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HB 203:2006 Environmental risk management - Principles and process

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Environmental risk management —Principles and process

handbook

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Handbook

Environmental risk management—Principles and process

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Preface

This guide was prepared by the Joint Standards Australia/Standards New Zealand Task Group on Environmental Risk Management, operating under and with guidance from, Committee OB-007, Risk Management. The principal editors and contributors to the 2000 edition were:

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The guide was revised for reissue in 2005 by Mrs Janet Gough, Professor Jean Cross and Dr Dale Cooper.

This guide is intended to help individuals and organizations to understand environmental risk management, and to implement environmental risk management programs based on the generic process set out in the Joint Australian/New Zealand Standard, AS/NZS 4360:2004, *Risk management.*

Section 1 introduces fundamental concepts and principles of environmental risk management, and outlines the environmental issues and criteria that need to be considered during decision making and in developing an environmental risk management strategy.

Section 2 is based on the steps described in AS/NZS 4360:2004, and elaborates on issues noted in Section 1 by detailing how the principles and process can be applied in implementing environmental risk management.

Section 3 comprises an illustrative case study.

A series of informative appendices further expands on particular concepts. These include a glossary of terms and a bibliography for further reading that includes Standards referred to in the text.

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1 Introduction

1.1 Using the guide

This guide presents an integrated framework of principles, practices and criteria for implementing best practice in environmental risk management. It offers readers with a broad range of skills and experience of technological systems and environmental applications a clear, credible and consistent model for environmental risk management, its process and component parts.

Guidance is based on the risk management process developed in AS/NZS 4360:2004, which involves communicating and consulting with stakeholders, setting the context, identifying risks, then analysing, evaluating, treating and monitoring risks. The special features of environmental risk management and the links with environmental management tools are discussed.

The guide can be used:

- to inform management and staff about environmental risk management;
- as a framework for strategic planning and decision making;
- to implement environmental risk management at operational and strategic levels;
- as a tool within an organization's environmental management system;
- to provide guidance for drafting briefs when engaging consultants; and
- as a basis for consistent terminology, see Clause 1.8 and Appendix A.

1.2 Risk management

Risk is the chance of something happening that will have an impact on objectives (AS/NZS 4360:2004).

Risk may arise from an event, an action, or from lack of action. Consequences can range from beneficial to catastrophic. Risk to the environment can be in the form of stresses caused by human activity (or inactivity) which lead to degradation or loss of sustainability.

Risk management is the culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects (AS/NZS 4360:2004).

Risk management involves *everyone*, and is never just the responsibility of the CEO, managers, or the organization's risk consultant. It requires commitment and energy from top management through to the employee who may be the first to see an incident, a potential hazard, or an opportunity for improvement. Input may also come from stakeholders.

As illustrated by the feedback pathways in Figure 1, the entire risk management process is iterative. The process may be repeated many times with additional or modified risk evaluation criteria, leading to a process of continual improvement.

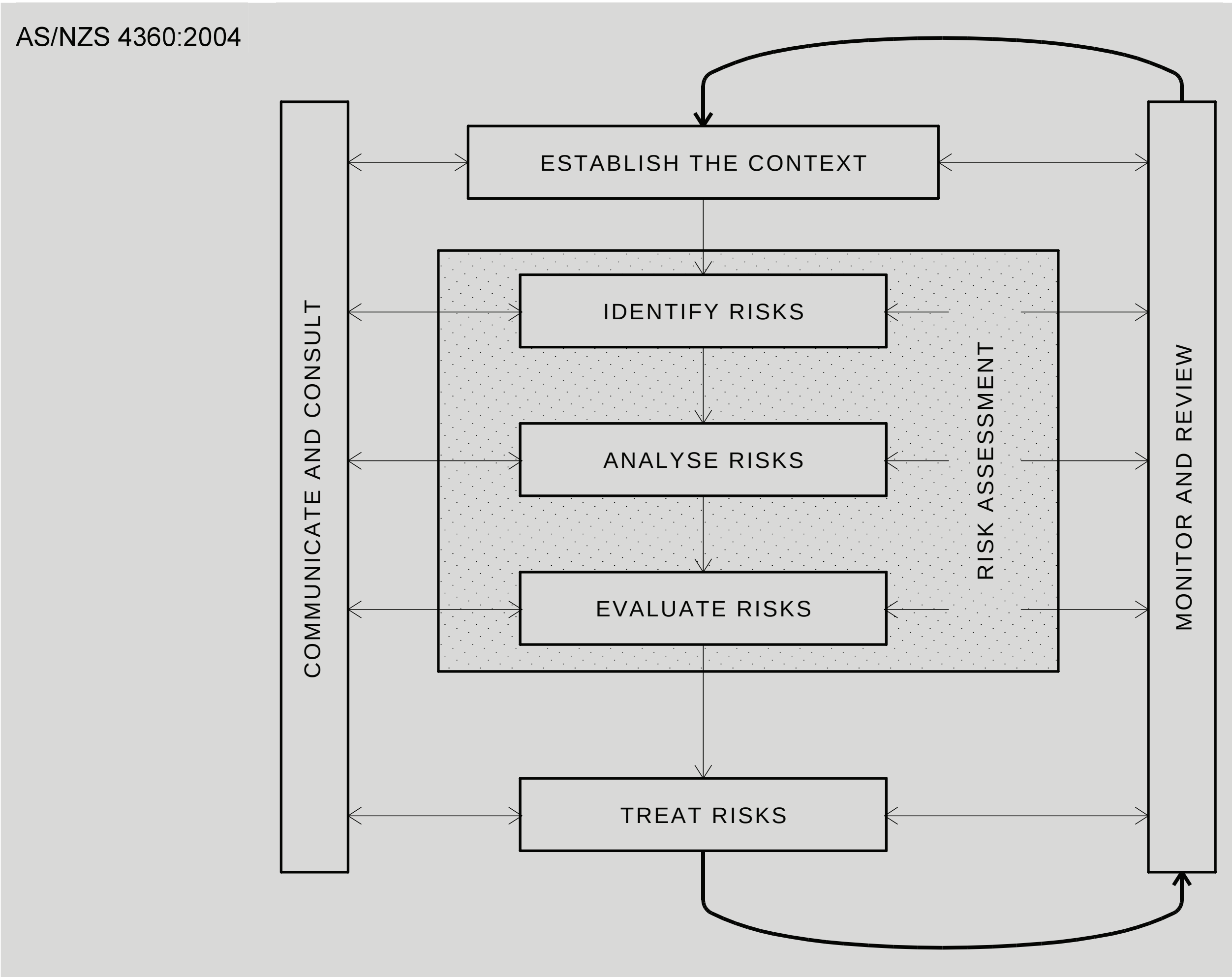

FIGURE 1 RISK MANAGEMENT PROCESS – OVERVIEW

The steps of the generic risk management process are:

(a) *Communicate and consult*

Communicate with and consult the internal and external stakeholders as appropriate at each step of the risk management process and concerning the process as a whole (see Clause 2.2).

(b) *Establish the context*

Determine the external, internal and risk management context, and establish the structure of the analysis and the criteria against which risk will be assessed. Identify stakeholders and define the communication and consultation policies (see Clause 2.3).

(c) *Identify risks*

Identify, as the basis for further analysis, what can happen, when, where, why and how. This includes identifying hazards, environmental aspects and environmental impacts (see Clause 2.4).

(d) *Analyse risks*

Analyse the risks in terms of consequence and likelihood; analyse controls, and the range of consequences in the context of those controls. Consequence and likelihood may be combined to produce an estimated level of risk (see Clause 2.5).

(e) *Evaluate risks*

Compare the estimated levels of risk with pre-established criteria. Risks can then be ranked to identify priorities for their management (see Clause 2.6). Risks identified as low priority can possibly be accepted without treatment, but subject to monitoring and review.

(f) *Treat risks*

Develop and implement a management plan, which should include consideration of funding and other resources, and time frames (see Clause 2.7).

(g) *Monitor and review*

Monitor and review the risks, the performance of the risk management system, and the changes that may affect it (see Clause 2.8)

Although they are shown as separate activities, in practice the steps interact. For example, when risks are being identified the context and criteria will also need to be reviewed, and some aspects of analysis considered.

The two steps, (a) *Communicate and consult* and (g) *Monitor and review,* are overarching concepts and activities. At each step of the process, and for the process as a whole, there should be appropriate communication and consultation, both within the organization and between the organization and external parties. There should also be appropriate review and monitoring of the risks, the performance of the risk management system and the changes that may affect it.

Each step of the risk management process should be documented. Documentation should include assumptions, methods, data sources and results.

There are other risk-based models that involve similar steps, but may apply slightly different terminology.

1.3 Environmental risk

Environmental risk arises from the relationship between humans and human activity and the environment.

Ecological risk management, which deals with risks associated with past, present and future human activities on flora, fauna and ecosystems, is a subset of environmental risk management.

Environmental risks can be grouped into two categories.

- ***Risk to the environment.***

  This type of risk recognizes that activities of an organization can cause some form of environmental change. Environmental risks can relate to flora and fauna; human health and wellbeing; human social and cultural welfare; earth, air and water resources; energy and climate. The scope of each particular study needs to be defined.

- ***Risk to an organization from environment-related issues***.

  This includes the risk of not complying with existing (or future) legislation and criteria. Other risks include business losses an organization may suffer as a result of poor management, such as loss of reputation, fines, costs of litigation, and from failure to secure and maintain permission for development and operational activities.

Health and safety issues and risk management for emergency management can be significant issues for environmental risk. However, as other guidance documents specifically address these issues, and to avoid duplication, they are not addressed in this guide.

Environmental risk management provides a formal set of processes that help when making decisions affecting the environment, and assists the decision-maker to deal with uncertainty.

1.4 Benefits of environmental risk management

Environmental risk management provides a structured, systematic approach to environmental decision making. The strength of the risk management approach is that it allows various technical assessments and consultative approaches to be combined into a process that supports informed, consistent and defensible decision making.

Undertaking risk management gives an organization a better understanding of its operations, and an ability to respond more effectively to changes in internal and external circumstances.

Environmental risk management may lead to direct benefits to an organization, by improving the information available to management. For example, it can:

- save money and add value;
- reduce the organization’s exposure to risk;

- increase the likelihood of continued operation and new approvals, and make compliance with legislation easier to demonstrate; and
- improve the organization's image and reputation.

Organizations may undertake environmental risk management to achieve :

- informed decision making;
- management planning based on prioritized environmental risks;
- more effective allocation and use of resources, and improved capacity to manage environmental outcomes in the face of competing obligations;
- better environmental accountability and management, in terms of better processes and better outcomes;
- greater transparency in decision making and management;
- more flexibility for identifying and evaluating alternative actions, by better understanding the sources of risk and their implications;
- compliance with relevant legislation;
- an approach for managing uncertainty; and
- better identification and development of opportunities.

Possible broader or longer-term benefits are:

- effective strategic planning as a result of increased knowledge and understanding of key risk exposures;
- less costly surprises, and possibly lower costs, because undesirable outcomes are foreseen and contingencies can be provided;
- better preparedness for and facilitation of positive outcomes;
- improved audit processes, and better value and outcomes from internal and external reviews;
- better outcomes in terms of the effectiveness, efficiency and appropriateness of programs, including improved environmental management and better use of resources (people, funds and equipment);
- provision of a basis for effective communication between organizations and their stakeholders, to assist in formulating program priorities and directions; and
- sustainable management.

The sophistication and breadth of the environmental risk management program should maintain a balance between the costs of managing the risks and the benefits to be gained.

1.5 Special features of environmental risk management

Environmental risk management differs from managing many other types of risk because its particular characteristics reflect the complexity of the environment. The large number of ecosystems and organisms, and the way they interact with one another and their surroundings, create a high degree of complexity and introduce significant uncertainty.

Decisions often involve long time spans and assumptions about projected impacts, such as effects on future generations. Because of the difficulty in making accurate projections in these circumstances, decisions must often be made when there is still significant scientific uncertainty about potential outcomes.

Factors that affect environmental risk management include:

- a lack of data, or limited data sets, and the need to make assumptions;
- natural variability;
- application of immature sciences, with large differences of opinion at a scientific level on the most suitable actions to take or outcome to be achieved;
- long time spans, in which ecological change may emerge slowly, due to delays and lack of clear or direct links between causes and effects[1];
- potential effects on the environment and economic welfare locally, and on regional, national, international and global scales, and the potential for irreversible outcomes (see Appendix B); and
- the complex and extensive web of stakeholders, with the possibility that those with little control over their exposure may be adversely affected (see Clause 2.2).

1.6 Applying environmental risk management

Environmental risk management can be applied at all levels in an organization, including *strategic* and *operational* levels. It also needs to take into account both the external and internal context in which the organization operates.

Strategic level

Strategic level environmental risk management commonly involves dealing with environmental issues and how these might affect the business, i.e. risk to an organization from environment-related issues.

Application of environmental risk management at this strategic level might include:

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[1] Some regulatory circumstances require explicit consideration of future generations.

- creating, or updating, the organization's environmental policy and management systems to incorporate the objectives and principles of risk management;
- undertaking strategic planning for the organization, using a risk-based approach;
- incorporating risk management concepts and processes into an environmental management system;
- setting of environmental risk tolerability criteria (generally undertaken within specific limits set by current legislation and statutory requirements); and
- overall risk management for the purposes of good corporate governance.

Operational level

Environmental risk management often involves a focus on specific risks to the environment. Application of environmental risk management in an operational context might include:

- determining the risk to an ecosystem surrounding an operation;
- undertaking a regulatory environmental impact assessment that incorporates risk management principles;
- determining conformance with regulatory or organizational risk acceptance criteria or standards; and
- providing information to aid in environmental reporting.

Operational risk management is linked to the day-to-day operational activities of an organization, where decisions are made on a continual basis. For example, it may include the use of risk analysis methods to determine the risk to ecosystems from planned or existing developments. These risks may arise from direct impacts of construction or business activities, or through indirect impacts such as gradual loss or modification of habitat, reduction of air, water or land and soil quality, or removal or degradation of amenity.

1.7 Environmental risk management in the organization

Support from senior management is essential for developing an organizational risk management philosophy, and ensuring awareness of risk at all levels in the organization.

The implementation of risk management at different levels within the organization requires establishing programs to manage risks at each level. Processes for communicating the policy and programs should be considered. The process for managing risk should be integrated with other planning and management activities[2].

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[2] HB 436:2004, *Risk Management Guidelines—Companion to AS/NZS 4360:2004* provides further information on developing and implementing a risk management program.

The responsibility and authority of personnel involved in work affecting risk management, and their interrelationships, should be documented, particularly for people in the organization who need the freedom and authority to do one or more of the following.

- Initiate action to prevent or reduce the adverse impacts of risk.
- Control a risk treatment regime until the level of risk becomes acceptable (see Clause 2.6).
- Identify and record any problems relating to the management of risk.
- Initiate, recommend or provide solutions through designated channels.
- Verify that solutions are implemented.
- Communicate and consult internally and externally as appropriate.

Managing environmental risk should form part of the overall management approach. Decide the way in which risk management processes fit into, or interact with, the environmental management system, or any other management system in place. This should not require duplication of resources.

An organization's environmental management system may be a formal system, relatively informal, or restricted to specific procedures designed to comply with regulations, such as safe storage of toxic materials. A formal Environmental Management System, to comply with AS/NZS ISO 14001, requires the following elements: environmental policy, planning, implementation and operation, checking; management review and continual improvement.

The analysis and evaluation aspects of risk management help delineate and rank those risks over which the organization has some control. This ranking helps decision making about treatment options, and planning to achieve continual improvement in environmental performance, in conjunction with the environmental management system. (See Appendix C for details).

Risk management is an ongoing process, and may be used initially as a screening tool to decide which risks require further investigation and analysis. This screening might involve a qualitative analysis that groups and ranks risks, often based on very conservative assumptions that take account of the preliminary nature of the initial assessment.

Preliminary screening will also show whether there is enough data on which to base a more extensive assessment and management process. In other cases, preliminary screening may provide sufficient information to make an informed decision, e.g. by identifying risks that are unacceptable in a particular location. It may be possible to establish that something is acceptable on the basis of a preliminary qualitative analysis alone – if an activity is acceptable under very conservative assumptions, then additional data will only confirm that judgement.

Few environmental risks remain static, so the whole risk management cycle needs to be repeated regularly. Repeating the risk management process with increasingly rigorous acceptability criteria also promotes continual improvement in managing risks.

1.8 Terminology

There are a number of key concepts that are important to environmental risk management, and the terms used and their relationships should be understood before undertaking a risk study. These concepts are presented pictorially in Figure 2, and explained in the text that follows.

NOTES:

1 Terms used on Figure 2 are shown in **bold** type in the explanatory text that follows, and also in Clauses 2.4 and 2.5.

2 The terms used here are consistent with AS/NZS 4360:2004. A full glossary of terms is provided in Appendix A.

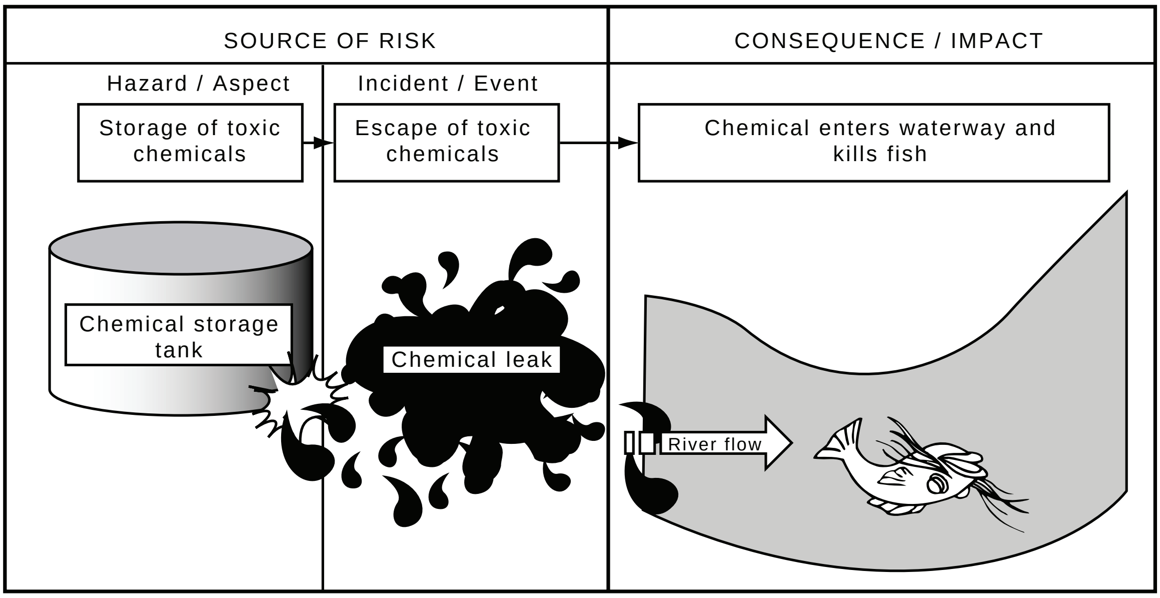


FIGURE 2 TERMINOLOGY

Source of risk

The term '**source of risk**' is an encompassing term that includes all sources of a risk where there is a cause–effect relationship, as well as the terms '**hazards', 'environmental aspects**', '**incidents'** and '**events**'.

