Chapter Eight

Uncertainty, risk and the precautionary principle

8.1 Introduction

Uncertainty, which may be both scientifically and socially based, is an inherent feature of environmental management and arises at many points through the environmental decision-making process. Many examples are evident in the previous chapters.

As emphasised throughout this book, environmental decisions are complex decisions. By definition, the environment comprises many components, numerous processes and complex interconnections and feedback mechanisms. We use the term "ecosystem" to describe these components and processes within a defined area. The complexity of ecosystems exceeds that of human-created technological systems and our scientific understanding is limited because we cannot be sure we have identified all the components of ecosystems, let alone that we understand more than a small part of the processes and interactions between them.

However, uncertainty over the workings of the "natural" world is further complicated by adding influences from human activities. Social processes are equally as complex as those in the "natural" world and we cannot be sure how the interaction between humans and the environment will unfold in the future. Will our society remain anthropocentric (human-centred) with emphasis on consumption of goods and a high throughput of materials and energy? Or, will we move to a society which emphasises a low throughput of materials and energy and in which "stewardship" of the earth and its natural systems is of primary importance? What will be the environmental outcomes of political choices concerning technology and systems of governance and management that we are making at present? There is much uncertainty surrounding these social questions.

Whilst uncertainty generally remains an "unconsidered" factor in the environmental decision-making process, there have been some recent developments which integrate the treatment of risk and uncertainties into formal processes. Two examples include the requirement for risk assessment as part of Environmental Impact Assessment (EIA) in some circumstances and the incorporation of the "precautionary principle" into legislation concerning environmental decision-making.

In this chapter we take another pause along the environmental decision-making road, this time to examine the nature and origins of uncertainty and its treatment in environmental decision-making. By definition (see 8.2.1 and 8.3), risk is the most quantifiable and "measurable" type of uncertainty. We explore some of the formal ways of dealing with risk, shedding light on the subjectivity involved in these approaches.

Scientists and engineers whose work involves environmental effects are continually operating in the face of uncertainty. In this role it is important not only to manage and minimise risk, but to communicate these risks to the public and where appropriate to involve the public in risk management. In this regard it is important to acknowledge that members of the public may perceive risks differently and to understand the reasons for this and ways of handling differing perceptions in decision-making.

The final portion of this chapter is devoted to the precautionary principle, a key principle of Ecologically Sustainable Development (ESD) (see Chapter 2) which provides guidance on how we should make decisions when confronted with scientific uncertainty.
8.2 Types of uncertainty

Uncertainty is a complex concept which is not well understood. Rather like peeling the layers of an onion, as we delve more deeply into the uncertainty surrounding an environmental management issue, we reveal different forms of uncertainty. The outcome is that whilst we can reduce uncertainty of one kind by application of more science to the problem, we will not totally remove uncertainty.

Brian Wynne (1992) has identified four kinds of uncertainty: risk, uncertainty, ignorance and indeterminacy. His descriptions of these categories are as follows:

8.2.1 Risk
The behaviour of the system in question is "basically well known, and the chances of different outcomes can be defined and quantified by structured analysis of mechanisms and probabilities" (Wynne, 1992, p 114).

This is a good description of technical risk associated with machinery failure in an industrial complex. "Uncertainty" (in the popular sense) is present to the extent that we can't be sure when machine failure will occur or how environmental factors will influence outcomes. For example, depending on the weather conditions, pollution released after equipment failure may be blown towards or away from sensitive environments or human settlements. In addition, other types of uncertainty may be present simultaneously as we will see below.

8.2.2 Uncertainty
We "know the important system parameters but not the probability distributions"; that is we "Don't know the odds" (Wynne, 1992, p 114).

The enhanced greenhouse effect is a good example. The science concerning the role of greenhouse gases (eg carbon dioxide) in retaining heat within the Earth's atmosphere is well established. The wide range of parameters that go to make up the Earth's climate are also known (eg clouds, global air circulation, heat absorption by water, land and so on). However, the precise relationships between these parameters are uncertain because of the complexity of the many potential feedback mechanisms and the relationships between them. Hence there is much uncertainty about the precise effects of the build up of greenhouse gases in the atmosphere and the future impacts on climate at local levels across the globe.

8.2.3 Ignorance
We "Don't know what we don't know" (Wynne, 1992, p 114).

To explain this we will use the example, discussed in Chapter 5 (see Box 5.7), of predictions on the behaviour of radioactive cesium in soils in Cumbria (United Kingdom), which was fall-out from Chernobyl (Wynne, 1989). The predictions made by British scientists were based on the assumption that radioactive cesium would behave in the same way as observed in alkaline clay soils in another region. In fact radioactive cesium behaved quite differently in the peaty acid soils of Cumbria and this different behaviour led to uptake of the cesium by vegetation and hence to its presence in sheep inhabiting the region. This meant that a ban on sheep sales predicted by scientists to last for three weeks was still in place six years later. The message from this example is that scientists conduct such ecological assessments by containing their analysis within a set of assumptions assumptions about what information or parameters are appropriate to include in their analysis and what can be omitted; about the physical and chemical processes that are in operation, and so on. Importantly, the uncertainty associated with these assumptions is generally not transparent.

Wynne (1992) suggests that this only becomes a problem when we build external commitments onto the outcomes of the analysis as if these uncertainties or limitations did not exist. In the case of the above
example, the external commitments were those to farmers about the time before sheep could be sold. Environmental Impact Assessment is another process in which many commitments are built upon scientific predictions, generally without these limitations, or ignorance, being revealed.

A further example of ignorance is the development of chlorofluorocarbons (CFCs) as propellants in spray cans and as refrigerants. These compounds were considered highly suitable for these purposes because they were seen as very stable and apparently not harmful to humans or ecosystems. Scientists did not predict that CFCs would enter into a chain reaction with ozone molecules in the stratosphere destroying this vital filter for ultraviolet radiation. We were ignorant regarding this possibility.

8.2.4 Indeterminacy
Science can define a risk, or uncertainties, only by artificially 'freezing' a surrounding context which may or may not be this way in real-life situations. The resultant knowledge is, therefore, conditional knowledge depending on whether these pre-analytical assumptions might turn out to be valid (Wynne, 1992, p 116).

However, this is indeterminate since we don't know all the factors influencing the causal chains or networks. That is, these networks or chains are open rather than bounded or closed as in cases of technical uncertainty.

Indeterminacies can arise from:

- not knowing whether the type of scientific knowledge and the questions posed by scientists are appropriate and sufficient for the circumstances,
- the social context in which that knowledge is applied through policy commitments,
- the stability of that social context.

For example, in relation to the latter two points, will quality control be maintained in maintenance, operations and procedures associated with risky technologies? Will such control be equal in many different countries and cultures around the world in which these technologies may operate? Our assumptions regarding the risk associated with such situations is conditional on these factors remaining the same.

8.2.5 Can “uncertainty” be easily classified?
Wynne’s (1992) classification of uncertainty is but one of a number of models that have been proposed. For example, in Chapter 5 (see 5.3.4), the role of science in informing decision-making under different types of uncertainty, described as technical, methodological and epistemological, was discussed. The terms risk, uncertainty and indeterminacy, loosely relate to situations in which uncertainty derives respectively from technical, methodological and epistemological questions. It would detract from the key purpose of this chapter to discuss further models here, but a few comments on Wynne's classification are relevant.

It would be a mistake to see Wynne’s four types of “uncertainty” simply as points along a continuum of increasing uncertainty, with risk at one end and indeterminacy at the other. Whilst this may provide a valid illustration of the relationship between risk and uncertainty, it is important to note that both risk and uncertainty are set within a context of ignorance and indeterminacy. Even matters that we think we understand may well provide surprises - remember CFCs!

In addition, the term "risk" is used far more broadly than in the sense described by Wynne (see 8.2.1). Recently there has been much attention given to "ecological risk assessment" and as shown below (see 8.6) this does not involve the level of system understanding suggested by Wynne's (1992) definition of risk.

