Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 1.3: An Introduction to Risk Assessment

Author

S.G Oldfield[1]

Affiliation

1. MWH New Zealand Ltd., PO Box 9624, Te Aro, Wellington

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1. Introduction

This and other documents within the Toolbox are specifically concerned with the risks that will arise from climate change effects and uncertainties and not the risks and uncertainties associated with the drivers of climate change.

1.1 Background

This document gives introductory information and guidance on methods that can be used to gain a risk-based understanding of the implications of climate change on communities and community assets. These methods provide a basis on which priorities can be established and alternative adaptations can be compared and judgements formed about their relative merits.

Climate change effects do not introduce fundamentally new or different risks, rather they modify risks that that already exist. Detrimental climate change effects tend to increase the loading on assets increasing the chance of premature failure. Uncertainties increase because the rate and magnitude of the changes are not known with certainty.

All the usual risk assessment methods can be used in assessing climate change risks and uncertainty, however there are some fundamental principles that should be followed to ensure that treatments are appropriate and robust.

The principles to be followed are outlined and brief descriptions are given of the more commonly used risk assessment methods. High-level guidance is given on selecting the most appropriate method(s). The reader is directed to key legislation, standards and guidance documents for more information.

The purpose of this document is to provide a starting point for choosing the most appropriate risk assessment methods to employ, depending on the nature of the climate change issues of concern and the decisions to be made. A related document [Tool 3.1 Climate Change Risk Assessment Good Practice] provides more in-depth information and guidance on quantifying climate risks.

2. Overview of Key Reference Documents

Ref	Title	Content relating to Climate Change Risks
CDEM 2002	Civil Defence and Emergency Management Act	Places a requirement on Councils to identify, assess and manage hazards and risks, consult and communicate about risks, identify and implement cost-effective risk reduction measures.
RMA 1991	Resource Management Act	Requires particular regard to be given to the national benefits derived from the use and development of renewable energy and the efficient use of energy, and the impacts of climate change (Sections 104E and 70A). Requires the consideration of the effects of climate change (Section. 7), where effects to be considered are given in Section 3 and include low probability high consequence events [see MfE, 2007].
LGA 2002	Local Government Act	Requires Councils to identify all forecasting assumptions and risks underlying financial estimates.
BA 2004	Building Act	Gives effect to building codes that dictate the standards which buildings must meet in respect of land that is likely to be subject to one or more natural hazards.
MfE 2008a	Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand	Provides quantitative predictions of climates change (temperature, rainfall, etc) for New Zealand and guidance on setting up different predicted future scenarios in order to quantify possible impacts; includes an introduction to risk management principles and the statutory framework within which decisions need to be made.
MfE 2008b	Coastal Hazards and Climate Change – A Guidance Manual for Local Government in New Zealand	Provides details of how to take account of climate change in assessing marine inundation hazards to coastal communities and assets. Gives broad guidance on the appropriate risk assessment principles and methods for assessing and selecting adaptations to reduce the risks to coastal communities and assets.
MfE 2010	Tools for Estimating the Effects of Climate Change on Flood Flow – A Guidance Manual for Local Government in New Zealand	Provides `good practice' guidance on incorporating climate change impacts into flood flow estimation, including estimating the frequency and/or magnitude of rainfall, the resulting fluvial flows and inundation.
AS/NZS ISO 31000:2009	Risk Management – Principles and Guidelines	Provides the principles and framework within which all forms of risks are to be managed, including those arising from climate change effects.
NZS 9401:2008	Managing Flood Risk – A Process Standard	Provides the principles to be followed in managing flood risk. Puts the onus on the local community to decide on the level of residual risk they are prepared to tolerate.

3. Definitions of Risk

Risk is defined in AS/NZS ISO 31000:2009 as: "The effect of uncertainty on objectives".

