are randomly selected from different stratum or clusters.

Recruitment methodology must be explored prior to EDSS development as methodology can significantly change the outcomes. It is recommended that judgemental interviews be conducted for criterion questions such as economic, environmental and technological criteria that require advanced specialist knowledge of the options' advantages and disadvantages, whereas generation of learned scores for social criterion can be assisted by random or systematic samples provided the interviewee has an understanding of the option either through experience, discussion or imagery. It is important when developing these scores whether through interviews, literature review etc. that bias (intentional or sub-conscious) is accounted for, particularly for qualitative based criterion. Bias can occur, particularly in deriving appropriate ratings for intangible option criteria such as social criterion through mechanisms like judgmental interviews as the scores may be biased (perhaps even unconsciously) resulting from the selected responses. To ensure the scores are relatively unbiased and justifiable, sensitivity analysis and consistency checks of the scores should be undertaken post-system development to assess the robustness and stability of the scoring outcome. Sensitivity analysis can be completed through Automatic Sensitivity Analysis, utilising software packages to analyse variable ranges and their influence on results; and/or Trial and Error Sensitivity Analysis, such as the 'What-If' technique, namely What will happen to the output if an input (variable; assumption; or decision rule parameter) is changed? (Lemass and Carmichael 2008). Consistency checks can be conducted through peer review and probability sampling techniques.

Further, once learned scores are agreed upon fact sheets should be developed that document how each option performs against each of the criterion and why. These fact sheets should breakdown complex technical engineering information into relevant and understandable knowledge packets for each of the options without jargon. The fact sheets should be viewed as an educational platform for the user including non-technical users, to learn about and potentially gain a greater appreciation of the tradeoffs involved in flood risk management and thus should be structured appropriately including graphic content. However, the intent of these fact sheets goes beyond an educational platform for users towards effectively becoming an information hub that everybody can access, critique and build upon potentially fostering innovative solutions to identified deficiencies and refined learned scores. Moreover, it provides transparency and a strong auditability foundation as to why options are preferred over others, effectively building trust and reliability into the outcomes of the EDSS for everybody including decision-makers.

4.7.5 User weighting

User defined weights reflect how important a criterion question is to the user and as such, for the option to be preferenced highly it must score well against highly weighted criterion questions. Weightings like learned scores should utilise a ranking system that is equidistantly distributed but in a cardinal way rather than in a utility space. This could involve weights selections such as:

w_i = not at all important = 0
w_i = slightly important = 1
w_i = moderately important = 2
w_i = very important = 3
w_i = extremely important = 4

Within an EDSS it is important the scoring is understandable, transparent and easily interpreted. This may include supplying text that is relatively interpreted as consistent in interval, providing corresponding graphical representations, and numbers. It should be acknowledged like learned scores however, that users even with these aids may not interpret the weight selection as equal interval and thus limitations should be documented including non-equidistant skew.

4.7.6 Ranking

Ranking is an important functionality of the model and EDSS as it allows the user to ultimately submit their preferred options for dissemination, aggregation and recommendation. Re-ranking can be facilitated in the standalone system via a supplied questionnaire form. This form can be mailed to the flood risk management principal authority or committee overseeing the flood risk management cycle. The online system can a have a simple ranking function available such the #sortable# jQuery element (Figure 31), embedded in the front end interface linked to the backend database. It is hoped that through the weighting of criterion questions in step 6 that users investigate and understand why options ranked the way they did, learn about their specific advantages/ disadvantages and constraints prior to re-ranking. In doing so, it is envisaged that users can bring rational judgement about their values and preferences thus leading to more informed balanced recommendations.

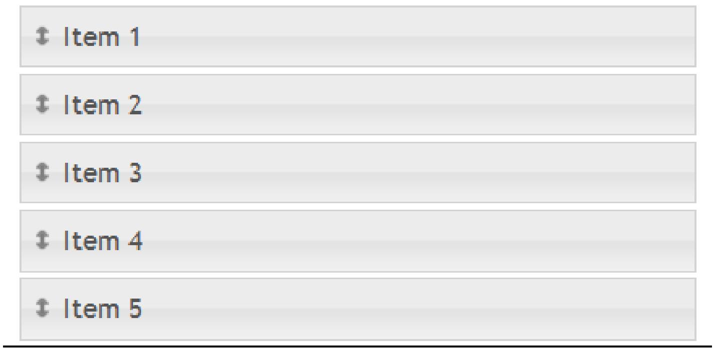


Figure 31: #Sortable# jQuery element (jQuery Foundation 2013).

4.7.7 Demographic information

Demographic information, although not vital can provide useful insight into user representativeness. This is collected at stage 8 in the model and within the flood risk management option EDSS could include questions regarding: location of dwelling, dwelling type, residence or ownership time, family composition, experience of flooding, preferred mechanisms for further communication etc. As identified by Wyse 2012, a balance needs to be struck between information that can assist with representativeness analysis and information that is futile. This includes tactfully choosing questions that limit respondent fatigue, are culturally sensitive, do not compromise confidentiality and comply with legal and ethical requirements (Wallace 1954; Bradburn et al. 1979; Bruce 2008).

4.7.8 Decision

The decision by the principal flood authority or committee on the identified flood risk management options that will be hydraulically modelled in detail with site specific assessments conducted, should be clearly communicated and documented. This includes providing clear and concise information about how the decision was made, how the aggregated users responses were utilised and the next steps in the flood risk management cycle. This is an important step as it provides positive affirmation to the user that they contributed to the decision making process that affects them. Thus fostering the normative, substantive and instrumental benefits of the EDSS for flood risk management options, such as, increased buy-in, robust and potentially innovative sustainable solutions, ownership, responsibility, accountability, credibility, trust and consensus in the decisions made.

4.8 Conclusion

There are numerous decision making methodologies and support systems available to practitioners to assist with complex decision making. However, it appears none have been specifically targeted to support the public (i.e everyone) including non-technical users to make informed decisions through an engagement-focused decision support system. As such, it is envisaged the new generic engagement decision support model via an EDSS can provide a powerful consultation mechanism particularly when involve, collaborate and engage levels of influence are selected by decision-makers. It is illustrated that the model is relatively simple, inclusive, organisationally flexible. and transparent. Resultantly, it can be foreseeably applied to a range of engineering and non-engineering decisions such as coastal, bushfire, mining, land-use planning, infrastructure renewal etc.

Although processes and considerations of the model are required (as documented during the development and application of an EDSS such as system design, selection of criterion and options, derivation of a learned-score matrix, ranking, decision making communication and documentation), these are relatively straight forward and finite. Thus, it is envisaged that government and private organisations could utilise the model, combining heuristic, engineering and scientific knowledge with public participation, multi-criteria and decision support theory through an EDSS to truly foster a deliberative environment where citizens can make informed choices about decisions that affect them, such as preferencing options at the identify risk management measure stage of the flood risk management cycle.

Chapter 5

System development, testing, results and evaluation

5.1 Introduction

Adapting Keeney and Raiffas (1976) rhetoric it is not possible to achieve the 'best' utilisation of the floodplain, 'for everybody, in every possible way, in the shortest time with the least inconvenience,' and thus robust systems to facilitate balanced informed decisions of preferred options is a step in the right direction to find congruency by those directly or indirectly affected by flooding.

This chapter examines the development of both a standalone excel macro and online engagement decision support system for flood risk management options based on the new engagement decision support model methodology established in chapter 4. Application of the online engagement decision support system for three trial New South Wales catchments on the east coast of Australia will then be presented, in addition to the trials results and evaluation. In doing so, this chapter aims to demonstrate that the model, supported by an engagement decision support system, can not only be organisationally adjusted to meet stakeholder/ legislative requirements but to also fundamentally improve the outcomes of flood risk management through a transparent, repeatable, auditable framework that allows users to overcome narrow uninformed preferences, selecting robust decision-making solutions that reflect preference choices of learned flood managers.

5.2 System design

The system was redesigned on a number of occasions, further refining and incorporating learnings. This sub chapter details the final standalone excel macro and online engagement decision support system branded 'Floodenagage' for flood risk management options. Both standalone and online systems are presented to offer flexibility on the desired approach by the public, committee and/or decision-makers. The excel macro can be utilised by the committee and/or decision-makers if they, or the community in which they are engaging have restricted access to the internet. Both

follow the model and can be organisationally adjusted to suit jurisdictional roles and responsibilities.

5.2.1 Selection of flood risk management criteria

As flood risk management is indeed a multi-objective discipline, and in light of Belton and Stewarts (2002) and Keeney and Raiffa (1976) recommendations as previously described in chapter 4, the following 10 criteria, and with their corresponding questions (cq_i) were selected for inclusion in the system.

5.2.1.1 Social criteria

Amenity: Amenity relates to the desirability, attractiveness and usefulness of the option. This can be a potentially important criterion for the community as amenity although highly subjective has been shown to contribute to health and wellbeing (Moro et al. 2008). Amenity in relation to flood risk management can include visual appearance, recreational use, access, sound, smell etc. Within the system the following criterion question was asked:
cq_1 : 'How important is it that the flood management option improves community access and recreational use?' provided with an explanatory statement, 'This question is asking how important community access and recreational use is to you. Some options increase community use and recreational potential. Other options reduce recreational and community access. A concrete levee for example may increase public space that may be suitable for recreation such as sporting fields, parks, walking and cycle paths etc. However, a concrete levee may also create physical barriers between the township and watercourse if it is tall.'

Equality: Equality in the social context means the options disadvantages and advantages, benefits and burdens are equally shared across the community. As explored by Westen (1982) this is a highly subjective criterion, as equal 'treatment is achieved by either uniformly granting or uniformly denying that treatment' and a construct of moral standards (p.546). In flood risk management, options vary considerably on the social equity scale from measures that have no social equality disadvantages to those that significantly impact others. Within the system the following criterion question was utilised to differentiate alternatives:
cq_2 : 'How important is it that the flood management option does not disadvantage individual members of the community?' provided with the explanatory statement, 'This question is asking how important equality is to you. Some options may disadvantage

individual members of the community for the benefit others. Other options will have no impacts on individuals and benefit others. A flood mitigation dam for example can cause equality issues and impact individual members of the community as it is typically a large structure requiring large amounts of land to provide sufficient water storage. As a result, particularly in urban catchments, large areas of land need to be purchased causing the relocation and disruption of local community members in those surrounds'.

5.2.1.2 Safety criteria

Risk to life: Risk to life relates to the options ability to reduce physical injury and mortality during times of flood. Reflecting on the literature review of international best practice (refer chapter 2), reduction in casualties was a primary aim for all jurisdictions examined. This sub criterion further relates to reducing physical injury and mortality for both current and future conditions up to and including the PMF, as a number or measures actually increase casualties once the design height of the option is exceeded if consequences are not accounted for. Due to the general importance of this criterion to many, the system utilised the following criterion question:

cq_3 : 'How important is it that the flood management option provides safety to the community during flooding?' provided with an explanatory statement, 'This question is asking how important safety and reducing risk to life is to you. Some options may provide safety to particular flood levels but may cause significant risk to life if these levels are exceeded. Other options provide mechanisms to reduce risk to life and improved safety no matter what level the flood waters reach. Local flood warning systems and flood forecasting for example provides safety to the community as these systems give community members in advance the opportunity to know what is likely to occur, prepare for flooding, and move to a safe area or evacuate. They also provide a heads-up to emergency service personal to prepare for and respond to flood impacts'

Community awareness: Community awareness, although not as directly linked to improving preparedness as one may first think, as examined in Wachinger et al. (2013) dubbed the 'risk paradox,' community awareness can improve understanding, measure implementation, situational awareness and emergency management co-operation (Paton 2000; Tierney et al 2001; Peek and Mileti 2002; Duffy 2010). As a result the following criterion question was included in the system:

cq_4 : 'How important is it that the flood management option raises community awareness and understanding of the local flood risk?' provided with an explanatory statement, 'This question is asking how important it is that a flood management option raises community awareness and understanding of the local flood risk. Some options directly promote community awareness and understanding of the local flood risk such as educational campaigns and planning certificates. Other options do not increase awareness or understanding at all'.

5.2.1.3 Environmental / ecological criteria

Environmental/ ecological: This criterion relates to options impact or improvement of ecological biodiversity, habitat, connectivity, flora and fauna migration and geomorphological impacts such as scour and sedimentation. Recognition of human interdependency with the surrounding natural environment including the aquatic and terrestrial ecosystems is ever increasing. The following criterion question was included in the system:

cq_5 : 'How important is it that the flood management option does not threaten local plants and animals and their habitat?' provided with an explanatory statement, "This question is asking how important it is that the flood management option does not cause any adverse impacts on local plants and animals and their habitat. Some options can have considerable impacts on the natural environment threatening the survival of local plants and animals. Other options may enhance the natural environment, improving local plant and animal habitat".

Water quality: This criterion relates to the water quality impacts or improvements by options. Water quality is vital for sustaining ecological processes that supports health, recreation, tourism, industrial processes and ecosystem services. Thus water quality has a significant environmental, social and economic value. The system incorporated the following criterion question to address this criterion:

cq_6 : 'How important is it that the flood management options do not cause water quality issues?' with the explanatory statement, 'This question is asking how important it is that the flood management option does not cause adverse water quality impacts. Some options can increase pollution, nutrients and/or turbidity in the waterway. Others actually improve water quality. Riparian vegetation management for example can be negative in the short term, as it can reduce the ability for the river or stream to regulate its flows, which causes scour and erosion, increases turbidity and reduces the ability for the floodplain to recharge which collectively decreases water

quality. However over the long term the planting of suitable local plants can create a buffer for urban pollutants and stabilise the river or stream, improving water quality'.

5.2.1.4 Economic criteria

Construction and design cost: The construction and design costs relates to all monetary costs related to topographic survey, site specific flood modelling, concept design, community consultation, economic evaluation, detailed design, movement of services, mechanical equipment, materials, labour costs, and other incidental construction costs and or contingencies at the outset. This is typically an important criterion, and the following criterion question was utilised:
cq_7 : 'How important is it that the flood management options initial costs (i.e. design / construction) require minimal expenditure?' with the explanatory statement, 'This question is asking how important it is to you that initial costs have minimal expenditure. Some options have significant initial costs while others have no initial cost. Flood mitigation dams for example can cost hundreds of millions of dollars where as private rainwater tanks have minimal cost'.

Ongoing/ maintenance cost: This criterion relates to as the title implies the operation and maintenance costs of the floodplain management option. Depending on the measure these cost can outweigh the initial costs over the design life of the measure. This criterion includes monetary costs such as employee wages, material, machinery, external auditing etc. It is an important consideration to maintain currency and design standards. In relation to the system, the following criterion question was asked:
cq_8 : 'How important is it that the flood management option requires minimal ongoing expenditure after implementation?' with the explanatory statement, 'This question is asking how important it is to you that ongoing/maintenance costs have minimal expenditure. Some floodplain management options have significant ongoing/maintenance costs associated with them while others have no ongoing cost. For example a large earthen levees maintenance bill can exceed tens of thousands of dollars every year whereas voluntary house raising has limited ongoing costs related to routine house maintenance'.

5.2.1.5 Flood behaviour criteria

Reduction in consequence: Reduction in consequences relates to the options ability to decrease both direct and indirect tangible and intangible damages associated with hazardous flood behaviour. These damages may include physical damage to

buildings and infrastructure, loss of life, social disruption, lost productivity, health issues etc. To accommodate this criterion the system utilised the following criterion question:

cq_9 : 'How important is it that the flood management option reduces flood damages to the community?' with the explanatory statement, 'This question is asking how important it is that the flood management option reduces flood related damages to the community including property damage, health issues, stress and anxiety. Some options have the ability to significantly reduce flood damages while others do not. Flood detention basins for example have the ability to reduce flood damages particularly for more frequent flood events however, they are usually small and are designed to overtop in major floods causing increased damages if appropriate planning decisions have not been made'.

Adverse hydraulic impact: Adverse hydraulic impact relates to the flood behaviour both upstream and downstream of the option. This can be negative when flow is attenuated or increased to the extent that it causes damage that cannot be offset. To address this criterion the flowing criterion question was utilised:

cq_{10} : 'How important is it that the flood management option does not cause negative flood impacts to other areas (both upstream and downstream)?' with the explanatory statement, 'This question is asking how important it is that the flood management option does not cause any adverse hydraulic flood impact to other areas. Some options may cause water to back-up causing flood waters to impact properties upstream, while other options have no adverse impacts. Concrete lined channels for example can potentially cause significant adverse flood impacts to other areas as they are designed to increase both the speed and amount of water flowing down a channel which could cause downstream damage'.

5.2.1.6 Limitations

The 10 criterion questions (cq_i) selected for input into the system cover a variety of value clusters and represent typical objectives and concerns raised by individuals directly or indirectly affected by flooding. However, due to a limited ability to influence the entrained floodplain management process in which the systems were trialled, the options reflected preference choices based on prior stakeholder experience rather than a deliberative process derived with public involvement. This is not the ideal, as the selection reverts back to authoritarianism, dictating what is important to the public

rather than the public raising their values and concerns from which the criterion should ideally have been derived.

In addition, mutually independent criterion was difficult to obtain, due to the inherent dependencies between the clusters and typical desires and tradeoffs experienced in flood risk management. This is viewed as a partial limitation due to what Kenney (1992) termed ‘double counting’. However, as the criterion questions reflected criterion from different angles thus demonstrating their importance to the decision-making sphere and the public’s views and desires this was not deemed a significant risk. Rather, reducing criterion to limit the exposure of ‘double counting’ may have introduced its own risks by limiting the user’s comprehension of the heterogeneous but interrelated tradeoffs involved in floodplain management thus potentially undermining confidence in the system and the intrinsic learning it provides by allowing users to assess these trade-offs.

Political and organisational criterion such as legislative constraints, political will and compatibility with the existing system were also not included in the system. This was decided, as the options selected for the system trials were required to satisfy political and organisational criteria prior to selection as alternatives. This was an important consideration as to not interrupt the existing process with counterproductive analysis of unfeasible solutions and stem false hope. Ideally this would have been conducted in a deliberative environment yet the outcomes would have been the same.

5.2.2 Selection of flood risk management options

With over one hundred flood risk management options presently available, and new measures continuously being developed, a robust understanding of the options social, safety, environmental/ecological, economic, flood behaviour, organisational and political tradeoffs is required prior to inclusion in the system. An approach to extract feasible measures is hypothesised in chapter 7 however, due to time constraints and thesis scope, the model and system did not delve into this aspect. As a result, the selection of options was based on an organisational and heuristic understanding of the advantages and disadvantages of each option, their practical feasibility in the trial catchments, as well as including two misguided flood risk management options (rainwater tanks and increased infiltration capacity measures) that are consistently raised during stakeholder consultation. Twenty flood management options (O_j) were selected for appraisal covering all four categories:

flood management measures; building management measures; land use planning management measures; and response management measures. These options are covered from 5.2.2.1 to 5.2.2.20:

5.2.2.1 Earthen levee (O_1: flood management measure)

An earthen levee also known as a flood levee, main levee, embankment, stop bank, dyke, dike, summer dike, confinement dike, ring dike or bund, is an embankment built along a river with the primary purpose of providing flood protection to adjacent land or human settlement from inundation (Green et al. 2000). It is predominantly an embankment consisting of consolidated earth properly keyed into the underlying soil, with an impermeable packed clay, reinforced concrete or sheet pile core and flat batters either side (Lees 2010). A levee operates in most cases by confining and increasing the discharge capacity of the river. This is achieved as the raised embankments make the channel deeper giving it an ability to hold more water before it overtops and floods adjacent land.

5.2.2.2 Concrete levee (O_2: flood management measure)

A concrete levee like an earthen levee, also known as a flood wall, flood levee, main levee, dyke or dike is a wall built along a river with the primary purpose of providing flood protection to adjacent land or human settlement from inundation (Green et al. 2000). They are typically gravity floodwalls constructed of solid concrete and use weight for stability or cantilever floodwalls consisting of a wall and footing constructed of cast-in-place concrete that relies partly on the weight of the floodwater and soil for stability (FEMA 2009).

5.2.2.3 Flood mitigation dam (O_3: flood management measure)

A flood mitigation dam typically comprises a wall or embankment that provides a water storage or reservoir, an outlet or flood gates to control water flow and a spillway to pass flows that exceed the dams design capacity. The majority of dams in Australia are built for water supply however, some are designed for flood mitigation purposes and have a built-in storage area that is kept free for temporarily storing floodwater with the aim of reducing peak flood heights downstream.

5.2.2.4 Flood detention basin (O_4: flood management measure)

A flood detention basin, also known as retarding basin or storage basin, typically comprises walls or embankments that provide an area for water storage, an outlet to

control water flow and a spillway to pass water flows that exceed the basins design capacity. They can be dry or permanently wet and can be located online (i.e. along streams or watercourse) or located offline (located away from streams and watercourses). Like dams they operate by temporarily storing flood water which reduce downstream flood heights but can increase the time that land is inundated.

5.2.2.5 Increased infiltration capacity mechanisms (M5: flood management measure)

Increased infiltration capacity mechanisms include: permeable pavements, porous pavement, infiltration trenches, filter strips, infiltration basins, bio retention basins and swales. Increased infiltration capacity is one principle of Water Sensitive Urban Design (WSUD) whereby water is retained onsite to infiltrate into the ground or be reused at a later time. These mechanisms are excellent for a whole range of reasons including protecting natural storm water drainage systems, increasing natural habitat and ecosystems, increasing amenity and access to open land, protecting water quality, and minimising the cost of drainage infrastructure. However, they are generally not considered an effective flood risk management measure.

5.2.2.6 Channel realignment (O_6: flood management measure)

Channel realignment, as the title implies, is the realignment of an existing channel. Realigning a channel generally involves straightening and widening or redirecting water flow. This is typically done to increase the discharge capacity of the channel or build a bypass floodway that redirects excess water away from the main stream before it re-joins at a later time reducing the flood height and potential damages. The negatives can include increasing the velocity, timing and severity of flooding downstream, causing flooding to areas that did not previously flood and potentially causing stream bed and bank stability issues.

5.2.2.7 Riparian vegetation management (O_7: flood management measure)

Riparian vegetation management also known as stream vegetation maintenance, riparian corridor management or vegetation management schemes, involves the select removal of exotic and/or non-flood compatible vegetation and the replanting of suitable native species around the stream or river. This management measure can be useful to increase the discharge capacity of the channel, reduce the severity of erosion and culvert blockage and increase the aesthetics of the waterway. The potential negative impacts include increasing the velocity, timing and severity of flooding downstream and short term environmental impacts of riverine habitat

destruction and stream bed and bank stability issues. This option is not the complete removal of all vegetation around the stream or river.

5.2.2.8 Culvert / bridge upgrade (O_8: flood management measure)

As the title implies, it is the modification of a culvert or bridge by increasing the size of, repositioning, and/or adding additional culverts or bridges to increase water flow. This can be useful to increase the discharge capacity of the channel particularly through a structure, and may reduce the severity of culvert/bridge blockage during a flood event. The negatives may include increasing velocity, timing and severity of flooding downstream and potentially causing stream bed and bank stability issues if not designed appropriately.

5.2.2.9 Concrete lined channel (O_9: flood management measure)

A concrete lined channel, as the title implies, is a channel usually trapezoidal or rectangular in shape lined with concrete. The process typically involves removing all in bank vegetation straightening, re-profiling the channel and utilising reinforced concrete to build the channel. Concrete lined channels were utilised a lot in the past to convey more water through relatively narrow areas. The negatives of this practice include increasing the velocity, timing and severity of flooding downstream, environmental impacts such as riverine habitat destruction, loss of important breeding areas and ecosystems, stream bed and bank stability issues and significant decreases in water quality.

5.2.2.10 Debris control structure (O_{10}: flood management measure)

A debris control structure is a structure that collects and controls debris during flood events. There are four typical debris control structures. These are 1) Debris deflectors: A series of vertical or horizontal poles that are 45° to the inlet of drainage structures and divert medium to large debris to collection areas; 2) Debris racks: A series of large vertical poles concreted into the stream at 90° to capture large debris such as trees and cars; 3) Trash racks or trash screens: A series of metal or wooden bars enclosed in a frame that are placed at 90° to the inlet or outlet of drainage structures to collect smaller debris or trash; 4) Debris sumps or debris dams: A pit designed to slow the speed of water and allow for the deposition of heavy debris such as sediment and rock. These structures are important in reducing the blockage or failure of drainage structures in streams with high debris loads assisting with conveyance.

5.2.2.11 Local flood policies and development controls (O_{11}: land-use planning management measure)

Local flood policies and development controls are non-legal documents that help achieve aims of the local environmental plans and the objectives of its planning zones by providing specific and comprehensive requirements for certain development types at different locations. Local flood policies and development controls are very important as they can steer away inappropriate development from areas with high hazard flows or development that can have significant impacts upon flood behaviour in other areas. In conjunction with local environment plans, local flood policies and development controls are the most important mechanisms to manage both existing and future flood risk.

5.2.2.12 Planning certificates notifying prospective buyers and developers of flood prone land (O_{12}: land-use planning management measure)

Planning certificates provide land owners, prospective buyers and developers information about the land-use zoning and development controls applying to the land, as well as information about potential development constraints or other planning-related characteristics of the land. In NSW, Australia these are called Section 149 Certificates and local government must disclose whether the land is subject to flood related development controls.

5.2.2.13 Voluntary purchase / removal (O_{13}: building management measure)

Voluntary purchase as the title implies, is the voluntary offering and purchasing of flood-prone property in particularly hazardous locations, where it may not be feasible or economic to mitigate the effects of flooding. After a property has been purchased it is removed or demolished and the land is rezoned to a flood compatible use (DIPNR 2005).

5.2.2.14 Voluntary house raising (O_{14}: building management measure)

As the title implies it is the voluntary house raising of property in low flood hazard areas of the floodplain. House raising typically involves using hydraulic jacks and beams to raise a house typically a few meters off its foundations and allowing a new non-liveable area to be built underneath from which the house now sits on. The purpose of voluntary house raising is to reduce flood related damages to that property and as such reduce the stress and post trauma of flooding (DIPNR 2005).

5.2.2.15 Flood proofing (O_{15}: building management measure)

As the title implies it involves designing, retrofitting or constructing buildings with appropriate water resistant materials to reduce the structural and non-structural damages of flooding to the building. Some techniques include having double brick or concrete walls as opposed to timber wall frames, using fibre cement sheeting or waterproof plywood instead of plasterboard or chipboard for internal fittings and utilising sheet metal roofing (i.e. Colorbond®) instead of roof tiles which can be easily dislodged and absorb moisture (HNFMSC 2006).

5.2.2.16 Upper story flood free refuge (O_{16}: building management measure)

A flood free refuge is a specially designed area in a property where occupants can escape to during rapidly rising flood water. It is essential that a flood free refuge is fail safe i.e. the building is able to withstand water pressure and debris impact forces, the refuge floor level is above the possible maximum flood height, it is accessible to all people on site, there is an escape option and it is fitted with emergency lighting, an emergency first aid kit including candles and a fire extinguisher. Upper story flood-free refuges are usually only considered appropriate when: 'there are no other practical flood management options available; evacuation is not possible due to lack of flood warning i.e. generally flash flood situations; flooding is of short duration; or it is safer to shelter than evacuate,'(AEMI 2013).

5.2.2.17 Rainwater tank (O_{17}: building management measure)

A rainwater tank also known as a water tank, rain barrel or water butt, is a water storage tank that collects and stores rainwater runoff. This runoff is typically collected from all or part of the roof and can be utilised around the home to reduce demand on 'town' water. Rainwater tanks are not considered an effective flood risk management measures, because rainwater tanks usually provide little storage. For example 10mm of rain over a 200 square metres of roof or 20mm over a 100 square metres of roof, would add 2 cubic metres or 2000 L to a tank. During a flood, rainfall would typically exceed the tanks capacity very early, limiting its ability to reduce down-stream flood flows. It is possible however, that rainwater tanks may retard some floodwater, reducing the peak flow at some localised sites but in general rainwater tanks should not be considered a flood risk management measure (DECC 2007).

5.2.2.18 Flood awareness (O_{18}: response management measure)

As the title implies they are generally mechanisms that increase the awareness of the potential local flood impacts and provide information about how to prepare for and reduce life threatening situations during flood events. These mechanisms typically include: flood information kits; displays and information sessions about flood risks; and flood related information on websites.

5.2.2.19 Local flood warning and flood forecasting systems (O_{19}: response management measure)

Local flood warning and flood forecasting systems consist of rainfall and river gauging stations, weather and flood forecasters, local flood intelligence and modelling, and mechanisms to deliver a warning to the community. It is the intention of these systems 'to help flood management agencies and the members of flood-prone communities to understand the nature of developing floods so that they can take action to mitigate their effects,'(AAGD 2009).

5.2.2.20 Local flood and disaster plans (O_{20}: response management measure)

Local flood and disaster plans are action plans for areas with significant flood risk. These plans describe 'the various measures to be undertaken before, during and after a flood including warning, evacuation, resupply, recovery and other procedures,'(DIPNR 2005). These plans are extremely important for government agencies involved in emergency response as they typically outline roles and responsibilities at each stage of a flood event.

5.2.2.21 Limitations

The 20 options (O_j) were selected based on organisational and heuristic understanding. As a result, the public was not afforded the opportunity to contribute to the decision-making process of choosing the options to be appraised. However, like the criterion selection there was limited ability to influence the entrained floodplain management process in which the systems were to be trialled. Again this not ideal however, opportunity was provided to generate new innovative solutions as part of the system.

5.2.3 Matrix development

Scoring the floodplain management options (O_j) against the criterion questions (cq_i) is a fundamental aspect of the model, as the integrity of the system relies on

comprehensive, transparent, apolitical, justifiable learned-scores (ls_{ij}). As flood management constraints are a combination of qualitative and quantitative variables across different scales exceptional care is required to achieve relative option comparison. In order to achieve this feat, the learned-score matrix (ls_{ij}) was derived from case studies, literature review, research queries, interviews and expert judgement.

5.2.3.1 Step 1: Measurement scale

For simplicity and user understanding bipolar and unipolar 9 point rating scales measurement scales were utilised in the system for each criterion question (cq_i) as categorised in Table 3.

Table 3: Criterion question measurement

No	Criterion description	Measurement scale
cq_1	Access/ recreational use	Bipolar 9 point rating scale
cq_2	Equality	Bipolar 9 point rating scale
cq_3	Risk to life	Bipolar 9 point rating scale
cq_4	Awareness	Bipolar 9 point rating scale
cq_5	Environment/ ecology	Bipolar 9 point rating scale
cq_6	Water quality	Bipolar 9 point rating scale
cq_7	Initial costs	Unipolar 9 point rating scale
cq_8	Ongoing costs	Unipolar 9 point rating scale
cq_9	Flood damages	Unipolar 9 point rating scale
cq_{10}	Adverse impact	Bipolar 9 point rating scale

A 9 point rating scale was selected based on extensive testing and review conducted by a range of scholars including Cox (1980), Friedman and Friedman (1986) and Krosnick and Fabrigar (1997) finding the optimal number of interval points for rating scales between 5 and 11 points. Bipolar scales were selected for criterion questions where the floodplain management measures could improve, have no effect or cause negative impact, that is,'they can fall on one side or the other of a midpoint' that is neutral (Garland 2012). Unipolar scales were selected were this did not occur. These scales consisted of equidistant points 1 through to 9, with 5 being the neutral midpoint for the bipolar suited criterion questions.

It was acknowledged that all questions excluding cq_7 and cq_8 utilising the above approach were unlikely to be entirely equidistant due to the dimensionless nature of the alternative option measurement and interpretation. Mechanisms however, such as equal interval descriptors in combination with numeric scales were adopted to limit non equidistant skew. As it was the role of the system to derive informed preference choices between options (O) based on criterion questions and not necessarily to ascertain relative distance between alternatives for criterion, the 9-point rating scale was viewed as the most appropriate measuring scale for the engagement decision support system application.

5.2.3.2 Step 2: Literature review of learned scores

An extensive literature review was conducted to assist with the population of flood risk management option learned scores (ls_{ij}) in the matrix. This literature review included case studies, current best practice manuals, scholarly articles and online research queries. The literature review further assisted with the development of the flood risk management option fact sheets that were employed to assist discussion during expert interviews (step 3). Matrix scores for criterion questions cq_1, cq_3, cq_9 and cq_{10} in the absence of extensive literature were difficult to derive and resulted in subjective assumptions. However, this is not a significant limitation as the scores for questions cq_1, cq_3, cq_9 were further refined during expert interviews as discussed in subsection 5.2.3 prior to use in trials. As the intent of the system during the trials was to differentiate between flood risk management options for then detailed analysis, site specific catchment information was not included and resulted in generalised management options learned scores based on common limitations and advantages. The results of the initial literature review matrix are documented below in Table 4.

Table 4: Initial matrix based on literature review.

Options (O_j)	Criterion questions (cq_i)									
	cq_1	cq_2	cq_3	cq_4	cq_5	cq_6	cq_7	cq_8	cq_9	cq_{10}
O_1	6	2	5	7	1	1	1	3	8	2
O_2	4	2	5	8	2	2	1	6	9	2
O_3	7	4	6	5	1	1	1	1	7	1
O_4	7	4	5	6	3	3	2	4	7	3
O_5	Excluded, as not a flood risk management option (*ls* =0)									
O_6	6	5	6	5	1	1	3	3	6	3

O_7	8	7	7	7	5	5	2	7	6	5
O_8	7	6	8	3	4	5	2	6	8	5
O_9	6	5	4	4	1	1	2	6	6	1
O_{10}	5	6	7	5	6	7	5	3	8	4
O_{11}	9	8	9	7	7	7	9	8	9	5
O_{12}	5	8	6	7	5	5	8	8	8	5
O_{13}	8	5	8	6	7	7	3	8	8	4
O_{14}	5	5	6	7	5	5	6	9	7	6
O_{15}	5	5	6	7	5	5	9	9	8	6
O_{16}	5	4	6	6	5	5	9	9	7	6
O_{17}	Excluded, as not a flood risk management option (*ls*=0)									
O_{18}	5	8	6	9	5	5	8	8	6	5
O_{19}	5	7	9	9	5	5	6	7	9	5
O_{20}	5	8	9	6	5	5	7	9	7	5

5.2.3.3 Step 3: Expert interviews

Interviews were conducted with 10 experts within the NSW flood risk management field. These interviews were conducted on an exploratory, semi-structured basis to further refine the literature review matrix and deliberate on the flood risk management options advantages and disadvantages. The recruitment of interviewees in accordance with University of Wollongong Human Research Ethics Committee approved application (Appendix B) was conducted on an opportunistic voluntary judgemental basis with individuals requiring a minimum of 10 years of practical experience in the flood risk management field. Those recruited were asked the following questions for each of the flood risk management options (O_j):

1. In your opinion does "$option_j$" improve community access and recreational use?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

2. In your opinion does "$option_j$" disadvantage individual members of the community?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

3. In your opinion does "$option_j$" provide safety to the community during flooding?

a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
b) Why?

4. In your opinion does “$option_j$” raise community awareness and understanding of the local flood risk?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

5. In your opinion does “$option_j$” threaten local plants and animals and their habitat?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

6. In your opinion does “$option_j$” cause water quality issues?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

7. In your opinion does “$option_j$”s initial costs (i.e. design/construction) require minimal council expenditure?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

8. In your opinion does “$option_j$” require minimal ongoing council expenditure after implementation?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

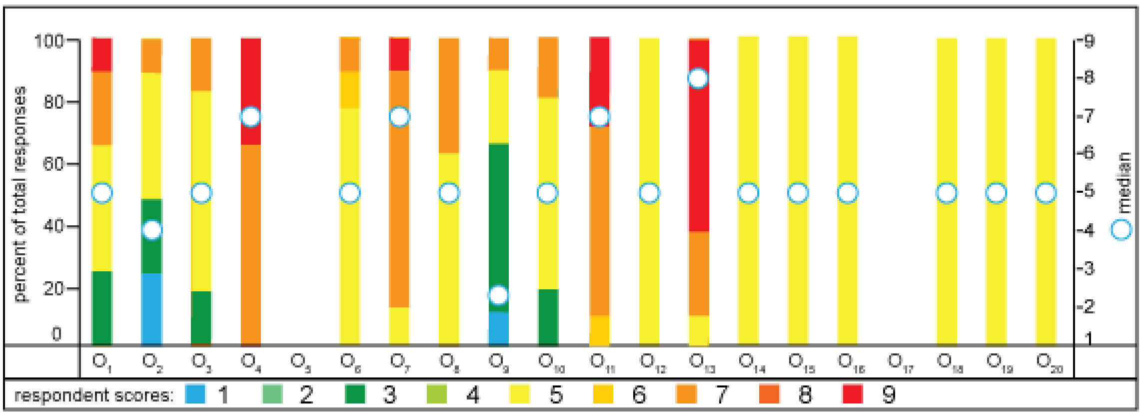
9. In your opinion does “$option_j$” reduce flood damages to the community?
   a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
   b) Why?

10. In your opinion does “$option_j$” cause negative flood impacts to other areas (both upstream and downstream)?
    a) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    b) Why?

Whilst conducting interviews it was made clear that interviewees could select intervals between the 5 point Likert-type scale effectively becoming a 9-point rating scale. The bipolar 9-point rating scale was therefore: 1= strongly disagree; 2; 3= disagree; 4; 5= neutral or N/A; 6; 7= agree; 8; 9= strongly agree. The results of the 9-point rating scale from the semi structured interviews for each question are as follows, noting statistical distribution analysis based on arithmetic mean was not conducted due to the identified equidistant limitations previously discussed. Rather,

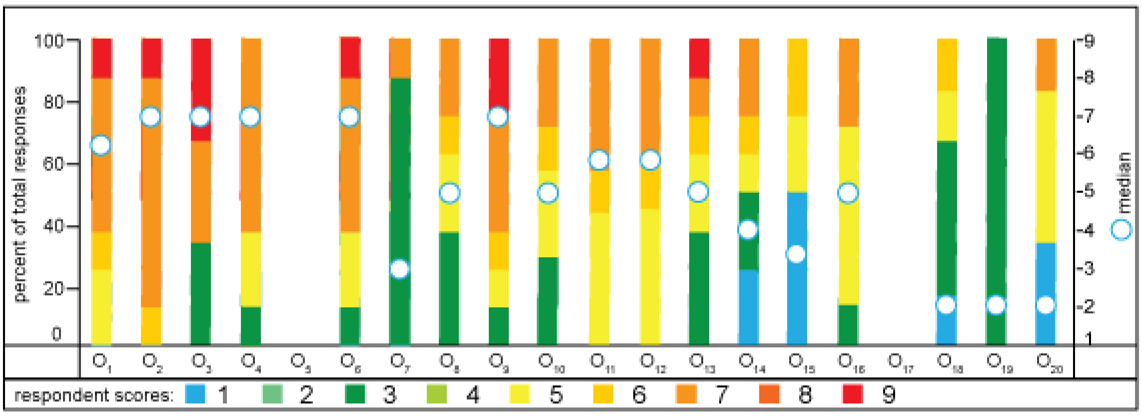
examination of the median as the measure for central tendency was conducted to identify preference.

1. In your opinion does “$option_j$” improve community access and recreational use?



Respondents favoured voluntary purchase, flood detention basins, riparian management and local flood planning and development control options for this criterion. Discussion primarily focused on the options ability to transform and utilise highly hazardous locations for public benefit for purposes such as private walking and cycle paths, sporting fields, community gardens and native vegetation corridors. Numerous options primarily building and response management measures were not applicable to this criterion and resultantly scored neutral. Overall response deviation for this criterion question between respondents was generally limited.

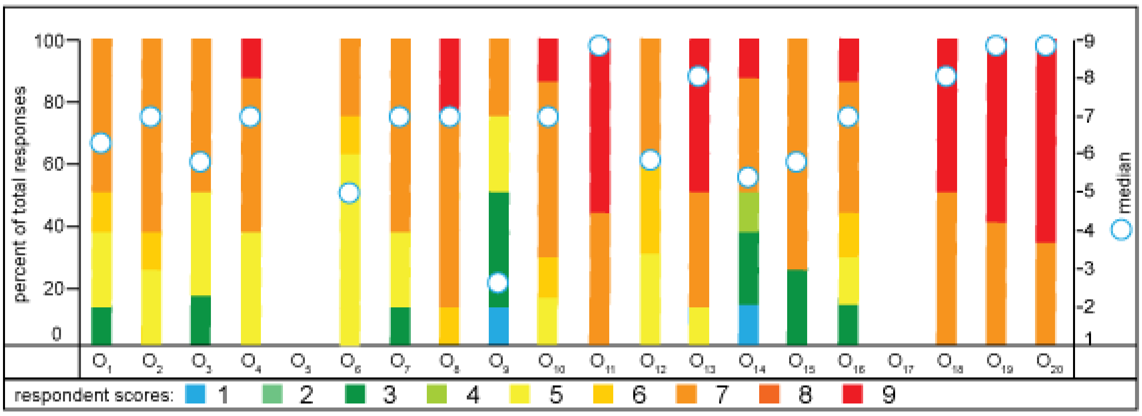
2. In your opinion does “$option_j$” disadvantage individual members of the community?



Flood management measures, particularly options that contain flood water such as flood mitigation dams, flood detention basins and levees were strongly identified as disadvantaging individual members of the community. This primarily stems from these works requiring considerable land take leading to the relocation and disruption

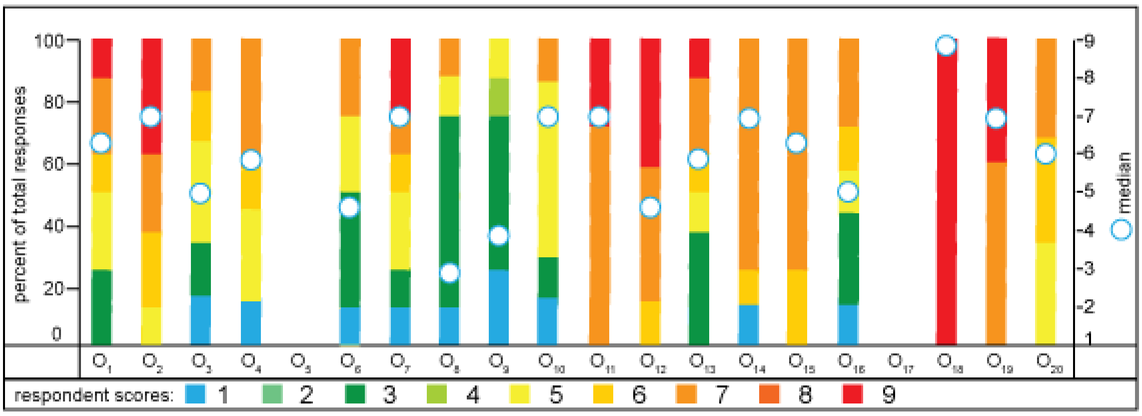
of local community members. In comparison response management measures such as flood awareness, warning, forecast tools and disaster plans were not viewed to negatively impact individuals. Responses varied significantly on options O_9: concrete lined channels and O_{13}: voluntary purchase due to the interviewee's positive and negative experiences with these measures. For example, positive voluntary purchase experiences stemmed from removing residents from extremely hazardous locations by purchasing property at equitable market rates (without the impacts of flooding being considered) on their terms and transforming this land to public open space, parkland and/or other flood compatible uses. Other interviewees however, reflected on their negative voluntary purchase feedback such as disjointing neighbourhoods and leaving remaining residents feeling 'isolated' and 'vulnerable'. Due to the subjective nature of this criterion, increased interview sample size potentially involving stratified sampling of residents across geographically dispersed areas with surrounding management measures would improve confidence in the allocation of learned scores for this criterion.

3. In your opinion does " $option_j$" provide safety to the community during flooding?



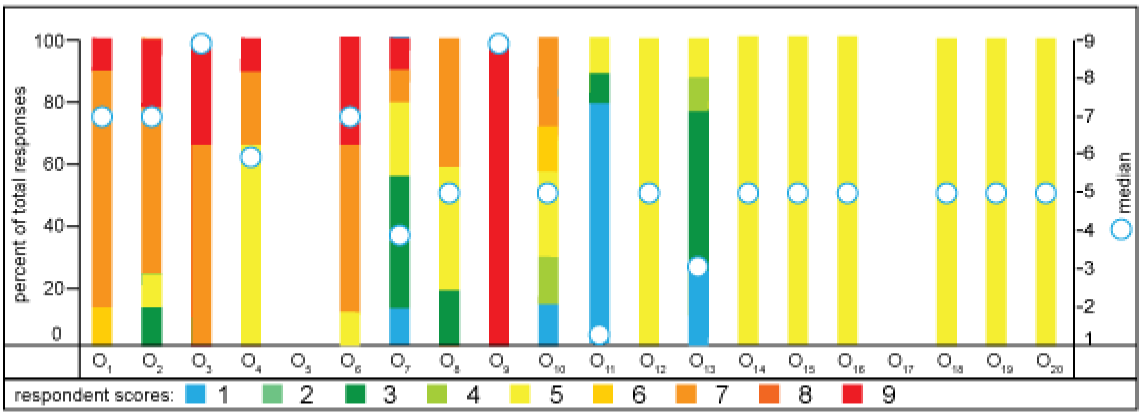
Response management measures ranked highly against this criterion question as they were viewed as mechanisms that directly relate to increasing safety through their various modes whether it be planning or providing lead time. Other options such as levees and flood mitigation dams were regarded by some whilst acknowledging the additional level of protection they provided as significantly decreasing safety due to the false sense of security they create, leading to life threatening situations when they overtop and fail. Overall however, responses where uniform besides outliers such as concrete lined channels and voluntary house raising resulting again from experience and conjecture.

4. In your opinion does "$option_j$" raise community awareness and understanding of the local flood risk?



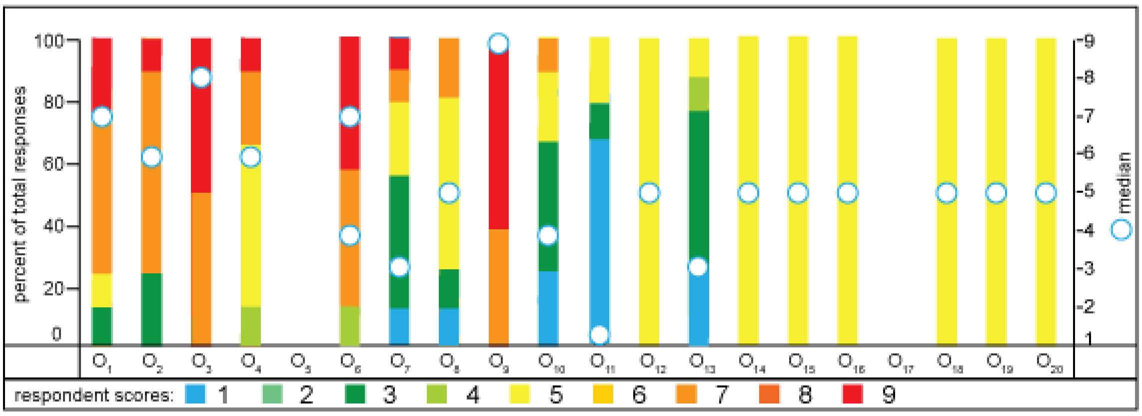
Respondents understandably favoured the community awareness option for this criterion. This reflects the general perception that increased community awareness leads to increased preparedness which in turn increases resilience. Yet scholars (see Paton et al. 2000; Wachinger et al. 2013) have shown that 'despite significant effort and expenditure on public education, levels of preparedness remain low,'(Paton et al. 2000). Notwithstanding the same scholars and institutions recognise the need for effective awareness and risk communication potentially deviating from traditional approaches (Tierney et al. 2001; Firus et al 2011; Faulkner et al. 2007; Jha et al. 2012; Wachinger et al. 2013). In regards to other measures, interviewees critically reflected on stakeholder perception leading to conclusions such as: highly visible concrete lined channels actually being detrimental to public awareness by generating a false sense of security due to the commonly perceived notion that these measures convey all flood water.

5. In your opinion does "$option_j$" threaten local plants and animals and their habitat?



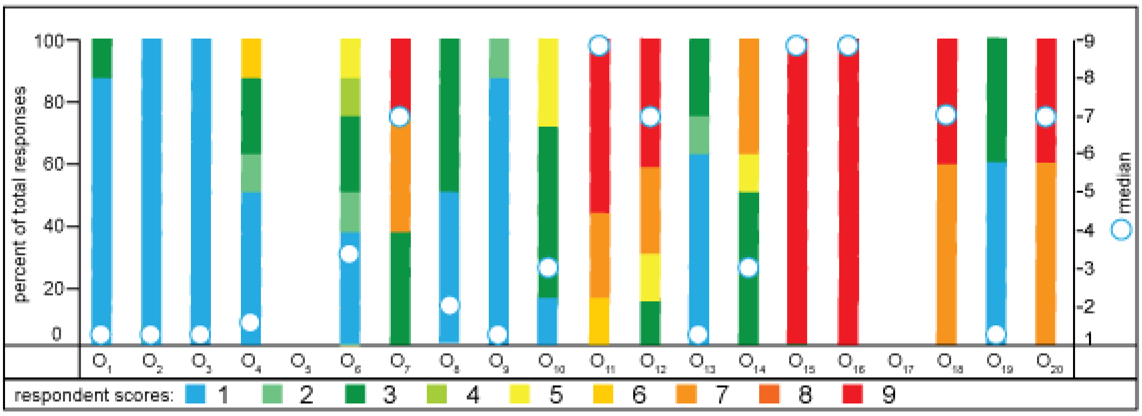
Interviewees strongly acknowledged the environmental and ecological impacts of concrete lined channels with all strongly agreeing they threaten flora and fauna. Numerous practitioners stated concrete lined channels were traditional engineering approaches with seldom application in modern practice due to their recognised environmental impacts. Conversely local flood policies and development controls were highlighted to improve ecosystem conservation as they typically take into consideration the natural function of flooding within the floodplain, preserving environmental corridors and reducing development related impacts in high flow / environmentally sensitive locations. Again a range of measures were non-applicable to this criterion.

6. In your opinion does "$option_j$" cause water quality issues?



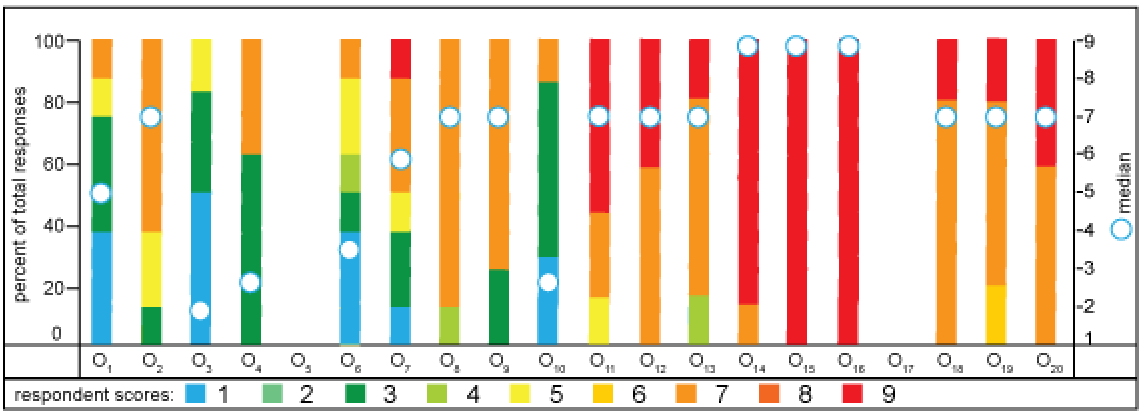
Respondents identified flood management measures such as levees, concrete lined channels, dams and detention basins as negatively impacting water quality. Discussion primarily focused on the measures ability to significantly alter natural flow regimes causing scour and erosion, chemical water composition shifts, and floodplain recharge, collectively diminishing water quality. Deviation between respondents was relatively low with general awareness of the options advantages and disadvantages in relation to this criterion.

7. In your opinion does "$option_j$"s initial costs (i.e. design/construction) require minimal council expenditure?



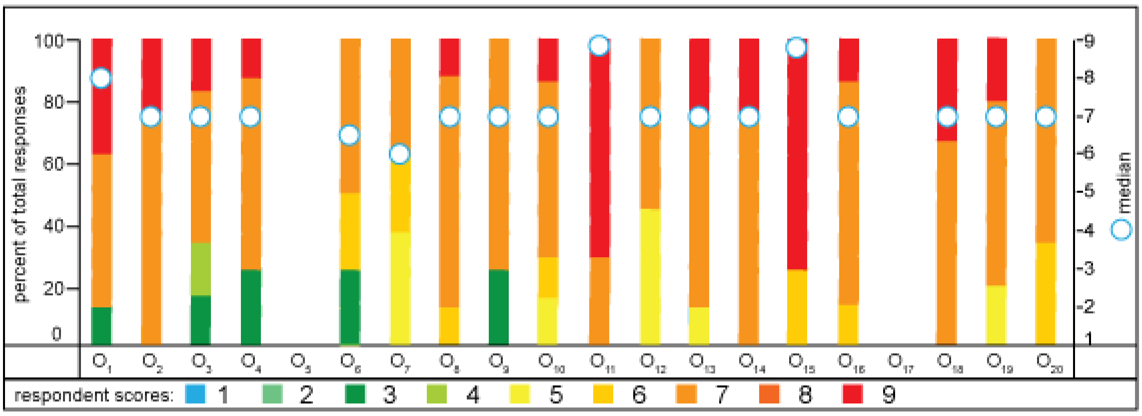
A range of options particularly large capital works such as flood mitigation dams, levees, local flood warning systems, culvert/ bridge upgrades were uniformly identified as having high initial costs. This criterion was well understood with a range of interviewees producing documented cost to validate their responses. Differences in responses primarily related to professional experience. These differences were extremely valuable to differentiate skews from the preliminary finical analysis conducted as part of stage 2: literature review learned scores enabling further refinement.

8. In your opinion does “$option_j$” require minimal ongoing council expenditure after implementation?



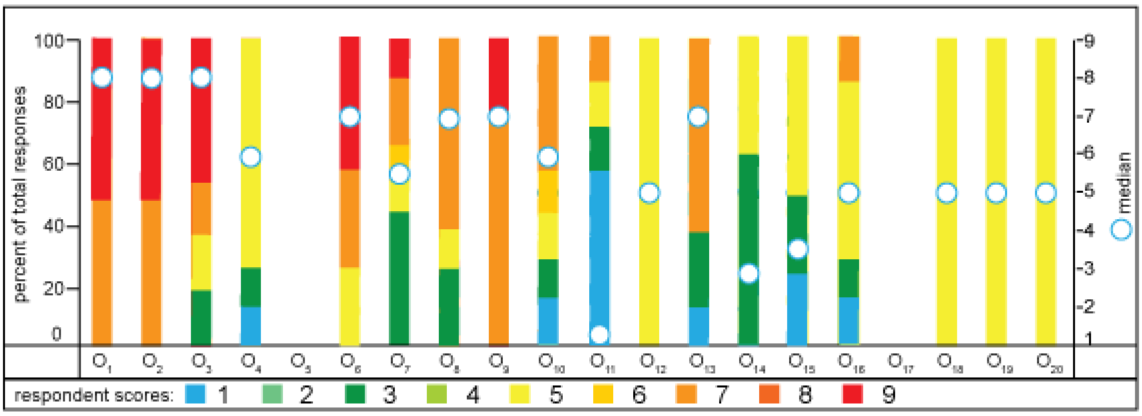
Respondents identified a range of options that had no additional ongoing costs in context to the local government authority in which the matrix was being derived for. These measures being voluntary house raising, flood proofing and upper story refuge as it was deemed the responsibility of the property owner to maintain, if in private ownership. Deviation was fairly limited with earthen levees and flood detention basins being the outliers, due to variations in localised projects interviewees had been associated with.

9. In your opinion does "$option_j$" reduce flood damages to the community?



No significant distinction between measures was identified through the criterion question. This is largely attribute to measures with limited flood damage reduction benefits being excluded from the survey such as rainwater tanks and increased infiltration capacity mechanisms. Flood proofing, local flood policies and development controls, and levees were scored relatively high by all interviewees.

10. In your opinion does "$option_j$" cause negative flood impacts to other areas (both upstream and downstream)?



Respondents recognised levees, flood mitigation dams, channel realignment, concrete lined channels, culvert and bridge upgrades as well as voluntary purchase as causing potential significant adverse flood impact to other areas. Discussion focused around these options ability to amplify conveyance, change flow direction, and/or store water having impacts. All interviews identified this criterion question was highly variable on location specifics and detailed design studies for a full range of flood events would be required to assess the upstream and downstream impacts from the measures.

Limitations of the survey include representativeness and bias. Representativeness is unlikely to be achieved in any engagement decision support matrix due to time and technical constraints with each semi structured interview on average taking over 2 hours to complete and respondents in the judgemental sampling design requiring a minimum of 10 years experience. As a result those selectively interviewed are unlikely to be representative of the population and in this case the population of learned flood practitioners however were selected based on the informed experiences respondents had to offer. This limited number or respondents resultantly introduces bias based on their professional experiences. However, as the intent was to gain learned insights into professional practice and stakeholder preference, the judgmental sampling design were interviewees were screened and selected based on professional experience was deemed necessary in order to maintain standards in the learned scores. Further not all respondents answered every criterion question for each option due to limited practical experience with that option and/or time constraints. Overall confidence is placed in the respondents insights however, increased sample size would reduce these identified limitations.

5.2.3.4 Step 4: Final learned-scores

The final learned-scores (ls_{ij}) presented in Table 5 were the outcome of combining both the expert surveys and literature review information. Green represents integers that moved up and red represents integers that moved down in comparison to the literature review learned scores compiled previously in table 4.

