The Urban Impacts Toolbox: An overview

A. Tait[1], S. Allan[2], S. Oldfield[3] and A. Semadeni-Davies[4]

[1]*National Institute of Water and Atmospheric Research (NIWA), Private Bag 14901, Wellington, New Zealand*
[2]*Allan Planning & Research Ltd, 26 Patrick St, Petone, Lower Hutt, New Zealand.*
[3]*MWH New Zealand Ltd, PO Box 9624, Te Aro, Wellington, New Zealand.*
[4]*National Institute of Water and Atmospheric Research (NIWA) Private Bag 99940, Newmarket, Auckland, New Zealand.*
Corresponding author address: Andrew Tait, National Institute of Water and Atmospheric Research (NIWA), Private Bag 14901, Wellington, New Zealand Email: Andrew.tait@niwa.co.nz

Abstract

Climate change is likely to increase the frequency and intensity of weather-related hazards such as flooding, heavy rainfall and drought as well as coastal hazards such as coastal inundation and erosion. Many of New Zealand's urban areas, due to their location near the coast and/or on major rivers and their reliance on ageing infrastructure, are particularly vulnerable to these natural hazards and therefore to the likely impacts of climate change. It is therefore vital that local and regional government, upon whom the task of protecting urban communities from such hazards primarily falls, are better able to understand and evaluate these potential future hazards, the associated risks to infrastructure and buildings, and the options available to maintain a sufficient level of protection and service.

This paper describes a new suite of guidance and decision tools that have been designed to enhance the understanding of the potential impacts of climate change in urban environments in New Zealand. A web-based *Toolbox* is presented, which has been produced to package the tools in a logical risk assessment-based structure. We also present a decision-making framework for climate change adaptation in urban environments which steps users through a staged process of assessing priorities, identifying high risk areas, selecting risk-reduction options, and establishing a preferred solution.

The paper is the first of three papers published in this special issue. The second and third papers demonstrate the use of some of the tools described in the *Toolbox*. Paper 2 steps through an analysis of changes to future rainfall and sea levels and the effect on flood peaks and inundation. It also demonstrates a hazards risk model, Riskscape, which can estimate the impact of flooding on buildings and infrastructure (e.g. in terms of repair costs etc.). Paper 3 then looks at methods to narrow down and evaluate adaptation options to reduce the effect of flooding. Both papers use the town of Westport as a case study example.

1 Introduction

This paper is the first of three papers in this special edition on climate change and the New Zealand urban environment, all related to a new online resource called the '*Impacts of Climate Change on Urban Infrastructure and the Built Environment Toolbox*' (NIWA, MWH, GNS and BRANZ, 2012), hereafter referred to as 'the *Toolbox*'. In this paper, we provide an overview of the *Toolbox* including its purpose and need; the second paper describes the use of a set of modelling tools that can be used in sequence to examine scenarios of future flooding, inundation and risk to buildings and infrastructure (McMillan et al., 2012; this issue); and the third paper describes a set of tools that can be used to begin the process of evaluating adaptation options for flooding (Keenan and Oldfield, 2012; this issue).

The structure of this paper is as follows: Section 2 provides a brief review of some of the key concepts of climate change adaptation

and Section 3 gives some context of climate change issues for urban environments in New Zealand. An overview of the *Toolbox* and its structure are presented in Sections 4 and 5, followed by an outline of a decision-making framework in Section 6. Lastly, Section 7 describes a selection of tools that can be used to assess changes to hazards and their associated risks (as demonstrated more fully in McMillan et al., 2012 and Keenan and Oldfield, 2012; this issue).

New Zealand communities need to be prepared for climate change and the hazards that come with it. Around 75% of the $1.5 billion insurance pay-out for damages from natural hazards in New Zealand over the last 40 years (prior to the Canterbury earthquakes) has been for weather-related hazards (Insurance Council of NZ, 2012). Many of these hazards, including coastal storm surge, are projected to become more frequent and/or intense in the future because of climate change (Ministry for the Environment, 2008a and b). Urban environments are particularly vulnerable to these changes for a range of reasons, including the significant investment in long-lived infrastructure and buildings.

Urban environments are also where the large majority of New Zealanders live for all or most of their lives (Statistics NZ, 2004). Urban environments contribute significantly to economic activity and the country's gross domestic and gross national product, and contain most of the country's educational, cultural and health facilities, both in number and significance. Urban environments also contain the large majority of the country's public and community investment, and much of the private investment.

Some territorial and regional councils in New Zealand have developed, or are in the process of developing, climate change adaptation plans (e.g. Christchurch City Council, 2010; Wellington City Council, 2010). These plans are closely aligned with central government guidelines for assessing climate change impacts (Ministry for the Environment, 2008a and b; and 2010). However, there is a need for a standardised and centralised resource that all councils can access and use to assess the potential climate change impacts and adaptation options for their own urban environments. This paper describes a resource that has been developed to assist local government agencies assess impacts on urban infrastructure and buildings.