Clearly climate change effects are included in this definition. The definition also recognises that the concept of risk can be applied to both unwanted outcomes as well as opportunities. Put another way, risk represents an expectation of loss or gain in a specified, but uncertain, future context.

In its most general sense, risk is a probability which may vary in time or space. It is a function of the probability of an event occurring (also referred to as Likelihood) and the probability that a defined outcome occurs as a result (also referred to as Consequence).

Often, simple risk assessments are carried out by applying scores or ratings to the `Likelihood' of an event occurring and to the `Consequence' should it occur. A simple indicator of the level of risk is then obtained by multiplying the two scores together. These types of technique are described as semi-quantitative because they provide a relative rather than an absolute measure of risk. Fully quantitative risk analysis methods are required in order to obtain an absolute measure of risk. These methods require significantly more information and resources, and are discussed more fully in document [Tool 3.1 Climate Change Risk Assessment Good Practice].

4. Types of Hazard and Risk

4.1 Scope and Scale

Climate change is of national and international concern. The impacts are likely to be widespread, and affect both the human and natural environments. In gaining an understanding of climate change impacts, it is therefore important to give consideration to economic, environmental, social[1] and cultural impacts (the 'four well-beings), as well as the science and technology impacts and requirements, to effectively and sustainably manage such impacts.

Climate change effects should not be seen as a separate 'class' of risks, rather climate change needs to be taken into account when considering all types of risks impacted by weather-related natural processes and events. In some instances, climate change impacts will have little or no effect; in other situations, climate change may

[1] Includes human life risk

substantially change both the risk and the choice of appropriate method of managing the risk.

Natural hazard risks vary from place to place. Uncertainty in the occurrence, severity and extent of climate change effects only adds to this variability. In assessing natural hazard risks on anything but a local area scale, it may be necessary to sub-divide the area of interest for purposes of assessment. In addition, because climate change effects are expected to increase with time it will be necessary to assess risk at different future time horizons spanning the life expectancy (design life) of the measures being considered to manage the risk.

4.2 Perceived and Objective Risk

In general, different individuals will have different interpretations of a particular risk, depending amongst other things on the benefit they derive from the risky activity, and also how much personal control they believe they have over their exposure to the risk. This perceived risk is often at odds, sometimes greater than and sometime less than, objective levels of risk that unbiased interpretations of the evidence would suggest. For example, some people accept the risk of living on flood prone land, possibly through ignorance of the risk or because they consciously or subconsciously feel that the benefits from living close to a river or the coast outweigh the risks of flooding. In the latter case the perceived risk is lees than the objective risk.

Decision-making under New Zealand legislation, such as the RMA, should be based on objective risk backed up by robust analysis, but also needs to take account of local community concerns. Hence it is important that flood risk, for example, is not over or understated. Equally it is important that decisions made about flood controls should be measured and balanced against objective levels of risk.

4.3 Opportunity Risk

In considering climate change effects, there is a tendency to focus on the downside risk, but there may be instances where climate change could have beneficial effect. For example, it is predicted that average winter temperatures in the south of New Zealand will increase, extending the growing season for crops. Similar analysis methods can be used to analyse these up-side risks or opportunities. However, this document and the Toolbox as a whole is principally concerned with the downside risks from climate change.

5. The Risk Management Framework

Risk Management is the term applied to a logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process, and in a way that will enable organisations to minimise losses and maximise opportunities.

The risk management framework given in the current joint Australian and New Zealand Risk Management standard AS/NZS ISO 31000:2009 is presented in Figure 5.1.