Table 5: Final learned scores based on literature review and expert surveys.

Options (O_j)	Criterion questions (cq_i)									
	cq_1	cq_2	cq_3	cq_4	cq_5	cq_6	cq_7	cq_8	cq_9	cq_{10}
O_1	6	2	6	6	1	1	1	3	8	2
O_2	3	3	6	8	2	2	1	6	8	2
O_3	7	4	6	5	1	1	1	2	7	1
O_4	7	3	5	6	4	3	3	4	7	3
O_5	Excluded, as not a flood risk management measure (*ls*=0)									
O_6	6	4	6	4	1	1	4	3	6	3
O_7	8	7	7	7	5	4	6	6	6	5
O_8	7	6	8	3	4	5	3	6	8	5
O_9	5	4	4	3	1	1	3	6	6	1

O_{10}	5	6	7	5	6	7	5	4	8	4
O_{11}	9	7	9	7	7	7	9	8	9	5
O_{12}	5	7	6	7	5	5	8	8	8	5
O_{13}	8	6	8	6	7	7	4	8	8	4
O_{14}	5	5	6	7	5	5	7	9	7	6
O_{15}	5	5	6	7	5	5	9	9	8	6
O_{16}	5	4	6	6	5	5	9	9	7	6
O_{17}	Excluded, as not a flood risk management measure (*ls* =0)									
O_{18}	5	8	6	9	5	5	8	8	6	5
O_{19}	5	7	9	9	5	5	5	7	9	5
O_{20}	5	8	9	6	5	5	7	9	7	5

In conjunction with the formulation of the learned scores, facts sheets were further refined as part of this process for each of the management options examined in line with the EDSS methodology contained in chapter 4.4.4. These fact sheets documented in Appendix C, were then utilised in the system to provide 'plain English' popup window content discussed in subchapters 5.2.4 and 5.2.5 below.

5.2.4 Standalone system design

To provide flexibility in the engagement decision support systems application, a standalone Microsoft Excel version of the system was designed. This version was designed so that users non connected to the internet could systematically and equitably consider the social, safety, economic, environmental/ecological and flood behaviour tradeoffs to make informed choices about flood risk management options that affect them, as advocated by the engagement decision support model. The Microsoft Excel system contains the same steps as the online version with the exception of the re-ranking functionality afforded in step 3 of the online system. In the standalone system users must complete their preference choices on a paper-based questionnaire which is then mailed in for aggregation and dissemination. It is envisaged that re-ranking would be occur during this process when the user completes the questionnaire. As stated in chapter 4, it is not the intention of these systems to make the decision but rather to provide a structured, interactive tool that provides a knowledge base of information (organisational, scientific and heuristic) in an easy-to-use and understandable format to stimulate informed preference choices about options to address complex issues.

The following subchapter provides documentation of the standalone systems setup for principal authorities and/or committees, and the steps involved in deriving informed recommendations utilising the system from a user's perspective. The Visual Basic programming code is not discussed but rather contained in the Appendix D.

5.2.4.1 Setup

The standalone system was programmed via the Microsoft Visual Basic programming language with an Excel front-end, to allow principal authorities and/ or committees with basic Excel skills the ability to tailor the system including updating and defining locally relevant options, criterion and corresponding learned scores. For example to update learned scores the principal authorities and/ or committee (henceforth termed administrator) could simply 1) click on the corresponding matrix cells, enter the new learned scores for O_j and cq_i as illustrated in Figure 32.

	A	B	C	D	E	F
1	**Options**					
2	**Flood Management Measures**		**cq1**	**cq2**	**cq3**	**cq4**
3	*Exclusion of floodwater*					
4	Earthen Levee	Flood Management Measure-*Exclusion of floodwater*	6	2	6	6
5	Concrete Levee	Flood Management Measure-*Exclusion of floodwater*	3	3	6	8
6						
7	*Containment of floodwater*					
8	Flood Mitigation Dam	Flood Management Measure-*Containment of floodwater*	7	4	6	5
9	Flood Detention Basin	Flood Management Measure-*Containment of floodwater*	7	3	5	6
10	Increased Infiltration Capacity	Flood Management Measure-*Containment of floodwater*	0	0	0	0
11						
12	*Conveyance of Floodwater*					
13	Channel Realignment	Flood Management Measure-*Conveyance of floodwater*	6	4	6	4
14	Riparian Vegetation Managemnt	Flood Management Measure-*Conveyance of floodwater*	8	7	7	7
15	Culvert/Bridge Upgrade	Flood Management Measure-*Conveyance of floodwater*	7	6	8	3
16	Concrete Lined Channel	Flood Management Measure-*Conveyance of floodwater*	5	4	4	3
17	Debris Control Structure	Flood Management Measure-*Conveyance of floodwater*	5	6	7	5
18						
19	**Building Management Measures**					
20	Voluntary Purchase/ Removal	Building Management Measure	8	6	8	6
21	Voluntary House Raising	Building Management Measure	5	5	6	7
22	Flood Proofing	Building Management Measure	5	5	6	7
23	Upper Story Flood Free Refuge	Building Management Measure	5	4	6	6
24	Rain Water Tank	Building Management Measure	0	0	0	0

Sheet1 Sheet2 Sheet3

Figure 32: Learned scores in standalone system matrix.

To add new, change or remove criterion questions and options increased experience is required from the administrator however; guidance is available from both textbooks (see Jinjer 2005; Birnbaum 2005; Web 1994; etc.) and online forums (see mrexcel.com etc.). For example, to add a new criterion question, the administrator must click on a column in the spread sheet i.e. column 'L' in spreadsheet 2 and insert a new column i.e cq_{11}. The administrator must then open the Macro 'Floodengage' » click on forms » double click 'Step_1,' add the new question and add the corresponding new buttons to the form. The administrator can then simply double click on each of the buttons and relate them to corresponding cells in spreadsheet 2 by updating the code i.e.

```
Private Sub J2_Click()
Sheets(2).Select
 If J2.Value = True Then
 [X4:X72] = 2
LabelJ2.Caption = "Moderately important"
End If
End Sub
```

Where J2 is the moderately important button for cq_{11}, and X4:X72 are the cells to which the user weighting score 2 is applied in spreadsheet 2 when ‘True’ (clicked).

A supporting help information form must also be developed by the administrator, achieved by right clicking an C_ form in Visual Basic » exporting the file » saving the file with a new C_ name (C_J) » opening the new file in a different Excel workbook » changing the name and contents in Visual Basic » saving the file » importing the saved file into the original macro and relating it to the information button on the ‘Step_1’ form in which it corresponds i.e:

```
Private Sub I_11_Click()
C_J.Show
End Sub
```

Where I_11 is the information button for the J criterion question cq_{11}, and C_J is the form that displays the content for cq_{11} when requested by the user.

Learned-scores (ls_{ij}) are then developed as outlined in chapter 4.4.4 for the new criterion question J against each option and added to the corresponding column L.

Although this may appear complex, the process to achieve these changes is relatively straightforward for an inexperienced programmer when the system is open in Microsoft Excel. It would require a couple of hours for a novice user to become accustomed to the structure and implement the desired changes. Once updated the Excel Macro can then be security locked and sent to users with limited or no internet availability along with questionnaires to gather their respective preferences for flood risk management options.

5.2.4.2 Users experience: welcome

The user is initially presented with the Floodengage start EDSS button on the first page of the Microsoft Excel spreadsheet. If they choose to click the start button the Macro is initiated and the user is brought to the Floodengage home page (Figure 33).

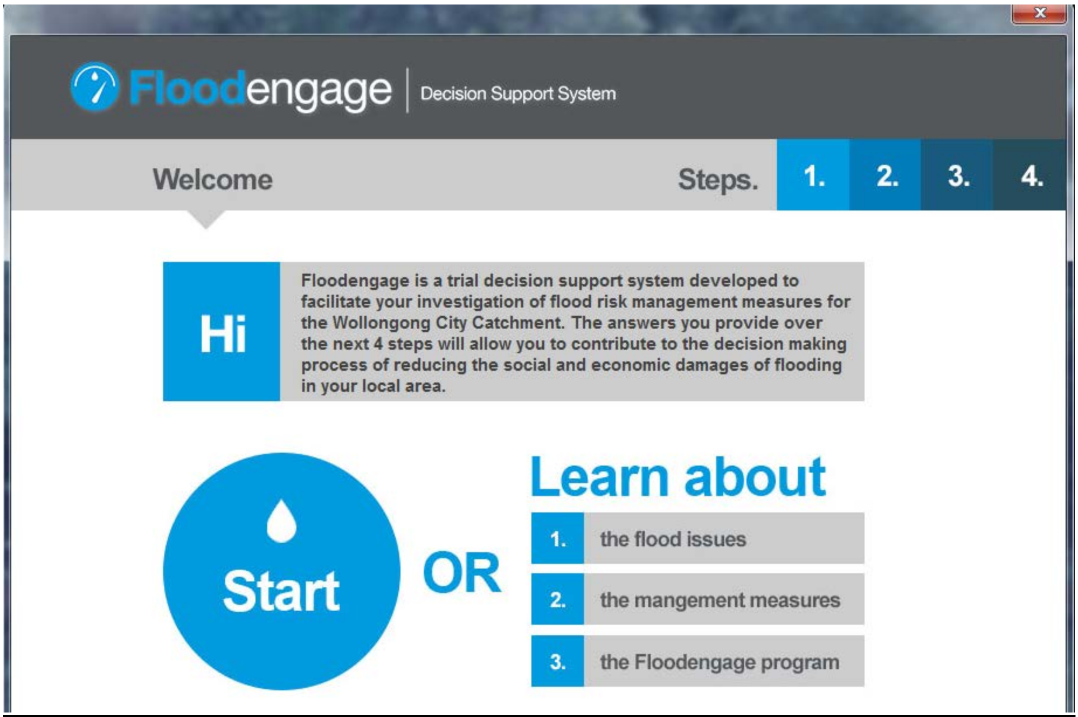


Figure 33: A screen shot of the standalone Floodengage home page.

On this home page, the user is provided with a short recruitment paragraph and the opportunity to learn about 1) the flood issues, 2) the management measures, and 3) the Floodengage program. These three elements are separate content rich popup windows with both text and graphic content. These windows are seen as an important feature of the home page as they allow the user in the environment in which they are interacting with the system whether it be at home, school, library etc, to become familiar with the risk, options available, methodology and mechanics of the EDSS and how their feedback will be utilised by the decision-making authority. For example the learn about the management measures popup displays all flood risk management options available in the catchment as shown in Figure 34, with a further link to the management measure fact sheets documented in Appendix C that are displayed in a successional popup box if clicked by the user. Pre or post examination of the pop-up windows, the user can click the large start button on the left of the home page.

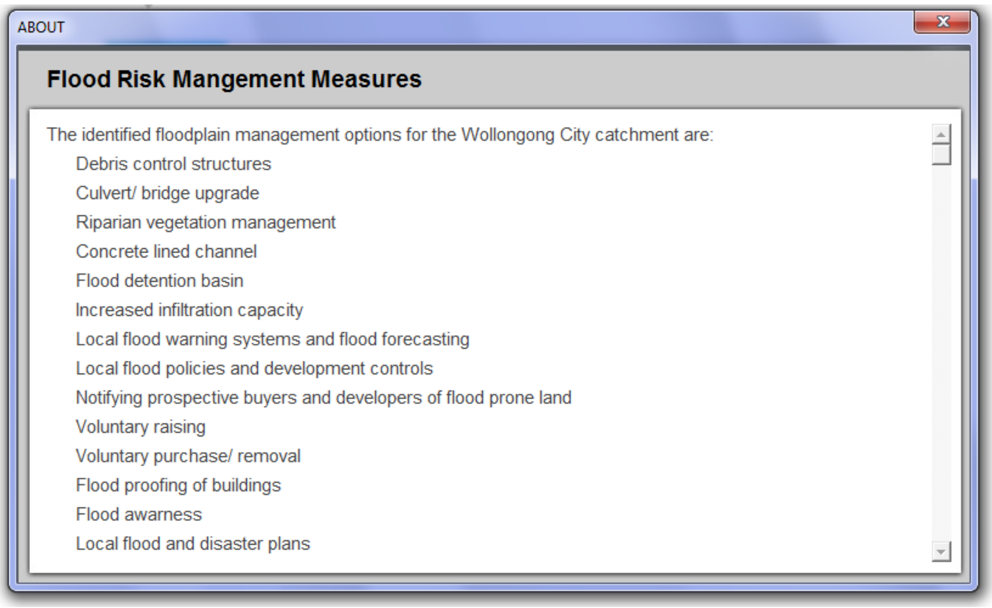


Figure 34: A screen shot of the learn about flood risk management measures pop-up window.

5.2.4.3 Users experience: step 1

Post clicking the start button, the user is transferred to step 1 of the system. This step involves the user defining the relative weight (w_i) of how important it is, that the flood risk management option meets criterion question *i*. This opportunity to select importance weighting is provided by 5 linear option buttons for each criterion question illustrated in Figure 35. These being:

w_i = not at all important = 0
w_i = slightly important = 1
w_i = moderately important = 2
w_i = very important = 3

In line with Amoos (1999) recommendations, categorical descriptors in conjunction with numbers were utilised to limit non-equidistant skew through interpretation error. An interactive element of the user visually seeing the importance weighting change between selections was also incorporated into the system to intrinsically aid interpretation. Should the user not understand a criterion question, they can click on the corresponding information symbol which intern generates a pop up window displaying categorical information about the criterion question and an example. To finalise this step all questions must be weighted. If this is not the case, a programmed error popup message is displayed expressing that the user is required to select a

weighting to *i* question is displayed. The user can then proceed to the next step of the EDSS via the 'next' button once weightings have been selected for all questions.

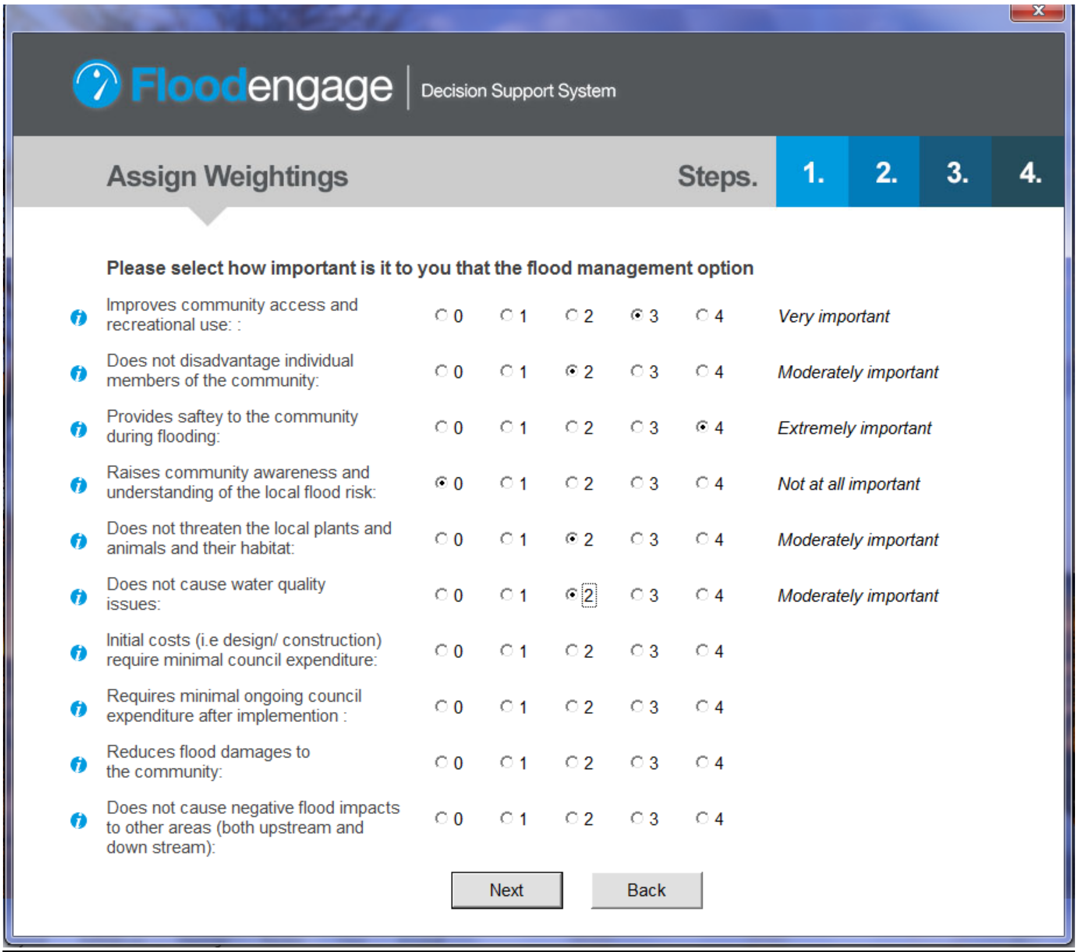


Figure 35: A screen shot of the standalone systems 'step 1' – assign weightings.

5.2.4.4 Users experience: step 2

Based on the importance weightings entered into the system, the user is presented with the top 10 options in order from most preferred to least preferred shown in Figure 36. The user is then prompted to click 'Back' to the management measure home page and investigate why certain options are preferred. In doing so, the user is able gain an appreciation of the various flood risk management options available and these options performance against social, safety, environmental/ecological, economic and flood behaviour criteria. It also suggested that the user adjust their importance weightings in 'Step 1' thus promoting What-If sensitivity analysis to be performed, namely **What** will happen to the preferences, **if** I (the user) change this importance weighting or a combination of weightings. It is envisaged in allowing this functionality the user can reflect on their values and decide the relative tradeoffs they are willing to

make to facilitate an option being preferenced highly. Moreover from a normative perspective this can lead to a greater appreciation of alternative views and development of shared common values and social cohesion. This functionality would be of most use by users of with a limited understanding of the flood risk management options and their relative advantages and disadvantages.

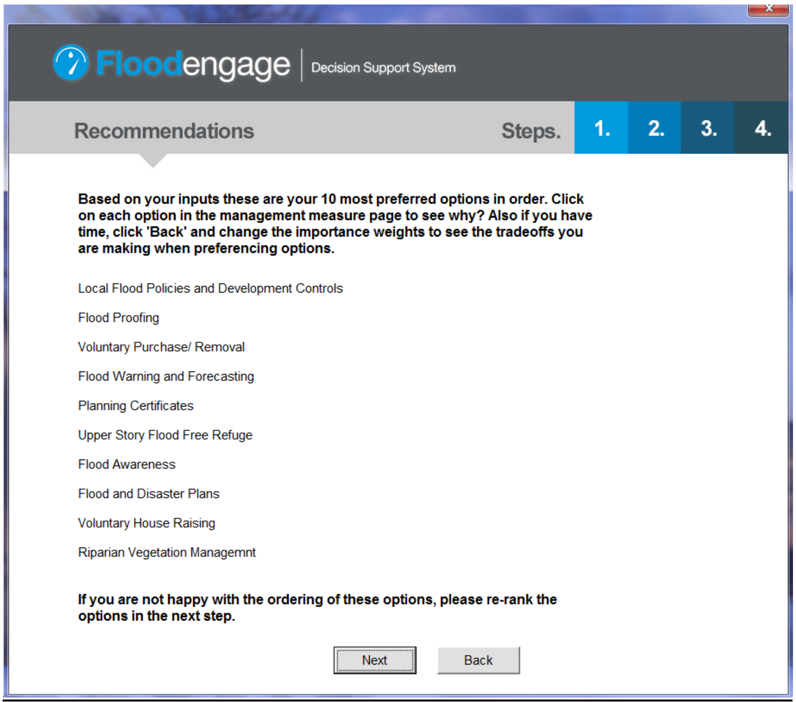


Figure 36: A screen shot of the standalone systems 'step 2' – recommendations.

5.2.4.5 Users experience: step 3

If the user is not satisfied with the option rankings determined via the matrix and their importance weightings, they can re-rank the options at this step before submitting their preferences. Within the standalone system this is achieved by the user completing the supporting questionnaire, prompted by the Step 3 screen (Figure 37).

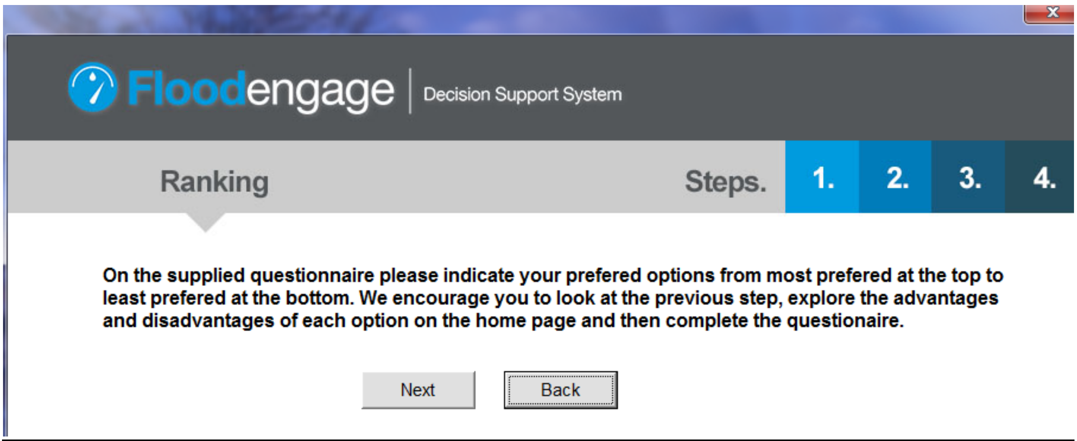


Figure 37: A screen shot of the standalone systems 'step 3' – ranking.

5.2.4.6 Users experience: step 4

To conclude the users EDSS journey they are asked if they have any additional flood risk management options they wish to include. This step from a substantive perspective can lead to the creation of innovative representative sustainable solutions that can be investigated through detailed modelling and assessment prior to the 'Make decision stage' of the flood risk management cycle. If the user desires, they have the opportunity to click the 'Back' button to return to the previous steps or exit the system by closing the window as shown in Figure 38.

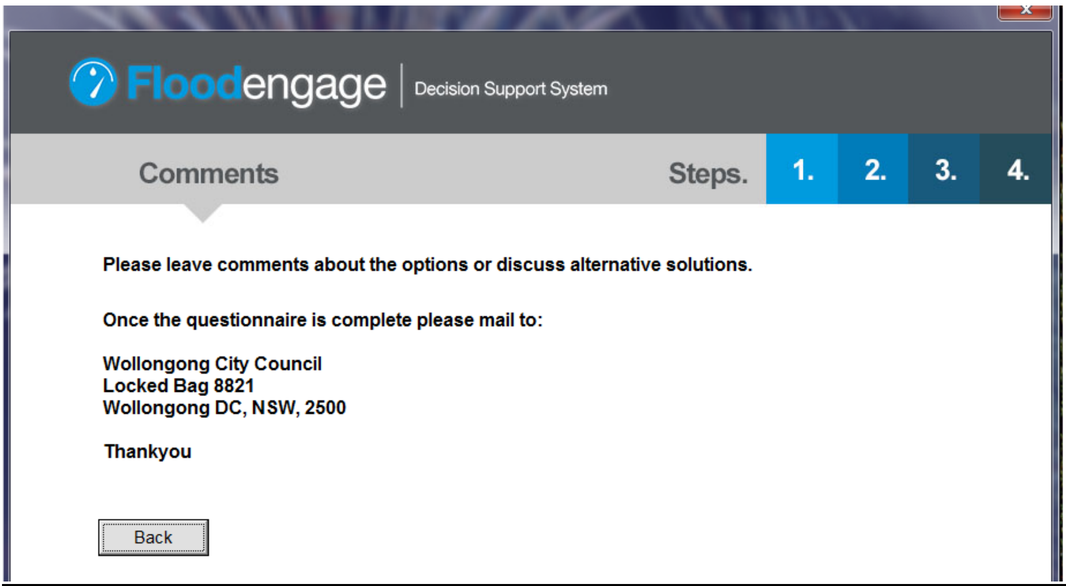


Figure 38: A screen shot of the standalone systems 'step 4' – comments.

5.2.5 Online system design

The online system is an advanced version of the standalone system due to its added functionality afforded by PHP/MySQL programming. These advanced functions for the administrator include being able to easily upload, change the system content, gather data on user weightings and swiftly compile and compare user responses. Advanced functionalities for the user include interactively re-ranking options, the content being accessed enabled meaning it can be magnified and deciphered by text-to-speech software packages, and the ability to complete demographic information and submit preferences recommendations in a quick easy-to-use mobile compatible website. Notwithstanding both the online system and standalone system are essentially uniformly programed corresponding to the steps outlined in engagement decision support model.

The following subchapter provides documentation of the online system setup for principal authorities and/or committees, and the steps involved in deriving informed recommendations from a user's perspective. The PHP/MySQL programing code that was developed with assistance from Wanta Digital, is not discussed but rather contained in the Appendix E.

5.2.5.1 Setup

The online system comprises of a PHP coded web content management system (CMS) linking multiple MySQL databases at the backend and a PHP generated HTML web front end. The CMS illustrated in Figure 39 allows principal authorities and/ or committees via a password protected entry, the ability to tailor the system including updating and defining locally relevant options, criterion and corresponding learned scores for their catchment/s of interest. For example to add a new option, the administrator simply clicks within the CMS content management » options » add new » completes the content in predefined tables and presses save. This new option can then be disabled or deleted from the CMS and database through one click. The same process is undertaken for new criterion i.e. content management » questions » add new etc.

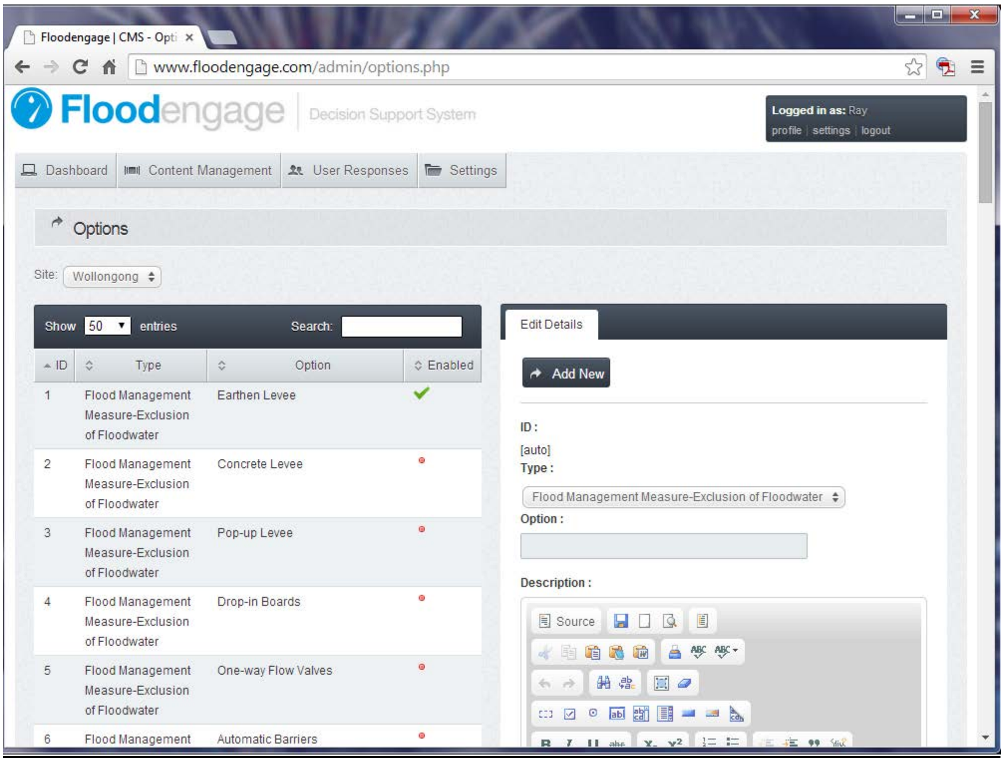


Figure 39: Adding options to the online Floodengage CMS.

A similar straightforward process is undertaken by the administrator to add new or modify learned scores in the matrix by clicking content management » weighting » adding the new learned score in the corresponding cell and pressing save as represented in Figure 40. Similarly the same process of clicking the desired tab is undertaken within the CMS to update flood issues, demographic questions, and retrieve user responses. As such, the online system from an administrator perspective is an effortless process with no programing experience required to achieve a tailored EDSS for flood risk management options provided the steps are homogeneous to the model.

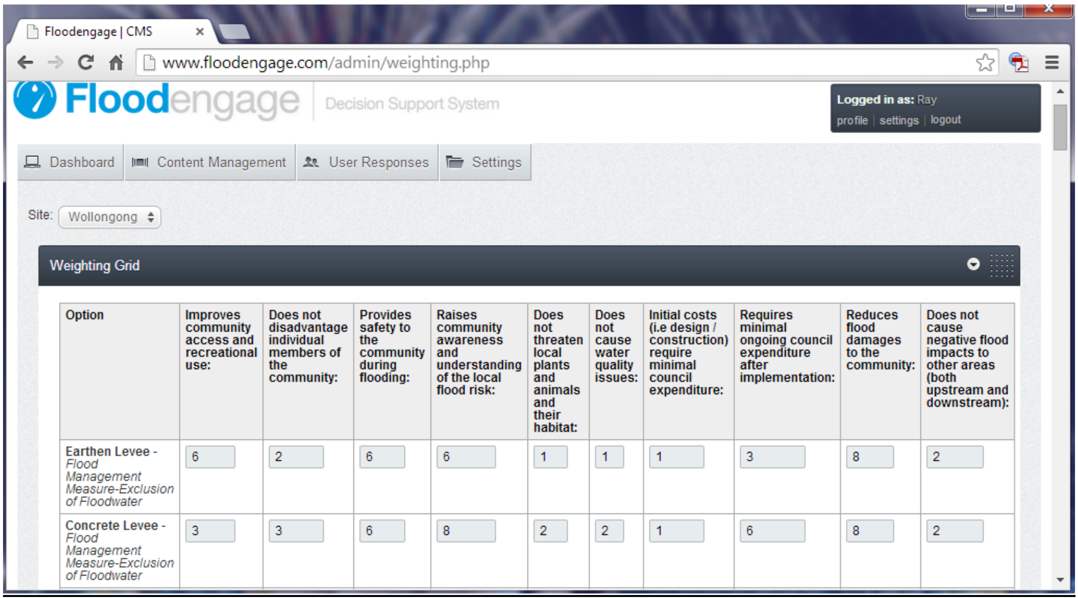


Figure 40: Learned score matrix in online Floodengage CMS.

5.2.5.2 Users experience: welcome

The user enters the system via the uniform resource locator (URL) typically http://www.floodengage.com/name_of_the_catchment. For example the URL for the Wollongong City Catchment was http://www.floodengage.com/wollongongcity. Once in, the user is presented with the same welcome screen as the standalone system allowing them to learn about 1) the flood issues (Figure 41), 2) the management measures, and 3) the Floodengage program. Like the standalone system these popup windows provide content rich text and graphic information. The advantage of the online system is the ability to embed hyperlinks in the popup windows. These hyperlinks enable the user to explore relevant information not contained in the system such as flood studies, flood risk management studies, local government emergency

management plans etc. providing an additional source of information to aid informed decision making should the user have the desire.

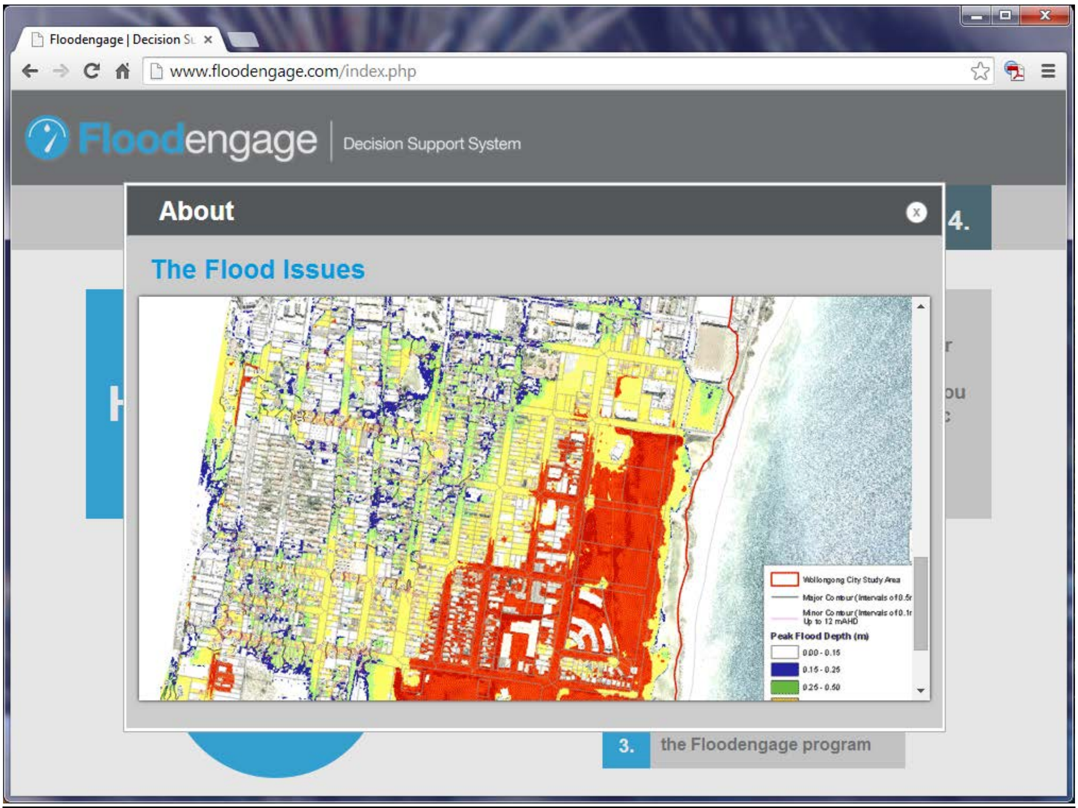


Figure 41: Learn about the flood issues pop-up window screen shot.

5.2.5.3 Users experience: step 1

Once the large blue start button is selected on the welcome page, the user is transferred to step 1 of the online system. Like the standalone system this step involves the user defining the relative weight (w_i) of how important it is that the flood risk management option meets criterion question *i*. This opportunity to select importance weighting differentiates from the standalone system as the user is able to click a dynamically enabled 5 point gauge for each criterion question illustrated in Figure 42. The weights, and categorical descriptors however are the same i.e. w_i = not at all important = 0 etc.

Similarly should the user not understand a criterion question, they have the option of clicking the corresponding information symbol to generate a content rich popup window to aid comprehension. To finalise this step, all questions like the standalone system must be assigned weights with the 'Next Step' button not being displayed until this occurs. Once complete the user has the choice to progress to the next step or return to the welcome page.

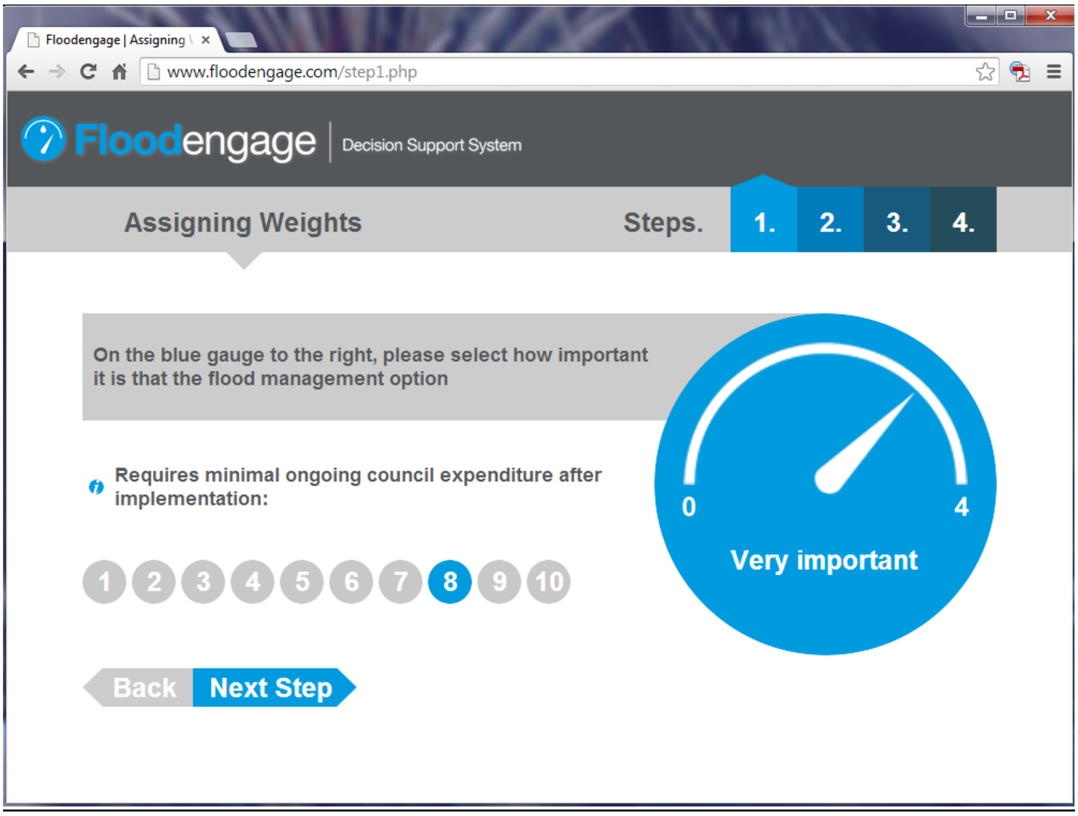


Figure 42: A screen shot of the online systems 'step 1' – assigning weights.

5.2.5.4 Users experience: step 2

Once the importance weightings have been selected, the system in Step 2 displays the options from most preferred to least preferred. The user is then afforded the opportunity to click on each option to reveal the fact sheet information popup windows. Like the standalone system, it is hoped in doing so the user can gain a greater appreciation of alternative views, the tradeoffs and complexities incumbent in the selection of flood risk management options leading to enriched social learning and decisions beyond egocentricity. If the user is not happy with the ranking they are given the opportunity to re-rank options (hopefully informed about the tradeoffs they are making) in the next step.

5.2.5.5 Users experience: step 3

The user can re-rank options by simply clicking and dragging the selected option up or down as shown in Figure 43. This function operates on both mobile and computer platforms and provides the ranked order on the left hand side of the options to indicate preference. Once the user is satisfied with the ranking they click Next Step.

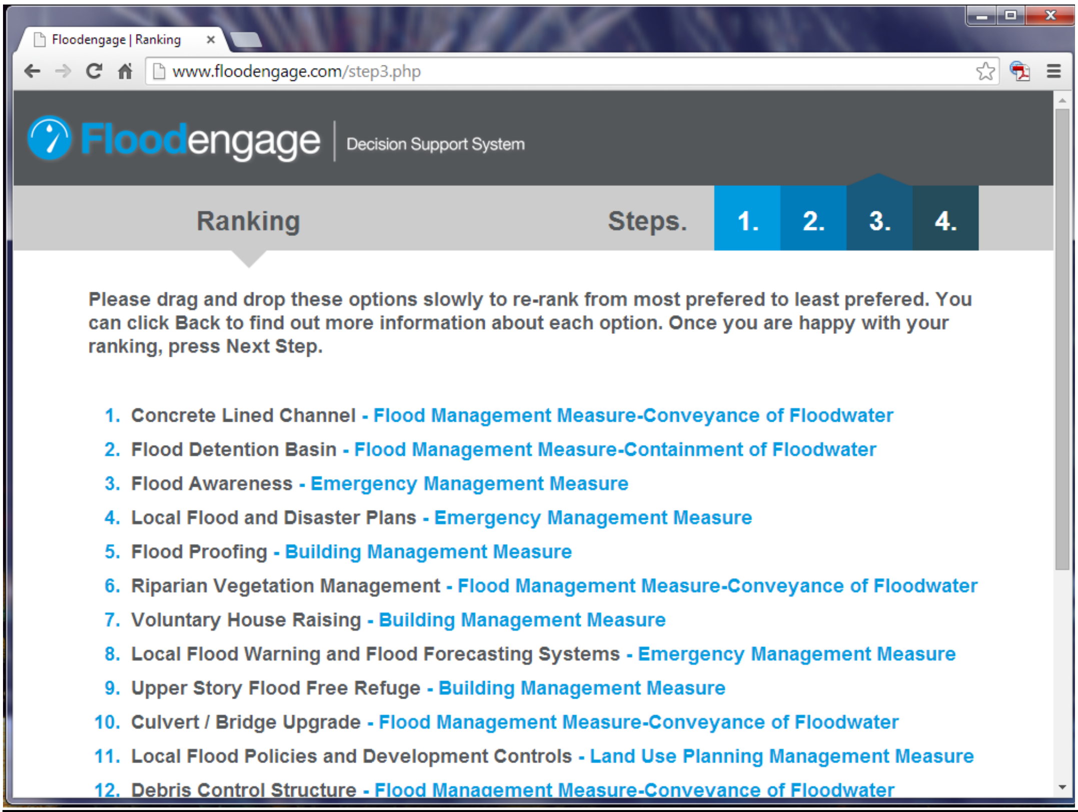


Figure 43: A screen shot of the online systems ‘Step 3’ – ranking.

5.2.5.6 Users experience: step 4

Like the standalone system the user is asked if they have any additional flood risk management options or comments they wish to include in step 4 show in Figure 44. In conjunction demographic information is collected at this stage through single selection or multi selection tick box surveys and text entry panels. As noted in chapter 4.4.6, questions must be tactfully chosen if demographic information is desired by the principal flood risk management authority and or committee. Once complete the user clicks submit and the responses are sent to a MySQL database for storage, retrieval and export.

5.2.6 Sensitivity analysis

Prior to system trials, sensitivity analysis was conducted on the systems performance to understand the relationship between weightings and recommendations, and to search for errors in the system to ensure stability and confidence when trialled. Two trial and error sensitivity analysis techniques ‘What If’ and ‘Goal seeking’ were applied. What If analysis was conducted on the weightings w_i in step 1 to see **What** would happen to the option ranking **If** the weightings were changed. It was found as

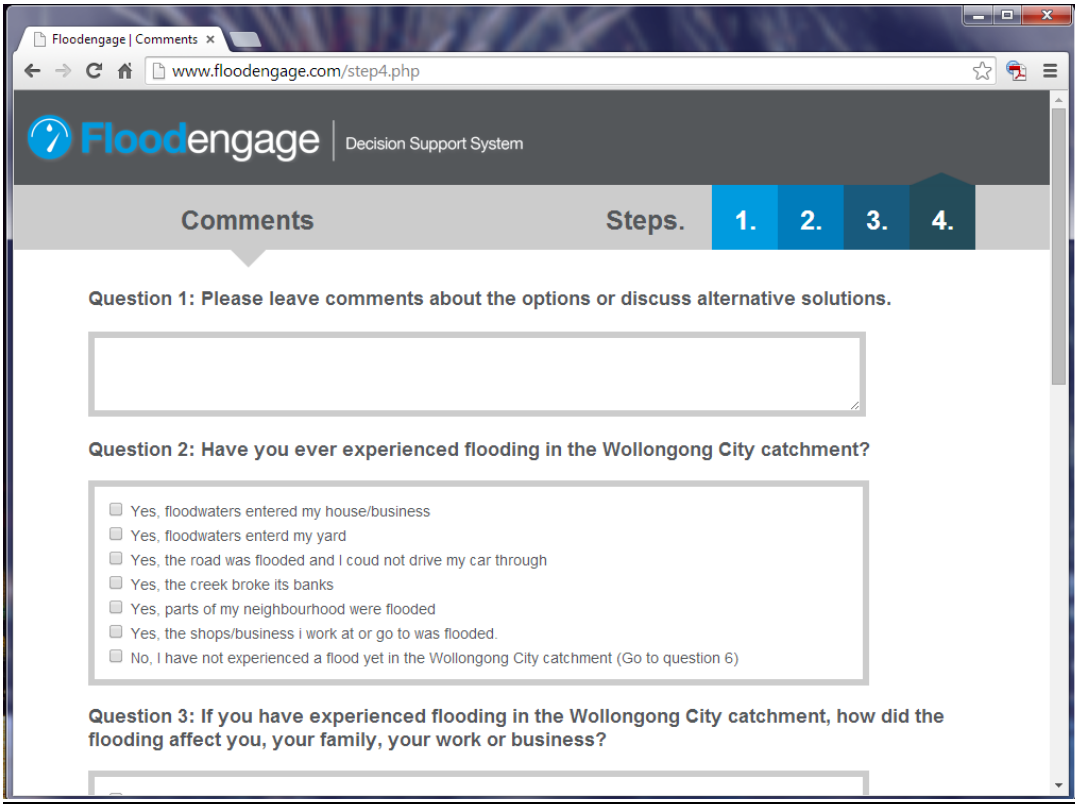


Figure 44: A screen shot of the online systems 'step 4' – comments.

expected (due to the simple Wsum methodology employed by the model) that criterion questions with large variance among learned scores were more sensitive to producing output changes over those with small learned score variance. These criterion questions with marginally larger variance were cq_7 'initial costs require minimal council expenditure' and cq_8 'requires minimal ongoing council expenditure after implementation' respectively. The criterion question with a relatively small comparable variance was cq_9 'reduces flood damages to the community', as all options selected excluding O_5 and O_{17} preformed reasonably well against this criterion.

Goal seeking analysis was conducted on importance weightings w_i in step 1 of the system to achieve option O_j being preferenced highest. This was achievable for 5 options. These options being O_{11}: Local flood policies and development controls; O_{15}: Flood proofing; O_{18}: Flood awareness; O_{19}: Flood warning and forecasting systems; and O_{20}: Local flood and disaster plans. All other options could not be preferenced highest, as the above 5 options were superior on one or more criterion questions. Most options however, could be ranked within the top five, through optimisation of w_i to suit each options advantages and disadvantages. This is a non-surprising outcome

and demonstrates the superiority of some options over others. However as previously noted, flood risk management is rarely achieved by a single option rather requiring a combination of measures that need to be considered collectively (DIPNR 2005). Thus caution needs to be placed on limiting analysis and assessment to identified superior options.

To further evaluate the performance and ensure consistency of the system prior to the public trials being conducted, system testing by experts in the flood risk management field was undertaken. It was found the system performed well with minor programming errors being discovered and later rectified prior to launch. As a result, the system was found to perform as intended thus being subjectively determined as suitable for public trials.

5.3 System trials

The system was trialled for three catchments on the NSW east coast of Australia. These catchments being Horsley Creek in the local government area of Shellharbour City Council, Black Creek in the local government area of Cessnock City Council, and Wollongong City in the local government area of Wollongong City Council. These catchment trials were undertaken on an opportunistic basis within entrained flood risk management processes with established flood risk committees comprising state and local government representatives, residents and business owners. All three locations had completed their respective flood behaviour studies and were embarking on community consultation through traditional mail-out surveys to seek input on flood risk management options for their catchments. The online Floodengage decision support system was offered as an additional consultation mechanism to gather feedback. While technically feasible options were slightly different for each catchment, all utilised the same 10 criterion questions outlined in sub chapter 5.2.1 agreed upon by the respective flood risk management committees or technical sub committees. The following is a summation of the three catchment trials and their respective results with further detail provided in the Floodengage Online Community Consultation Reports contained in Appendices E, F and G for each catchment.

5.3.1 Trial one – Horsley Creek catchment

The Horsley Creek catchment is located 100 kms south of Sydney, on the south-east coast of Australia. The catchment drains an area approximately 9 km^2 of mostly urbanised land which includes the township of Albion Park (Reinco 2011). The

catchment has around 13,000 occupants with two thirds occupying flood prone land. The median age is 33 years, 16% of homes are leased with a medium individual income of $550 AUD per week (Qpzm 2014). The Floodengage program was utilised by Shellharbour City Council to supplement traditional mail-out surveys conducted by GHD for the Horsley Creek Floodplain Risk Management Study and Plan (Appendix I). The online Floodengage consultation was launched on the 30th of May 2013 remaining open for submissions until the 12th of July 2013. During this consultation period the website received some 592 website views. Of these views, 47 valid responses were submitted via the system. The results of the online Floodengage submissions received for each step are documented below:

<u>Step 1:</u> Respondents importance weights for the 10 criterion questions (cq_i).

The total number responses for each importance weight category w_i corresponding to cq_{1-10} submitted are displayed in Table 6.

Table 6: Weighting responses for the Horsley Creek catchment.

w_i	n responses for cq_{1-10}.									
	cq_1	cq_2	cq_3	cq_4	cq_5	cq_6	cq_7	cq_8	cq_9	cq_{10}
Extremely	8	10	22	12	11	11	8	5	14	19
Very	6	15	10	12	13	12	14	13	19	12
Moderately	13	13	5	9	8	8	12	16	3	7
Slightly	15	8	9	12	11	12	7	9	9	7
Not at all	5	1	0	1	4	3	6	3	1	2

Result analysis indicates it was extremely important to respondents in the Horsley Creek trial that flood risk management options cq_3 improve safety and cq_{10} have no negative adverse impact. Respondents viewed cq_1 improve community access and recreational use as a less favourable criterion for flood risk management options. It is evident criterion cq_4 raise community awareness; cq_5 does not threaten local plants and animals and their habitat; and cq_6 does not cause water quality issues, split respondents providing an asymmetrical bimodal distribution.

<u>Step 2:</u> Recommended options.

The recommended flood risk management options based on the aggregation of all users w_i for cq_{1-10}, multiplied by the corresponding learned score and summated as outlined via Equation 1 in chapter 4.6.1 were:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Local flood warning systems and flood forecasting
7. Voluntary house raising
8. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
9. Riparian vegetation management
10. Upper story flood free refuge
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin
14. Concrete Levee
15. Channel realignment
16. Concrete lined channel
17. Increased infiltration capacity
18. Rainwater tanks

<u>Step 3:</u> Re-ranking

The aggregated results of the respondents re-ranking were:

1. Local flood policies and development controls
2. Flood awareness
3. Flood proofing of buildings
4. Voluntary house purchase / removal
5. Local flood and disaster plans
6. Local flood warning systems and flood forecasting
7. Voluntary house raising
8. Riparian vegetation management
9. Upper story flood free refuge
10. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin

14. Channel realignment
15. Concrete lined channel
16. Concrete Levee
17. Increased infiltration capacity
18. Rainwater tanks

Local flood policies and development controls were the respondents most preferred floodplain management option with 30 respondents (64%) ranking it as their 1st preference. Rainwater tanks were the least preferred option with 27 respondents (57%) leaving it as their last choice. Although over half of the respondents re-ranked one or more options, only option O_{15} flood proofing of buildings and O_{13} voluntary house purchase / removal shifted positions post aggregation largely as a result of 10 users preferencing O_{13} lower. A preference scale documenting the combined users most to least preferred options was developed as presented in Figure 45. Each option within this diagram was linearly rescaled with zero assigned to the lowest ranked option and one assigned to the highest ranked option with all other options rescaled within these upper and lower bounds. In doing so the scale visually allows decisions makers to see the relative preferencing of one option over another thus informing their decisions.

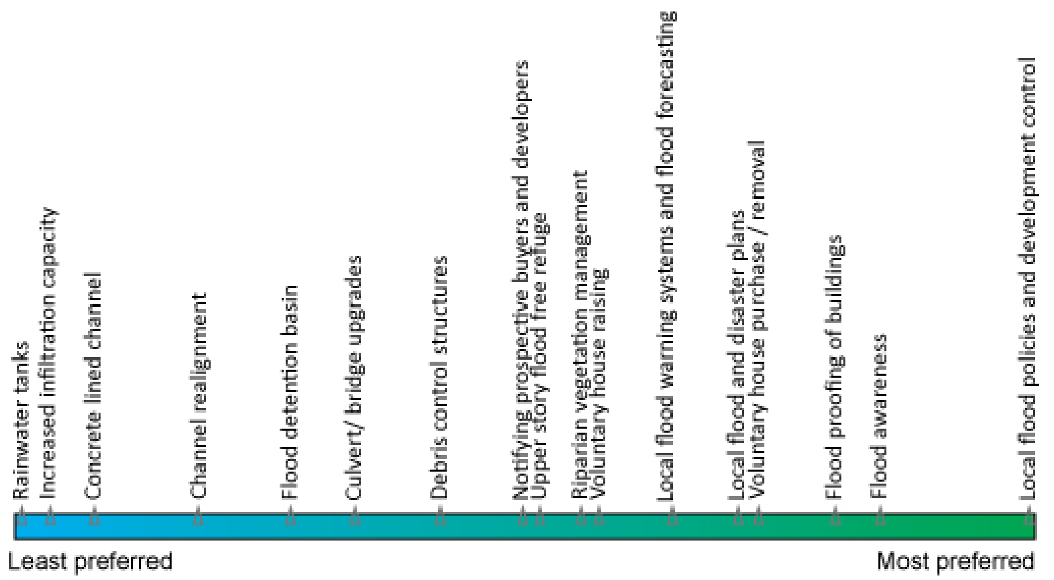


Figure 45: Horsley Creek floodplain management measure preference scale (Laine 2014a).

The traditional mail-out surveys conducted by GHD for the Horsley Creek Floodplain Risk Management Study and Plan collected 245 valid responses (GHD 2014). The aggregated flood risk management option preferences from these responses are:

1. Vegetation Management
2. Watercourse enhancement
3. Flood related planning and development controls
4. Culvert/ bridge enlargement or improvement
5. Emergency response
6. Detention/ retention basin
7. Improvements to warning systems
8. Flood embankment levees
9. Flood education/ awareness
10. Flood proofing

Although the methodology for deriving preferences in the paper-based surveys were different as users indicated preference for options on a scale from 1 to 5 for the survey, rather than individually ranking options as in the EDSS, the following comparisons were made: 1) vegetation management and watercourse enhancement options were the most preferred options on the paper-based survey whereas the same options were preferenced mid to low range in the Floodengage responses; 2) Local flood policies and development controls in the Floodengage system were the most preferred options however, were ranked third and second-last respectively in the traditional paper-based surveys; and 3) response management measures were generally unchanged in ranking between the two approaches.

5.3.2 Trial two – Black Creek catchment

The Black Creek catchment is located 150 kms north of Sydney, on the south-east coast of Australia. The catchment drains approximately 26 km^2 of agricultural, urban and uncleared native land which includes the Cessnock City CBD (DHI 2010). The catchment has around 14,000 occupants with around half the urbanised land identified as flood prone. The median age is 39 years, 34% of homes are leased with a medium individual income of $426 AUD per week (Qpzm 2014). The Floodengage program was utilised by Cessnock City Council to supplement traditional mail-out surveys conducted by Cardno for the Black Creek Floodplain Risk Management Study and Plan (Appendix J). The online Floodengage consultation was launched on the 26th of September 2013 remaining open for submissions until the 24th of October 2013. During this consultation period the website received some 351 website views. Of these views only four valid responses were submitted. The results of the online Floodengage submissions received for each step are documented below:

Step 1: Respondents importance weights for the 10 criterion questions (cq_i).

The total number responses for each importance weight category w_i corresponding to $cq_{1\text{-}10}$ submitted are displayed in Table 7.

Table 7: Weighting responses for the Black Creek catchment

w_i	n responses for $cq_{1\text{-}10}$.									
	cq_1	cq_2	cq_3	cq_4	cq_5	cq_6	cq_7	cq_8	cq_9	cq_{10}
Extremely	0	2	2	2	1	2	0	1	3	2
Very	1	1	2	1	2	2	0	1	1	1
Moderately	3	0	0	1	0	0	2	1	0	1
Slightly	0	1	0	0	1	0	2	1	0	0
Not at all	0	0	0	0	0	0	0	0	0	0

Analysis is trivial due to the small sample however completed with recognition of this limitation. The results indicate that it was extremely important to the 4 respondents that flood risk management options cq_9 reduce flood damages, cq_3 provide safety to the community, and cq_6 do not cause water quality issues. Respondents viewed cq_6 initial costs requiring minimal council expenditure as the least important criterion for flood risk management options.

Step 2: Recommended options.

The recommended flood risk management options based on the aggregation of the 4 users w_i for $cq_{1\text{-}10}$, multiplied by the corresponding learned score and summated as outlined via Equation 1 in chapter 4.6.1 were:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Local flood warning systems and flood forecasting
7. Riparian vegetation management
8. Voluntary house raising
9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
10. Culvert/ bridge upgrades

11. Upper story flood free refuge
12. Debris control structures
13. Flood detention basin
14. Concrete levee
15. Earthen Levee
16. Channel realignment
17. Concrete lined channel
18. Increased infiltration capacity
19. Rainwater tanks

<u>Step 3:</u> Re-ranking

The aggregated results of the respondents re-ranking were:

1. Local flood policies and development control
2. Voluntary house purchase / removal
3. Flood awareness
4. Local flood warning systems and flood forecasting
5. Flood proofing of buildings
6. Local flood and disaster plans
7. Riparian vegetation management
8. Voluntary house raising
9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
10. Culvert/ bridge upgrades
11. Debris control structures
12. Upper story flood free refuge
13. Flood detention basin
14. Concrete levee
15. Channel realignment
16. Concrete lined channel
17. Increased infiltration capacity
18. Rainwater tanks
19. Earthen Levee

Three quarters of the respondents ranked local flood policies and development controls their most preferred floodplain management measure of the 19 feasible options. One quarter of the repondents re-ranked the preferences resulting in shifts

downward for O_1 earthern levee and O_{18} flood awareness flood risk management options. To provide consistency with the other trials, a preference scale was developed shown below in Figure 46 however, it is noted that significant bias is evident due to the limited response rate.