The *Toolbox* is the culmination of a four year research programme funded by the Ministry for Business, Innovation and Employment. The central purpose of the *Toolbox* is as a fundamental resource for New Zealand councils who are undertaking analyses of the potential effects of climate change on their urban areas. The ultimate goal is for all councils in New Zealand to use the tools in the *Toolbox* when assessing future land developments, infrastructure upgrades, zoning provisions, protection schemes, supply of services, and changes to policies and plans so that the potential effects of climate change are taken into account.

2 Concepts for adapting to climate change – a review

Adapting to the projected effects of climate change has been recognised as a necessity, as even rapid international action to reduce greenhouse gases in the atmosphere is unlikely to prevent the changes that are already in train (Ministry for the Environment, 2008a). From a review of recent literature, we summarise here a number of key concepts (italicised) which need to be considered when developing adaptive responses to climate change.

Firstly, projected climate change effects should be seen as *additional stressors*, rather than isolated effects. It is expected that climate change will generally add to existing hazards, rather than create new ones. For example, flood risk may increase in areas which already experience flooding events; droughts may increase in frequency or last longer (Danilenko et al, 2010). The additional stressor concept can be regarded as a positive factor for climate change-related policy development and adaptation, as it means that information from climate change assessments can be included with existing hazard

assessment and asset/infrastructure development, upgrade or renewal assessments and plans rather than be presented in isolation. Smit and Wandel (2006) conclude that it is extremely unlikely for any adaptive work to be undertaken based on analyses of projected climate change impacts alone. Recognising this, the New Zealand Ministry of the Environment recommends a mainstreaming approach, whereby 'adaptation to climate change is integrated and anchored in policy mechanisms that are already established to respond across the different sectors' (Ministry for the Environment, 2008a).

Adaptation actions should focus on *no regrets* or *low regrets* approaches, meaning that decisions should assist present as well as future communities to meet their needs (Danilenko et al, 2010). A related concept is that of *co-benefits* where a decision focussed on addressing climate change risk has other benefits (Rojas Blanco, 2006). No or low-regrets examples could be the provision of enhanced flood or stormwater protection at relatively low additional cost by small additions to stopbank heights or through larger pipes in stormwater systems, or taking into account future temperatures and water availability in the choice of long-lived urban tree species. An example of a co-benefit response could be reverting to more natural drainage systems, which as well as providing greater drainage capacity may also enhance ecological and amenity values in an urban area. The concept of *scalability*, or designing in a way that can be readily added to if and when needed, is a related concept that aids climate change adaptation (Smit et al., 2000). Of course, careful consideration needs to be taken of all the effects of an action (not just those related to the projected effects of climate change) to avoid maladaptation, or perverse outcomes (Danilenko et al., 2010).

Jones (2010) describes how adaptation as a *series of small steps* that have co-benefits or, at least, are reversible is an effective method of slowly reducing climate risks. Alternative possibilities can be easily tested based on limited quantitative or even subjective information (Ibid). This concept is expanded upon by Howden-Chapman et al. (2010) who argue that a range of incremental policy improvements based on early indications of change and the precautionary principle in relation to future change is essential if communities are to protect their well-being in the face of climate change.

A key element of effective adaptive responses to projected climate change relates to *community understanding of risks* associated with climate change and acceptance of and agreement on the need for responses (Hunter et al., 2010). In recent years, with recognition of climate change effects in a range of legislation including, in New Zealand, legislation directed at greenhouse gas reduction, discussion has moved from 'whether to adapt' to 'how to adapt' (Ministry for the Environment, 2008a). Local authorities have leading roles in analyses and decisions, but must converse with communities and ensure their practices embody community values.

Deriving regional projections of climate change and its potential impacts based on scenarios of future greenhouse gas emissions and concentrations is the most common method of generating information upon which adaptation decisions can be based. However, Wilby et al. (2009) discuss the limits to top-down scenario-based assessments. They conclude that the information from such assessments needs to be carefully matched to the intended application and *well-communicated* to the intended end-users. Recognition of this issue is made in the *Toolbox* with reference to the need to work closely with end-users in workshop environments, and to ensure that results of model- and scenario-based assessments are communicated effectively.

Related to the issue of using and communicating scenario-based information is the problem of how to manage the inherent uncertainty in such projections. Policy-makers must *deal with the uncertainty* they are presented with, and learn how to effectively communicate it to the general public (Baker et

al., 2010). Planning for an uncertain future must take a reasoned, justifiable and risk-based approach of determining what elements of the system are likely to be impacted, what information will be needed to make adaptations, and what the timing of such adaptations should be (Major and Goldberg, 2000). The likelihood of an uncertain future climate means that existing best practices should be continually revised and viewed as providing a source of tactical responses (short-term) to a changing environment (Glantz et al., 2009).