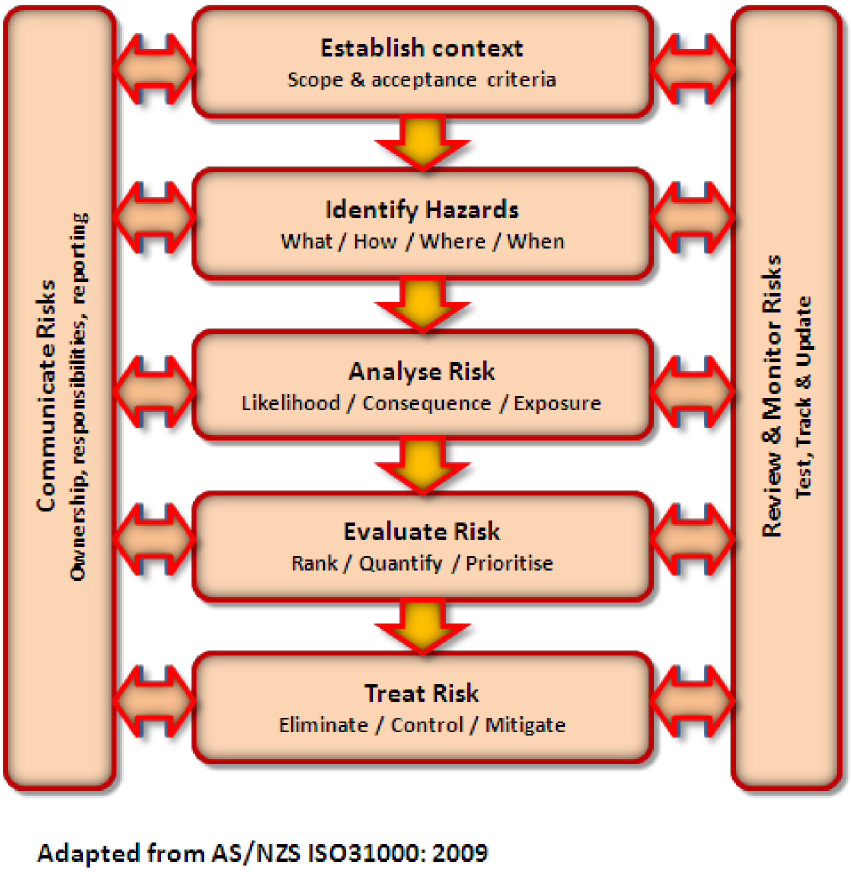

Figure 5.1: Risk Management Framework

The risk assessment process is embedded within the Analyse – Evaluate – Treat Risk elements of the management framework given in Figure 5.1. These aspects are the main focus of this document and much of the Toolbox. However, this is not intended to diminish the importance of the other steps in the process.

6. Risk Principles

It is widely recognised that there are some general principles which should be followed in developing assets that are more resilient to climate change. While there is a good deal of agreement in the themes that run through the principles, various internationally recognised agencies have identified there is, as yet, no universal set of principles.

The general principles most commonly cited and used in a New Zealand are as follows:

- Adopt an integrated and sustainable approach in planning [#1] [#2] [#3]
- Adopt a precautionary approach in the face of uncertainty [#1] [#2] [#3]
- Account for the reasonably foreseeable needs of future generations [#1] [#2]
- Avoid, remedy or mitigate adverse effects [#1] [#2]
- Ethical stewardship / prudent stewardship / kaitiakitanga [#1] [#2]
- Consultation and participation [#1] [#2]
- Working partnership with local communities [#1] [#2]
- Financial responsibility and liability of local government [#1] [#2]
- Seek flexible and adaptable solutions [#1] [#2]

(#1: MfE 2008a; #2: MfE 2008b; #3: MfE 2010)

The core principles of adopting a precautionary approach in assessing climate change risk and seeking flexible and adaptable solutions to manage these risks are particularly important in seeking sustainable solutions.

In addition to these general overarching principles, there are a number of internationally recognised risk-based principles that are often invoked in determining the appropriate depth of analysis required, and for making judgements about the tolerability of risk. These risk-based principles are outlined in a companion document [Tool 3.1 – Climate change risk assessment good practice].

7. Overview of Risk Assessment Methods

There are many different techniques which can be used to assess risk, ranging from qualitative methods (which purely describe the risk exposure), through to fully quantitative methods from which absolute measures of risk can be derived. All of these methods have their advantages and disadvantages depending to some degree on the application.

In selecting an appropriate method to use, one of the major considerations is the level of detail of treatment that would be considered ‘fit-for purpose’. Increasing detail generally means increasing accuracy (assuming the data is available), however, there is a price to pay for the increased accuracy, namely the resources required in data gathering, model preparation, results generation and verification. This dichotomy is illustrated in Figure 7.1.

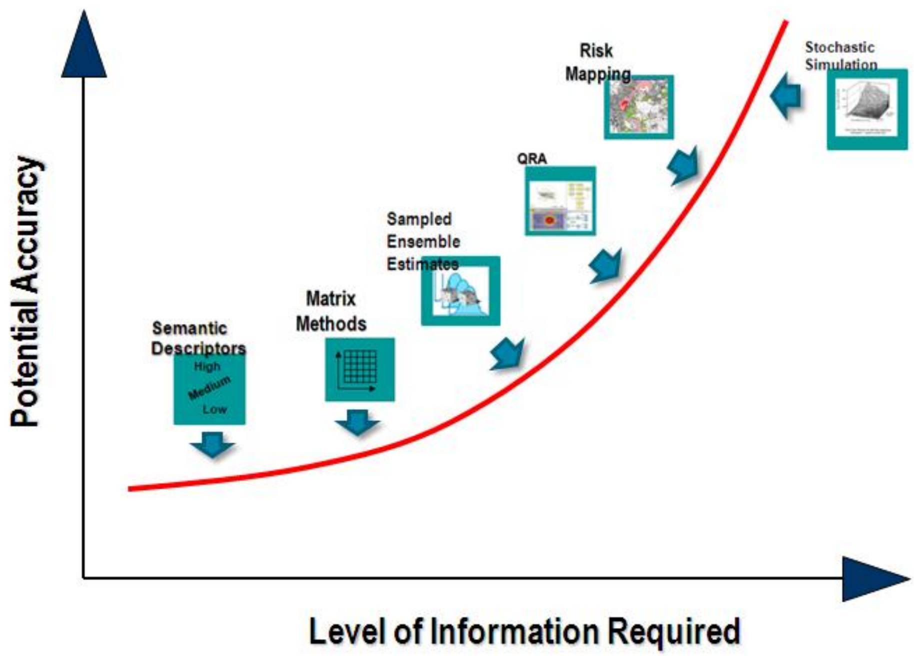

Figure 7.1: Risk Assessment Detail versus Resource Requirements

A short description of a range of different risk assessment techniques illustrated in the graphic above is given in Table 7.1 below.

Table 7.1: Non-exhaustive List of Types of Risk Assessment

Approach	Method	Description
Qualitative	Natural language descriptions	Natural language statements are used to indicate the degree of vulnerability or risk under different conditions. The sensitivity matrix [Tool 1.6] is an example of this type of method.
Semi-quantitative	Subjective scoring of likelihood and consequence as components of risk – matrix methods	A relative measure of risk is derived from a combination of subjectively defined likelihood and consequence scores. Descriptive prompts are used to aid in the assignment of these scores. See Section 8 for a description; also see MfE, 2008a and 2008b.
	Assignment of likelihood and consequence against a common natural scale to form risk	Probability based estimates of likelihood. Severity of outcome derived in terms of utility or dollar value. [Tool 3.5] is an example of this type of method.
Statistical Estimators	Statistically derived ensemble estimators; simple Monte Carlo methods	Risk is characterised as a statistical distribution generated from an ensemble of the risk components, each generated by sampling the likelihood and consequences from simple statistical models.
	Probabilistic scenario-based methods – multi-model methods	Risk derived from a finite set of scenarios. Scenario likelihood determined from a probability tree approach; consequences generated from separate models of each scenario.
Quantified	Risk mapping methods	A GIS-based approach to the mapping of the spatially varying hazard and risk in which a series of alternative predicted outcomes are combined according to their annual exceedance probability (AEP). Riskscape [Tools 3.2 & 3.3] is an example of this type of method.
	Stochastic simulation methods	A simulation model is developed representing the complete end-to-end representation of all the processes which govern the risk context of interest. The simulation model is run within a sampling framework; values for all the uncertain inputs are sampled from distributions of possible values and many hundreds of simulations generated to generate a risk profile.

Each of the above approaches has its merits in different contexts. The key is adopting an approach that is fit-for-purpose, and that provides a depth of treatment that is consistent with the level of detail of the data being used to characterise the risks.

Figure 7.2 gives a high-level comparison of adopting a qualitative or quantitative approach to assessing risk.

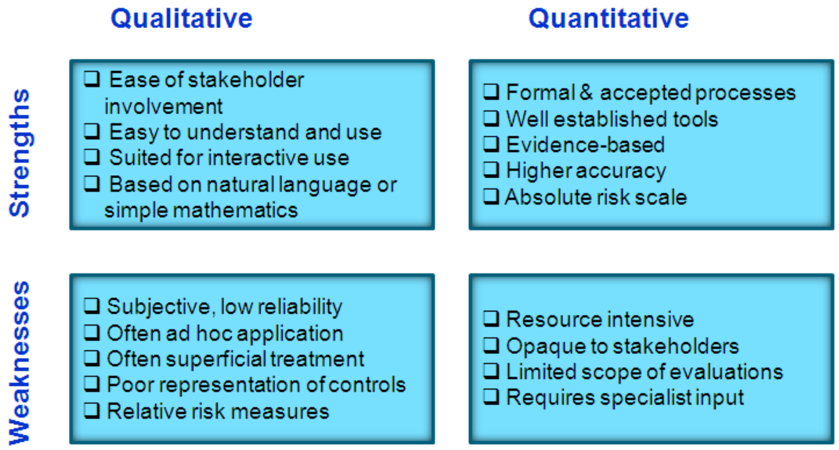

Figure 7.2: Quantitative Versus Qualitative Risk Assessment

Typically, the simpler qualitative or semi-quantitative methods are used to screen and prioritise different risks for attention. More quantitative assessment of the short-listed risks may then be undertaken in order to make informed judgements about the cost-effectiveness of alternative risk reduction measures. As a general principle, it is widely accepted is that the depth of analysis should be commensurate with the level of risk involved.

Additional guidance on selecting the appropriate risk assessment technique is given in a separate Toolbox guidance document [Tool 3.1].

8. Illustration of Risk Matrix Method

A semi-quantitative risk assessment technique commonly known as the `risk matrix method' is described in this section by way of an illustration. This method is often used to gain an understanding of the relative magnitude of a wide range of independent risks and to set priorities for attention.

Figure 8.1 shows schematically a five-by-five risk matrix. The objective in using this method is to identify and place each risk in this matrix according to the likelihood that each will occur, and the severity of the outcome if they did occur. This is a semi-quantified method as it produces relative risk rankings that can take a finite number of discrete levels. A fully quantified method produces an absolute measure of risk on a continuous scale.

Because of its relative simplicity, the risk matrix method is used to screen and prioritise risks. The method is briefly described in MfE climate change guidance documents [MfE 2008a and MfE 2008b].