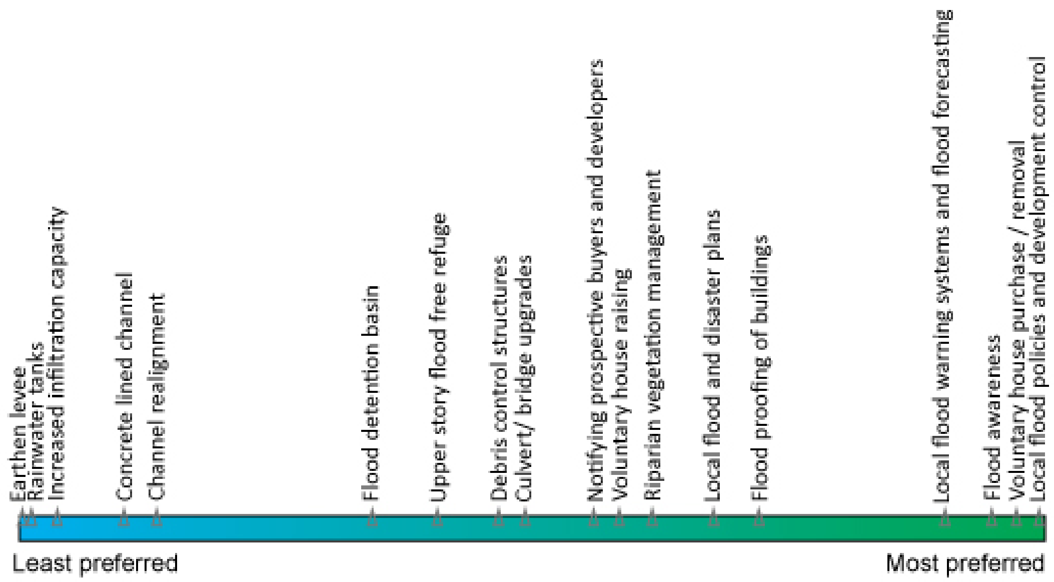


Figure 46: Black Creek floodplain management measure preference scale (Laine 2014b).

The traditional mail-out surveys conducted by Cardno for the Black Creek Floodplain Risk Management Study and Plan collected 80 valid responses (Cardno 2014). The aggregated flood risk management preferences for these responses are:

1. Environmental channel improvements, including removal of weeds and bank stabilisation
2. Improved flow paths
3. Culvert/bride/pipe enlarging
4. Retarding or detention basins
5. Planning and flood-related development controls
6. Education of community, providing greater awareness of potential hazards
7. Stormwater Harvesting such as rainwater tanks
8. Flood forecasting, flood warning, evacuation planning and emergency response
9. Levee banks
10. Diversions of creeks and channels

A comparison of the traditional paper-based survey and Floodengage responses was not conducted for the Black Creek trial, as the sample population of 4 responses via the EDSS was deemed inadequate. However, it should be noted that vegetation management and improved flow paths were the most preferred options, with planning and flood related development controls being mid-preferenced by the Cessnock community in the paper-based surveys. Of note 'Stormwater Harvesting such as rainwater tanks' were preferenced higher than 'flood forecasting, flood warning, evacuation and emergency response' demonstrating the difference in a learned flood managers preferences when compared to submissions attained via traditional surveys techniques.

5.3.3 Trial three – Wollongong City catchment

The Wollongong City catchment is located 84 kms south of Sydney, on the south-east coast of Australia. The catchment drains approximately 7.3 km^2 of urbanised land which includes the Wollongong City CBD. The catchment has around 18,000 occupants with more than 2500 commercial and residential properties identified as flood prone (WMAwater 2013). The median age is 32 years, 56% of homes are leased with a medium individual income of $500 AUD per week (Qpzm 2014). The Floodengage program was utilised by Wollongong City Council to supplement traditional mail-out surveys conducted by WMAwater for the Wollongong City Floodplain Risk Management Study and Plan (Appendix K). The online Floodengage consultation was launched on the 10th of December 2013 remaining open for submissions until the 17th of January 2014. During this consultation period the website received some 874 website views. Of these views, 49 valid responses were submitted. The results of the online Floodengage submissions received for each step are documented below:

<u>Step 1:</u> Respondents importance weights for the 10 criterion questions (cq_i).

The total number responses for each importance weight category w_i corresponding to cq_{1-10} submitted are displayed in Table 8. Respondents in the Wollongong City trial considered it extremely important that flood risk management options cq_3 improve safety, cq_9 reduce damages and cq_{10} have no negative adverse impact. Respondents viewed cq_1 improve community access and recreational use and cq_8 minimal ongoing council expenditure the least important criterion for flood risk management options. 8 of the criterion questions with the exception of cq_1 and cq_{10} split respondents providing

an asymmetrical bimodal distribution. This is particularly evident for the two environmental criteria cq_4 and cq_5.

Table 8: Weighting responses for the Wollongong City catchment.

w_i	n responses for cq_{1-10}.									
	cq_1	cq_2	cq_3	cq_4	cq_5	cq_6	cq_7	cq_8	cq_9	cq_{10}
Extremely	7	9	20	7	8	9	10	3	13	19
Very	8	21	12	16	16	15	17	17	16	10
Moderately	20	7	6	7	4	8	8	10	5	10
Slightly	10	10	11	17	15	13	10	16	14	7
Not at all	4	2	0	2	6	4	4	3	1	3

Step 2: Recommended options.

The recommended flood risk management options based on the aggregation of the 4 users w_i for cq_{1-10}, multiplied by the corresponding learned score and summated as outlined via Equation 1 in chapter 4.6.1 were:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Riparian vegetation management
7. Local flood warning systems and flood forecasting
8. Voluntary house raising
9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
10. Upper story flood free refuge
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin
14. Concrete lined channel
15. Increased infiltration capacity
16. Rainwater tanks

Step 3: Re-ranking

The aggregated results of the respondents re-ranking were:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Riparian vegetation management
7. Local flood warning systems and flood forecasting
8. Voluntary house raising
9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
10. Upper story flood free refuge
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin
14. Concrete lined channel
15. Increased infiltration capacity
16. Rainwater tanks

Local flood policies and development controls were the respondents most preferred flood risk management options with 37 (76%) ranking it as their 1st preference. Under a quarter of the repondents re-ranked their preferences however, no change in ranking was observed with limited distance change between options. The preference scale documenting the combined users most to least preferred options for the Wollongong City catchment is shown in Figure 47 below.

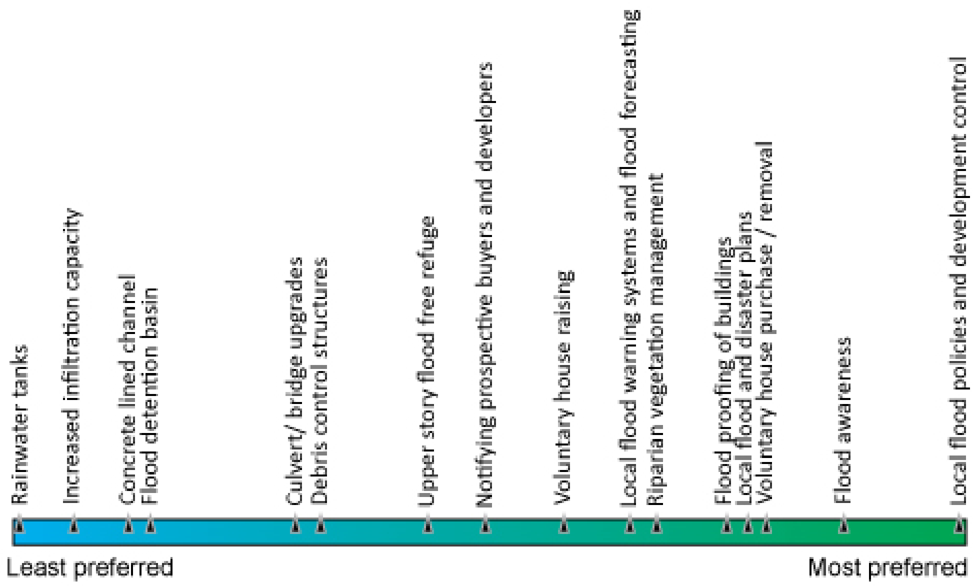


Figure 47: Wollongong City floodplain management measure preference scale (Laine 2014c).

The traditional mail-out surveys conducted by WMAwater for the Wollongong City Floodplain Risk Management Study and Plan are collected 195 valid responses (WMAwater 2014). The aggregated flood risk management preferences from these responses are:

1. Removal of silt, weeds and/or bank stabilisation
2. Blockage prevention devices
3. Increased channel or flow path capacity
4. Culvert/ pipe bridge enlargement
5. Flood forecasting, flood warning, evacuation planning and emergency response
6. Planning and development control measures
7. Detention basins
8. Property modification measures

The methodology for deriving preferences via the traditional paper-based surveys for the Wollongong City catchment was different to Floodengage with the users indicating preference for options on a scale from 1 to 5 on the survey rather than individually ranking options as in the EDSS. In light of this the following comparisons were made: 1) vegetation management and debris control structure options were the most preferred options on the paper-based survey whereas the same options were preferenced in the upper mid to lower mid rankings respectively in the Floodengage responses; 2) Local flood policies and development controls was the most preferred option in the Floodengage however, was ranked third last in the traditional paper-based surveys; 3) property management measures were less favourable in the survey compared to the online system response; and 4) detention basins are ranked comparatively between the response mechanisms at the least preferred end of the spectrum.

5.4 System evaluation

Evaluation was conducted on the online systems performance through the Beierle framework (Beierle 1998). This framework was selected due to its robust capabilities in assessing public participation mechanisms such as an engagement decision support system for flood risk management options. The framework is based on achieving a set of ‘social goals’ these being: 1) educating the public; 2) incorporating public values and knowledge into decision making; 3) building trust; 4) reducing

conflict; and 5) assuring cost effective decision making (Beierle 1998). In doing so, strengths and weakness of the system are identified. It must be recognised that this is largely a subjective process due to the inherent subjective nature of what is being evaluated. For example, value judgements of trust building has significant ambiguity. The results of this evaluation are detailed below:

1) Educating the public: The system provides information in a quick-to-run, easy-to-use, digestible, interactive format that the public can relate to and understand. In application this understanding was triggered by the user's ability to conduct 'What If' sensitivity analysis and read clear concise informative fact sheets for each of the various options. Results indicate, through analysis of the user response logs, that a number of respondents post receiving the preferred options list in Step 3 of the system, preceded back to Step 2 changing value inputs, sparking examination of their own values and triggering user 'what-if' sensitivity analysis. In doing so, this subjectively indicates that the user was able to gain a greater appreciation of alternate views, the social, safety, economic, environmental/ecological and flood behaviour tradeoffs, and complexities involved in flood risk management. To improve this finding, In-page analytic software such as Google analytics could be embedded within the system to track user movement and interaction. This in turn would provide a relatively simple way to quantify details of interaction and thus potential learnings facilitated by the system without undertaking resource intensive processes such as randomised surveys and interviews.

2) Incorporating public values and knowledge into decision making: The fundamental core of the system is to incorporate public values and knowledge to drive informed sustainable decision making. This was evident in the trials with the users weighting criterion questions based on common values to generate a list of preferenced flood risk management options that were then user re-ranked and submitted for consideration. Further the opportunity was provided to input new innovative solutions or additional information on Step 4 of the system however, this did not occur in the 100 valid submissions across either of catchments. This non participation in providing solutions is a limitation in the system, and could be better understood with surveys and monitored trials. To build upon incorporating public values, the public could be given the opportunity to suggest and select values they would utilise to appraise options as discussed in chapter 4.7.2. However, this could not be completed for the three trials due to limited ability and desire to interfere with the entrained flood risk management processes for the respective catchments. With potential uptake of the

flood risk management cycle proposed in chapter 2, opportunities may arise for the public to truly incorporate their own values into the system.

3) Building trust: Congruent with the engagement decisions support systems architecture, trust is subjectively built via the structured methodology that is repeatable, coherent, comprehendible, transparent and able to withstand challenges via a well-documented audit trial. It must be recognised that trust is a two-way street with decision-makers needing to define and articulate the level of influence at each stage in the decision-making process and trusting the outcomes; and users trusting that the decision makers will utilise the outcomes derived, to the defined level of commitment when decisions are made. Through feedback provided during and post the EDSS trials, it is clear the system increases confidence in the recommendations made firstly through the more informed submissions and secondly through the transparent auditable framework that was clearly communicated and reported to the public i.e. the Floodengage community consultation reports (appendices E, F and G) which will be subsequently contained in each respective catchments flood risk management study and plan.

4) Reducing conflict: The system provides the opportunity for every individual to contribute to and be recognised as a valued member of society with something worthwhile to contribute, as there is no restriction on access. In the trials it was evident that users explored the salient differences and similarities between their own values and interests and those of their fellow citizens through What If sensitivity tests. In doing so users may have felt a sense of community connectedness, consensus and potential ownership when they saw how their input meaningfully contributed to the decisions made about which options were precedently modelled and assessed for their catchments. Further reduced public opposition is also testimony to reduced conflict however; this was ungauged for the trial catchments.

A significant limitation of the system trials was the small sample population that utilised the system. This was particularly evident in the Black Creek trial with only four responses. Limited representation may be one trigger to generate potential conflict at the decision-making stage. Although this low representation for Black Creek has been attributed to the older demographic and workforce patterns of the sample population, it is an undesirable outcome. As such, it is evident a range of public participation mechanisms are required not only web-based tools such as Floodengage, to actively engage and attain representation from those affected by or the management of

flooding. For example in the Black Creek catchment this could have involved further public awareness of the system, manned stalls with the EDSS, door knocking, public workshops and/or town hall meetings.

5) Assuring cost effective decisions: Cost effective decisions are sustainable decisions. If the decision is not sustainably derived or is ill-conceived it has the potential to drain significant resources to rectify the decision. This may include legal action, protests, re-establishment of the entire decision-making process. Thus, a system that empowers users to make informed decisions about flood risk management options considering value based tradeoffs can only lead to more sustainable decisions. It was evident in the trials that recommendations via the online system more closely reflected preference choices of a learned flood managers and thus are typically more sustainable i.e the ranking of flood policies and development controls as the highest flood risk management option in all catchments. This compares to narrow uninformed preferences witnessed in the paper based surveys i.e. channel clearing being the most preferred option in both Wollongong City and Horsley Creek catchments which are generally viewed by flood risk management practitioners as less sustainable options due to the ongoing costs, limited benefit and potential to cause negative environmental and flood behaviour impacts.

The systems performance to achieve this goal is further verified by WMAwater in the Wollongong City Floodplain risk management study Stage 1 report stating:

> ‘The order of preference for mitigation measures from the Floodengage tool closely aligned with the recommendations and outcomes of previous Floodplain Risk Management Studies/Plans undertaken in similar catchments. This is likely to be a result of the clear information that Floodengage provides to participants about the relative advantages, costs and practical issues with each measure. For example when the expense of some measure is explained, this can affect the preference. As a result of the more sophisticated methodology with regards to comparison of alternative mitigation measures, the Floodengage results are therefore likely to be more informative and reliable than the ranking derived from the posted questionnaire’ (WMAwater 2014).

5.5 Conclusion

It is evident that both a standalone and online engagement decision support system for flood risk management options is achievable, with the systems easily tweaked to suit organisational and/or legislative requirements. The system not only provides a knowledge hub platform for flood risk management option information but more importantly demonstrated that it can be utilised as an important mechanism to collaborate with and empower the public (including: community members, politicians, developers, planners, engineers etc.) to learn about, prioritise and make informed decisions about flood risk management options for their local catchment in a transparent objective facilitated process.

Through application in three trial locations, it was evaluated that systems like Floodengage can 1) increase understanding, social cohesion and connectedness; 2) enrich social learning through incorporating public values; 3) increase trust; 4) reduce conflict; and 5) lead to the selection of more sustainable decisions with user preference choices reflecting more closely the decisions of learned flood practitioners compared to traditional paper-based surveys.

Like all tools limitations apply such as limited respondent representation and significant time investment to derive the critical learned-score matrix. However, it is envisaged with future technological uptake, advancements, developed knowledge hubs and increased institutional and public desire to build participatory culture, engagement focused-decisions support systems like Floodengage will continue to improve complex decision-making outcomes.

Chapter 6

Application of engagement decision support model to further fields

6.1 Introduction

Decision-makers in numerous fields face the daily challenge of balancing perplexing often incongruent tradeoffs to facilitate multi-objective outcomes. These complex decision-making fields in addition to flood risk management include mining, transport, water supply, waste disposal, electricity generation and supply, bushfire risk, landslide risk, cyclone risk, avalanche risk, land-use planning etc. Incumbent in these fields is the requirement for repeatable, transparent, auditable, understandable and increasingly inclusive decision making. It is no longer satisfactory nor acceptable as identified by Belton and Stewart (2002), particularly in the public sector but increasingly in the private realm, to have decisions based on ‘gut feel’ with limited analysis, justification and consultation. As identified by numerous political and social theorists (Habermas 1987; Cohen 1996; Dryzek 2002; Rosenberg 2007; Stirling 2008) it is desirable to build a more deliberative, consensual, and robust environment allowing individuals to participate in the decision making processes that affect them.

This chapter will briefly explore the application of the engagement decision support model to both coastal zone management and highway realignment decision-making processes in order to theoretically demonstrate the model’s broader application in a range of engineering and non-engineering fields. In doing so, decision-makers may see the linkages and potential opportunities an engagement-focused decision support model, supported by engagement decision support systems can offer in respective fields as an additional mechanism to facilitate and aid objective informed public consultation and participation.

6.2 Coastal zone management

The coastal zone is the interface between the land and water, 'extending from the coastal plains to the outer edge of the continental shelves' (Fabbri 1998 p. 1; Pernetta and Milliman 1995). This dynamic area is extremely important from a biophysical perspective, with the majority of the world's population residing in the coastal zone attracted by and dependent on its socio-economic and bio-physical advantages i.e. resources, land for residential and industrial development, transport, shipping, tourism, recreation, aesthetics, habitat for a range of flora and fauna, ecosystem services etc (Nelson 2013; European Commission 2014). Residing in this zone does not come without physical risk. These risks include: coastal storms generating high wave energy, elevated water levels, high wind and intense rainfall causing erosion, flooding, and potentially landslides; tsunamis; tidal inundation exacerbated by increasing sea level; and catchment flooding. These risks coupled with intensive settlement and environmental degradation require informed balanced tradeoffs between social, environmental, economic, safety, cultural, legislative objectives to ensure the coastal zone can sustain current and future needs. The following sub chapter briefly examines how the model can be applied to the coastal zone management process, both domestically and internationally, to assist informed decision making.

6.2.1 Coastal zone management processes

From the examination of coastal management frameworks in Australia, the United States, the United Kingdom, Canada, France, China and Chile, coastal zone management processes, like flood risk management are generally similar (NOAA 2010; Environment Agency 2011b; Fisheries and Oceans Canada 2002; Macquarie et al. 2011; European Communities 2009; IBRD 2012). This framework typically involves: 1) understanding the processes, vulnerabilities and risks; 2) identifying objectives or goals; 3) identifying options to meet the objectives/goals; 4) making a decision; and 5) adopting and implementing the decision, with consultation, evaluation and review largely specified. To implement this framework the following steps are undertaken:

<u>Step 1)</u> Understanding the processes, vulnerabilities and risks is conducted through socio-economic analysis, environmental assessment and physical process, strategic development and emergency management modelling.

Step 2) Identifying objectives is typically conducted through consultation mechanisms such as surveys, town hall meetings, workshops and advocated by the European commission ‘consultative bodies, inquiries or public hearings, and may extend to partnerships’(European Commission 2009). These objectives may include increased access, amenity preservation or improvement, increased and better managed recreation facilities, habitat restoration and conservation, increased biodiversity, reduced pollutants, improvement in water quality, increased community education and volunteerism, limiting development in high-risk hazardous or vulnerable locations, promoting sustainable development, increasing fish productivity, increase sustainable coastal tourism, protect and enhance cultural heritage etc.

Stage 3) Identifying options to meet objectives/goals is typically undertaken through expert opinion. However, increasingly public participation mechanisms are being utilised (Stead and McGlasham 2006; Few et al. 2007; Fontalvo-Herazo et al. 2007; Stokke and Hovik 2009; Schmidt et al. 2014). A range of coastal zone management measures including planning; building; environmental; and protection options such as buffer zones, planned retreat, voluntary purchase, relocatable buildings, dune restoration, coastal estuary restoration, access improvements, seawalls, groynes, beach nourishment, artificial offshore reefs etc. are required to be considered both collectively and individually (NSW Government 1990).

Stage 4) Making informed decisions balancing social, environmental, economic, cultural, safety, legislative tradeoffs.

Stage 5) Adopting and implementing the decision made, including allocating resources to achieve outcomes in specified accountable timeframes.

Stage 2, 3 and 4 in particular due to the decisions having significant economic, environmental ramifications and requiring representative input from a range of stakeholders, could benefit from the application of involve and collaborate mechanisms such as world cafes, citizen panels, deliberative polling and engagement decision-support systems. Application of an EDSS to support informed decision making at Stage 4 of the coastal zone management process is foreseen to assist transparent, auditable, inclusive balanced decision making and is explored further below.

6.2.2 The development of an EDSS for coastal zone management

An EDSS for coastal zone management as outlined in the model requires : 1) development of a quick-to-run, easy-to-use, flexible computer based system; 2) derivation of coastal zone management criterion; 3) a suite of modelled and assessed coastal zone management options; and 4) and the corresponding development of a learned-score matrix from which the adapted weighted sum equation is applied. This system could be developed utilising the generic standalone Microsoft Excel macro or online PHP coded CMS presented in chapter 5.2. These two options provide flexibility to the decision-making authority or committees allowing them to tweak the system to suit organisational, legislative and/or user requirements.

The online system would provide the following user experience:

Welcome: The user is presented with the welcome screen as illustrated in Figure 48 allowing them to learn about: 1) the coastal tradeoffs i.e. criterion such as; maintain coastal amenity; improve access and recreational use; improve habitat etc. 2) the management measures such as protect, accommodate and retreat measures; and 3) the Coastalengage program via popup windows. Within these popup windows the user is able to access a knowledgebase of information on the issues and criterion, the proposed management measures and their relative advantages and disadvantages in-relation to selected trade-offs. The user can then click 'Start' to continue, or close the system by clicking the exit button.

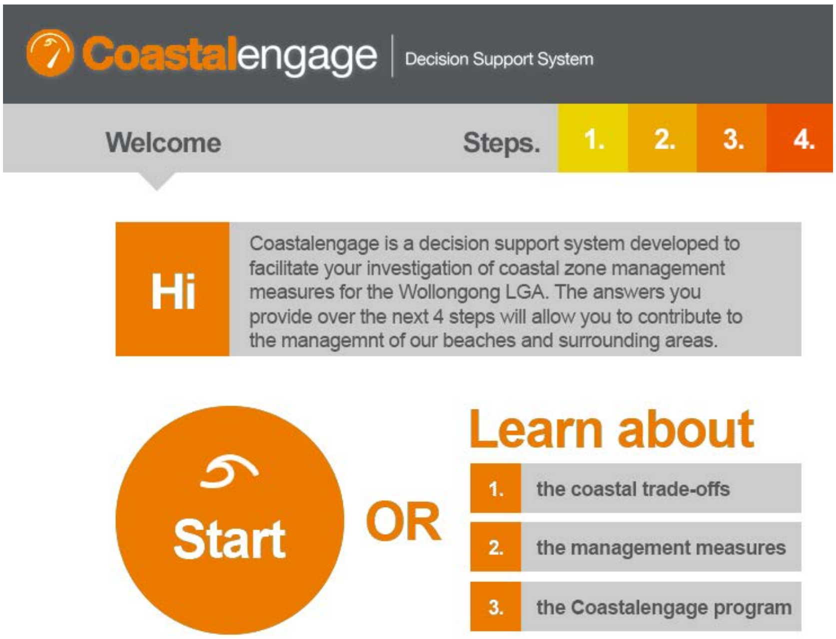


Figure 48: A screen shot of the Coastalengage 'Welcome' page.

Assigning weights: The next step allows the user to weight on the 5 point orange gauge ($w_{0,\ldots,4}$) how important it is to them that the coastal management option meets criterion question i where $i = 1, \ldots\ldots, 10,$ as depicted in Figure 49. The user must assign a weighting for each of the cq_i on this step to enable them to progress.

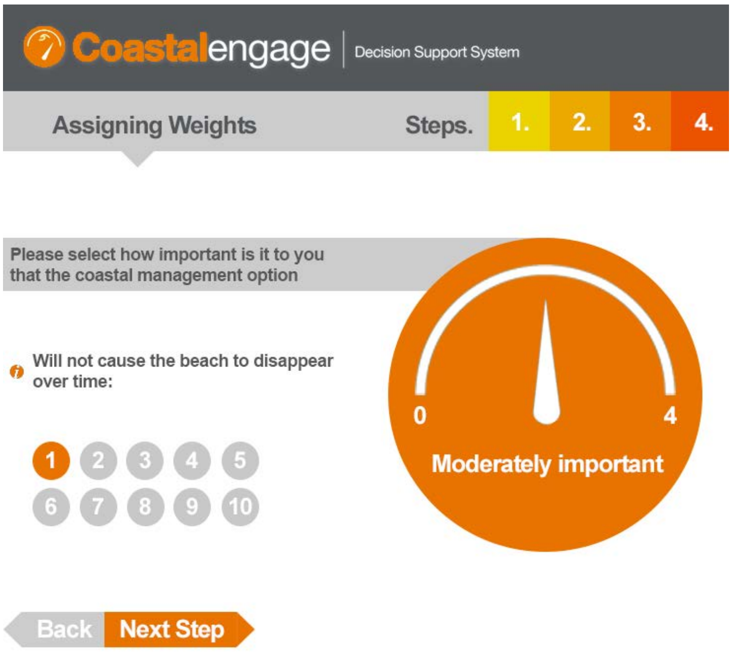


Figure 49: A screen shot of Coastalengage 'step 1' – assigning weights.

Step 2: Once the importance weightings have been selected, the system in Step 2 displays the options from most preferred to least preferred (Figure 50). The user is

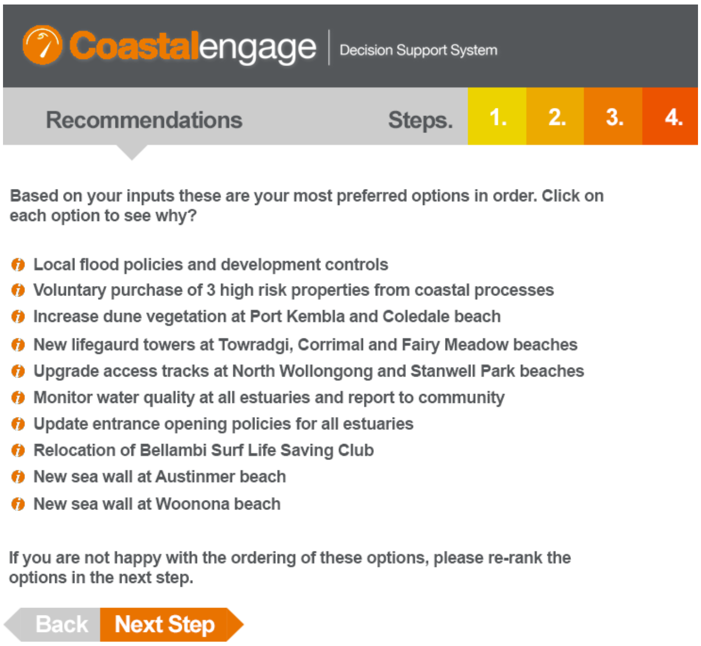


Figure 50: A screen shot of Coastalengage 'step 2' – Recommendations.

then afforded the opportunity to click on each option to reveal the fact sheet information popup windows. As detailed in chapter 2.6.1 providing this information in an interactive and comprehensible way facilitates the user's discovery of not only the advantages and disadvantages of coastal zone management options but more importantly their values. It is the correlation of values to the options that allows users to gain a greater appreciation of alternative views, the value tradeoffs that need to be made and thus complexities incumbent in the selection of the coastal zone management options leading to enriched social learning, buy-in, and potential acceptance and responsibility.

Step 3: The user is given the opportunity to re-rank the coastal zone management options from most preferred to least preferred (Figure 51). This provides the user the ability to still pursue options that don't necessarily reflect their inputted values. However, when promoting or relegating options users may be more aware of the value based tradeoffs they are making to preference some options over others.

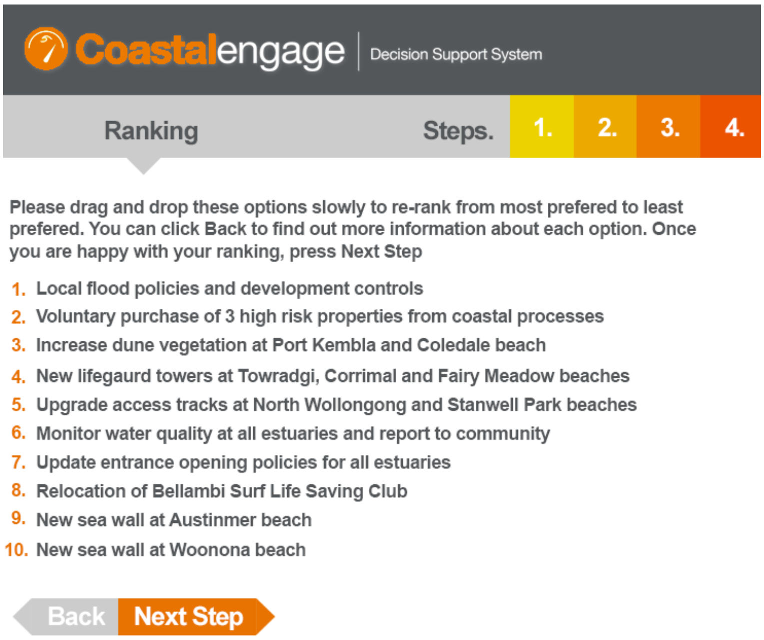


Figure 51: A screen shot of Coastalengage 'Step 3' - Ranking.

Step 4: Once rankings are complete the user is asked to provide comment on the system or options. Users are then also prompted to complete demographic information prior to clicking the 'Submit' button. Post submission the answers are compiled for aggregation and dissemination to the decision-making authority.

The work presented above shows, how the Coastalengage system could be readily utilised in the coastal zone management decision makings sphere upon derivation of site specific criterion; a suite of options; and the corresponding learned-score matrix. In doing so it is envisaged that an EDSS for coastal zone management could provide an innovative mechanism to empower the community to make informed learned contributions to the decision-making process.

6.3 Highway realignment

Major transport decisions affect many people, involve multiple options, underpin most economic and social services and are thus extremely complex. Sound transport decision making takes into account competing economic, social, environmental, technological and political considerations such as transport system interdependencies, interactions between transport and the surrounding environment both current and future, transport benefit, safety, congestion, demand, accessibility etc. These decisions can be ranked on a spectrum from strategic overarching international policies such as the EU Transport Policy (European Commission 2011) down to operational detailed design specifications such as road resurfacing material selection as represented in the inverted triangle decision spectrum (Figure 53). A commonly occurring transport decision is the upgrade of major highways. Highway upgrades are on the rise, with an increasing trend in global motor vehicle usage (World Bank 2014). Australia is no exception with major highway upgrades occurring in all states and territories, in response to a national average annual registered motor vehicle growth rate of 2.5% (ABS 2014). The subchapters below will investigate the application of an EDSS for the Princes Highway upgrade between small towns, Gerringong and Bomaderry in NSW, Australia as an example of the model application to the transport field. Application of the model for this case study was selected, as it is fairly representative of transport related complex decisions, with a number of alternative alignments feasible. As the mode of transport (a motor vehicle), and location for the upgrade (Gerringong to Bombaderry) had been pre-decided it was determined consultation was being sought on a mid-range decision in the decision spectrum (Figure 52). As a

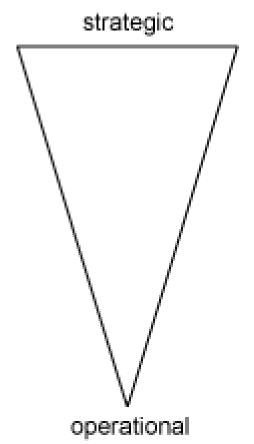


Figure 52: Decision spectrum (adapted from S Waters 2014, pers.comm., 14 April)

result public investment in other modes of transport or different locations was neither the focus of consultation nor the application of the decision support model.

6.3.1 Highway realignment process

From examination of typical upgrade projects both domestically and internationally, the standard process appears to be: 1) establishing a need, typically through infrastructure failure, renewal mandates, safety concerns and incidents, current or predicted demand increases and political/ economic stimulus agendas; 2) engineers and planners deriving a range of alternative options to address the need; 3) consultation being conducted at the inform and consult level on the public participation spectrum (Figure 23) as detailed in chapter 3.2.1; 4) option refinement; 5) further consultation at the inform and consult level to gather feedback; 5) detailed design; 6) make decision; and 7) implement decision.

Of all examined projects only one involved public participation mechanisms above the inform and consult level of engagement. This project was an extension to the Roe Highway in Perth, Western Australia. The decision-making authority provided the opportunity for the community to see and comment on preliminary drawings and to collaborate with the government and consultant design and environment teams at two workshops, firstly selecting the triple bottom line criteria and then completing a traditional multi-criteria analysis exercise (IPA2 2011). The synopsis states, 'for the first time ever, the community was provided with opportunities during the entire project development stage to collaborate with the design team and influence the design outcomes for the entire highway alignment' with the process reportedly "widely praised by both the client (WA Government) and participants"(IPA2 2011).

The Roe Highway example is confirmation that the utilisation of mechanisms beyond the inform and consult level of influence can be utilised in the highway upgrade sphere to deliver an improved outcome not only for the government but ultimately the community.

6.3.2 The development of an EDSS for highway realignment

An engagement decision support system for highway realignment like all EDSSs requires the development of a quick-to-run, easy-to-use, flexible computer-based system; derivation of options/alternatives, a selection of criterion for which the options are appraised; and the corresponding development of a learned-score matrix. With

application to the Gerringong to Bomaderry case study the criterion questions would ideally be developed via a committee comprising key stakeholders with input from the broader community. These criterion questions could include for example: improve safety, reduce travel time, provide access during times of flood, have minimal initial costs, have minimal ongoing costs, have limited impact on local plants and animals and their habitat, have minimal impact on water quality, reduce visual impact, minimise noise, limit the social impact of buying people's homes, maintain productivity of agricultural land etc. the options would include the feasible alternative routes with slight variations from A –Z, and the matrix developed through literature review; transport modelling; economic, social and environmental assessments; expert interviews. This system again could be developed utilising the generic standalone excel macro or online PHP coded CMS presented in chapter 5.2, providing the decision-making authority (in this case the NSW Roads and Maritime Service) the flexibility to tweak the system to suit organisational, legislative and user requirements.

Like all EDSS online systems the following user experience would result:
Welcome: The user is presented with the welcome screen as illustrated in Figure 53 allowing them to learn about: 1) the upgrade need i.e. increased demand, safer travel, reduced travel times, local economic construction stimulation etc. 2) the alignment options; and 3) the Transportengage program via popup windows. Within each of the popup windows the user is given access to the knowledgebase of information on each topic. For example if the user clicks 'Learn about the alignment

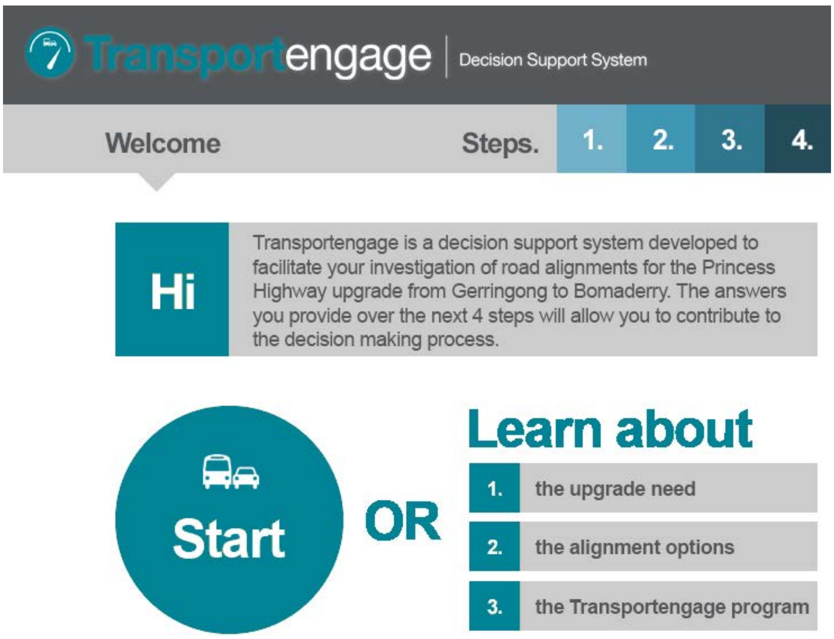


Figure 53: A screen shot of the Transportengage 'Welcome' page.

options' tab, they would be provided with maps and information regarding the relative advantages and disadvantages of each option they select. Once the user is satisfied with the methodology they user can click 'Start' to continue or exit the program.

Step 1: The next step allows the user to weight on the 5 point gauge $(w_{0,\ldots,4})$ how important it is to them that the road alignment option meets criterion question i as depicted in Figure 54. If they are unsure what the criterion question is asking, the user can click on the question to reveal a popup tab with detailed information. Once the user assigns a weighting to each question they can progress to the next step.

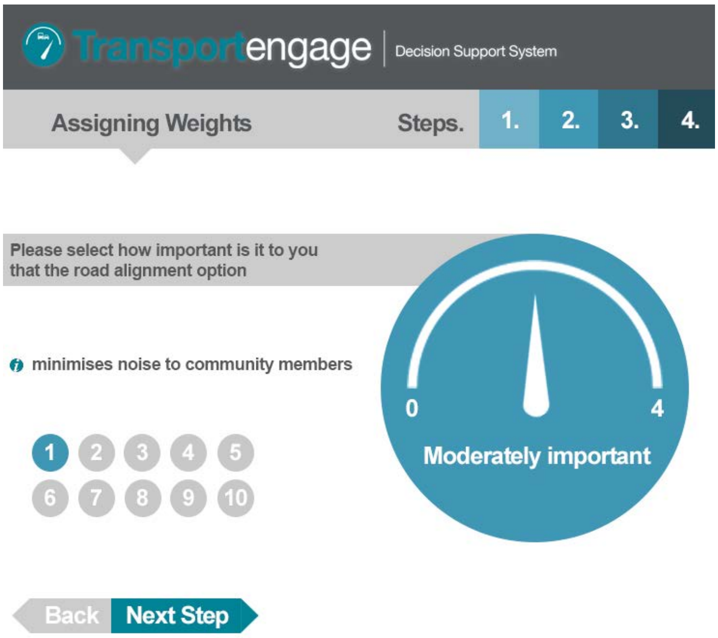


Figure 54: A screen shot of Transportengage 'step 1' – Assigning Weights.

Step 2: Based on the user's input and the learned-score matrix via Equation 1 in chapter 4.6.1, recommended options from most preferred to least preferred are displayed (Figure 55). The user can then click on each of the alignment options to reveal the information fact sheet popup windows. This would provide the user an opportunity to read about and visually see the proposed option, and in doing so hopefully gain a greater appreciation of not only the options tradeoffs and site constraints but awareness of considerations relevant to the entire upgrade project.

Step 3: This step provides the opportunity for the user to re-rank option alignments. It is hoped they have gained an understanding of the relative trade-offs they are making when they place one option over another; once they are satisfied with their ranking they can click 'Next Step'.

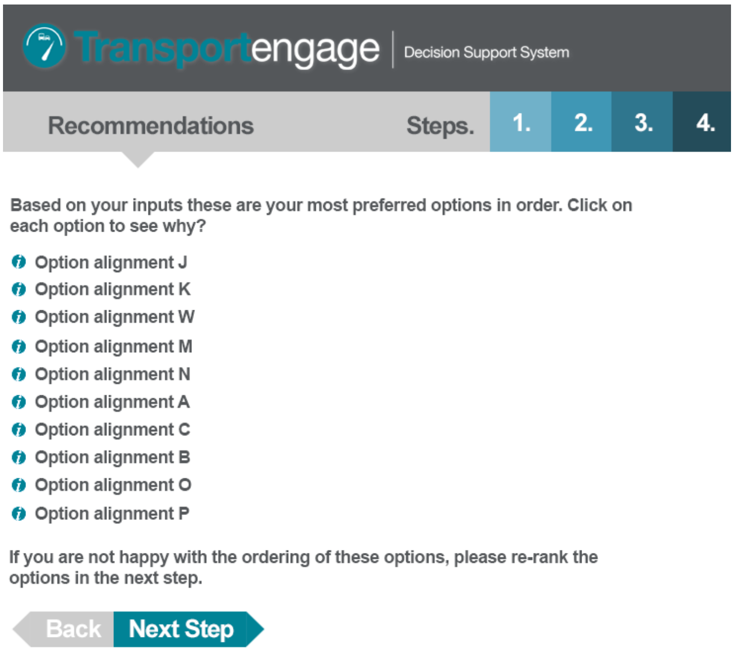


Figure 55: A screen shot of Transportengage ‘step 2’ – Recommendations.

Step 4: Comments are sought in this step about the options. A unique functionality that could be utilised at this stage for a transport EDSS is integrating a Front End Geographic Information System (GIS) web application such as ESRI Australia’s proprietary software Dekho, into the step as depicted in Figure 56. This would provide an opportunity for the user to turn on and off different layers including flood maps, acid sulphate soil, geotechnical, environmental layers etc. and draw alternative routes. Map algebra could be utilised during this drawing stage to provide real time direct feedback to the user such as: your road is crossing a floodplain so will have to be raised X meters costing approximately Y million per kilometre, as a result your current proposed route would cost Z. It is likely through undertaking this mapping task the user gains an understanding of the upgrade project and why the options A-Z have been recommended, modelled and assessed. Further due to the overt transparency the user may gain increased trust in the decision-making authority and confidence in the decision-making process and decisions made. Demographic information and user contact information could also be gathered at this stage prior to the user clicking the ‘Submit’ button. Post submission the answers are compiled for aggregation and dissemination to the decision-making authority.

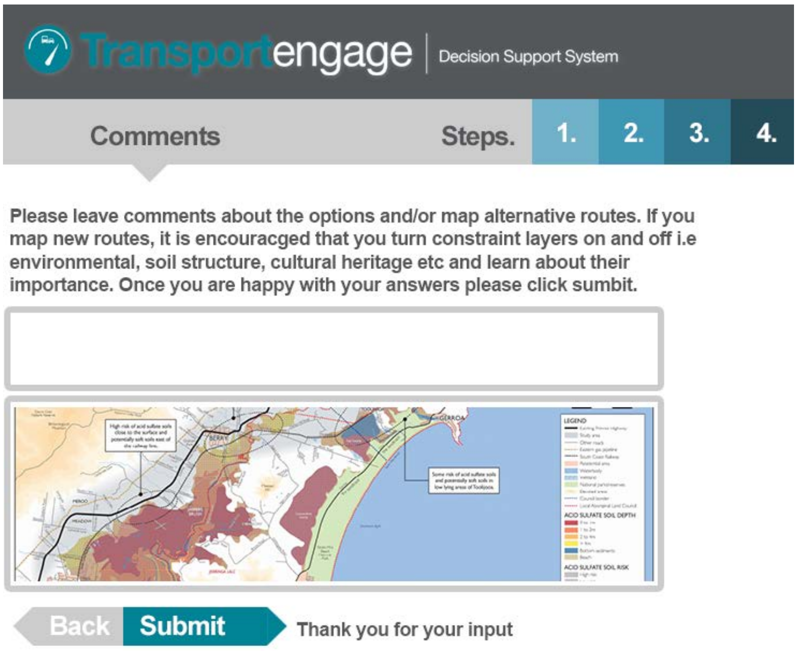


Figure 56: A screen shot of Transportengage 'Step 4' – Comments.

Like Coastalengage and Floodenegage, there are no reasons why the Transportengage system could not be utilised in this field based on the engagement decision support model. The model's application could create meaningful opportunities to involve, collaborate and potentially empower the community to make informed inclusive choices about transport options such as in this example decisions about highway realignment alternatives for the Pacific Highway upgrade from Gerringong to Bomaderry.

6.4 Conclusion

This chapter suggests, with practical examples, how the engagement decision support (EDS) model could be applied to both coastal zone management and highway realignment decision-making processes. This also shows the flexibility and robustness of the EDS model in application to other fields. Although the coastal and highway engagement decision support systems were not trialled with a community, it is envisaged they could be routinely utilised post development of the learned-score matrix and site specific options and criterion. In providing these examples it is hoped decision-makers can see the linkages and potential opportunities an engagement-focused decision support model, supported by an engagement decision support system, can offer in both engineering and non-engineering fields as an additional mechanism to facilitate and aid objective informed public consultation and participation during complex decision making.

Chapter 7

Conclusions and recommendations

7.1 Conclusions

This research provides significant contributions in four specific areas:

1- a comprehensive examination of flood risk management processes both nationally and internationally documenting legislation, policies, roles, responsibilities and programs to ascertain best practice and identify deficiencies;

2- the development of a new flood risk management cycle that builds upon best practice addressing process related deficiencies principally public participation;

3- the development, application and validation of an innovative engagement decision support model for the selection of flood risk management options to assist informed decision making in the flood risk management cycle and;

4- the identified application of the innovative engagement decision support model to further engineering and non-engineering fields, allowing the public to not only be involved in the decision-making process but be empowered to make informed balanced decisions based on civic inclusive deliberative exchanges of ideas and values.

Sub-chapters 7.1.1 to 7.1.4 provide specific conclusions on each of the four major research contribution areas.

7.1.1 Domestic and international flood risk management best practice

The concluding research findings drawn from the comprehensive examination of flood risk management process and practices both nationally and internationally including legislation, policies, strategy, roles, responsibilities and programs, are:

1. Flood risk management best practice has a specific legislative framework with supporting policies. This ensures: 1) a consistent and integrated approach to flood risk management throughout national, state and local authorities; 2) clear statutory roles and responsibilities; and 3) specified resources allocated (both financial mechanisms and technical capacity) to manage flood risk.
2. Both New Zealand and Australia has no national legislation or policies specific to flood risk management rather opting for guidelines in Australia and a generic flood risk standard in New Zealand. This has resulted in states, territories and regional councils addressing flood risk through resource, land-use planning and emergency management acts with limited integration. Further, public disclosure of programs and investment in flood risk management was not forthcoming in these jurisdictions in comparison to countries with specific legislative frameworks, programs, roles and responsibilities.
3. All jurisdictions notably undertake flood risk assessments up to and including the 1% AEP. However, the full range of floods up to and including the PMF (or Qmax) is not always examined for example in United States, England and New Zealand.
4. All jurisdictions have overarching strategic documents typically consisting of flood risk management plans at a catchment level.
5. All jurisdictions follow a similar flood risk management process involving 1) Identifying the risk, 2) Identifying the risk management measures, 3) Making a decision, and 4) Adopting and implementing the decision, with communicating and consulting, and monitoring and reviewing being a fundamental part of the strategy.
6. All jurisdictions have requirements to undertake public participation. However, no process was found which explicitly identifies or discusses participation within the framework; rather tokenistic inform and consult statements were used.
7. Performance evaluation is another standard requirement by all governments examined, yet it is not incorporated into the flood risk management process with guidance very rarely provided.
8. Opportunity exists for a new flood risk management cycle that integrates deficiencies and builds upon current flood risk management best practice.

7.1.2 A new flood risk management cycle

The new flood risk management cycle was developed to build upon the public participation and performance evaluation short comings identified in current domestic and international best practice. As governance shifts from,'hierarchical to markets to networks;(Bevir and Rhodes 2006) with increasing institutional and citizen requirement to engage the public in decisions that affect them, the cycle is seen as an improvement to address these requirements. It was not the intent to mandate a new framework nor interfere with long established existing processes, rather introduce and justify new elements that can be incorporated into current flood risk management best practice. The elements and perceived benefits of the new flood risk management cycle include:

1. Clear recognition of the public's role and level of influence at the various stages in the flood risk management cycle.
2. A concise and structured process outlining the activities and requirements of each stage in the cycle with suggested timeframes to maintain continuity.
3. Providing an opportunity for the public including minorities to share balanced and objective information in order to gain a mutual understanding of the current and future residual risk of utilising the floodplain and deciding collectively whether this is acceptable. If the residual risk is not acceptable then inclusive informed choices on the approach forward should be made.
4. Providing explicit opportunities for the public to discover and learn about the risks of flooding for the full range of floods up to and including the PMF.
5. Empowering the public to identify a combination of sustainable and technically feasible flood risk management options for further assessment.
6. Establishing a range of local public performance criteria from which decisions can be made and subsequently evaluated.
7. Facilitating informed balanced decisions about the flood risk objectives, performance criteria, current and future residual risk, management measures and resultant roles and responsibilities in a transparent, auditable process.
8. Providing the opportunity for the public to monitor and evaluate the desired outcomes and decisions made via the established performance criteria, which in turn can collectively build trust and resilience through endowing individuals to recognise specific tasks they can assist with or are responsible for.

7.1.3 A new engagement decision support model for flood risk management options

The innovative engagement decision support model presented in this thesis is seen as a significant advancement in providing an opportunity for the public (i.e. everyone including the community, planners, engineers, emergency management professionals etc.) to input personal values, derive preference recommendations, equitably compare a number of feasible solutions, learn about the trade-offs and be empowered to make informed flood risk management decisions in a transparent, objective, facilitated process. The evaluated benefits arising from the application of the flood risk management model in three trial catchments on the south east coast of Australia, although notably subjective, are that the system:

1. Is flexible, meeting the needs of the principal flood authority and community.
2. Provides increased understanding, demonstrated by users accessing the popup information boxes and conducting their own 'What if' sensitivity analysis to gain a greater appreciation of alternate views the tradeoffs and complexities incumbent in flood risk management. This encourages decision making beyond self-interests to shared common values in recognition of the public good.
3. Enriched social learning, as witnessed by the users being able to develop a list of preferenced flood risk management options based on their inputted importance weightings to value based questions, overcoming significant heuristic, scientific and engineering knowledge constraints required to make informed balanced decisions.
4. Produced increased trust, demonstrated from feedback resulting from the models structured methodology that is repeatable, coherent, comprehendible, transparent and able to withstand challenges via a well-documented audit trail including clear communication to decision-makers and the public via freely available consultation reports.
5. Is likely to reduce conflict, as the additional one hundred responses collected over the trials allowed more citizens to meaningfully contribute to, influence and make informed choices about decisions that affected their lives. This in turn can reduce conflict as citizens feel included in the decision-making process and recognise the complex tradeoffs involved in flood risk management.
6. Lead to more informed sustainable decisions, demonstrated by user preference choices reflecting more closely the decisions of learned flood

practitioners, overcoming narrow salient unconsidered preferences collected via traditional paper-based surveys.

Unevaluated but likely benefits of the models' application include:

1. More inclusive decisions accommodating multiple perspectives including minority groups.
2. Increased understanding of the current and future residual risk in the community.
3. User recognition of the various roles and responsibilities in flood risk management including their own.
4. Ownership and acceptance of the decisions made.
5. Enhanced social capital, such as building civic interest and involvement,
6. Fostering informed discussions with the community.

Limitations of the model include:

1. Relatively limited response rates demonstrating that a combination of public participation mechanisms should be utilised such as newsletters, public meetings, workshops, citizen panels, world cafes etc.
2. Relative time to populate the backend database including the learned-score matrix for the first time. However, once established it becomes a single knowledge-hub of data, with information on a range of flood risk management options, their specific advantages and disadvantages inclusive of social, safety, environmental/ecological, economic, technological, political, as well as cases studies documenting past successes and lessons learnt.

7.1.4 Application of the engagement decision support model to other fields

As the model uniquely combines heuristic, engineering and scientific knowledge with multi criteria, decision support and public participation theory in an astutely designed simple generic flexible system, it is envisaged that it can be utilised in many complex decision-making fields. It was shown how the model could be applied in principle to both coastal zone management and highway realignment decision-making processes. Although this has not been publicly trialled this shows its inherent ability to be utilised in engineering and non-engineering fields. It is envisaged future application of the model in a range of fields will provide an enhanced mechanism and

opportunity to involve, collaborate with and potentially empower the public to make informed choices about complex decisions.

7.1.5 General conclusion

If decision-makers truly want to move beyond the top-down, paternalistic, institutional traditional decision making of the past towards more inclusive, deliberative, transparent, sustainable decisions then this thesis offers some valuable insight and techniques. Both the new cycle and engagement-focused decision support model introduce elements to not only enable the public to interact with decision-makers but to potentially reshape, modernise and build upon how decision-makers plan for public involvement and the mechanisms they utilise. This thesis does not provide a panacea to complex decision making, but is an innovative contribution with practical application that can normatively, substantively and instrumentally improve public decisions in the civic sphere, by bridging the gap between community values and complex choices.

7.2 Recommendations for further research

This research successfully set out to: 1) examine flood risk management processes and practices, identify if they were disparate or analogous and establish if opportunities existed for improvement; 2) find whether a new engagement-focused decision support model could be applied to assist these processes and practices; 3) demonstrate that the model could improve the outcome of flood risk management; and 4) examine if the engagement decision support model could be applied to other fields. In achieving these aims, a range of research opportunities have emerged to support the future evolution of both the flood risk management cycle and the engagement decision support model. These opportunities include: 1) evaluation of the flood risk management cycle post implementation in both domestic and international flood risk management processes; 2) further validation of the flood risk management learned-score matrix; 3) expansion of the engagement decision support model for flood risk management options; 4) Trial application and continued development of new engagement decision support systems for application in a range of complex decision making fields particularly when greater levels of involvement, collaboration and empowerment of the public influence are seen as desirable by decision makers.

7.2.1 Post implementation evaluation of the flood risk management cycle

Evaluation of the new flood risk management cycles' implementation in both domestic and international flood risk management process would provide significant insight into its functional ability to be integrated. The evaluation framework would involve the examination of each step's application and outcome achievements comparative to the outcome achievements identified in chapter 3.3. For example the one outcome achievement for the review stage was, 'a range of collaborate/empowerment mechanisms including those that include minorities, to share balanced and objective information to gain a mutual understanding of the residual risk,' etc. thus evaluation would take place based on these goals.

As the cycle was developed with the intent to justify new elements within current best practices and not mandate nor interfere with long established processes, evaluation could prove problematic. This may occur as some stages are implemented while others are not. Therefore, future evaluation will likely have to assess outcome achievements compartmentally.

7.2.2 Further validation of flood risk management learned-score matrix

The learned-score matrix was derived from a limited pool of experienced floodplain risk management engineers. As a result, additional expert interviews incorporating a range of interdisciplinary expert views would provide an increased level of confidence in the derived learned score matrix for flood risk management options. Robust application claims would also be strengthened if international perspectives were collected and incorporated with local expert judgment based on an intimate knowledge of the catchment.

The system was developed based on 20 options that specifically applied to the three trials undertaken on the south east coast of Australia. Therefore, if additional new options outside of the 20 are required in future trial catchments, expert surveys would have to be re-explored or a complementary methodology such as pairwise analysis applied (as explained in subchapter 4.7) noting its limitations i.e. bias, to gain learned scores. Ultimately as the system evolves and with future application it is seen that a range of options outside of the 20 could be utilised with only small tweaks required to suit local legislation, policies, strategies, roles and responsibilities.

7.2.3 Expansion of the system

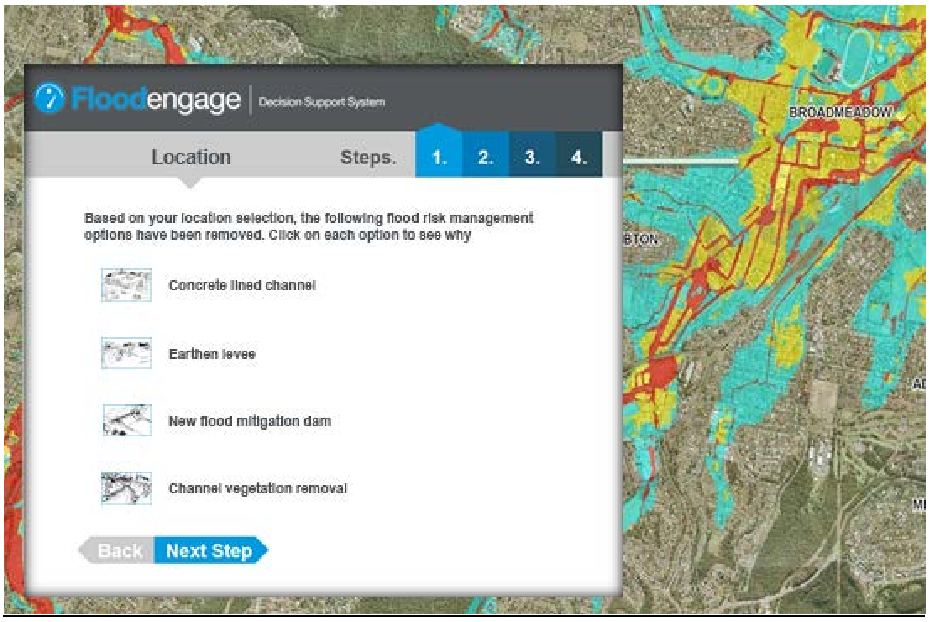


Figure 57: Screen shot of EDSS expansion to incorporate locality criterion.