The source of risk can also include environmental issues that may result in business consequences to the organization. In many cases, a risk to the environment will have a corresponding risk to the organization's business. For example, the introduction of carbon taxes in one country (the source of risk) may result in greenhouse gas intensive industry relocating to countries without carbon tax regimes, and in strategies such as forest planting to obtain carbon credits (the business consequences).

In the specific area of ecological risk analysis, the term '**stressor**' is sometimes used as an equivalent term to '**source of risk**'. A **stressor** is defined as a physical, chemical or biological entity that induces an adverse response.

Hazards and environmental aspects

A **hazard** is a source of potential harm, or a situation with the potential to cause loss or adverse impacts. A hazard contains an intrinsic potential (or energy) that can be released; for example explosive or radiation potential. In Figure 2, the example of a hazard is the storage of a toxic chemical, such that the toxic potential may be released.

Environmental aspects are those elements of an organization's activities, products or services that can interact with the environment. For example, they could involve a discharge, an emission, waste, consumption or reuse of a material. They could also involve noise, odour, light or vibration.

Environmental aspects and hazards can sometimes be of a continuous nature, such as an ongoing emission or consumption, or a slow leak. In some cases the ongoing environmental aspect can also be intentional and acceptable, such as a licensed emission.

They can sometimes result from a design flaw or lack of knowledge, rather than a failure in the system or process, and may only become apparent over time. For example, asbestos was once used widely but is now known to be a hazardous material.

Incidents and events

An **incident** is any occurrence that can have an adverse impact (or impacts) on the environment. An **incident** releases the intrinsic potential of the **hazard**.

For the example in Figure 2, an incident (the chemical leak) releases the toxic potential of the hazard (i.e. the toxicity of the chemical).

The term **'event'** is also used in a similar sense to **'incident'**. An incident or event can be a short, one-off occurrence, such as an explosion or spill, or ongoing, such as a continuous emission or slow leak. An ongoing incident may also be considered as an 'event'. (See Clause 2.4.2.)

Environmental impacts and consequences

Impacts include, where relevant, effects and consequences.

A **consequence** is the outcome or impact of an event (AS/NZS 4360:2004). It may be expressed qualitatively or quantitatively, being a loss, injury, an expressed concern, disadvantage or gain. There may be a range of possible outcomes associated with an event.

An **environmental impact** is defined as any change to the environment, whether adverse or beneficial, wholly or partly resulting from an organization's activities, products or services.

An impact often results from an incident that releases the potential of the source of risk. For example, in Figure 2, the leak of toxic chemicals from storage (the source of risk) enters the waterway and kills the fish (the environmental impact). A source of risk may have a number of different environmental impacts (e.g. people may eat the poisoned fish and become ill).

The scope of the term **'impact'** also includes impacts to the organization's business arising from environmental related issues (e.g. regulatory fines, cleanup costs, and damaged reputation).

An **environmental impact** may be described in terms of the severity of **consequences**.

Environment and receptors

The **environment** is made up of physical, biological, chemical and social components. One or more of these components may be subject to an **environmental impact**.

In ecological risk analysis the term **'receptor'** is used to refer to the ecological entity exposed to the **'stressor'** (i.e. the 'receptor' can refer to those specific component(s) of the environment under study that might be impacted, see Clause 2.5.2).

Frequency, probability and likelihood

Frequency is the rate of occurrence of an effect, expressed as the number of such occurrences in a given time. By definition, frequency is a numerical measure and can be used in quantitative risk approaches. Frequency can also be expressed in other suitable quantitative measures, such as per million units, per head of population, or per thousand births.

Probability is the likelihood of a specific event, measured by the ratio of specific events to the total number of possible events. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible event and 1 indicating an event that is certain. By definition, probability is a numerical measure and can be used in quantitative risk approaches.

Likelihood is used as a general description of probability or frequency, i.e. it relates to how likely it is that something will occur. Likelihood is often used in qualitative risk analysis approaches. It is commonly used in environmental risk management.

Risk

Risk is defined (in AS/NZS 4360:2004) as the chance of something happening that will have an impact on objectives.

It is measured in terms of a combination of the **consequences** and their **likelihood**.

When considering **'risk'** in the environmental context, it should be thought of as the environmental **consequences** of a given severity, and the **likelihood** of that particular consequence occurring. For example, using Figure 2, the risk would be the toxic chemicals entering the waterway and killing the fish (the environmental consequences of a given severity), and the likelihood of this consequence occurring in a set timeframe.

Note that, when dealing with environmental risk, the **likelihood** component of the risk definition applies specifically to the end-point environmental impact, and not the incident.

Risk assessment

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation, as illustrated in Figures 1 and 3.

Communication and consultation

Communication and consultation refers to a process of dialogue between stakeholders that focuses on mutual consultation rather than one-way directed information. The process may be internal to the organization, or between the organization and external stakeholders (see Clause 2.2).

2 The risk management process

2.1 General

This Section provides guidelines on environmental risk management based on AS/NZS 4360:2004.

The risk management process that AS/NZS 4360:2004 describes can be used to provide a consistent framework and terminology for environmental risk management.

Figures 1 and 3 and the text in the shaded boxes are extracts from AS/NZS 4360:2004.

Risk management is a multi-faceted process, and parts of the process are often carried out by multidisciplinary teams. Inputs may come from various experts, organizations and other sources. The common framework of reference provided by AS/NZS 4360:2004 assists communication of information and understanding between the parties involved.

It is an iterative process of continual improvement.

As outlined in Clause 1.2, the main elements in the risk management process are as follows:

(a) ***Communicate and consult,*** (see Clause 2.2).

(b) ***Establish the context,*** (see Clause 2.3).

(c) ***Identify risks,*** (see Clause 2.4).

(d) ***Analyse risks,*** (see Clause 2.5).

(e) ***Evaluate risks,*** (see Clause 2.6).

(f) ***Treat risks,*** (see Clause 2.7).

(g) ***Monitor and review,*** (see 2 Clause.8).

Figure 3, reproduced from AS/NZS 4360:2004, shows in more detail the steps of the risk management process illustrated in Figure 1. (For additional guidance, see also HB 436:2004, *Risk Management Guidelines—Companion to AS/NZS 4360:2004.*)

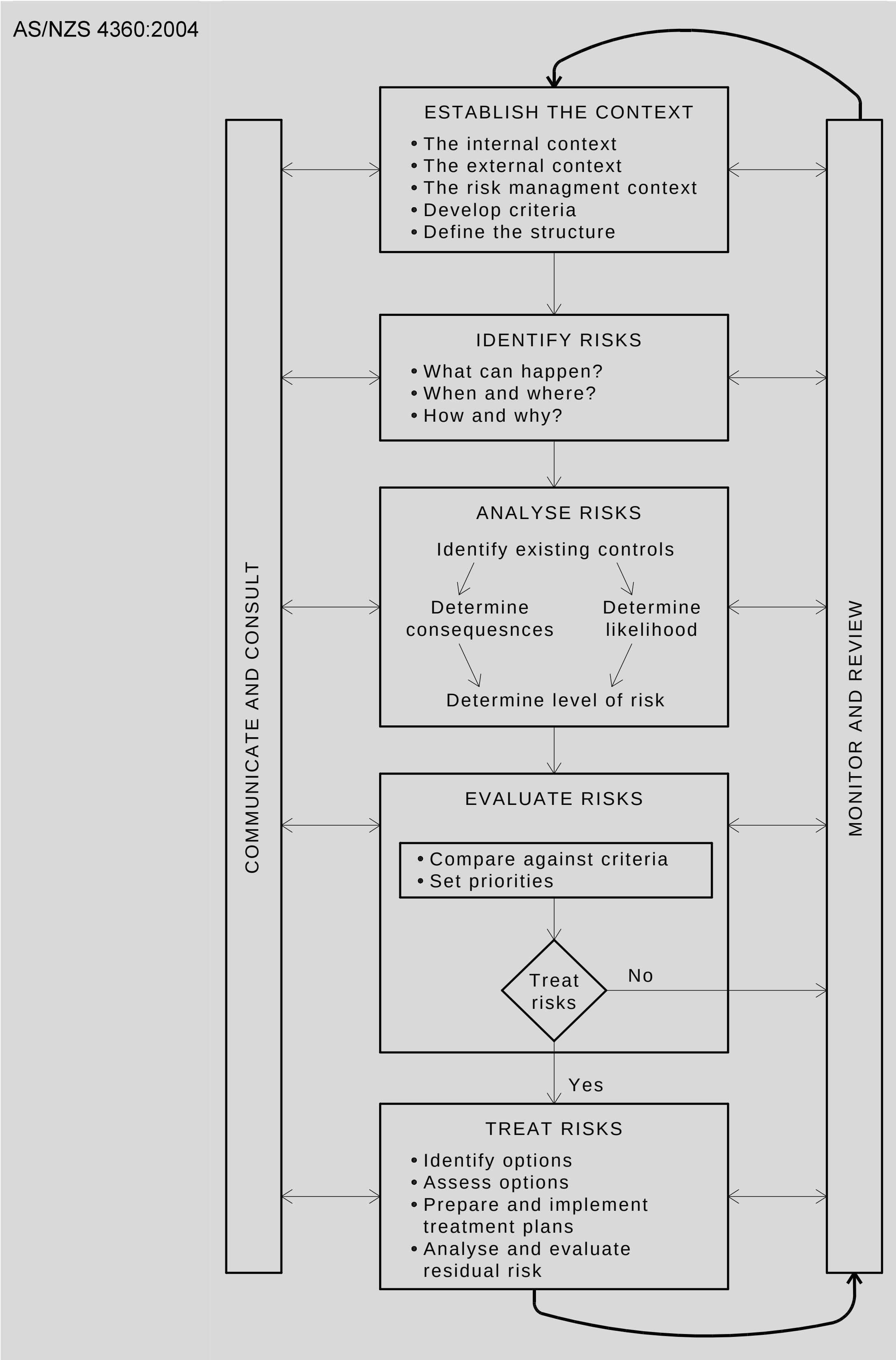
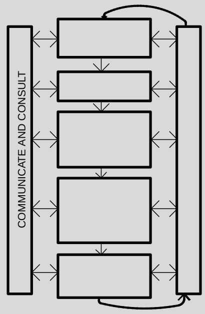


FIGURE 3 RISK MANAGEMENT PROCESS – IN DETAIL

2.2 Communicate and consult

AS/NZS 4360:2004

Communicate and consult



Communication and consultation are important considerations at each step of the risk management process. They should involve a dialogue with stakeholders with efforts focused on consultation rather than a one-way flow of information from the decision maker to other stakeholders.

It is important to develop a communication plan for both internal and external stakeholders at the earliest stage of the process. This plan should address issues relating to both the risk itself and the process to manage it.

Effective internal and external communication is important to ensure that those responsible for implementing risk management, and those with a vested interest, understand the basis on which decisions are made and why particular actions are required.

Stakeholders are likely to make judgements about risk based on their perceptions. These can vary due to differences in values, needs, assumptions, concepts and concerns as they relate to the risks or the issues under discussion. Since the views of stakeholders can have a significant impact on the decisions made, it is important that their perceptions of risk be identified and recorded and integrated into the decision making process.

2.2.1 Overview

This guide uses the term 'communication and consultation' when referring to the process of engaging internal and external stakeholders in the exchange of information. It may be internal to an organization, or external, between the organization and its stakeholders.

Consultation is a broad two-way process. It typically involves talking to a range of stakeholder groups and exchanging information and views. It can employ a variety of techniques, ranging from networking with key individuals to full-scale public campaigns.

It can provide input into the decision-making process from a range of external sources, and access to information that would not be available otherwise. When setting up a consultation process, the extent to which external input should influence the organization's final decision must be carefully defined.

Good external communication can be a critical aspect of environmental risk management, and effective internal communication is essential. In many circumstances a communication and consultation plan should be established, so that all members of the organization are aware of their roles and responsibilities.

Perceptions of risk can vary due to differences in assumptions and concepts and the needs, issues and concerns of stakeholders as they relate to the risk or the issues under discussion. Stakeholders are likely to make judgements about the acceptability of a risk based on their perception of the risk and its consequences. Since stakeholders can have a significant impact on the decisions made, it is important that their perceptions of risk, as well as their perceptions of benefits, be identified and documented and the underlying reasons for them understood and addressed.

2.2.2 Objectives

Within the environmental risk management process, the objectives of communication and consultation are to:

- ensure that appropriate internal and external communication and consultation systems are considered and developed;
- assist in identifying stakeholders and interested parties, and to provide the organization with information about their expectations;
- identify clearly the roles and responsibilities of the organization and its staff for communication and consultation; and
- avoid business risk.

Good internal communication is part of good management and can enhance productivity and minimize errors through ensuring that key staff understand the purpose of guidelines and assignments.

Establishing external stakeholder preferences and perceptions may be part of establishing the external context. If issues with external stakeholders are identified at an early stage, the risk of later conflict may be averted or ameliorated.

External risk communication can improve community understanding and awareness of an organization's environmental activities. It is part of good practice and helps an organization to fulfil its legislative responsibilities, provide due diligence and obtain necessary permits.

2.2.3 How to communicate and consult

Communication and consultation are part of each step of the risk management process. Therefore, a communication and consultation plan should be prepared that includes objectives and strategies for each step.

The communication plan should include details of:

- *why* communication and consultation are required;
- *whether* communication and consultation are to be internal, external or both;
- *who* is going to be involved;
- *when* the different parties are going to be involved;
- *what* is to be the subject of the communication and consultation; and
- *how* the process is to be undertaken throughout the risk management cycle.

Some guidelines for planning communication and consultation include:

- *What are the objectives of the specific communication?* All participants should have a clear understanding of what they need to do.
- *What is to be communicated?* The message should be specific to each situation and should be clearly related to the objectives of the particular process.
- *How will the information be communicated?* General criteria for good communication are clarity, objectivity, timeliness, regularity, and an opportunity for input or exchange of views.
- *How will the communication channels work, and who needs to be involved?* Lines of communication need to be established to and from different stakeholders, i.e. who transmits messages to whom? In internal communications, this should be consistent with the roles, responsibilities and interrelationships between personnel or sections. In external communications, the credibility of individual participants is critical.
- *Has general acceptance been achieved?* The way in which material is presented and the timing of the presentation are major aspects of achieving acceptance that the information is credible.

Business risk

If an appropriate communication plan is not established, there is an increased likelihood of business risk.

Relevant business risks that may be affected by an adverse relationship with stakeholders include (but are not limited to) impacts on public image, reputation and share price, consumer acceptability of products, ability to obtain environmental approvals, ability to maintain a licence to operate, actions by regulators, legal exposure including class action law suits, and capital costs to fix problems. Financial impacts can include costs of remediation, increases in control measures requiring capital expenditure and additional operating costs, and costs due to loss of business continuity.

If an organization's operations are causing harm to the environment, this may subsequently come to the attention of the regulator, the media and the public. Unless the organization is able to stop causing the impact and rectify the situation, the government, public and media pressure may force the regulator to withdraw the organization's 'licence to operate'. The business risk in this case is the closure of operations and associated loss of income and business.

In some cases there might be risks to the business as a result of *perceived* environmental risks when, in fact, no physical risk to the environment exists. Nonetheless, these risks need to be identified and managed.

Stakeholders

Stakeholders are those people and organisations who may affect, be affected by, or perceived themselves to be affected by, a decision or activity (see also Clause 2.3.2).

Where it is agreed that stakeholders have a role in establishing the acceptability of certain environmental impacts, stakeholders should be considered before establishing the broad criteria to be used.

Stakeholders can include user interests such as tourism, boating and fisheries in multi-use areas. In environmental risk management identification of stakeholder and other interested parties should include consideration of non-human populations and future generations. Identification should also extend to those with an interest in drawing attention to any shortcomings on the part of the organization, e.g. business competitors or the media.

Communication and consultation with the public

Consultation is not the same as 'public education' or 'public participation'. Public education or public awareness programs are generally a one-way process to present information and to increase understanding of certain issues, and are about getting information out to audiences. However, during public awareness programs, information may be gathered that is useful to the organization because it reflects public views, and in some cases may provide experience or expert advice. The objectives of public education programs can extend beyond providing information to seeking change in attitudes and ultimately behaviour. In contrast, 'consultation' is a mutual process, where information is provided to participants and new information and views are absorbed.

'Public participation' is a particular type of consultation that reaches out to a wide public audience, and is aimed at involving the community in a process of decision making. It is premised on the right of the public to know what the decision-makers are doing on their behalf, and to be involved, and so is relevant only to organizations where the public are viewed as key stakeholders.

Establishing the context

Communication and consultation ensure that the context is considered broadly and all stakeholder interests are considered for incorporation into the scope of the risk management activity. Stakeholder analysis may form part of establishing the context and this can only be done effectively if there is good communication and consultation. As part of the context the criteria which will be used to make decisions about risk will be defined. These should take into account the views of stakeholders.

Identifying risks

Communication and consultation may add value to the risk identification process by providing the organization with local or historical information about the physical and social environment in which it operates, and how its activities affect stakeholders and the physical environment. (See Clause 2.4.5)

Analysing risks

Quantitative risk analysis is sometimes used to calculate levels of compliance with specified environmental standards. It can be difficult to communicate the results of quantitative analysis to non-specialist stakeholders. If people are involved throughout the process it can help them understand the outcomes of complex analyses. Where appropriate, stakeholder assistance can be sought in designing plans for communication and consultation to ensure that information is relevant, appropriately presented and timely. (see Clause 2.5.6)

Environmental risk analysis often involves many disciplines including engineering, ecotoxicology, hydrogeology, biological and social sciences. Specialists with the relevant blend of professional skills should be used to undertake the work, and they need to understand each other. Resources for communication and consultation between the different specialists involved in a project need to be planned and factored in.

Evaluating risks

The evaluation step involves decisions on actions to be taken. Costs and benefits often differ for different stakeholder groups, and this information is needed as input to the decision-making process. Risks are perceived differently by different people, and the concerns of stakeholders need to be taken into account in making decisions. Communicating the rationale for decisions often aids their acceptance. (See Clause 2.6.6)

Treating risks

Treating risks may involve placing restrictions and controls on activities. Internal communication is essential here, to ensure that those responsible for implementing the controls understand their purpose, and what to do if anything goes wrong. Often this means making sure that operational staff know why particular procedures are required.

2.2.4 Implementing the risk communication plan

It is advisable to plan and commence communication early, particularly where an organization’s activities seem likely to involve public interest. As shown in Figure 3, communication and consultation activities run parallel to all stages of the risk management process.

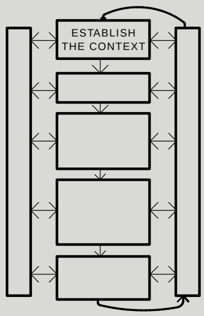
Means of communication and consultation with and between stakeholder groups should be set up as part of a process of ensuring that all relevant parties are involved and informed to an appropriate degree.

The communication and consultation plan should be monitored and reviewed in the same way as the risk management process, to ensure that it is meeting the objectives specified when the context was being established.

2.3 Establish the context

AS/NZS 4360:2004

Establish the context



Establishing the context defines the basic parameters within which risks must be managed and sets the scope for the rest of the risk management process. The context includes the organization's external and internal environment and the purpose of the risk management activity. This also includes consideration of the interface between the external and internal environments.

This is important to ensure that the objectives defined for the risk management process take into account the organizational and external environment.

2.3.1 Overview

The risk management process first considers the organization itself, its objectives, and the external context and environment in which it operates (the strategic context), and its operations, capabilities and constraints (the organizational context).

This step establishes a framework of reference, and identifies factors that may drive decisions, or influence an organization's ability to manage risks.

The organization's general policy and goals, financial status, available technology, how it operates, and the political, regulatory and cultural climate within which it operates, can all influence decisions about acceptability or treatment of risks.

2.3.2 External context

AS/NZS 4360:2004

Establish the external context

This step defines the external environment in which the organization operates.

It also defines the relationship between the organization and its external environment. This may, for example, include:

- *the business, social, regulatory, cultural, competitive, financial and political environment;*
- *the organization's strengths, weaknesses, opportunities and threats;*
- *external stakeholders; and*
- *key business drivers.*

Establishing the external context focuses on the broad external environment in which the organization operates. The aim is to determine the crucial elements that might support or impair an organization's ability to manage its risks.

These elements are identified by examining the organization's relationship to its external and strategic environment, including financial, operational, competitive, political, social, client, cultural and legal considerations. The organization needs to consider its relationship to each of these elements in terms of its strengths, weaknesses, opportunities and threats.

Identify stakeholders and develop communication policies

As part of establishing the external context, identify stakeholders and interested parties. Stakeholders are people and organizations who may affect, be affected by, or perceive themselves to be affected by, a decision or activity. Stakeholders need to be identified:

- to take into account their interests in setting risk evaluation criteria and determining methods for treating risks;
- to help develop appropriate communication plans; and
- because their responses can significantly affect the success of risk treatment.

The objectives and perceptions of an organization and its stakeholders may not be the same. In some cases this can, for example, result in a project or organization being unable to gain regulatory approval to operate, or to continue to operate. Therefore organisations should identify and consider the views of their stakeholders.

Examples of stakeholders, in an environmental risk management context, are as follows:

- Individuals within the organization, such as managers and decision-makers, employees and shareholders.
- Customers, suppliers, service providers and contractors to the organization.
- Non-government organizations such as environmental groups and public interest groups, and individuals or groups with an interest in issues related to an activity or proposal.
- Government organizations, regulatory authorities, and politicians at all levels of government.
- Financial institutions and insurers.
- Local communities, indigenous populations and society as a whole.

When setting risk evaluation criteria it may be necessary to interpret stakeholders more broadly and to include user interests, for example tourism, boating and fisheries in multi-use areas. Stakeholders may also include the environment itself and future generations. Those with an interest in drawing attention to any shortcomings on the part of the organization, e.g. business competitors or the media, should also be identified.

The objectives and perceptions of an organization and stakeholders may not be the same. In some cases, this can result in a project being unable to gain regulatory approval to operate, or continue to operate. Therefore an organization should identify and consider the views of its stakeholders.

Stakeholders' judgements on the acceptability of a risk may be based on their perception of the risk. These perceptions will vary due to differences in assumptions, conceptions, issues, needs and concerns.

Means of communication and consultation with, and between, stakeholder groups, should be set up as part of a process of ensuring that all relevant parties are involved and informed to an appropriate degree. It is advisable to plan communication early if an organization's activities are likely to involve matters of public interest.

2.3.3 Internal context

AS/NZS 4360:2004

Establish the internal context

Before a risk management activity, at any level, is commenced, it is necessary to understand the organization. Key areas include:

- *culture;*
- *internal stakeholders;*
- *structure;*
- *capabilities in terms of resources such as people, systems, processes, capital; and*
- *goals and objectives and the strategies that are in place to achieve them.*

Managers need to identify their role in contributing to the organization's wider goals, objectives, values, policies and strategies when making decisions about risk in the organizational context. This helps to define the risk evaluation criteria from which it is decided whether a risk is acceptable or not, and to form the basis of management options and controls.

The geographic, economic, political, social and technological factors that may influence an organization's decision making should be considered.

Example:

Consider a local government authority with responsibility for planning decisions that have a potential impact on the environment, and for managing the risks associated with its decisions.

The general, external and internal context of a local government authority includes the size and content of the area governed, the laws and regulations of the state, region or country, and the needs and concerns of ratepayers. The time to the next election, the need to balance the budget without increasing rates, and other pressing financial commitments may also be factors that affect decision making.

2.3.4 The risk management context

AS/NZS 4360:2004

Establish the risk management context

The goals, objectives, strategies, scope and parameters of the activity, or part of the organization to which the risk management process is being applied, should be established. The process should be undertaken with full consideration of the need to balance costs, benefits and opportunities. The resources required and the records to be kept should also be specified.

Determine the objectives of the risk management study.

For example, objectives may include gaining regulatory and community acceptance for a development, and defining actions required to minimize any adverse effects on the environment.

Define:

- the objectives and scope;
- the activities to be carried out;
- the expected benefits;
- issues of concern and decisions to be made;
- the composition of the multi-disciplinary team, roles and allocated resources; and
- the extent of external involvement in the study.

It is essential to give the risk management team, or the individuals carrying out risk management activities, the necessary authority, resources and support.

Environmental risk management potentially covers a very wide range of issues. Therefore, it is necessary to define all risks that are relevant in a particular situation, or that should be considered in a particular study.

Defining the scope of risk management activities includes defining space and time within which risks are to be considered. The benefits from taking an environmental risk can be relatively short term and easily measurable, i.e. the benefits are local and high. On the other hand, environmental risks can extend into a wide geographic area, be both difficult to measure and highly uncertain, and can last for many years, possibly for generations.

2.3.5 Decide risk evaluation criteria

AS/NZS 4360:2004

Develop risk criteria

Decide the criteria against which risk is to be evaluated. Decisions concerning whether risk treatment is required may be based on operational, technical, financial, legal, social, environmental, humanitarian or other criteria. The criteria should reflect the context defined above. These often depend on an organization's internal policies, goals and objectives and the interests of stakeholders.

Criteria may be affected by the perceptions of stakeholders and by legal or regulatory requirements. It is important that appropriate criteria be determined at the outset.

The risk evaluation step (Clause 2.6) compares risks against risk evaluation criteria or tolerability, and considers the costs and benefits.

Before this step can proceed, the criteria against which risks will be judged, the principles and policy that will be followed, and the way in which costs and benefits will be compared, must be defined.

Many arguments and disagreements on environmental issues occur because the parties involved are using different criteria for assessment, and because these criteria have never been articulated and negotiated. While criteria should be specified as part of establishing the context, they should also be kept under review, and may be refined or modified as the process proceeds.

Criteria may also be derived from one or more of the following:

- Legislation.
- Regulatory policy.
- Corporate policy.
- Ethical guidelines.
- Project objectives.
- Standards, guidelines and codes of practice.
- Experience and professional judgement.

Criteria may be influenced by community or interest group opinion, and by financial, technological or other constraints. Appendix D contains examples of types of criteria.

Money is invariably a factor in decisions concerning risks. The financial costs and benefits of taking an action that may affect the environment may be clearly identifiable, and have a specific dollar value. The financial value of environmental loss is often harder to quantify, as only a small percentage of environmental losses can be given a tangible value. Loss of biodiversity, loss of quality of life, or loss of the traditions and culture of a people are intangible losses in strictly economic terms.

Key questions in establishing context

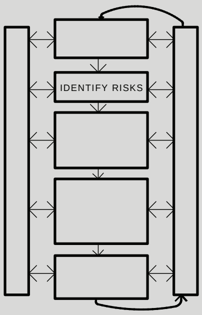
Key questions in establishing the context are as follows:

- What is the policy, program, process or activity?
- What are the major outcomes expected?
- What are the financial implications?
- What are the major threats and opportunities the program presents?
- What are its strengths and weaknesses?
- Who are the stakeholders?
- What are the significant factors in the organization's internal and external environment?
- What problems were identified in previous reviews?
- What risk criteria should be established?
- What is the best way of structuring the risk identification task?

2.4 Identify risks

AS/NZS 4360:2004

Identify risks



This step seeks to identify the risks to be managed. Comprehensive identification using a well-structured systematic process is critical, because a risk not identified at this stage may be excluded from further analysis. Identification should include risks whether or not they are under the control of the organization.

2.4.1 Objectives

Informed decisions, and developing an orderly plan for treating risks, depend on knowing exactly what the risks are, and how and why they might arise. Risk identification considers what can happen, when and where, and why and how it can happen.

The risk identification process should be structured and systematic, and include positive outcomes (i.e. opportunities) as well as threats. This will help ensure that all risks are comprehensively identified, and will demonstrate good risk management practice. The risk identification process should always be documented.

Pay careful attention to the identification step, otherwise there is a danger that the system which is 'understood' may not be the system which should have been identified and under study.

2.4.2 How to identify risks

Identification of environmental risks occurs at several stages. Initially, environmental issues and aspects are identified both at the strategic and the operational or project level. Subsequently, a more detailed examination may consider natural ecosystems, the general environment, people and communities, and the business.

The following steps provide a practical guide on how to identify sources of risk and potential environmental impacts:

- Identify **sources of risk.**
- Describe the surrounding environment.
- Identify potential **environmental impacts**.

Table 1 gives examples of sources of risk and areas of impact.

Table 1
Examples of sources of impacts

Source		Pathway	Barrier	Receptor	Impact
Hazard/Aspect	**Event**				
Energy sources: -chemical -electrical -mechanical -pressure -noise -gravity -heat & cold -radiation -bio-mechanical -microbiological Machinery Processes Activities Materials inventory	Plant failure Toxic release Fire Contamination Land-clearing Dredging activities Waste disposal	Atmospheric dispersion & deposition Surface water: -site drainage & run-off -streams and river systems Groundwater Soil Bio-pathways: -ingestion -food chain -bio-vectors	Physical Procedural Administrative Regulatory	Human Social Economic Amenity Natural heritage Cultural heritage	Measures relating to: -sustainability -human -social -economic -amenity -natural heritage -cultural heritage

Identify sources of risk

Identifying **sources of risk** involves identifying **hazards, environmental aspects**, and potential **incidents** that can occur (refer Clause 1.8). Identify and document those things that affect the environment, and environmental issues that may result in business consequences for the organization.

This hazard analysis should produce a list of all hazards, and the potential incidents that may occur to release the hazard. In most cases the information collected on hazards and incidents will be relevant (and similar) to environmental aspects.

To start, collect information on all agents, activities and processes associated with the operation, or the situations and activities being considered. Record those that have the potential to affect the environment.

For a new activity, this could be done by examining the project description, and for existing activities by carrying out physical checks and monitoring to identify environmental issues.

An **incident** may be a short, one-off occurrence (e.g. an explosion or a spill). It may also be an ongoing situation such as a continuous emission or leak, or degradation due to over-use, such as poor farming practices.

An incident may occur due to a fault. A single incident can result from one or several faults, so it is important to consider all possible faults that could lead to an incident. Fault Tree Analysis is one method for doing this.

Any activity, change or development can potentially affect the environment without a specific incident being readily identified, e.g. population growth, or logging forests.

Describe the surrounding environment

The scope of the study should be defined clearly in terms of the application: e.g. to determine all significant environmental impacts associated with a project for an environmental impact assessment for submission to a regulatory authority.

Where the scope is to determine all significant environmental impacts associated with a particular operation or project, efforts should be made to identify, describe and understand all major components of the surrounding environment. This could include, for example, biological (e.g. flora, fauna, ecosystems); physical (e.g. atmosphere, groundwater, soil); and social components (e.g. cultural heritage, social demographics) of the environment.

A **receptor** is the specific component of the environment under study that might be impacted. Examples of receptors include:

- a subset of a species population, or an entire species population;
- ecosystem-health indicator species;
- a habitat or habitats;
- a food chain;
- a biological component (e.g. fauna, flora, habitat, ecology, biodiversity);
- a physical component (e.g. soil, groundwater, surface water, air sheds, water currents, land form);
- a social component (e.g. cultural heritage, social demographics); and
- an entire ecosystem, inclusive of all species, habitats and their interactions.

Identify potential environmental impacts

Brainstorming, checklists and comparison with similar projects are examples of ways of identifying potential environmental impacts. However, none of these approaches on their own is sufficiently rigorous to assure that all significant impacts will be identified.

There may be multiple impacts such as:

- behaviour;
- reproduction;
- mild illness;
- fatality;
- ecosystem damage;
- species extinction;
- visual amenity;
- social amenity;
- resource depletion; and

- climate change.

A systematic, but simple, approach involves using the information on hazards, environmental aspects, incidents, and the surrounding environment. Each environmental aspect is considered in turn against each component of the surrounding environment for a potential interaction or interface. Where this exists between the environmental aspect and component of the surrounding environment, there is a potential environmental impact. This concept is illustrated in Table 2, where X denotes an interface or possible interaction, and therefore a potential impact.

The steps are:

- list all environmental aspects and components of the surrounding environment in a matrix;
- consider each environmental aspect against each component of the surrounding environment for a possible interaction or interface; then
- where an interaction or interface occurs, a potential environmental impact exists and requires further assessment.

Table 2
Example of a systematic environmental impact identification process

Components of environment	**Environmental aspects**			
	Air emissions (NO_x and SO_x)	**Chemical storage and handling**	**Noise emissions**	**Dust emissions**
Social demographics	X	X	X	X
Soil and groundwater		X		
Atmosphere	X			X
National Park	X	X	X	X

Table 3 provides a more detailed example of interactions.

Table 3
Incidents, surrounding environment and potential environmental impacts

Environmental aspects/hazards	Potential incidents	Potential consequences	Receptor/ surrounding environment	Potential environmental impacts
Production process involving toxic chemicals	Escape of toxic chemicals	Vapour cloud	Workers, fauna	Inhalation leading to illness
		Spill to ground	Soil and groundwater	Use of groundwater limited because of contamination
Oil tanker transporting oil cargo	Collision with another vessel	Oil spill to water travelling to shore	Nearshore has mangroves, fish breeding, birds	Impact on fish breeding habitat, loss of biota
	Accidental release		Boat marina	Oil slicks on boats
Environmental aspect (inclusive of incident concept): Preparation of construction site involving land clearing		Top soil removed	Top soil Creek	Soil erosion Dust, noise nuisance Sediment load in creek
		Vegetation removed	Vegetation Habitat for important species	Loss of habitat Water table rise leading to salinity in soils
		Landform altered	Landform	Natural water course interrupted; loss of species dependent on creek habitat
Environmental aspect (inclusive of incident concept): Production process involving continuous emissions to air (NOx, SOx) and water (Zn, Hg) of contaminants		Contribute contaminants to atmosphere	Regional atmosphere	Smog production dependent upon weather and terrain
		Ongoing discharge of contaminants to marine ecosystem	Marine ecosystem Humans (who catch and eat fish)	Uptake of metals into the food chain and bioaccumulation Human illness from metal poisoning
Environmental aspect (inclusive of incident concept): Harbour dredging activities including disposal of dredge spoil		Plume of suspended sediment	Nearshore ecosystem including corals	Smothering of corals by sediment
		Disposal of dredge spoil containing TBTs	Seagrass beds at disposal site	Smothering of seagrass beds by dredge spoil Contamination of disposal site by TBTs
		Spread of exotic organisms in dredged spoil, from inner harbour to outer marine environment.	Ecosystems near deposit site.	Infestation, loss of biodiversity as exotic species displace native species.

Points to address

Consider sources of risk and impacts and work from both ends. Look for:

- very long-term impacts;
- acute and chronic impacts; and
- cumulative and synergistic impacts.

Remember that:

- a single source of risk may have multiple impacts;
- many sources of risk may contribute to the same impact; and
- multiple sources may have multiple impacts.

Examine:

- risks to the environment from the organization and its activities; and
- risks to the organization and the business from the environment.

'Environment-related' business risks are those risks to an organization that occur as a result of environmental issues or risks. In most cases an environmental risk (i.e. the likelihood of impact upon the environment) will be associated with a corresponding risk to the organization's business.

2.4.3 Uncertainty of risk identification

Factors that introduce uncertainty into the identification process include:

- risk identification is not necessarily objective, because the process of identification may depend on subjective evaluations of what constitutes a risk;
- many environmental risks have long time spans, and significant lags between cause and effect;
- interactions and complexity introduce uncertainty about the detailed structures, components and processes of ecosystems;
- environmental stressors often impact on multiple receptors that may be difficult to identify; and
- risks are not static, and may change over time.

For these reasons techniques based on historical data are unlikely to identify all risks.

Issues that should be considered in risk identification include the possibility of human error, the difficulty in predicting the behaviour of complex systems, overconfidence in current scientific knowledge, and incomplete knowledge of the likely impacts of actions that cannot be tested easily.

2.4.4 Tools and techniques

Examples of environmental risk identification tools and techniques are:

- interviews and focus group discussions, personal or past organizational experience, consultation;
- audits or physical inspections;
- brainstorming;
- local or overseas experience, history, failure analysis;
- scenario analysis and *what if* analysis;
- systems engineering techniques, systems analysis, flow charting, fault trees, event trees, hazard and operability (HAZOP) studies;
- life cycle assessment; and
- databases of incidents.

Not all of the techniques listed above have universal application, and their suitability for any given circumstances will be a matter of expert judgement.

Practical examples of sources of information for input to the risk identification process are listed in Appendix E.

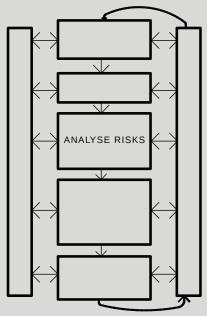
2.4.5 Communication and consultation

It is important to consult stakeholders when identifying risks and benefits, to ensure that all risks to all stakeholders are recognized. Comprehensive identification is not easy, and wide communication helps to ensure that nothing is overlooked.

2.5 Analyse risks

AS/NZS 4360:2004

Analyse risks



Risk analysis is about developing an understanding of the risk. It provides an input to decisions on whether risks need to be treated and the most appropriate and cost-effective risk treatment strategies. Risk analysis involves consideration of the sources of risk, their positive and negative consequences and the likelihood that those consequences may occur. Factors that affect consequences and likelihood may be identified. Risk is analysed by combining consequences and their likelihood. In most circumstances existing controls are taken into account.

A preliminary analysis can be carried out so that similar risks are combined or low-impact risks are excluded from detailed study. Excluded risks should, where possible, be listed to demonstrate the completeness of the risk analysis.

2.5.1 Objectives

The objectives of an environmental risk analysis are to provide information to:

- allow you to determine how big the risks are;
- allow the risks to be prioritized;
- obtain information to decide whether a risk is tolerable; and
- make informed decisions about treating risks.

The analysis should provide data to assist in the evaluation of risks, and in separating minor tolerable risks from the major risks.

2.5.2 How to analyse risks

Risks are analysed by combining their possible **consequences** and the **likelihood** of the occurrence of those consequences, in the context of existing measures to control the risk. The consequences of each risk and their likelihood determine the level of risk. Factors that affect consequences and likelihood should be identified. These may be estimated either quantitatively or qualitatively. The two measures are then considered together.

Remember the consequences may be impacts on the environment or impacts on the business.

'Likelihood' applies specifically to the resulting **environmental impact** (refer Clause 1.8). The frequency or probability solely of the *initial* incident or hazard event should not be used (as it sometimes is in the safety discipline). Often a chain of events, each with an associated likelihood, leads to a final environmental impact. Each event in the chain is dependent upon the previous event occurring in the first place. These 'conditional probabilities' or 'conditional likelihoods' need to be factored into determining the final likelihood of the environmental impact occurring.

Example:

Consider the following situations:

- Probability of an oil spill of a given volume occurring from a tanker.
- Probability of the oil, once spilled into the water, travelling to a shoreline.
- Likelihood of causing environmental impacts on the shoreline ecosystem.

The first two events need to be factored into determining the final likelihood of environmental impact. The final likelihood of environmental impact is calculated by multiplying the probabilities together. Where only qualitative data is available, an estimation of the final likelihood of environmental impact will need to be made.

Historical data can be a useful reference in estimating likelihood of a similar event occurring, if the technology and the management practices are comparable.

Analyse risks in the context of existing controls.

Existing controls depend on the culture, behaviour, attitude, skills, training, processes and procedures within the organization. There may also be physical barriers.

There are two extremes to the level of risk that may be determined:

- a level of risk assuming existing controls are working effectively; and
- a level of risk assuming all controls fail.

Depending on the circumstances, determine one or both of these levels.

For example, it is useful to know the maximum credible risk when preparing for emergencies. However, when deciding on the allocation of resources, it is usually more cost effective to focus on the risks which are not already well controlled. Determining both the maximum risk level assuming all controls fail and the level of risk assuming controls work can help draw attention to those risks for which the controls are particularly crucial, and which should therefore be verified and monitored regularly.

Residual risk is the risk remaining when levels of risk are determined with controls in place. The risk of existing controls not working may be addressed. Evaluating the *effectiveness* of existing controls is part of the analysis process.

Methods of determining levels of risk are generally categorized as qualitative analysis, semi-quantitative analysis and quantitative analysis. The depth of the analysis depends on the magnitude of the risk. The approach used should be appropriate and cost-effective. For example, risk analysis of a major valley system could justify a very detailed and costly analysis, whereas risk analysis for a small warehouse may require only a simple screening.

Environmental risk studies are usually qualitative in nature, except in a few specific circumstances. There may be no easy alternative to qualitative analysis if there are high levels of complexity, many inputs, many receptors and multiple impacts.

Where the scope of analysis is limited to a single receptor variable and a single impact variable, it may be feasible and cost-effective to undertake quantitative risk studies.

Sometimes the overall risk to an ecosystem is predicted by the response of a single indicator species, for which chemical dose-response data is available. This simplistic approach should be used with caution, as it is highly unlikely for the response of one species to be representative of the complex interactions of an entire ecosystem.

2.5.3 Qualitative and quantitative analysis

Qualitative analysis

Tables 4(A), 4(B), and 4(C) give examples of qualitative analysis (see also Sections 6.2 and 6.3 of HB 436:2004, *Risk Management Guidelines—Companion to AS/NZS 4360*).

Qualitative analysis is used where full quantitative analysis is not possible, for example because of lack of appropriate information. It is useful for prioritising risks for more detailed attention, or to allocate a budget. Qualitative analysis can be used where the level of risk does not justify the time and resources needed to do a numerical analysis, or where the numerical data are inadequate, or for initial screening prior to a more detailed analysis.

Qualitative analysis uses a scale of words or descriptions to examine the impacts of each event arising and its likelihood.

A risk matrix based on these qualitative (or adjudged) measures of consequences and likelihood may be used as a means of combining consequences and likelihood to give a measure of risk as shown in Table 4(C), so that risks can be prioritised.

Table 4(A)
Qualitative measures of likelihood

Level	Descriptor	Description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Could occur
D	Unlikely	Could occur but not expected
E	Rare	Occurs only in exceptional circumstances

Table 4(B)
Qualitative measures of impact

Level	Descriptor	Example detail description
1	Catastrophic	Death, toxic release off-site with detrimental effect, huge financial loss
2	Major	Extensive injuries, loss of production capability, off-site release contained with outside assistance and little detrimental impact, major financial loss
3	Moderate	Medical treatment required, on-site release contained with outside assistance, high financial loss
4	Minor	First aid treatment, on-site release immediately contained, medium financial loss
5	Insignificant	No injuries, low financial loss, negligible environmental impact.

NOTE: Measures used should reflect the needs and nature of the organization and activity under study.

Table 4(C)
Qualitative risk analysis matrix: Level of risk

	Consequence				
Likelihood	**Catastrophic**	**Major**	**Moderate**	**Minor**	**Insignificant**
Almost certain	E	E	E	H	H
Likely	E	E	H	H	M
Possible	E	E	H	M	L
Unlikely	E	H	M	L	L
Rare	H	H	M	L	L

LEGEND:

E = Extreme risk; immediate action required.

H = High risk; senior management attention needed.

M = Moderate risk; management responsibility must be specified.

L = Low risk; manage by routine procedures.

The number of categories should reflect the needs of the study, and the ability to distinguish between categories reliably.

Information gained in trying to determine qualitative measures of consequences and likelihood can also help identify risk treatment strategies.

In Appendix F, Tables F1 and F2 show more detailed examples of qualitative matrices for ranking risks to the environment and business, arising out of environmental management issues. Table F3 contains an example of a qualitative risk register.

Semi-quantitative analysis

Semi-quantitative analysis assigns values to qualitative scales, then applies one of a range of formulae to produce a ranking of the risks.

Semi-quantitative analysis is not intended to produce quantitative estimates for risk. The number allocated to each description does not have to bear an accurate relationship to the actual magnitude or likelihood of consequences, provided that the system used for prioritising matches the system chosen for assigning the numbers and combining them.

Care must be taken in interpreting semi-quantitative analyses, since choosing numbers that do not fully reflect relativities can lead to inconsistent outcomes. Also, semi-quantitative analysis may not adequately differentiate between risks when either the likelihood or the consequences are extreme.

Quantitative analysis

Quantitative analysis uses numerical values for both consequences and likelihood. It commonly uses data from a variety of sources. The quality and validity of the risk analysis is dependent on the availability of data, and on the accuracy and completeness of the numerical values and the methods used.

Impacts may be estimated by modelling the possible outcomes of an event or set of events, or by extrapolation from experimental studies or past data. In some cases, more than one numerical value is required to specify consequences for different times, places, groups or situations.

Examples of quantitative analysis of consequence or likelihood include:

- failure probabilities for engineering facilities and management systems;
- release mechanisms and spread models for the dispersal of excess energy or materials with toxic or harmful properties; and
- physiological models of impact, including dose-response models where appropriate, on identified receptors or target species taken as indicators of environmental health.

Use models appropriate to the application and the degree of detail available.

Since some of the estimates made and the data used in quantitative analyses are often imprecise, a sensitivity analysis should be carried out to test the effect of changes in values and limits. Guidance on calculations and their uncertainties is also relevant.

Risk analyses can depend, to varying degrees, on assumptions, extrapolations from known cases, estimates, and approximations. Even quantitative techniques that appear sophisticated can have weaknesses that need to be kept in mind. Any assumptions and conclusions should be documented and kept under review.

2.5.4 Uncertainties

The analysis of environmental risk often produces results with a high degree of uncertainty. Reasons for this are:

Complexity

The environment has a large number of components that interact in complex ways, and may not be fully understood. A single source of risk may have many different impacts on different species or components of the environmental system. Also, different components of the environment may be affected by a large number of different sources of risk. It is seldom possible to find a single measure of either the impacts on the environment, or the likelihood they will occur.

Statistical fluctuations

The likelihood of a particular outcome is a statistical measure, and will depend on various contingencies and the vulnerability of the various components of the system under study. For example, the likelihood of environmental impact on a particular area from an accidental airborne release of a substance will depend on the probability of the release occurring, the nature of the release, weather patterns, and whether those at risk are protected or not. Also, people (and other species), when exposed to the same contaminant for the same length of time, will not all react in the same way.

Lack of reliable data

Data on the environmental impact of particular events or circumstances is frequently not available, as detailed monitoring of the effect of change seldom occurs.

Time factors

The time scale relevant to environmental risk analysis may be long. This means extrapolations become increasingly uncertain.

Since some of the estimates made and data used in quantitative analysis are imprecise, a sensitivity analysis should be carried out to test the effect of uncertainty in values and limits on the outcome of the analysis.

Ways of dealing with uncertainty in the analysis of a level of risk need to be discussed including, for example, use of the precautionary principle (see Appendix B).

Even if an environmental risk analysis is uncertain, the process of analysis can provide understanding of the structure of environmental risks, and the factors that affect the magnitude of risks. The rigour associated with a formal process provides those involved with the benefit of a greater depth of understanding of the issues than a more superficial analysis would provide. It can also provide a sound basis for subsequent studies.

Risks may change. For example, technological developments may introduce new methods of control, or research may identify previously unknown risks.

Environmental risks may have both tangible and intangible outcomes. Although it is seldom possible to quantify the impact of intangible outcomes, they should not be ignored.

Example:

Consider the risk to humans from eating fish from a waterway contaminated with carcinogens.

A health risk evaluation would then commonly be carried out, typically involving the following steps:

(a) *Identify the risk*

In this case the risk is the probability of a member of the target group (cohort) developing cancer over a lifetime of exposure.

(b) *Analyse the risk*

This requires an estimate of the dose of the substance received by individuals in the cohort, the expected amount of fish eaten, and the average human body weight. Ideally a probabilistic distribution of each of the parameters would be estimated and combined to obtain a probabilistic distribution of the exposure (probabilistic exposure assessment).

Where probability distributions are not available it is common to calculate a point estimate of the dose for the 'worst-case' individual in the cohort, and to then determine the dose-response relationship (referring to toxicological literature for common relationships derived from animal tests or epidemiological studies).

The risk is then estimated by combining the dose with the dose-response relationship. Safety factors are built in to account for uncertainties.

(c) *Evaluate the risk*

The risk estimate is compared to the previously established acceptable risk criteria to evaluate the acceptability of the risk. Where clear, quantitative, acceptable risk criteria are not available, risks can be compared to risks for alternative treatment options.

Contrast this example with risk analysis for a complex natural ecosystem that is subject to mixed industrial discharges. Here, potentially, there are multiple chemicals of unknown acute or chronic toxicology that may affect a range of species in the impacted ecosystem. It is unlikely that all of the species present will be identified (particularly micro-organisms), nor will all their roles within the ecosystem be understood.

It is necessary to obtain quantitative data where possible and cost effective to do so, and to make a judgement based on both those things for which quantitative data is available and those things for which information is descriptive and no quantitative information is available.

In circumstances where there is high uncertainty, decisions are likely to be more conservative than where risks are better understood.

2.5.5 Tools

Appendix G lists risk analysis methods that have been applied to technological systems.

Many of these methods can be applied to environmental systems. In situations such as air quality modelling, assessment of new chemicals, and the analysis of contaminated sites, environmental authorities have accredited particular methods or particular computer models. In other situations the choice of analysis method will rely on professional judgement.

2.5.6 Communication and consultation

The use of quantitative risk analysis to determine environmental standards provides a relatively objective method of setting such standards. However, to ensure that there is widespread community awareness of the process and acceptance of such standards, appropriate consultation should take place from the outset.

Environmental risk analysis involves numerous disciplines such as engineering, ecotoxicology, hydrogeology, biological and social sciences. A relevant blend of professional expertise should be used to undertake the work, and all the people involved need to understand each other clearly.

The results of quantitative analysis can be difficult to communicate to stakeholders. If people are actively involved throughout the process, this can help them to understand the outcomes of complex analyses.

2.5.7 Monitoring and validation

It may be difficult to analyse the extent of immediate and future harm from an identified environmental hazard, but it is usually possible to monitor indicators of environmental health, sometimes called 'state indicators'. Such environmental monitoring is an integral part of environmental risk management. It can be used to decide whether things are getting worse or better, especially if undertaken over a period of time.

Validation consists of determining whether the analysis is appropriate and suitable for the intended purpose. Validation steps may include, for example, sensitivity analysis of the analytical models and physical validation of model predictions through bioassays or bioassessments.

2.5.8 Documentation

Document the analysis, so that sufficient information is available to allow the process to be repeated and validated.

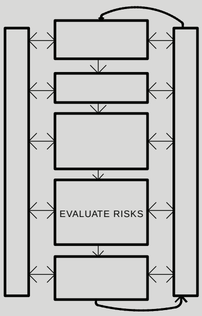
Documentation should include details of the following.

- Methodology applied.
- Assumptions and approximations made.
- Sources of data.
- Modelling processes used.
- Any uncertainties in data and in the results of analysis.
- Procedures used for validation of data or outcomes.

2.6 Evaluate risks

AS/NZS 4360:2004

Evaluate risks



The purpose of risk evaluation is to make decisions, based on the outcomes of risk analysis, about which risks need treatment and treatment priorities.

Risk evaluation involves comparing the level of risk found during the analysis process with risk criteria established when the context was considered.

The objectives of the organization and the extent of opportunity that could result should be considered. Where a choice is to be made between options, higher potential losses may be associated with higher potential gains and the appropriate choice will depend on an organization's context.

Decisions should take account of the wider context of the risk and include consideration of the tolerability of the risks borne by parties other than the organization that benefits from it.

In some circumstances, the risk evaluation may lead to a decision to undertake further analysis.

2.6.1 Objectives

Risk evaluation sets priorities for decisions about risk. The purpose of risk evaluation is to compare the level of risk found during the analysis process against previously established criteria, to determine:

- whether to proceed or continue with an activity;
- whether risk treatment is required; and
- whether to prioritise (rank) the risks for treatment.

Risk evaluation should take account of society's values, perceptions and attitudes. It is linked to social and community values and attitudes through the process of establishing criteria. The preceding steps of risk identification and analysis can provide valuable insight and understanding, and an initial ranking, but cannot capture all the variables that are relevant to assessing and making decisions about environmental risk. Benefits and costs are highly relevant considerations in evaluating risks. Careful, informed judgements are a critical component of understanding and managing environmental risks.

2.6.2 Criteria

The process of risk evaluation requires effective communication between the organization and its stakeholders, to ensure that the criteria chosen and the decisions reached reflect values and concerns appropriately.

Some criteria are fixed, often specified by legislation or industry practice, while others are only guidelines for making decisions. Fixed criteria usually specify acceptable and unacceptable levels of risk (see 2.6.3, 2.6.4).

The previously established criteria (refer 2.3.4) against which the level of risk is to be judged should be reviewed in this step to confirm that they remain relevant, and to determine whether additional criteria are required.

The outcome of risk evaluation is a decision on the level of risk that is considered acceptable in comparison with the previously determined criteria for the activities that are being evaluated. Decisions about acceptable risk levels derived from risk evaluation are specific to the activity being analysed and managed, and cannot be transferred from, or to, other activities.

2.6.3 Risk categories

Risks can generally be placed into three categories.

- Risks that are at an acceptable level, and do not need to be considered further.
- Risks that are currently too high to be acceptable, and for which risk treatment measures have to be considered to bring them to an acceptable level. These risks are sometimes referred to as 'tolerable', because they are tolerated under specific circumstances or for a specified time.
- Risks that are unacceptable in any circumstances or at any level (intolerable).

These categories of risk can then be used as a basis for setting priorities.

Figure 4 illustrates the three categories and the effect of risk reduction processes. It is a simplified model, and does not necessarily cover all circumstances. Risks may, for example, be cumulative or may change with time.

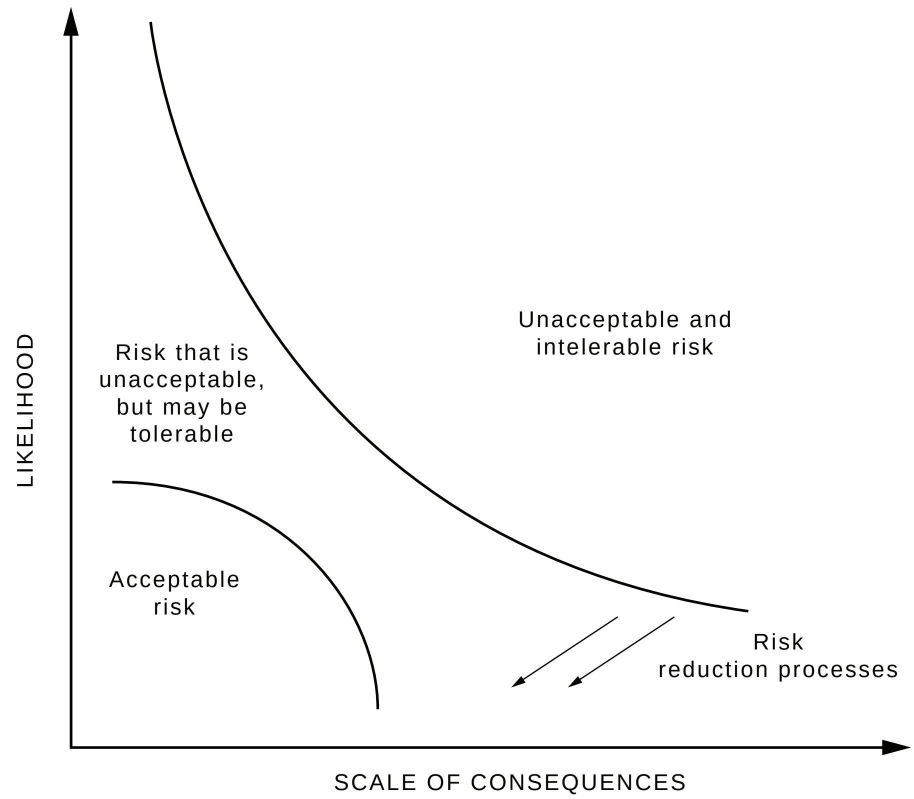


FIGURE 4 ILLUSTRATION OF CATEGORIES OF RISK

2.6.4 Tolerability and acceptability

'Tolerability' refers to the willingness to live with a risk to secure benefits, on the understanding that it is being properly controlled. 'Tolerability' does not mean 'acceptability'. (Refer 2.6.3). Tolerating a risk does not mean that it is regarded as negligible, or something we may ignore, but rather as something we need to keep under review and reduce still further, if and when we can.

Individuals 'tolerate' risk in return for the benefits that it brings them, such as employment. In a similar way society may tolerate environmental risk in return for benefits. However, if alternatives that are viewed as lower risk are available, then society may no longer 'accept' the risk. For example, communities have 'tolerated' sewerage systems that send raw sewage out to sea because they believed that there was no feasible alternative. Many communities are now refusing to continue to accept this, knowing that better systems are available.

'Acceptability' relates to risks that do not need further treatment at this stage. The expression *acceptable level of risk* refers to the level at which it is decided that further restricting or otherwise altering the activity is not worthwhile, e.g. additional effort will not result in significant reductions in risk levels.

2.6.5 Uncertainty

Evaluating risk must account for variability, lack of knowledge or understanding of the possible outcomes that may result from making a decision, and the implications of those outcomes.

There are different types of uncertainty. The simplest differentiation is between variability and ignorance (lack of knowledge of physical and biological processes and cause-effect relationships). For example, Wynne[3] describes four levels of risk and uncertainty:

- Risk — where we know the odds;
- Uncertainty — where we don't know the odds but may know the main parameters;
- Ignorance — where we 'don't know what we don't know'; and
- Indeterminacy — where causal chains or networks cannot be specified.

It may be possible to specify variability, or measurement uncertainty, in terms of upper and lower bounds, or to set confidence limits using sampling theory.

Organizations have to take decisions, but in some cases the decision-maker must explicitly recognize that unknown factors exist, and apply a precautionary approach.

2.6.6 Communication and consultation

The evaluation step involves decisions on setting priorities for actions to be taken. Consulting stakeholders may be required as part of this process, so include planning for appropriate communication and consultation from the outset. Costs and benefits are likely to be different for different stakeholders, and stakeholders' concerns need to be considered when making decisions. It may also be necessary to communicate the rationale for decisions to aid their acceptance.

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[3] WYNNE Uncertainty and environmental learning: preconceiving science and policy in the preventative paradigm. *Global Climate Change*. June 1992

2.7 Treat risks

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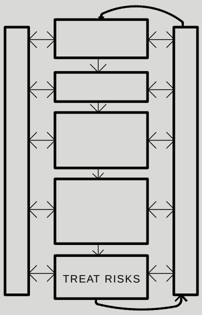
Treat risks



Risk treatment involves identifying the range of options for treating risks, assessing these options and the preparation and implementation of treatment plans.

2.7.1 General

Risks that are not tolerable must be treated.

Risk treatment is the process of identifying the range of options, assessing the options for minimizing adverse impacts, preparing risk treatment plans, and implementing them.

Risk analysis and evaluation result in a ranked list of risks. Treatment of high-ranked risks will generally be given first priority. If lower-ranked risks can be mitigated simply and cheaply, this may be done concurrently. Consider the circumstances and levels at which high-ranked risks become intolerable, and at which low-ranked risks are negligible and can be left without treatment other than monitoring to ensure they remain negligible.

As well as addressing risks to the environment from the organisations activities, also consider risks to the organization associated with the environment.

2.7.2 Identify treatment options

Risk treatment options designed to minimize adverse impacts follow one or more of the following strategies.

Avoid the risk

Avoid exposure to the hazard, e.g. by deciding not to proceed with an activity, by choosing a more suitable location, or by adopting alternative processes or materials. A manufacturer might avoid risk by adopting materials and techniques that reduce emissions and contribute to cleaner air.

Mitigate the risk

Progressive tightening of air quality standards can be considered as an application of this option. Improvements in technology and changes in behaviour may lead to ever-lower levels of pollutants in the ambient environment. There may also be indirect benefits. For example, issuing air pollution forecasts (i.e. a 'smog alert') based on meteorological predictions can prompt sufficient change in emission-related activities for the actual smog event to be much less severe than it would have been without warning.

Reduce the likelihood

Actions to reduce or control likelihood can include, for example, the initial planning of activities or design of processes and controls, and ongoing compliance monitoring, preventive maintenance, training, supervision, audits and reviews.

An example of planning activities to reduce likelihood could be an organization restricting its activities to a particular time of day or season, such as an orchard choosing to spray in the early morning when there are few people about and there is less likelihood of wind causing spray drift.

Reduce the consequences

Environmental impact can be reduced by measures such as:

- minimizing exposure to sources of risk;
- contingency and emergency response planning and preparedness.

Examples include providing animal underpasses to reduce adverse consequences when roadways or oil pipelines are built across the paths of migrating animals.

Reducing consequences and likelihood, referred to as risk control, may involve determining the potential benefits of new controls relative to the effectiveness of existing controls.

Share the risk

Risk sharing involves another organization bearing or sharing part of the risk, usually via a contract. For example, it may be possible to subcontract activities to an organization that is able to manage them better. Buying an insurance policy, so that there will be a financial recompense if an adverse impact occurs, is a common example of risk sharing. However, it may not be possible to share environmental risk, as in many jurisdictions accountability for environmental damage remains with the source polluter (known as the polluter pays principle).

Retain the risk

Risks which cannot be reduced or shared are retained, and plans should be put in place to deal with the outcomes if the risks are realized. This may include emergency and disaster planning, and planning recovery strategies. Remember that retained risks include residual risks that remain after the initial risks have been reduced or transferred, as well as all unidentified risks.

Physically separate

Separating the environment from the source of hazard by physical barriers or buffer zones may be feasible as a local option, but may not be possible on a large scale. Examples are barriers to reduce noise and cofferdams to control spills or run off. Re-siting a facility away from sensitive areas such as schools or wildlife habitat would be an example of physical separation.

Duplicate resources

Some endangered species can be preserved only by introducing them into suitable habitats. For example, in New Zealand, many indigenous species have been retained by introducing populations to predator-free islands.

Transform the risk

Installing scrubbers in chimney stacks is an example of transforming a risk. The chemicals within the scrubbers eventually have to be disposed of, which means that the operation of scrubbers converts an air pollution issue into an issue of solid or liquid waste disposal.

Consider in context

Risk treatment options should be evaluated in a broad context, and their wider effects considered. For example, biological controls introduced to control one form of pest may introduce other problems more or less destructive than the problem they were intended to resolve.

2.7.3 Assessing risk treatment options

Options and strategies for treating risk are assessed in terms of:

- their potential benefits;
- their effectiveness in reducing losses;
- the cost to implement the option(s); and
- the impact of control measures on other stakeholder objectives, including the introduction of new risks or issues.

The options preferred will generally optimize the reduction in environmental impact and the costs of achieving this, and create the least adverse side effects.

The same methods used to estimate frequency and consequence in the risk analysis can be applied to estimate the potential changes in these parameters expected to result from the application of risk treatment measures; e.g. historical data, fault tree and event tree analyses, hazard warnings and professional judgement. As with other estimates, all associated assumptions and uncertainties should be recognized and documented.

Treatment measures reduce risks from identified sources. However, implementing a treatment measure may introduce new environmental risks or increase other identified risks. For example, the use of a non-phosphate detergent reduces the risks posed by phosphates, but may introduce risks associated with the chemicals used to replace the phosphates.

Considering the comparative risks of the options available may shed new light on the initial determination of the acceptability of an individual risk. Any new risk scenario which the treatment options generates should be assessed like other scenarios, beginning with the risk analysis step.

Costs are a significant consideration when seeking approval for a risk treatment project or program. The initial and ongoing costs of implementing and maintaining an environmental risk management system should be monitored, preferably as part of the organization's normal cost accounting procedures.

The baseline against which organizations usually measure costs in environmental risk management is the cost of compliance, or the 'cost of staying in business'. To establish this baseline, a model must be developed that contains or can provide the relevant figures for comparison, such as:

- the current cost of operations and activities;
- the cost and economic impacts if no risk treatment is carried out; and
- the cost of operations after the proposed risk treatment is implemented.

Often, financial control systems are not set up to capture costs in a way that relates to risk management, and the actual full financial and other costs of operations and activities may be difficult to identify and measure.

Treating each environmental risk management strategy or plan as a separate project can be a useful means of identifying and isolating its total costs.

Further information on costs and economic consideration is provided in Appendix H.

2.7.4 Risk treatment plans

Before implementing any of the chosen risk treatment or risk communication strategies, develop and document a risk treatment plan. This plan should provide sufficient information for people to understand their assigned accountabilities and responsibilities, and include resource allocation details and a time frame. It may be part of a business plan, an environmental impact assessment for a new project, or planning within an organization's environmental management system. Such planning may also be required by legislation, e.g. as part of an environmental impact statement (EIS) process.

Considering the economic as well as the ecological integrity of the strategy and plan is essential during the development phase. The final documentation should include a budget, appropriate objectives, and milestones on the way to achieving those objectives. An environmental risk treatment plan needs to identify environmental objectives; the *environmental endpoints* to be used to determine the efficacy of the implementation options, and the means of monitoring progress.

Implementing the risk treatment plan involves ensuring that resources are available, and defining a time scale, responsibilities and a method for monitoring progress against the plan.

In this step, risk control options are usually selected and then implemented through the environmental management system. Key messages are delivered using contacts identified through the environmental risk management communication planning process. A broad public communication effort may be necessary.

2.8 Monitor and review

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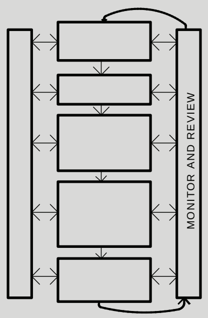
Monitor and review



Ongoing review is essential to ensure that the management plan remains relevant. Factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect the suitability or cost of the treatment options. It is therefore necessary to repeat the risk management cycle regularly.

Actual progress against risk treatment plans provide an important performance measure and should be incorporated into the organization's performance management, measurement and reporting system.

Monitoring and review also involves learning lessons from the risk management process, by reviewing events, the treatment plans and their outcomes.

2.8.1 General

It is necessary to monitor risks, the effectiveness of the risk treatment plan, strategies and objectives, and the management system which is set up to control implementation. Risks and the effectiveness of control measures need to be monitored to ensure changing circumstances do not alter risk priorities.

It is therefore necessary to regularly repeat the risk management cycle. Review is an integral part of the risk management treatment plan.

2.8.2 Objectives

The objective of the monitor and review stage of the risk management process is to assess the effectiveness of the risk management strategy and plan adopted, and to reassess their relevance from time to time.

The following two functions should be addressed separately, however there will be some overlap in the way they are implemented.

- It is necessary to monitor the risks themselves, each step of the risk management process, risk treatment strategies, the effectiveness of communication strategies, and the overall risk management system.
- Few environmental risks remain static, so the whole risk management cycle needs to be repeated regularly. In particular, the criteria used need to be reviewed regularly.

By measuring and monitoring changes to the environment, improved information can be obtained for identification and analysis.

Without regular monitoring, auditing and review, any management plan or system begins to lose effectiveness over time, and eventually breaks down completely.

2.8.3 Methods

Methods of monitoring include the following.

- ***Monitor the environment itself,*** so that early warning of change can be detected. Define indicators of environmental health, and methods of measurement appropriate to the types of risks envisaged. Because risk analysis is often hampered by inadequate knowledge of possible outcomes, monitoring may identify new risks. The outcomes of such environmental monitoring need to be communicated, and to be fed back into future risk analyses.
- ***Monitor and record losses and incidents.*** Incidents or conditions that have the potential to lead to environmental damage should be documented and reviewed, so that there is a process of learning from losses and near misses.
- ***Monitor each step of the risk management process,*** to ensure that it is carried out in an appropriate way, such as by monitoring the effectiveness of communication strategies.
- ***Monitor the risk treatment plan,*** to ensure that it is effective. Check performance indicators and milestones to ensure that the treatment is implemented according to plan. Emergency plans to deal with retained risks should be reviewed and tested regularly.
- ***Use internal audits*** to verify that ecological objectives are being attained. (See AS/NZS ISO 19011 for further information on auditing environmental management systems, and Appendix C and the AS/NZS ISO 14000 series of environmental management system Standards for review, audit and applications of environmental management systems generally.)

Independent external audits may be arranged by the organization's management to verify both the attainment of ecological objectives and the accuracy of reporting. This verification step may be required to satisfy the needs of the organization's customers, a regulatory authority, or other stakeholders.

Review is an ongoing activity, and normally requires the risk treatment plan to be reassessed from two different but complementary approaches.

- A requirement for a periodic (often annual) review by the organization's management to summarize progress and maintain tracking;
- A process of regular ongoing review, which repeats the complete AS/NZS 4360:2004 risk management process to the level of detail appropriate, to ensure that the strategy or plan being followed remains the best option.

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3 Case study

3.1 Environmental risk management for a suburban crash repair shop

This case study is not intended to be comprehensive, but is included to provide an illustrative example of the way the steps of the risk management process may be followed.

3.2 Context

The external and internal context

The spray shop is situated in an area that is partly residential and partly small business. The houses in the area are gradually being renovated and sites bought up and redeveloped, so the area is becoming more 'up-market residential'.

The business has been operating for 40 years (it previously belonged to the present owner's father) and it is profitable, although not highly so. The majority of work is for insurance companies who pay fixed rates. Major stakeholders in the organization are the manager and his family, the employees and local residents. Regulatory authorities also have an interest.

Six full-time people are employed in addition to the manager who deals with quotations and all the paperwork for managing the business. The owner/manager is environmentally aware, and wishes to do his best to manage his business safely and responsibly, within the limitations of the economic situation.

The risk management context

Major risks faced by the business are:

- losing business so the shop becomes uneconomic and has to close down;
- health and safety of employees (physical and chemical hazards in particular);
- disputes with neighbours leading to complaints to authorities and making it difficult to work; and
- risks to the environment from the solvents and paints used.

All of these risks carry a significant likelihood of major loss and even business closure, and therefore have to be managed.

The particular issue that has brought about the current review is complaints from the neighbours about the smell from the spray shop.

3.3 Scope

It is decided to assess all risks to the environment which may come under scrutiny from the EPA in the event of the neighbours taking the complaint further, and to demonstrate due diligence by employing a consultant to assess the human health risk to the near neighbours. Other risks to the business arising from the dispute, such as possible civil actions, are not considered here.

Criteria for assessment

Although the neighbours wish to eliminate the smell, this is not likely to be possible because the nose is sensitive to only a few molecules. Therefore, in deciding whether a risk is acceptable, the objectives are:

- to fulfil legislative requirements and regulations. (Emissions should be below threshold limit values specified for human exposure, and effects eliminated as far as possible.)
- to reduce smell, and also visual contamination of neighbours' property (e.g. from cars parked awaiting repair, car washing, tow truck lights, scrap bins etc), to as low as is reasonably practical.

3.4 Communication and consultation

The owner is to visit the neighbour who complained, to discuss problems and try to identify which particular activities in the workshop result in the worst problems, and whether they can negotiate particular times to have these activities carried out to minimize nuisance. The other near neighbours are to be assured that a health risk assessment is being carried out by an external consultant, and that they will be kept informed of the progress and outcomes.

3.5 Identification of environmental risks

Environmental risks from the paint spray shop arise from:

Disposal of chemical wastes (mostly solvent-based fluids)

This risk is managed by having all chemical wastes collected in special containers and collected by a waste management specialist. This treatment is considered to be satisfactory from an environmental point of view. There are some occupational health and safety (OHS) risks which need separate consideration.

Contaminated water (from washing down the workshop)

This goes into a drain with a trap for contaminants. This method of treatment has been approved by authorities.

Contaminated soil

Some work invariably takes place out in the yard and, although the bulk of waste and washing water is collected properly, some inevitably washes into the soil. This is a potential problem, as the shop has been on the same site for more than 30 years.

Atmospheric emissions

Atmospheric emissions are the immediate source of the neighbour's complaints, and the efficiency of the spray booth filter system, and particularly its effectiveness for isocyanates, is not known. Therefore this risk needs more detailed assessment.

A list is made of the solvents and paints used. The major solvents used were xylene, toluene and butyl acetate, and the majority of the paints were two-pack isocyanates. The solvents are used in spraying and for cleaning. The spray activities are the chief environmental risk. The work also involves sanding fibreglass, and the dust from this activity is a significant occupational health and safety risk.

The material safety data sheet (MSDS) of each material was obtained to see which are the most hazardous.

Existing controls

The spray shop has a single spray booth that is used for all major spray painting work. Sometimes small areas of spraying will take place near the open doorway of the shop when another job is in the spray booth. Emissions from the spray booth exit through a seven metre stack which is about 20 m from the nearest house. (The local authority now suggests 50 m as the required distance, but this was not the case when the spray shop was opened). The filter has a nominal pore size of four microns, and will effectively collect the majority of paint spray particles, so there should not be any emission of paint to damage property, provided the filters are fitted, maintained, replaced and disposed of properly.

Sanding of fibreglass does not take place in the spray booth, which is used for painting only. Sanding is mostly done close to a door, with the dust washed down into the drain and caught by the trap. To avoid complaints, sanding is not done in a place where the wind would take the dust towards the nearest neighbour's house.

3.6 Risk analysis

Qualitative prioritisation of the identified risks could be carried out using a risk matrix.

However, in this instance, the neighbour's complaints mean that the top priority is a further analysis of the risk of exposure to organic emissions. The analysis must consider the two major concerns of neighbours, i.e. the smell and the possible health hazard.

A preliminary analysis of the MSDS indicates that the materials of greatest concern from the human health perspective are the isocyanates in the two-pack paints. However, the threshold limit values for these materials are lower than the odour threshold, and it is the less hazardous chemicals that cause the nuisance smells. The smell arises from a variety of different solvents used in the workshop at concentrations well below those where any risk to health would be anticipated.

Exposure to isocyanates can result in irritation, deterioration of lung function and lung diseases, so there is a potential for health risks if local residents are exposed. However, a computer search fails to uncover any published data on health problems in residents living near crash repair workshops or similar facilities, and there appears to be no data on the prevalence of non-occupational respiratory disease associated with isocyanate emissions.

Specific risk evaluation criteria

The occupational exposure limit for isocyanates is low (20 micrograms of function isocyanate group (NCO) per cubic metre of air as an 8 hour average). Since this is below the odour threshold, it is necessary to sample to see whether the concentration is above the acceptable limit. It is decided that the risk of complaints proceeding further is high enough to make it worth employing a consultant hygienist to take some samples to reassure neighbours and authorities.

Analysis method

Emissions from the stack were sampled, and measurements were also made at ground level 30 m from the stack and at the perimeter of the premises.

No isocyanates were detectable at ground level, and concentrations of solvent vapours were extremely low. Therefore, concentrations at ground level were estimated from the stack emissions using the following assumptions.

- Manufacturer’s data on content of paints, and air flow in the stack.
- Maximum paint usage and proportion of over-spray estimated by spray painter.
- Efficiency of the filter, and proportion of active non-condensable organics (NCO).
- The 7 m stack would have an effective height of stack (i.e. height to which fumes rise) of a minimum of 10 m, due to the ejection velocity and turbulence effects.

The maximum measured stack concentration was 438 micrograms/m^3 of NCO.

Based on approximate dispersion modelling and worst case wind direction, it was estimated that the dilution factor at a distance of 30 m would be at least 100. That is, the instantaneous ground level concentration of isocyanates while spraying was actually in progress would be a maximum of 4 micrograms/m^3 of NCO. Spraying occurs in bursts of a few seconds at a time, so the time weighted average over sampling times greater than 5 min is estimated as 1 microgram/m^3.

3.7 Evaluation

Model 1 — that continuing low level exposure will induce asthma and accelerate deterioration in lung function with age.

The safe level to prevent this is reported to be an average of 1.2–2.4 micrograms/m^3 of NCO over an 8 hour period. Given that the maximum spraying time in any one day is 2 hours, and the maximum concentration at ground level under worst conditions and during the peak bursts of spraying is 4 micrograms/m^3, the average over 8 hours will be significantly below the recommended limit.

Model 2 — that short term peak exposures can give rise to lung effects.

The peak estimated ground concentrations of 4 micrograms/m^3 were well below the exposure limit of 70 micrograms/m^3.

The stack emissions themselves, for both isocyanates and solvents, were of the same order of magnitude as the exposure limits, and it was evident that most of the plume rose vertically and was dispersed over a wide area under most meteorological conditions.

Overall, the health risks due to isocyanates were judged to be acceptable and requiring no additional treatment. However, there is still the possibility of nuisance smell due to organic solvents depending on wind directions. Concentrations would be well below hazardous levels.

3.8 Treatment

The measurements show that there is no significant health risk to neighbours. Therefore the existing filter arrangements are adequate, and no action is needed to reduce this risk.

While emissions to the environment should be as low as reasonably practicable, neither increasing the height of the exhaust stack nor dilution would reduce the total emission to the environment, and no practicable methods of further reduction of emissions could be devised.

Spraying is an essential part of the business and cannot be avoided. The use of two-pack isocyanate based paints has been identified as a potential OHS risk to workers, and this is controlled by personal protective measures. Although the ideal would be to eliminate two-pack paints and use acrylics, their use is unavoidable at present, as the finish of acrylic paints is not acceptable to customers.

Since the smell cannot be avoided, the risk of upsetting neighbours can only be minimized by trying to avoid spraying when they are at home and the wind is in their direction. In the long term it is worth considering moving to premises in a different area, as complaints about a spray shop are likely to increase as the area progressively changes from industrial to residential.

Every effort should be made to ensure that any complaints are dealt with politely and considerately, to minimize the risk that they will escalate.

Measures taken to minimize environmental problems will be documented, filed and kept up to date, so as to be able to demonstrate due diligence.

3.9 Monitoring

Activities will be monitored to identify those which tend to create the worst smells.

The procedures for ensuring that filters are properly maintained will be monitored.

The neighbour's satisfaction with measures taken will also be checked.

All processes required by the relevant authorities will be monitored and documented.

This study raised awareness of OHS risks to employees and, therefore, more formal processes of risk management will be applied to looking at OHS risks.

Environmental risks will be reconsidered in two years time to see whether any new issues have arisen, or whether anything has changed.

A Glossary

Many definitions given in this Appendix derive from either AS/NZS 4360:2004 (marked *), or AS/NZS ISO 14004 and AS/NZS ISO 14050 (marked †).

Further explanation of a number of key terms and their relationships is also given in the text, in particular in Clause 1.8 and Figure 2.

Acceptable risk: the outcome of a decision process of determining an acceptable option. The choice of an option (and its associated risks, costs, and benefits) depends on the set of options, impacts, values, and facts examined in the decision-making process (Fischhoff *et al*., 1981).

NOTE: The expression 'acceptable level of risk' refers to the level at which it is decided that further restricting or otherwise altering the activity is not worthwhile; e.g. will not result in significant reduction in risk; or the additional expenditure will not result in significant advantages of increased safety.

Benefit: the gain to a human population. Expected benefit incorporates an estimate of the probability of achieving the gain (Royal Society, 1992).

Comparative risk assessment: can be used as a means of setting environmental priorities. Comparative risk assessment uses the methods of risk analysis, but applies them to problems in which the actual probabilities and impacts cannot be determined from actual historic data. Instead, the probabilities and impacts need to be determined on the basis of community polling or other subjective elicitation techniques in which the various risks are compared.

Consequence*: outcome or impact of an **event**

NOTE 1: There can be more than one consequence from one event.

NOTE 2: Consequences can range from positive to negative.

NOTE 3: Consequences can be expressed qualitatively or quantitatively.

NOTE 4: Consequences are considered in relation to the achievement of objectives.

(Refer also Clause 1.8.)

Cost: of activities, both direct and indirect, involving any negative impact, including money, time, labour, disruption, goodwill, political and intangible losses.

Ecological risk assessment: a set of formal scientific methods for estimating the likelihoods and magnitudes of effects on plants, animals and ecosystems of ecological value resulting from the release of chemicals, other human actions or natural incidents (modified from EC, 1994).

Ecologically sustainable development: using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased. (*Australian Government National Strategy for Ecologically Sustainable Development* (1992)).

Ecosystem: the biotic and abiotic environment within a specified location in space and time. (*Guidelines for Ecological Risk Assessment*, United States Environmental Protection Agency, 1998).

Environment †: surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelations.

NOTE: Surroundings in this context extend from within an organization to the global system.

Environmental aspect †: element of an organization's activities, products or services that can interact with the environment.

NOTE: A significant environmental aspect is an environmental aspect that has or can have a significant environmental impact. (Refer also Clause 1.8.)

Environmental audit †: systematic, documented verification process of objectively obtaining and evaluating audit evidence to determine whether specified environmental activities, events, conditions, management systems, or information about these matters conform with audit criteria, and communicating the results of this process to the client

Environmental effect: see *environmental impact*.

Environmental impact †: any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services. (Refer Clause 1.8.)

Environmental management system †: part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

Environmental policy †: a statement by the organization of its intentions and principles in relation to its overall environmental performance which provides a framework for action and for the setting of its environmental objectives and targets.

Environmental objective †: the overall environmental goal, arising from the environmental policy, that an organization sets itself to achieve, and which is quantified where possible.

Environmental target †: a detailed performance requirement, quantified where practicable, applicable to the organization or parts of the organization, that arises from the environmental objectives and that needs to be set and met in order to achieve those objectives.

Environmental performance †: the measurable results of the environmental management system, related to an organization's control of its environmental aspects, based on its environmental policy, objectives and targets.

NOTE: Performance requirements must encompass requirements for regulatory compliance, and objectives should include improving overall environmental performance.

Event tree analysis: a technique that describes the possible range and sequence of the outcomes which may arise from an initiating event.

Event*: occurrence of a particular set of circumstances

NOTE 1: The event can be certain or uncertain.

NOTE 2: The event can be a single occurrence or a series of occurrences.

(ISO/IEC Guide 73, in part)

(Refer also Clause 1.8).

Exposure: the contact or co-occurrence of a stressor with a receptor (*Guidelines for Ecological Risk Assessment*, United States Environmental Protection Agency, 1998).

Failure mode and effects analysis (FMEA): a procedure by which potential failure modes in a system are analysed. An FMEA can be extended to perform what is called failure modes, effects and criticality analysis (FMECA). In a FMECA, each failure mode identified is ranked according to the combined influence of its likelihood of occurrence and the severity of its consequences.

Fault tree analysis (FTA): A systems engineering method for representing the logical combinations of various system states and possible causes which can contribute to a specified event, called the top event.

NOTE: FTA is usually represented by a logic diagram beginning with an undesired consequence, and systematically deducing all the different possible root causes of action leading to the outcome or 'top' event.

Frequency*: a measure of the number of occurrences per unit of time. (Refer also *likelihood* and *probability*, and Clause 1.8).

NOTE: Frequency may also be expressed in other suitable measures, such as per million units, per head of population, per thousand births.

Harm: Physical injury or damage to the health of people, or damage to property or the environment

Hazard: a source of potential harm, or a situation with a potential to cause loss or adverse effect (adapted from ISO/IEC Guide 51:1999). (Refer also Clause 1.8.)

Health risk analysis: Comprises four steps, i.e. hazard identification, dose-response relationship, exposure assessment and risk characterization. Dose-response functions are established either by laboratory experiments with animals or by epidemiology studies in humans. Exposure assessment is used to estimate the magnitude, duration and frequency of exposure (to pollutants of concern) and to determine pathways of exposure and the number of people likely to be exposed. Risk characterization combines the hazard identification, dose-response and exposure assessment to estimate the risk associated with each exposure scenario.

Incident: refer Clause 1.8.

Interested party †: individual or group concerned with or affected by the environmental performance of an organization.

NOTE: To be consistent with AS/NZS 4360, this document uses 'stakeholder' as the preferred term. However, when used in the broad sense, the terms are virtually interchangeable.

Likelihood*: used as a general description of probability or frequency. (Refer also Clause 1.8.)

Life cycle assessment (LCA) †: compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (AS/NZS ISO 14040).

NOTE: The phases of an LCA are definition of goal and scope, inventory analysis, impact assessment and interpretation of results.

Loss*: any negative consequence or adverse effect, financial or otherwise.

Organization*: group of people and facilities with an arrangement of responsibilities, authorities and relationships.

EXAMPLE: Includes company, corporation, firm, enterprise, institution, charity, sole trader, association, or parts or combination thereof.

NOTE 1: The arrangement is generally orderly.

NOTE 2: An organization can be public or private.

NOTE 3: This definition is valid for the purposes of quality management system standards. The term 'organization' is defined differently in ISO/IEC Guide 2.

(AS/NZS ISO 9000)

Perceived risk: see *risk perception.*

Precautionary principle: see Appendix B.

Probability*: a measure of the chance of occurrence expressed as a number between 0 and 1.

NOTE 1: ISO/IEC Guide 73 defines probability as the 'extent to which an event is likely to occur'.

NOTE 2: ISO 3534-1:1993, definition 1.1, gives the mathematical definition of probability as 'a real number in the scale 0 to 1 attached to a random event'. It goes on to note that probability 'can be related to a long-run relative frequency of occurrence or to a degree of belief that an event will occur. For a high degree of belief, the probability is near 1.'

NOTE 3: 'Frequency' or 'likelihood' rather than 'probability' may be used in describing **risk**.

Qualitative risk assessment: As explained in the text, where the likelihood or the magnitude of the consequences are not quantified, the risk assessment is referred to as qualitative (refer Clause 2.5.3).

Quantitative risk assessment: risk assessment where the probability or frequency of the outcomes can be estimated numerically and the magnitude of consequences quantified so that risk is calculated in terms of probable extent of harm or damage over a given period (see Clause 2.5.3).

Receptor: the ecological entity exposed to the stressor. (*Guidelines for Ecological Risk Assessment*, United States Environmental Protection Agency, 1998). (See also Clause 1.8.)

Remediation: the elimination or minimization of the environmental contamination/degradation which has already occurred.

Residual risk*: risk remaining after implementation of **risk treatment**

NOTE: See ISO/IEC Guide 51 for safety related applications.

Risk*: the chance of something happening that will have an impact on objectives

NOTE 1: A risk is often specified in terms of an event or circumstance and the consequences that may flow from it.

NOTE 2: Risk is measured in terms of a combination of the consequences of an event and their likelihoods.

NOTE 3: Risk may have a positive or negative impact.

NOTE 4: See ISO/IEC Guide 51, for issues related to safety.

NOTE 5: In the context of this guide, risk is the chance of something happening that will have an impact on the environment.

Risk acceptance: an informed decision to accept the consequences and the likelihood of a particular risk.

Risk analysis*: systematic process to understand the nature of and to deduce the level of risk.

NOTE 1: Provides the basis for risk evaluation and decisions about risk treatment.

NOTE 2: See ISO/IEC Guide 51 for risk analysis in the context of safety.

Risk assessment*: the overall process of risk identification, risk analysis and risk evaluation. (See also Figures 1 and 3, and 1.8.)

Risk avoidance*: a decision not to become involved in, or to withdraw from, a risk situation.

Risk control: that part of risk management which involves the implementation of policies, standards, procedures and physical changes to eliminate or minimize adverse risks.

NOTE: Some literature uses the term ‘risk management’ to describe a range of activities similar to what AS/NZS 4360:2004 defines as risk control, i.e. a limited range of activities that omits parts of the overall process of risk management.

Risk estimation: a systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences.

NOTE: AS/NZS 3931 defines risk estimation as 'Process used to produce a measure of the level of risks being analysed. Risk estimation consists of the following steps: frequency analysis, consequence analysis and their integration.'

Risk evaluation: the process in which judgements are made on the tolerability of the risk on the basis of risk analysis and taking into account factors such as socio-economic and environmental aspects (AS/NZS 3931).

NOTE: Risk evaluation is also defined as the process of comparing the level of risk against risk criteria. It assists in decisions about risk treatment. (see AS/NZS 4360:2004).

Risk identification*: the process of determining what, where, when, why and how something could happen.

Risk management*: the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.

Risk management process*: the systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk.

NOTE: Environmental risk management deals with the risks associated with past, present, and future activities on humans, flora and fauna.

Risk mitigation: steps taken to reduce the probability of occurrence or the magnitude of the consequences

Risk perception: the way in which individuals estimate risk. Risk perception cannot be reduced to a single parameter of a particular aspect of risk, such as the product of the probabilities and consequences of any event. Risk perception is inherently multi-dimensional and personal, with a particular risk or hazard meaning different things to different people and different things in different contexts. (Adapted from Royal Society, 1992).

Risk reduction: a selective application of appropriate techniques and management principles to lessen either the likelihood of an occurrence or the negative consequences associated with a risk, or both.

Risk treatment*: process of selection and implementation of measures to modify **risk**.

NOTE 1: The term 'risk treatment' is sometimes used for the measures themselves.

NOTE 2: Risk treatment measures can include avoiding, modifying, sharing or retaining risk.

(ISO/IEC Guide 73, in part)

Additional note: Some literature refers to risk treatment as risk control.

Safety: freedom from unacceptable risk (ISO/IEC Guide 51:1999)

NOTE: The use of the words 'safety' and 'safe' as descriptive adjectives should be avoided because they convey no useful extra information. In addition they are likely to be interpreted as an assurance of guaranteed freedom from risk. Safety is achieved by reducing risk to a tolerable level.

Sensitivity analysis: examines how the results of a calculation or model vary as individual assumptions are changed.

Source of risk: refer Clause 1.8.

Stakeholders*: those people and **organizations** who may affect, be affected by, or perceive themselves to be affected by, a decision, activity or risk.

NOTE: The term stakeholder may also include interested parties as defined in AS/NZS ISO 14004 and AS/NZS ISO 14050. (Examples are given in Clause 2.3.2.)

Stressor: a physical, chemical or biological entity that induces an adverse response (*Guidelines for Ecological Risk Assessment*, United States Environmental Protection Agency, 1998).

Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (*Our Common Future*)

Tolerable risk: risk which is accepted in a given context based on the current values of society (ISO/IEC Guide 51:1999). (See discussion in Clause 2.6.4.)

Uncertainty: a lack of knowledge arising from changes that are difficult to predict or events whose likelihood and consequences cannot be accurately predicted.

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B Sustainability principles

B1 General

Guiding principles are formal declarations that express the basis on which an environmental policy can be built, and which provide a foundation for a range of actions. Environmental issues such as climate change and sustainable development are generally seen as Global concerns.

The Rio Declaration on Environment and Development, adopted by the United Nations Conference on the Human Environment in 1992, is an example of international environmental guiding principles.

Its 27 Principles include recognition of the rights and responsibilities of States, and that—

'to achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption, and promote appropriate demographic policies' (Principle 8, see AS/NZS ISO 14004, Annex A).

These and similar principles are reflected in national and international regulations and agreements. For example, in Australia these include the principles of ecologically sustainable development as outlined in the Intergovernmental Agreement on the Environment (IGAE) which was signed by the Heads of Australian Governments in May 1992[4].

In New Zealand many of these concepts are enshrined in the Resource Management (RMA) Act (1991) and the Hazardous Substances and New Organisms (HSNO) Act (1996).

B2 Principles of ecologically sustainable development

The Australian National Strategy for Ecologically Sustainable Development (ESD) contains a package of seven guiding principles and three core objectives. No objective or principle should predominate; a balanced approach is required, that takes account of all these objectives and principles to pursue the goals of ESD.

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[4] Full text is available at http://www.environment.gov.au/psg/igu/pubs/igae.html

The three core objectives of ESD are:

- to enhance individual and community wellbeing and welfare by following a path of economic development that safeguards the welfare of future generations;
- to provide for equity within and between generations; and
- to protect biological diversity and maintain essential ecological processes and life-support systems.

The guiding principles are as follows.

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equity considerations.
- The global dimension of environmental impacts of actions of actions and policies should be recognized and considered.
- The need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection should be recognized.
- The need to maintain and enhance international competitiveness in an environmentally sound manner should be recognized.
- Cost-effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms.
- Decisions and actions should provide for broad community involvement on issues which affect them.
- Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

This last is the precautionary principle, which applies to the situations in which serious or irreversible damage to the environment is *possible* as a result of some action (or inaction), but for which science cannot provide certain prediction.

A useful Australian reference for applications of the principles of ESD is Hamilton and Throsby (1998)[5].

B3 The precautionary principle, or a precautionary approach

The precautionary principle is defined as follows (IGAE, 1992):

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[5] HAMILTON, C. and THROSBY, D. (eds). 1998. *The ecologically sustainable development process: evaluating a policy experiment*. Academy of the Social Sciences. Canberra.

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, private and public decisions should be guided by:

(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and

(ii) an assessment of the risk weighted consequences of various options.

The principle requires that, in such situations, we do not use scientific uncertainty as a reason for not taking measures to prevent environmental degradation, but rather that we put *appropriate* measures in place in advance of more certain scientific evidence.

What might constitute appropriate measures will depend not only on the nature of the threats and the environmental parameters which are threatened, but also on the possible measures available to safeguard the environment, and the social and economic context. As well, there will be many views on what constitutes *serious* damage, what is *reversible*, and what measures may be *appropriate*.

These issues are discussed in Deville and Harding (1997)[6], which attempts to provide a systematic basis to the application of the precautionary principle, taking into account the difficulties arising from subjectivity and scientific uncertainty. Deville and Harding suggests that it is necessary to work through the following stages in applying the precautionary principle (and provides guidance for doing so).

- What is the potential for threats of environmental damage?
- Are precautionary measures required?
- What precautionary measures *can be* applied?
- How much precaution is warranted?
- What precautionary measures *should be* applied?

The precautionary principle is sometimes seen as a 'no risk is acceptable' policy, but this is not the intent in the IGAE definition, where Items (i) and (ii) clearly require risks associated with other options and socio-economic factors to be taken into account. However, it must be considered as one of a 'package' of principles of ESD.

The precautionary principle is particularly relevant in environmental risk management because of the inherent complexity of ecosystems, as referred to throughout this Guide. This complexity means that our scientific understanding of ecosystems is far from complete and that uncertainty, indeterminacy and ignorance are common.

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[6] DEVILLE, A. and HARDING, R. 1997. *Applying the Precautionary Principle.* The Federation Press. Sydney.

B4 Sustainable management and the precautionary approach in New Zealand legislation

In New Zealand, the guiding principles are reflected in the *Resource Management Act* (1991)[7] which guides all applications for land use, as well as discharges to air, land and water.

SECTION 5: PURPOSE—The Purpose of the Resource Management Act

The purpose of this Act is to promote the sustainable management of natural and physical resources.

(a) In this Act, 'sustainable management' means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while—

   (a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

   (b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

   (c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment

The *Hazardous Substances and New Organisms (HSNO) Act (1996*) provides for the administration of new organisms and hazardous substances. The Environmental Risk Management Authority (ERMA)[8] has been set up to administer the HSNO Act. Relevant sections of this Act are:

SECTION 4: PURPOSE OF THE HNSO ACT

The Purpose of this Act is to protect the environment, and the health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms.

SECTION 5: PRINCIPLES RELEVANT TO PURPOSE OF ACT

All persons exercising functions, powers, and duties under this Act shall, to achieve the purpose of this Act, recognize and provide for the following principles:

(a) The safeguarding of the life-supporting capacity of air, water, soil, and ecosystems.

(b) The maintenance and enhancement of the capacity of people and communities to provide for their own economic, social, and cultural wellbeing and for the reasonably foreseeable needs of future generations.

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[7] http://www.rma.govt.nz/

[8] http://www.ermanz.govt.nz/, and http://www.hsno.govt.nz/

SECTION 7: PRECAUTIONARY APPROACH

All persons exercising functions, powers, and duties under this Act, including but not limited to, functions, powers, and duties under sections 29, 32, 38, 45, and 48 of this Act, shall take into account the need for caution in managing adverse effects where there is scientific and technical uncertainty about those effects.

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C Links between environmental risk and environmental management systems

Many people dealing with environmental issues within an organization will be familiar with the use and application of environmental management systems, and some specifically with the International Standard for Environmental Management Systems, ISO 14001:2004 (adopted in Australia and New Zealand as AS/NZS ISO 14001). The Standard does not explicitly define requirements for management of environmental risk. However, an environmental management system can provide a systems-based approach to defining and implementing the steps of a risk management process, and can be further developed into an environmental risk management system. The integration of these steps within an environmental management system is not meant to specify definitive requirements, but rather to provide guidelines and suggestions for how to go about integrating risk management into a new or existing environmental management system.

This discussion follows the structure of ISO 14001. The steps are as follows:

- ***Environmental policy***

  In defining the organization's environmental policy, consideration may be given to including a specific statement on the organization's approach or philosophy for risk management. The policy might also include specific reference to the management of the organization's most significant risks (e.g. waste management, air pollution).

- ***Environmental aspects***

  This is a key management system element in relation to environmental risks, as this is largely the area where environmental risks are identified. The concepts discussed in Clause 2.3 of this guide apply here. ISO 14001 requires that an organization identify the environmental aspects of its activities, products and services in order to determine those which can have significant impact upon the environment. The determination of the significance of environmental impacts can be undertaken using the concepts discussed in Clause 2.4. An output of this process could be the production of an environmental risk register that contains categories for environmental aspects, potential environmental impacts (risks), consequences rating, likelihood rating, risk rating. Table F3, Appendix F, gives an example of a risk register format.

- ***Legal and other requirements***

  The organization is required to have identified and have access to applicable legal and other requirements. Environmental legal requirements are often established in order to control activities so that protection of some part of the environment results. There is an implicit intention in these legal requirements, that their effective implementation will result in lowering of risk to the environment. Hence, compliance with legal requirements should in theory result in a reduction in risk to the environment. Furthermore, legal compliance should also reduce risks to the business, for example through reduction in fines and ability to maintain licence to operate. Legal and other requirements, such as codes of practice, should also assist in identifying potential environmental aspects and impacts.

- ***Objectives and targets***

  When an organization establishes and reviews its objectives and targets it is to consider its significant environmental aspects. In other words once the environmental risks have been identified and analysed, objectives and targets should be set based on the significant risks. In this way the significant environmental risks will be a priority to be addressed by the management system. The objectives and targets should also be consistent with the environmental policy, such that if the policy contains specific risks, these should be reflected in the objectives and targets.

- ***Environmental management program***

  This element is essentially the plan for achieving the defined objectives and targets, and will include the significant environmental risks.

- ***Structure and responsibility***

  This element requires that roles, responsibilities and authorities are defined, documented and communicated. This is relevant to risk management whereby responsibilities for management of significant environmental risks are specifically identified. This element also requires that resources essential to the implementation and control of the management system are provided, and this can be extended to include resources required for effective management of significant risks.

- ***Training, awareness and competence***

  This element requires that personnel performing tasks that can cause significant environmental impacts are competent to perform these tasks. This can be extended to include risk such that tasks which involve a high level of risk. Specific risk training and awareness may be warranted to achieve required competency.

- ***Communication***

  This element requires that an organization consider processes for external communication of its significant environmental aspects—this can be extended to include environmental risks. Although not specifically required by ISO 14001, organizations should consider how to ensure that effective communication of risks throughout the organization occurs.

- ***Operational control***

  Operations and activities that are associated with significant environmental aspects should plan these activities to ensure they are carried out under specified operating conditions. This requirement should be extended to include operations and activities that are associated with significant risks.

- ***Emergency preparedness and response***

  ISO 14001 requires, amongst other things, that the potential for accident and emergency situations and associated environmental impacts are identified. Risk identification and management is of particular importance in this element, so that accident and emergency situations and associated environmental impacts are comprehensively identified, and the relative risk of these impacts is determined. For example, emergency response plans may need to address the range of risk including high consequence/low likelihood and low consequence/high likelihood events.

- ***Monitoring and measurement***

  ISO 14001 requires that the organization monitor and measure the key characteristics of its operations and activities that can have a significant impact on the environment. The purpose of the monitor and review stage of the AS/NZS 4360 process is to access the effectiveness of the risk management strategy and plan adopted to re-assess their relevance from time to time. The ISO 14001 monitoring and measurement element substantially covers the monitoring requirements of the monitor and review stage of AS/NZS 4360.

- ***Nonconformance and corrective and preventative action***

  ISO 14001 requires that the organization defines responsibility and authority for handling and investigating nonconformance, taking action to mitigate any impacts caused and for initiating and completing corrective and preventative action. These requirements extend to cover the risk management system, and any nonconformances from it.

- ***Environmental management system audit***

  The audit component would extend to determining whether the environmental risk management system conforms to planned arrangements for environmental risk management.

- ***Management review***

  The review component would be extended to include review of the environmental risk management system to ensure its continuing suitability, adequacy and ongoing effectiveness. The ISO 14001 management review element is part of the monitor and review process step of AS/NZS 4360:2004.

D Risk criteria: What is a tolerable risk?

D1 Introduction

Risk assessment is increasingly used as a rational basis for analysing complex environmental problems. Although guidelines and regulations provide great detail on risk identification and characterization, there is less guidance on what constitutes an acceptable or tolerable level of risk. This lack of guidance causes inconsistencies, unnecessary costs to business and avoidable harm to individuals and the environment.

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. It comprises estimating risk in terms of likelihood and consequence, combining these elements to obtain a level of risk and comparing this level against predetermined criteria.

Risk assessors need to choose risk criteria carefully. This is seldom a simple task. Some of the issues to be considered include the following.

- What are the appropriate endpoints?
- How severe is the risk? How many people is it likely to affect? What is the ecosystem impact likely to be?
- Who is determining acceptability, and for whom?
- What process is used to decide acceptable or tolerable risk; individual assessor, group or community; regulators, politicians or scientists and over what defined or flexible time frame, etc.
- Has the process addressed the necessary requirements for acceptance or tolerance in a democratic society, e.g. involving and gaining ownership of affected stakeholders, and achieving equitable distribution of benefits and costs?
- Have all relevant guidelines and regulations been considered and where necessary complied with?
- What is best practice? Are there any overseas regulations or guidelines which could be regarded as best practice?
- What form should the criterion take; fixed numerical levels or incorporating statistical considerations? Has the decision been based on a comprehensive review of the available accepted criteria and/or case studies?

- What level of conservatism should be used to accommodate uncertainty?
- Have the risk management implications of each criteria option been considered?
- Have the costs and benefits of each management option been estimated? Whatever process is used to choose acceptable risk criteria will implicitly incorporate an assumption of the acceptable benefit and cost. While it is seldom possible to obtain accurate costs and benefits, it is critical that decisions are informed by best estimates.
- Have the criteria been compared against other criteria for comparable risks and is a similar level of benefit/cost achieved? Will resources be allocated in proportion to risk if the recommended criterion is adopted? Potential for mis-allocation of resources.
- Has the practicality of monitoring and enforcement been considered? This is important to address at the assessment stage otherwise the criterion will be meaningless.

D2 Risk criteria

Risk criteria may be specified on a case-by-case basis, or may be predetermined by regulation. For example, the New Zealand Environmental Risk Management Authority (ERMA) makes decisions about the importation, development, field testing and release of new organisms on a case-by-case basis. The Authority sets criteria based on the characteristics of the organism and its intended use. Local authorities and government agencies often use regulatory guidelines as criteria for making decisions about risks to the environment.

Most of the regulatory guidelines that have been established in Australia and New Zealand are concerned with human health risk. There are relatively few examples of acceptable risk criteria explicitly for environmental exposures.

Surrogate concentration standards are used in the National Environment Protection Measure (NEPM) for Air Quality. The level of risk which these standards equate to are described (National Environmental Protection Council, 1998[9]) as ‘The standards . . . represent a high degree of consensus among leading health professionals, varied to reflect what is realistically achievable in Australia over the next ten years.’

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[9] National Environmental Protection Council, 1998. *National Environment Protection Council Act*, Introduction: National Air Quality Standards for Australia, Commonwealth Government.

Guideline concentration levels for soil contamination above which an investigation of site-specific risk assessment and consideration of remediation options is recommended are provided in the Australian and New Zealand Environment and Conservation Council document (ANZECC 1992[10]). These threshold levels are commonly back-calculated from toxicity factors such as receptor-specific reference dosages, or potency factors (in combination with acceptable risk) through application of risk assessment. These toxicity factors are commonly obtained from various United States Environmental Protection Agency documents (e.g., USEPA 1991[11]).

ANZECC Water Quality Guidelines (ANZECC, 1999[12]) set acceptable concentrations based on the intrinsic toxicity to marine organisms for a broad range of substances. These have been revised with new information for local fish species included, and ranges for chronic and acute toxicity.

For new facilities in the Netherlands, soil criteria require it to be demonstrated that all risks have been reduced to a level as low as reasonably achievable. The maximum tolerable individual risk criteria is set as one excess fatality in a million (annual probability).

The United States Food and Drug Agency (USFDA) and United States Environmental Protection Agency (USEPA) have defined acceptable risk for cancer as 1×10^{-6} over a lifetime. This level of risk is used as a screening tool by USEPA to guide the agency's priorities for setting standards on residual emissions. However, it is clear that the Superfund program (USEPA, 1998 and Graham, 1993[13])have accepted risks in the range of 1×10^{-4} to 1×10^{-6} over a lifetime for known or suspected carcinogens to reflect site-specific considerations such as the number of people exposed, presence of multiple contaminants, feasibility and cost effectiveness.

These and further examples to illustrate the range of and basis for acceptable risk criteria are summarized in Table D1.

Care needs to be taken when comparing risk information to ensure that a common set of units is used, as published information will sometimes quote probability and frequency interchangeably, sometimes in decimal, faction or scientific notation.

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TABLE D1
Basis for choosing risk criteria used by regulators

Criteria	Comments	Examples
Zero risk	Regardless of the costs or benefits. Impossible to achieve	United States Food and Drug Administration (USFDA) Delaney clause 'substances demonstrated to be carcinogens banned'.
To the extent economically feasible	Considers costs only Regardless of how trivial the benefit	US CAA MACT (USEPA, 1990), Best Available Technique not Entailing Excessive Cost (Duffus & Worth, 1996), etc.
Realistically achievable	Judged by a consensus of health professionals.	Air National Environmental Protection Measure (see earlier reference)
No Observable Adverse Effect Level (NOAEL).		Widely used by the United States Environmental Protection Agency (USEPA).
De minimus	Defined in Whipple (1987[14]) as trivial, insignificant or minimal Ignores costs of controls	—
Natural standard	Risks from naturally occurring events provide a benchmark, e.g., probability of death	—
Unreasonable risks	Considers both costs and benefits	—
Significant risk	No explicit consideration of either costs or benefits Determined on a case-by-case basis Requires both statistical significance and large enough to require remedial control action	Paustenbach, 1989 (p1031[15]) USFDA definition of insignificant cancer risk as < 1×10^{-6} per lifetime.
Reasonably necessary or appropriate	Balancing of cost and benefit with substantive evidence requirement	—
Ample margin of safety	Emphasis on serious illness or mortality No explicit consideration of either costs or benefits	—
As Low As Reasonably Achievable (ALARA)	Balancing of cost and benefit	The Netherlands
Adequate margin of safety	No explicit consideration of either costs or benefits Protects health of more sensitive portion of population	USEPA
Precautionary Principle (see Appendix B)	Requires both a threat of serious and irreversible environmental damage and a lack of scientific certainty about these threats	Intergovernmental Agreement on the Environment (IGAE, 1992)

[14] WHIPPLE C. 1987. *De Minimis Risk*. Plenum Press.

[15] PAUSTENBACH, D. 1989. *The Risk Assessment of Environmental Hazards*. Wiley.

E Sources of information for risk identification

Practical examples of sources of information for input to the risk identification process include the following:

- Material safety data sheets (MSDS)
- MSDS updates
- Material container labels
- Material suppliers
- Material transporters
- Environmental Protection Agency (EPA) and other regulators staff (local, state and federal)
- EPA, dangerous goods and other regulations
- EPA publications
- Immediate neighbour informal discussions
- Environmental audits (self assessment, corporate, regulatory, system, implementation, etc)
- Environmental incidents
- Environmental incident statistics
- Corrective actions database
- Environmental monitoring data
- Mass balance data
- Community complaints
- Community complaints statistics
- Policy and/or compliance database
- EPA newsletters
- Newspapers
- Structured risk assessment process
- Business plan development
- Business plans
- Sovereign and country risk assessments
- Customer, suppliers, shareholders surveys and comments
- Supplier audits
- Environmental impact assessments
- Synergistic/antagonistic risks
- Non Governmental Organization) NGO consultation
- Industry databases
- Business/process mapping
- Literature reviews of technical literature, both recent and historical
- Structured risk identification reviews
- Walk-through surveys
- Consultant/legal advice
- Team discussions
- Industry codes of practice
- Industry association meetings
- Conferences, seminars and workshops

- Community consultation surveys, group meetings, statistics
- Visitor comments
- Research and development conducted internally, industry groups, regulators or others
- Employee suggestion and involvement programs
- Environmental improvement plans development
- Company newsletter feedback forms
- Experiences of other industries
- Expert computer systems
- Brainstorming sessions
- Structured process review meetings
- Transport certificates
- Dangerous goods classifications
- Toxicity assessments
- Biological toxicity testing
- Ecological surveys

F Examples

Table F1
Potential environmental impact rating: example

Area impacted	Level 1 (low severity)	Level 3	Level 5 (high severity)
General environmental and social impacts	No lasting detrimental effect on the environment, e.g. minor transient release of pollutant (including odour dust and noise), or minor social impact.	Long-term detrimental environmental or social impact, e.g. chronic and/or significant discharge of pollutant, a possible source of community annoyance.	Significant extensive detrimental long-term impacts on the environment, the community and/or public health. Catastrophic and/or extensive chronic discharge of persistent hazardous pollutant.
Human health	Minor short-term inconvenience or symptoms.	Objective but reversible impairment to human health.	Fatal, long-term or permanently disabling effects on human health, (more than one person affected)
Land-based ecosystem	Minor impacts on fauna / flora and habitat, but no negative impacts on ecosystem function. Limited damage to a minimal area of land of no significant value. (i.e. no nature reserves, parks or unique habitats).	Significant changes in flora / fauna populations and habitat, but not resulting in eradication or any impact on endangered or beneficial species. Non-persistent but possibly widespread damage to land; damage that can be remediated without long-term loss; or localized persistent damage.	Long-term and significant change in population (e.g. eradication of beneficial or endangered species) or habitat with negative impact on ecosystem function. Widespread and persistent damage to a significant area of land and/or groundwater resource (having regard for the importance of the land, e.g. unique habitat / national park).
Aquatic eco-system	Minor impact on aquatic ecosystem, including flora, fauna and habitat. No significant impact on water resources.	Significant localized impacts but without longer-term impact on aquatic ecosystems, and/or short term impacts on water resources.	Damage to an extensive portion of aquatic ecosystem resulting in severe impacts on aquatic populations and habitats and /or long-term impact on water resources.
Cultural heritage	Minor repairable damage to commonplace structures, or minor infringement of cultural values.	Damage to structures / items of cultural significance, or significant infringement of cultural values / sacred locations.	Irreparable damage to highly valued structures / items / locations of cultural significance or sacred value.

Table F2

Potential environment-related business impacts rating: Example

Area impacted	Level 1 (low severity)	Level 3	Level 5 (high severity)
Public / media reaction	Public concern restricted to local complaints.	May attract attention from local media, heightened concern by local community, and/or condemnation from green NGOs.	Probable public or media outcry (with national or international coverage). Significant green NGO campaign.
Legal	Minor technical / legal issues. No serious breach of regulation. Minor licence non-compliances. Minor on-the-spot fines.	Probable serious breach of regulation identified with serious prosecution or fine. Involved in significant litigation.	Major breach of regulation identified and/or serious incident notification and/or major investigation by authority with prosecution and very significant fines. Very serious litigation, including class actions.
Reputation	Minor negative impacts on reputation. Limited to site or operation.	Environmental or general management credentials are moderately affected. Business group reputation tarnished.	Significant negative impacts on reputation as an environment and general manager. Share price may be affected.
Licence to Operate	Some difficulties experienced with regulator in gaining approvals.	Significant difficulties or delays experienced in gaining approvals or ability to continue operating.	Licence to operate likely to be revoked or not granted.
Capital fix	Set up levels of capital suitable for your organization		
Total cost	Set up levels of total cost suitable for your organization (potential clean-up, corrective actions, fines, liabilities, etc.)		

Table F3
Qualitative risk register: Example

Aspects (activities/emissions for each phase of project)	Description of potential impacts on the environment	Proposed management strategies	Consequence severity rating	Likelihood/ Frequency	Level of risk*
Planning/design		Identify impacts early and incorporate management strategies into design.			
Construction					
Site clearing	Minor destruction of grassland habitat; soil erosion; dust. Habitat is not considered particularly significant.	Baseline mapping: Use previously disturbed areas; avoid sensitive habitats; rapid rehab. Dust control measures. Contour site to avoid erosion from rain .	1	B	M
Waste generation					
Construction crew					
Commissioning/Start-up					
Testing of flare	Noise; visual impact; random flare may kill birds	Undertake noise modelling to site flare in position to cause least noise impact on community, and shield from view; sound horn to scare birds prior to flaring.	1	C	L
Operations					
NOx emissions	Adds to existing urban pollution of regional atmosphere by 5%. Existing pollution occasionally above air quality guidelines.	Undertake modelling to determine % contribution; consider reducing technologies (low-NOx burners, gas instead of diesel).	3	C	S
Brine disposal to ocean	Increased salinity and temperature, and heavy metal contaminants may cause impact on marine species. Moderate potential impact.	Undertaken dispersal modelling to determine design to meet water quality criteria; undertake detailed baseline studies to select least sensitive location, and commit to ongoing monitoring; assess risks to individual species.	3	C	S
Emissions to air					
Emissions to water (near shore marine, sensitive). Include low but chronic levels of zinc, lead and hydrocarbons	Potential for build-up of metals and hydrocarbons by bioaccumulation in food chain. Consumers of seafood may be affected.	All emissions to water to be kept below water quality guidelines. Ongoing monitoring of impacts.	4	D	S
De-commission and remove facility	May leak contaminants during removal; may leave residual contamination. May attract interest of green groups.	Design facility to enable effective de-commissioning and removal, and conduct baseline, operation, and post-op site surveys.	2	D	L

NOTE: Level of risk indicated should be ‘residual’, i.e. still present after the management measures have been applied.

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G Methods used in risk analysis (from AS/NZS 3931)

Method	Description and usage
Event tree analysis	A hazard identification and frequency analysis technique which employs inductive reasoning to translate different initiating events into possible outcomes
Fault modes and effects analysis Fault modes, effect and criticality analysis	A fundamental hazard identification and frequency analysis technique which analyses all the fault modes of a given equipment item for their effects both on other components and the system
Fault tree analysis	A hazard identification and frequency analysis technique which starts with the undesired event and determines all the ways in which it could occur. These are displayed graphically
Hazard and operability study	A fundamental hazard identification technique which systematically evaluates each part of the system to see how deviations from the design intent can occur and whether they can cause problems
Human reliability analysis	A frequency analysis technique which deals with the impact of people on system performance and evaluates the influence of human errors on reliability
Preliminary hazard analysis	A hazard identification and frequency analysis technique that can be used early in the design stage to identify hazards and assess their criticality
Reliability block diagram	A frequency analysis technique that creates a model of the system and its redundancies to evaluate the overall system reliability
Category rating	A means of rating risks by the categories in which they fall in order to create prioritized groups of risks
Checklists	A hazard identification technique which provides a listing of typical hazardous substances and/or potential accident sources which need to be considered. Can evaluate conformance with codes and standards
Common mode failure analysis	A method for assessing whether the coincidental failure of a number of different parts or components within a system is possible and its likely overall effect
Consequence models	The estimation of the impact of an event on people, property or the environment. Both simplified analytical approaches and complex computer models are available

Method	Description and usage
Delphi technique	A means of combining expert opinions that may support frequency analysis, consequence modelling and/or risk estimation
Hazard indices	A hazard identification/evaluation technique which can be used to rank different system options and identify the less hazardous options
Monte-Carlo simulation and other simulation techniques	A frequency analysis technique which uses a model of the system to evaluate variations in input conditions and assumptions
Paired comparisons	A means of estimation and ranking a set of risks by looking at pairs of risks and evaluating just one pair at a time
Review of historical data	A hazard identification technique that can be used to identify potential problem areas and also provide an input into frequency analysis based on accident and reliability data
Sneak analysis	A method of identifying latent paths that could cause the occurrence of unforeseen events

H Cost benefit analysis

(See also Section 8.4 of HB 436:2004, *Risk Management Guidelines—Companion to AS/NZS 4360:2004*)

H1 Introduction

Cost-benefit analysis, or CBA, is a formal framework that is used to identify and analyse direct and indirect costs and benefits. CBA involves the weighing of all direct and indirect costs against all direct and indirect benefits, including monetary and non-monetary costs and benefits, i.e. a balancing approach. The difficulties of cost-benefit analysis are well understood, with the main limitations including the problems of non-commensurate scales, distortions due to aggregation, and equity problems relating to the distribution of the costs and benefits.

Some of the particular issues that arise in CBA are as follows:

Valuation of 'intangibles' (see H3).

Valuation of future benefits and costs (see H5).

Distribution of both benefits and costs (see H6).

Methods of valuation can be split into two categories, *implicit* and *explicit.* Individuals, when making personal decisions and risk evaluations, tend to include the benefits *implicitly*, and may not take account of the full range of benefits.

Risk-benefit balancing requires considering benefits alongside risks *explicitly*, so that a more complete consideration can be given to defining all the benefits and associated costs. If valuation is made explicit, then a similar valuation can be used in all cases involving the intangible. If not, then ex-post analysis of the implicit valuation may reveal inconsistencies in policies and decisions.

H2 Cost-benefit analysis as a decision-making tool

Many decisions are based on a comparison of the costs and benefits of the expected outcomes. When undertaking a formal cost-benefit analysis, the decision-maker needs to establish the boundaries for the analysis, part of which requires determining from whose perspective the analysis will be done. Early analyses were concerned with the national interest, therefore costs and benefits to the nation were considered. As experience and techniques for measuring costs and benefits developed, regional analyses were undertaken. More recently it has become common for CBA to be used to analyse particular projects and activities. This, however, highlights one of the key identified deficiencies of CBA, that the group receiving the benefits may be quite different from the group that bears the costs.

Some stakeholders may advocate that costs and benefits should not be compared because a particular consequence is regarded as being non-negotiable (which is implicitly saying that the consequence is of infinite value). Others reject this approach because they feel it leads to sub-optimal (if not irrational) decision making. This has led to the development of sophisticated techniques for valuing goods that cannot be easily measured in market prices. This area of welfare economics has become known as non-market valuation.

H3 Valuing intangibles

Intangibles are things with no explicit monetary value, generally because they are not traded and hence have no price. The two principal approaches to dealing with intangibles are either to put a monetary value on the intangibles in some way, or to ascertain the value of the tangible outcomes and to compare these with the (quantified but not valued) intangible outcomes and make a decision.

Increasingly, government policies value human life either explicitly or implicitly. For example, funding of safety projects by Transit New Zealand equates to a basis that a human life is worth about $2 million *explicitly*. Health funding, by funding different services at different levels and applying priorities to such funding, values lives and health *implicitly*.

Implicit valuation is seldom debated publicly, however decisions involving intangibles may reveal implicit upper and lower bounds. For example, assume a decision is being made on whether to permit a new herbicide to be used. The benefit has been assessed as a cost reduction (compared to using an existing herbicide) equivalent to $5 million per year. The cost is that use of the new herbicide has been demonstrated to lead to the death of invertebrate aquatic life in adjacent streams. If the decision is made to permit the herbicide, then the death of invertebrate aquatic life has been valued implicitly at less than $5 million per year. Conversely, if the herbicide is not approved, then the implicit valuation of the invertebrate aquatic life is more than $5 million per year.

The following three kinds of value are generally recognized.

- *Use value*—the value an individual gets through direct use (e.g. recreational use).
- *Option value*—the value to an individual of retaining the option to use it if desired.
- *Existence value*—the value an individual gets from simply knowing that something still exists, even they have no expectation of ever seeing it or using it (for example, the black stilt, the Wollemi pine).

The implicit values discussed previously generally only reveal limits to values (more than or less than a certain sum), although a series of decisions may provide both upper and lower bounds to the value of an intangible.

A further source of implicit valuation is the so-called 'travel cost' valuation. This is suitable for attractions that people travel to and use, such as a national park. As one gets farther from the attraction, the proportion of people willing to travel to it reduces. The rate of reduction can be used to estimate the use value of the attraction. This form of valuation is only useful for a limited range of items and, in any case, only includes use value while excluding option and existence value.

An explicit valuation measure is to ask people what they are willing to pay (or willing to accept) to achieve an outcome. This method has been used in a wide range of situations and, although subject to error, gives a useful indication of value (use, option and existence).

Accuracy depends on appropriate questions being asked, and there is some evidence that estimating value via 'willingness to pay' (WTP) questions reveals values which are perhaps half of the values revealed via a 'willingness to accept' question. Where both methods are used they provide useful upper and lower bounds.

The limitations of WTP or contingent valuation approaches are that they are expensive to apply, and also it is sometimes difficult to provide respondents with enough information to allow them to make informed decisions.

Where dissimilar costs or benefits are to be combined in a CBA, a common unit of valuation needs to be used. The most logical one to use is money, which (in spite of the opprobrium that often attaches to it) is simply a medium of exchange that reflects the relative value that citizens place on various commodities.

H4 Alternatives to valuation

In practice there are often activities or items that it is not possible to value because no explicit value exists, and no implicit valuation can be derived from previous experience. This latter case is likely where a previous decision has balanced a range of intangibles against a specified tangible value, and it is not possible to allocate the implicit valuation between the intangibles. It is only possible to give a valuation to that particular bundle of intangibles.

Techniques that may be used in these circumstances include environmental accounting, and multi-criteria analysis.

Environmental accounting requires the decision maker to list all costs and benefits. All monetary costs and benefits are combined and a balance is struck. Non-monetary costs and benefits are described clearly, and any values that are available are applied. The decision maker must make a subjective balancing decision.

Multi-criteria analysis, or multi-attribute decision-making (MADM), is a three-stage process. A set of options or different outcomes is established, and a set of attributes associated with these outcomes is determined. Decision makers are first asked to establish relative weights for the attributes (reflecting the relative importance of these attributes). Secondly, each attribute is scored for each option or outcome. Finally weighted scores are calculated for each of the options. MADM systems have been programmed, and are most often used when there are a number of decision makers.

H5 Future values

Two problems exist where costs and benefits of a decision occur in the future. The first relates to whether we can realistically assess future values, and the second relates to how concerned we should be about these future values.

Where a consequence is irreversible (e.g. the use of a finite resource), and where there is an increasing scarcity (which assumes that demand continues and is relatively price-inelastic), then real prices may rise significantly. Some CBAs assume an increase in the relative value of such a commodity.

Where a consequence is reversible, or resources are virtually unlimited, the valuation problem is less severe, principally because it is less likely that the reversal technology will suffer a relative price increase. The final problem in estimating future price is that it is simply not known whether preferences will change over time, and current values are possibly the best guide to future values.

Cost-benefit analysis generally incorporates a discounting of the future (something in the future is worth less than something now). Discounting has its justification in both human nature (social rate of time preference) and economic efficiency (resources invested now can increase resources available in the future). Typical rates of social preference are of the order of 3% to 5%, while typical rates of economic return suggest a discount rate of around 10% (a range of 5% to 15%).

Any discount rate has implications for inter-generational equity. It is not clear that future generations will maintain similar values, and this is a particular problem in cases where outcomes are not reversible. Also, one generation (which gets the benefits) may not compensate the next generation (which suffers the future costs).

Another concern this raises with some people is that those in the present do not care about those in the future. The discount rate, when viewed from the efficiency perspective, does not imply this at all. However, since there is no guarantee that those in the present will transfer resources to those in the future to compensate them for any losses they may suffer, there is a distributional issue involved. This distributional issue arises even with a zero discount rate.

Where a decision involves a non-reversible action, those in the future lose an option value. However, this is equally true for those in the present, and hence the issue of a loss of options should not be confused with inter-generational issues.

H6 Distribution of costs and benefits

Cost-benefit analysis, as generally applied, considers the overall balance, but ignores the distributional outcomes of an action (i.e. the actual final distribution of benefits and costs, such as whether there is a net loss for some in the community).

The rationale for this is that, if deemed to be an issue, and provided total benefits are greater than total costs, it is feasible to compensate all those who lose such that they are at least as well off as they were before, while still leaving some better off (termed a Pareto-superior outcome).

Many decisions give benefits to one group while imposing costs on others. Where a project has benefits greater than costs, in principle the beneficiaries are able to compensate the losers so that on balance everyone is as well off as, or better off than, without the project.

In many analyses, no formal consideration is given as to whether or how such compensation will be made. If compensation is not made, then even where a project *could* lead to net benefits for society, there is no assurance that there *will* be net benefits. It depends on assumptions about the relative value attached to gains for one person and losses to another.

In many cases it is difficult to identify the individuals who will gain or lose, let alone ensure that transfers take place from one group to another. However, in other cases, at least one of the groups can be identified, and perhaps compensation payments should be made to (or from) that group from (or to) government, with government acting on behalf of the group that is not identifiable. The purpose of making such transfer payments is that it acts as some sort of surety that net benefits actually exist. Making such payments involves assumptions about appropriate property rights.

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