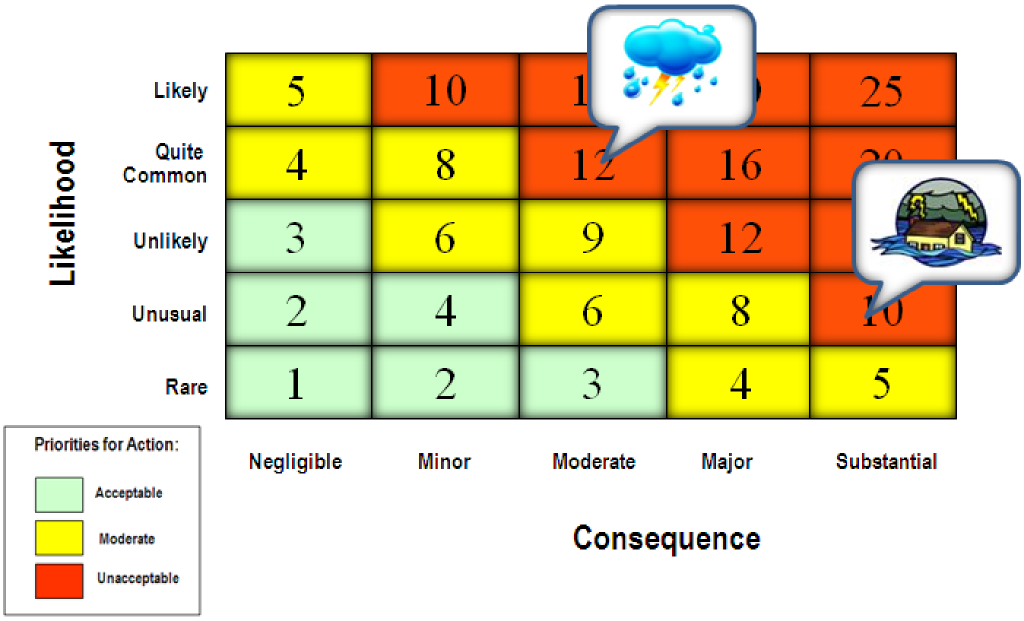

Figure 8.1: Schematic of the Risk Matrix Method

In the above illustration, flooding is rated as a relatively “Unusual” event with a “Substantial” impact, assuming it occurs in a highly populated area. A lightening strike is rated as a “Quite Common” occurrence with a “Moderate” impact, as typically its effect is limited to a single building.

Prompt lists are provided to aid in the rating of the likelihood consequence pairs for each of the independent risks. Examples of a prompt list for both the likelihood scale and the consequence scale are given in Tables 8.1 and 8.2, respectively.

Table 8.1: Example Likelihood Rating Table

Rating	Name	Guiding Description
5	Almost Certain	1 in 50 chance of occurring annually (0.02 AEP)
4	Likely	1 in 100 chance of occurring annually (0.01 AEP)
3	Possible	1 in 200 chance of occurring annually (0.005) AEP)
2	Unlikely	1 in 500 chance of occurring annually (0.002 AEP)
1	Rare	1 in 1000 chance of occurring annually (0.001 AEP)

Table 8.2: Example Consequence Rating Table

Rating	Name	Marine inundation
5	Catastrophic	Foreshore protection breached over a significant length of the foreshore. Many properties and or significant assets are inundated and damaged, multiple fatalities. Greater than 10 of millions of dollars of damages
4	Major	Major break or numerous small breaches of coastal protection. Several properties and or significant assets inundated and damaged. multiple serious injuries or a fatality Between $1 million to $10 million damages.
3	Moderate	Moderately large breach causing significant and reasonably widespread inundation and damage to multiple properties and or significant assets. Between $100,000 and $1 million damages
2	Minor	Small breach of coastal defences, localised damage to only one or two properties and or minor damage to a significant asset. Single serious health effect and/or several minor health effects - requiring medical attention. Between $10,000 to $100,000 damages
1	Negligible	Negligible impact, no significant damage beyond what would naturally occur in a normal year. No significant breach, no significant land or property damage. Less than $10,000 damages

9. Managing Risk

Whichever method is used to assess the levels of inherent risk, the risk will remain unless something is done to eliminate, avoid or mitigate it. Figure 9.1 gives the basic elements of a decision process to achieve the required risk reduction. This process comprises: an assessment of risks against limits and targets of acceptability and, for unacceptable risks, a consideration of alternatives for reducing the risk.