Expansion to enable the user to click on a location and derive suitable options for a specific location prior to 'Step 1'- user importance weights in the flood risk management option EDSS, is seen as an advantageous possibility particularly for organisations or novice engineers that have limited technical understanding on the suitability of flood risk options based on location specifics. To achieve this, flood risk data collected at the 'Identify risk stage' of the flood risk management cycle namely velocity, depth and V*D outputs for a range of design events could be coupled with digital terrain elevation and other spatial data. Algorithmic relationships would then need to be derived for each option based on a range of parameters i.e. velocity, depth, V*D, slope, position in the catchment, land-use etc. to enable the user to prune options based on the location selection in an embedded GIS frontend such as ESRI Dekho as illustrated in Figure 57.

To visualise such an application, if a user, for example, clicked on a location upstream of medium density housing, it is likely that concrete lined channels would be removed from the available options list, as increased conveyance would cause significant downstream adverse flood impacts. The removed items could then be clicked on to see what constraints lead to that option being pruned, inducing what-if sensitivity analysis and accelerated learning. The system expansion although not particularly useful to aid public participation due to the added steps potentially causing participant fatigue, could be advantageously applied in jurisdictions with

limited technical capacity. For example in a developing country or a regional local government area, this expanded functionality could empower the user e.g a traffic engineer, planner, graduate engineer etc., to have an informed discussion with specialist water resource engineers about the location of options and the relative tradeoffs that should be considered. Application of this model could then lead potentially to the selection of more balanced sustainable options based on deliberation incorporating a range of perspectives, rather than pursuing biased options identified by a specialist water resource engineer.

7.2.4 Apply, test and validate the model in additional fields

Application of the engagement decision support model was preliminarily explored for both the coastal zone management and highway realignment decision-making processes to theoretical demonstrate the model's broader application in a range of engineering and non-engineering fields. Trial application of these systems post development of site specific criterion, options and a learned-score matrix would validate the model's practical application to these fields. Further application to a range of engineering and non-engineering fields such mining, water supply, waste disposal, bushfire risk, land-use planning, would also be of further research interest to validate or disprove the theory, that the generic engagement decision support model presented has broad and beneficial application.

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Glossary

Source: DIPNR (2005) and Samuals (2009)

Accuracy: closeness to reality.

Adaptive capacity/ Adaptability: Is the ability to plan, prepare for, facilitate, and implement adaptation options. Factors that determine a community adaptive capacity include its economic wealth, its technology and infrastructure, the information, knowledge and skills that it possesses, the nature of its institutions, its commitment to equity, and its social capital.

Annual Exceedance Probability (AEP): The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m3/s or larger event occurring in any one year (see ARI).

Attenuation (flood peak): lowering a flood peak (and lengthening its base).

Australian Height Datum (AHD) : A common national surface level datum approximately corresponding to mean sea level.

Average Recurrence Interval (ARI): The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 5% AEP flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

Bias - The disposition to distort the significance of the various pieces of information that have to be used.

Catchment: The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

Characterisation - The process of expressing the observed/predicted behaviour of a system and it’s components for optimal use in decision making.

Confidence interval: A measure of the degree of (un)certainty of an estimate. Usually presented as a percentage. For example, a confidence level of 95% applied to an upper and lower bound of an estimate indicates there is a 95% chance the estimate lies between the

specified bounds. Confidence limits can be calculated for some forms of uncertainty (see knowledge uncertainty), or estimated by an expert (see judgement).

Consent authority: The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.

Consequence: An impact such as economic, social or environmental damage/improvement that may result from a flood. May be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

Damage potential: A description of the value of social, economic and ecological impacts (harm) that would be caused in the event of a flood.

Decision uncertainty: The rational inability to choose between alternative options.

Defence system: Two or more defences acting to achieve common goals (e.g. maintaining flood protection to a floodplain area/ community).

Design objective: The objective (put forward by a stakeholder), describing the desired performance of an intervention, once implemented.

Design discharge: See Design standard and Design flood

Design flood: A theoretical **flood** likely to occur, on average, every “x” years, eg a 100 year ARI flood is a design flood likely to occur, on average, every 100 years.

Design standard: A performance indicator that is specific to the engineering of a particular defence to meet a particular objective under a given loading condition. Note: the design standard will vary with load, for example there may be different performance requirements under different loading conditions.

Discharge (stream, river): as measured by volume per unit of time.

Emergency management: A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

Error - Mistaken calculations or measurements with quantifiable and predictable differences.

Evacuation scheme - plan for the combination of actions needed for evacuation (warning, communication, transport etc.).

Flexibility: Within the context of assessing the sustainability of flood risk systems, flexibility is the ease with which a flood risk system (or strategic alternative) can adapt to changing circumstances without future regrets about decisions and measures implemented

Flood: Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping**** coastline defences excluding tsunami.

Flood awareness: Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

Flood education: Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

Flood event management: If flooding is imminent or already taking place, there are activities that can be carried out to reduce the impact of the flood. These actions are described as "flood event management" or "flood incident management" or more rarely "operational flood management". There are four main types of activities:

- **Detection** of the likelihood of a flood forming (hydro-meteorology);
- **Forecasting** of future river flow conditions from the hydro-meteorological observations;
- **Warning** issued to the appropriate authorities and the public on the extent, severity and timing of the flood; and
- **Response** to the emergency by the public and the authorities, including
  - Operation of barriers, gates, demountable defences, etc.
  - Provision of temporary flood protection measures (e.g. sandbags)
  - Evacuation (including the use of safe havens), and
  - Rescue.

Flood damage: damage to receptors (buildings, infrastructure, goods), production and intangibles (life, cultural and ecological assets) caused by a flood.

Floodplain risk management options: The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

Flood peak: highest water level recorded in the river during a flood.
Flood proofing: A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

Flood prone land: Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

Flood readiness: Flood readiness is an ability to react within the effective warning time.

Hazard: A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

Hydraulics: Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

Hydrograph: A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

Hydrology: Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

Integrated risk management: An approach to risk management that embraces all sources, pathways and receptors of risk and considers combinations of structural and non-structural solutions.

Intervention: A planned activity designed to effect an improvement in an existing natural or engineered system (including social, organisation/defence systems).

Inundation: Flooding of land with water. (NB: In certain European languages this can refer to deliberate flooding, to reduce the consequences of flooding on nearby areas, for example. The general definition is preferred here.)

Knowledge uncertainty: Uncertainty due to lack of knowledge of all the causes and effects in a physical or social system. For example, a numerical model of wave transformation may not include an accurate mathematical description of all the relevant physical processes. Wave breaking aspects may be parameterised to compensate for the lack of knowledge regarding the physics. The model is thus subject to a form of knowledge uncertainty. Various forms of knowledge uncertainty exist, including:

- **Process model uncertainty .** All models are an abstraction of reality and can never be considered true. They are thus subject to process model uncertainty. Measured data versus modelled data comparisons give an insight into the extent of model uncertainty but do not produce a complete picture.
- **Statistical inference uncertainty -** Formal quantification of the uncertainty of estimating the population from a sample. The uncertainty is related to the extent of data and variability of the data that make up the sample.
- **Statistical model uncertainty -** Uncertainty associated with the fitting of a statistical model. The statistical model is usually assumed to be correct. However, if two different models fit a set of data equally well but have different extrapolations/interpolations then this assumption is not valid and there is statistical model uncertainty.

Mathematical/computer models: The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

Merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the States rivers and floodplains.

Measures: Measures are direct physical interventions that are usually implemented by flood risk managing authorities. Measures can be divided between control measures (such as flood defences), retreat measures (i.e. moving receptors out of flood hazard areas) and adaptation measures (such as compatible land management).

Pathway : Route that a hazard takes to reach Receptors. A pathway must exist for a Hazard to be realised.

Peak discharge: The maximum discharge occurring during a flood event.

Precautionary Principle: Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Preparedness: The ability to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.

Probable Maximum Flood (PMF): The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.

Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP): The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

Probability: A statistical measure of the expected chance of flooding (see AEP).

Receptor: Receptor refers to the entity that may be harmed (a person, property, habitat etc.). For example, in the event of heavy rainfall *(the source)* flood water may propagate across the flood plain *(the pathway)* and inundate housing *(the receptor)* that may suffer material damage *(the harm or consequence).* The vulnerability of a receptor can be modified by increasing its resilience to flooding.

Recovery time: The time taken for an element or system to return to its prior state after a perturbation or applied stress.
Resilience: The ability of a system/community/society/defence to react to and recover from the damaging effect of realised hazards.

Resistance: The ability of a system to remain unchanged by external events.

Risk: Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment. Risk = Probability multiplied by consequence

Risk Curve: A two-dimensional plot of real or projected financial harm/risk (vertical axis) versus real or projected financial reward (horizontal axis). Generally speaking, the curve balloons when the underlying item offers greater returns and contracts when it offers lower returns compared to risk.

Risk management: The complete process of risk analysis, risk assessment, options appraisal and implementation of risk management measures

Risk perception: Risk perception is the view of risk held by a person or group and reflects cultural and personal values, as well as experience.
Risk reduction: The reduction of the likelihood of harm, by either reduction in the probability of a flood occurring or a reduction in the exposure or vulnerability of the receptors.

Risk profile : The change in performance, and significance of the resulting consequences, under a range of loading conditions. In particular the sensitivity to extreme loads and degree of uncertainty about future performance.

Robustness . Capability to cope with external stress. A decision is robust if the choice between the alternatives is unaffected by a wide range of possible future states of nature. Robust statistics are those whose validity does not depend on close approximation to a particular distribution function and/or the level of measurement achieved.

Runoff: The amount of rainfall which actually ends up as streamflow, also known as rainfall excess

Sensitivity: Refers to either: the resilience of a particular receptor to a given hazard. For example, frequent sea water flooding may have considerably greater impact on a fresh water habitat, than a brackish lagoon; or: the change in a result or conclusion arising from a specific perturbation in input values or assumptions.

Sensitivity Analysis: The identification at the beginning of the appraisal of those parameters which critically affect the choice between the identified alternative courses of action.

Social learning: Processes through which the stakeholders learn from each other and, as a result, how to better manage the system in question.

Social resilience - The capacity of a community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Source: The origin of a hazard (for example, heavy rainfall, strong winds, surge etc).

Survey plan: A plan prepared by a registered surveyor.

Sustainable Development - is development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Sustainable flood risk management: involves:

- ensuring quality of life by reducing flood damages but being prepared for floods
- mitigating the impact of risk management measures on ecological systems at a variety of spatial and temporal scales
- the wise use of resources in providing, maintaining and operating infrastructure and risk management measures
- maintaining appropriate economic activity (agricultural, industrial, commercial, residential) on the flood plain

Sustainable flood risk management strategy: An approach which

- aims to be effective in the long term, and
- can be combined ('integrated') with other international, national and regional activities (transport, environment, conservation etc.)

Susceptibility: The propensity of a particular receptor to experience harm.

Uncertainty: A general concept that reflects our lack of sureness about someone or something, ranging from just short of complete sureness to an almost complete lack of conviction about an outcome.

Variability: The change over time of the value or state of some parameter or system or element where this change may be systemic, cyclical or exhibit no apparent pattern.

Variable: A quantity which can be measured, predicted or forecast which is relevant to describing the state of the flooding system e.g. water level, discharge, velocity, wave height, distance, or time. A prediction or forecast of a variable will often rely on a simulation model which incorporates a set of parameters.

Vulnerability: Characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value.

Appendix A

International literature review summary

Summary of international flood risk management case studies

	United States of America	England	Netherlands	New Zealand	Australia
National Flood Legislation	Yes[1, 2]	Yes[8]	Yes[13]	Piecemeal [18]	No
National Flood Policy	Yes[3]	Yes[9]	Yes[14]		No
Analogous Process	Yes[4]	Yes[10]	Yes[10]	Yes[19]	Yes[21]
Primary Flood Responsibility	Federal	Federal	Federal	Local	Local
Cost of Flooding Each Year (million)	$6000 AAD[5]	£1000 AAD[11]	?	$85 AAD[20]	$314 AAD[22]
National Flood Risk (million)	>9 (households) [6]	>5.2 (people) [11]	≈9 (people) [16]	?	>0.2 (households) [22]
Annual Flood Program Expenditure (million)	$1500[5,7]	£529[12]	€3300[16,17]	$176[18]	($22 Federal) [2]

(1) US CODE 1938; (2) U.S Congress 2012; (3) ASFPM 2007; (4) FEMA 2011; (5) King 2005; (6) Scawthorn 1999; (7) USACE 2011; (8) Flood and Water Management Act 2010; (9) Crown 2010; (10) Environment Agency 2011b; (11) Environment Agency 2009; (12) Guardian 2011; (13) MTPWWM 2010; (14) Water Information Network; (15) Han van den Berg 2012; (16) Ruimtevoorderiver 2007; (17) Glas 2010; (18) Ministry of the Environment 2011; (19) New Zealand Standards 2008; (20) IPCC 2007; (21) AEMI 2013b; (22) SCARM 2000; (23) AAGD 2012.

Legislation and strategy summary of the jurisdictions examined

Country	Primary legislation and strategy
United States Of America	**Federal:** Flood Control Act 1938, National Flood Insurance Extension Act 2012, Unified National Program for Floodplain Management **State:** Varying legislation for different states e.g. North Carolina: Flood Hazard Prevention Act 2000; California: Safe Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act 2000.
England	**Central:** Flood and Water Management Act 2010, Land and Drainage Act 1991, Flood Risk Regulations 2009, Planning Policy 25: Development and Flood Risk 2010, National flood and coastal erosion risk management strategy 2011. **European:** EU Directive 2007/60/EC Assessment and Management of Flood Risk and EU Water Framework Directive (2000/60/EC)
Netherlands	**Federal:** Water Act 2009, Spatial Planning Act 2008, “Room for Rivers” policy 2008,National Water Plan 2009 **European:** EU Directive 2007/60/EC Assessment and Management of Flood Risk and EU Water Framework Directive (2000/60/EC)
New Zealand	**Central:** Resources Management Act 1991, Civil Defence and Emergency Management Act 2002, Drainage Act 1908, Soil Conservation and Rivers Control Act 1941, Local Government Act 2002, Local Government (Rating) Act 2002, Building Act 2004, Flood Risk Principals, NZS 9401:2008 Managing Flood Risk – A Process Standard. **Local:** Varying flood policies e.g. Greater Wellington Regional Councils Flood Policy 20011.
Australia	**Federal:** No legislation, instead Managing the Floodplain: A guide to best practice in flood risk management in Australia (2013), Floodplain Management in Australia: Best Practices and Guidelines (2000) and the National Emergency Risk Assessment Guidelines (2009). **State:** Varying legislation and policies documented below
Victoria, Australia	**State:** Water Act 1989, Planning and Environment Act 1987, the Local Government Act 1989, the Building Act 1993 and the Emergency Management Act 1986, Victorian Flood Management Strategy, Regional Floodplain Management Strategies, Numerous supporting guidelines. **Local:** Planning and development controls

Queensland, Australia	**State:** Sustainable Planning Act 2009, Queensland Reconstruction Authority Bill 2011, Local Government Act 2009, Plumbing and Drainage Act 2002, Building Act 1975, Disaster Management Act 2003. Environmental Protection Act 1994, Water Act 2000, State Planning Policy 1/03, statutory regional plans and the Urban Drainage Manual 2007 **Local:** planning schemes and development controls
Northern Territory, Australia	**Territory:** Water Act 1992, Planning Act 2009, Northern Territory Planning Scheme and development controls.
Australian Capital Territory, Australia	**Territory:** Planning and Development Act 2007 and Emergencies Act 2004 Floodplain Protection Guideline (1995), Territory Plan and development controls.
Western Australia, Australia	**State:** Water Resources Legislation Amendment Act 2007, Waterways Conservation Act 1976, Local Government Act 1995, Planning and Development Act 2005, Emergency Management Act 2005 and the State Planning Policy No.34 **Local:** planning schemes, development controls and varying flood policies
South Australia, Australia	**State:** Water Resources Act 1997, Development Act 1993, Local Government Act 1999, South Western Suburbs Drainage Act 1959, Natural Resources Management Act 2004, Fire and Emergency Services Act 2005, Urban Stormwater Management Policy 2005, Stormwater Strategy 2011, Guidelines for Urban Stormwater Management 2002. **Local:** Development plans and varying flood policies
Tasmania, Australia	**State:** Building Act 2000, Building Regulations 2004. Land Use Planning & Approvals Act 1993, and a Draft Planning Directive - Statewide Codes 2011. **Local:** Development plans and varying flood policies.
New South Wales, Australia	**State:** Environmental, Planning and Assessment Act 1979. Water Act 1912, Local Government Act 1993, Fisheries Management Act 1994, State Emergency and Rescue Management Act 1989, Planning Direction No.15 2007, NSW Flood Prone Land Policy 2005. Floodplain Development Manual 2005, and supporting guidelines. **Local:** Local Environmental Plans and Development Control Plans with varying flood policies.

Appendix B

University of Wollongong human research ethics committee approved application

Research Office use only

HE13/235

UNIVERSITY OF WOLLONGONG/ILLAWARRA SHOALHAVEN LOCAL HEALTH DISTRICT

Human Research Ethics Committee

APPLICATION FOR APPROVAL TO UNDERTAKE RESEARCH INVOLVING HUMAN PARTICIPANTS

A. GENERAL INFORMATION

1. Descriptive Title of Project:

A generic organisational decision support model for floodplain risk management

2. 7 line summary of project aims:

This research will assist in developing a tool, which can be utilised by government, engineers, developers, planners and the broader community to aid the selection of flood management options that will reduce the social and economic impacts of flooding. This tool will assist to: 1) Identify adaptation and mitigation solutions to flood inundation; 2) facilitate objective community flood risk management consultation and 3) Justify floodplain management decisions in a transparent and structured manner to all stakeholders.

3. Participating Researchers

Summarise the qualifications and experience of all personnel who will be participating in the project.

NB: For student research, a Supervisor must be the Principal Investigator.

Principal Investigator/Supervisor		
Title	First Name	Family Name
Professor	Chris	Cook
Qualifications	PhD (UNSW), BE, BSc (AU)	
Position	Executive Dean, Faculty of Engineering and	

	Information Sciences, UOW
Role in project, relevant research experience (if experience, describe how relevant experienc be obtained)	Chris is the principle supervisor of the research project. Chris has a research interest in the development of decision support systems for the engineering sector.

Second Investigator (in absence of PI)		
Title	First Name	Family Name
Qualifications		
Position		
Role in project, relevant research experience (if no experience, describe how relevant experien will be obtained)		

5. **Expected duration of Research** (Please specify as near as possible 'start' and 'finish' dates for the conduct of research):

FROM: May 2013 TO: July 2013

6. **Purpose of Project**

Indicate whether the research is one or more of the following:

- ☐ Staff Research (University of Wollongong)
- ☐ Staff Research (ISLHD)
- X Student Research - specify:
  - Course undertaken: PhD Civil Engineering
  - Unit/Faculty/Department: Engineering & Information Sciences
  - Supervisor/s: Professor Chris Cook
- ☐ Other (Please specify) _____

7. **Has this research project been reviewed by any other Institutional Ethics Committee?**

YES ☐ NO X

If no, go to Section B. If YES:

7.a What committees has the application been submitted to?

N/A

7.b What is the current status of these applications? Please include copies of *all correspondence* between the sponsor or researcher and the other Ethics Committee(s) to this point.

N/A

B. FINANCIAL SUPPORT FOR RESEARCH

8. What is the source and amount of funding from all sources for this research?

Source (Name of Organisation / Funding Scheme)	Amount
N/A	

For sponsored research please include the budget for the trial including information about capitation fees, payments to researchers, institutions or organisations involved in the research, current and consequential costs and costs which may be incurred by participants.

If the research is sponsored:

8.a Is there any affiliation/association or financial interest between the researcher(s) associated with this research and the sponsor/funding body/supplier of a drug, surgical device or other therapeutic device to be used in the study?

YES ☐ NO X

If Yes, Please detail.

8.b Are there any conditions placed on this research by the funding body?

YES ☐ NO X

If YES, please provide details and provide a copy of the contract/letter of agreement with the funding organisation detailing the terms on which the research is being supported.

8.c Is a copy of the HREC approval to be forwarded to the Granting Body?

YES ☐ NO X

If YES, please advise of any deadlines.

C. RESEARCH METHODS

9. Research Categories

Please mark the research categories relevant to this research proposal. At least one category should be marked for each grouping. You should mark as many categories as are relevant to the proposed research. For "Other", please specify.

A Research procedures used

- ☐ Anonymous questionnaires/ surveys
- ☐ Coded (potentially identifiable) questionnaires/ surveys
- ☐ Identifiable questionnaires/ surveys
- ☐ Examination of student work, journals etc
- ☐ Examination of medical, educational, personnel or other confidential records
- ☐ Observation (overt)
- ☐ Observation (covert)
- X Interviews (structured or unstructured)
- ☐ Telephone interviews
- ☐ Procedures involving physical experiments (e.g. exercise, reacting to computer images)
- ☐ Procedures involving administration of substances (e.g. drugs, alcohol, food)
- ☐ Physical examination of participants (including eg. blood glucose, blood pressure and temperature monitoring)
- ☐ Collection of body tissues or fluid samples
- ☐ Surgical procedures
- ☐ Other: _____

BResearch areas

- X Qualitative research
- ☐ Social Science research
- ☐ Humanities research
- ☐ Educational research
- ☐ Health research
- ☐ Psychological research
- ☐ Comparison or evaluation of drugs or surgical or other therapeutic devices
- ☐ Comparison or evaluation of clinical procedures
- ☐ Comparison or evaluation of counselling or training methods
- ☐ Investigation of the effects of an agent (drug or other substance)
- ☐ Investigation of bio-mechanical processes
- ☐ Biomedical research
- ☐ Epidemiology
- ☐ Genetic research
- ☐ Other: _____

10. Does the project involve: the use of drugs, a surgical device, a therapeutic intervention, or a physiological trial?

YES ☐ NO X

If no, go to Q11. If YES:

10.a Please give details of the type of intervention and provide evidence that appropriate indemnity and compensation arrangements are in place to ensure adequate compensation to participants for any injury suffered as a result of participation in the trial (Indemnification forms and, if the research is being undertaken in a private practice, evidence of adequate and appropriate insurance coverage).

10.b Is the research registered:

- ☐ **As a CTN Trial with the TGA**
- ☐ **As a CTX Trial with the TGA**
- ☐ **On any national or international clinical trial registers**
- ☐ **Other (Please detail)**

11. Research design and justification

Describe what you want participants to do and justify the design. Please provide an explanation in <u>terms understandable by a non-expert reader.</u> A flow chart or other diagram illustrating the sequence of research activities should be included if possible. For research involving a treatment or physical intervention (eg clinical studies, physiological trials, mental health interventions) a protocol should be provided.

There are two components to this research:

1) Semi-structured interviews of water resource engineers and scientists.

2) A website that provides a mechanism for stakeholders (community members, engineers, developers, planners, councillors etc.) to learn about, rank and make informed decisions about floodplain management options for the local government trial catchments. Which at this stage are Horsley Creek Catchment (Shellharbour City Council), Black Creek Catchment (Cessnock City Council), and Swamp and Fisheries Creek (Cessnock City Council):

<u>Component 1: Is discussed in this application</u>

1) Semi-structured interviews of water resource engineers and scientists.

This will involve asking water resource engineers and scientists in my contact circle i.e State Government, Local Government, Academics and Consultants, to validate the decision support systems heuristic and researched outputs. This will be undertaken by asking each participant 225 questions for this initial trial.

The questions I will ask, for each of the 20 flood management options (i.e. 20 options x 11 questions = 220) are:

1. Do you agree with the wording? Would you make any changes and adjustments?
2. In your opinion does "x option" improve community access and recreational use:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?
3. In your opinion does "x option" disadvantage individual members of the community::

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?
4. In your opinion does "x option" provide safety to the community during flooding:

Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

Why?

5. In your opinion does “x option” raise community awareness and understanding of the local flood risk:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?

6. In your opinion does “x option” threaten local plants and animals and their habitat:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?

7. In your opinion does “x option” cause water quality issues:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?

8. In your opinion does “x option”s initial costs (i.e design/construction) require minimal council expenditure:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?

9. In your opinion does “x option” require minimal ongoing council expenditure after implementation:

   Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

   Why?

10. In your opinion does “x option” reduce flood damages to the community:

    Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

    Why?

11. In your opinion does “x option” cause negative flood impacts to other areas (both upstream and downstream)::

    Not sure/ Strongly Disagree/ Disagree/ Neutral or N/A/ Agree/ Strongly Agree

    Why?

The other 5 questions I will ask:

12. Do you think this system will assist in facilitating objective community flood risk management consultation?

    Yes/ No

    Why?

13. Do you think this program can improve stakeholders (Community, Developers, Engineers, Planners, Councillors etc.) awareness of, and accelerate their learning about, the various pros and cons of floodplain management options?

    Yes/ No

    Why?

14. If people use this program, do you think the system will improve the outcomes of a Floodplain Risk Management Plan?

    Yes/ No

    Why?

15. If people use this program, do you think the system will improve the ability for Councils to justify the floodplain management decisions made?

    Yes/ No

    Why?

The methodological framework for my research process is outlined below.

Research Process

In order to validate my research to date (i.e. document analysis, exploration of multiple case studies, preliminary system testing, and heuristic knowledge), I will asking experts in the water resources field their opinions about the system and various floodplain risk management options

using a semi-structured interview methodology. This will allow me to tap into a wealth of expert knowledge through the collection and analysis of experiences, practices, opinions and beliefs about the 20 initial trial floodplain management options.

I intend to interview at a minimum 20 water resource engineers and/ or scientists within my contact circle i.e. State Government, Local Government, Academics and Consultants. It is expected that each semi-structured interview will take approximately 1 hour and will be recorded with the interviewee's permission.

12. Statistical design

Any research project that involves the collection of data should be designed so that it is capable of providing information that can be analysed to achieve the aims of the project. Usually, although not always, this will involve various important statistical issues. It is important that the design and analysis be properly planned in the early stages of the project. You should seek statistical advice. The University of Wollongong has a Statistical Consulting Service that provides such advice to research students and staff undertaking research.

Are statistical issues relevant to this project?

YES ☐ NO X

Primary data collected through the semi-structured interviews will be qualitative data.

If no, go to Q13. If YES:

12.a Have you discussed this project with the Statistical Consulting Service or any other statistical advisor?

YES ☐ NO ☐

If NO, please explain why not.

12.b Provide the calculations used to determine the appropriate sample size. If no power calculations have been done please explain the reason for choosing the sample size.

D. ETHICAL CONSIDERATIONS

13. What are the ethical considerations relevant to the proposed research, specifically in relation to the participants' welfare, rights, beliefs, perceptions, customs and cultural heritage? How has the research design addressed these considerations? Consideration should be at both individual and collective level.

The semi-structured interviews will be conducted individually. The semi-structured interviews will be seeking participants understanding, explanation, experiences and opinions of current floodplain management options available to practitioners. As these are professionals in the water resource industry it is highly unlikely that these questions will evoke any distress. If any participant becomes distressed they will be referred to Lifeline on 13 11 14.

Participants will be provided with a Participant Information Sheet (refer attachment 1) which outlines the background of this research, their role and reinforce that participation is voluntary. It will also reinforce that if they choose to participate, they may withdraw at any time without any consequences to their employment or their relationship with the University of Wollongong.

All interviews will be recorded with the interviewee's permission. It will be made clear to all participants that any information they provide as part of the semi-structured interviews will not be communicated to or passed onto any third party in any identifiable format, and that I will be the only one with access to the interview data provided and this will not be shared. The information the participants provide will be held securely in pass word protected files. All data will be de-codified to maintain privacy. All hard data will be held securely by the University of Wollongong. Where publications from this research highlights an example opinion/quote, a pseudonym will be assigned.

E. RISKS AND BENEFITS

14. Does the project involve the risk of emotional distress or physical harm, or the use of invasive procedures (e.g. blood sampling)?

YES ☐ NO X

If YES

14.a What are the risks?

14.b Explain how the risks of harm or distress will be minimised. In the case of risks of emotional distress, what provisions have been made for an exit interview or the necessity of counselling?

15. Is information about criminal activity likely to be revealed during the study?

YES ☐ NO X

If YES, have you included a caution regarding any relevant mandatory reporting requirements in the Participant Information package?

16. Detail the expected benefits of the study to the participants and/or the wider community.

The outcomes of this research will significantly improve significantly improve the ability of flood practitioners to: 1) Identify adaptation and mitigation solutions to flood inundation; 2) Facilitate objective community flood risk management consultation and 3) Justify floodplain management decisions in a transparent and structured manner to all stakeholders. Fundamentally this will to assist local government or similar authorities internationally, with the selection for floodplain risk management measures to reduce the social and economic damages of flooding.

F. PARTICIPANTS

17. Mark the categories relevant to this proposal.

☐ Healthy members of the community
☐ University students
X Employees of a specific company/organisation
☐ Members of a specific community group, club or association
☐ Clients of a service provider
☐ Health Service clients (e.g. users/clients of a health service)
☐ School children
☐ Hospital in-patients
☐ Clinical clients (e.g. patients)
☐ Aboriginal/Torres Strait Islander people
☐ Members of socially disadvantaged groups
☐ Cadavers/ cadaveric organs
☐ Other (please specify): _____

18. Expected age(s) of participants – please mark one or more

☐ Children (under 14)
☐ Young people (14-18)
X Adults (> 18)

19. What is the rationale for selecting participants from this/these group/s?

They are experts in the field and will provide a mechanism to validate the decision support systems outputs.

G. RECRUITMENT

20. How will potential participants be approached initially and informed about the project? e.g. direct approach to people on the street, mail-out to potential participants through an organisation, posters or newspaper advertisements, etc. Please explain in detail and <u>include copies of any letters, advertisements or other recruitment information</u>.

I will initially make personal contact with each participant i want to be involved in the validation exercise via phone call. I will explain what the research is about, what i hope to gain from the research, what i am going to ask, and what the information will be used for. If they agree to participate in the survey i will email them a copy of the *Participant Information Sheet and Consent Form* (refer attachment 1 & 2).

The recruitment phone call script:
I
As I know all the participants, this would be:

Me: Hi “”
Me: Its Raymond Laine here
Participant: Hi Raymond
Me: As you may or may not be aware I am currently undertaking a PhD at the University of Wollongong. As a subsection of my PhD research I am developing a decision support system for floodplain management options. I am calling, as I would like to show you the system I have

developed and interview you about the range of options available to floodplain risk managers and what you think about them in regards to their social, environmental/ ecological, safety, economic and flood behaviour constraints

Participant: Sound's interesting?

Me: What I am proposing is a completely voluntary 1 hour semi-structured interview. In the interview i will ask a range of questions about floodplain management measures and the constraints that govern their application. These questions will be emailed to you if you are interested in participating and are contained within the Information Participant Sheet.

Participant: Go-on

Me: The data collected from these semi-structured interviews will be analysed and utilised to validate both the broader generic organisational decision support model for flood risk management measures i am developing and the Floodengage trial program. To ensure the responses are transcribed correctly, Interviews will be audio recorded with your permission for the purposes of assisting with writing up transcripts. Once transcripts are written up, the audio tapes will be securely destroyed. The results of this study, in aggregate form, may be presented, discussed and published in appropriate academic forums and journals for the purpose of contributing to the advancement of knowledge. The data will be de-codified to remove any reference to the individual. You will not be named, but if a quote is required a pseudonym reference to your generic position and the organisation you are employed will be given, e.g. Engineer from Local Government.

Participant: Sounds good, when and where do you want to do this interview?

Me: I am flexible, we can do the interview at one of your meeting rooms or at a place of your choosing, at a time that suits you.

Participant: Ok what about at meeting 2 at 10 am?

Me: Sounds good, What i will do now is email you a Information Participant Sheet and Consent Form for you to have a read prior to the interview. Again this is completely voluntary and if you choose to participate, you may withdraw at any time without any consequences to your employment or your relationship with the University of Wollongong. if you have any concerns please don't hesitate to contact me on 4224 4160 or alternatively you can contact the University of Wollongong Ethics Officers on 4221 4457 or email: rso-ethics@uow.edu.au.

Participant: Ok great

Me: thank you and see you see on Thursday at 10am, if I don't hear from you sooner.

Participant: See ya then

Me: Bye

The follow up email script:

Hi "

As discussed, please find attached the Information Participant Sheet and Consent Form. Again this is completely voluntary and if you choose to participate, you may withdraw at any time

without any consequences to your employment or your relationship with the University of Wollongong. if you have any concerns please don't hesitate to contact me on 4224 4160 or alternatively you can contact the University of Wollongong Ethics Officers on 4221 4457 or email: rso-ethics@uow.edu.au.

See you on Thursday at 10am.

Regards

Ray Laine

21. Where will potential participants be approached by the researchers to seek their participation in the research, and where will research activities involving participants be conducted?

The participants will be contacted via phone at the workplace and I will follow up with an email including the *Information Participant Sheet and Consent Form* (refer attachment 1 & 2). The participants will be asked to seek the management permission for the field study to proceed.

Once consent is granted I will make contact again to ensure they understand their role in the study and reinforce the voluntary nature of their participation. Their interviews will be conducted at a convenient place of their choosing (preference would be a meeting room at their office place).

22. How many participants in total do you anticipate will be involved in the project? If the research has several stages and/or groups of participants, please provide the total number of participants expected as well as the number and participant group involved in each stage.

The intended total number of semi-structured interviews is 10-30. The following table outlines the numbers as per participant categories.

State Government Engineers	6
Local Government Engineers	6
Private Water Resource Consultants	6
UOW Academics	4

Generally the consent of participants must be obtained prior to conducting research. If you do not intend to seek people's permission to use information about them which may be identifying, you may need an exemption from State and Federal Privacy requirements. This is addressed in Section I.

<u>Attach copies</u> of any letters of invitation, information packages, consent forms, proxy/substitute consent forms, debriefing information, identification cards, contact detail cards, etc.

The following is a list of relevant attachments:

Attachment 1 - *Participant Information Sheet*
Attachment 2 - *Consent form for participant*

23. Will consent for participation be obtained from participants or their legal guardians?

YES X NO ☐

If NO, go to Q31.

24. How will consent for participation be obtained?

X in writing

☐ verbally

☐ tacit (eg indicated by completion and return of survey)

☐ other (please specify) _____

☐ consent not being sought

Please explain why the method chosen is the most appropriate and ethical.

My research will source data from State Government, Local Government, Academics and Consultants. Within these organisations I will be interviewing multiple participants. These participants have been deliberately selected as they will provide the most appropriate data including their experiences, knowledge and opinions of the floodplain management options that are being researched.

All interviewees will need to provide formal written consent to participate (refer attachment 2). Attaining this written formal consents is practically appropriate given the number of participants involved. It is also ethically constructive to remind participants that their participation is voluntary prior to any consent form being completed. In the *Participant Information Sheet* (refer attachment 1) the participants are informed of the field study and their rights to volunteer. They are also informed of their choice to withdraw from the field study at any time. This voluntary consent is also reinforced on the *Consent Form* (refer attachment 2).

25. Is it anticipated that all participants will have the capacity to consent to their participation in the research?

YES X NO ☐

If NO, please explain why not (e.g. children, incompetent participants, etc.) and explain how proxy or substitute consent will be obtained from the person with legal authority to consent on behalf of the participant.

26. For participants who have the capacity to consent, how does the process ensure that informed consent is freely obtained from the participant?

Participation in the semi-structured interview is voluntary and will be clearly indicated both on the *Participant Information Sheet* and the *Consent Form* (refer attachment 1 & 2) distributed to the participants. At the time of semi-structured interviews, the participant's attendance will also confirm their consent. In any correspondence the participant will be reminded that their participation is entirely voluntary and they may withdraw their participation and data at any time.

27. Are any participants in a dependant relationship with the researcher, the institution, or the funding body (for example the researcher's clinical clients or students; employees of the institution; recipients of services provided by the funding body)? If so, what steps will be taken to ensure that participants are free to participate or refuse to participate in the research?

The researcher has a working relationship with the participants as I provide technical advice to State and Local governments and consultants.

As I am a junior engineer I do not have any influence over whether the people I approach participate or not. They will only participate in the survey if they are interested in the research area. To answer the question "what steps will be taken to ensure that the participant is free to participate and can refuse to participate in the research". The steps are:

1) During the initial phone call: I will stress this is completely voluntary and if they choose to participate, they may withdraw at any time without any consequences to their employment or their relationship with the University of Wollongong.

2) In the follow-up email again I will write that “this is completely voluntary and if you choose to participate, you may withdraw at any time without any consequences to your employment or your relationship with the University of Wollongong. if you have any concerns please don’t hesitate to contact me on 4224 4160 or alternatively you can contact the University of Wollongong Ethics Officers on 4221 4457 or email: rso-ethics@uow.edu.au.”

3) On both the Information Participant Sheet and Consent Form it also states that it is completely voluntary.

4) At the start of the interview I will state that this is completely voluntary and if you choose to participate, you may withdraw at any time without any consequences to your employment, or your relationship with me or the University of Wollongong.

28. How does the project address the participants’ freedom to discontinue participation? Will there be any adverse effects on participants if they withdraw their consent and will they be able to withdraw data concerning themselves if they withdraw their consent?

Participants are free to withdraw from the research activity without any adverse effect by contacting the researcher directly as per the *Participant Information Sheet and Consent Form (refer attachment 1 & 2).* Their data can also be withdrawn from the study should they choose to withdraw their consent. This is expressed clearly on the *Participant Information Sheet and Consent Form.* It is also made clear on the *Participant Information Sheet and Consent Form* that discontinuing will not affect any relationship the participant has with their employer (council) or the University of Wollongong.

29. Does the project involve withholding relevant information from participants or deceiving them about some aspect of the research?

YES ☐ NO X

If YES, what is the justification for this withholding or deception and what steps will be taken to protect the participants’ interest in having full information about their participation?

30. Will participants be paid or offered any form of reward or benefit (monetary or otherwise) for participation in the research? If so, please detail and provide a justification for the payment, reward or benefit.

No

I. CONFIDENTIALITY AND PRIVACY

31. How will the privacy of individual subjects be protected when recording and analysing the data?

Interviewee confidentiality and privacy will be maintained. The data will be de-codified to remove any reference to an individual. Interviewees will not be named, except by a pseudonym reference to their generic position and the organisation they are employed by, e.g. Engineer from NSW Office of Environment and Heritage. The analysis and results of this study, in aggregate form, may be presented, discussed and published in appropriate academic forums and journals for the purpose of contributing to the advancement of knowledge. In any publication, information will be provided in such a way that individuals cannot be identified. This may be achieved for example by the use of pseudonyms where quotations attributed to individuals are expressed.

32. Will information collected from data or interview be published or reported?

YES X NO ☐

If YES, what form this will take? All uses of data must be explicitly consented to.

Semi-structured interview material will be published as part of the thesis submitted for the PhD qualification. The analysis and results of this study, in aggregate form, may be presented, discussed and published in appropriate academic forums and journals for the purpose of contributing to the advancement of knowledge.

33. Will any part of the research activities be placed on a visual or audio recording (eg audiotape, photograph or video-tape)?

YES X NO ☐

Once transcribed, tapes will be securely destroyed.

If YES,

33.a What will the recording be used for?

Semi-structured interviews will be audio recorded for the purposes of assisting with writing up transcripts. Interviewees will be informed of this using the *Participation Information Sheet* and *Consent Form* (refer attachment 1 & 2).

33.b Who will see/hear the recording?

The researcher and possibly the identified Supervisor only

34. Data (including questionnaires, surveys, computer data, tapes, transcripts and specimens) must be stored at all times. Where will the data be held and who will have access to it:

a. during the project?

Data will be stored securely on the researcher's password-protected personal computer and backed up at the University of Wollongong onto the principal investigator's password-protected work computer. The data will only be accessible to the investigators names in this HREC application.

Any hard copy data will be stored in safe custody of the principal investigator's secured filing cabinet. The data will be securely held by Ray Laine.

b. on completion of the project?

Any remaining hard data will be held securely by the University of Wollongong.

This data will be contained on a CD in the principal supervisor's office and a copy will also be stored on his password secured network drive that is regularly backed up by ITS.

35. Data should be held securely for a minimum of 5 years (15 years for clinical research) after completion of the research. How long will the data be stored for? If it is not being stored, please provide an ethical justification for this.

The data will be stored for at least 5 years at the location outlined above.

36. Does this project involve obtaining identifiable information (e.g. data) from a third party without prior consent from the participant or their legal guardian?

YES ☐ NO X

If NO: You have completed the questionnaire. Please ensure that the form has all the appropriate signatures and attachments (see checklist) before submission.

If YES: go to question 37.

37. Who will be providing the information? Please include copies of any correspondence regarding permission to access this information from a responsible officer of the Agency.

38. Will the information be deidentified during collection, use, or disclosure?

YES ☐ NO ☐

If NO: You must apply for an exemption to the State and Federal Privacy Acts. Please complete the Privacy Exemption Application Form available from the 'Forms' Section of the Ethics webpage.

If YES:

38.a Who will be deidentifying the information? Is this is a person who would normally have access to the information?

38.b How and when will the data be deidentified?

J. DECLARATION BY INVESTIGATORS

Principal Investigator:

- I certify that I am the Principal Investigator named on the front page of this application form.
- I undertake to conduct this project in accordance with all the applicable legal requirements and ethical responsibilities associated with its carrying out. I also undertake to take all reasonable steps to ensure that all persons under my supervision involved in this project will also conduct the research in accordance with all such applicable legal requirements and ethical responsibilities.

- I certify that adequate indemnity insurance has been obtained to cover the personnel working on this project.

- I have read the *National Statement on Ethical Conduct in Human Research* and the *Australian Code for the Responsible Conduct of Research*. I declare that I and all researchers participating in this project will abide by the terms of these documents.

- I make this application on the basis that it and the information it contains are confidential and that the Human Research Ethics Committee of The University of Wollongong/SESIAHS will keep all information concerning this application and the matters it deals with in strict confidence.

Raymond Laine 15/5/2013

Name (please print)	Signature	Date

Signature/s of other researcher/s: The first named researcher will assume responsibility for the project in the absence of the Chief Investigator. All investigators must sign the application.

Name (please print)	Signature	Date

Name (please print)	Signature	Date

Include additional lines if necessary.

K. APPROVAL BY HEAD OF UNIT

This person must not be a member of the research team.

I am aware of the content of this application. I am satisfied that:

- All appropriate safety measures have been taken;

- The research is in accordance with UOW/SESIAHS Policy;

and approve the conduct of the project within this unit.

Name (please print)	Signature	Date

NOTE: RESEARCH MUST NOT COMMENCE UNTIL THE APPLICATION HAS BEEN APPROVED BY THE HREC.

Attachment 1

University of Wollongong

PARTICPANT INFORMATION SHEET – Floodengage: Decision Support System

A generic organisational decision support model for flood risk management measures

RESEARCHER'S NAME: Ray Laine

PURPOSE OF THE RESEARCH

This is an opportunity to participate in a research study conducted by Ray Laine at the University of Wollongong. The aim of this field study is to validate a trail decision support system called "Floodengage". The research is investigating how decision support systems such as Floodengage could be utilised to assist transparent and auditable decision making for floodplain management measures while also facilitating community consultation.

INVESTIGATOR

Ray Laine University of Wollongong rtl103@uowmail.edu.au

METHODS AND DEMANDS ON PARTICIPANTS

The study is designed in the form of exploratory, semi-structured interviews with identified key participants in the water resource field. Data collected will be collected, analysed and utilised to validate both the broader generic organisational decision support model for flood risk management measures the Floodengage trial program. If you choose to participate in the interview with Ray Laine, you will be asked to respond to a number of open-ended questions, which would need approximately one hour. The typical questions for the semi-structured interview are:

For each of the 20 trial floodplain risk management options:

11. Do you agree with the wording? Would you make any changes and adjustments?

12. In your opinion does “option x” improve community access and recreational use?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

13. In your opinion does “option x” disadvantage individual members of the community?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

14. In your opinion does “option x” provide safety to the community during flooding?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

15. In your opinion does “option x” raise community awareness and understanding of the local flood risk?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

16. In your opinion does “option x” threaten local plants and animals and their habitat?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

17. In your opinion does “option x” cause water quality issues?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

18. In your opinion does “option x”s initial costs (i.e. design/construction) require minimal council expenditure?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

19. In your opinion does “option x” require minimal ongoing council expenditure after implementation?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

20. In your opinion does “option x” reduce flood damages to the community?

c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
d) Why?

21. In your opinion does “option x” cause negative flood impacts to other areas (both upstream and downstream)?
    c) Not sure / Strongly Disagree / Disagree / Neutral or N/A / Agree / Strongly Agree
    d) Why?

You will also be asked the following 4 questions:

22. Do you think this system can assist in facilitating objective community flood risk management consultation?
    a) Yes, Why?
    b) No,Why?

23. Do you think this program can improve stakeholders (Community, Developers, Engineers, Planners, Councillor etc.) awareness of, and accelerate their learning about, the various pro’s and con’s of the floodplain risk management options?
    c) Yes, Why?
    d) No,Why?

24. If people use this program, do you think the system will improve the outcomes of a Floodplain Risk Management Plan?
    e) Yes, Why?
    f) No, Why?

25. If people use this program, do you think the system will improve the ability for Councils to justify the floodplain management decisions made?
    g) Yes, Why?
    h) No, Why?

POSSIBLE RISKS, INCONVENIENCES AND DISCOMFORTS

Your involvement in the field study is voluntary and you may choose not to respond to any questions. You are also able to discontinue participating in the study at any stage and withdraw your data. Withdrawal from this study will not affect any relationship you have with your employer or the University of Wollongong. Apart from the time spent on participating in the study, we can foresee no significant risks for you. Any information obtained in connection with this study and that can be identified with you will remain confidential and be disclosed only with your permission except as required by law. Interviews will be audio recorded for the purposes of assisting with writing up transcripts. Once transcripts are written up, the audio tapes will be securely destroyed. The results of this study, in aggregate form, may be presented, discussed

and published in appropriate academic forums and journals for the purpose of contributing to the advancement of knowledge. In any publication, information attributed to an individual will be provided in such a way that you cannot be individually identified.

The information collected as part of this study is related to your work experiences in the area floodplain risk management. It is highly unlikely that the questions asked will cause you any distress. However, you are able to stop at any time and are not obliged to continue with the interview. If you do become distressed and would like to talk to someone not involved in the research project, please contact Lifeline on 13 11 14.

FUNDING AND BENEFITS OF THE RESEARCH

The findings of the study are expected to assist local government or similar authorities internationally, with the selection for floodplain risk management measures.

ETHICS REVIEW AND COMPLAINTS

This study has been reviewed by the Human Research Ethics Committee of the University of Wollongong. If you have any issues regarding the study, you can contact Ray Laine (email: rtl103@uowmail.edu.au). If you have any concerns or complaints regarding the way this research is or has been conducted, you can contact the University of Wollongong Ethics Officers (phone: 02 4221 4457 or email: rso-ethics@uow.edu.au).

Thank you for your interest and time taken to consider this study.

Attachment 2

University of Wollongong

CONSENT FORM FOR PARTICIPANTS – Floodengage: Decision support system

A generic organisational decision support model for flood management measures

RESEARCHER'S NAME: Ray Laine

I have been given information about a research study titled: "A generic organisational decision support model for flood management measures". It seeks to achieve a greater understanding of how decision support systems such as Floodengage could be utilised to assist transparent and auditable decision making in floodplain management while also facilitating community consultation. I have discussed the research project with Ray Laine of the University of Wollongong who is conducting this research, as part of his PhD in Civil Engineering the University of Wollongong.

I have been advised of the potential risks and burdens associated with this research, which include the time, spent on participating in the interview, and have had an opportunity to ask Ray Laine any questions I may have about the research and my participation.

I understand that my participation in this research is voluntary, I am free to refuse to participate and I am free to withdraw my data from the research at any time. My refusal to participate or withdrawal of consent will not affect my treatment in any way my relationship with my employer or my relationship with the University of Wollongong.

If I have any enquiries about the research, I can contact Ray Laine (email: rtl103@uowmail.edu.au), or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human

Research Ethics Committee, Office of Research, University of Wollongong on phone: (02) 4221 4457 or email: rso-ethics@uow.edu.au.

By signing below I am indicating my consent to participate in the interview, as outlined in the participant information sheet provided to me.

I understand that the data collected from my participation in this study will be used in aggregate form in conference and journal publications for the advancement of knowledge. If in those publications the researcher is highlighting an opinion or quotation from an individual participant, a pseudonym will be assigned and I consent for it to be used in that manner.

❑ I agree to have my interview audio recorded by the researchers

Signed Date

..../....../......

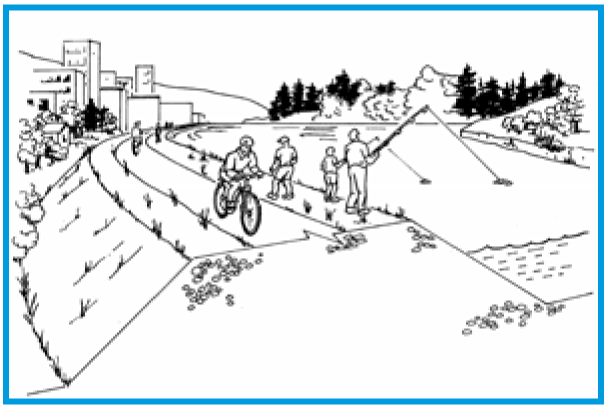
Name (please print)

....

Appendix C

Flood risk management option fact sheets

Earthen Levee



(Also known as a flood levee, main levee, embankment, stop bank, dyke, dike, summer dike, confinement dike, ring dike, bund)

What is an earthen levee: A earthen levee is an embankment built along a river with the primary purpose of providing flood protection to adjacent land or human settlement from inundation (Green et al. 2000). It is predominantly an embankment consisting of consolidated earth properly keyed into the underlying soil, with an impermeable packed clay, reinforced concrete or sheet pile core and flat batters either side (Lees 2010). A levee operates in most cases by confining and increasing the discharge capacity of the river. This is achieved as the raised embankments make the channel deeper giving it an ability to hold more water before it overtops and floods adjacent land.

Improves community access and recreational use:
An earthen levee generally improves community access and recreational use. *Why?* The levee embankment can increase public space that may be suitable for walking, cycle paths, improved recreational fishing access and sometimes roads.

Does not disadvantage individual members of the community:
An earthen levee usually causes equality issues and impacts individual members of the community. *Why?* As levees rely on their mass to resist floodwater pressure, to provide structural stability, resist erosion and allow the sides (batters) to be mown, batters have to be designed with a 4 to 1 or 5 to 1 batter slope in order to permit the operation of mowing machinery and prevent slump and failure. As a result, a levee at its base is usually 6 to 8 times its height and hence, requires a significant land area for construction. This land is usually both river frontage and located on private land.

As a result this causes the situation whereby a property owner rather than having a river view and a level backyard now (with the construction of a 3 metre high levee) has a large mound of earth covered in grass, no backyard and no river views.

Provides safety to the community during flooding:

Levees in general provide an additional level of flood protection to the community and allow communities to function during long-duration floods provided they are constructed and maintained to the best design practices. However, it has been evident that levees provide a false sense of security to the people living behind them, as residents continually choose not to evacuate their houses believing a levee would protect them. *Why?* If people stay rather than evacuate and the levee overtops or fails, floodwater rapidly inundates the township placing those residents and sometimes emergency management personnel at significant risk to life. Please note: that a levee is designed to protect property and not people, and should be treated that way during emergency management responses as every flood is different and the levee could overtop or fail.

Raises community awareness and understanding of the local flood risk:

An earthen levee can improve community awareness and understanding of the local flood risk however, as noted above it can also lead to a false sense of security leading to significant risk to life. *Why?* Its presence can be an everyday reminder of the potential flood water levels and the role it plays in the community to reduce damages during times of flood. It is essential that ongoing community education is conducted to ensure that the population is aware of the risk of overtopping, is informed about emergency management plans in the event of overtopping and does not lapse into the common belief that a levee provides protection against all floods (AEMIb 2013).

Does not threaten local plants and animals and their habitat:

A typical levee has significant negative environmental and ecological impacts. *Why?* A major levee is usually designed to straighten the river channel and reduce roughness, which in effect quickens the flow of water through the stream channel. This increased conveyance of water has the negative environmental and ecological impacts of pushing the flood peak downstream, increased erosion and scour, habitat destruction, and interrupting natural animal migration patterns.

A new approach is set back levees. These levees are sufficiently set back from the river's edge, allowing the river to maintain its natural low flow meandering channels and preserving to a degree the critically important riparian vegetation while also providing property protection during flood events due to increased flood storage.

Does not cause water quality issues:

A typical levee causes negative water quality impacts. Why? As noted above a levee is designed to increase conveyance (move water downstream quicker) which in turn diminishes the capacity of the river to regulate its flows, which causes scour and erosion, increases turbidity and reduces the ability for the floodplain to recharge which collectively decreases water quality (Freitag et al. 2009).

Initial costs (i.e design/construction) require minimal council expenditure:

Levees typically due to the length required have a major initial costs but are frequently utilised in flood mitigation, as they are an economically attractive measure as they protect a lot of pre-existing development in large flood prone areas (DIPNR 2005). *Why?* Levees are relatively simple to construct, have low cost materials and are easy to maintain. In NSW the construction costs for an earthen levee are typically around $1,100 per linear metre for a 2 metre high levee and $1,300 per linear metre for a 3 metre high levee. However, the cost and availability of: borrow materials; machinery; labour/ project management; design and feasibility studies, easements and/or the acquisition of land; resolving internal drainage issues and legislative costs can skew this typical cost per linear metre significantly.

Requires minimal ongoing council expenditure after implementation:

A levee has moderate ongoing maintenance costs. *Why?* As levees remain unused for long periods of time and are required to perform to a predetermined level at short notice, it is vital that ongoing maintenance is undertaken. Maintenance includes: 1) Inspecting for rabbit burrows, trees, scour of banks, cracking, build up of debris or weed growth, slump or failure; 2) Repairing any faults that which would affect the capacity, and consequently the function of the levee. 3) Mowing and general maintenance of the levee and associated drainage systems. On average this equates to an annual maintenance cost of $30 per linear metre/ per annum (derived from the Hunter Flood Mitigation Scheme, NSW).

Reduces flood damages to the community:

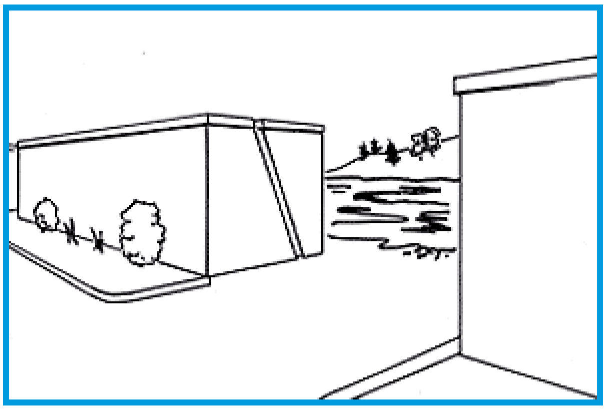
Levees significantly reduce flood related damages in large flood prone areas (DIPNR 2005). *Why?* As detailed above Levees can cost a lot of money however, they can substantially reduce damage costs particularly for more frequent flood events. Note: When a levee does overtop or fail it can cause significant economic damages to the township.

Does not cause negative flood impacts to other areas (both upstream and downstream):

A levee can cause adverse flood impacts to other areas. *Why?* As mentioned previously a levee is designed to increase water flow through the stream channel. This amplified conveyance therefore moves flood water downstream quicker and with more energy, causing possible damage to downstream assets. Also mentioned previously when a levee is overtopped, floodwaters can rapidly inundate the township with increased velocities causing structural damage. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to assess the upstream and downstream impacts of levees.

Concrete Levee

(Also known as a Flood Wall, Flood Levee, Main Levee, Dyke, Dike)



What is a concrete levee: A concrete levee is a wall built along a river with the primary purpose of providing flood protection to adjacent land or human settlement from inundation. They are typically gravity floodwalls constructed of solid concrete and use weight for stability or cantilever floodwalls consisting of a wall and footing constructed of cast-in-place concrete that relies partly on the weight of the floodwater and soil for stability (FEMA 2009). A levee operates in most cases by confining and increasing the discharge capacity of the river. This is achieved as the raised walls make the channel deeper giving it an ability to move and hold more water before it overtops and floods adjacent land.

Improves community access and recreational use:

A concrete levee is generally neutral in improving community access and recreational use. *Why?* A well designed concrete levee may increase public space that may be suitable for recreation such as sporting fields, parks, walking and cycle paths etc. However, a Concrete levee may also create physical barriers between the township and watercourse partially if it is tall.

Does not disadvantage individual members of the community:

A concrete levee may cause equality issues and impact individual members of the community. *Why?* A concrete levee may reduce access, views of the water and require the acquisition or easement of private property depending on its size and location. For example, a property owner rather than having a river view and direct access to the water now has a large 3 metre high concrete wall.

Provides safety to the community during flooding:

Levees have the potential to slightly improve safety for the community and allow communities to function during long-duration floods up to their design height provided they are constructed and maintained correctly and internal drainage is not an issue. Recent events however, have shown that levees may decrease safety for the community as they provide a false sense of security, as residents continually choose not to evacuate their houses believing the levee will protect them. *Why?* If people stay rather than evacuate and the levee overtops or fails, floodwater can rapidly inundate the township placing those residents and emergency management personnel at significant risk to life. Please note: A levee is designed to protect property and not people, and should be treated that way during emergency management responses as every flood is different and the levee may overtop or fail. In addition if rain falls inside the levee, the community may still experience flooding as the water may not be able to drain out without the use of water pumps.