Many of the above concepts have been identified and further discussed in the *Toolbox*, especially in Tray 1 'Understanding the issues' and Tray 5 'Using the tools and improving practice'. In addition, all of the tools which describe the use of scenario-based modelling include a section on assumptions and uncertainty.

3 Urban environments and climate change

In New Zealand, an urban area is a settlement with a population of a thousand people or more (Statistics NZ, 2004). An urban environment can be described as the spatial area containing an aggregation of buildings, infrastructure and open spaces which provide for the interaction of an urban community. In 2006, 86% of New Zealand's population lived in an urban area (Statistics NZ, 2010). As in many countries, New Zealand's main urban centres, with a population of 30,000 or more, are usually the centres of productive rural regions, and provide transport and communications links to other centres, including international connections. These interactive roles of urban areas, along with their economic, social and cultural significance, mean that the ongoing efficiency and effectiveness of urban environments and systems is extremely important in modern society (United Nations Environment Program, 2002).

The urban environments of today are expected to provide for the needs of future generations. Many buildings and much urban infrastructure has a life of 50 or 100 years or more. The patterns of streets and land subdivisions that were initially laid out can change only slowly, if at all. As such, infrastructure is effectively permanent, and upgraded or changed to meet changing circumstances and new demands over periods of decades through consent renewal and plan changes.

Many of New Zealand's urban areas are vulnerable to natural hazards and the projected impacts of climate change. Historically, many settlements developed near the coast and/or on major rivers because of ease of water transport. Such centres later expanded over flood plains or onto hillsides. Many of these settlements are now at risk from sea level rise and/or increased exposure to flood and landslide hazards associated with projected climate change effects. Flooding may be associated with sea level rise, storm surges, river flooding from wider catchment rainfall events, or localised heavy rainfall events which exceed the capacity of local stormwater systems.

Other potential effects of climate change which may affect some of New Zealand's urban areas are drought (particularly in water supply areas) and enhanced fire risk, and potentially (although to a less well-understood degree) changes in extreme wind, hail, lightning, fog, ice and snow events. All urban centres are likely to be subject to increased average temperatures over time, and greater high temperature extremes.

Because of the geographical diversity of New Zealand's urban areas and the nature of the legislative and regulatory structure, identifying, analysing and prioritising the risks that an urban community is exposed to is a task that falls primarily to regional and local government. In responding to climate change, there is no single or simple solution. Communities will identify different risks and wish to develop their own responses.

Although New Zealand's local government agencies' purposes, roles and responsibilities are under review at the time of preparing this paper (NZ Department of Internal Affairs,

2012), it is not proposed to change the core services which local government must have particular regard to when performing their roles. Amongst the core services are "the avoidance or mitigation of natural hazards" (NZ Government, Local Government Act, 2002, section 11A). Alongside this service are other core services including energy and water infrastructure, public transport, waste management and community infrastructure such as reserves, recreational facilities and cultural facilities. Climate change may affect both a community's exposure to natural hazards, and how local government delivers on its core services. Although the purpose of local government (NZ Government, Local Government Act, 2002, section 10) is proposed to be modified, both the present purpose and the proposed modified purpose of local government refer to the future, as well as the present, community. With this future focus, local government needs to be well aware of the potential effects of climate change.

Local government's role of providing for the avoidance or mitigation of natural hazards is also provided for in terms of land use management within the wider resource management responsibilities of regional and territorial local authorities (NZ Government, Resource Management Act, 1991, sections 30 and 31). The responsibility of planning for future use, protection and development of land in a way, or at a rate, that mitigates natural hazards and provides for community health, safety and wellbeing is an ongoing challenge for local authorities, to which climate change adds a further complex dimension. This has recently been emphasised in national guidance under the New Zealand Coastal Policy Statement, where national policy now requires that coastal hazards risk must be assessed at least 100 years ahead, taking into account risks associated with climate change (NZ Government, Coastal Policy Statement, 2010, Objective 5).

4 An overview of the *Toolbox*

The *Toolbox* is an online resource which provides an array of tools populated with worked-through examples which will assist councils in evaluating and potentially adapting to projected changes to the climate. In particular, the *Toolbox* goes beyond providing methods and approaches for assessing likely future changes to the climate and the potential effects of these changes on hazards such as flooding and storm surge, and demonstrates tools for assessing the resultant change in risk and methods for identifying and weighing up viable adaptation options for reducing this risk. It must be made clear however, that the tools presented in the *Toolbox* are not the only tools or approaches for performing such assessments.