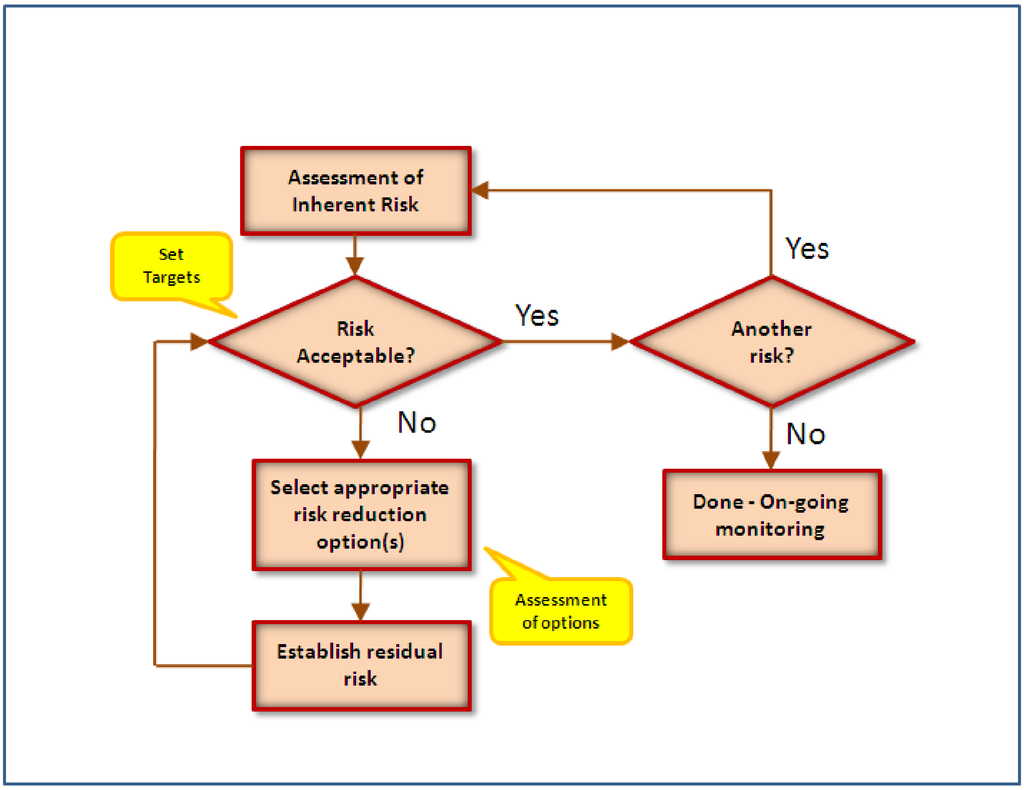

Figure 9.1: Risk Management Decision Process

Having selected appropriate risk reduction measures, their effectiveness and hence the risk that remains, needs to be established. This 'residual risk' can then be compared against the limits and targets, and the process repeated if the risk remains unacceptably high.

Tools are provided within the Toolbox to assist in the assessment of risks, quantifying the effectiveness of risk reduction measures and in the options selection process. Reference should be made to the Toolbox Overview document for more information on the Tools available.

10. Advanced Risk Concepts

This document has given a brief overview of the fundamental risk concepts with particular reference to assessing and managing weather-related natural hazard risk, including the effects of climate change. Additional guidance on quantifying risk; different measures of risk; making judgements about the tolerability of risk and more advanced good practice principles and guidance is given in [Tool 3.1].

11. References

AS/NZS ISO 31000:2009, Risk Management – Principles and Guidelines, Standards New Zealand, Wellington.

MfE (2007) Making Good Decisions – Climate Change Effects, Ministry for the Environment, Wellington.

MfE (2008a) Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand (2nd Edition), Ministry for the Environment, Wellington.

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