Raises community awareness and understanding of the local flood risk:

A concrete levee can improve community awareness and understanding of the local flood risk however, as noted above it can also lead to a false sense of security leading to significant risk to life. *Why?* Its presence can be an everyday reminder of the potential flood water levels and the role it plays in the community to reduce damages during times of flood. It is essential that ongoing community education is conducted to ensure the community is aware that levees do not provide protection against all floods and there is significant risk when they do overtop or fail (NFRAG,

2012). Some Council's actually use the space on flood walls to create public art and murals about local flood impacts, with the aim to increase community flood awareness.

Does not threaten local plants and animals and their habitat:

A traditional concrete levee can have significant negative environmental and ecological impacts. *Why?* A concrete levee is usually designed to reduce inundation, straighten the river channel and reduce roughness, which in effect quickens the flow of water through the stream channel. This increased conveyance of water has the negative environmental and ecological impacts of increasing the flood peak downstream, increased erosion and scour, habitat destruction, and interrupting natural animal migration patterns.

An alternative approach is set back levees. These levees are sufficiently set back from the river's edge, allowing the river channel to maintain its natural meander stream functions and preserves to a degree the critically important riparian vegetation. This has multi objectives as it can provide property protection during flood events due to increased flood storage as well as recognise the importance of the natural stream functions.

Does not cause water quality issues:

A concrete levee has the potential to cause negative water quality impacts. *Why?* As noted above a levee is designed to increase conveyance (move water downstream quicker) which in turn increases velocities and flow in the river channel which can lead to increased scour and erosion causing bank failure and turbidity issues in addition to reducing the ability for the floodplain to recharge.

Initial Costs (i.e design/construction) require minimal council expenditure:

Levees typically due to the length required have a major initial cost but are frequently utilised in flood mitigation, as they are an economically attractive measure as they protect a lot of pre-existing development in large flood prone areas up to their design height (DIPNR 2005). *Why?* Concrete levees although generally more expensive than earthen levees are still relatively simple to construct, have moderate cost materials and are easy to maintain. In NSW, the construction costs for a concrete levee would typically be around $1,300 per linear metre for a 2 metre high levee and $1,600 per linear metre for a 3 metre high levee. However, the cost and availability of: materials; machinery; labour/ project management; design and feasibility studies, easements

and/or the acquisition of land; resolving internal drainage issues and legislative costs can skew this typical cost per linear metre significantly.

Requires minimal ongoing council expenditure after implementation:

A concrete levee generally has minor to moderate ongoing maintenance costs. *Why?* As levees remain unused for long periods of time and are required to perform to a predetermined level at short notice, it is vital that ongoing maintenance is undertaken. Maintenance includes: 1) inspecting for rabbit burrows, trees, scour of banks, cracking, concrete cancer, the build up of debris or weed growth, slump or failure; 2) repairing any faults that which would affect the capacity, and consequently the function of the levee; 3) general maintenance of the levee and associated drainage systems; and 4) testing the operation of flood gates. Maintenance of concrete levees are generally are less than earthen levees.

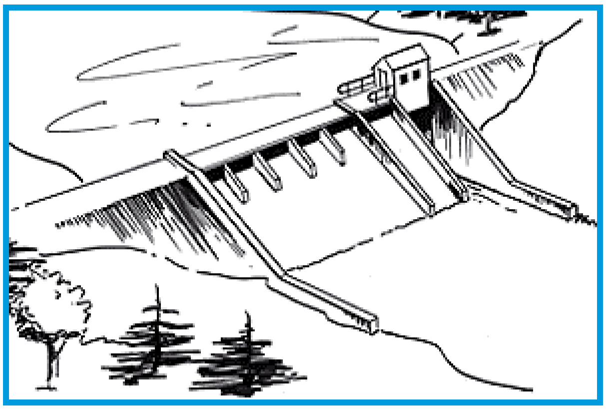
Reduces flood damages to the community:

Levees can reduce flood related average annual damages in large flood prone areas (DIPNR 2005). *Why?* As detailed above an earthen levee can cost a lot of money however, it can reduce damage costs particularly for more frequent flood events below their design height. *Note:* When a levee does overtop or fail it can cause significant and potentially greater economic damages to the township then if no levee was present in the first place.

Does not cause negative flood impacts to other areas (both upstream and downstream):

A levee has the potential to cause adverse flood impacts to other areas. *Why?* As mentioned previously a levee is designed to increase water flow through the stream channel. This amplified conveyance therefore moves flood water downstream quicker and with more energy, causing possible damage to downstream assets. Also mentioned previously when a levee is overtopped, floodwaters can rapidly inundate the township with increased velocities causing structural damage. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to assess the upstream and downstream impacts levees. Typically offset works are required to reduce these impacts such as flood storage areas.

Flood Mitigation Dam



What is a flood mitigation dam: A flood mitigation dam typically comprises of a wall or embankment that provides a water storage or reservoir, an outlet or flood gates to control water flow and a spillway to pass flows that exceed the dams design capacity. Most dams in Australia are built for water supply however, some are designed for flood mitigation purposes and have a built-in storage area that is kept free for temporarily storing floodwater with the aim of reducing peak flood heights downstream.

Improves community access and recreational use:

A flood mitigation dam generally does not improve community access and recreational use. *Why?* Although some dams permit fishing, kayaking and non-powered boating, commonly dams restrict access for safety and environmental reasons particularly if water is used for supply. This can mean areas that you once use to visit for fishing and bushwalking etc. may no longer be accessible.

Does not disadvantage individual members of the community:

A flood mitigation dam usually causes equality issues and can impact individual members of the community. *Why?* A dam is typically a large structure requiring large amounts of land to provide sufficient water storage. As a result particularly in urban catchments, large areas of land need to be purchased causing the relocation and disruption of local community members.

Provides safety to the community during flooding:

Flood mitigation dams in general provide an additional level of flood protection to the community during flooding. *Why?* The dams “free” storage can be filled by flood waters and later released. This in effect reduces the flood water level downstream but increases the time that land is inundated. Please note: Sometimes community safety may not result from dams because: 1) the dam may be kept full for water security reasons particularly after drought periods, which in turn significantly diminishes the ability for the dam to temporarily store flood water during an event; 2) dams usually

only collect water from one major river (as it is not feasible to have dams on every major river) so rainfall on other streams and rivers may cause flooding; 3) floods may generate much greater volumes of water than even large dams can store.

Raises community awareness and understanding of the local flood risk:

A flood mitigation dam can improve community awareness and understanding of the local flood risk. *Why?* Flood mitigation dams are usually seen as water supply areas, but with signage can prove to be valuable flood reminders.

Does not threaten local plants and animals and their habitat:

Flood mitigation dams have significant negative environmental and ecological impacts. *Why?* A flood mitigation dam can cause the mass flooding of productive forests and habitats, have significant impacts on animal migration patterns, increase erosion and cause stream lowering downstream, and cause large releases of greenhouse gases from rotting organic material such as trees and vegetation found now at the bottom of the dam.

Does not cause water quality issues:

A flood mitigation dam causes negative water quality impacts. *Why?* Dams change the flow regime of a river both upstream and downstream. The impacts of this include: diminishing the capacity of the river to regulate its flows causing scour and erosion, changing temperature and oxygen content as reservoirs can be oxygen poor and cold, increases salinity downstream and reduces the ability for the lower floodplain to recharge.

Initial Costs (i.e design/construction) require minimal council expenditure:

Flood mitigation dams have major initial costs and are typically not economically viable if only used for flood mitigation purposes. *Why?* Dams require significant capital investment and range from hundreds of millions to billions. The construction of dams is relatively complex requiring numerous engineering design and feasibility studies, purchasing large amounts of land, providing environmental offsets, and then construction costs including material and labour.

Requires minimal ongoing council expenditure after implementation:

Flood mitigation dams have moderate ongoing maintenance costs. *Why?* The maintenance of dams is critical due to the fact that failure of a dam causes catastrophic impacts downstream. Maintenance can include routine inspection for

deficiencies such as cracking and movement, seepage, flood gate testing and operation, and ensuring operation plans are up to date.

Reduces flood damages to the community:

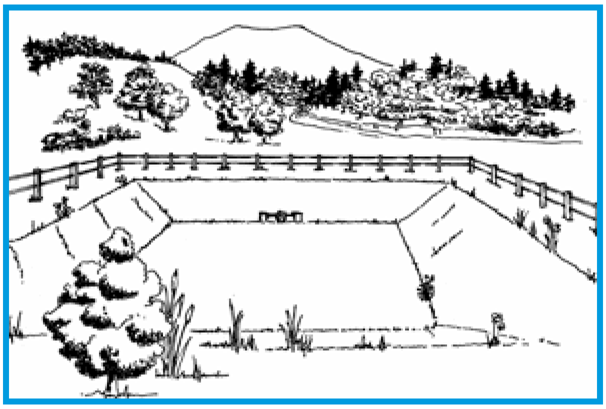
Flood mitigation dams have the ability to significantly reduce flood related damages in large flood prone areas (NSW Government 2005). Why? As detailed previously Flood mitigation dams can substantially reduce damage costs particularly for more frequent flood events. Note: Failure however, can cause catastrophic downstream damages.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Flood mitigation dams cause adverse flood impacts to other areas. *Why?* As mentioned previously a dam is created by placing a wall or embankment in a river and then allowing the upstream area to flood. This therefore, has significant adverse impacts to the inundated land.

Flood Detention Basin

(Also known as detention basin, retarding basin, storage basin)



What is a flood detention basin: A flood detention basin typically comprises of walls or embankments that provide an area for water storage, an outlet to control water flow and a spillway to pass water flows that exceed the basins design capacity. They can be dry or permanently wet and can be located online (i.e. along streams or watercourse) or located offline (located away from streams and watercourses). Like dams they operate by temporarily storing flood water which reduce downstream flood heights but can increase the time that land is inundated.

Improves community access and recreational use:

A flood detention basin may improve community access and recreational use. *Why?* A flood detention basin particularly in urban areas can covert private land to public

land for varying uses. A dry detention basin for example may be utilised as sporting fields, skateboard parks, golf courses and general parkland. A wet detention basin for example can create nice picnic areas and recreational fishing opportunities. However, in some instances detention basin may turn currently utilised recreation areas into non-usable basins due to extreme safety risks during flooding.

Does not disadvantage individual members of the community:

A flood detention basin may cause equality issues and can impact individual members of the community. *Why?* Flood detention basins generally occupy large areas of land to provide sufficient water storage. As a result particularly in urban catchments, large areas of land need to be purchased causing the relocation and disruption of local community members.

Provides safety to the community during flooding:

Flood detention basins are generally neutral in providing safety to the community during flooding. *Why?* The flood detention basins "free" storage can be filled by flood waters and later released. This in effect reduces the flood water level downstream but increases the time that land is inundated up to the design height. However, these basins can quickly fill causing life threatening situations particularly if utilised for recreational purposes. Please note: Flood detention basins need to be designed to accommodate different flood events by having varying outlet structures. It is not uncommon for detention basins to be designed to the 1% annual exceedance probability flood event and as a result they provide little benefit when larger flood events occur. Larger events that cause overtopping or failure can cause increased risk to life due to large volumes of water moving extremely fast.

Raises community awareness and understanding of the local flood risk:

Flood detention basins may improve community awareness and understanding of the local flood risk. *Why?* Flood detention basins are usually seen as parkland or sporting fields, but with signage can prove to be valuable flood reminders. However, they may also create a false sense of security for community members, as detention basins are usually only constructed to store minor to moderate flood events.

Does not threaten local plants and animals and their habitat:

Flood detention basins can both have negative and positive environmental and ecological impacts. *Why?* Inline flood detention basins can alter the ability for streams to regulate their flows causing erosion and scour, they can also cause habitat

disturbance and alter migration patterns. On the other hand wet detention basins may create habitat for local plants and animals and multi-level outlet controls can accommodate naturally fluctuating flow patterns.

<u>Does not cause water quality issues:</u>

A flood detention basin may cause water quality impacts. *Why?* Flood detention basins are typically designed in small rainfall events to remove pollutants and sediment. However, during large flood events these pollutants and sediments can be carried downstream in large plumes causing major water quality issues.

<u>Initial Costs (i.e design/construction) require minimal council expenditure:</u>

Flood detention basins have major initial costs. *Why?* Although flood detention basins are relatively simple to construct, feasibility studies and detailed design studies are vital to insure their placement and function does not cause adverse impacts both upstream and downstream. Detention basins typically costs around $10 per square metre for smaller basins and $5 per square metre for larger basins if Council owns the land (Brown et. al. 1997). However, the cost and availability of: materials; machinery; labour/ project management; design and feasibility studies, easements and/or the acquisition of land and legislative costs can skew this typical cost per square metre significantly.

<u>Requires minimal ongoing council expenditure after implementation:</u>

Flood detention basins have moderate ongoing maintenance costs. *Why?* As flood detention basin remain unused for long periods of time and are required to perform to a predetermined level at short notice, it is vital that ongoing maintenance is undertaken. Maintenance includes: 1) Inspecting for rabbit burrows, bank scour, cracking, build up of debris, slump or failure; 2) Repairing any faults that which would affect the capacity, and consequently the function of the flood detention basin. 3) Mowing and general maintenance of the flood detention basin and associated drainage systems.

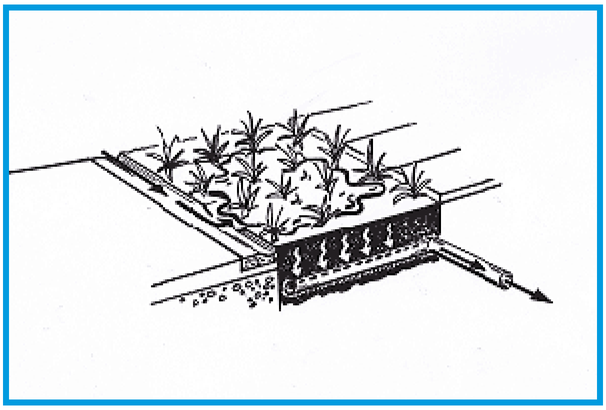
<u>Reduces flood damages to the community:</u>

Flood detention basins have the ability to reduce flood related annual average damages for small areas of flood prone land (NSW Government 2005). *Why?* As detailed previously flood detention basins can reduce the height of floodwater downstream which can reduce flood damages particularly for more frequent flood events. Note: Detention basins are usually small and are designed to overtop in major

floods. Failure can also occur which can cause catastrophic downstream damages if appropriate planning decisions have not been made.

Does not cause negative flood impacts to other areas (both upstream and downstream):
Flood detention basins have the potential to cause adverse flood impacts to other areas. *Why?* As discussed previously, detention basins are designed to be either inline or offline. Inline basins may cause water to build up and flood land upstream while offline basins may result in flooding of areas that had previously not experienced inundation. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to insure their placement and function does not cause adverse impacts both upstream or to other areas..

Increased Infiltration Capacity Mechanisms



What is increased infiltration capacity: Increased infiltration capacity is one principle of Water Sensitive Urban Design (WSUD) whereby water is retained onsite to infiltrate into the ground or be reused at a later time. Increased infiltration capacity mechanisms include: permeable pavements, porous pavement, infiltration trenches, filter strips, infiltration basins, bioretention basins and swales. These mechanisms are excellent for a whole range of reasons including protecting natural storm water drainage systems, increasing natural habitat and ecosystems, increasing amenity and access to open land, protecting water quality, and minimising the cost of drainage infrastructure.

Increased infiltration capacity mechanisms however, are generally not considered an effective flood risk management measure. *Why?* These mechanisms are usually designed to store water and then slowly release water through ground infiltration or use. The storage and infiltration capacity of most of these systems are usually small relative to flood producing rainfall events. For example 10mm of rain over a 500

square metre property (assuming that 5mm of rain is initially soaked up by the ground) would produce 2.5 cubic metres or 2500 L of water that an infiltration mechanism would have to process. During a flood, rainfall would typically exceed the storage and infiltration capacity of most systems very early, limiting their ability to reduce down-stream flood flows. It is true however, increased infiltration capacity mechanisms generally retard some floodwater particularly in small flood events which will reduce the peak flow downstream but in general increased infiltration capacity mechanisms should not be considered a flood risk management measure..

Channel Realignment

What is a channel realignment: As the title implies it is the realignment of the existing channel. Realigning a channel generally involves straightening and widening or redirecting water flow. This is typically done to increase the discharge capacity of the channel or build a bypass floodway that redirects excess water away from the main stream before it rejoins at a later time reducing the flood height and potential damages. The negatives can include increasing the velocity, timing and severity of flooding downstream, causing flooding to areas that did not previously flood and potentially causing stream bed and bank stability issues.

Improves community access and recreational use:

Channel realignments are generally neutral in improving community access and recreational use. *Why?* Channel realignment can increase public space that may be suitable for walking, cycle paths and sporting fields. However, channel realignment may also occupy previously accessible public land.

Does not disadvantage individual members of the community:

Channel realignments can disadvantage individual members of the community. *Why?* Although channel realignments typically occur within the footprint of the existing channel, there are some instances where private land will need to be purchased to

accommodate the streams increased width or new flow direction. A redirected channel may also isolate properties during flood events that had previously not been isolated.

Provides safety to the community during flooding:

Channel realignments are generally neutral in providing safety to the community during flooding. *Why?* The realignment can re-divert flow and reduce flood heights in one location, but it can also increase the velocity, timing and severity of flooding downstream. As stated above, this can also isolate properties placing those residents and emergency management personnel at increased risk.

Raises community awareness and understanding of the local flood risk:

Channel realignments do not typically raise community awareness and understanding of the local flood risk. *Why?* Channel realignments are usually perceived as a local drainage measure and not as a flood reminder.

Does not threaten local plants and animals and their habitat:

Channel realignments can have negative environmental and ecological impacts. *Why?* Channel realignments are generally undertaken to quicken the flow of water down a stream or redirect water to another area. This increased conveyance of water can have the negative environmental and ecological impact of pushing the flood peak downstream, increased erosion and scour leading to bed and bank instability both upstream and downstream, and destroying valuable plant and animal habitat. On the other hand a secondary channel may create new habitat for plants and animals and restore the channels flow regime offsetting the non-permeable urban surfaces.

Does not cause water quality issues:

Channel realignments can have negative water quality impacts. *Why?* As noted above channel realignments change the flow regime of streams both upstream and downstream usually by moving water downstream quicker. The impacts of this include: diminishing the capacity of the river to regulate its flows causing scour and erosion, changing temperature and oxygen gradients and increasing turbidity.

Initial Costs (i.e design/construction) require minimal council expenditure:

Channel realignments generally have moderate initial costs to council *Why?* Although they are relatively simple to construct, feasibility studies and detailed design studies are vital to insure their placement and function does not cause adverse impacts both

upstream and downstream. The costs for channel realignment can vary significantly from $60,000 for local channel straightening works to millions for by-pass channels. The cost of the works can also significantly vary if easements and/or the acquisition of private land is required.

<u>Requires minimal ongoing council expenditure after implementation:</u>

Channel realignments have minor to moderate ongoing costs to council post implementation. *Why?* Maintenance generally involves works to reduce bed and bank stability issues and riparian vegetation management.

<u>Reduces flood damages to the community:</u>

Channel realignments generally reduces flood related annual average damages to the community. *Why?* Channel realignment can reduce flood levels and damages in critical locations but may increase the velocity, timing and severity of flooding downstream or to other areas. If flood modelling indicates there will be no adverse impact downstream or to other areas as a result of channel realignments, then this can reduce annual average flood damages to the community.

<u>Does not cause negative flood impacts to other areas (both upstream and downstream):</u>

Channel realignments have the potential to cause adverse flood impacts to other areas. *Why?* As mentioned previously channel realignments are generally undertaken to quicken the flow of water down a stream or redirect water to another area. This amplified conveyance therefore moves flood water quicker and with more energy, causing possible damage to assets. On the other hand channel realignment could reduce flood heights at critical locations through redirecting and slowing down the flow through other areas. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to assess the upstream and downstream impacts of channel realignment.

Riparian Vegetation Management

(Also known as stream vegetation maintenance, riparian corridor management, vegetation management schemes)

What is riparian vegetation management: This involves the select removal of exotic and/or non-flood compatible vegetation and the replanting of suitable native species around the stream or river. This management measure can be useful to increase the discharge capacity of the channel, reduce the severity of erosion and culvert blockage and increase the aesthetics of the waterway. The potential negative impacts include increasing the velocity, timing and severity of flooding downstream and short term environmental impacts of riverine habitat destruction and stream bed and bank stability issues. Please note: This is not the complete removal of all vegetation around the stream or river as this can cause major negative environmental and flood behaviour impacts for the catchment.

Improves community access and recreational use:

Riparian vegetation management may improve community access and recreational use. *Why?* Over grown banks and the natural varying channel sections can be replaced with more uniform geometry and landscaped features. These landscaped features may generally be more aesthetically appealing and provide increased recreational access opportunities however, can cause adverse environmental impacts including bed and bank stability issues particularly in the short term.

Does not disadvantage individual members of the community:

Riparian vegetation management on public land may disadvantage individual members of the community. *Why?* Depending on the nature and extent of vegetation removal prior to reestablishment of native plants, flood events have the increased potential to cause scour and erosion which could significantly alter flood behaviour and undercut peoples properties. Additionally some people may like the natural aesthetics of the current stream or river and feel like a loss of environmental features occurs when landscaping is undertaking.

Provides safety to the community during flooding:

Riparian vegetation management, if undertaken correctly, can slightly improve safety to the community during flooding. *Why?* A well planned vegetation management scheme involving the propagation and planting of native vegetation that is well suited to the local flood conditions, can stabilise the channel banks which can reduce debris loads and unpredictable flow conditions increasing safety to the community. Just removing vegetation on the other hand can cause significant instability in the channel leading to erosion and sedimentation, unpredictable flow conditions, and increases to the velocity, timing and severity of flooding downstream.

Raises community awareness and understanding of the local flood risk:

Riparian vegetation management generally does not raise community awareness and understanding of the local flood risk. *Why?* Riparian vegetation management for flood management purposes is usually quickly forgotten or perceived as a beatification measure and not as a flood reminder. However, local communities are often involved in the planning and implementation of vegetation management through the formation of a Bushcare groups and public meetings. This may locally increase awareness of the local flood risk.

Does not threaten local plants and animals and their habitat:

Riparian vegetation management can improve native habitat helping local plants and animals if undertaken correctly. *Why?* This measure generally involves the select removal of exotic and/or non flood compatible vegetation and the replanting of suitable native species around the stream or river. In the long term this can create important habitat for local plants and animals and stabilise the stream or rivers banks. However, if not properly designed or implemented vegetation removal in particular can quicken the flow of water through the stream channel causing negative environmental and ecological impacts including erosion and scour, habitat destruction, unpredictable flow paths and increased urban pollution runoff.

Does not cause water quality issues:

Riparian vegetation management is generally neutral for water quality. *Why?* Riparian vegetation management in the short term can be negative as it can reduce the ability for the river or stream to regulate its flows, which causes scour and erosion, increases turbidity and reduces the ability for the floodplain to recharge which collectively decreases water quality. However over the long term the planting of

suitable local plants can create a buffer for urban pollutants and stabilise the river or stream, improving water quality.

Initial Costs (i.e design/construction) require minimal council expenditure:

Riparian vegetation management has minor to moderate initial costs to Council. *Why?* It is a relatively simple process that involves a works crew physically removing and mulching exotic or non flood compatible vegetation, and then replanting with suitable native plants. Costs for riparian vegetation management schemes generally range from $5 to $50 per linear metre of stream. If a local bush care group is involved Council labour costs can be reduced. Sometimes mitigating downstream impacts including, bank stability measures, flood management works, and associated legislative costs can skew riparian vegetation management costs per linear metre significantly.

Requires minimal ongoing council expenditure after implementation:

Riparian vegetation management generally has minor to moderate ongoing costs to council particularly in the short term. *Why?* Although maintenance generally only involves weeding and replanting of vegetation, post a storm event works may need to be undertaken to fix stream instability issues such as erosion, scour and head cuts and replanting of native vegetation.

Reduces flood damages to the community:

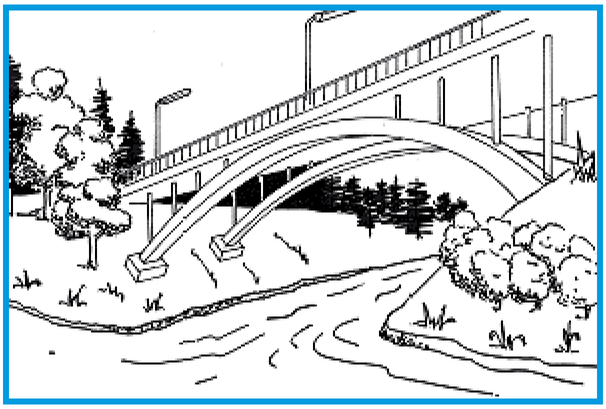
Riparian vegetation management may slightly reduce annual average damages to the community during flooding. *Why?* A well planned vegetation management scheme involving the propagation and planting of native vegetation that is well suited to the local flood conditions, can stabilise the channel banks which can reduce debris loads and unpredictable flow conditions which can reduce annual average flood damages for the community.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Riparian vegetation management has the potential to cause adverse flood impacts to other areas. *Why?* As mentioned previously riparian vegetation management particularly in the short has the potential to increase water flow through the stream channel. This amplified conveyance can move flood water downstream quicker and with more energy, causing possible damage to downstream assets and cause erosion and scour within the stream. It is vital that careful planning and consultation

with the community and various government agencies is undertaken to ensure riparian vegetation management maximises both environmental and flood management goals.

Culvert/ Bridge Upgrade



What are culvert/ bridge upgrades:
As the title implies it is the modification of a culvert or bridge by increasing the size of, repositioning, and/or adding additional culverts or bridges to increase water flow. This can be useful to increase the discharge capacity of the channel particularly through a structure, and may reduce the severity of culvert/bridge blockage during a flood event. The negatives may include increasing the velocity, timing and severity of flooding downstream and potentially causing stream bed and bank stability issues if not designed correctly.

Improves community access and recreational use:
Culvert/ bridge upgrades are generally neutral in improving community access and recreational use. *Why?* Culvert and/or bridges upgrade typically occur in the footprint of an existing structure and as a result neither limit community access and recreational use nor improve it. Some Council's however, incorporate riparian vegetation management into these upgrades increasing recreational use of the stream or river and provide access points.

Does not disadvantage individual members of the community:
Culvert/ bridge upgrades may slightly disadvantage individual members of the community. *Why?* Private land either upstream or downstream of the structure may be acquired to allow water flow transitions through the structure. However, generally culvert and bridge upgrades typically occur in the footprint of an existing structure on public land and as a result usually do not disadvantage individual members of the community.

Provides safety to the community during flooding:

Culvert/ bridge upgrades generally increase safety to the community during flooding. *Why?* The upgrade can reduce debris build-up that may cause the culverts to block and re-divert flow. However they can also increase the velocity, timing and severity of flooding downstream so flood management offsets are typically required such as detention basins or increased vegetation.

Raises community awareness and understanding of the local flood risk:

Culvert/ bridge upgrades do not typically raise community awareness and understanding of the local flood risk. *Why?* Culvert/ bridge upgrades are usually perceived as a local drainage measures and not as a flood reminder.

Does not threaten local plants and animals and their habitat:

Culvert/ bridge upgrades typically improve habitat for local plants and animals. *Why?* Culvert/ bridge upgrades are generally undertaken to increase undersize culverts or bridges that typically restrict natural flow paths and cause an increase in water levels upstream. Upgrades typically improve this previous restriction allowing opportunities for increased animal migration and potential habitat creation. However, poorly designed structures have the potential to increase conveyance causing erosion and scour leading to bed and bank instability both upstream and downstream of the structure, and possibly destroying habitat during and after construction.

Does not cause water quality issues:

Culvert/ bridge upgrades can potentially improve water quality. *Why?* As noted above culvert/ bridge upgrades are designed to enlarge the water passage partially aiming to restore natural flow conditions which can improve riparian corridors that in turn buffer pollutants increasing water quality. If the upgrade is poorly designed however, the structure can increase velocities and flows in the river channel which can lead to increased scour and erosion diminishing water quality.

Initial Costs (i.e design/construction) require minimal council expenditure:

Culvert/ bridge upgrades can have major initial costs to council *Why?* Culvert and bridge upgrades generally require the removal and replacement of existing structures or require an additional structure to be built. This generally involves geotechnical, flood behaviour studies, survey, feasibility studies, detailed designs and construction. A small culvert upgrade would typically cost thousands of dollars where as a bridge upgrade could exceed a million dollars. One significant aspect that can increase costs

particularly with bride upgrades is the moving of existing utilities such as water/ electricity/ sewer that are typically housed on, in or under the structure.

<u>Requires minimal ongoing council expenditure after implementation:</u>

Culvert/ bridge upgrades have minor ongoing costs to council post implementation. *Why?* Maintenance generally involves routine inspection for deficiencies such as cracking, slumping movement, and concrete spoiling. Further works may also be necessary to remediate riparian corridors, reduce bed and bank stability issues and remove debris that may be located in and around the structure.

<u>Reduces flood damages to the community:</u>

Culvert/ bridge upgrades are generally undertaken to reduce the annual averages damages of flooding to the community. *Why?* Culvert/ bridge upgrades are only undertaken if they reduce potential flood damages to the community. As mentioned although culvert/ bridge upgrades can reduce flood levels in critical locations they significantly increase the velocity, timing and severity of flooding downstream. If flood modelling indicates there will be no adverse impact downstream as a result of culvert/ bridge upgrades, then this can reduce annual average flood damages to the community.

<u>Does not cause negative flood impacts to other areas (both upstream and downstream):</u>

Culvert/ bridge upgrades can potentially cause adverse flood impacts to other areas if poorly designed. *Why?* As mentioned previously culvert/ bridge upgrades are designed to increase water flow through the structure. This amplified conveyance therefore moves flood waters downstream quicker and with more energy, causing possible damage to downstream assets unless offsets have been undertaken such as detention basins or riparian vegetation management. Furthermore the upgrade could reduce the potential for debris blockage reducing flood impacts for upstream areas. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to assess the upstream and downstream impacts of culvert/ bridge upgrades.

Concrete lined channel

What is a concrete lined channel: As the title implies it is a concrete lined channel usually trapezoidal or rectangular in shape. The process typically involves removing all in bank vegetation straightening, re-profiling the channel and utilising reinforced concrete to build the channel. Concrete lined channels were utilised a lot in the past to convey more water through relatively narrow areas. The negatives of this practice include increasing the velocity, timing and severity of flooding downstream, environmental impacts such as riverine habitat destruction, loss of important breeding areas and ecosystems, stream bed and bank stability issues and significant decreases in water quality.

Improves community access and recreational use:

A concrete lined channel is generally neutral in improving community access and recreational use. *Why?* A concrete channel can replace over grown vegetation and limit the occurrence of overbank flooding, potentially increasing the recreational use of surrounding public space. However, often concrete lined channels have to be closed to public access due to their high hazard as small amounts of rain can cause life threatening situations for people within them and their rescuers. In addition concrete lined channels can reduce access across a watercourse and reduce the streams “natural” aesthetics and recreational usability.

Does not disadvantage individual members of the community:

A concrete lined channel slightly disadvantages individual members of the community that may have utilised the existing stream for recreational purposes such as fishing and access. *Why?* Although concrete lining a stream is usually straight forward and does not cause significant disruption, members of the community that utilised the stream previously would no longer be able to do so, as the stream becomes unusable and access is often restricted.

Provides safety to the community during flooding:

Concrete lining a channel is slightly negative in providing safety to the community during flooding. *Why?* Although concrete lined channels can reduce flood levels in critical locations they can significantly increase the velocity, timing and severity of flooding downstream. This can cause loss of life to both people that become trapped in fast flowing channels and their potential rescuers. In addition, this increased

conveyance can cause cars to become lodged in channels redirecting critical flow paths and causing flooding elsewhere.

Raises community awareness and understanding of the local flood risk:

A concrete lined channel does not raise community awareness and understanding of the local flood risk. *Why?* A concrete lined channel is usually perceived as a local drainage measure, or a mechanism to convey all flood water causing a false sense of security and creating potentially life threatening situations.

Does not threaten local plants and animals and their habitat:

Concrete lined channels have significant negative environmental and ecological impacts. *Why?* A concrete lined channel clears all habitat and is designed to reduce the streams roughness, which in effect quickens the flow of water through the stream channel. This increased conveyance of water and habitat destruction causes major negative environmental and ecological impacts including pushing the flood peak downstream, increased erosion and scour leading to bed and bank stability both upstream and downstream of the channel, extensively altering plant and animal communities and destroying their homes.

Does not cause water quality issues:

Concrete lined channels have significant negative water quality impacts. *Why?* As noted above concrete lined channels are designed to increase conveyance (move water downstream quicker) which in turn diminishes the capacity of the river to regulate its flows, which causes scour and erosion, increases turbidity, reduces the ability for the floodplain to recharge, increases pH and limits the ability of the system to buffer nutrient and pollutant loads which all decrease water quality.

Initial Costs (i.e design/construction) require minimal council expenditure:

A concrete lined channel has major initial costs to council *Why?* Concrete lined channels are simple to construct, have moderate cost materials and are easy to maintain but overall have major initial costs to council. In NSW the construction costs for a concrete lined channel are typically around $1,000 per linear metre for a 2 metre wide channel. However, the cost and availability of: materials; machinery; labour/ project management; design and feasibility studies, easements and/or the acquisition of land, flood offsets and legislative costs can skew this typical cost per linear metre significantly.

Requires minimal ongoing council expenditure after implementation:

A concrete lined channel has minor ongoing costs to council post implementation. *Why?* Maintenance only generally involves implementing further works to reduce bed and bank stability issues and removing sediment or pollutants. However, failure can result in large ongoing costs to Council.

Reduces flood damages to the community:

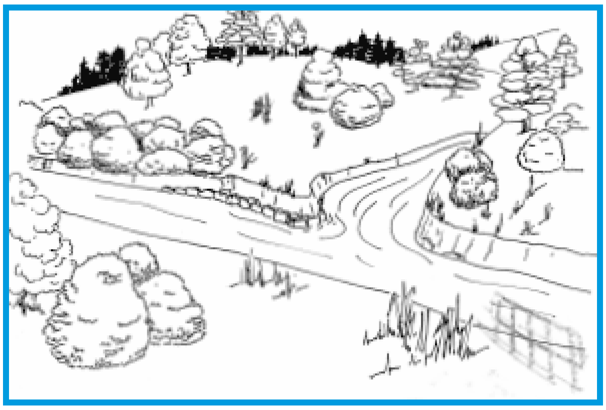
A concrete lined channel generally reduces flood related annual average damages to the community. *Why?* As mentioned above a concrete lined channel can reduce flood levels in critical locations particularly for small events but can significantly increases the velocity, timing and severity of flooding downstream. If flood modelling indicates there will be is no adverse impact downstream as a result of concrete lining the channel, then this option can reduce annual average flood damages to the community.

Does not cause negative flood impacts to other areas (both upstream and downstream):

A concrete lined channel can potentially cause significant adverse flood impacts to other areas. *Why?* As mentioned previously a concrete lined channel is designed to increase water flow through the stream channel. This amplified conveyance therefore moves flood water downstream quicker and with more energy, causing possible damage to downstream assets. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to assess the upstream and downstream impacts of concrete lining a channel.

Debris Control Structure

What is a debris control structure: As the name implies it is a structure that collects and controls debris during flood events. There are 4 typical debris control structures. These are 1) Debris Deflectors: A series of vertical or horizontal poles that are 45° to the inlet of drainage structures and divert medium to large



debris to collection areas; 2) Debris Racks: A series of large vertical poles concreted into the stream at 90° to capture large debris such as trees and cars; 3) Trash Racks or Trash Screens: A series of metal or wooden bars enclosed in a frame that are placed at 90° to the inlet or outlet of drainage structures to collect smaller debris or trash; 4) Debris Sumps or Debris Dams: A pit designed to slow the speed of water and allow for the deposition of heavy debris such as sediment and rock.

Although these structures do not manage floods, they are important in reducing the blockage or failure of drainage structures in streams with high debris loads.

<u>Improves community access and recreational use:</u>
Not applicable. *Why?* Debris structures are designed purely to reduce debris impacting and blocking critical structures. As a result they cannot improve community access and recreational use.

<u>Does not disadvantage individual members of the community:</u>
Debris control structures generally do not disadvantage individual members of the community. *Why?* Debris control structures are usually unobtrusive and located on public property within the watercourse.

<u>Provides safety to the community during flooding:</u>
Debris control structures provide safety to the community during flooding. *Why?* It can reduce debris impact and build-up that can cause bridges and culverts to block and re-divert flow, or fail.

<u>Raises community awareness and understanding of the local flood risk:</u>
Debris control structures generally do not raise community awareness and understanding of the local flood risk. *Why?* Debris control structures are usually perceived as water quality improvement measures and not as flood reminders.

<u>Does not threaten local plants and animals and their habitat:</u>
Debris control structures may threaten local plants and animals and their habitat particularly in the short term. *Why?* Construction typically involving excavation is required at the site which can cause initial habitat destruction. If not well designed debris control structures can affect the free movement and migration of local aquatic and terrestrial animals. Ongoing access is also required to the site to clear debris and/or pollutants. However, debris control structures may also act like natural log

jams or riffle ponds and if completed with a riparian vegetation management scheme can create new habitat opportunities for local plants and animals.

<u>Does not cause water quality issues:</u>

Debris control structures in general do not cause water quality impacts. *Why?* They act like natural log jams or riffle ponds and do not significantly alter the flow regime. In some instances they actually remove trash and pollutants improving water quality downstream.

<u>Initial Costs (i.e design/construction) require minimal council expenditure:</u>

Debris control structures have moderate to major initial costs to council. *Why?* Although they are relatively simple to construct, feasibility studies and detailed design studies are vital to insure their placement and function does not cause adverse impacts both upstream and downstream. The costs for debris control structures for reducing medium to large debris as required in flood events typically range from $50,000 to $200,000 for deflectors and large racks.

<u>Requires minimal ongoing council expenditure after implementation:</u>

Debris control structures have moderate ongoing maintenance costs to council. *Why?* Maintenance generally involves removing and dumping debris, and routine inspections for defects or vandalism.

<u>Reduces flood damages to the community:</u>

Debris control structures can reduce annual average flood related damages to the community if there are high debris loads and blockage is a significant issue. *Why?* As stated previously debris control structures can reduce potential debris impact and build-up that can cause bridges and culverts to block and re-divert flow, or fail.

<u>Does not cause negative flood impacts to other areas (both upstream and downstream):</u>

Debris control structures have the potential to cause adverse flood impacts to other areas. *Why?* Debris control structures have the potential to block 100% which then turns them into a weir or dam. As a result feasibility and detailed design studies for a full range of flood events (from regular to extremely rare floods) are required to insure their placement and function does not cause adverse impacts both upstream and/or downstream.

Local Flood Policies and Development Controls

What are local flood policies and development controls: Local flood policies and development controls are non-legal documents that help achieve aims of the local environmental plans and the objectives of its planning zones by providing specific and comprehensive requirements for certain development types at different locations. Local flood policies and development controls are very important as they can steer away inappropriate development from areas with high hazard flows or development that can have significant impacts upon flood behaviour in other areas. In conjunction with local environment plans, local flood policies and development controls are the most important mechanisms to manage both existing and future flood risk.

Improves community access and recreational use:

Local flood policies and development controls can improve community access and recreational use. *Why?* Local flood policies and development controls typically take into consideration the natural function of flooding within the floodplain. As a result development is usually restricted from highly hazardous locations and are opened up for more suitable land uses such as parks, walking and cycle paths, sporting fields, community gardens and native vegetation corridors.

Does not disadvantage individual members of the community:

Local flood policies and development controls are perceived to disadvantage individual members of the community. *Why?* These policies and controls generally place restrictions on what a property owner can build or what a property can do with their flood prone land. It is the intention of these policies and controls however, to reduce the property owners or future owner's exposure to the devastating effects of flooding to an acceptable level.

Provides safety to the community during flooding:

Local flood policies and development controls provide safety to the community during flooding. *Why?* Local flood policies and development controls try to ensure that

development is not inappropriately constructed or positioned to cause increased risk to life to both the occupants and their potential rescuers.

Raises community awareness and understanding of the local flood risk:

Local flood policies and development controls generally improve community awareness and understanding of the local flood risk. *Why?* If a property has flood related development controls placed on that land consistent with the flood policy, a owner (particularly if they had previously not know) becomes aware of the local flood risk up to heights where the planning controls apply. Sometimes however, floods greater than the flood planning height may not be known to the owner, which can cause a false sense of security.

Does not threaten local plants and animals and their habitat:

Local flood policies and development controls do not cause negative environmental and ecological impacts. *Why?* Local flood policies and development controls typically take into consideration the natural function of flooding within the floodplain. This can provide a mechanism to reduce the clearing of local plants and animals and their habitat as development is generally not permitted in high flood flow areas.

Does not cause water quality issues:

Local flood policies and development controls generally do not cause water quality issues. *Why?* As stated above local flood policies and development controls typically take into consideration the natural function of flooding within the floodplain. This can provide a mechanism to ensure water quality is not impacted by development or redevelopment.

Initial Costs (i.e design/construction) require minimal council expenditure:

Local flood policies and development controls have minimal to moderate initial costs to council *Why?* These policies and development controls are typically developed by Council staff with guidance from State Government and recommendations from strategic planning documents such Floodplain Management Plans or commissioned studies. These policies and controls are then publically exhibited and passed by Council with possible amendments.

Requires minimal ongoing council expenditure after implementation:

Local flood policies and development controls require minimal ongoing costs to council. *Why?* As mentioned above Council staff typically develop these policies and development controls and from time to time these may need to be updated.

Reduces flood damages to the community:

Local flood policies and development controls reduce flood damages to the community. *Why?* Local flood policies and development controls can steer away inappropriate development from high hazard areas and set specifications for building requirements that reduce potential damages to an acceptable level of risk.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Local flood policies and development controls generally do not cause adverse flood impacts. *Why?* As stated above local flood policies and development controls typically take into consideration the natural function of flooding within the floodplain. As such they generally ensure that flood flow paths are maintained and that flood water storage areas not filled reducing the potential for development or redevelopment adversely impact other areas. This is usually assessed through individual site specific flood studies and/or a Floodplain Management Study and Plan.

Planning Certificates Notifying Prospective Buyers and Developers of Flood Prone Land

What are planning certificates:

Planning certificates provide land owners, prospective buyers and developers information about the land use zoning and development controls applying to the land, as well as information about potential development constraints or other planning-related characteristics of the land. In NSW, Australia these are called Section 149 certificates and local government must disclose whether the land is subject to flood related development controls.

Improves community access and recreational use:

Not applicable. *Why?* Section 149 certificates are an education tool that provides information about land use zonings and controls. As a result they cannot directly improve community access and recreational use.

Does not disadvantage individual members of the community:

Section 149 certificates are perceived to disadvantage individual members of the community. *Why?* Some property owners perceive that 149 certificates could disadvantage them when selling a property that has flood related development controls. This is may be true to an extent however, it would disadvantage the community and particularly the buyers if this information was not disclosed as people would not realise the properties known exposure to flooding.

Provides safety to the community during flooding:

Not applicable. *Why?* As stated previously Section 149 certificates are an education tool that provide information about land use zonings and controls. As a result they cannot directly improve safety unless it improves community members awareness of the local flood issues and causes behavioural changes.

Raises community awareness and understanding of the local flood risk:

Section 149 certificates improve community awareness and understanding of the local flood risk. *Why?* A 149 certificate directly informs the land owner, prospective buyer and/or developer if there are flood related development controls applied to that land. This increases the awareness of the local flood risk up to heights where the planning controls apply. Sometimes however, floods greater than the flood planning height may not know to the owner, prospective buyer and/or developer which can cause a false sense of security.

Does not threaten local plants and animals and their habitat:

Not applicable. *Why?* As stated previously Section 149 certificates are an education tool that provide information about land use zonings and controls. As a result do not directly threaten local plants and animals and their habitat.

Does not cause water quality issues:

Not applicable. *Why?* As stated previously Section 149 certificates are an education tool that provide information about land use zonings and controls. As a result do not cause water quality issues.

Initial Costs (i.e design/construction) require minimal council expenditure:
Section 149 certificates have no initial costs to council *Why?* These certificates are typically populated by Council staff when a member of the public applies. The Council staff costs are generally re-covered by the associated application fee.

Requires minimal ongoing council expenditure after implementation:
Section 149 certificates have no ongoing costs to council. *Why?* As mentioned above Council staff typically populate these certificates upon application. The associated application costs cover the Council staff's costs to populate the certificate.

Reduces flood damages to the community:
Section 149 certificates may slightly reduce flood damages to the community. *Why?* Section 149 certificates can inform the public about potential flood risks and such indirectly reduce flood damages a community member takes action to reduce their damages.

Does not cause negative flood impacts to other areas (both upstream and downstream):
Not applicable. *Why?* As stated previously Section 149 certificates are an education tool that provide information about land use zonings and controls. As a result do not cause negative flood impacts to other areas.

Voluntary Purchase / Removal

What is a voluntary purchase: As the title implies it is the voluntary offering and purchasing of flood prone property in particularly hazardous locations, where it may not be feasible or economic to mitigate the effects of flooding. After a property has been purchased it is removed or demolished and the land is rezoned to a flood compatible use (DIPNR 2005).

Improves community access and recreational use:
Voluntary purchase generally improves community access and recreational use. *Why?* The property that is bought and removed is now public land that may be

suitable for walking, cycle paths, parks, sporting fields and more recently community gardens.

Does not disadvantage individual members of the community:

Voluntary purchase generally does not disadvantage individual members of the community. *Why?* As the title implies the property is purchased at an equitable price (priced without the impacts of flooding being considered) and only when it is voluntarily offered. However, some neighbourhoods may become disjointed as resident's offer their houses for purchase while one individual in the middle does not.

Provides safety to the community during flooding:

Voluntary purchase increases safety to the community during flooding. *Why?* The properties that are identified for voluntary purchase are particularly vulnerable to high hazard flood flows. This can cause significant risk to life to both the residents and emergency management personnel that try to rescue the residents. In addition the purchased property can be utilised to store or convey water which can reduce flood impacts to other areas.

Raises community awareness and understanding of the local flood risk:

Voluntary purchase does not generally raise community awareness and understanding of the local flood risk. *Why?* In the short term the community may know why that property has been removed however, in the longer term the land is usually seen as its current use i.e. parkland and not as a flood reminder.

Does not threaten local plants and animals and their habitat:

Voluntary purchase generally does not cause negative environmental and ecological impacts. *Why?* The removal of a property can create opportunities for the re-establishment of riparian vegetation, which can improve habitat for local plant and animals.

Does not cause water quality issues:

Voluntary purchase does not generally have negative water quality impacts. *Why?* As noted above, the removal of a property can create opportunities for the re-establishment of riparian vegetation that can create a buffer for urban pollutants improving the water quality of the stream or river.

Initial Costs (i.e design/construction) require minimal council expenditure:

Voluntary purchase generally have major initial costs to council *Why?* The acquisition of a single property costs the market rate. If a whole street is deemed high hazard and eligible for voluntary purchase, then this can become a costly venture for Council if they all offer their properties for sale. The NSW state government generally provides some assistance for the purchase and demolition of properties built prior to 1984.

Requires minimal ongoing council expenditure after implementation:

Voluntary purchase requires minimal ongoing costs to council post demolition. *Why?* Maintenance generally involves up keep of the land i.e. mowing.

Reduces flood damages to the community:

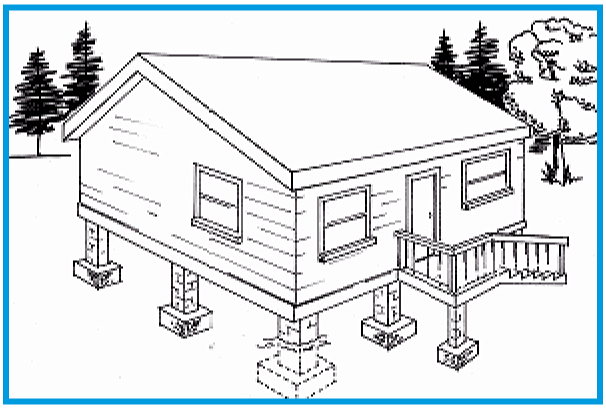
Voluntary purchase reduces flood damages to the community. *Why?* The removal of a high hazard flood prone property reduces the repetitive damages caused by flooding to both the property that is removed, and surrounding properties both upstream and downstream.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Voluntary purchase and the subsequent removal of the property has the potential to cause adverse flood impacts to other areas. *Why?* As the property is removed it can increase the speed at which floodwater travels to downstream areas. This occurs as the property is no longer there to obstruct and slow down floodwater. However, it must be noted that the removal of the property increases the flood storage area which can offset the floodwater flows.

Voluntary House Raising

What is a voluntary house raising: As the title implies it is the voluntary house raising of property in low flood hazard areas of the floodplain. House raising typically involves using hydraulic jacks and beams to raise a house typically a few meters off its



foundations and allowing a new non-liveable area to be built underneath from which the house now sits on. The purpose of voluntary house raising is to reduce flood related damages to that property and as such reduce the stress and post trauma of flooding (DIPNR 2005).

Improves community access and recreational use:

Voluntary house raising does not improve community access and recreational use. *Why?* The property that is raised is private property and located on private land and as such creates no improvement to community access and recreational use.

Does not disadvantage individual members of the community:

Voluntary house raising may disadvantage individual members of the community. *Why?* Voluntary house raising in typical construction methodologies may limit access to mobility impaired individuals as stairs are utilised to get to the new occupiable floor level. In addition, the raising of properties may cause neighbourhood tensions as one property is raised potentially reducing the views of another property.

Provides safety to the community during flooding:

Voluntary house raising may provide safety to the community during flooding. *Why?* The properties that are raised particularly in flash flood environments may create a refuge for vulnerable individuals if designed accordingly. Generally however, voluntary house raising is undertaken to protect property damages and not people, and should be treated that way during emergency management responses as fires can occur, the utilities generally cease operation, and vermin enter properties creating potentially life threatening situations. As a result, they can provide a false sense of security and increase risk to life.

Raises community awareness and understanding of the local flood risk:

Voluntary house raising may improve the community awareness and understanding of the local flood risk. *Why?* In the short term the occupants and nearby residents are generally reminded of the potential flood heights in the local community however, over the longer term this may be forgotten.

Does not threaten local plants and animals and their habitat:

Voluntary house raising does not cause negative environmental and ecological impacts. *Why?* The raising of a property generally does not threaten local plants and animals as the works are usually within the footprint of the existing dwelling.

Does not cause water quality issues:

Voluntary house raising generally does not cause negative water quality impacts. *Why?* The raising of a property generally does not adversely affect the nearby stream or rivers water quality as the works are undertaken with strict building controls.

Initial Costs (i.e design/construction) require minimal council expenditure:

Voluntary house raising generally has a minor initial costs to council *Why?* The house raising of a single property typically costs around $60,000 to $100,000. Of this Council and the NSW State Government may pay a portion. Raising homes with slab-on-ground construction can however, can skew costs significantly as lifting methodologies become more complicated as either the entire slab is lifted or the house is detached from the slab and lifted. Sometimes if this is the case, it may be more economically feasible to demolish the house or raise the floor within the house, moving the living space to an upper story.

Requires minimal ongoing council expenditure after implementation:

Voluntary house raising requires no ongoing costs to council. *Why?* The raised house is the responsibility of the property owner.

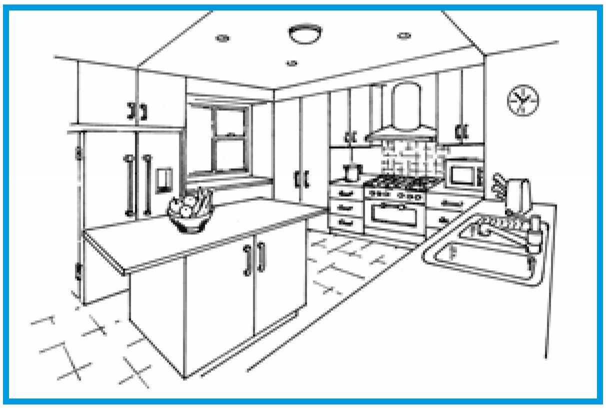
Reduces flood damages to the community:

Voluntary raising can reduce flood related annual average damages to the community. *Why?* The raising of flood prone houses when other alternatives are not feasible or justifiable can reduce the repetitive damages caused by flooding and as such can be economically justified in some cases.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Voluntary house raising generally does not adverse impacts to other areas. *Why?* The property is usually raised within the footprint of the existing dwelling and as such has usually has no adverse impacts in comparison to the existing dwelling.

Flood Proofing



What is flood proofing: As the title implies it involves designing, retrofitting or constructing buildings with appropriate water resistant materials to reduce the structural and non-structural damages of flooding to the building. Some techniques include having double brick or concrete walls as opposed to timber wall frames, using fibre cement sheeting or waterproof plywood instead of plasterboard or chipboard for internal fittings and utilising sheet metal roofing (i.e. colourbond) instead of roof tiles which can be easily dislodged and absorb moisture.

Improves community access and recreational use:

Not applicable. *Why?* Flood proofing is designed to reduce the structural and non-structural damages of private property. As a result flood proofing cannot improve community access and recreational use.

Does not disadvantage individual members of the community:

Flood proofing generally does not disadvantage individual members of the community. *Why?* Flood proofing can typically involve retrofitting existing development or incorporating flood proof materials and designs into new buildings. This typically does not disadvantage individual members of the community as it reduces flood related damages to private properties during times of inundation.

Provides safety to the community during flooding:

Flood proofing may provide safety to the community during flooding. *Why?* Flood proofed properties that are designed to withstand inside and outside water pressure differences and the energy of moving water particularly in flash flood environments, may improve safety to vulnerable individuals. Generally however, flood proofing is undertaken to reduce property damages and not to save people, and should be treated that way during emergency management responses as fires or medical emergencies can occur creating potentially life threatening situations. As a result, they can provide a false sense of security and increase risk to life.

Raises community awareness and understanding of the local flood risk:

Flood proofing may improve community awareness and understanding of the local flood risk. *Why?* If a property has been designed with flooding in mind the occupants and nearby residents are generally reminded of the potential flood damages that could occur in the local community.

Does not threaten local plants and animals and their habitat:

Flood proofing does not cause negative environmental and ecological impacts. *Why?* Flood proofing generally does not threaten local plants and animals as the works are usually within the footprint of the existing dwelling or future dwelling.

Does not cause water quality issues:

Flood proofing generally does not cause negative water quality impacts. *Why?* Flood proofing generally does not adversely affect the water quality of nearby stream or rivers, as the works are undertaken within strict building controls.

Initial Costs (i.e design/construction) require minimal council expenditure:

Flood proofing has no initial costs to council *Why?* Flood proofing is undertaken by the individual property owner and there are no subsidies available. The works are generally undertaken as they directly reduce the property owners exposure to flood related damages.

Requires minimal ongoing council expenditure after implementation:

Flood proofing requires no ongoing costs to council. *Why?* As mentioned above flood proofing is the responsibility of the property owner.

Reduces flood damages to the community:

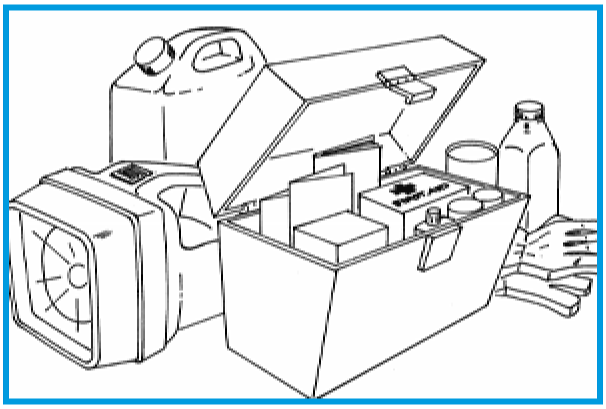
Flood proofing reduces flood related annual average damages to the community. *Why?* Flood proofing flood prone properties when other alternatives are not feasible or justifiable can reduce the repetitive damages caused by flooding and as such can be economically justified by the property owner.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Flood proofing generally does not cause adverse impacts to other areas. *Why?* Flood proofing is usually undertaken within the footprint of an existing dwelling or must

adhere to strict Council development controls and as such should have no adverse impacts both upstream and downstream.

Upper Story Flood Free Refuge



<u>What is a upper story flood free refuge:</u> A flood free refuge is a specially designed area in a property where occupants can escape too during rapidly rising flood water. It is essential that a flood free refuge is fail safe i.e. the building is able to withstand water pressure and debris impact forces, the refuge floor level is above the possible maximum flood height, it is accessible to all people on site, there is an escape option and it is fitted with emergency lighting, an emergency first aid kit including candles and a fire extinguisher. Upper story flood free refuges are usually only considered appropriate when: “there are no other practical flood management options available; evacuation is not possible due to lack of flood warning i.e. generally flash flood situations; flooding is of short duration; or it is safer to shelter than evacuate” (AEMI 2013b)

<u>Improves community access and recreational use:</u>

Not applicable. *Why?* The upper story flood free refuges are designed to create a safe refuge area above maximum possible flood heights. As such upper story flood free refuges cannot improve community access and recreational use

<u>Does not disadvantage individual members of the community:</u>

Upper story flood free refuges may disadvantage individual members of the community. *Why?* Upper story flood free refuge construction methodologies may limit access to mobility impaired individuals as stairs are typically utilised to reach the refuge.

<u>Provides safety to the community during flooding:</u>

Upper story flood free refuges may provide safety to the community during flooding. *Why?* Well designed flood free refuges can improve safety to vulnerable individuals

particularly in flash flood locations. Generally however, upper story flood free refuges should be treated as a last resort as fires and medical emergencies can occur, creating potentially life threatening situations for the occupants. As a result, they can provide a false sense of security and increase risk to life.