8.3 What is risk?
Risks to people and the environment are part of life on planet Earth. Some such risks derive from natural
hazards for example, lightning and meteorite strikes, earthquakes and hurricanes. Others result from human constructions and activities dams, hazardous industries, discharge of pollutants and travelling in cars. Whilst we cannot prevent risks from natural events, human actions and decisions may greatly influence their consequences. For example, siting a nuclear facility in an area of high earthquake potential, location of a tailings dam in an area prone to torrential rain and flooding and using routine building methods and materials in a cyclone-prone area, are all high risk choices. In some cases human activity may also increase the scale and frequency of natural hazards. For example models indicate that greenhouse induced climate change will generate severe storms leading to flash flooding in coastal urban centres of northern New South Wales and southern Queensland.

Risk is a term we use loosely in day-to-day conversation but it has a more technical meaning:

- **Risk** refers to a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. In other words:
  - ⇒ how often is a particular potentially harmful event going to occur?
  - ⇒ what are the consequences of this occurrence?

- **Hazard** refers to "a source of potential harm or a situation with a potential to cause loss" (Standards Australia/Standards New Zealand, 1995, p 4). This may involve a situation that could occur during the lifetime of a product, system or plant that has the potential for human injury, damage to property, damage to the environment or economic loss.

For example, the existence of pipes carrying a toxic gas in a chemical plant is a hazard. The combination of the likelihood of pipe failure leading to leakage of the toxic gas and the consequences of this leak, is the risk. Consequence may depend on a range of factors - does the leak occur in the middle of the day when many people are in the vicinity and will be exposed, or does it occur in the middle of the night when the surrounding streets are deserted? Do prevailing winds carry the toxic release to sensitive downwind environments, or across far less sensitive environments?

### 8.4 Dealing with risk in environmental decision-making

As our awareness of the impact of human activities on the environment (including on human well-being) has increased we have sought means to develop a process for rigorous consideration of risks to the environment and humans and a means for using the outcomes of this process to inform environmental decision-making. This process is known as "risk management" and it may be divided into a number of phases as shown in Figure 8.1 and discussed below.

The terminology used here to describe these phases in risk management broadly follows that of the Australian/New Zealand Risk Management Standard (Standards Australia/Standards New Zealand, 1995). However, it is important to note that there is much variation in terminology. This is true not only between different areas of interest (eg financial risk, toxicological risk, environmental risk) but also between countries within the same area of interest. For example, Australians generally use the term risk analysis to describe what is called risk assessment in the United States (see Beer and Ziolkowski, 1996). Because of this difference in usage of terms it has not been possible to rigorously follow the Australian use of risk "analysis" and "assessment" in this chapter.

The following sections examine these processes of risk management in greater detail.
Figure 8.1 Risk management

**Establish the context**  
Why undertake the risk management process and what should it involve?  
- what criteria are risks to be judged against?  
- who are the stakeholders?  
- what is the scope for analysis?  
- what is the management, institutional and strategic context?

**Hazard/risk identification**  
What can go wrong?  
How can adverse situations arise?

**Risk analysis**  
What are the:  
- range & severity of adverse consequences?  
- potential probability & frequency of occurrence?

**Risk assessment**  
How acceptable is the risk?  
- comparison against pro-determined objectives  
- determination of risk treatment priorities

**Risk treatment**  
What options are appropriate for dealing with risk?  
- technologies or other strategies to minimise or eliminate risk  
- regulations/policies to achieve objectives  
- communication
8.4.1 Establishing the context
The initial step is to establish the context for risk management. This involves:
- defining the reasons for the risk management process,
- setting this within the broader management context of the organisation or issue under consideration,
- setting criteria against which identified risks are to be assessed, identifying stakeholders and determining a process for their involvement,
- determining the scope of the hazard and risk identification and analysis.

Following these considerations the system to be analysed is defined and the plan for risk analysis is documented.

8.4.2 Hazard/risk identification
The second phase in the risk management process involves identifying hazards and risks. This is an extremely important component of Environmental Impact Assessment and more broadly, environmental management. It is not a simple task and requires a good knowledge of the workings of the processes being examined together with an ability to think imaginatively and laterally. The "human element" must also be included since this is often a contributing cause to disasters.

Hazards associated with human activities can include (ADB, 1990):
- chemicals toxic to humans, animals or plants,
- materials which are highly flammable or explosive,
- mechanical equipment or plant which may fail and damage people or property, structural failure (e.g., involving a dam or containment vessel), natural disasters that exacerbate hazards associated with technology or developments,
- activities which disturb ecosystems (e.g., those leading to eutrophication; acidification, soil erosion).

Hazards may be broadly grouped as "acute" or "chronic". Consider the following examples concerning human health effects:
- Acute refers to the immediacy and intensity of the effect, not its seriousness. An explosion followed by a fire is an immediate and intense event but depending on the circumstances its effects may not be very serious. The single event of a leak of poisonous methyl isocyanate gas at Bhopal in India in 1984 had an acute effect on people in the vicinity leading to death and disability within a short time period.
- Chronic implies a low level hazard whose effect may be delayed for some time. Noise from machinery may be repeated over years without apparent harm before hearing impairment becomes obvious. Lead from car exhausts will not have an acute effect on humans at the concentration found in Sydney's air, but can build up gradually in children's blood potentially affecting the development of the nervous system.

Hazard identification needs to employ an appropriate framework and "tools" in order to systematically link causes and effects. Matters that must be considered include:
- the nature of the activity (e.g., chemical plant, dam and so on),
- its surrounding environment (ecosystem components),
- the effectiveness of the safeguards and management systems put in place to minimise chance of failure of equipment and processes,
- where to draw the "boundaries" of the system to be examined (that is, what should be included in the analysis and what can be left out).

The "tools" involved in hazard identification will depend on the nature of the activity and the environment in which it is occurring. For example in dealing with chemicals, hazard identification might involve
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determination of a cause-effect relationship between a chemical and human health. Epidemiology, animal toxicology tests, mutagenicity tests and assessment of the molecular structures of the chemical are likely to be employed. Extending this to ecosystem health will require information from a range of complex ecotoxicological tests.

In an industrial plant hazard identification is likely to involve identification of parts of the plant that may fail and result in damaging consequences to humans and/or the environment. It may be based on past experience or theoretical modelling. HAZOP - hazard and operability studies - are useful in identifying hazards associated with complex plant or equipment. These are structured sessions carried out by a group of people who possess a range of expertise and experience in relation to the system under investigation. A series of guide words or prompts are used as the components of the system are studied sequentially.

Both past experience and use of imaginative "what if" scenarios (to help identify possible problems or combinations of events not previously experienced) are required in hazard identification. For example, despite very detailed analyses on hazards associated with nuclear power plants, hazard identification failed to include the possibility of fire resulting from a technician using a candle to seek out an electrical fault! Yet a fire arising from this cause led to a major hazard event at the Browns Ferry nuclear plant in Alabama in the United States in 1975 (Cutter, 1993).

Establishing boundaries for assessment

A most important early phase of hazard and risk identification is setting the boundaries for consideration. This can profoundly influence the outcome of the exercise and hence should involve appropriate "experts" (see Chapter 5) and a wide range of stakeholders in an early "scoping" exercise (see Chapters 6 and 7 for discussion of scoping).

Issues of relevance in setting boundaries include (ADB, 1990):

- Should routine releases of a pollutant from an activity be considered or accidental releases, or both?
- Where should the demographic boundaries be set? Just those people occupation-ally exposed to a hazard? Potential exposure of the general public?
- Is there a need to identify potentially vulnerable groups such as children, the elderly, the chronically ill.
- Which part/s of the "flow cycle" should be included? For example, the siting of a chemical plant may have effects beyond the presence of the plant. These may include the transport routes of raw materials and wastes and the impacts of secondary industries necessary for its operation.
- Where should geographic boundaries be set? These may extend way beyond the immediate boundaries of a project or facility, in relation to supply of raw materials, use of products and disposal of wastes. In addition some pollutants or other impacts may pose particular hazards in sensitive or especially important localities such as nature conservation areas.
- Which phases of the project should be included? For example, construction, operation and disestablishment of a facility. What is the time span of concern? For some impacts of a proposal there may be a considerable delay between an action and its effect.
- What human health effects should be measured? Just mortality rates, or should chronic low level effects, effects transferred across generations through genetic damage, and so on, also be considered?
- What ecosystem parameters should be measured? Due to the complexity of ecosystems this is perhaps the most open-ended of issues to be considered in establishing boundaries of concern (see 8.6).