Techniques such as use of an options screening tool, multi-criteria analyses, rapid cost-benefit and traditional cost-benefit analysis, all tools explained in Tray 4 of the *Toolbox* (see Section 5 for an outline of the *Toolbox* structure), are examples which allow for the systematic evaluation (often including an assessment of non-monetary community values and wide-ranging implications) of a range of possible responses to identified risks. The example of flood risk in Westport (further elaborated in Keenan and Oldfield, 2012; this issue) has applied some of these tools. The tools provided will be more applicable in some circumstances than others, usually depending on the type of decision to be made, and the particular stage in a council process. For example, a number of the tools will give 'first cut' decisions which help eliminate or refine options. The outcomes may be sufficient for the purpose, or a further stage of application of one of the more detailed tools may be needed.

A key element which applies to all the 'decision' tools in the *Toolbox* is the need for the evaluation to start with a wide range of possible responses, including the 'do nothing' option. Generating possible responses requires the ability to take a wide-ranging approach and identify proposals which will provide partial or total solutions to the identified problem over a specific timeframe. Nominating a timeframe is particularly important as it relates to both the lifespan of the assets and the magnitude and uncertainty of the projected impacts. The broader

screening tools also specifically provide opportunities for the modification of a response and/or the addition of new and composite responses as part of the overall process. It is recognised that councils work under considerable constraints ranging from policy to budgetary limitations, to requirements for community input into decisions. The *Toolbox* provides a range of means of accommodating such requirements.

The final tray in the *Toolbox* 'Using the tools and improving practice', presents a series of key messages. This recognises that climate change adaptation is a relatively recently identified global issue which is now starting to be addressed by urban communities world-wide. Not only is the understanding of the range and extent of future projected climate changes still an area of developing understanding, but the range of possible responses is currently the subject of considerable research and emerging practice. Councils can learn from the experience of others. Through their responsibilities for future as well as present communities, there is a strong basis for local authorities to ensure they keep up-to-date with this developing field and remain well-informed so that they do not overlook effective opportunities to build climate change adaptation into all relevant decisions.

Many types of information need to be brought together in developing adaptive responses to climate change. This includes information about climate science and the translation of information from global climate models into local scenarios for the future; information on adaptive concepts, both international and local; and information on the legislative context and the opportunities and constraints offered by current legislation, standards and best practice guidance and their modification over time. Some of the tools in Tray 5 of the *Toolbox* provide suggestions as to where information can be obtained or advice can be sought.

While not all councils will be in a position to do this, an effective way of keeping up-to-date and ensuring climate change related advice is integrated into all relevant decisions, is through the role of a dedicated officer with a 'whole of council' responsibility for climate change advice across all areas of local authority business. This information and integration focus, as well as recognition of the important relationships between councils and community organisations, households and individuals (including individuals involved in development processes), is emphasised in the first two tools in Tray 5. Other tools in the same tray emphasise the need for a long-term view when considering climate change adaptation and the need for a broad and balanced approach, acknowledging the many factors other than climate change that affect urban environments. Successful adaptation will involve numerous actions by many people over a long period of time.

The Intergovernmental Panel on Climate Change (IPCC) (2012) states that some of the key features of resilient communities are the devolution of key responsibilities to democratically-based local government organisations, the strong presence of independent community organisations and networks, well-developed physical infrastructure and a relatively well-educated and affluent population. New Zealand, it can be argued, has all these key features and therefore can be said to have many of the components of community resilience. However, one of the challenges of climate change is to make sure that communities retain their resilience. In this respect, urban communities face different issues to rural communities, and each urban community must consider and respond to its own set of circumstances. The final tool in Tray 5 identifies three categories of climate change effects, each of which requires a different type or level of response; changes in ambient climate indicators, changes in the range of predictable extremes, and unpredictable extreme events. Each will require a different type of assessment and different types of responses, with the latter situation requiring emergency management readiness (IPCC, 2012). Potential sea level rise is a specific effect of climate change which brings a parallel set of planning issues into play (for

example sustainable development and erosion hazard assessment), and has particular importance for the many coastal New Zealand urban communities (Ministry for the Environment, 2008b).

A key final message in the *Toolbox* is that adaptive responses will never be comprehensive or completed. It is essential that the adaptive response to climate change includes monitoring of the effectiveness of actions that are taken, and on-going review, reconsideration and adjustment on a regular, cyclic basis (Glantz et al., 2009).

5 The *Toolbox* structure

The *Toolbox* structure follows a science-based risk assessment process (e.g., as described in the Joint Australian/New Zealand Standard for Risk Management, AS/NZS ISO 31000:2009). The first stage is an information gathering phase, followed by a hazard assessment at stage two. Stage three is a risk analysis, which considers what the hazard may impact. Stage four involves considering options (and their costs and benefits) to reduce the risk, and stage five is the integration of information into the planning and decision-making process. Users can enter the *Toolbox* at any stage, depending upon their needs.