Raises community awareness and understanding of the local flood risk:

Upper story flood free refuges may improve community awareness and understanding of the local flood risk. *Why?* If a property has been designed with flooding in mind the occupants and nearby residents are generally reminded of the potential flood damages that could occur in the local community.

Does not threaten local plants and animals and their habitat:

Upper story flood free refuges do not cause negative environmental and ecological impacts. *Why?* Upper story flood free refuges generally do not threaten local plants and animals as the works are usually within the footprint of the existing dwelling or permissible future dwelling.

Does not cause water quality issues:

Upper story flood free refuges generally do not cause negative water quality impacts. *Why?* Upper story flood free refuges generally do not adversely affect the nearby stream or rivers water quality, as the works are undertaken within strict building controls.

Initial Costs (i.e design/construction) require minimal council expenditure:

Upper story flood free refuges have no initial costs to council *Why?* The construction of upper story flood free refuge works are undertaken by the individual property owner and there are no subsidies available.

Requires minimal ongoing council expenditure after implementation:

Upper story flood free refuges require no ongoing costs to council. *Why?* As mentioned above Upper story flood free refuges are the responsibility of the property owner to reduce risk to life.

Reduces flood damages to the community:

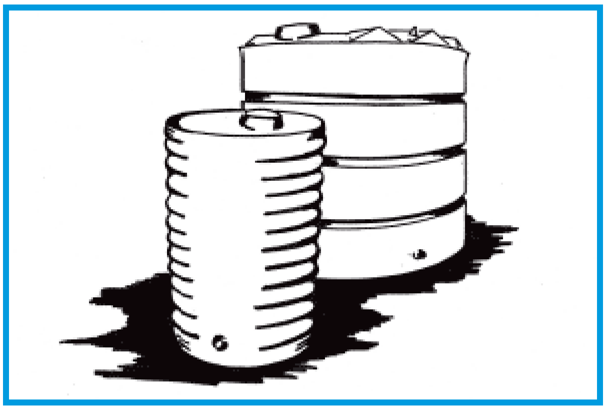
Upper story flood free refuges may reduce flood related annual average damages to the community. *Why?* Properties that are designed with upper story flood free refuge, are constructed to withstand high levels of water pressure and impact. As a result

they are usually constructed of pre-cast concrete or masonry which generally reduce damages during flood events.

Does not cause negative flood impacts to other areas (both upstream and downstream):
Upper story flood free refuges generally do not cause adverse impacts to other areas. *Why?* The construction of upper story flood free refuge works are usually undertaken within the footprint of an existing dwelling or must adhere to strict Council development controls and as such should have no adverse impacts both upstream and downstream.

Rainwater Tank

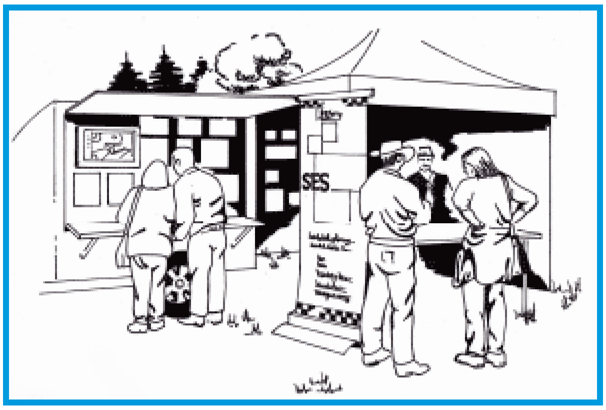
Also known as a water tank, rain barrel or water butt



What is a rainwater tank: A rainwater tank is a water storage tank that collects and stores rainwater runoff. This runoff is typically collected from all or part of the roof and can be utilised around the home to reduce demand on "town" water.

Rainwater tanks are not considered an effective flood risk management measures. *Why?* A rainwater tank usually provides little storage. For example 10mm of rain over a 200 square metres of roof or 20mm over a 100 square metres of roof, would add 2 cubic metres or 2000 L to a tank. During a flood, rainfall would typically exceed the tanks capacity very early, limiting its ability to reduce down-stream flood flows. It is possible however, that rainwater tanks may retard some floodwater, reducing the peak flow at some localised sites but in general rainwater tanks should not be considered a flood risk management measure (DECC, 2007).

Flood Awareness



What is flood awareness: As the title implies they are generally mechanisms that increase the awareness of the potential local flood impacts and provide information about how to prepare for and reduce life threatening situations during flood events. These mechanisms typically include: flood information kits; displays and information sessions about flood risks; and easily accessible flood related information on the Councils website.

Improves community access and recreational use:
Not applicable. *Why?* Flood awareness mechanisms are education tools to provide the community with information about the local flood risk, how to prepare and what to do during a flood event. As a result they cannot improve community access and recreational use.

Does not disadvantage individual members of the community:
Flood awareness mechanisms generally do not disadvantage individual members of the community. *Why?* Flood awareness can occur through a range of formats such as brochures, letter, speeches, videos, and information stalls. Flood awareness can also be communicated in varying languages and pictures to be inclusive of different people's needs in the community.

Provides safety to the community during flooding:
Flood awareness mechanisms generally provide safety to the community. *Why?* If people are prepared for flood events they know the likely consequences and can react quickly to provide safety for not only themselves, but to their family and potentially their neighbours.

Raises community awareness and understanding of the local flood risk:
Flood awareness mechanisms improve community awareness and understanding of the local flood risk. *Why?* This is the primary aim of flood awareness as the

mechanisms can provide the community with knowledge about the local flood risk, how to prepare and what to do during a flood event.

<u>Does not threaten local plants and animals and their habitat:</u>

Not applicable. *Why?* Flood awareness mechanisms are education tools to provide the community with information about the local flood risk, how to prepare and what to do during a flood event. As a result they generally do not threaten local plants and animals and their habitat.

<u>Does not cause water quality issues:</u>

Flood awareness mechanisms can improve water quality *Why?* These mechanisms can allow community members to prepare for flooding which can include placing contents and chemicals above predicted flood heights hence, reducing the potential impacts of these items washing into nearby rivers or streams causing water quality issues.

<u>Initial Costs (i.e design/construction) require minimal council expenditure:</u>

Flood awareness mechanisms have minor initial costs to council *Why?* Flood awareness programs generally include costs related to the preparation and printing of flood awareness material in conjunction with Council or State Emergency Service (SES) staff time to educate the community.

<u>Requires minimal ongoing council expenditure after implementation:</u>

Flood awareness mechanisms have minor ongoing costs to council. *Why?* Follow-up awareness programs are extremely important to ensure the entire community is aware about the local flood risk, how they can prepare and what to do during a flood event. This becomes vital if the community has a high turn-over rate with new residents moving in and out regularly. As such the ongoing costs generally include as stated above the preparation and printing of flood awareness material in conjunction with Council or SES staff time to educate the community.

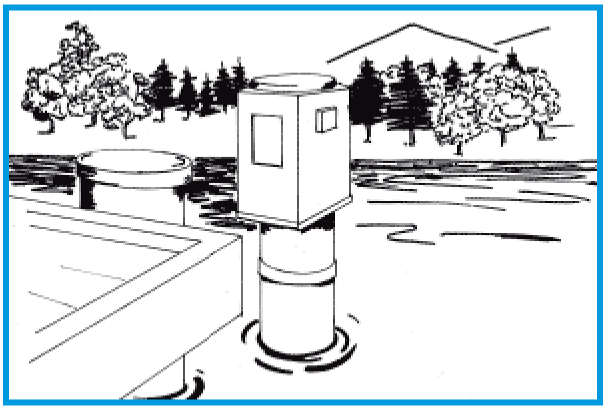
<u>Reduces flood damages to the community:</u>

Flood awareness mechanisms can reduce flood related damages to the community. *Why?* Flood awareness can ensure that the community is aware of the risk leading to the packing, raising or relocation of valuable objects and possessions post flood warning reducing flood related damages. Note: This may not always be possible as

warning times in flash flood environments may be very limited only providing enough time to community members to evacuate or move to refuge areas.

Does not cause negative flood impacts to other areas (both upstream and downstream):
Not applicable. *Why?* Flood awareness mechanisms are education tools to provide the community with information about the local flood risk, how to prepare and what to do during a flood event. As a result they do not generally cause negative flood impacts to other areas.

Local Flood Warning and Flood Forecasting Systems



What are local flood warning and flood forecasting systems: As the title implies it is a system that consists of rainfall and river gauging stations, weather and flood forecasters, local flood intelligence and modelling, and mechanisms to deliver a warning to the community. It is the intention of these systems "to help flood management agencies and the members of flood-prone communities to understand the nature of developing floods so that they can take action to mitigate their effects"(Attorney-General's Department, 2009).

Improves community access and recreational use:
Not applicable. *Why?* Local flood warning systems and flood forecasting are designed to predict when a flood will occur, how high and fast will the water flow, and what you should do. As a result they cannot improve community access and recreational use.

Does not disadvantage individual members of the community:
Local flood warning systems and flood forecasting generally do not disadvantage individual members of the community. *Why?* Local flood warnings derived from flood forecasting are generally provided to the entire community at risk through multiple modes such as telephone calls, media broadcasts, text messaging, and door knocking.

Provides safety to the community during flooding:

Local flood warning systems and flood forecasting provide safety to the community. *Why?* These systems give community members in advance the opportunity to know what is likely to occur, prepare for flooding, and move to a safe area or evacuate. They also provide a heads-up to emergency service personal to prepare for and respond to flood impacts.

Raises community awareness and understanding of the local flood risk:

Local flood warning systems and flood forecasting improve community awareness and understanding of the local flood risk. *Why?* These systems can predict flood heights and flows prior to events, informing the community of the likely flood event impacts.

Does not threaten local plants and animals and their habitat:

Not applicable. *Why?* Local flood warning systems and flood forecasting are designed to predict when a flood will occur, how high and fast will the water flow, and what you should do. As a result they may allow for the rescue of local animals prior to a flood event however, this rarely occurs as the focus is on disseminating information to protect lives and property.

Does not cause water quality issues:

Local flood warning systems and flood forecasting can improve water quality *Why?* These systems can allow community members to prepare for flooding which can include placing contents and chemicals above predicted flood heights hence, reducing the potential impacts of these items washing into nearby rivers or streams.

Initial Costs (i.e design/construction) require minimal council expenditure:

Local flood warning systems and flood forecasting have major initial costs to council Why? As previously stated these systems usually consist of a network of rainfall and river gauging stations, local flood modelling, and mechanisms to deliver the warning to the community. To provide indicative costs: individual river and rain gauge stations typically cost around $15,000 per station to set up, if you have a network of 3 this totals $45,000; local flood modelling to determine timings and impacts typically cost around $100,000 for a catchment, but is usually completed as part of a flood risk management study and plan; and mechanisms to alert the public through dissemination systems such sirens and text messaging services have establishment

costs of around $30,000. This equates to total initial costs of between $70,000 to $180,000.

Requires minimal ongoing council expenditure after implementation:

Local flood warning systems and flood forecasting have moderate ongoing costs to council *Why?* As previously stated these systems usually consist of a network of rainfall and river gauging stations, local flood modelling, and mechanisms to deliver the warning to the community. Maintenance needs to be performed on the rainfall and river gauging stations, in conjunction with the alert mechanisms to ensure their use during critical times. In addition flood modelling should be reviewed and updated following changes in the catchment (i.e. a major flood event, significant development). These maintenance costs typically range from $5,000 to $20,000 a year.

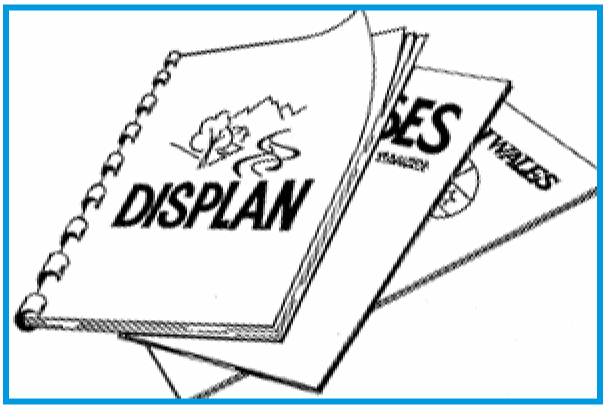
Reduces flood damages to the community:

Local flood warning systems and flood forecasting reduce flood related damages to the community. *Why?* These systems give community members in advance the opportunity to know what is likely to occur and prepare for flooding. This can allow the community to pack, raise or relocate valuable objects and possessions above prior to the flood event reducing the devastating damages associated with flooding. Note: The warning time in flash flood environments may be very limited only allowing community members to evacuate or move to refuge areas.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Not applicable. *Why?* As stated previously, local flood warning systems and flood forecasting are designed to predict when a flood will occur, how high and fast will the water flow, and what you should do. As a result they do not cause negative flood impacts to other areas.

Local Flood and Disaster Plans



What are local flood and disaster plans: As the title implies these are action plans for areas with significant flood risk. These plans describe "the various measures to be undertaken before, during and after a flood including warning, evacuation, resupply, recovery and other procedures"(DIPNR, 2005). These plans are extremely important for government agencies involved in emergency response as they typically outline roles and responsibilities at each stage of a flood event.

Improves community access and recreational use:
Not applicable. *Why?* Local flood and disaster plans are a set of procedures and measures to be undertaken before, during and after floods of various sizes. As a result they do not improve community access and recreational use.

Does not disadvantage individual members of the community:
Local flood and disaster plans generally do not disadvantage individual members of the community. *Why?* These plans are designed to plan for and reduce the greatest risks in the community with the resources available. As such they generally do not disadvantage individual members of the community.

Provides safety to the community during flooding:
Local flood and disaster plans generally provide safety to the community. *Why?* These plans describe the various roles, responsibilities and procedures of various agencies before, during and after floods. This ensures that emergency response agencies know their role and responsibilities which leads to an increased ability to provide safety to the community prior to, during and after a flood event.

Raises community awareness and understanding of the local flood risk:
Local flood and disaster plans generally do not improve community awareness and understanding of the local flood risk. *Why?* Members of the community would rarely read a local flood and/or disaster plan.

Does not threaten local plants and animals and their habitat:

Not applicable. *Why?* Local flood and disaster plans are a set of procedures and measures to be undertaken before, during and after floods of various sizes. As a result they do not threaten or generally take into consideration local plants and animals their habitat.

Does not cause water quality issues:

Local flood and disaster plans can improve water quality Why? These plans can assign responsibility for the safety of hazardous substances or materials and as a result reduce the potential impacts of these substances or materials washing into nearby rivers or streams causing water quality issues.

Initial Costs (i.e design/construction) require minimal council expenditure:

The preparation of local flood and disaster plan have minor initial costs to council *Why?* Costs generally relate to Council, State Emergency Service (SES) and other agencies staff time to prepare the plans.

Requires minimal ongoing council expenditure after implementation:

Local flood and disaster plans have minor ongoing costs to council. *Why?* Ensuring that these plans are up to date and current is extremely important particularly if there have been changes to the catchments landforms or there is newer flood intelligence information available. Costs therefore generally relate to Council, State Emergency Service (SES) and other agencies staff time to update the plans.

Reduces flood damages to the community:

Local flood and disaster plans can reduce flood related damages to the community. *Why?* These plans can ensure that procedures for prompt dissemination of information to the community occurs which may give individuals a chance to pack, raise or relocate valuable objects. Note: This may not always be possible as the dissemination of information in flash flood environments may be very limited only providing enough time for community members to evacuate or move to refuge areas.

Does not cause negative flood impacts to other areas (both upstream and downstream):

Not applicable. *Why?* Local flood and disaster plans are a set of procedures and measures to be undertaken before, during and after floods of various sizes. As a result generally do not cause negative flood impacts to other areas.

Appendix D

Microsoft VBA code for standalone system

Module

```
Sub Floodengage()
Welcome_1.Show
End Sub
```

Welcome

```
Private Sub Floodissues_Click()
Flood_Issues.Show
End Sub
Private Sub Mangementmeasures_Click()
Mangement_Measure.Show
End Sub
Private Sub Floodengage_Click()
Floodengage_Program.Show
End Sub
Private Sub Start_Click()
Unload Me
STEP_1.Show
End Sub
Private Sub Step1_Click()
Unload Me
STEP_1.Show
End Sub
Private Sub Step2_Click()
Unload Me
STEP_2.Show
End Sub
Private Sub Step3_Click()
Unload Me
STEP_3.Show
End Sub
Private Sub Step4_Click()
```

```
Unload Me
STEP_4.Show
End Sub
```

<u>Mangement_Measure</u>

```
Private Sub Image1_Click()
End Sub
Private Sub Label36_Click()
O_DCS.Show
End Sub
Private Sub Label37_Click()
O_Culvert.Show
End Sub
Private Sub Label38_Click()
O_Riparian.Show
End Sub
Private Sub Label39_Click()
O_Con.Show
End Sub
Private Sub Label40_Click()
O_Basin.Show
End Sub
Private Sub Label41_Click()
O_Infil.Show
End Sub
Private Sub Label42_Click()
O_Warning.Show
End Sub
Private Sub Label43_Click()
O_Pol.Show
End Sub
Private Sub Label44_Click()
O_Cert.Show
End Sub
Private Sub Label45_Click()
O_Raise.Show
End Sub
```

```
Private Sub Label46_Click()
O_Pur.Show
End Sub
Private Sub Label47_Click()
O_Proofing.Show
End Sub
Private Sub Label48_Click()
O_Aware.Show
End Sub
Private Sub Label49_Click()
O_Plan.Show
End Sub
```

STEP_1

```
Private Sub CommandButtonBack_Click()
STEP_1.Hide
Welcome_1.Show
End Sub
Private Sub CommandButtonNext_Click()
If Sheets(2).Range("M4") = "" Then
MsgBox "Please select a amenity/aesthtics weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("N4") = "" Then
MsgBox "Please select a social equality weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("O4") = "" Then
MsgBox "Please select a risk to life weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("P4") = "" Then
MsgBox "Please select a community awareness weighting.", vbCritical, "Select
Contraint"
End If
If Sheets(2).Range("Q4") = "" Then
MsgBox "Please select a ecosystem sustainabilty weighting.", vbCritical, "Select
Contraint"
End If
If Sheets(2).Range("R4") = "" Then
```

```
MsgBox "Please select a water quality weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("S4") = "" Then
MsgBox "Please select a construction cost weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("T4") = "" Then
MsgBox "Please select a ongoing/maintenance weighting.", vbCritical, "Select
Contraint"
End If
If Sheets(2).Range("U4") = "" Then
MsgBox "Please select a conveyance weighting.", vbCritical, "Select Contraint"
End If
If Sheets(2).Range("V4") = "" Then
MsgBox "Please select a negative hydraulic impact weighting.", vbCritical, "Select
Contraint"
End If
If Sheets(2).Range("M4") <> "" And Sheets(2).Range("N4") <> "" And
Sheets(2).Range("O4") <> "" And
Sheets(2).Range("P4") <> "" And Sheets(2).Range("Q4") <> "" And
Sheets(2).Range("R4") <> "" And She
ets(2).Range("S4") <> "" And Sheets(2).Range("T4") <> "" And
Sheets(2).Range("U4") <> "" And Sheets
(2).Range("V4") <> "" Then
Call STEP_1.Hide
Call STEP_2.Show
End If
End Sub
Private Sub I_1_Click()
C_AmenityAesthetics.Show
End Sub
Private Sub I_2_Click()
C_Equality.Show
End Sub
Private Sub I_3_Click()
C_RiskToLife.Show
End Sub
Private Sub I_4_Click()
```

```
C_CommunityAwareness.Show
End Sub
Private Sub I_5_Click()
C_EcosystemSustainability.Show
End Sub
Private Sub I_6_Click()
C_WaterQuality.Show
End Sub
Private Sub I_7_Click()
C_InitialCost.Show
End Sub
Private Sub I_8_Click()
C_OngoingCost.Show
End Sub
Private Sub I_9_Click()
C_Conveyance.Show
End Sub
Private Sub I_10_Click()
C_NegHydImpact.Show
End Sub
Private Sub Step2_Click()
STEP_1.Hide
STEP_2.Show
End Sub
Private Sub Step3_Click()
STEP_1.Hide
STEP_3.Show
End Sub
Private Sub Step4_Click()
STEP_1.Hide
STEP_4.Show
End Sub
Private Sub CommandButton2_Click()
Unload Me
Help_1.Show
End Sub
Private Sub CommandButton3_Click()
```

```
Help_2.Show
End Sub
Private Sub AA0_Click()
Sheets(2).Select
If AA0.Value = True Then
[M4:M72] = 0
LabelAA.Caption = "Not at all important"
End If
End Sub
Private Sub AA1_Click()
Sheets(2).Select
If AA1.Value = True Then
[M4:M72] = 2
LabelAA.Caption = "Slightly important"
End If
End Sub
Private Sub AA2_Click()
Sheets(2).Select
If AA2.Value = True Then
[M4:M72] = 2
LabelAA.Caption = "Moderately important"
End If
End Sub
Private Sub AA3_Click()
Sheets(2).Select
If AA3.Value = True Then
[M4:M72] = 3
LabelAA.Caption = "Very important"
End If
End Sub
Private Sub AA4_Click()
Sheets(2).Select
If AA4.Value = True Then
[M4:M72] = 4
LabelAA.Caption = "Extremely important"
End If
End Sub
```

```
Private Sub E0_Click()
Sheets(2).Select
If E0.Value = True Then
[N4:N72] = 0
LabelEq.Caption = "Not at all important"
End If
End Sub
Private Sub E1_Click()
Sheets(2).Select
If E1.Value = True Then
[N4:N72] = 1
LabelEq.Caption = "Slightly important"
End If
End Sub
Private Sub E2_Click()
Sheets(2).Select
If E2.Value = True Then
[N4:N72] = 2
LabelEq.Caption = "Moderately important"
End If
End Sub
Private Sub E3_Click()
Sheets(2).Select
If E3.Value = True Then
[N4:N72] = 3
LabelEq.Caption = "Very important"
End If
End Sub
Private Sub E4_Click()
Sheets(2).Select
If E4.Value = True Then
[N4:N72] = 4
LabelEq.Caption = "Extremely important"
End If
End Sub
Private Sub RTL0_Click()
Sheets(2).Select
```

```
If RTL0.Value = True Then
[O4:O72] = 0
LabelRTL.Caption = "Not at all important"
End If
End Sub
Private Sub RTL1_Click()
Sheets(2).Select
If RTL1.Value = True Then
[O4:O72] = 1
LabelRTL.Caption = "Slightly important"
End If
End Sub
Private Sub RTL2_Click()
Sheets(2).Select
If RTL2.Value = True Then
[O4:O72] = 2
LabelRTL.Caption = "Moderately important"
End If
End Sub
Private Sub RTL3_Click()
Sheets(2).Select
If RTL3.Value = True Then
[O4:O72] = 3
LabelRTL.Caption = "Very important"
End If
End Sub
Private Sub RTL4_Click()
Sheets(2).Select
If RTL4.Value = True Then
[O4:O72] = 4
LabelRTL.Caption = "Extremely important"
End If
End Sub
Private Sub CA0_Click()
Sheets(2).Select
If CA0.Value = True Then
[P4:P72] = 0
```

```
LabelCA.Caption = "Not at all important"
End If
End Sub
Private Sub CA1_Click()
Sheets(2).Select
If CA1.Value = True Then
[P4:P72] = 1
LabelCA.Caption = "Slightly important"
End If
End Sub
Private Sub CA2_Click()
Sheets(2).Select
If CA2.Value = True Then
[P4:P72] = 2
LabelCA.Caption = "Moderately important"
End If
End Sub
Private Sub CA3_Click()
Sheets(2).Select
If CA3.Value = True Then
[P4:P72] = 3
LabelCA.Caption = "Very important"
End If
End Sub
Private Sub CA4_Click()
Sheets(2).Select
If CA4.Value = True Then
[P4:P72] = 4
LabelCA.Caption = "Extremely important"
End If
End Sub
Private Sub ES0_Click()
Sheets(2).Select
If ES0.Value = True Then
[Q4:Q72] = 0
LabelES.Caption = "Not at all important"
End If
```

```
End Sub
Private Sub ES1_Click()
Sheets(2).Select
If ES1.Value = True Then
[Q4:Q72] = 1
LabelES.Caption = "Slightly important"
End If
End Sub
Private Sub ES2_Click()
Sheets(2).Select
If ES2.Value = True Then
[Q4:Q72] = 2
LabelES.Caption = "Moderately important"
End If
End Sub
Private Sub ES3_Click()
Sheets(2).Select
If ES3.Value = True Then
[Q4:Q72] = 3
LabelES.Caption = "Very important"
End If
End Sub
Private Sub ES4_Click()
Sheets(2).Select
If ES4.Value = True Then
[Q4:Q72] = 4
LabelES.Caption = "Extremely important"
End If
End Sub
Private Sub Welcome_Click()
STEP_1.Hide
Welcome_1.Show
End Sub
Private Sub WQ0_Click()
Sheets(2).Select
If WQ0.Value = True Then
[R4:R72] = 0
```

```
LabelWQ.Caption = "Not at all important"
End If
End Sub
Private Sub WQ1_Click()
Sheets(2).Select
If WQ1.Value = True Then
[R4:R72] = 1
LabelWQ.Caption = "Slightly important"
End If
End Sub
Private Sub WQ2_Click()
Sheets(2).Select
If WQ2.Value = True Then
[R4:R72] = 2
LabelWQ.Caption = "Moderately important"
End If
End Sub
Private Sub WQ3_Click()
Sheets(2).Select
If WQ3.Value = True Then
[R4:R72] = 3
LabelWQ.Caption = "Very important"
End If
End Sub
Private Sub WQ4_Click()
Sheets(2).Select
If WQ4.Value = True Then
[R4:R72] = 4
LabelWQ.Caption = "Extremely important"
End If
End Sub
Private Sub CC0_Click()
Sheets(2).Select
If CC0.Value = True Then
[S4:S72] = 0
LabelCC.Caption = "Not at all important"
End If
```

```
End Sub
Private Sub CC1_Click()
Sheets(2).Select
If CC1.Value = True Then
[S4:S72] = 1
LabelCC.Caption = "Slightly important"
End If
End Sub
Private Sub CC2_Click()
Sheets(2).Select
If CC2.Value = True Then
[S4:S72] = 2
LabelCC.Caption = "Moderately important"
End If
End Sub
Private Sub CC3_Click()
Sheets(2).Select
If CC3.Value = True Then
[S4:S72] = 3
LabelCC.Caption = "Very important"
End If
End Sub
Private Sub CC4_Click()
Sheets(2).Select
If CC4.Value = True Then
[S4:S72] = 4
LabelCC.Caption = "Extremely important"
End If
End Sub
Private Sub MC0_Click()
Sheets(2).Select
If MC0.Value = True Then
[T4:T72] = 0
LabelMC.Caption = "Not at all important"
End If
End Sub
Private Sub MC1_Click()
```

```
Sheets(2).Select
If MC1.Value = True Then
[T4:T72] = 1
LabelMC.Caption = "Slightly important"
End If
End Sub
Private Sub MC2_Click()
Sheets(2).Select
If MC2.Value = True Then
[T4:T72] = 2
LabelMC.Caption = "Moderately important"
End If
End Sub
Private Sub MC3_Click()
Sheets(2).Select
If MC3.Value = True Then
[T4:T72] = 3
LabelMC.Caption = "Very important"
End If
End Sub
Private Sub MC4_Click()
Sheets(2).Select
If MC4.Value = True Then
[T4:T72] = 4
LabelMC.Caption = "Extremely important"
End If
End Sub
Private Sub CON0_Click()
Sheets(2).Select
If CON0.Value = True Then
[U4:U72] = 0
LabelCON.Caption = "Not at all important"
End If
End Sub
Private Sub CON1_Click()
Sheets(2).Select
If CON1.Value = True Then
```

```
[U4:U72] = 1
LabelCON.Caption = "Slightly important"
End If
End Sub
Private Sub CON2_Click()
Sheets(2).Select
If CON2.Value = True Then
[U4:U72] = 2
LabelCON.Caption = "Moderately important"
End If
End Sub
Private Sub CON3_Click()
Sheets(2).Select
If CON3.Value = True Then
[U4:U72] = 3
LabelCON.Caption = "Very important"
End If
End Sub
Private Sub CON4_Click()
Sheets(2).Select
If CON4.Value = True Then
[U4:U72] = 4
LabelCON.Caption = "Extremely important"
End If
End Sub
Private Sub NHI0_Click()
Sheets(2).Select
If NHI0.Value = True Then
[V4:V72] = 0
LabelNHI.Caption = "Not at all important"
End If
End Sub
Private Sub NHI1_Click()
Sheets(2).Select
If NHI1.Value = True Then
[V4:V72] = 1
LabelNHI.Caption = "Slightly important"
```

```
End If
End Sub
Private Sub NHI2_Click()
Sheets(2).Select
If NHI2.Value = True Then
[V4:V72] = 2
LabelNHI.Caption = "Moderately important"
End If
End Sub
Private Sub NHI3_Click()
Sheets(2).Select
If NHI3.Value = True Then
[V4:V72] = 3
LabelNHI.Caption = "Very important"
End If
End Sub
Private Sub NHI4_Click()
Sheets(2).Select
If NHI4.Value = True Then
[V4:V72] = 4
LabelNHI.Caption = "Extremely important"
End If
End Sub
```

<u>STEP_2</u>

```
Private Sub CommandButton1_Click()
STEP_2.Hide
STEP_3.Show
End Sub
Private Sub CommandButton2_Click()
STEP_2.Hide
STEP_1.Show
End Sub
Private Sub Step1_Click()
STEP_2.Hide
STEP_1.Show
End Sub
```

```
Private Sub Step3_Click()
STEP_2.Hide
STEP_3.Show
End Sub
Private Sub Step4_Click()
STEP_2.Hide
STEP_4.Show
End Sub
Private Sub Welcome_Click()
STEP_2.Hide
Welcome_1.Show
End Sub
Private Sub UserForm_Initialize()
Dim c As Range
Dim msgAddress As String
msgAddress = ""
For Each c In Sheets(2).Range("AB1AB10")
If c <> "" Then msgAddress = msgAddress & c.Value & " " & vbNewLine &
vbNewLine
Next
With STEP_2
Label1.Caption = msgAddress
End With
End Sub
```

STEP_3

```
Private Sub CommandButton1_Click()
STEP_3.Hide
STEP_4.Show
End Sub
Private Sub CommandButton2_Click()
STEP_3.Hide
STEP_2.Show
End Sub
Private Sub Step1_Click()
STEP_3.Hide
STEP_1.Show
```

```
End Sub
Private Sub Step2_Click()
STEP_3.Hide
STEP_2.Show
End Sub
Private Sub Step4_Click()
STEP_3.Hide
STEP_4.Show
End Sub
Private Sub Welcome_Click()
STEP_3.Hide
Welcome_1.Show
End Sub
```

STEP_4

```
Private Sub ComboBox1_Change()
userMsg = ComboBox1
Sheets(3).Select
If userMsg <> "" Then
[A2] = userMsg
End If
End Sub
Private Sub CommandButton2_Click()
STEP_4.Hide
STEP_3.Show
End Sub
Private Sub Step1_Click()
STEP_4.Hide
STEP_1.Show
End Sub
Private Sub Step2_Click()
STEP_4.Hide
STEP_2.Show
End Sub
Private Sub Step3_Click()
STEP_4.Hide
STEP_3.Show
```

```
End Sub
Private Sub Welcome_Click()
STEP_4.Hide
Welcome_1.Show
End Sub
```

Appendix E

PHP code for online system

Configuration File

```
<?php
/*
======================= QUESTIONS ====================
*/
require ('_config.php');
/*
------------------------------------ page -----------------------------------
*/
setRs("DROP TABLE IF EXISTS `page`");
setRs("CREATE TABLE `page` (
`page_id` int(11) NOT NULL auto_increment,
`page_name` varchar(255) default NULL,
`title` varchar(255) default NULL,
`header1` varchar(255) default NULL,
`content1` text,
`content2` text,
`content3` text,
`meta_title` varchar(255) default NULL,
`meta_description` text,
`meta_keywords` text,
`sort` int(11) NOT NULL default 0,
`is_home` int(1) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`page_id`)
)");
setRs("INSERT INTO page (title, header1, content1, meta_title, date_created,
date_modified) VALUES ('Welcome','Hi','Floodengage is a trial University of
Wollongong decision support system developed to facilitate your investigation of
```

```
floodplain management measures for the Black Creek Catchment. The answers you provide over the next 4 steps (approx. 5mins) will be considered by Cessnock City Council. This will allow you to contribute to the decision making process of reducing the social and economic damages of flooding in your local area.','Floodengage | Decision Support System','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, content1, meta_title, date_created, date_modified) VALUES ('Assigning Weights','Please select how important is it to you that the flood management option','Floodengage | Assigning Weights','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, content1, content2, content3, meta_title, date_created, date_modified) VALUES ('Recommendations','Based on your inputs these are your most preferred options in order. Click on each option to see why?','If you are not happy with the ordering of these options, please re-rank the options in the next step.','Please assign weightings to all options in Step 1 before proceeding.','Floodengage | Recommendations','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, content1, content3, meta_title, date_created, date_modified) VALUES ('Ranking','Please re-rank these options from most prefered to least prefered. Once you are happy with your ranking, please press Next.','Please assign weightings to all options in Step 1 before proceeding.','Floodengage | Ranking','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, content1, content3, meta_title, date_created, date_modified) VALUES ('Comments','Please leave comments about the options or discuss alternative solutions.','Please assign weightings to all options in Step 1 before proceeding.','Floodengage | Comments','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, content1, content3, meta_title, date_created, date_modified) VALUES ('Complete','Thank you for your input.','Please assign weightings to all options in Step 1 before proceeding.','Floodengage | Complete','" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, header1, is_home, date_created, date_modified) VALUES ('the flood issues','The Flood Issues',1,'" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, header1, is_home, date_created, date_modified) VALUES ('the management measure','The Management Measure',1,'" . time() . "','" . time() . "')");
setRs("INSERT INTO page (title, header1, is_home, date_created, date_modified) VALUES ('the Floodengage program','The Floodengage Program',1,'" . time() . "','" . time() . "')");
/*
------------------------------------ answer -----------------------------------
```

```
*/
setRs("DROP TABLE IF EXISTS `answer`");
setRs("CREATE TABLE `answer` (
`answer_id` int(11) NOT NULL auto_increment,
`answer_name` varchar(255) default NULL,
`weight` int(11) NOT NULL default 0,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`answer_id`)
)");
setRs("INSERT INTO answer (answer_name, weight, date_created, date_modified)
VALUES ('Not at all important',0,'" . time() . "','" . time() . "')");
setRs("INSERT INTO answer (answer_name, weight, date_created, date_modified)
VALUES ('Slightly important',1,'" . time() . "','" . time() . "')");
setRs("INSERT INTO answer (answer_name, weight, date_created, date_modified)
VALUES ('Moderately important',2,'" . time() . "','" . time() . "')");
setRs("INSERT INTO answer (answer_name, weight, date_created, date_modified)
VALUES ('Very important',3,'" . time() . "','" . time() . "')");
setRs("INSERT INTO answer (answer_name, weight, date_created, date_modified)
VALUES ('Extremely important',4,'" . time() . "','" . time() . "')");
/*
------------------------------------ question ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `question`");
setRs("CREATE TABLE `question` (
`question_id` int(11) NOT NULL auto_increment,
`question_name` varchar(255) default NULL,
`description` text,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`question_id`)
```

```
)");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Improves community access and recreational use:','" . time() . "','" . time() .
"')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Does not disadvantage individual members of the community:','" . time() .
"','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Provides safety to the community during flooding:','" . time() . "','" . time() .
"')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Raises community awareness and understanding of the local flood risk:','" .
time() . "','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Does not threaten local plants and animals and their habitat:','" . time() .
"','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Does not cause water quality issues:','" . time() . "','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Initial costs (i.e design / construction) require minimal council
expenditure:','" . time() . "','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Requires minimal ongoing council expenditure after implementation:','" .
time() . "','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Reduces flood damages to the community:','" . time() . "','" . time() . "')");
setRs("INSERT INTO question (question_name, date_created, date_modified)
VALUES ('Does not cause negative flood impacts to other areas (both upstream and
downstream):','" . time() . "','" . time() . "')");
/*
------------------------------------ option_type ------------------------------------
*/

setRs("DROP TABLE IF EXISTS `option_type`");
setRs("CREATE TABLE `option_type` (
`option_type_id` int(11) NOT NULL auto_increment,
`option_type_name` varchar(255) default NULL,
```

```
`description` text,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`option_type_id`)
)");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Flood Management Measure-Exclusion of floodwater','" . time() . "','" .
time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Flood Management Measure-Containment of floodwater','" . time() . "','" .
time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Flood Management Measure-Conveyance of floodwater','" . time() . "','" .
time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Existing Building Management Measure','" . time() . "','" . time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Future Building Management Measure','" . time() . "','" . time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Land Use Planning Management Measure','" . time() . "','" . time() . "')");
setRs("INSERT INTO option_type (option_type_name, date_created, date_modified)
VALUES ('Emergency Management Measure','" . time() . "','" . time() . "')");
/*
------------------------------------ option ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `options`");
setRs("CREATE TABLE `options` (
`option_id` int(11) NOT NULL auto_increment,
`option_type_id` int(11) NOT NULL default 0,
`option_name` varchar(255) default NULL,
`description` text,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
```

```
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`option_id`)
)");
setRs("INSERT INTO options (option_type_id, option_name, description,
date_created, date_modified) VALUES (1, 'Earthen Levee','<img
src=\"media/page/earthen_levee.jpg\" width=\"279\" height=\"177\" alt=\"Earthen
Levee\" align=\"right\" />
/*
------------------------------------ question_option ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `question_option`");
setRs("CREATE TABLE `question_option` (
`question_option_id` int(11) NOT NULL auto_increment,
`question_id` int(11) NOT NULL default 0,
`option_id` int(11) NOT NULL default 0,
`weight` int(11) NOT NULL default 0,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`question_option_id`)
)");
/*
------------------------------------ users ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `users`");
setRs("CREATE TABLE `users` (
`user_id` int(11) NOT NULL auto_increment,
`city_id` int(11) NOT NULL default 0,
`user_name` varchar(255) default NULL,
`first_name` varchar(255) default NULL,
`last_name` varchar(255) default NULL,
`email` varchar(255) default NULL,
`comment` mediumtext,
`ip_address` varchar(15) default NULL,
```

```
`user_agent` varchar(255) default NULL,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`user_id`)
)");
/*
------------------------------------ city ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `city`");
setRs("CREATE TABLE `city` (
`city_id` int(11) NOT NULL auto_increment,
`city_code` varchar(255) default NULL,
`city_name` varchar(255) default NULL,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`city_id`)
)");
setRs("INSERT INTO city (city_code, city_name, date_created, date_modified)
VALUES ('cessnock', 'Cessnock','" . time() . "','" . time() . "')");
setRs("INSERT INTO city (city_code, city_name, date_created, date_modified)
VALUES ('shellharbour', 'Shell Harbour','" . time() . "','" . time() . "')");
/*
------------------------------------ user_question ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `user_question`");
setRs("CREATE TABLE `user_question` (
`user_question_id` int(11) NOT NULL auto_increment,
`user_id` int(11) NOT NULL default 0,
`question_id` int(11) NOT NULL default 0,
`answer_id` int(11) NOT NULL default 0,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
```

```
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`user_question_id`)
)");
/*
------------------------------------ user_option ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `user_option`");
setRs("CREATE TABLE `user_option` (
`user_option_id` int(11) NOT NULL auto_increment,
`user_id` int(11) NOT NULL default 0,
`option_id` int(11) NOT NULL default 0,
`weight` int(11) NOT NULL default 0,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`user_option_id`)
)");
/*
------------------------------------ admin ------------------------------------
*/
setRs("DROP TABLE IF EXISTS `admin`");
setRs("CREATE TABLE `admin` (
`admin_id` int(11) NOT NULL auto_increment,
`admin_name` varchar(50) default NULL,
`access_level_id` int(11) NOT NULL default 1,
`username` varchar(50) default NULL,
`password` varchar(50) NOT NULL,
`email` varchar(50) default NULL,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`admin_id`)
)");
```

```
------------------------------------ access_level -----------------------------------
*/
setRs("DROP TABLE IF EXISTS `access_level`");
setRs("CREATE TABLE `access_level` (
`access_level_id` int(11) NOT NULL auto_increment,
`access_level_name` varchar(50) default NULL,
`sort` int(11) NOT NULL default 0,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY  (`access_level_id`)
)");
setRs("INSERT INTO access_level (access_level_name, date_created,
date_modified) VALUES ('Admin','" . time() . "','" . time() . "')");
------------------------------------ setting -----------------------------------
*/
setRs("DROP TABLE IF EXISTS `setting`");
setRs("CREATE TABLE `setting` (
`setting_id` int(11) NOT NULL auto_increment,
`setting_name` varchar(255) default NULL,
`setting_value` varchar(255) default NULL,
`is_enabled` int(1) NOT NULL default 1,
`is_active` int(1) NOT NULL default 1,
`date_created` int(11) default NULL,
`date_modified` int(11) default NULL,
PRIMARY KEY (`setting_id`)
)");
setRs("INSERT INTO setting (setting_name, setting_value, date_created,
date_modified) VALUES ('# options to recommend','10','" . time() . "','" . time() . "')");
$i = 0;
foreach ($a as $j) {
        $i++;
  setRs("INSERT INTO question_option (option_id, question_id, weight, date_created,
date_modified) VALUES (56,{$i},{$j}," . time() . "," . time() . ")");
}
echo "<p>all tables updated successfully</p>";
```

```
?>
```

Index

```
<?php
include ('inc/header.php');
?>
          <div class="banner">
          <table>
          <tr>
          <th><?php echo $header1; ?></th>
         <td><?php echo $content1; ?></td>
       </tr>
     </table>
   </div>

   <div class="home">
     <div class="home_left">
     <a href="/start.php" class="start">Start</a>
     </div>
     <div class="home_mid">
       OR
     </div>
     <div class="home_right">
       <div class="learn_more">
         <h4>Learn about</h4>
         <div class="learn">
          <?php
$rs = getRs("SELECT page_id, title FROM page WHERE is_home = 1 AND " . is_enabled() . " ORDER BY sort, page_id");
          $i = 1;
          while ($row = mysql_fetch_assoc($rs)) {
          echo '<a href="/page.php?id=' . $row['page_id'] . '">
            <span class="num" style="text-decoration:none;border:0">' . $i++ . '.</span><span class="txt">' . $row['title'] . '</span>
          </a>
                                    ';
                                    }
```

```
                                                    ?>
          </div>
        </div>
      </div>
      <div class="clr"></div>
    </div>

<?php
include ('inc/footer.php');
?>
<?php
require_once('inc/init.php');
```

<u>start</u>

```
$rs = $user->getQuestions(true);
if ( mysql_affected_rows() > 0 ) {
        $_SESSION['user_id'] = 0;
}
redirectTo('step1.php');
?>
```

<u>Step 1</u>

```
<?php
$page_id = 2;
include ('inc/header.php');
$rs = $user->getQuestions();
$q = '';
$p = '';
$i = 0;
while ($row = mysql_fetch_assoc($rs)) {
        $i++;
        $q .= '<li id="question_' . $row['question_id'] . '" class="question_' . $i . '"><a href="question.php?id=' . $row['question_id'] . '" title="About">' . $row['question_name'] . '</a></li>';
        $p .= '<a href="javascript:void(0)" id="question_sel_' . $row['question_id'] . '" rel="' . $row['answer_id'] . '" title="' . $row['answer_name'] . '" class="question_sel question_sel_' . $i . '">' . $i . '</a> ';
```

```
}
$rs = $user->getAnswers();
$ans = '';
$i = 0;
while ($row = mysql_fetch_assoc($rs)) {
        $i++;
        $ans .= '<a href="javascript:void(0)" id="select_' . $row['answer_id'] . '"
class="select_' . $i . '" title="' . $row['answer_name'] . '" hidefocus="hidefocus"></a>';
}
?>
  <div class="questions_block">
    <div class="instr"><?php echo $content1; ?></div>
    <ul class="questions">
        <?php echo $q; ?>
    </ul>
    <div class="question_sels">
        <?php echo $p; ?>
    </div>
    <div class="dail">
        <div class="gauge_preview rotate_1_preview hide"></div>
        <div class="gauge rotate_1"></div>
        <h4 class="error">Please select weighting</h4>
        <h5></h5>
      <div class="btns_gauge">
        <?php echo $ans; ?>
        <div class="clr"></div>
      </div>
    </div>
  </div>

  <div class="btns">
        <a href="index.php" class="back">Back</a><a href="step2.php"
class="next">Next Step</a>
  </div>
  <?php
include ('inc/footer.php');
?>
```

Step 2

```
<?php
$page_id = 3;
include ('inc/header.php');

$rs = $user->getOptions(true);

if ( mysql_affected_rows() > 0 ) {

?>

		<p><?php echo $content1; ?></p>
  <ul class="questions_list">
    <?php
    while ($row = mysql_fetch_assoc($rs)) {
						echo '<li id="option_' . $row['option_id'] . '"><a href="option.php?id=' . $row['option_id'] . '">' . $row['option_name'] . ' <span>- ' . $row['option_type_name'] . '</span></a></li>';
				}
				?>
  </ul>
  <p><?php echo $content2; ?></p>
  <div class="btns">
		<a href="step1.php" class="back">Back</a><a href="step3.php" class="next">Next Step</a>
  </div>
  <?php
}
else {
  echo '<p>' . $content3 . '</p>
  <div class="btns">
		<a href="step1.php" class="back">Back</a>
  </div>';
}
include ('inc/footer.php');
?>
```

Step 3

```
?php
$page_id = 4;
include ('inc/header.php');
$rs = $user->getOptions(true, true);
if ( mysql_affected_rows() > 0 ) {
?>
        <p><?php echo $content1; ?></p>
  <ol class="questions_list sortable">
    <?php
                $i = 0;
    while ($row = mysql_fetch_assoc($rs)) {
                        $i++;
                        echo '<li id="option_' . $row['option_id'] . '"><span
class="num">' . $i . '.</span>' . $row['option_name'] . ' <span>- ' .
$row['option_type_name'] . '</span></li>';
                        //echo '<li id="option_' . $row['option_id'] . '"><span
class="move_icon"></span><a href="option.php?id=' . $row['option_id'] . '">' .
$row['option_name'] . ' <span>- ' . $row['option_type_name'] . '</span></a><div
class="clr"></div></li>';
                }
                ?>
  </ol>
  <div class="btns">
        <a href="step2.php" class="back">Back</a><a href="step4.php"
class="next">Next Step</a>
  </div>

<?php
}
else {
  echo '<p>' . $content3 . '</p>
  <div class="btns">
        <a href="step1.php" class="back">Back</a>
  </div>';
}
```

```
include ('inc/footer.php');
?>
```

Step 4

```
<?php
$page_id = 5;
include ('inc/header.php');
$rs = $user->getOptions(true, true);
if ( mysql_affected_rows() > 0 ) {
	$rs = $user->getFollowups();
  echo '<form action="javascript:void(0)" id="followups">';
		while ( $row = mysql_fetch_assoc($rs) ) {
		if ( strlen($row['description']) == 0 ) {
			echo '<p>' . $row['followup_name'] . '</p>';
		}
		else {
			echo '<p><a href="followup.php?id=' . $row['followup_id'] . '" title="About">' . $row['followup_name'] . '</a></p>';
		}

		$rs1 = $user->getFollowupOptions($row['followup_id']);
		switch ( $row['followup_type_id'] ) {
			case 1:
				echo '<select id="followup_' . $row['followup_id'] . '" class="followup">';
				echo '<option value="">- Select -</option>';
				while ($row1 = mysql_fetch_assoc($rs1)) {
					echo '<option value="' . $row1['followup_option_id'] . '">' . $row1['followup_option_name'] . '</option>';
				}
				echo '</select>';
			break;
			case 2:
				echo '<div id="followup_' . $row['followup_id'] . '" class="followup followup-options">';
				while ($row1 = mysql_fetch_assoc($rs1)) {
```

```
					echo		'<label><input		type="checkbox"
name="followup_' . $row['followup_id'] . '" value="' . $row1['followup_option_id'] . '" /> '
. $row1['followup_option_name'] . '</label>';
				}
				echo '</div>';
			break;
			case 3:
				echo '<textarea name="followup_' . $row['followup_id'] .
'" id="followup_' . $row['followup_id'] . '" rows="3" class="followup"></textarea>';
			break;
		}
	}
	echo '
  </form>
    <div class="btns">
	<a		href="step3.php"		class="back">Back</a><a
href="javascript:void(0)"id="btn_followup" class="next">Submit</a>
    <span id="followup_status"></span>
  </div>';
}
else {
  echo '<p>' . $content3 . '</p>
  <div class="btns">
	<a href="step1.php" class="back">Back</a>
  </div>';
}
include ('inc/footer.php');
?>
```

As outlined in the acknowledgements, PHP and MySQL coding was developed with assistance from Wanta Digital. Without their support, database functionality would have been limited. An individual thankyou goes to Al, for enduring the constant stream of questions and providing robust solutions.

Appendix F

Floodengage- Horsley Creek FRMS&P online community consultation report

Floodengage

2013

Horsley Creek FRMS&P Online Community Consultation Report

Document Control

Project Title	Horsley Creek Catchment Online Community Consultation Report
Synopsis	This report summarises community submissions collected through Floodengage- a trial online engineering engagement decision support system for the Horsley Creek Floodplain Risk Management Study and Plan. This document does not summarise nor represent submissions submitted to Shellharbour City Council through other formats i.e: paper based surveys.
Prepared for	Shellharbour City Council
Prepared by	Raymond Laine PhD Candidate, University of Wollongong RAYMOND LAINÉ 3 February 2014

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1. Overview

Floodengage- a trial engineering engagement decision support system currently being developed by PhD candidate Raymond Laine was utilised by Shellharbour City Council to supplement traditional mail-out paper based submissions for the Horsley Creek Floodplain Risk Management Study and Plan. The online Floodengage consultation was launched on the 30th of May 2013 by Shellharbour Mayor Marianne Saliba, Engineering Dean Professor Chris Cook and Raymond Laine with the website www.floodengage.com/shellhabour remaining open for submissions until July 12th 2013. During this consultation period the Floodengage website received some 592 website views. Of these views 47 valid responses were submitted. 30 respondents (64%) ranked local flood policies and development controls their most preferred floodplain management measure of the 18 options listed.

2. Introduction

The premise behind Floodengage is to provide a mechanism for stakeholders (community members, councillors, developers, planners, engineers etc.) to learn about, rank and make informed decisions about floodplain management options for the particular catchment being investigated. Floodengage is a 4 step web-based decision support system that operates by:

1) The consultant with their expertise in floodplain management develops a list of options that may be suitable for the catchment (Figure 1).

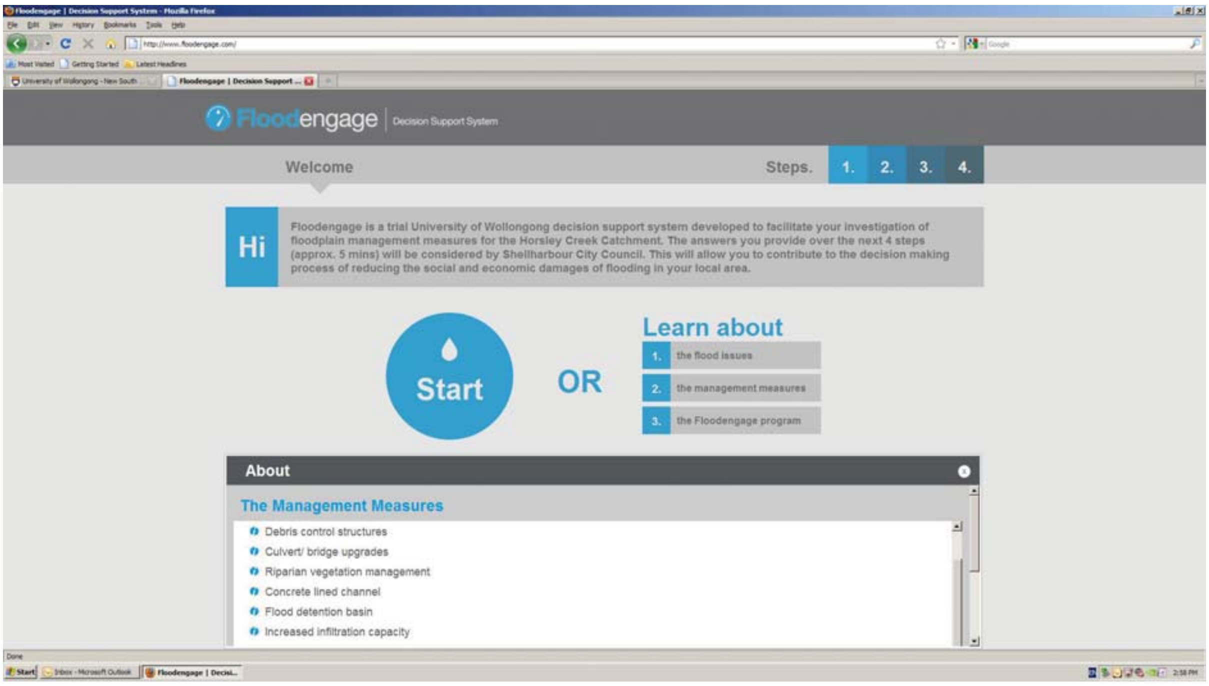


Fig 1: Floodengage welcome screen and management measure information portal.

2) Ray Laine from the University of Wollongong with input from various experts, assigns justifiable and consistent scores to the floodplain management options for social, safety, environmental/ecological, economic and flood behaviour constraints and enters it into a matrix.

3) The stakeholder assigns an importance weighting for each of the 10 constraints asked (Step 1)(Figure 2).

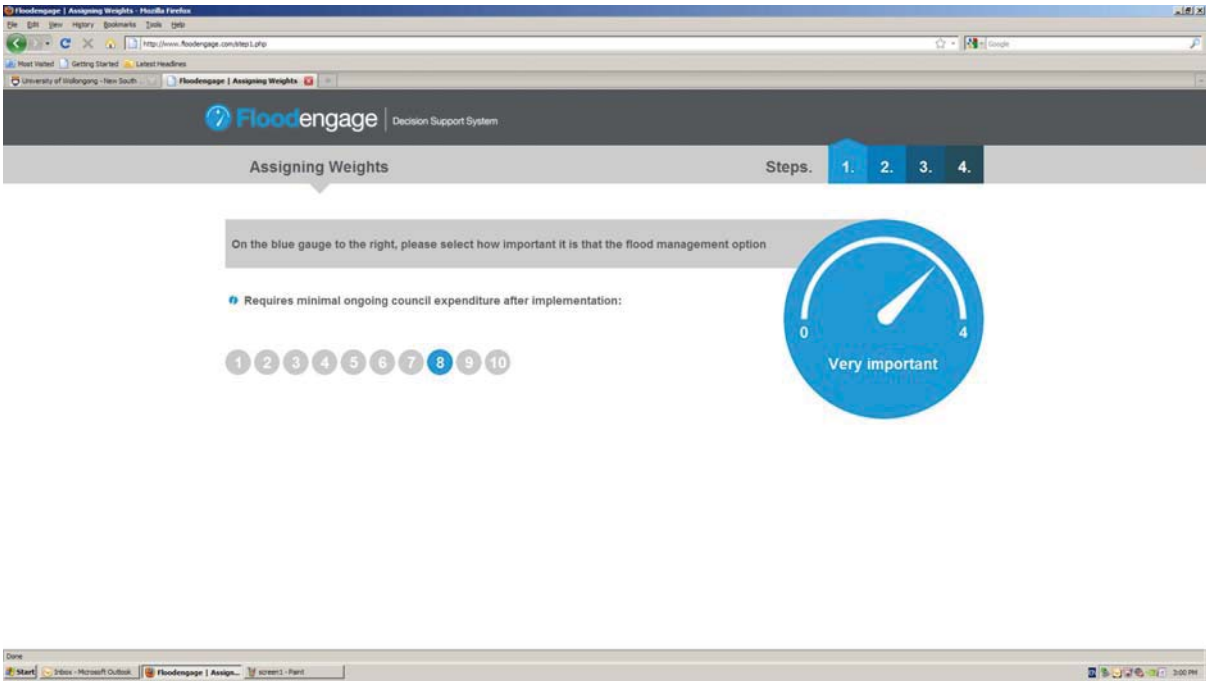


Fig 2: Floodengage step 1- user based importance weighting for various constraints.

4) This stakeholder data is then aggregated and inputted, combining the weights and scores for each option in the matrix to derive equitably ranked preferences. (Step 2)(Figure 3). It is hoped that the stakeholder investigates why certain options are preferenced and learns about the management options specific advantages/ disadvantages, the governing process and the constraints.