Hazard and risk identification - scope for subjectivity

Hazard and risk identification cannot be a strictly objective exercise since scope for subjectivity arises from at least two areas:

1. The quality and comprehensiveness of hazard/risk identification is dependent on the skills,
knowledge and imagination of those involved in the task - different teams are unlikely to reach exactly the same conclusions.

2. Information about the range of possible hazard types listed above is likely to be far from complete. Uncertainty may derive from (ADB, 1990):
   - Lack of understanding of important cause-effect relationships, lack of scientific theory to explain these (e.g., effects of chemicals on humans and other organisms, concentration of chemicals in food chains).
   - Models that do not correspond to reality because they are simplifications and/or because we lack understanding of processes (e.g., models of the flow of chemicals through an ecosystem and the impacts of those chemicals on ecosystem components).
   - Lack of evidence on where the boundaries should be set for assessment of hazards (e.g., How many factors may influence the hazard? What type of consequences may occur? Over what area and time span?).
   - Poor quality of available data because of sampling or measurement inadequacies, lack of replication, lack of time series data (see Chapter 5).
   - Data gaps, such as no measurements on baseline environmental conditions at a project site.
   - Toxicological data that have been extrapolated from animals to humans and from high dose short-term experiments to low dose longer term situations.
   - Natural variation in environmental parameters due to weather, climate change.
   - Necessary assumptions on which estimates are based and the sensitivity of the resulting estimates to changes in assumptions.
   - Novelty of the project in terms of technology, chemicals, or siting - lack of experience or historical data.

_Dealing with subjectivity in hazard/risk identification_

In relation to (1) above, use of a team which includes a wide range of appropriate technical expertise and experience together with people having understanding of local conditions and management structures and processes, will enhance the quality and comprehensiveness of the hazard/risk identification. Local and traditional or indigenous knowledge (see Chapter 5) may make an important contribution, and therefore community input should be considered. Whilst the exercise will still be subjective, the chance of important hazards being "missed" should be reduced if an appropriately diverse team is used.

In relation to (2) above, uncertainty may be reduced by collecting more and/or better quality data and by drawing on other sources of knowledge (see Chapter 5), but it cannot be entirely eliminated. Apart from the potential for ignorance and indeterminacies (as discussed above), in the time frames usually available for environmental decision-making it would not be possible, for example, to collect appropriate time series data. Hence, simplification and assumptions will need to be made and this will necessarily involve subjectivity.

As stressed frequently through this book, failure to acknowledge subjectivity, and therefore that other assessments may be equally valid, is a major source of conflict in environmental decision-making. This is clearly an important issue in relation to hazard/risk identification and the steps outlined above may go some way to addressing this.

8.4.3 Risk analysis

Following hazard/risk identification an estimate is made of the level of risk. As shown in Figure 8.2 this involves:
- analysis of probability/frequency of occurrence of a defined hazard,
- analysis of the magnitude of the consequences.

Risk analysis may produce quantitative and/or qualitative results. Both past experience (historical records) and modelling of the systems concerned are used. Qualitative analysis may be used as a first step in indicating which risks are minor and "acceptable" and which are more serious and deserve
detailed quantitative analysis (see Figure 8.3). Risk analysis provides information for the later processes of risk assessment and risk treatment and helps set priorities for action in managing various risks.
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Figure 8.3
A format for qualitative risk analysis

<table>
<thead>
<tr>
<th>Industrial and Community Facilities</th>
<th>Negligible</th>
<th>Marginal</th>
<th>Critical</th>
<th>Catastrophic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruption: &lt;1 day for repair</td>
<td></td>
<td>A few days required for repair of facilities</td>
<td>Loss of facilities for &gt;1 month</td>
<td>Widespread destruction of property; total loss of some facilities</td>
</tr>
<tr>
<td>Monetary: &lt;$100,000 damage</td>
<td>&lt;$1 million damage</td>
<td>$1 million damage</td>
<td>&gt;$10 million damage to property</td>
<td></td>
</tr>
<tr>
<td>Human Health and Safety: Minor illness or injury; ≤ 12 mo. lost work time</td>
<td>≥ 12 mo. lost work time from illness or injury</td>
<td>Death or severe illness or injury to ≥1 person(s)</td>
<td>Death to &gt;10 persons; severe injury/illness to &gt;100</td>
<td></td>
</tr>
<tr>
<td>Pollution Damage to Ecosystem: Slight, quickly reversible damage to few species/ecosystem parts</td>
<td>Temp., reversable damage. Reversion to earlier successional stage</td>
<td>Loss of key-stone species and widespread habitat destruction</td>
<td>Complete, irreversible and immediate destruction of all life</td>
<td></td>
</tr>
</tbody>
</table>

(Source: ADB, 1990)

This format provides a means to combine frequency of occurrence and extent of consequences to give a qualitative estimate of whether a risk is likely to be judged “acceptable”, “unacceptable” or requiring risk “treatment” to reduce the risk to an acceptable level. This also helps decisions on which risks require further, more quantitative, analysis.
8.4.4 Risk assessment
The next phase of the risk management process involves assessing the risk. Risk assessment is concerned with the significance and "acceptability" of risk probabilities and consequences, not only in relation to the risk generators but also those likely to be affected. It is primarily concerned with social rather than scientific assessment and involves consideration of social, political, financial, legal and cultural factors.

The purpose of risk assessment is to provide a structured means of comparing risks against other risks to which the public and the environment are exposed and with predetermined criteria for desired environmental and social outcomes, so as to assist decision-making. The principles of Ecologically Sustainable Development (see Chapter 2), including the precautionary principle (see 8.10), now provide an important pan of the framework for risk assessment.

The key task of risk assessment is to find the level of risk which is "acceptable" to society in the circumstances under decision. The "perceptions" of different risks held by members of the public (see 8.7) may be an important consideration in risk assessment.

8.4.5 Risk treatment
Having assessed the risks it is necessary to determine how they can be "appropriately" managed. The aim of risk treatment should be to reduce or eliminate the risk to an "acceptable" level through control measures, alternative technologies, separation of target organisms from exposure, or substitution of products. These matters all have to be weighed up within the socio-political context and a cost-benefit framework (see Chapter 7) to arrive at an appropriate treatment of risk to meet the desired outcomes identified in the risk assessment process.

Finally, the chosen strategy has to be implemented to achieve the desired outcomes. An important pan of risk treatment is communication in order to inform affected parties of the risks involved and treatment strategies adopted. Of course, it should be evident from discussion in earlier chapters that such communication will not be restricted to this final phase. Public participation is likely to play an important role in risk assessment and also in the earlier phases of the risk management process (see Chapter 6).

8.5 The uses of risk analysis and assessment
The uses of risk identification, analysis and assessment in relation to the environment have broadened considerably in recent years. Previously, emphasis was on the hazards or sources of the risk and on technical matters such as failure of machinery and industrial plants based on historical data. Consequences dealt primarily with acute effects involving human injury and death and property damage. Quantitative Risk Assessment (QRA) became an important tool for this task.

More recently the scope has broadened to give increasing attention to a wider range of potential consequences of hazardous events and to use QRA as a tool for land use planning and decision-making (Department of Planning, 1994). The consequences considered now tend to include damage to flora and fauna of ecosystems (ecological risk assessment) in addition to humans and property (see 8.6). There has also been increasing emphasis on chronic hazards.

Risk assessment has now become an important pan of overall environmental planning and management and is incorporated into a wide range of government and corporate activities to inform decision-making. Sections 8.5.1 to 8.5.4 provide examples of some of the uses of risk assessment.

8.5.1 Setting standards
Quantitative risk assessment may be used to set standards for environmental management. This may involve the adverse effects of pollutants in the environment on human health. For example, an analysis may be made of the risk to human health from lead in urban air. Medical authorities will consider the risks
to human health from a range of ambient air lead levels and make recommendations to government on a
level which should not be exceeded in particular situations. Government, in turn will consider the sources
of air-borne lead and may set in place standards aimed at reducing the emissions; for example,
standards regarding the amount of lead in petrol.