Adopting the above risk assessment-based structure, the *Toolbox* has five levels, or 'trays', which step users through an end-to-end evaluation process. The five trays are:

1. Understand the issues;
2. Assess the likely hazard (or potential change in the hazard);
3. Identify the risks;
4. Evaluate options and their costs and benefits; and
5. Using the tools and improving practice.

Within each tray, users are presented with a list of tools and brief synopses indicating their purpose. Each tool is a stand-alone downloadable document, designed to help the user with a specific task. Some tools provide information and guidance, while others describe models or approaches for estimating impacts and dealing with uncertainty. Wherever possible, worked-through examples are provided as well as critical sections on data needs, model assumptions and limitations. The authors are identified on each tool and can be contacted directly for more information, particularly regarding the use of models and other analytical methods. A summary list of the tools in each tray is provided in Table 1.

The *Toolbox* is primarily designed to help planners, engineers, asset managers and hazard analysts working in councils in New Zealand understand and evaluate the potential impacts of climate change in their cities and towns. Thus, the principal 'end-users' are New Zealand council staff with the following roles and responsibilities:

- Infrastructure management;
- Asset management;
- Consents;
- Transport;
- Urban development;
- Strategic planning; and
- Emergency management.

Council staff can use the tools in the *Toolbox* to aid and inform decisions on upgrades to flood protection schemes, flexible management options for potable water supply, or the size of new storm-water pipes, for example. Climate change is likely to affect each town or city differently. The *Toolbox* enables councils to logically assess their specific situation and the hazards that are particularly relevant to their location, and make informed choices to minimise the risk of present-day and projected future climate-related hazards.

Tray		Tool	Title
First Tray Understand the issues		1.1	Urban environments and climate change
		1.2	General climate change information and guidance for New Zealand
		1.3	An introduction to risk assessment
		1.4	Urban environments and climate change – Statutory context
		1.5	Council policy and plan auditing tool
		1.6	Sensitivity matrix prioritisation tool
		1.7	Sources of information, help and expertise for climate change impact assessments and glossary
Second Tray Assess the likely hazard	**Bin 2.1 Flooding**	2.1	Overview of flooding tools
		2.1.1	General guidance on climate change and flood modelling methods used in New Zealand
		2.1.2	Modelling future heavy rainfall
		2.1.3	Hydrological modelling of present-day and future floods
		2.1.4	Inundation modelling of present-day and future floods
		2.1.5	Linkages to risk assessment, adaptation options and decision tools
	Bin 2.2 Sea level rise	2.2	Overview of sea level rise and storm surge tools
		2.2.1	Guidance on assessing sea level rise in New Zealand
		2.2.2	Causes of sea level variation
		2.2.3	Guidance on assessing extreme sea level in New Zealand
		2.2.4	Inundation mapping of future high tides, SLR and storm surge
		2.2.5	Linkages to risk assessment, adaptation options and decision tools
	Bin 2.3 Landslides	2.3	Overview of landslide tools
		2.3.1	General information on the causes of rainfall-induced landslides
		2.3.2	Collection and analysis of historical landslide information and data
		2.3.3	Modelling present-day and future landslide potential
		2.3.4	Mapping the landslide hazard
		2.3.5	Linkages to risk assessment, adaptation options and decision tools
	Bin 2.4 Urban drainage	2.4	Overview of urban drainage tools
		2.4.1	Climate change and urban drainage modelling – data, issues and assumptions
		2.4.2	Incorporating climate change into urban stormwater management
		2.4.3	Climate change guidance material for urban stormwater management
		2.4.4	Modelling the North Shore City Council wastewater network – a case study of potential climate change impacts
		2.4.5	Linkages to risk assessment, adaptation options and decision tools
	Bin 2.5 Potable water	2.5	Overview of potable water tools
		2.5.1	General information on water supply and demand methods and issues
		2.5.2	Bulk water demand trend modelling
		2.5.3	SYM approach to present-day and future potable water supply and demand
		2.5.4	Linkages to risk assessment, adaptation options and decision tools
	2.6 Other hazards	2.6	General information on the assessment of climate change effects on high winds, very high temperatures, snowfall, fog, lightning & hail and drought

Tray	Tool	Title
Third Tray Identify the risks	3.1	Climate change risk assessment good practice
	3.2	Using RiskScape for risk analysis.
	3.3	Case study example of risk assessment using RiskScape
	3.4	Investigating urban growth and change to inform the risk assessment process
	3.5	Subjective qualified risk analysis tool
	3.6	Linkages to hazard assessment, adaptation options and decision tools.
Fourth Tray Evaluate the options and their costs/benefits	4.1	Climate change adaptation – key concepts
	4.2	Overview of an option screening tool
	4.3	Rapid cost/benefit evaluation of impacts and adaptation options
	4.4	Individual house flood mitigation measures - benefit/cost tool
	4.5	Overview of a multi-criteria analysis based decision tool
	4.6	Overview of a top-down decision tool
	4.7	Adaptation by design: impact of climate and land use change on the sizing of stormwater management devices
	4.8	Overview of a building flood protection decision framework
	4.9	Linkages to hazard and risk assessment tools
Fifth Tray Using the tools and improving practice	5.1	Managing information (including use of climate change check-lists)
	5.2	Keeping up to date
	5.3	Climate change - the long-term view
	5.4	Adopting a balanced approach
	5.5	Community resilience and sustainable development