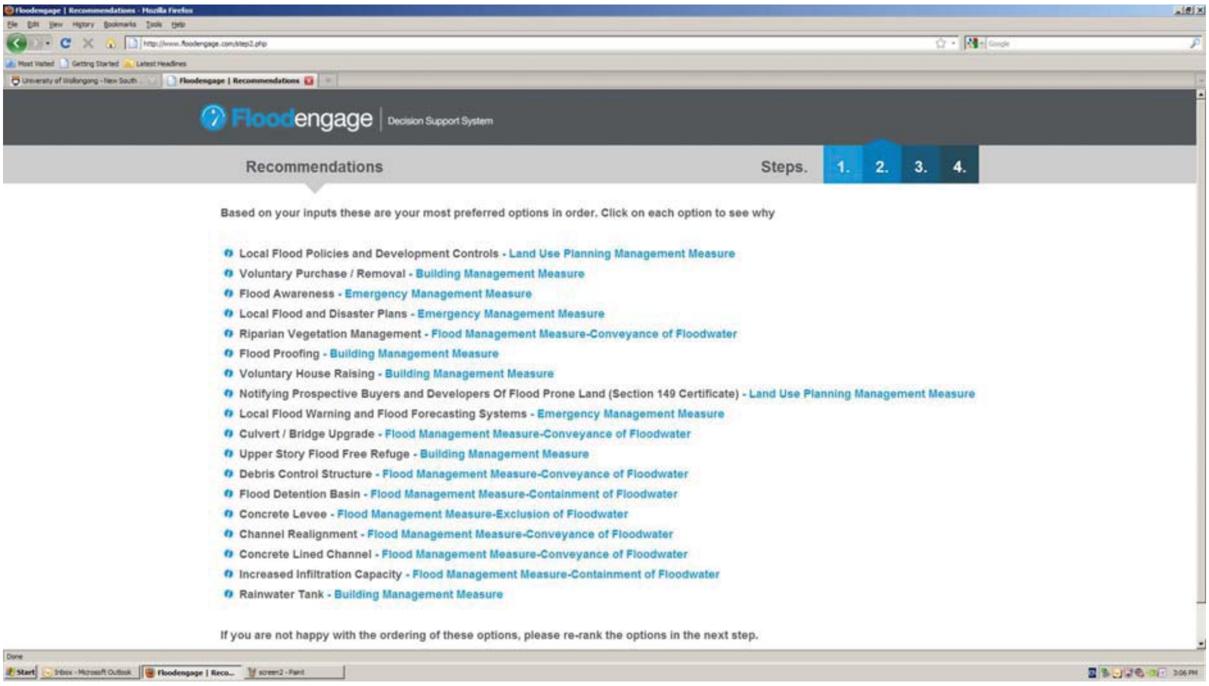


Fig 3: Floodengage step 2- floodplain management option recommendations.

5) The stakeholder can then re-rank the options (hopefully informed about the options advantages and disadvantages) in Step 3 (figure 4).

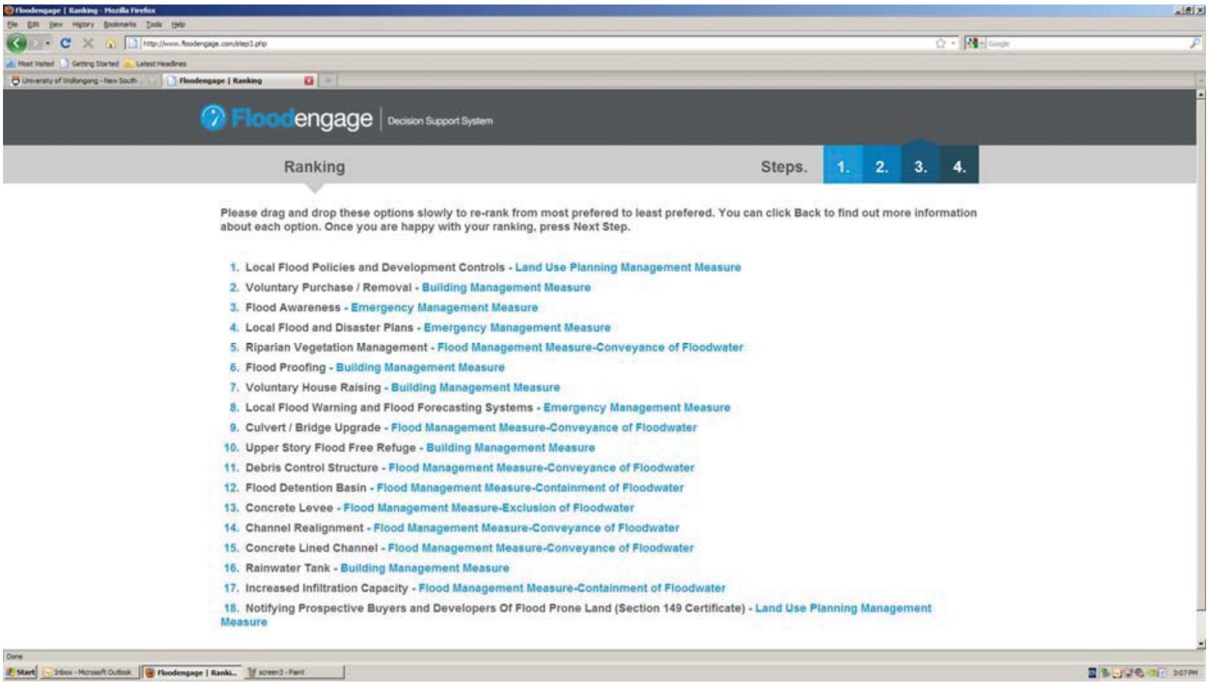


Fig 4: Floodengage step 3- option re-ranking opportunity.

6) The stakeholder is then given the opportunity to provide feedback or list other options that might have been missed, provide survey answers and press submit (figure 5).

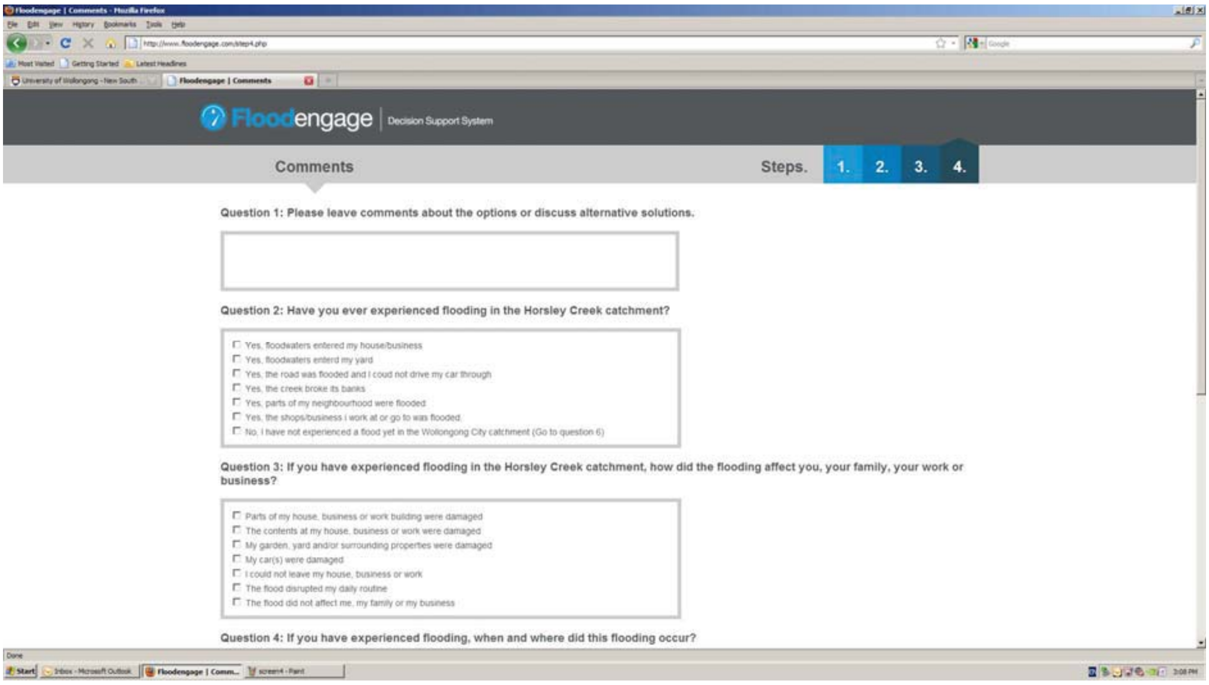


Fig 5: Floodengage step 4- feedback and comments page.

3. Media Release and Launch

A media release was prepared, with the website being launched on the 30th of May 2013 by Shellharbour Mayor Marianne Saliba, Engineering Dean Professor Chris Cook and Raymond Laine via a press gathering and presentation at the SMART Infrastructure Building, University of Wollongong. Press reporting included television (figure 6), radio, print (figure 7) and online media coverage (figure 8). The Floodengage hyperlink was also advertised on the Shellharbour City Council website under the Horsley Creek Floodplain Risk Management Study and Plan banner and located on all mailed paper-based surveys.

Fig 6: Television interview.

City seeking a flood of opinion

ANGELA THOMPSON

SHELLHARBOUR City has adopted an online tool to get residents involved in flooding solutions in the Horsley Creek catchment.

The tool, Floodengage, is an interactive survey devised by a 27-year-old PhD candidate at the University of Wollongong.

Users are asked to rate the importance of 10 different qualities of a flood management plan, including effect on water quality, and maintenance costs.

The result is a list of 18 potential solutions, ranked according to the user's priorities, with their pros and cons explained.

Civil Engineering PhD candidate Raymond Laine (pictured) created Floodengage after he began working in the field and realised the gulf between community expectations of engineering work, and the realities.

"Hopefully people will look at the different options and start realising what the trade-offs are," he said at a launch event yesterday.

Responses from Floodengage will be fed into the flood management plan proposal for the Horsley Creek water catchment area.

The plan proposal covers Albion Park Rail, Croom and western parts of Blackbutt and Oak Flats.

Shellharbour Mayor Marianne Saliba said residents could make a valuable contribution to flood management despite their lack of engineering know-how.

"One of the things the community do have is experience, particularly in my local area where they have lived maybe 40, 50, 60 or 70 years in the same place," she said.

"While they may not have the expertise in engineering, they do have that understanding of what's happened in the past."

The survey will be made available through the council's website, or at floodengage.com/shellharbour, for six weeks until July 12.

Fig 7: Illawarra Mercury article 31/5/2013

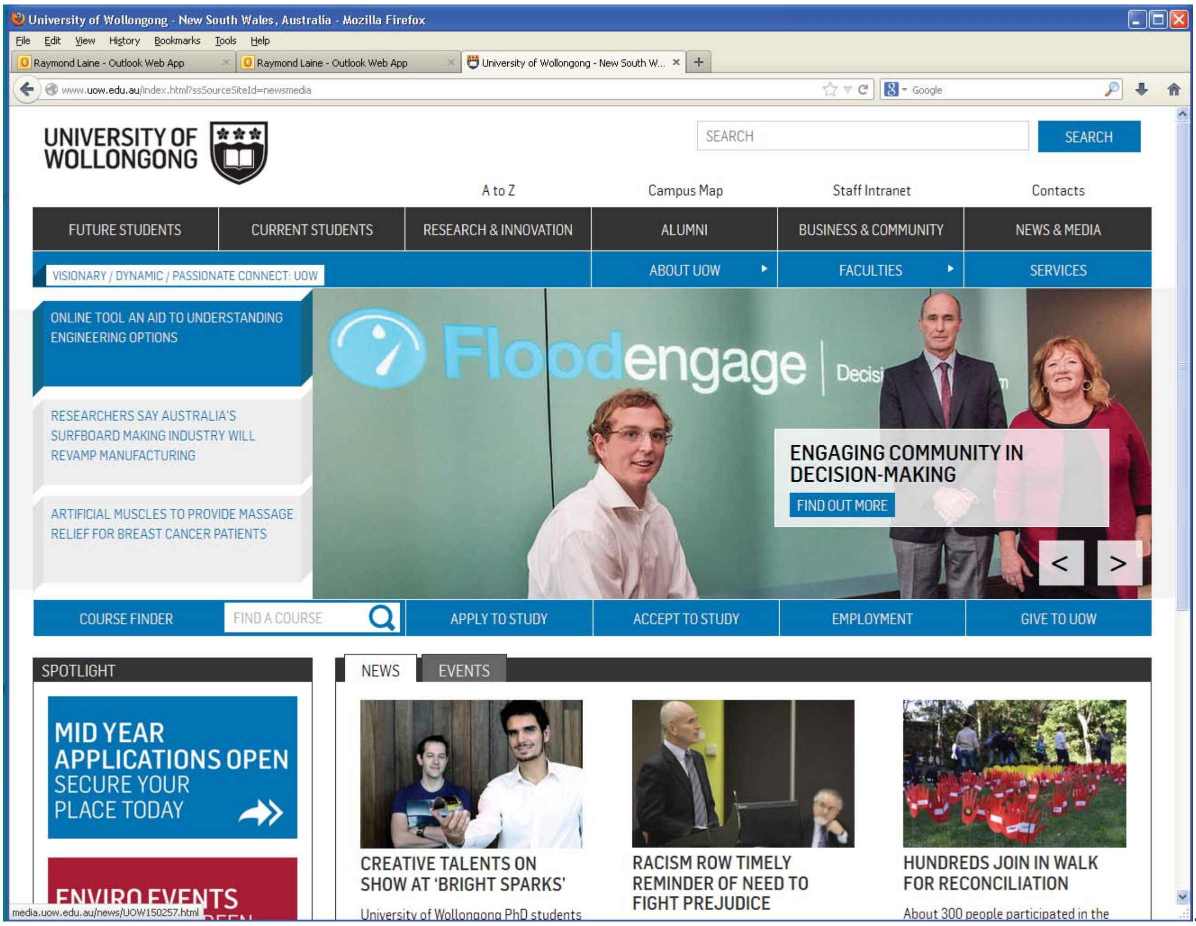


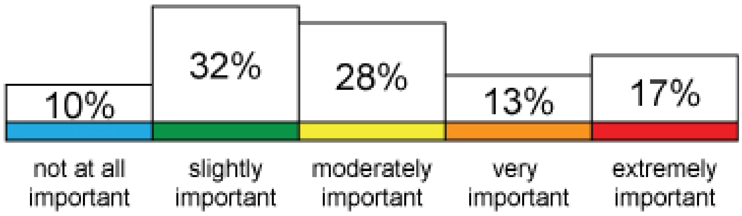
Fig 8: Online media coverage example

4. Submission Summary

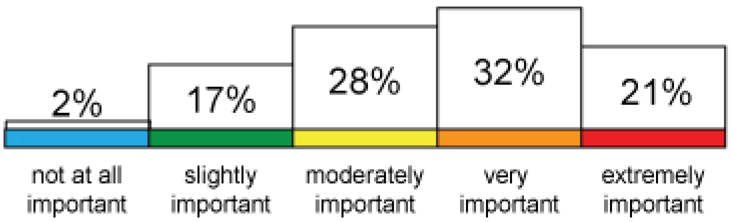
The results of the online Floodengage submissions received are as follows:

Step 1: Respondents importance weights for the 10 constraints.

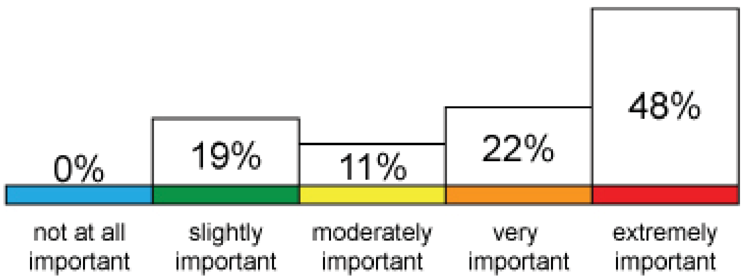
Question 1- How important is it that the flood management option improves community access and recreational use: 32% of respondents believed it was slightly important that floodplain management options improve community access and recreational use. 28% believed it was moderately important with the remaining responses documented below.



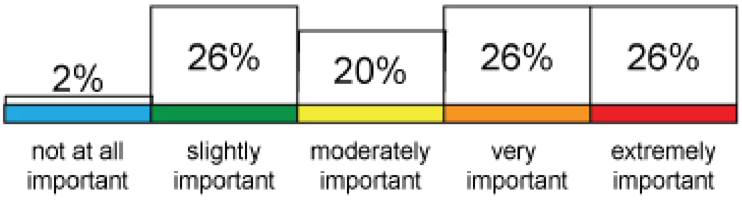
Question 2- How important is it that the flood management option does not disadvantage individual members of the community: 32% of respondents believed it was very important that floodplain management options do not disadvantage individual members of the community. 28% believed it was moderately important with the remaining responses documented below.



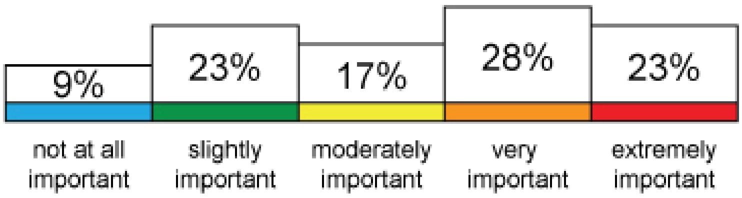
Question 3- How important is it that the flood management option provides safety to the community during flooding: 48% of respondents believed it was extremely important that floodplain management options provide safety to the community during flooding. 22% believed it was very important with the remaining responses documented below.



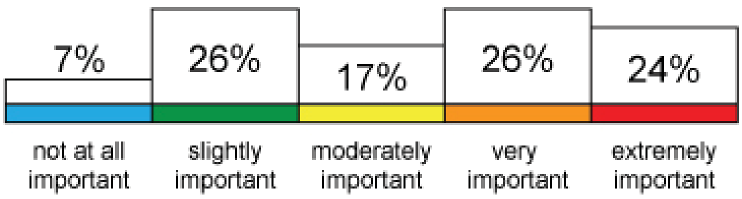
Question 4- How important is it that the flood management option raises community awareness and understanding of the local flood risk: 26% of respondents believed it was extremely important, very important and slightly important that floodplain management options raise community awareness and understanding of the local flood risk with the remaining responses documented below.



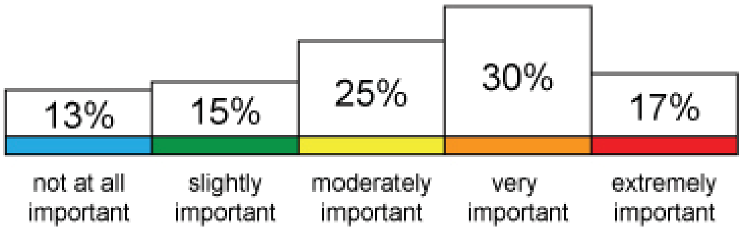
Question 5- How important is it that the flood management option does not threaten local plants and animals and their habitat: 28% of respondents believed it was very important that floodplain management options do not threaten local plants and animals and their habitat. 23% believed it was extremely important and a further 23% believed it was slightly important with the remaining responses documented below.



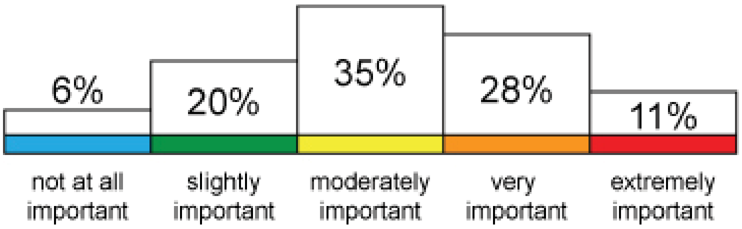
Question 6- How important is it that the flood management options do not cause water quality issues: 26% of respondents believed it was both very important and a further 26% believed it was slightly important that floodplain management options do not cause water quality issues. 24% believed it was extremely important with the remaining responses documented below.



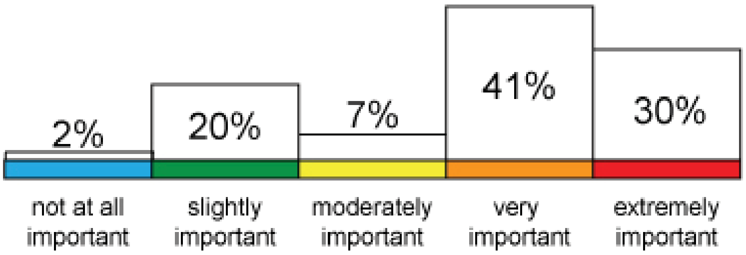
Question 7- How important is it that the flood management options initial costs (i.e. design / construction) require minimal council expenditure: 30% of respondents believed it was very important that floodplain management options initial costs (i.e design / construction) require minimal council expenditure. 25% believed it was moderately important with the remaining responses documented below.



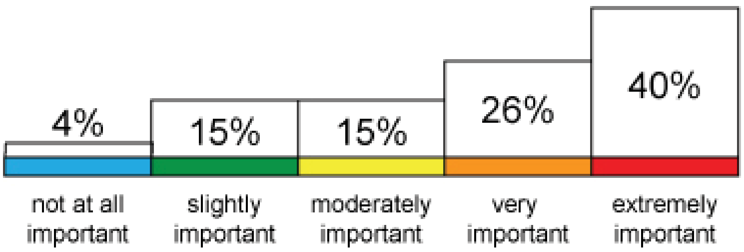
Question 8- How important is it that the flood management option requires minimal ongoing council expenditure after implementation: 35% of respondents believed it was moderately important that floodplain management options require minimal ongoing council expenditure after implementation. 28% believed it was very important with the remaining responses documented below.



Question 9- How important is it that the flood management option reduces flood damages to the community: 41% of respondents believed it was very important that floodplain management options reduce flood damages to the community. 30% believed it was extremely important with the remaining responses documented below.



Question 10- How important is it that the flood management option does not cause negative flood impacts to other areas (both upstream and downstream): 40% of respondents believed it was extremely important that floodplain management options do not cause negative flood impacts to other areas (both upstream and downstream). 26% believed it was very important with the remaining responses documented below.



Step 2: Recommended options.

As a result of the respondents importance weights and expert assigned option scores, the floodplain management measures subsequently ranked:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Local flood warning systems and flood forecasting
7. Voluntary house raising
8. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
9. Riparian vegetation management
10. Upper story flood free refuge
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin
14. Concrete Levee
15. Channel realignment
16. Concrete lined channel
17. Increased infiltration capacity
18. Rainwater tanks

Step 3: Re-ranking

Respondents were given the opportunity to re-rank the floodplain management measures. The final results of this process were:

1. Local flood policies and development controls
2. Flood awareness
3. Flood proofing of buildings
4. Voluntary house purchase / removal
5. Local flood and disaster plans
6. Local flood warning systems and flood forecasting
7. Voluntary house raising
8. Riparian vegetation management
9. Upper story flood free refuge
10. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
11. Debris control structures
12. Culvert/ bridge upgrades
13. Flood detention basin
14. Channel realignment
15. Concrete lined channel
16. Concrete Levee
17. Increased infiltration capacity
18. Rainwater tanks

Local flood policies and development controls were the respondents most preferred floodplain management measure with 30 respondents (64%) ranking it as their 1st preference. A preference scale was developed (figure 9), to visually display the communities level of support for each option from most preferred to least preferred. As indicated a large proportion of respondents strongly favoured local flood policies and development controls as the most preferred management option.

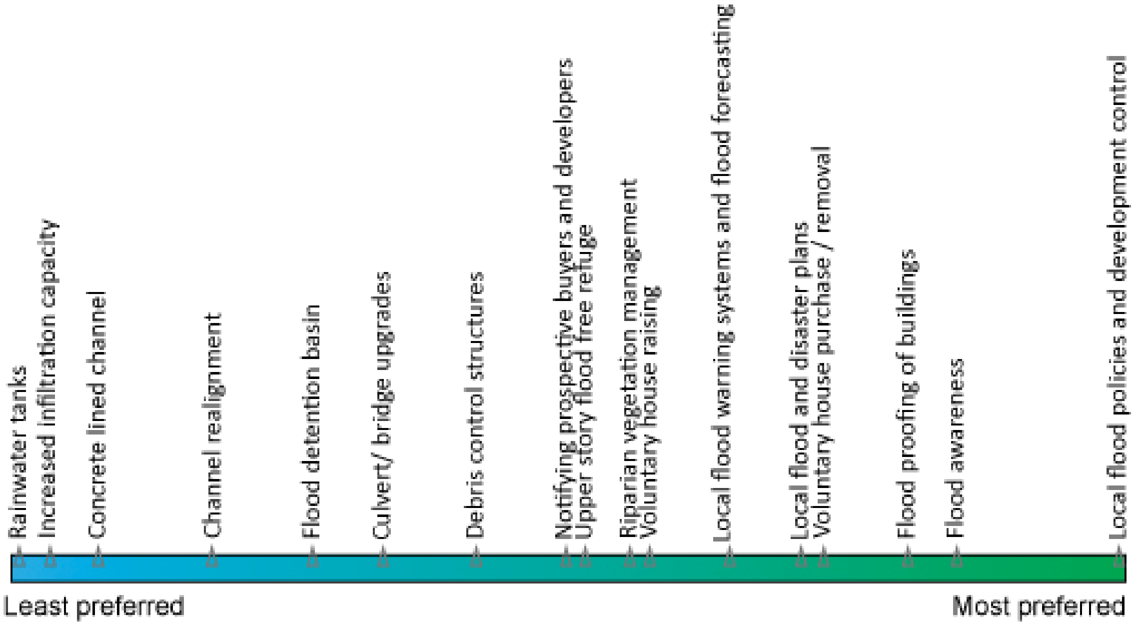


Fig 9: Floodplain management measure preference scale.

5. Conclusion

With 47 valid online submissions, respondents favoured floodplain management measures that provide safety to the community during times of flood, reduce flood damages to the community and do not cause adverse flood impacts. Local flood policies and development controls were the respondents most preferred floodplain management measure followed by flood awareness, with rainwater tanks and increased infiltration capacity measures the least preferred options.

The data collected as part of this trial will be used in conjunction with paper-based survey responses collected by Council to guide the next stage of flood modelling investigations for the Horsley Creek catchment.

The author is grateful to Shellharbour City Council for providing the opportunity to trial Floodengage.

Appendix G

Floodengage- Black Creek FRMS&P online community consultation report

Floodengage

2013

Black Creek Catchment Online Community Consultation Report

Document Control

Project Title	Black Creek Catchment Online Community Consultation Report
Synopsis	This report summarises community submissions collected through Floodengage- a trial online engineering engagement decision support system for the Black Creek Floodplain Risk Management Study and Plan. This document does not summarise nor represent submissions submitted to Cessnock City Council through other formats i.e: paper based surveys.
Prepared for	Cessnock City Council
Prepared by	Raymond Laine PhD Candidate, University of Wollongong RAYMOND LAINÉ 12 January 2014

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1. Overview

Floodengage- a trial engineering engagement decision support system currently being developed by PhD candidate Raymond Laine was utilised by Cessnock City Council to supplement traditional mail-out paper based submissions for the Black Creek Floodplain Risk Management Study and Plan. The online Floodengage consultation was launched on the 26th of September 2013 by Cessnock Mayor Bob Pynsent and Raymond Laine with the website www.floodengage.com/cessnock remaining open for submissions until the 24th of October 2013. During this consultation period the Floodengage website received some 351 website hits. Of these hits 4 valid responses were submitted. 3/4 respondents ranked local flood policies and development controls their most preferred floodplain management measure of the 19 options listed.

2. Introduction

The premise behind Floodengage is to provide a mechanism for stakeholders (community members, councillors, developers, planners, engineers etc.) to learn about, rank and make informed decisions about floodplain management options for the particular catchment being investigated. Floodengage is a 4 step web-based decision support system that operates by:

1) The consultant with their expertise in floodplain management producing a list of options that may be suitable for the catchment (Figure 1).

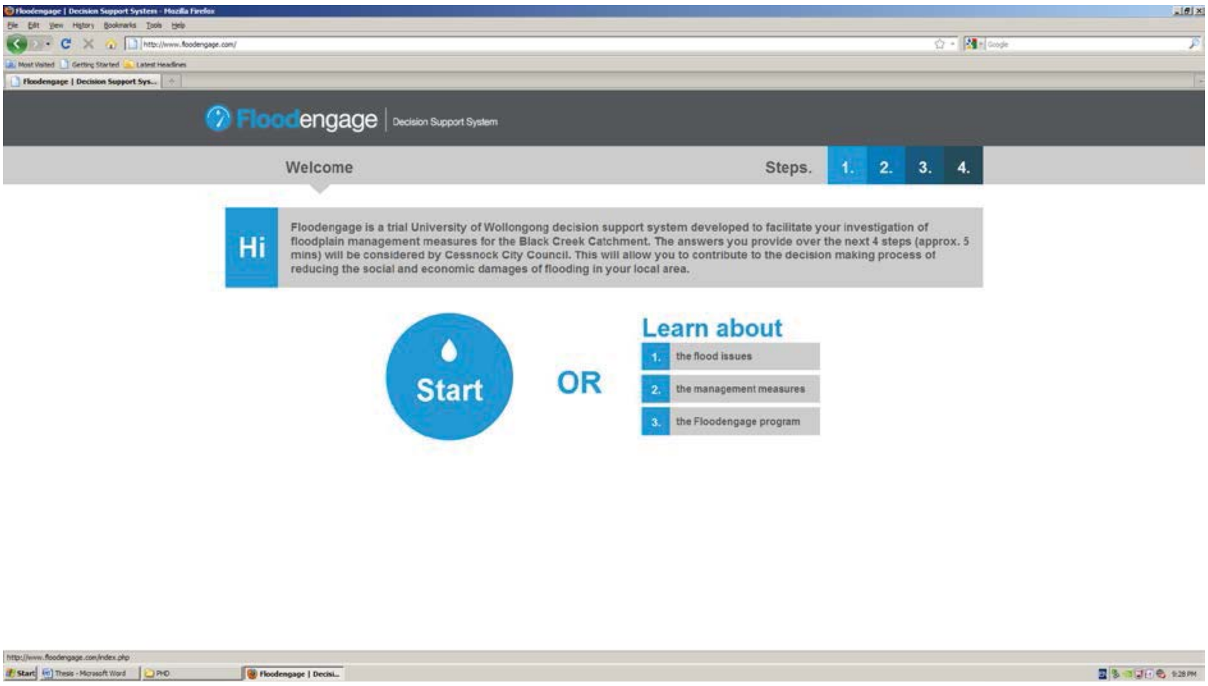


Fig 1: Floodengage welcome screen and information portal.

2) Ray Laine from the University of Wollongong with input from various experts, assigns justifiable and consistent scores to the floodplain management options for social, safety, environmental/ecological, economic and flood behaviour constraints and enters it into the matrix.

3) The stakeholder assigns an importance weighting for each of the 10 constraints asked (Step 1)(Figure 2).

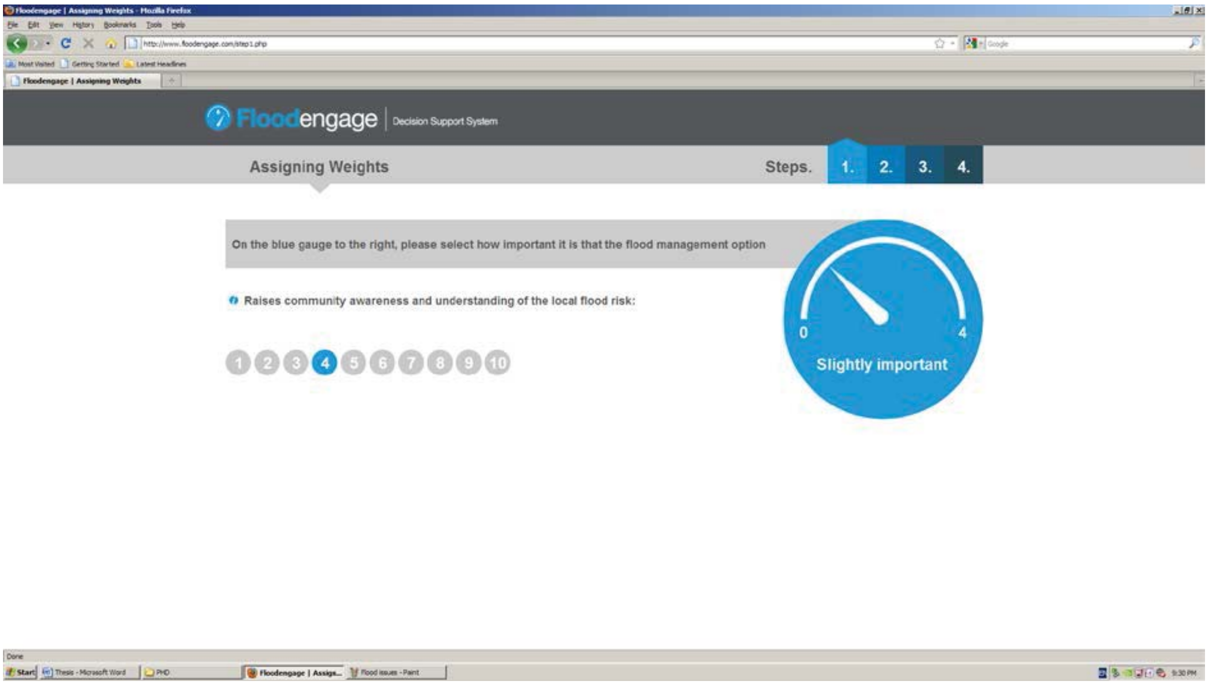


Fig 2: Floodengage step 1- user based importance weighting for various constraints.

4) This stakeholder data is then aggregated and inputted, combining the weights and scores for each option in a matrix to derive equitably ranked preferences. (Step 2)(Figure 3). It is hoped that the stakeholder investigates why certain options are preferenced and learns about the options specific advantages/ disadvantages, the governing process and the constraints.

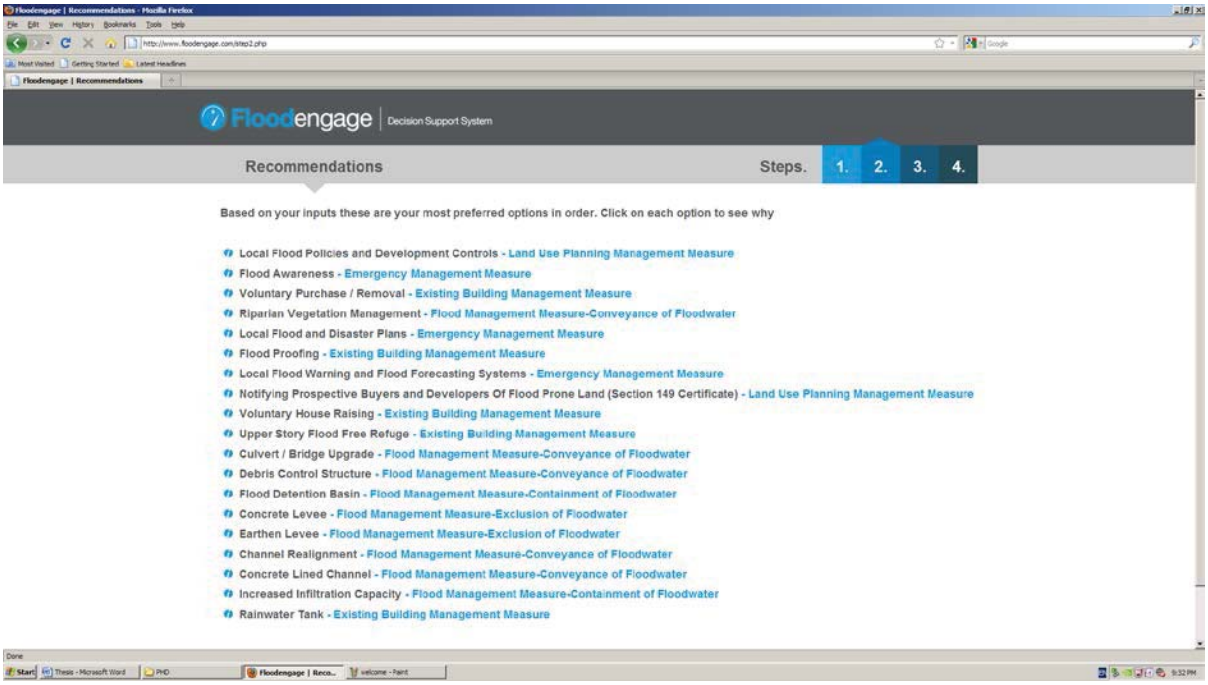


Fig 3: Floodengage step 2- floodplain management option recommendations.

5) The stakeholder can then re-rank the options (hopefully informed about the options advantages and disadvantages) in Step 3 (figure 4).

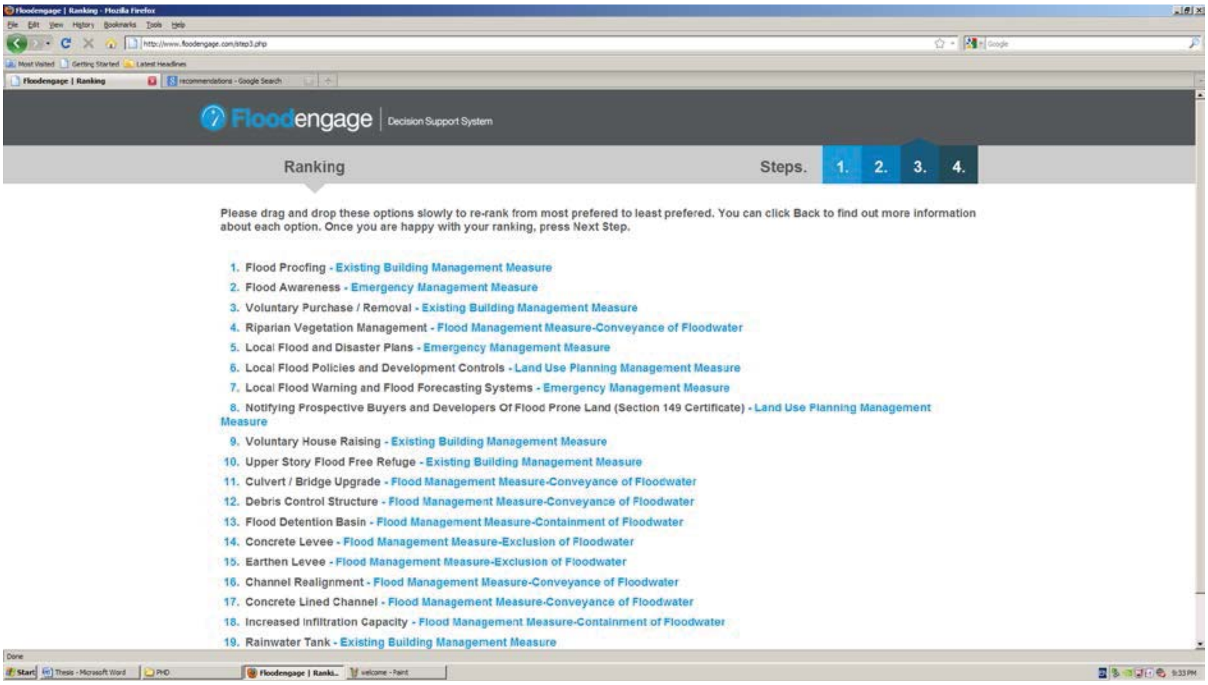


Fig 4: Floodengage step 3- option re-ranking opportunity.

6) The stakeholder is then given the opportunity to provide feedback or list other options that might have been missed, provide survey answers and press submit (figure 5).

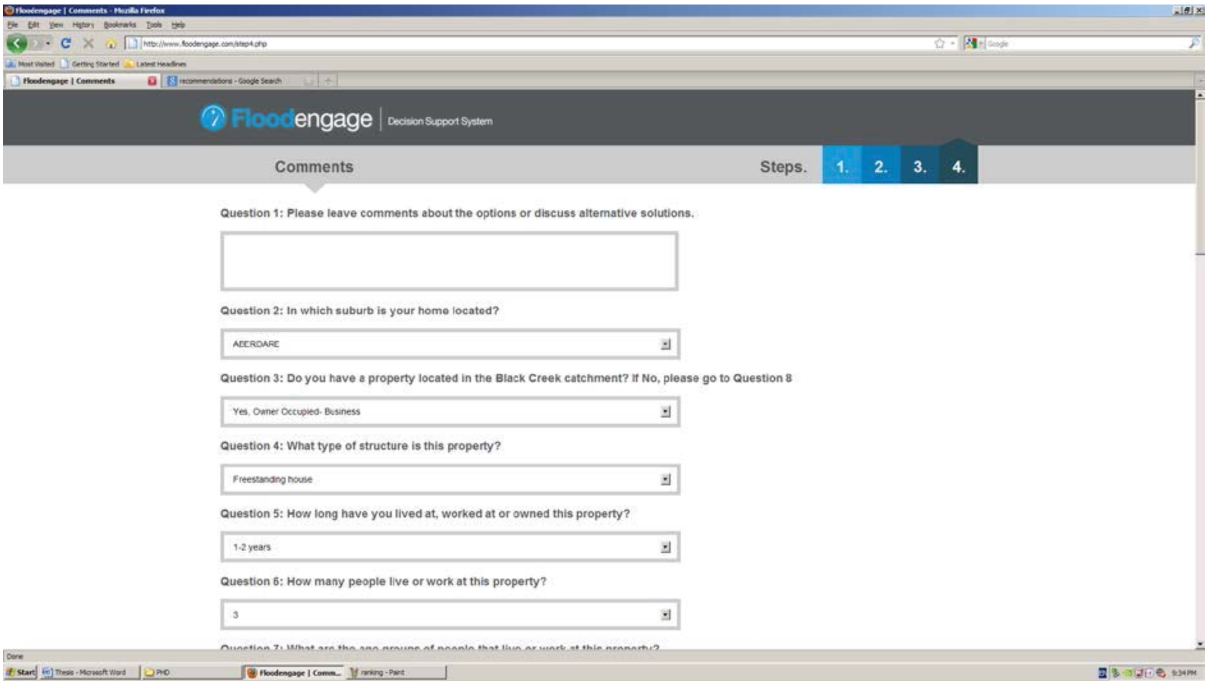
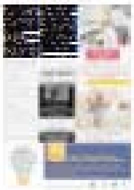


Fig 5: Floodengage step 4- feedback and comments page.

3. Media Release and Launch

A media release was prepared, with the website being launched on the 26th of September 2013 by Cessnock Mayor Bob Pynsent and Raymond Laine. Press coverage included an article in the Cessnock Advertiser on the 3rd of October 2013 (figure 6), and radio interviews with ABC Newcastle and 2NURFM.

iSENTIA



Advertiser (Cessnock), Cessnock NSW
02 Oct 2013

General News, page 7 - 258.42 cm²
Regional - circulation 16,923 (--W---)

ID 216076767 BRIEF CESSNOCK INDEX 1 PAGE 1 of 1

New tool for flood management discussion

Cessnock City residents now have access to an interactive online tool that will allow them get involved and make informed decisions about floodplain management in the Black Creek Catchment area.

Cessnock City Council and the University of Wollongong last Thursday launched FloodEngage – an innovative decision support system that uses engineering judgement, heuristics and latest research with community members' values and knowledge to assist with selecting preliminary floodplain management options for the catchment.

It has been developed by University of Wollongong civil engineering PhD candidate Raymond Laine, who has presented the research both nationally and internationally at various floodplain management conferences.

Mr Laine said the program is designed to get the community thinking subjectively.

"It's about making robust, transparent decisions," he said.

"You don't have to know about engineering; it's just about what you think is important."

Cessnock Mayor Bob Pynsent said he is really excited about the system.

"This is a new and innovative method to get our community involved with Council to identify the way forward when it comes to floodplain management," Cr Pynsent said.

"It is a simple yet practical approach and it will enable residents to examine all the options, use the local knowledge they have and give council feedback regarding what they believe are the most important issues."

In addition to traditional mail-out surveys distributed recently, Cessnock City Council will trial FloodEngage to assist in the development of a new floodplain management plan for the Black Creek Catchment Area.

Community members will be able to anonymously log onto the site at www.floodengage.com/cessnock.

Once logged on they will be able to quickly explore the various floodplain management options, learn about their advantages and disadvantages and provide their recommendations for council's consideration.

This system provides an opportunity for the community to constructively work together with council to reduce the social and economic damages of flooding for the Black Creek Catchment.

FloodEngage is attracting attention from local government authorities in NSW – Cessnock is the second council in NSW to trial the system, after Shellharbour, where the council is currently in the stage of assessing the feasibility of the top options.

University of Wollongong executive dean of engineering and information sciences, Professor Chris Cook said FloodEngage was an excellent example of how the university's research can benefit the community.

"Engineering systems can facilitate and aid informed decision-making about critical engineering options. This decision support system empowers community members in a really practical way to influence flood mitigation and reduce flood threats to life and property," Professor Cook said.

"It also demonstrates the social and community benefit of engineering."

INNOVATIVE: University of Wollongong PhD candidate Ray Laine demonstrates FloodEngage to Mayor of Cessnock, Bob Pynsent.

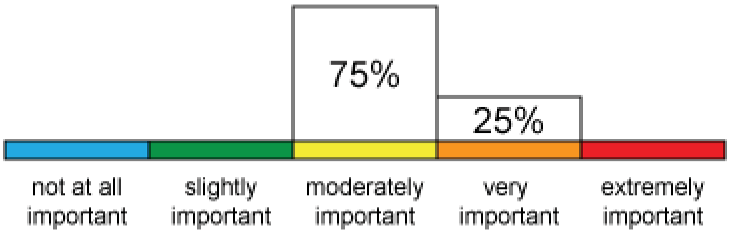
Fig 6: Cessnock Advertiser coverage 3/10/2013 .

4. Submission Summary

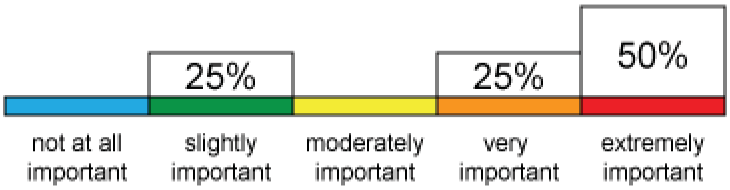
The results of the submissions received are as follows:

Step 1: Respondents importance weights for the 10 constraints.

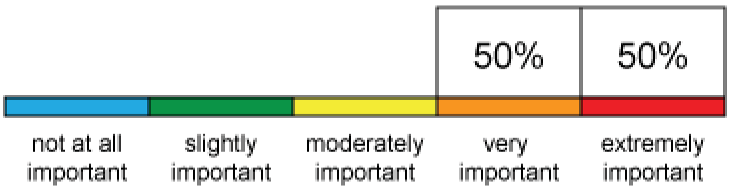
Question 1: 3/4 of respondents believed it was moderately important that floodplain management options improve community access and recreational use. 1/4 believed it was very important.



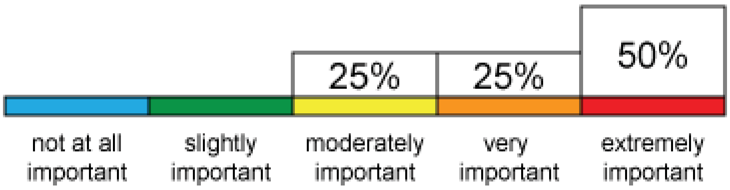
Question 2: 2/4 of respondents believed it was extremely important that floodplain management options do not disadvantage individual members of the community. 1/4 believed it was very important and 1/4 believed it was slightly important.



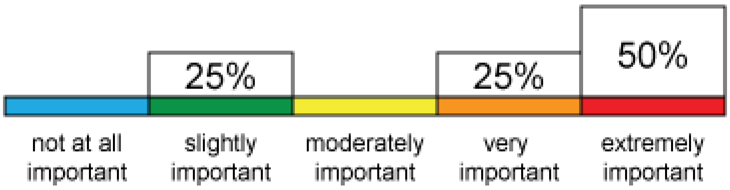
Question 3: 2/4 of respondents believed it was extremely important and 2/4 believed it was very important that floodplain management options provide safety to the community during flooding.



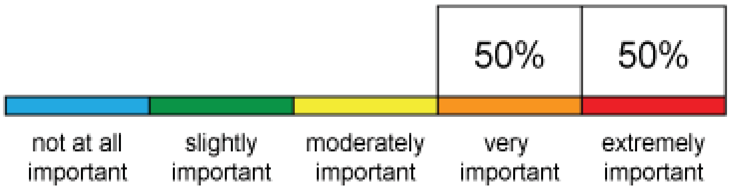
Question 4: 2/4 of respondents believed it was extremely important that floodplain management options raise community awareness and understanding of the local flood risk. 1/4 believed it was very important and 1/4 believed it was moderately important.



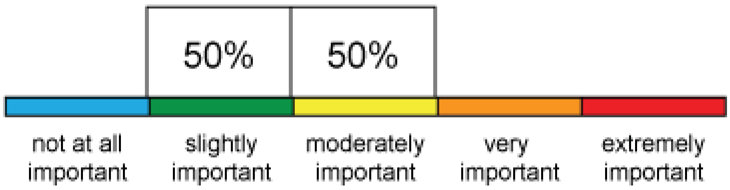
Question 5: 2/4 of respondents believed it was extremely important that floodplain management options do not threaten local plants and animals and their habitat. 1/4 believed it was very important and 1/4 believed it was slightly important.



Question 6: 2/4 of respondents believed it was extremely important and 2/4 believed it was very important that floodplain management options do not cause water quality issues.

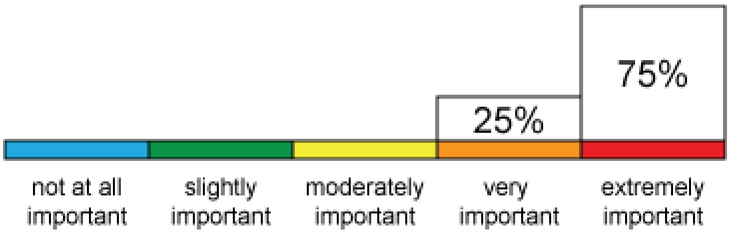


Question 7: 2/4 of respondents believed it was moderately important 2/4 believed it was slightly important that floodplain management options Initial costs (i.e design / construction) require minimal council expenditure.

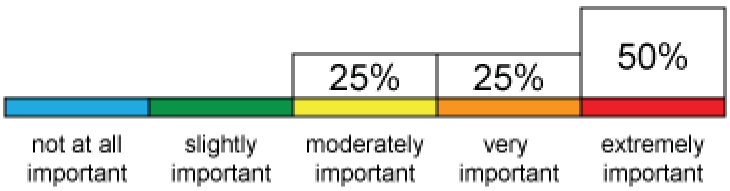


Question 8: 1/4 of respondents believed it was extremely important, 1/4 believed it was very important, 1/4 believed it was moderately important and 1/4 believed it was slightly important that floodplain management options require minimal ongoing council expenditure after implementation.

Question 9: 3/4 of respondents believed it was extremely important that floodplain management options reduce flood damages to the community. 1/4 believed it was very important.



Question 10: 2/4 of respondents believed it was extremely important that floodplain management options do not cause negative flood impacts to other areas (both upstream and downstream). 1/4 believed it was very important and 1/4 believed it was moderately important



Step 2: Recommended options.

As a result of the respondents importance weights and expert assigned option scores the floodplain management measures subsequently ranked:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Local flood warning systems and flood forecasting
7. Riparian vegetation management
8. Voluntary house raising

9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
10. Culvert/ bridge upgrades
11. Upper story flood free refuge
12. Debris control structures
13. Flood detention basin
14. Concrete levee
15. Earthen Levee
16. Channel realignment
17. Concrete lined channel
18. Increased infiltration capacity
19. Rainwater tanks

Step 3: Re-ranking

Respondents were given the opportunity to re-rank the floodplain management measures. The final results of this process were:

1. Local flood policies and development control
2. Voluntary house purchase / removal
3. Flood awareness
4. Local flood warning systems and flood forecasting
5. Flood proofing of buildings
6. Local flood and disaster plans
7. Riparian vegetation management
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9. Notifying prospective buyers and developers of flood prone land (Section 149 Certificate)
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17. Increased infiltration capacity
18. Rainwater tanks
19. Earthen Levee

5. Conclusion

Although 4 valid submissions were submitted, the exercise proved useful with 3/4 respondents ranking local flood policies and development controls their most preferred floodplain management measure. As this was a trial, the data collected will provide a useful starting platform for future methodology and programing refinement. The author is grateful to Cessnock City Council for providing the opportunity to apply and trial his research.

Appendix H

Floodengage- Wollongong City FRMS&P online community consultation report

Floodengage

2014

Wollongong City FRMS&P Online Community Consultation Report

Document Control

Project Title	Wollongong City Catchment Online Community Consultation Report
Synopsis	This report summarises community submissions collected through Floodengage- a trial online engineering engagement decision support system for the Wollongong City Floodplain Risk Management Study and Plan. This document does not summarise nor represent submissions submitted to Wollongong City Council through other formats i.e: paper based surveys.
Prepared for	Wollongong City Council
Prepared by	Raymond Laine PhD Candidate, University of Wollongong RAYMOND LAINÉ 6 February 2014

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1. Overview 1
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3. Media and Launch 4
4. Submission Summary 4
5. Conclusion 9

1. Overview

Floodengage- a trial engineering engagement decision support system currently being developed by PhD candidate Raymond Laine was utilised by Wollongong City Council to supplement traditional mail-out paper based submissions for the Wollongong City Floodplain Risk Management Study and Plan. The online Floodengage consultation was launched on the 10th of December 2013 with the website www.floodengage.com/wollongong remaining open for submissions until the 17th of January 2014. During this consultation period the Floodengage website received some 874 website views. Of these views 49 valid responses were submitted. 37 respondents (76%) ranked local flood policies and development controls their most preferred floodplain management measure of the 16 options listed.

2. Introduction

The premise behind Floodengage is to provide a mechanism for stakeholders (community members, councillors, developers, planners, engineers etc.) to learn about, rank and make informed decisions about floodplain management options for the particular catchment being investigated. Floodengage is a 4 step web-based decision support system that operates by:

1) The consultant with their expertise in floodplain management develops a list of options that may be suitable for the catchment (Figure 1).

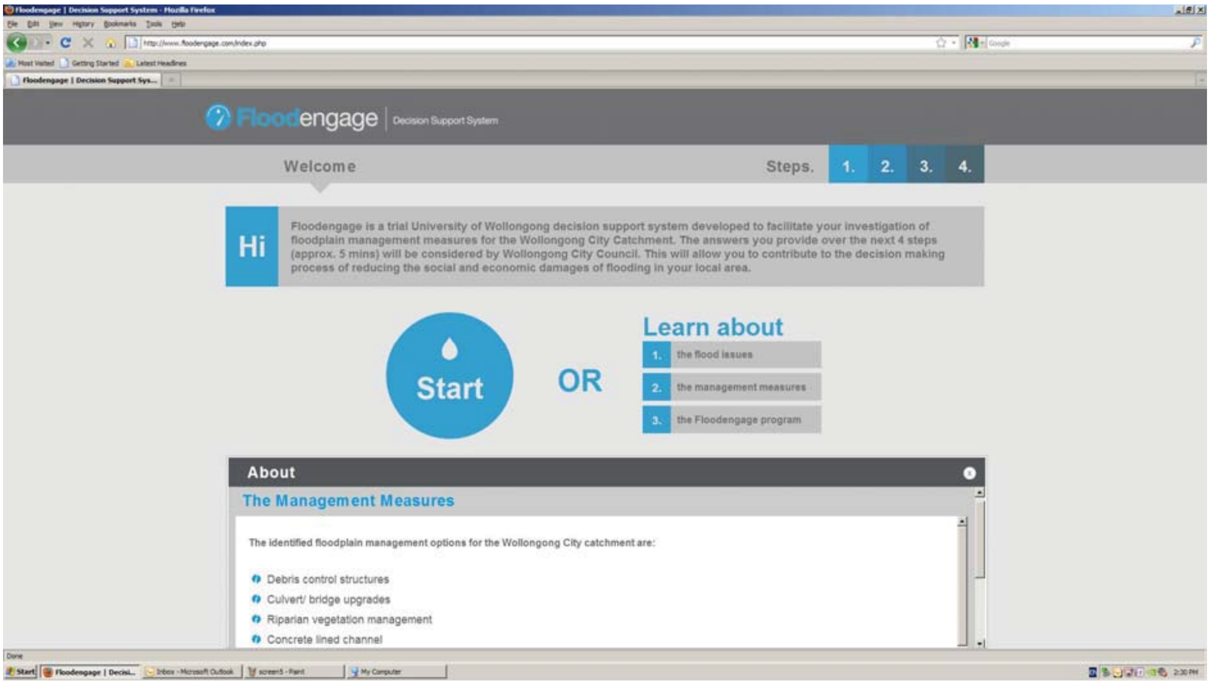


Fig 1: Floodengage welcome screen and management measure information portal.

2) Ray Laine from the University of Wollongong with input from various experts, assigns justifiable and consistent scores to the floodplain management options for social, safety, environmental/ecological, economic and flood behaviour constraints and enters it into a matrix.

3) The stakeholder assigns an importance weighting for each of the 10 constraints asked (Step 1)(Figure 2).