Standards may also be set in relation to risks to ecosystems. For example the risks of algal blooms
associated with release of phosphorus and nitrogen compounds to waterways.

8.5.2 Predicting impacts
Risk analysis and assessment may be used to predict impacts for Environmental Impact Assessment.
For example, in New South Wales since the mid-1980s risk assessment has been a formal part of
development approval procedures involving projects of a potentially hazardous nature (Department of
Planning, 1994, p I) (see Box 8.1).

<table>
<thead>
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<th>BOX 8.1</th>
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<td>Hazard analysis in EIA</td>
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In New South Wales the Environmental Planning and Assessment Act 1979 (EP and A Act) which governs planning
and development control, requires preparation of an Environmental Impact Statement (EIS) for particular
developments (see Chapter 7). For such developments that are also potentially hazardous, a "preliminary hazard
analysis" is required. If an EIS is not required but the development is considered potentially hazardous, a
preliminary hazard analysis is required under SEPP 33 (State Environmental Planning Policy number 33). Requirements for
considerations to be addressed in the preliminary hazard analysis are laid out in a 1994 regulation to the EP and A Act.

The hazard analysis should enable the decision-making authority to assess whether the proposed development will
operate without unacceptable risk impacts. Such assessment will include organisational matters concerned with
running the industrial site, as well as the technical details of safety measures in design and construction.

8.5.3 Strategic planning
Risk assessment is also used to compare risks in order to set priorities for environmental management.
Risk assessment for strategic planning purposes can take place at a number of levels. Government may
compare environmental risks in order to decide on priorities for use of scarce resources available for
environmental management. For example, should more attention be given to identification and
remediation of contaminated sites or to prevention of eutrophication of river systems caused by
agricultural run-off and discharge from sewerage systems? Use of risk assessment in this way is called
"comparative risk assessment". It involves community consultation to identify issues and quantify
concerns (Beer and Ziolkowski, 1995).

In considering possible risk treatment measures, governments not only take account of scientific and
technical solutions for lessening risks, but equally important may be work on improving management
systems so that the safety devices in place perform to expectation and the chance of accidents from
human error is minimised. Similarly, it may be important to use resources to educate the community
about risks and how to minimise them. The use of risk assessment by governments for these strategic
purposes is increasing rapidly at present.

Government may also use risk analysis and assessment for cumulative Environmental impact
Assessment (see 7.2.5) and hence to help in planning siting of a number of industries within a region.
Corporations likewise use risk analysis and assessment to help assess possible future financial liabilities
arising from their activities and products. These may include processes which lead to pollution, land
degradation or accidents (such as explosions), or products which harm human or environmental health
(eg hazardous chemicals). Assessments may be used to assist in designing ways to minimise identified
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risks or even to set a new direction or new priorities for the corporation's activities. Corporations are increasingly required to estimate these potential liabilities in their annual accounts.

8.5.4 Refining organisational Environmental Management Systems

Corporations and other organisations may use risk analysis and assessment to refine their Environmental Management Systems and policies. Risk analysis procedures can help identify "weak points" in the management system that require special attention in order to prevent an environmental risk event such as a chronic or acute pollution episode. Also, as new scientific information becomes available regarding the potential environmental impacts posed by an organisation's activities, comparative risk assessment across these activities can help identify the most efficacious and cost-effective changes in management arrangements to prevent environmental harm.

8.6 Environmental and ecological risk assessment

In an area as complex as the environment, there is, nowadays, a view that it is impossible to provide a truly objective measure of risk because, for example, there is subjective judgement involved in choosing the data set of historical statistics to be used to determine the objective risk. (Beer and Ziolkowski, 1996, p 7)

Environmental risk assessment is becoming increasingly important in planning and management by governments and corporations (see Box 8.2). However, it is still in the early stages of development. Much work is required to prove its worth in environmental decision-making and both scientists and engineers have important roles to play in this regard.

Environmental risk assessment refers to risks to "human health and welfare (including ecosystem health) that arise in, or are transmitted by, the natural environment" (ADB, 1990, p v). Ecological risk assessment is that part of environmental risk assessment which deals with risks to the non-human living components of ecosystems.8

The complexity of ecosystems, involving many organisms and multiple interactions between these and their inorganic surroundings, makes ecological risk assessment an extremely difficult task. Given this complexity, the best we can do at present is to use techniques which greatly simplify the "real world".

Such techniques include (ADB, 1990, p 64):

- Use of "indicator species" to provide information on ecological impacts. For example, a prawn species may be exposed under laboratory conditions to varying concentrations of a chemical which is a likely pollutant from a proposed marine development. On the basis of the results, assumptions are made about the harmful effects of the chemical on other species and even on the whole ecosystem in the vicinity of the development.

- Data on chemicals whose effects are known on at least some species may be used to infer the effects of similar, but untested chemicals.

- "Biomarkers" may be identified through studies in the field. For example thinning of eggshells in birds is an indication of pollution by certain pesticides. Certain deformities in oysters indicates pollution from tri-butyl-tin used as an anti-foulant on boats.

- "Microcosms" and "mesocosms" are built in laboratories in an attempt to mimic natural ecosystems. These involve samples from the environment placed in laboratory containers or the use of components from the environment to build replicas. These replicas can then be evaluated to determine their ecological impacts.

8 Note, however that these terms are still to be clearly defined, Some rise them synonymously others make the distinction drawn here.
manipulated by physical, chemical or biological agents to explore impacts, and the results extrapolated to the natural environment.

Field studies are carried out in parts of actual ecosystems. Again the environment may be manipulated to explore the effects of agents. However, the "natural" changes occurring in the environment may make interpretation of the results unclear. All these techniques are simplifications of real-world situations and results derived from them must be regarded as both subjective and uncertain. Subjectivity is involved when decisions are taken as to which species to use as indicator species, which components to include in mesocosms and so on (see 8.4.1 and 8.4.2).

**BOX 8.2**

**Ecological risk assessment by Sydney Water**

The *Water Board (Corporatisation) Act* 1994 (NSW) set up a publicly owned Corporation known as "Sydney Water" in place of the Sydney Water Board. The Act contains a number of environmental requirements including the adoption by Sydney Water of targets to reduce those chemicals in discharges from sewage treatment plants (STPs) which are identified as being of concern because of their potential to cause human health or ecological effects. The substances *potentially* of concern (more than 100) are listed in Schedule 10 to the Act.

The Act requires Sydney Water to undertake ecological risk assessments in relation to Schedule 10 substances discharged into waters from each of its sewage treatment plants. The methodology for the assessments must be approved by the NSW Environment Protection Authority (EPA). The risk assessments are displayed for public comment and the EPA sets the targets based on these ecological risk assessments together with public comment on these and other relevant factors. Using this process, targets for Sydney Water's *ocean* STPs were set in June 1996 and these are being followed by targets for the Hawkesbury-Nepean and George's River STPs.

Sydney Water uses a two stage process for the ecological risk assessment. *Screening level risk assessment (SLRA)* identifies which of the Schedule 10 chemicals might be causing problems, and where. A conservative approach is used to ensure that chemicals are not excluded from consideration too early in the assessment. The chemicals identified in the SLRA are then subjected to more *detailed risk assessment*.

Scientists use a range of sampling and statistical methods to determine:

- what chemicals are in the waterways and in what quantities and concentrations,
- whether they derive from STPs or other sources (or both),
- the behaviour (chemical and physical) of chemicals in the water, in sediments and in *biota*,
- what biota are present in the waterways and the diets and feeding behaviour of the fauna present,
- the pathways by which the chemicals enter human tissues and those of other animals and plants,
- any *synergistic* effects.

Information about the effects of chemicals on humans and other biota is sourced from the scientific literature, laboratory and field testing and statistical data. Not only mortality, but also effects on habitats of biota and on their growth and ability to reproduce, is also considered (ie both acute and chronic effects). Since it is not possible to test *all* biota, species for testing and assessment are selected on the basis of a range of criteria. These include the assumed importance of their role in the ecosystem and whether they may be considered particularly sensitive because of feeding behaviour or some other behavioural or physiological reason.

For human effects, assessments involve estimates of exposure to chemicals through contact with the water while swimming or wading (including accidental swallowing) and eating fish which live in the
waters. The likely degree and frequency of exposure is estimated (how much fish is eaten from the waters in question? how long would a person's skin be exposed during swimming or wading?), On the basis of these exposure studies risks are estimated. Non-cancer risks involve comparison with "safe" levels as judged from the scientific literature. For cancer-causing substances the risk is described as the increased likelihood of developing cancer during a person's lifetime, again using previous reports in the scientific literature. (SOURCE: Sydney Water, 1996b)

8.7 Risk perception and defining "acceptable" risk

The task of decision-makers in defining "acceptable" risk, as part of the risk assessment process (see 8.4.4), is complicated because people may not only hold different views about the "acceptability" of a particular risk, but also perceive "different risks differently". Hence risk perception is a critical element of risk assessment and treatment which is ignored at the decision-maker's peril!

8.7.1 Risk perception

Risk perception involves people's beliefs, attitudes, judgements and feelings, as well as the wider social or cultural values and dispositions that people adopt towards hazards and their benefits.

(Royal Society, 1992, p 897)

Some of us ride motor bikes, swim in a big surf with strong undertow, fly gliders or rock climb. Others may consider all these too risky but are happy to continue with their occupation as a coal miner or as a scientific researcher working on highly infectious diseases, or even just to sit in front of the television smoking cigarettes. Clearly people differ in their willingness to "accept" particular risks!

Undertake the exercise in Box 8.3, before reading further. This should provide a useful illustration of differences in risk perception.

BOX 8.3
Differences in risk perception?

Consider the risks associated with the activities in the list below and re-arrange them in order From the least (number 1) to the most (number 9) risky. Notate each risk as acceptable (A), unacceptable (U) or conditional (C) to you, where conditional means that your judgment may be subject to negotiation on presently unspecified benefits. Also note the factors which influenced your decision in each case.

List of activities imposing risks on individuals living in New South Wales:

• Swimming
• Travelling by train
• Being struck by lightning
• Playing rugby football
• An accident at home
• Smoking 20 cigarettes a day
• Living within 1 km of a chemical plant manufacturing pesticides ·
• Travelling by motor vehicle
• Poisoning from a venomous plant or animal.

Now turn to Table 8.1, located at the end of this chapter, and compare your ranking with that taken from statistical records and "expert" assessments. Also compare your ranking with that of your colleagues and especially explore similarities and differences in the factors which influenced your decisions.
If your group is typical of most other groups surveyed in this way, this exercise will have revealed that there is often a poor match between the risks that kill people and the risks that concern people.

Peter Sandman (1992), an American researcher on risk communication says that in relation to risks to people’s lives, the correlation between risks that kill people and risks that people demonstrate concern over in the United States, is only 0.2. This poor correlation indicates that people’s concerns do not match reality. He also says that a similar disparity is seen in comparing people’s concerns regarding ecosystems and the demonstrated risks to ecosystems. The problem with this poor correlation is that governments’ political response is generally to spend money addressing the matters that concern people, with the result that money may be directed away from far more needy (ie more at risk) environmental issues.

Sandman (1992) considers why there should be this disparity and concludes that "the meaning of risk to the risk assessor and to the public is different; the public defines risk more broadly" than the technical assessor (see Box 8.4).

Apart from highlighting the poor correlation between "actual" and "perceived" risks, the exercise just performed (see Box 8.3) may also have revealed that many factors influence risk perception (see Box 8.5).

**BOX 8.4**

**Nuclear fuels reprocessing: risk perception**

Brian Wynne, a United Kingdom sociologist, is a well-known researcher on risk and uncertainty. He analysed the United Kingdom inquiry into a proposal for a nuclear fuels reprocessing plant at Windscale (now Sellafield). He noted considerable differences in the frameworks within which the "experts" and the public assessed the risk associated with the development. In particular, he found that the "experts" made certain assumptions about the social and institutional processes associated with risk management (for example, that they are trustworthy, impartial and open-minded) and reduced the risk analysis primarily to technical matters. In contrast, the groups objecting to the proposal granted less credibility to, and placed far less trust in, the risk management institutions and processes. For this group, risk analysis could not be reduced solely to technical matters; rather the importance of the associated social factors in risk management was stressed.

(Source: Royal Society, 1992)

During the 1980s, perceived risk came to be seen as equally important as "objective" risk analysis/assessment in risk management. Consequently, much research has been directed towards understanding the nature of perceived risk. The following are some of the main conclusions (Royal Society, 1992):

- People appear to evaluate characteristics of hazards and risk rather than a single abstract concept such as risk (see Box 8.5).
- Perception of risk is influenced by many factors.
- A particular hazard may mean different things to different people depending in part on their value systems (see below and Chapter 4).
- A particular hazard may mean different things in different contexts.
- Perception and acceptability of risk may involve judgments not just of physical characteristics and consequences but also of social and organisational aspects. These may include the credibility and trustworthiness of those imposing or managing the risk-companies, their personnel and government regulatory institutions.
- Risk perception cannot be reduced simply to the product of probabilities and consequences.
derived from a mathematical model of risk, "because this imposes unduly restrictive assumptions about what is an essentially human and social phenomenon" (Royal Society, 1992, p 89).

BOX 8.5
Attributes of hazards which influence risk perception and acceptance

Risk assumed voluntarily- risk borne involuntarily
We are far more likely to accept risks or to perceive a lower level of risk if we are free to choose whether or not we are exposed to the risk. Voluntary risks may include hang-gliding, riding a motor bike, smoking cigarettes - situations in which we are free to choose involvement or non-involvement in the activity. Risks borne involuntarily are those imposed on us by another party whether that be government action or societal choice. These may include siting of a waste incinerator in our neighbourhood or fluoridation of the municipal water supply.

Natural - industrial
Sandman cites an example from New Jersey in the United States where some houses in north New Jersey have radon in their basements deriving from "natural" sources, sufficient to increase the rate of lung cancer by 1 to 3 per cent. It is apparently difficult to get the owners to spend $20 on a charcoal canister to test the radon levels. In contrast houses in New Jersey which have been built on slag containing radium waste from luminescent watch face manufacture are the target of a Superfund project which will remove the contaminated soil. This has occurred as a result of mass demonstration even though the radiation deriving from the slag is roughly equal to that from the "natural" sources in granite which are contaminating the basements described above. People apparently realise this but are not prepared to have the "industrial" risk added to the "natural".

Familiar - exotic
Things with which we become familiar and live with day-to-day tend not to be seen as risky. The unflued gas heater in a class-room, the sprayed-on concrete ceiling containing asbestos, the solvent fumes in a factory. However, once attention is drawn to the risk by officers arriving in special protective clothing and/or with special measuring equipment, or plans for a clean-up are announced, the perception of risk is likely to increase.

Not dreaded-dread hazard
Some risks seem to attract a high level of concern and publicity and are regarded as "dreaded" hazards. Escape of radiation from nuclear power and weapons, biological warfare and terrorism would all qualify as dread risks.

Knowable - unknowable
Sandman suggests that the public are more concerned by the unknown but likely low risk issue than by the lower uncertainty but demonstrated higher risk issue. For example there is likely to be greater risk perceived in relation to high temperature incineration of hazardous wastes for which risks are suspected but unknown, than say coal mining, for which the risk has been clearly demonstrated.

No alternatives - many alternatives
If no economically practical alternatives are available for particular technologies people are generally more willing to accept risks than if practical alternatives are available. We may be willing to spray our food crops with pesticides which pose some risk to humans if it is the only practical way to ensure the crop can be harvested. We have been fairly successful in reaching agreement to phase out CFCs as a propellant in spray cans in those cases where alternatives were available. We have not been prepared, however, to terminate use of fossil fuels as an energy source.
Uncertainty, risk and the precautionary principle

Chronic – catastrophic
We are more concerned when a large number of people are killed in a sudden "catastrophic" event such as a plane crash or bridge collapse than when an equally large number are killed one-by-one over a longer time period, such as by cigarette smoking or in car accidents. Cigarettes kill 400,000 people per annum in the United States; this number of fatalities would be regarded as totally unacceptable if they occurred in one event.

(Source: Sandman, 1992; Lowrance, 1976)

Research on risk perception has demonstrated even further levels of complexity:
- The hazard characteristics in Box 8.5 do not necessarily operate independently of one another, but may be interrelated. Three broad groupings of characteristics of hazards have been identified as "linked":
  1. A group of characteristics including uncontrollability, dread, involuntariness of exposure and unfair distribution of risk, collectively referred to as "dread risk" (nuclear weapons, nerve gas and crime rate highly here and use of bicycles and home appliances rate low rankings).
  2. A grouping called "unknown risk" including characteristics such as delayed effect, extent of familiarity, knowability (genetic engineering rates high and use of motor vehicles and mountain climbing rate low).
  3. The number of people exposed.

Of these three groupings the "dread" risk appears to lead to a higher perceived risk and a greater desire for regulatory control to reduce the risk to an "acceptable" level.

There are differences not only between individuals in how the qualitative characteristics of hazards influence risk perception, but also between groups in society and between different cultures. Individuals perceive risk not only through their "paradigm filter" (see 4.3.1), but also through their affiliation with a group or culture. Of course individuals may at any one time identify with more than one group. For example, they may identify with an age group, a gender group and a grouping based on "world-view" (see Chapter 4). All of these have been shown to influence risk perception. With regard to the influence of world-views, Buss et al (1986) (cited in Royal Society, 1992, p 111) found that those who emphasise the importance of economic growth and a high-technology society (the "technocentrics" or "dry greens") tend to place more importance on the benefits of technology than on the associated risks, and to endorse "rationality" in decision-making using quantitative techniques and primarily relying on advice from "experts". In contrast, "ecocentrics" emphasise the importance of the environmental impacts associated with a high growth society, the social impacts of such growth and the equity issues in terms of costs and benefits related to risks. They also favour an important role for public participation in decision-making on risk issues (see Chapter 4).

8.7.2 "Acceptable" risk
It is clear from this discussion that even if risk experts could agree on a ranking of risks and a demarcation of "acceptable" from "unacceptable" risk (see 8.4.4) society does not generally necessarily view "equal risks equally". As well as differing perceptions of risks and associated benefits, the "fairness" associated with risks and benefits is an important element in risk acceptance. Who bears the risk? Who obtains most of the benefit? How is this share of risk and benefit? Another important influence on "acceptability" is trust in the processes and institutional arrangements for management of risk (see 8.8 and Box 8.6).

Hence what is an acceptable risk to one individual or group or to one society may be quite unacceptable to another individual or group or to another society. It follows that risk assessment requires negotiation between the stakeholders to define an "acceptable" level of risk for each "risk situation".

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8.8 Subjectivity, objectivity and risk analysis

Risk analysis, and especially quantitative risk analysis is often portrayed as providing a rigorous and "objective" analysis of the relative risks facing humans and the environment and through this assisting in minimising those risks in a cost-efficient way. There is however growing recognition that risk analysis is far from objective and, as shown above, that subjectivity is present from the first stage of hazard/risk identification through to the much more obvious subjectivity inherent in risk assessment.

This inevitable subjectivity does not mean that risk analysis fails to provide a useful input for environmental decision-making and management. Rather, it is generally agreed that risk analysis is invaluable in providing a structured process of thinking through causes and effects, in assisting identification of priorities and in designing solutions to minimise risks to humans and the environment.

Nevertheless, it is important that uncertainty, assumptions and hence subjectivity are clearly acknowledged in reporting on risk assessments. Those weighing up costs and benefits in making the final decision need to know how much confidence to have in the estimates. The limitations of the methods used and the data available should be shown. Assumptions that have been made, the reasons for them and the sensitivity of the analysis to these assumptions should also be clear (that is, how different are the results using other plausible assumptions). As well, any factors considered, but regarded as negligible or irrelevant and hence deliberately left out of the analysis, should be shown (Cross, 1996).

Why is transparency important?

- the confidence that can be placed in the analysis is an important consideration in decision-making,
- different analysts may have very different views on the assumptions made,
- people hold very different views on how uncertainty (regarding data and assumptions) should be treated in decision-making.

These three points are potential sources of disagreement over the risk analysis. Failure to acknowledge them is likely to lead to unproductive dispute over the apparent “facts” - a key factor in many environmental "battles". Acknowledgment allows the debate to start at a more productive level - How should the inadequacies of information be treated? What process can we use to reach a fair decision?

Also, trust in the analysts and decision-makers is likely to be higher if the process is seen as transparent. Otherwise, people may be led to wonder - what are they trying to hide? Trust is likely to be enhanced also by having a representative range of stakeholders and "experts" provide input to decisions on the assumptions made in risk identification and analysis. The next section considers who should be involved.

8.9 Who should be involved in risk assessment?

8.9.1 Hazard/risk identification and risk analysis

The key personnel involved in these stages will be people with expertise in risk analysis (risk assessors), plus those with relevant expertise in the technologies, plant or equipment involved in the potential hazard (engineers, scientists and technicians), as well as those with expertise concerning the "targets" for the hazards - people and ecosystems (ecologists, other biologists, toxicologists, medical scientists, sociologists). It will be most important that the range of "experts" is appropriately broad so that key factors are not left out of consideration. There may also be a strong case for involving people with local and traditional or indigenous knowledge. As we have seen in Chapter 5 such knowledge can bring an alternative perspective which may span a long period of time and thus may make an important contribution where time series data from scientific sources are lacking. It may also provide valuable information on local conditions whether these concern the ecology of the area or the organisational structures and processes which influence the reliability of safety systems.

The key point is that in situations where subjectivity is inherent, "scoping" involving inputs from a broad
range of knowledge bases and viewpoints, will help to ensure that all relevant factors are considered.

**8.9.2 Risk assessment and risk treatment - the importance of risk communication**

As we have seen these are the stages at which acceptability of risks is considered and various options for reducing and treating risks are compared within their social context. Key questions are: What options are available? For each option what are the risks, the costs and the benefits? How are these risks, costs and benefits distributed in society? (ADB, 1990).

Whilst these questions must be well informed by science, technology and economics, ultimately they are social questions for which people's perceptions and preferences are all-important. Hence, appropriate and effective public participation involving all stakeholders is critical (see 6.7.2). For this to occur technical information regarding the risks under comparison and the treatment options must be in a form that is readily understood by the lay public. Data gaps, the confidence to be placed in data and the uncertainties should be given prominence in the information provided, it is also important that various options are compared as this can have an important influence on people's perceptions of the risks involved (ADB, 1990).

In other words good risk communication is vital and scientists and engineers (as well as other technical professionals and social scientists) will play a key role in this process through provision of information. As well as communicating risk to the community, scientists and engineers must also distribute information and ideas amongst themselves. Too often, decisions are restricted to specific disciplines in isolation from the broader context. It is vital that multidisciplinary approaches are adopted so that ideas are shared and all possible outcomes or strategies are considered.

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**BOX 8.6**

The importance of effective risk communication?

Sharon Beder and Michael Shortland (1992) used the 1990 attempt of the Australian Government to site a hazardous waste incinerator in rural New South Wales, as an example to explore risk communication. They describe government officials and industry experts, in seeking to reassure the public and gain community acceptance for the proposed incinerator, as using an "idealistic model" of technology. In this model, incinerator technology is depicted as predictable and controllable. The social institutions and structures within which the technology must operate were left out of their risk estimates because they were not seen as relevant. In contrast, the opponents of the incinerator used a "worst case model", representing incinerator technology as unreliable, uncertain and uncontrollable.

Seven years later, the high temperature incinerator has not been constructed in Australia. Poor risk communication on the part of government in its attempt to locate the incinerator is seen as a prime reason for its non-acceptance by the public. Beder and Shortland (1992) argued that government saw successful risk communication regarding the incinerator as consisting of correcting "the public's 'false' view of risk" bringing it "more in line with the 'correct' view of the risk experts" (p 140). However, they claim that this communication strategy was flawed because, among other reasons (p 155):

1. The portrayal of ideal technology working within perfect social systems was not credible
2. The effort at reassurance came across as salesmanship....
3. The failure to consult destroyed faith that the authorities were acting in the community’s best interests.

Hence, "good" risk communication requires exchange of information and views between decision-makers and the public and an emphasis on acknowledging uncertainties, leading to raising of the level of understanding of all concerned, and a building of trust.

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Beyond provision of information for comparison of options, the process by which decisions are made must not only be fair to all, but be seen to be fair. Special provisions may need to be made to encourage
participation by people or groups that are disadvantaged in some way. As discussed in Chapter 6, education, language barriers, finances, family responsibilities and broad experience in decision-making processes, all influence people’s ability to participate meaningfully.

At the end of this process it is important to remember that it is to be expected that people will have differing perceptions of the same risk. As we have seen this is quite consistent with differing rationalities, rather than evidence of rationality by some and irrationality by others!

8.10 The precautionary principle

We have seen that there may be considerable uncertainty regarding likely outcomes in risk situations involving impacts on the complex ecosystems which make up the "natural environment". How do we deal with these situations in decision-making?

Typically, past practice has been to wait for clear evidence that environmental harm has, or will, result from an activity before we cease the activity or put in place actions to protect the environment. Indeed, we have often used lack of proof of harmful effects as a reason for not taking protective measures. However, there are now many examples of where this lack of "precautionary" action has resulted in damage to the environment which has often been serious and in some cases irreversible. For example, species have become extinct, soil has been degraded and contaminated, and the health of humans and other species has been damaged.

The precautionary principle, has emerged as one of the principles of Ecologically Sustainable Development (see Chapter 2), to provide guidance in these situations of scientific uncertainty. This principle requires that we take precautionary action to protect the environment in advance of conclusive scientific evidence that some new or continuing human activity may cause harm. More formally it is defined as follows:

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, public and private 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.

(Intergovernmental Agreement on the Environment, May 1992, p 13)

BOX 8.7
Examples of situations requiring application of the precautionary principle

Pesticides
Within Australia numerous groups have lobbied for many years against the widespread use of a range of pesticides in agriculture and property protection, on the grounds that these were harming the health of humans and other species. Until relatively recently, the onus has been on the complainants to demonstrate direct cause-effect links. Of course this is very difficult when dealing with organisms which are part of a complex web of relationships within an ecosystem and which are exposed to many substances. It is especially difficult when the effects may be delayed, as for example with human carcinogens where there may be 30 years or more between exposure to the carcinogenic substance and manifestation of the cancerous effect. Today we need to feel confident that there will be no harmful long-term effects, before allowing use of such substances, rather than the other way around. As a result a number of pesticides in use for many years for activities such as termite protection in buildings, have been banned for this use.
**Acid rain**
For many years Scandinavian countries maintained that sulphur dioxide emission from British power plants and industry was the cause of acidification of Scandinavian lakes. The British used lack of direct cause-effect evidence as a reason for not taking costly action to reduce these acid emissions. Under a precautionary approach, the shifting of the onus of proof would have put pressure on the British to demonstrate that their emissions were not a primary cause of the acidification of the Scandinavian lakes.

**Asbestos**
It is now well accepted that asbestos causes the potentially fatal diseases of mesothelioma, lung cancer and asbestosis. The time between exposure and effect is delayed in some cases by up to 30 years or more, making cause-effect links difficult to prove conclusively. There were however, clear signs from the 1930s of the harmful effects of asbestos and a North American insurance company back in 1917 had the commercial "wisdom" not to insure asbestos workers. Nevertheless, it took until the early 1980s before asbestos was banned for most uses in Australia. Authorities waited for strong epidemiological evidence before responding, rather than taking precautionary action following the much earlier, suspicious but not conclusive, evidence available as early as the 1930s. A consequence of the lack of precautionary action is that many people have died from asbestos-related disease, there have been large claims against corporations involved with asbestos mining and manufacture, and Australia has the highest rate of mesothelioma in the world.

**The greenhouse effect**
The enhanced greenhouse effect is perhaps the best-known current example of a situation where we have made at least an "in principle" decision that we should take action to reduce emissions of potentially harmful agents (greenhouse gases), even though the extent of effects at particular sites remains uncertain.

(SOURCE: Deville and Harding, 1997)

The precautionary principle goes some way to shifting the “onus of proof” in environmental decision-making from those who claim that environmental harm may occur from some human activity to those whose actions may cause change. Those causing the impact need to provide a convincing argument that their actions will not have serious or irreversible impacts on the environment which exceed long-term benefits (Deville and Harding, 1997).

The precautionary principle is relevant to the professional practice of scientists and engineers as well as to decision-makers at levels ranging from strategic policy to day-to-day operations. It first appeared in international agreements relating to the environment and has moved from there into domestic legislation and policy in a number of countries, including Australia. Hence professionals working in fields with links to environmental management, may be required to consider whether application of the principle is necessary and what responses constitute appropriate application. For example, for scientists the principle is likely to mean an increasing focus on scientific uncertainty; that is, how much can science tell us about the likely impacts of an activity on the environment, but importantly also, what can it not tell us, and whether, how and over what time frame may the uncertainty be reduced? Engineers will be challenged to build precautionary measures into their development plans. These measures are likely to include “process” (eg post-development monitoring, Environmental Management Systems) as well as “structural” measures.

**8. 10. 1 Applying the precautionary principle**
In applying the precautionary principle, a useful starting point is to consider the key terms in its definition; scientific uncertainty; serious or irreversible threats; appropriate measures.

Is there scientific uncertainty about the possibility of environmental damage?
Firstly, it is important to note that the precautionary principle applies to those situations where there is scientific uncertainty about cause-effect relationships and about the environmental outcomes of an activity. Such uncertainty may derive from a number of sources as discussed in Sections 8.4.2 and 8.6. Hence judgment must be applied to decide the extent and nature of the uncertainty, and the potential to reduce uncertainty to a situation where we are confident about the impacts of our actions. If we have such confidence, the precautionary principle is, by definition, no longer relevant (rather, the decision is about preventing damage we know will result from these actions). However, even for such cases it is important to proceed in an "anticipatory" manner since the possibility of ignorance or indeterminacies regarding impacts cannot be ruled out (see 8.2).

Is there threat of serious or irreversible environmental damage?

Determining this involves social as well as scientific considerations (see Box 8.8); people's perceptions and values are involved (see Chapter 4). There are some matters that all/most would agree on - for example that extinction of the koala would be an irreversible and serious matter, or the long-term contamination of prime agricultural land by radioactivity or hazardous chemicals would also be considered a serious matter. Other matters may not find such ready consensus, For example, consider a proposal for land subdivision for new urban settlement which will involve the removal of a natural bushland community9 which is widespread in the area and is home to the Brush-tailed Possum. Some will no doubt consider that since the community and this particular species are common, then loss over this relatively small area is not "serious". Others will consider any reduction in the range of natural bushland and this species to be a serious matter.

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**BOX 8.8**

Judging serious or irreversible threats to the environment

Judging the seriousness of environmental damage depends on a number of factors For example, if a dam is constructed for the generation of electricity, the seriousness of potential threats depends on:

- the different values placed on the existing river and surrounding ecosystem by the general public, scientists and downstream irrigators (eg what is the degree of "acceptable" change?),

- the "boundaries" for defining and assessing the ecosystem and the possible threat (eg what is relevant to the assessment?),

- the completeness of knowledge about the area (eg are there endangered species?),

- the care taken in construction, the scale of the dam and the ecological effects of the dam (size, spatial scale and complexity of environmental impacts).

9 In this instance, "community" is used in the sense of ecology to refer to "Any naturally occurring group of organisms occupying a common environment" (Allaby, 1985).

Judging the reversibility of environmental damage is also a subjective matter

there may be scientific disagreement about the ability of the ecosystem to regenerate after construction, or the time needed for this regeneration,

there may be different assumptions about the resources available or needed to restore the area.

(SOURCE: Deville and Harding, 1997, p 25)
Despite the likely range of views as to what constitutes serious and irreversible environmental damage, it is possible to identify types of threats that most people would see as serious or irreversible. These include (Deville and Harding, 1997):

- loss of biodiversity,
- damage to ecological processes, contamination of soils, water bodies and food chains,
- introduction of "exotic" organisms to ecosystems (such as species which do not naturally occur in the area, or "new" genetically modified organisms),
- release of "new" chemicals (new human-made chemicals which are not found in nature).

**What measures should be put in place to prevent the possible environmental degradation?**

Once it has been decided that the existence of scientific uncertainty coupled with the potential for serious or irreversible environmental damage, warrants application of the precautionary principle, it is necessary to decide what precautionary measures should be put in place.

These could range from:

- Refusing that the development or activity go ahead/continue.
- Postponing the development or activity until more is understood about its impacts.
- Requiring actions designed to prevent the impact in case it is serious. For example, requiring that "pollution traps" are installed alongside a road adjoining a national park in case there is a spill from vehicles carrying hazardous chemicals.
- Requiring constant monitoring for impacts on the environment and agreement that an activity which it is suspected may cause harm, will be stopped immediately there is any indication of environmental degradation.
- Putting in place compensatory mechanisms in case environmental harm occurs from an activity. For example, mining in an area may cause irreversible loss of biodiversity. To compensate for this possibility, the mining company may be required to set aside, and fund management of, another area of similar habitat.

Precautionary measures may be both direct, as in these examples, or indirect, such as the introduction of administrative procedures, policies and legislation which make for a more precautionary approach in decision-making (Deville and Harding, 1997).

**8. 10.2 Who should participate in decisions on applying the precautionary principle?**

It is clear from the discussion above that decisions involving the application of the precautionary principle, whilst informed by science, essentially involve social questions and decisions. These include: Are "strong" or "weak" precautionary measures required? Which specific measures are most appropriate? (see Deville and Harding, 1997.)

Once the information that is available from science is in the decision-making forum, scientific and technology "experts" are no better placed to participate in decision-making than are other "experts" or members of the community. Indeed, there may be considerable advantage in ensuring broad participation in such decisions. We all may bear the consequences of detrimental impacts, and hence we all have an important stake in the decision. In addition, by putting decision-making on issues involving uncertainty (and hence socially-based choices) partly into the court of the community, professionals and institutions do not have to bear full responsibility for outcomes (Harding and Fisher, 1993). It is interesting to note that the Institution of Engineers, Australia argues the need to share responsibility between technical "experts" and the public in relation to decisions on risk (IEAust, 1990; 1993b).
8.11 Conclusion

The need to formally incorporate procedures for acknowledgment and treatment of uncertainty into environmental decision-making has been increasingly recognised over the past few years as one important means for preventing environmental degradation.

This started with the inclusion within EIA of risk analysis and assessment, primarily involving effects of industrial or technological activities on humans and infrastructure. More recently requirement for ecological risk assessment, involving much greater levels of uncertainty, has been included in legislation covering certain circumstances. As well, there has been a move towards formal requirement to use environmental risk assessment in setting strategic priorities for governments (Norton et al, 1996). The private sector has similarly adopted risk assessment procedures for planning and to minimise environmental impacts.

At the same time guidance on how to respond in cases of scientific uncertainty where environmental impacts may be serious or irreversible has been provided by the precautionary principle.

This "institutionalisation" of analysis and treatment of uncertainty in environmental decision-making is seen as an important step forward for protection of the environment. However, concern has been expressed at the unpredictability of the outcomes of decision-making in situations involving uncertainty. For example, judicial decisions from the NSW Land and Environment Court regarding application of the precautionary principle have been strikingly variable to date.

Hence there remains an important challenge to maintain a precautionary approach to decisions involving the environment, whilst simultaneously designing processes which will provide more predictable outcomes than at present.

SUMMARY

Uncertainty is inherent in environmental decisions and arises at many points along the decision making "road". This is because so little is known about complex natural systems, let alone how human activities affect these systems.

Engineers and scientists play an important role in managing and minimising risk and uncertainty. Apart from their technical inputs a key component of this role is effective communication to ensure that the public are aware of the issues and in turn have an opportunity to contribute to the different management options.

Brian Wynne (1992) has identified four kinds of uncertainty:

Risk
The behaviour of the system in question is basically well known and the chances of different outcomes can be defined and quantified by structured analysis of mechanisms and probabilities.

Uncertainty
We know the important system parameters but not the probability distributions; that is we don't know the odds.

Ignorance
"We don't know what we don't know."
Uncertainty, risk and the precautionary principle

Indeterminacy
We don't know all the factors influencing the causal chains or networks.

This is not a continuum of increasing levels of uncertainty since ignorance and indeterminacies may exist in situations we think we understand (ie risk).

More specifically, risk refers to a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

Since risk is the most quantifiable and "measurable" form of uncertainty, a number of formal processes have been developed to "deal" with it. Risk management comprises the following stages

- establishing the context for the risk management process,
- hazard/risk identification,
- risk analysis,
- risk assessment,
- risk treatment.

Risk analysis involves estimating the level of risk in terms of frequency of occurrence and magnitude of consequences, whilst risk assessment is concerned with the significance and acceptability of these probabilities and consequences. As such it concerns social questions.

In environmental decision-making risk analysis and assessment have a range of uses including: setting standards, predicting environmental impacts, strategic planning, and informing Environmental Management Systems of organisations.

There is growing recognition that subjective judgments are part of the entire risk management process, from the first stage of hazard/risk identification through to the much more obvious subjectivity inherent in risk assessment.

Environmental risk assessment, including that pan of it dealing with risks to the non-human components of ecosystems (ecological risk assessment), is becoming increasingly important in environmental planning and management. Because of the complexity of ecosystems, ecological risk assessment generally involves a high level of uncertainty.

A number of factors influence how an individual perceives risk and what level of risk is "acceptable". Some of these factors include beliefs, attitudes, judgments and feelings as well as the wider social and cultural values and disposition that people adopt towards hazards and their benefits. As a result, people may not view "equal risks equally".

Risk communication is a vital component of managing risk. For this to be effective, technical information regarding the risks under comparison and the management options must be in a form that is readily understood by the lay public.

There is a need to provide structured means of dealing with situations involving greater uncertainty than "risk". As a key component of Ecologically Sustainable Development, the precautionary principle provides guidance on how we should act in the face of scientific uncertainty. The principle requires that we take precautionary action to protect the environment in advance of conclusive scientific evidence that some new or continuing human activity will cause harm.

Decisions on the appropriate level of precaution and measures for application are informed by science, but cannot be decided by science alone; judgment by society is necessary.
DISCUSSION EXERCISES

**Exercise 8A**
(a) Why have formal processes for dealing with risk been developed but not for other forms of uncertainty such as ignorance and indeterminacy?

(b) What are the implications of the subjectivity involved in the way in which we formally "deal" with risk (ie through the risk management process)?

(c) How do the implications identified in b) relate to your role as a professional engineer or scientist?

**Exercise 8B**
(a) Why is there often a poor match between the risks that kill people and the risks that concern people?

(b) Identify five key environmental risks which you believe are perceived by the public as "acceptable". List five which you believe are considered "unacceptable". Does your personal ranking of these risks match that which you believe is held by society? Compare your lists with your colleagues. Are there any risks which appear in both lists (acceptable or unacceptable)? What does this say about the way in which individuals and society view acceptable levels of risk?

**Exercise 8C**
(a) How does the precautionary principle go some way towards "shifting the burden of proof"?

(b) What do you think the role of science and engineering might be in the application of the precautionary principle?

(c) Discuss how the precautionary principle could be applied to a current environmental issue which involves a high degree of uncertainty. (It might be useful to refer to Case Study B)
Further reading


Table 8.1

<table>
<thead>
<tr>
<th>Risks to individuals in New South Wales</th>
<th>Chances of a fatality per year for exposed persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking 20 cigarettes a day</td>
<td>$5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Travelling by motor vehicle</td>
<td>$1.45 \times 10^{-4}$</td>
</tr>
<tr>
<td>Having an accident at home</td>
<td>$1.1 \times 10^{-4}$</td>
</tr>
<tr>
<td>Swimming</td>
<td>$5 \times 10^{-5}$</td>
</tr>
<tr>
<td>Playing rugby football</td>
<td>$3 \times 10^{-5}$</td>
</tr>
<tr>
<td>Travelling by train</td>
<td>$3 \times 10^{-5}$</td>
</tr>
<tr>
<td>Living within 1km of a chemical plant manufacturing pesticides</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Being struck by lightning</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Poisoning from a venomous plant or animal</td>
<td>$1 \times 10^{-7}$</td>
</tr>
</tbody>
</table>

(SOURCE: Modified from Higson, 1989)