Table 1: Tools summarised by Toolbox tray

6 A decision-making framework for climate change adaptation

The *Toolbox* contains several 'decision' tools that are provided to inform decision making. These tools present a set of methods and examples for filtering and summarising complex information based on repeatable standardised methodologies so that decisions can be rationalised and documented. In many cases, it is suggested that these tools be implemented in a multi-disciplinary or multi-stakeholder workshop environment to ensure robustness in outcomes.

Workshops employ decision conferencing methods which foster stakeholder engagement, communication and participation and can lead to more robust outcomes than technical analysis alone (Phillips, 2006). A workshop provides a forum for sharing disparate knowledge, including tacit knowledge, from people with different values and fields of expertise. Workshops can allow successive iterations of alternatives to be presented, assessed and modified. Participation in workshops promotes partnerships and supports mutual learning and capacity building (Phillips, 2006). It can improve decision-making by making background information and outcomes transparent and by letting stakeholders have their say. The process leads to more informed, holistic and equitable decision making, promotes consensus and improves the acceptance by stakeholders of the decision. It may be argued that there is a democratic necessity of community deliberation as a way to embed adaptation decisions and values within wider concerns, policies and decisions about urban (and non-urban) development.

In an uncertain future, where climate change effects have the potential to change long-term decisions about the planning and development of the urban environment, councils and other service and utility providers are faced with some fundamental questions:

- Which climate change effects are of most concern? (Scoping issue);

- Where are the needs for action most pressing? (Prioritisation issue); and
- What actions provide the best solution? (Optimising the adaptation response).

Geographical and demographic differences mean that the answers to the above questions are very much regionally dependent. The answers are also dependent upon who is being asked the questions, as people's priorities will vary depending upon their personal circumstances and values. In uncertain situations, there is a real danger of over-compensating as well as under-compensating for projected climate change impacts that are still not well understood at a local scale. To minimise the likelihood of this occurring, a risk-based decision-making framework can be used. While there are many ways that priorities for action could be established, it is likely that a staged and risk-centred approach, involving a successive narrowing down and refinement of the issues of concern, will be an important part of setting priorities (e.g. NZ National Asset Management Steering Group, 2004).

With reference to the key questions listed above, there are three corresponding stages in the *Toolbox* decision-making framework:

1. Assessment of priorities across all relevant projected climate change effects for the geographical region of interest – this is to identify priority climate change effects and areas most vulnerable to these effects;
2. Risk mapping of priority (high risk) areas for the selected climate change effects, as identified from Stage 1; and
3. Identifying preferences among alternative adaptation methods to address the priority climate change effect (identified in Stage 1) and the risk identified in the priority locations (identified in Stage 2). This adaptation 'optioneering' stage has two steps:

    a. Identify and assess risk reduction options; and

    b. Establish a preferred solution, and carry it out.

Figure 1 shows a 'roadmap' of this staged decision making framework and indicates some of the decision tools from the *Toolbox* that can be used at different stages. The framework is part of the wider risk assessment and adaptation evaluation process whichforms the structure of the *Toolbox* and provides for a balanced and justifiable prioritisation of adaptation to climate change.

It is not intended, nor is it always necessary, to start at Stage 1 of the decision making framework. In some situations, depending on prior work, it is possible to apply the decision tools without completing earlier steps. However, there could be a danger that later steps may be compromised as a result. For example, inadequate consideration of alternatives may potentially result in delays in achieving the required consents and substantial re-work.

7 Assessments of hazard and risk

A core council function is the evaluation of natural (and other) hazards that may impact the built and natural environment, infrastructure, services, and the health and wellbeing of residents. A natural hazard can be defined as a natural phenomenon which has an intrinsic ability to cause harm or negative consequences (e.g. NZ Government, Resource Management Act, 1991, section 2). Many of these hazards are weather-related, such as river flooding, coastal inundation and erosion, rainfall-induced landslides, heavy rainfall-induced localised flooding, high winds, snow, hail and drought. It is a fundamental responsibility of councils to consider and respond to the exposure of their communities to these hazards (NZ Government, Local Government Act, 2002, section 11 and 11A; NZ Government, Resource Management Act, 1991, sections 30 and 31). In carrying out these responsibilities, councils need to understand and provide information on hazards (NZ Government, Resource Management Act, 1991, section 35).

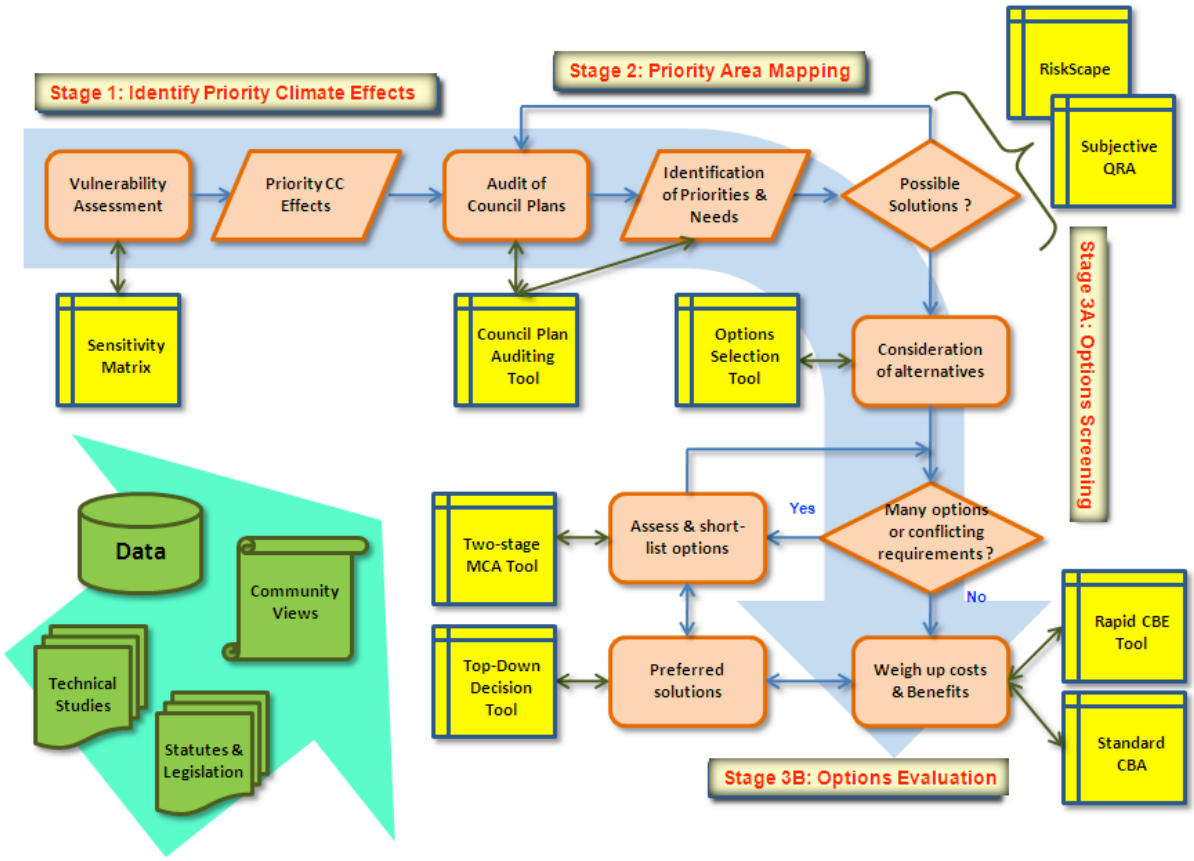

Figure 1: Toolbox Roadmap Decision-Making Framework. The yellow boxes are some of the tools (see Table 1) that could be used at different stages of the decision-making process.

Risk refers to the severity of the impacts of hazards and the probability of their occurrence. Natural hazards risk depends not only on the magnitude and frequency of the potential effect but also on the nature of the built environment (e.g., land use type and intensity, urban form, infrastructure) and the activities (e.g., residential, industrial or commercial) impacted. Ministry for the Environment (2008a, p73) defines risk associated with climate change as:

> "the chance of an event being induced or significantly exacerbated by climate change, that event having an impact on something of value to the present and/or future community".

The primary means of risk reduction explored by the *Toolbox* is adaptation (discussed more fully in Keenan and Oldfield, 2012; this issue). In the context of climate change, adaptation is defined by the IPCC (2007b, p750) as:

> "the adjustment of natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".

Adaptation can be reactive as a response to impacts as they occur or pro-active to avoid or mitigate impacts before they occur. The *Toolbox* addresses structural adaptation (e.g., adaptations to the design and structure of primarily public infrastructure) and non-structural adaptation (e.g., education and policy to modify behaviour).

The second tray in the *Toolbox*, 'Assess the likely hazard' (see Table 1), is dedicated to tools for assessing the likely effect of climate change on climate-related hazards. Each urban environment will be exposed to a

mixture of different hazards, depending on its location. For this reason, the tools in this tray are divided into six bins representing different hazards. The tools in each bin are specific to the modelling and assessment of a particular hazard. The bins are:

- Bin 2.1 Flooding;
- Bin 2.2 Sea level rise and storm surge;
- Bin 2.3 Heavy rainfall induced landslides;
- Bin 2.4 Heavy rainfall and urban drainage;
- Bin 2.5 Supply and demand of potable water; and
- Bin 2.6 Other hazards

Each bin includes a sequence of tools that demonstrate the suggested steps and exemplified methodologies, data and models required to assess the likely change in hazard. McMillan et al. (2012; this issue) employ the tools in Bin 2.1 to assess the future flooding hazard in Westport. In the decision-making framework presented above, such assessments generate crucial data and technical reports and inform community views (the green arrow in Figure 1), which are fundamental building blocks for the decision-making process. McMillan et al. (2012; this issue) also demonstrate how tools in Tray 3 of the *Toolbox* can be used to assess the flooding risk (i.e. Step 2 in Figure 1), with respect to damage to Westport's infrastructure and buildings.

Throughout the *Toolbox*, other New Zealand-based examples provide additional context and demonstrate how different combinations of tools can be used to address specific hazards and risks. The examples are drawn from six case studies chosen by councils and other service providers in Auckland, Wellington, Christchurch and Westport at a series of workshops. The case studies focus on different aspects of urban built environment that are vulnerable to different weather-related hazards. The case studies are listed along with tools illustrated by them in Table 2.

Hazard	**Case study**	**Urban centre**	**Tools (see Table 1)**	**Bin**
River flooding	Heavy rainfall and flooding of the Buller River	Westport	1.6, 2.1.2, 2.1.3, 2.1.4, 3.3	Bin 2.1
	Modelling the Heathcote River	Christchurch	1.6, 2.1.2, 2.1.3, 2.1.4	
Coastal inundation	Sea level rise and storm surge inundation of the Heathcote Estuary	Christchurch	1.6, 2.2.2, 2.2.3, 2.2.4	Bin 2.2
Landslides	Heavy rainfall induced landslides	Wellington	1.5, 1.6, 2.3.3, 2.3.4	Bin 2.3
Failure of urban water management systems	Heavy rainfall and urban drainage	Auckland	1.6, 2.4.2, 2.4.3, 2.4.4, 4.7	Bin 2.4
	Rainfall and potable water supply and demand	Wellington	1.6, 2.5.1, 2.5.3	Bin 2.5

Table 2: Tools summarised by case study

8 Summary and conclusions

This paper describes a new suite of guidance and decision tools, packaged in a web-based *Toolbox*, that have been designed to enhance the understanding of the potential impacts of, and adaptation options to, climate change in urban environments in New Zealand. The *Toolbox* is structured using a risk assessment framework. There are tools available to help users, particularly local government agencies, better understand climate change issues (and how these issues relate to their own urban

environment and governance); assess the hazards (or potential change in hazards) and the subsequent risk to buildings and infrastructure; and to evaluate options for mitigating these hazards and reducing risk.

We also present a decision-making framework for climate change adaptation in urban environments which steps users through a staged process of assessing priorities, identifying high risk areas, selecting risk-reduction options, and establishing a preferred solution.

In identifying and evaluating options for adapting to the likely effects of climate change, which for most urban environments is a hazard risk-reduction exercise, there are some key concepts that should be considered. Some of these concepts are that the likely effects of climate change should be considered as additional stressors to existing hazards, and should be mainstreamed into all hazard/risk assessments. Furthermore, options for reducing the risk should focus on no regrets or low regrets approaches, and if possible have significant co-benefits and have sufficient flexibility such that solutions can be modified easily if needed. Importantly, community consultation is critical such that those people most directly impacted by climate change (both via projected physical impacts and through changes to local government plans and policies) have an opportunity to participate in, and gain a full understanding of, the science-based assessment process.

Some key messages are also presented to help integrate hazard, risk, and adaptation information into the local government decision-making and planning process. Managing information (including use of climate change check-lists) and keeping up to date with the fast-moving nature of climate change information is vital. So too are adopting a long-term view and a balanced approach, recognising that urban environments are affected by multiple stressors, not just by potential climate changes. Lastly, concepts and approaches designed under a banner of improving community resilience and/or sustainable development are often equally effective at reducing the risks associated with climate change; so it should be recognised that there are multiple pathways available to achieving a desired outcome.

In conclusion, the '*Impacts of Climate Change on Urban Infrastructure and the Built Environment Toolbox*' (NIWA, MWH, GNS and BRANZ, 2012) is a comprehensive resource for understanding and assessing climate change impacts and adaptation options for urban environments in New Zealand. It is hoped that the tools will be well used, and that New Zealand urban communities will be better prepared and more resilient as a result.

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