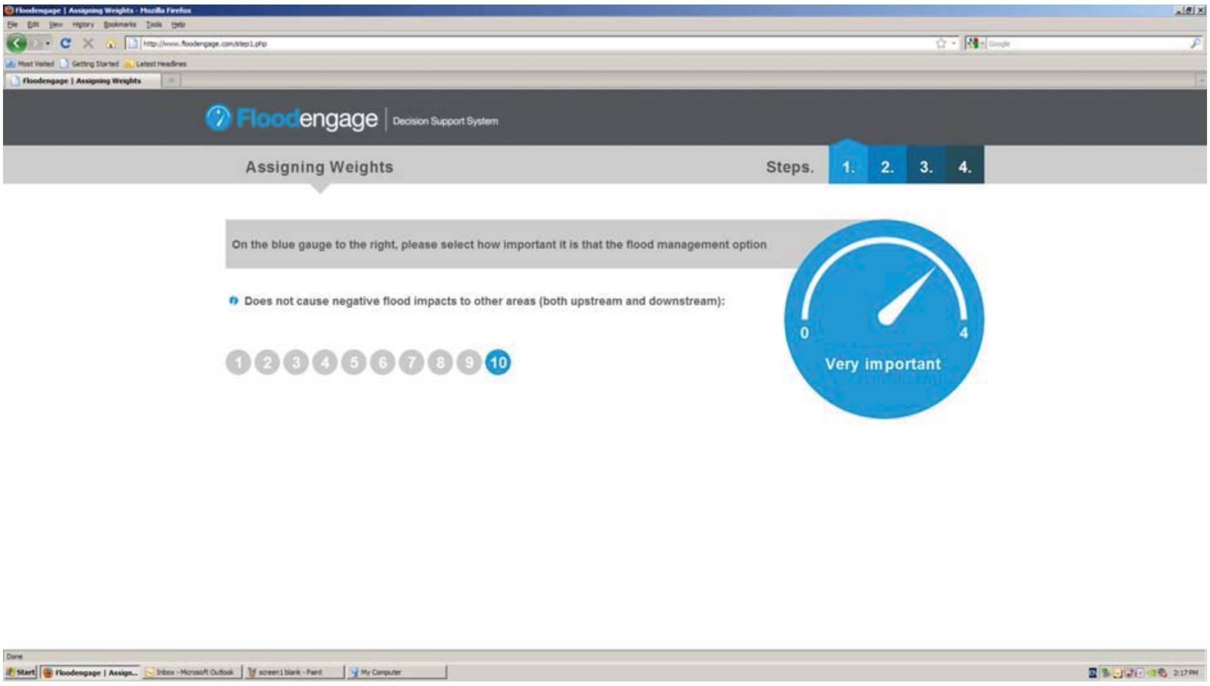


Fig 2: Floodengage step 1- user based importance weighting for various constraints.

4) This stakeholder data is then aggregated and inputted, combining the weights and scores for each option in the matrix to derive equitably ranked preferences. (Step 2)(Figure 3). It is hoped that the stakeholder investigates why certain options are preferenced and learns about the management options specific advantages/ disadvantages, the governing process and the constraints.

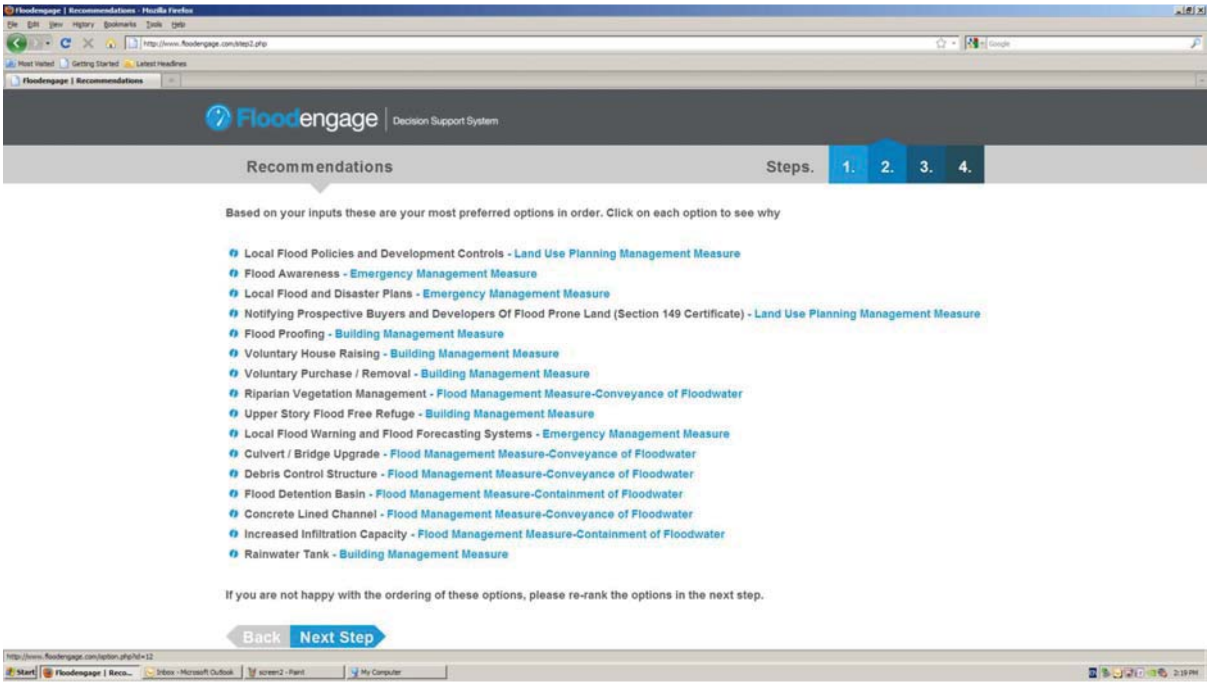


Fig 3: Floodengage step 2- floodplain management option recommendations.

5) The stakeholder can then re-rank the options (hopefully informed about the options advantages and disadvantages) in Step 3 (figure 4).

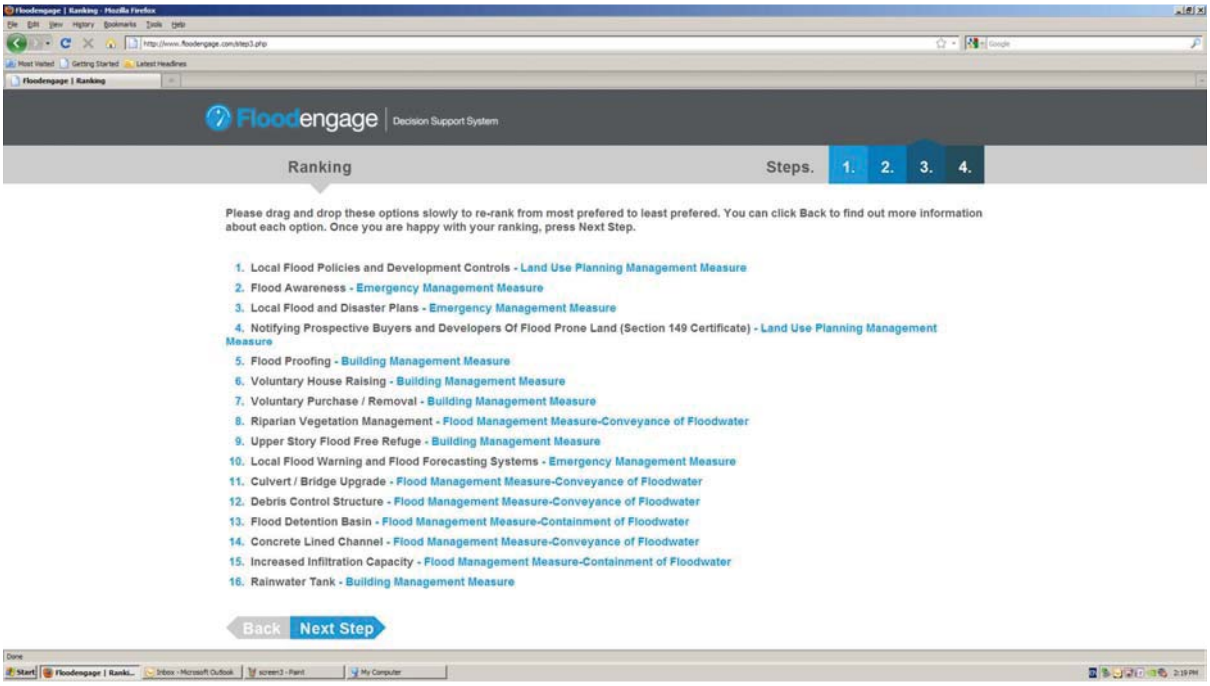


Fig 4: Floodengage step 3- option re-ranking opportunity.

6) The stakeholder is then given the opportunity to provide feedback or list other options that might have been missed, provide survey answers and press submit (figure 5).

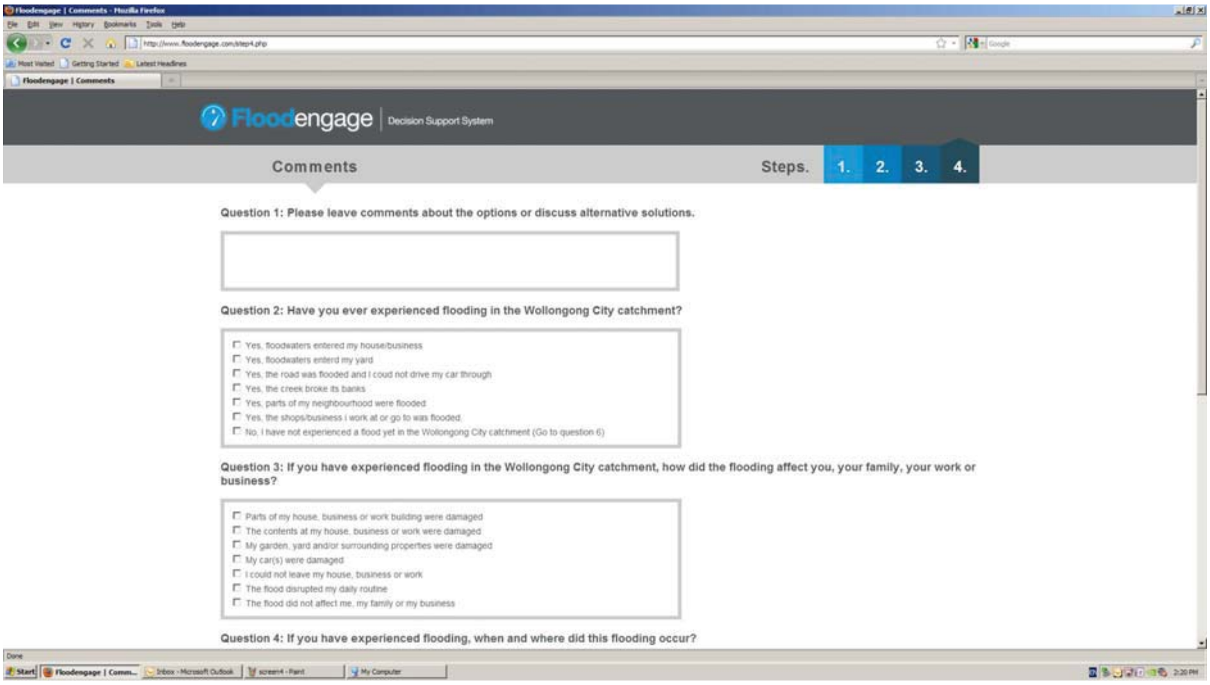
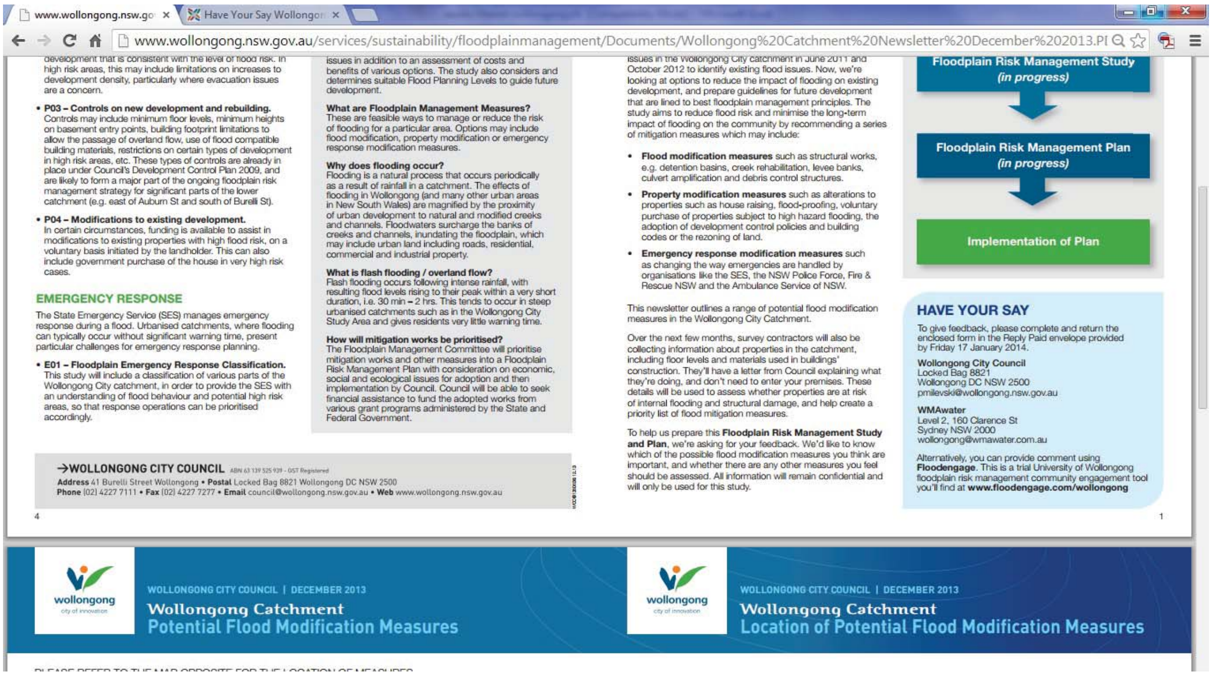


Fig 5: Floodengage step 4- feedback and comments page.

3. Media and Launch

The online Floodengage consultation was launched on the 10th of December 2013 with the website www.floodengage.com/wollongong remaining open for submissions until the 17th of January 2014. The Floodengage hyperlink was advertised on the Wollongong City Council "Have your Say" website under the Wollongong City Floodplain Risk Management Study and Plan banner and located on all 3,005 mailed paper-based surveys (figure 6).



www.wollongong.nsw.gov.au/services/sustainability/floodplainmanagement/Documents/Wollongong%20Catchment%20Newsletter%20December%202013.Pl

development that is consistent with the level of flood risk. In high risk areas, this may include limitations on increases to development density, particularly where evacuation issues are a concern.

- **P03 – Controls on new development and rebuilding.** Controls may include minimum floor levels, minimum heights on basement entry points, building footprint limitations to allow the passage of overland flow, use of flood compatible building materials, restrictions on certain types of development in high risk areas, etc. These types of controls are already in place under Council's Development Control Plan 2009, and are likely to form a major part of the ongoing floodplain risk management strategy for significant parts of the lower catchment (e.g. east of Auburn St and south of Burelli St).
- **P04 – Modifications to existing development.** In certain circumstances, funding is available to assist in modifications to existing properties with high flood risk, on a voluntary basis initiated by the landholder. This can also include government purchase of the house in very high risk cases.

EMERGENCY RESPONSE

The State Emergency Service (SES) manages emergency response during a flood. Urbanised catchments, where flooding can typically occur without significant warning time, present particular challenges for emergency response planning.

- **E01 – Floodplain Emergency Response Classification.** This study will include a classification of various parts of the Wollongong City catchment, in order to provide the SES with an understanding of flood behaviour and potential high risk areas, so that response operations can be prioritised accordingly.

issues in addition to an assessment of costs and benefits of various options. The study also considers and determines suitable Flood Planning Levels to guide future development.

What are Floodplain Management Measures?
These are feasible ways to manage or reduce the risk of flooding for a particular area. Options may include flood modification, property modification or emergency response modification measures.

Why does flooding occur?
Flooding is a natural process that occurs periodically as a result of rainfall in a catchment. The effects of flooding in Wollongong (and many other urban areas in New South Wales) are magnified by the proximity of urban development to natural and modified creeks and channels. Floodwaters surcharge the banks of creeks and channels, inundating the floodplain, which may include urban land including roads, residential, commercial and industrial property.

What is flash flooding / overland flow?
Flash flooding occurs following intense rainfall, with resulting flood levels rising to their peak within a very short duration, i.e. 30 min – 2 hrs. This tends to occur in steep urbanised catchments such as in the Wollongong City Study Area and gives residents very little warning time.

How will mitigation works be prioritised?
The Floodplain Management Committee will prioritise mitigation works and other measures into a Floodplain Risk Management Plan with consideration on economic, social and ecological issues for adoption and then implementation by Council. Council will be able to seek financial assistance to fund the adopted works from various grant programs administered by the State and Federal Government.

WOLLONGONG CITY COUNCIL ABN 63 139 525 939 - GST Registered
Address 41 Burelli Street Wollongong • **Postal** Locked Bag 8821 Wollongong DC NSW 2500
Phone (02) 4227 7111 • **Fax** (02) 4227 7277 • **Email** council@wollongong.nsw.gov.au • **Web** www.wollongong.nsw.gov.au

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issues in the Wollongong City catchment in June 2011 and October 2012 to identify existing flood issues. Now, we're looking at options to reduce the impact of flooding on existing development, and prepare guidelines for future development that are lined to best floodplain management principles. The study aims to reduce flood risk and minimise the long-term impact of flooding on the community by recommending a series of mitigation measures which may include:

- **Flood modification measures** such as structural works, e.g. detention basins, creek rehabilitation, levee banks, culvert amplification and debris control structures.
- **Property modification measures** such as alterations to properties such as house raising, flood-proofing, voluntary purchase of properties subject to high hazard flooding, the adoption of development control policies and building codes or the rezoning of land.
- **Emergency response modification measures** such as changing the way emergencies are handled by organisations like the SES, the NSW Police Force, Fire & Rescue NSW and the Ambulance Service of NSW.

This newsletter outlines a range of potential flood modification measures in the Wollongong City Catchment.

Over the next few months, survey contractors will also be collecting information about properties in the catchment, including floor levels and materials used in buildings' construction. They'll have a letter from Council explaining what they're doing, and don't need to enter your premises. These details will be used to assess whether properties are at risk of internal flooding and structural damage, and help create a priority list of flood mitigation measures.

To help us prepare this **Floodplain Risk Management Study and Plan**, we're asking for your feedback. We'd like to know which of the possible flood modification measures you think are important, and whether there are any other measures you feel should be assessed. All information will remain confidential and will only be used for this study.

Floodplain Risk Management Study (in progress)
Floodplain Risk Management Plan (in progress)
Implementation of Plan

HAVE YOUR SAY

To give feedback, please complete and return the enclosed form in the Reply Paid envelope provided by Friday 17 January 2014.

Wollongong City Council
Locked Bag 8821
Wollongong DC NSW 2500
pmilevski@wollongong.nsw.gov.au

WMAwater
Level 2, 160 Clarence St
Sydney NSW 2000
wollongong@wmawater.com.au

Alternatively, you can provide comment using **Floodengage**. This is a trial University of Wollongong floodplain risk management community engagement tool you'll find at **www.floodengage.com/wollongong**

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WOLLONGONG CITY COUNCIL | DECEMBER 2013
Wollongong Catchment
Potential Flood Modification Measures

WOLLONGONG CITY COUNCIL | DECEMBER 2013
Wollongong Catchment
Location of Potential Flood Modification Measures

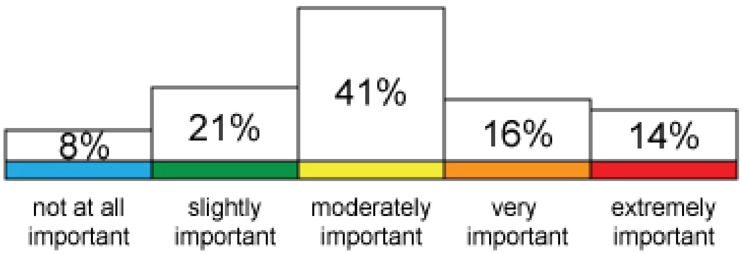
Fig 6: Wollongong Catchment mailed paper-based survey.

4. Submission Summary

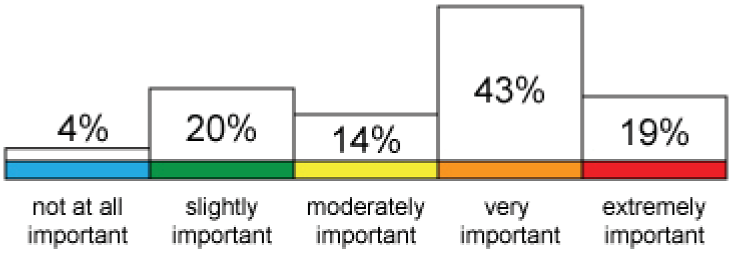
The results of the online Floodengage submissions received are as follows:

<u>Step 1: Respondents importance weights for the 10 constraints.</u>

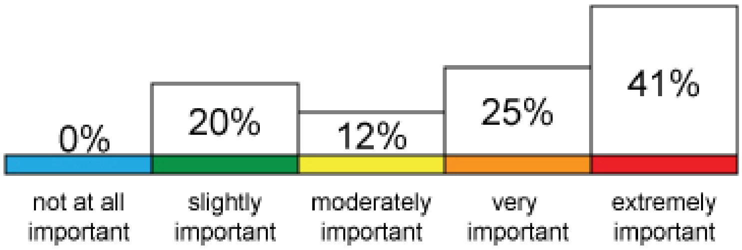
<u>Question 1- How important is it that the flood management option improves community access and recreational use:</u> 41% of respondents believed it was moderately important that floodplain management options improve community access and recreational use. 21% believed it was slightly important with the remaining responses documented below.



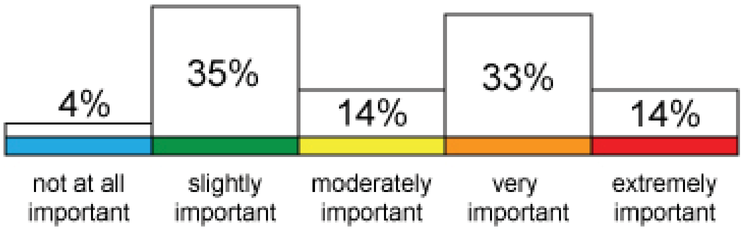
Question 2- How important is it that the flood management option does not disadvantage individual members of the community: 43% of respondents believed it was very important that floodplain management options do not disadvantage individual members of the community. 20% believed it was slightly important with the remaining responses documented below.



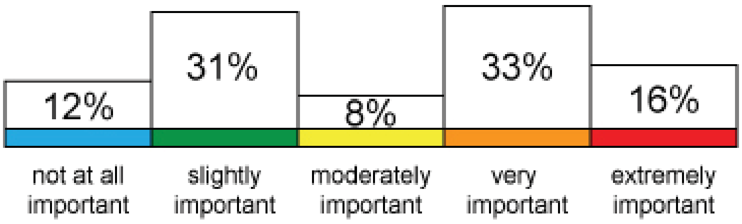
Question 3- How important is it that the flood management option provides safety to the community during flooding: 41% of respondents believed it was extremely important that floodplain management options provide safety to the community during flooding. 25% believed it was very important with the remaining responses documented below.



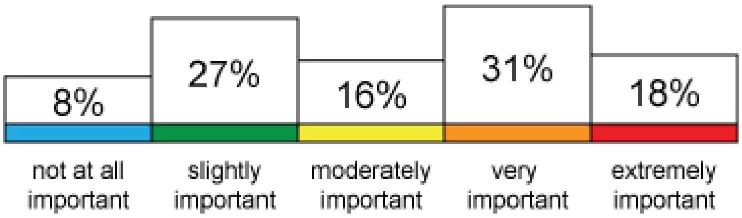
Question 4- How important is it that the flood management option raises community awareness and understanding of the local flood risk: 35% of respondents believed it was slightly important that floodplain management options raise community awareness and understanding of the local flood risk. 33% believed it was very important with the remaining responses documented below.



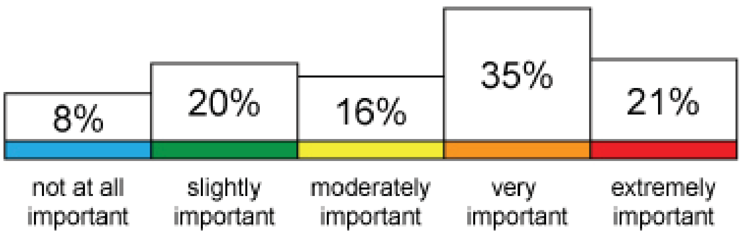
Question 5- How important is it that the flood management option does not threaten local plants and animals and their habitat: 33% of respondents believed it was very important that floodplain management options do not threaten local plants and animals and their habitat. 31% believed it was slightly important with the remaining responses documented below.



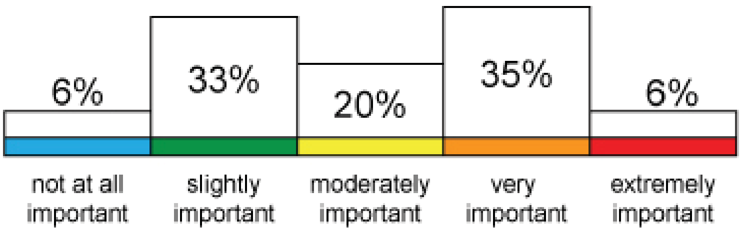
Question 6- How important is it that the flood management options do not cause water quality issues: 31% of respondents believed it was very important that floodplain management options do not cause water quality issues. 27% believed it was slightly important with the remaining responses documented below.



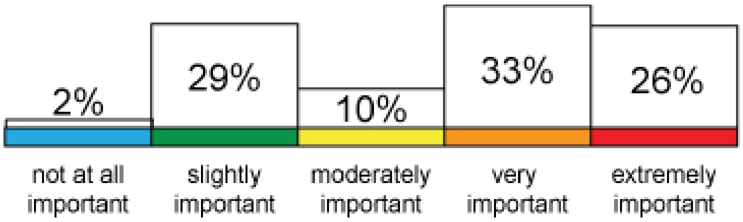
Question 7- How important is it that the flood management options initial costs (i.e. design / construction) require minimal council expenditure: 35% of respondents believed it was very important that floodplain management options initial costs (i.e design / construction) require minimal council expenditure. 21% believed it was extremely important with the remaining responses documented below.



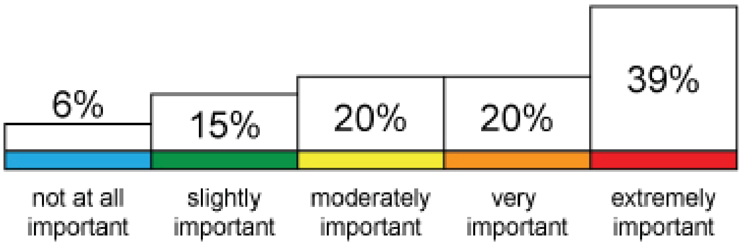
Question 8- How important is it that the flood management option requires minimal ongoing council expenditure after implementation: 35% of respondents believed it was extremely important that floodplain management options require minimal ongoing council expenditure after implementation. 33% believed it was slightly important with the remaining responses documented below.



Question 9- How important is it that the flood management option reduces flood damages to the community: 33% of respondents believed it was very important that floodplain management options reduce flood damages to the community. 29% believed it was slightly important with the remaining responses documented below.



Question 10- How important is it that the flood management option does not cause negative flood impacts to other areas (both upstream and downstream): 39% of respondents believed it was extremely important that floodplain management options do not cause negative flood impacts to other areas (both upstream and downstream). 20% believed it was very important and a further 20% believed it was slightly important with the remaining responses documented below.



Step 2: Recommended options.

As a result of the respondents importance weights and expert assigned option scores, the floodplain management measures subsequently ranked:

1. Local flood policies and development controls
2. Flood awareness
3. Voluntary house purchase / removal
4. Local flood and disaster plans
5. Flood proofing of buildings
6. Riparian vegetation management
7. Local flood warning systems and flood forecasting
8. Voluntary house raising
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16. Rainwater tanks

Step 3: Re-ranking

Respondents were given the opportunity to re-rank the floodplain management measures. The final results of this process were:

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12. Culvert/ bridge upgrades
13. Flood detention basin
14. Concrete lined channel
15. Increased infiltration capacity
16. Rainwater tanks

Local flood policies and development controls were the respondents most preferred floodplain management measure with 37 respondents (76%) ranking it as their 1st preference. A preference scale was developed (figure 7), to visually display the communities level of support for each option from most preferred to least preferred. As indicated a large proportion of respondents strongly favoured local flood policies and development controls as the most preferred management option.

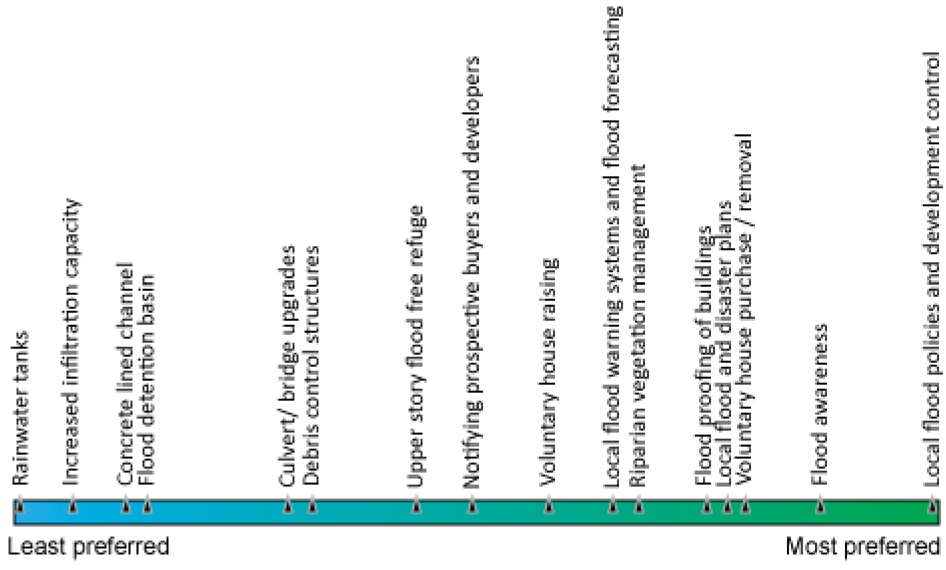


Fig 7: Floodplain management measure preference scale.

5. Conclusion

With 49 valid online submissions, respondents favoured floodplain management measures that provide safety to the community during times of flood and do not cause adverse flood impacts. Local flood policies and development controls were the respondents most preferred floodplain management measure with rainwater tanks the least preferred measure.

The data collected as part of this trial will be used in conjunction with paper-based survey responses to guide the next stage of flood modelling investigations for the Wollongong City catchment.

The author is grateful to Wollongong City Council for providing the opportunity to trial Floodengage.

Appendix I

Horsley Creek FRMS&P mail-out survey (GHD 2014)

More information

If you require more information on the study please contact:

Nicola Bailey
GHD
Level 15, 133 Castlereagh Street
Sydney 2000

P: (02) 9239 7100
E: nicola.bailey@ghd.com

If you would prefer to discuss directly with Council, please contact:

Bryce Short
Manager of Engineering Services
Shellharbour City Council
Locked Bag 155
Shellharbour City Centre NSW 2529

P: (02) 4221 6112
F: (02) 4221 6016
E: bryce.short@shellharbour.nsw.gov.au

Horsley Creek Floodplain Risk Management Study & Plan

Newsletter August 2012

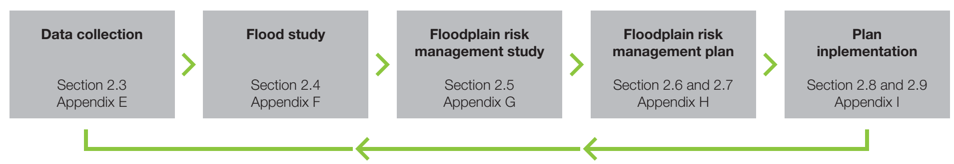
About the Project

Shellharbour City Council is responsible for local planning and land management in the Horsley Creek catchment, including the management of the floodplain.

As part of the NSW Government's Floodplain Risk Management Process, Council

is preparing a comprehensive Floodplain Risk Management Plan for the Horsley Creek catchment. The process for preparing a Flood Risk Management

Plan is shown below:



Our team appreciates the diverse effects of flooding – from its dynamic shaping of the environment through to its potential negative social and economic impact. With this knowledge we analyse and develop comprehensive plans.

Q 8. Have you ever experienced flooding since living/working in the Black Creek catchment? (please tick relevant boxes)

- ☐ Yes, floodwaters entered my house/business
- ☐ Yes, floodwaters entered my yard
- ☐ Yes, the road was flooded and I couldn't drive my car
- ☐ Yes, the creek broke its banks
- ☐ Yes, other parts of my neighbourhood were flooded
- ☐ No, I haven't experienced a flood (go to Q.11)

Q 9. If you have experienced a flood, how did the flooding affect you and your family/business? (please tick relevant boxes)

- ☐ Parts of my house/business building were damaged
- ☐ The contents of my house/business were damaged
- ☐ My garden, yard, and/or surrounding property were damaged
- ☐ My car(s) were damaged
- ☐ Other property was damaged (specify) ....
- ☐ I couldn't leave the house/business
- ☐ Family members/work mates couldn't leave/return to the house/business
- ☐ The flood disrupted my daily routine
- ☐ The flood affected me in other ways (specify) ....
- ☐ The flood didn't affect me

Q 10. Do you have any materials or photos you can provide to evidence the flooding you experienced? If yes, when did the flooding occur?

☐ Yes ☐ No

The flooding occurred on ....

Q 11. Do you think your property would be flooded sometime in the future? (please tick relevant boxes)

- ☐ No
- ☐ Yes, but only a small part of my yard
- ☐ Yes, most of my yard/outdoor areas of business could be flooded
- ☐ Yes, my house/office/business could flood over the floor

Q12. Where have you looked for information about flooding on your property? (please tick relevant boxes)

- ☐ Council's customer service centre
- ☐ Other information from Council (specify)..
- ☐ Viewed a Property Planning (Section 149) Certificate
- ☐ Information from a real estate agent
- ☐ Information from relatives, friends, neighbours, or the previous owner
- ☐ Other information (specify)..
- ☐ No information has been sought
- ☐ I do not believe my property is affected by flooding

If you answered yes to having looked for information on Council's website:

- ☐ What information have you looked for?
  (Please specify) ....
- ☐ Where were you able to find information?
  (Please specify) ....

Q13. As a local resident who may have witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for the Black Creek catchment (1=least preferred, 5=most preferred)? Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please circle)	Location/Other Comments?
Stormwater harvesting, such as rainwater tanks	1 2 3 4 5	
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Levee banks (note Glossary on next page)	1 2 3 4 5	
Diversion of creeks and channels	1 2 3 4 5	
Environmental channel improvements, including removal of weeds & bank stabilisation	1 2 3 4 5	
Planning and flood-related development controls	1 2 3 4 5	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5	
Other (please specify any options you believe are suitable). Please attach extra pages for other suggestions	1 2 3 4 5	

Q14. What do you think are the best ways to get input and feedback from the local community about this project? (please tick relevant boxes)

- ☐ Council's website
- ☐ Emails from Council
- ☐ Council's Floodplain Management Committee
- ☐ Formal Council meetings
- ☐ Council's information page in the local paper
- ☐ Other articles in the local paper
- ☐ Information days in the local area
- ☐ Community meetings
- ☐ Mail outs to all residents/business owners in the study area

Q15. What is the main language spoken at home?

- ☐ English
- ☐ Other (specify)..

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- ☐ Other (specify)..............................

Appendix J

Black Creek FRMS&P mail-out survey (Cardno 2014)

Glossary

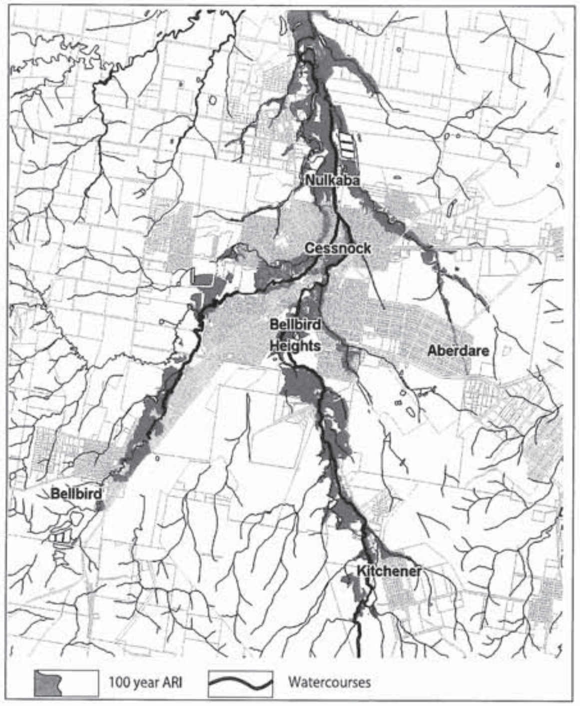
Culvert – a drain or covered channel that passes under a road or railroad.

Levee Banks – An embankment usually constructed from earth or concrete built along the banks of a river to help prevent overflow of its waters.

Retarding/Detention Basin - A naturally occurring or constructed depression in the land surface that detains stormwater runoff by allowing it to slowly drain out of the basin into the adjoining natural drainage line or creek.

Stormwater Harvesting - the collection, storage, treatment and use of stormwater runoff from urban areas.

If you have any further comments that relate to the Black Creek Floodplain Risk Management Study and Plan, please express them in the space below. Please feel free to attach additional pages if necessary.



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....

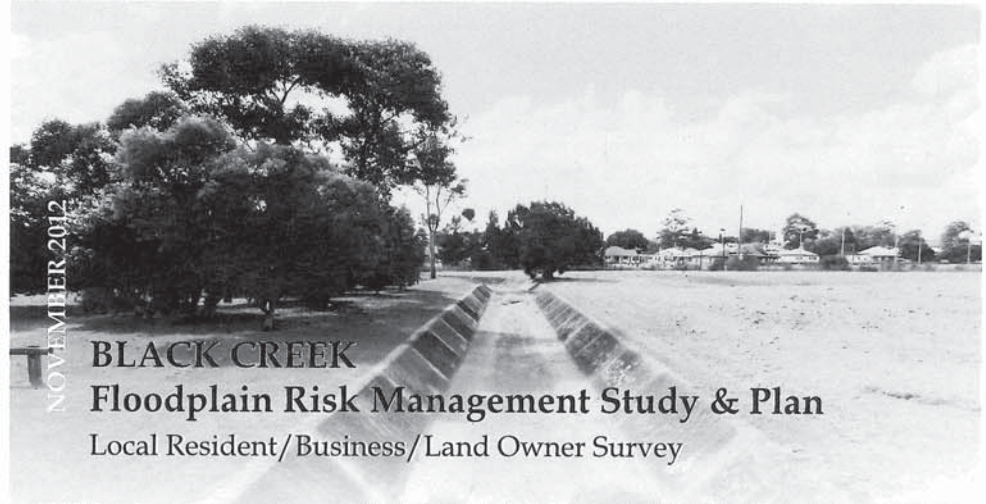
Thank you for providing the above information. Please remember to return the completed survey in the reply paid envelope by 11th January 2013. A representative from Cardno may contact you in the near future to discuss your response.

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact:

Peter Jennings
Cessnock City Council
P: (02) 4993 4119
F: (02) 4993 2503
E: peter.jennings@cessnock.nsw.gov.au

Kieran Geraghty
Cardno
P: (02) 9496 7700
F: (02) 9499 3902
E: kieran.geraghty@cardno.com.au



NOVEMBER 2012

BLACK CREEK
Floodplain Risk Management Study & Plan
Local Resident/Business/Land Owner Survey

Q1. Could you please provide us with the following details? We may wish to contact you to discuss some of the information you have provided us.

Name: ....

Address: ....

....

Daytime Ph: ....

Email: ....

Q2. Is your property (please tick)

☐ Owner occupied ☐ Occupied by a tenant

☐ Business ☐ Other

Operating hours:

Q3. What type of structure is your property/business? (please tick)

☐ Freestanding house ☐ Apartment/ dual occupancy

☐ Caravan/mobile home ☐ Other (Please Specify)

Q4. How long have you lived, worked and/or owned your property? .... Years

Q5. How long have you lived in the Black Creek Study Area? .... Years

Q6. How many people live/work at your property? ....

Q 7. Number of permanent residents at this address aged:

☐ 0 - 4 years ☐ 5 - 24 years

☐ 25 - 64 years ☐ 65+ years

prepared for CESSNOCK CITY COUNCIL

prepared by Cardno Shaping the Future

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Q15. What is the main language spoken at home?

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- [ ] Other (specify)..............................

Appendix K

Wollongong City FRMS&P mail-out survey (WMAWater 2014)

Wollongong Catchment
Property and Emergency Response Measures

PLANNING AND PROPERTY MODIFICATION

Property modification and planning measures are a vital part of effective floodplain management. In most urbanised areas such as the Wollongong City catchment, flood risk cannot simply be removed by building infrastructure. The cost to build pipe drainage to cater for the heaviest storm events is prohibitive, and in major storm events that exceed the drainage system capacity, structures like levees (walls) can reduce flood levels in one location, but increase them in others.

Planning and property modification measures are generally the most effective way to mitigate flood risk for existing and future development. The following measures will be considered as part of the Floodplain Risk Management Study:

- **P01 – Tagging of flood liable land.** Land subject to flood-related development controls is identified on Section 149 certificates. The nature of the controls varies based on the frequency and severity of flooding.
- **P02 – Land-use zoning.** Zoning may be adjusted to facilitate development that is consistent with the level of flood risk. In high risk areas, this may include limitations on increases to development density, particularly where evacuations issues are a concern.
- **P03 – Controls on new development and rebuilding.** Controls may include minimum floor levels, minimum heights on basement entry points, building footprint limitations to allow the passage of overland flow, use of flood compatible building materials, restrictions on certain types of development in high risk areas, etc. These types of controls are already in place under Council's Development Control Plan 2009, and are likely to form a major part of the ongoing floodplain risk management strategy for significant parts of the lower catchment (e.g. east of Auburn St and south of Burelli St).
- **P04 – Modifications to existing development.** In certain circumstances, funding is available to assist in modifications to existing properties with high flood risk, on a voluntary basis initiated by the landholder. This can also include government purchase of the house in very high risk cases.

EMERGENCY RESPONSE

The State Emergency Service (SES) manages emergency response during a flood. Urbanised catchments, where flooding can typically occur without significant warning time, present particular challenges for emergency response planning.

- **E01 – Floodplain Emergency Response Classification.** This study will include a classification of various parts of the Wollongong City catchment, in order to provide the SES with an understanding of flood behaviour and potential high risk areas, so that response operations can be prioritised accordingly.

Frequently Asked Questions

What is a Floodplain?
As the area of land subject to inundation by floods up to the probable maximum flood event (i.e. flood-prone land). This includes flooding from mainstream sources such as creeks and rivers as well as overland flow from intense localised rainfall.

What is the purpose of a Floodplain Risk Management Study?
The purpose of the study is to identify, assess and compare various risk management measures and consider opportunities for environmental enhancements as part of mitigation works. The management study draws together the results of the flood study and data collection exercises. It provides information and tools to allow strategic assessment of the impacts of management measures for existing, future and continuing flood risk on flood behaviour and hazard, and includes social, economic, ecological and cultural issues in addition to an assessment of costs and benefits of various options. The study also considers and determines suitable Flood Planning Levels to guide future development.

What are Floodplain Management Measures?
These are feasible ways to manage or reduce the risk of flooding for a particular area. Options may include flood modification, property modification or emergency response modification measures.

Why does flooding occur?
Flooding is a natural process that occurs periodically as a result of rainfall in a catchment. The effects of flooding in Wollongong (and many other urban areas in New South Wales) are magnified by the proximity of urban development to natural and modified creeks and channels. Floodwaters surcharge the banks of creeks and channels, inundating the floodplain, which may include urban land including roads, residential, commercial and industrial property.

What is flash flooding / overland flow?
Flash flooding occurs following intense rainfall, with resulting flood levels rising to their peak within a very short duration, i.e. 30 min – 2 hrs. This tends to occur in steep urbanised catchments such as in the Wollongong City Study Area and gives residents very little warning time.

How will mitigation works be prioritised?
The Floodplain Management Committee will prioritise mitigation works and other measures into a Floodplain Risk Management Plan with consideration on economic, social and ecological issues for adoption and then implementation by Council. Council will be able to seek financial assistance to fund the adopted works from various grant programs administered by the State and Federal Government.

→WOLLONGONG CITY COUNCIL ABN 63 139 525 939 - GST Registered
Address 41 Burelli Street Wollongong • **Postal** Locked Bag 8821 Wollongong DC NSW 2500
Phone (02) 4227 7111 • **Fax** (02) 4227 7277 • **Email** council@wollongong.nsw.gov.au • **Web** www.wollongong.nsw.gov.au

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Wollongong Catchment
Flood Study Newsletter

To Residents and Businesses in the Wollongong Catchment

Wollongong City Council has engaged WMAwater to prepare a **Floodplain Risk Management Study and Plan** for the Wollongong City Catchment. This catchment drains to Port Kembla Inner Harbour via the Gurungaty waterway, and includes parts of Coniston, Wollongong, Mangerton, Mount St Thomas and Spring Hill.

The study is being prepared under the guidance of the Wollongong City Floodplain Management Committee, which includes representatives from the local community, Council staff and state agencies such as the State Emergency Service (SES), the Office of Environment and Heritage (OEH), and Roads & Maritime Services (RMS). The study has been jointly funded by Council and the OEH. It fits into the overall floodplain management process, under the State Government's Flood Prone Land Policy.

We've previously consulted with the community on flood issues in the Wollongong City catchment in June 2011 and October 2012 to identify existing flood issues. Now, we're looking at options to reduce the impact of flooding on existing development, and prepare guidelines for future development that are lined to best floodplain management principles. The study aims to reduce flood risk and minimise the long-term impact of flooding on the community by recommending a series of mitigation measures which may include:

- **Flood modification measures** such as structural works, e.g. detention basins, creek rehabilitation, levee banks, culvert amplification and debris control structures.
- **Property modification measures** such as alterations to properties such as house raising, flood-proofing, voluntary purchase of properties subject to high hazard flooding, the adoption of development control policies and building codes or the rezoning of land.
- **Emergency response modification measures** such as changing the way emergencies are handled by organisations like the SES, the NSW Police Force, Fire & Rescue NSW and the Ambulance Service of NSW.

This newsletter outlines a range of potential flood modification measures in the Wollongong City Catchment.

Over the next few months, survey contractors will also be collecting information about properties in the catchment, including floor levels and materials used in buildings' construction. They'll have a letter from Council explaining what they're doing, and don't need to enter your premises. These details will be used to assess whether properties are at risk of internal flooding and structural damage, and help create a priority list of flood mitigation measures.

To help us prepare this **Floodplain Risk Management Study and Plan**, we're asking for your feedback. We'd like to know which of the possible flood modification measures you think are important, and whether there are any other measures you feel should be assessed. All information will remain confidential and will only be used for this study.

The Floodplain Risk Management Process

Data Collection
(completed)

Flood Study
(completed)

Floodplain Risk Management Study
(in progress)

Floodplain Risk Management Plan
(in progress)

Implementation of Plan

HAVE YOUR SAY

To give feedback, please complete and return the enclosed form in the Reply Paid envelope provided by Friday 17 January 2014.

Wollongong City Council
41 Burelli Street
Wollongong NSW 2500
pmilevski@wollongong.nsw.gov.au

WMAwater
Ph: 02 9299 2855
Wollongong NSW 2500
wollongong@wmawater.com.au

Alternatively, you can provide comment using **Floodengage**. This is a trial University of Wollongong floodplain risk management community engagement tool you'll find it at **www.floodengage.com/wollongong**

Wollongong Catchment
Potential Flood Modification Measures

PLEASE REFER TO THE MAP OPPOSITE FOR THE LOCATION OF MEASURES

WOLLONGONG CATCHMENT

L01 – Install blockage prevention devices for culvert under railway line, by construction of a metal cage over the inlet grate.

Aim of Measure – Reduce the potential for blockage of the pipe inlet, and resulting flooding from pooled water in low areas near the Gladstone Ave and Rowland Ave intersection.

L02 – Install blockage prevention devices for culvert under railway line, by construction of a trash rack and other filter devices.

Aim of Measure – Reduce the potential for blockage of the pipe inlet, and resulting flooding from pooled water in low areas near the Gladstone Ave and Union St intersection.

L03 – Localised creek modification works and installation of blockage prevention devices for the culvert under the railway line, including construction of a trash rack.

Aim of Measure – Reduce the potential for blockage of the culvert inlet and nearby stormwater inlet connections, and resulting flooding from pooled water in low areas near the Gladstone Ave and Robertson St intersection.

L04 – Construction of additional stormwater inlet points to reduce likelihood of blockage to sag inlets for the culvert under the railway line.

Aim of Measure – Reduce the potential for blockage of sag inlets near the intersection of Gladstone Ave and Vale St, and resulting flooding of the road and properties from pooled water in these areas.

L05 – Upgrade culvert size and/or install blockage prevention devices such as trash racks to improve drainage capacity and reliability under Master Rd.

Aim of Measure – Increase the flow capacity and mitigate against potential blockage, thereby reducing frequency of inundation over Masters Rd and the intersection with Springhill Rd.

L06 – Upgrade culvert size and/or install blockage prevention devices such as trash racks to improve drainage capacity and reliability under Springhill Rd.

Aim of Measure – Increase the flow capacity and mitigate against potential blockage, thereby reducing frequency of inundation over Springhill Rd.

L07 – Undertake channel works (rehabilitation of creek or possibly concrete-lined) and easement along existing swale through properties between Bridge St and Robertson St, and Robertson St to Gladstone Ave, and install blockage prevention devices.

Aim of Measure – Increase the flow capacity and reduce the frequency and severity of flooding within Robertson St properties and on the road reserve.

L08 – Undertake rehabilitation of open channel between railway line and Auburn St, including bank stabilisation, planting of native vegetation and installation of blockage prevention devices.

Aim of Measure – Increase channel capacity and reduce likelihood of blockageof the entry point to the Ellen St/Church St trunk drainage system, reducing frequency and severity of flooding on Auburn St and Ellen St.

L09 – Regrade landform within MacCabe Park, which currently acts as an informal detention basin, to improve the influence on overland flow behaviour compared to current conditions.

Aim of Measure – Improve the performance of the detention capability of the existing landform for local runoff, and alleviate flooding of road reserves and properties, particularly on Keira St and Church St in the vicinity of the park.

L10 and L11 – Upgrade culvert capacity and/or install blockage prevention devices for drainage structures under Springhill Rd and Tom Thumb Rd in the vicinity of the rail overpass.

Aim of Measure – Reduce the frequency and duration of flooding over Springhill Rd and associated road closures and risk to traffic.

L12 – Construct roadside swale, or modify landform of eastern hill of the football field near Vikings Rugby Union clubhouse, which currently acts as an obstruction to flow, to allow ponded water from low-points in Corrimal St and Springhill Dr to flow westwards into the open channel of the Gurungaty waterway.

Aim of Measure – Reduce the frequency and duration of flooding over Springhill Rd and associated road closures and risk to traffic.

L13 – Upgrade drainage outlet (culvert size and/or channel works) from Golf Course basins between Glebe St and Beach St.

Aim of Measure – Improve drainage capacity along the Eastern Branch flow path, particularly to reduce the frequency and severity of flooding along Corrimal St, Bank St (east), Stewart St (east), Glebe St (east) and within the golf course itself.

L14 – Undertake maintenance works (removal of silt) and install blockage prevention devices such as trash racks at the culvert inlet at Swan St.

Aim of Measure – Increase the capacity of the culvert drainage under Swan St and reduce the frequency and severity of flooding in Swan Street and lower Kembla St (these areas experienced significant flooding in March 2012).

L15 – Undertake maintenance works (removal of silt) and install blockage prevention devices such as trash racks at the Springhill Road bridge.

Aim of Measure – Reduce the frequency and severity of flooding over Springhill Rd and associated road closures and risk to traffic.

L16, L17, L18 and L19 – Upgrade or modify capacity of road and rail crossings in the lower Gurungaty waterway.

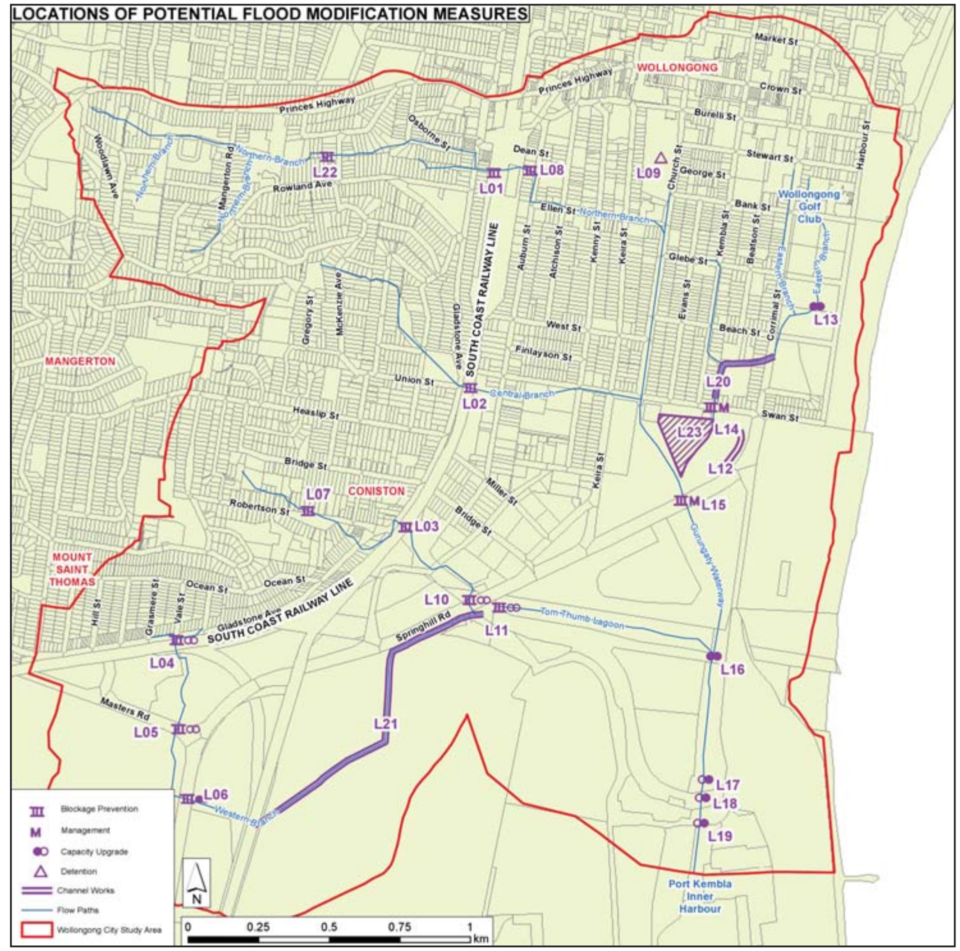
Aim of Measure – Increase the flow capacity of the waterway and alleviate flooding of roadways and developed areas of the lower catchment.

L20 – Undertake channel rehabilitation works, including clearing of silt and weeds, bank stabilisation and/or planting of native vegetation.

Aim of Measure – Improve channel capacity and alleviate flood issues along the Eastern Branch and within the golf course.

L21 – Upgrade (where possible) the drainage system along the Western Branch between the railway line and Tom Thumb Lagoon, including open channel rehabilitation works and blockage prevention devices.

Wollongong Catchment
Location of Potential Flood Modification Measures



Map of the Wollongong Catchment Flood Study Area

Aim of Measure – Improve high flow channel capacity adjacent to Springhill Rd, mitigating flood risk for the road, and potentially improving water quality for low flows to Tom Thumb Lagoon.

L22 – Localised overland flowpath modification works and installation of blockage prevention devices for the northern branch drainage line, in the vicinity of Allan St.

Aim of Measure – Reduce the potential for blockage of the culvert inlet and nearby stormwater inlet connections, and resulting flooding from overland flow along the Northern Branch.

L23 – Investigate potential modification to landforms in JJ Kelly Park between Swan St and Gurungaty waterway.

Aim of Measure – Reduce the frequency and duration of flooding to private property and Swan St, and associated road closures and risk to traffic.

wma water

WOLLONGONG CITY COUNCIL | DECEMBER 2013

Wollongong Catchment
Flood Study Feedback Form

Feedback Form - Preferred Measures

Have you been affected by flooding?

In previous rounds of consultation, we asked residents and businesses whether they had experienced any flood issues. This data is used to calibrate flood models and ensure they reflect observed historical flood behaviour.

Since the first data collection exercise, there have been additional storms which resulted in flooding of property and evacuation. If you were affected by these storms, such as the one in March 2012, or have information about other historical flooding, your input would be appreciated. All information will be treated as strictly confidential, and will only be used for the purposes of this study. It will not be provided to third parties.

1. Have you observed or been affected by flooding? ☐ **Yes** ☐ **No**

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2. Was your property/premises flooded above floor level? ☐ **Yes** ☐ **No**

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3. If yes to the above, when did this occur? ______________________________

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4. Where did the flooding occur? ______________________________

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5. Please provide any other relevant information (attach additional sheets if necessary)

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Wollongong Catchment
Flood Study Feedback Form

Feedback Form - Preferred Measures

Please indicate your preference for the types of flood risk mitigation you think are most appropriate in the catchment (1=strongly opposed, 2=moderately opposed, 3=neutral, 4=supported, 5=strong preference), and provide any location(s) to which your preference applies

Mitigation Measure	Preference Level	Location
Blockage prevention devices	1 2 3 4 5	
Culvert / pipe / bridge enlargement	1 2 3 4 5	
Increased channel or flowpath capacity	1 2 3 4 5	
Removal of silt, weeds and/or bank stabilisation	1 2 3 4 5	
Detention basins	1 2 3 4 5	
Planning and development control measures	1 2 3 4 5	
Property modification measures	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5	
Other (please describe below)	1 2 3 4 5	

COMMENTS ON SPECIFIC MEASURES

(Please refer to the ID code of the option, or write other for works that have not been listed)

Potential Measure: Comment:

Potential Measure: Comment:

Other Comments (please attach additional sheets if there is insufficient space):

Name:

Address:

Telephone: