The chimera of precision: Inherent uncertainties in disaster loss assessment

By John Handmer*

Loss assessments are undertaken to support decisions about disaster mitigation. There is considerable pressure to use economic principles and to make such assessments a condition of funding for all mitigation. A fundamental underlying assumption is that loss assessments are accurate and comparable – and that this accuracy makes comparisons more valid. Unfortunately, it appears that this is not the case. A key question concerns whether loss assessments can be made accurate and comparable through improved knowledge and training – as implied by many critics of the approach – or whether the problems are inherent in the idea of loss assessment. Drawing primarily on Australian flood loss assessment work, these issues are examined. Results suggest that the uncertainties may be larger than generally acknowledged, that at least some are irreducible, and that comparisons may not be assisted by improved accuracy. The implication is that loss assessment methods should aim to make comparisons valid and reliable rather than chase unachievable precision.

The development and implementation of disaster mitigation strategies have long relied on political support with occasionally some financial analysis. However, treasury and finance departments everywhere have always sought economic justification for any significant expenditure. Now, in many jurisdictions, these government entities have increased influence and are demanding that expenditure be based on case-by-case sound economic justification. Sound economic analysis is desired so that there is confidence that expenditure is worthwhile, and importantly that the expenditure is worthwhile compared with other mitigation proposals.

There are strong assumptions here about the accuracy and comparability of loss assessments. Cochrane (1991) among others has argued that economic loss assessment in disaster management has been of highly variable and often very low quality. The development and application of cost-benefit analysis has been matched by outpourings of criticism – generally directed at the economic and other methodological assumptions underpinning the approach including its sensitivity to assumptions about the future, in particular the way the future is discounted, and the inherent bias of many assessments against what is difficult to measure – with the result that the approach supports measurement of property rather than human capital losses, and favours structural mitigation in flood risk management.

A key question concerns whether loss assessments based on economic principles can be made accurate and comparable through improved knowledge and training – as implied by many critics of the approach – or whether the problems are inherent in the idea of loss assessment. This is not the only issue. Loss assessment does not take place on the basis of sound datasets and modelling as documented by, among others, Blong (2002), Cutter (2001), and Granger (2002).

A major project undertaken recently for the Australian state of Queensland (Handmer, Read, and Percovich 2002) highlighted a range of issues – some methodological and some of a more public-policy nature – which help answer the above question. This paper builds on this and other work, and takes it further by suggesting a way of managing the problem of inherent uncertainties.

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Reasons for lack of accuracy

Loss estimates typically vary greatly between similar events, and estimates for the same event may vary greatly. This is the case whether the event being examined is hypothetical or has actually occurred. When assessing losses resulting from actual events, minor differences in hazard characteristics may result in major differences in loss. For example, flood depth may be just below or just above a critical level – such as floor level or levee top.

Reasons for variations in estimates appear to fall into four general categories:

1. the inherent complexity of loss assessments;
2. the level of knowledge. This includes lack of data for a specific event as well as vested interests (e.g., major enterprises, land developers, environmental interests) emphasising certain types of data over others. In addition, it is often uncertain what data are being used, and appropriate metadata are often unavailable (Cutter [2001] makes these comments for earthquake loss assessment);
3. differences in the philosophy and approach brought to the loss assessment – for example, is the need for a rapid assessment for political purposes, a thorough economic analysis to persuade treasury officials, something to guide recovery planning, or deciding on mitigation between competing areas or between competing proposals in the same area? Each approach and accompanying mindset will have its own gaps and limitations; and
4. variations in the funds, expertise, and time available for assessments.

Appreciation of all four basic reasons is needed to understand why loss estimates vary and why their accuracy and comparability is an issue. It is reasonably clear that lack of knowledge and variations in the available resources and expertise will affect the scope and quality of assessments. It should also be clear that assessments conducted for different purposes will often quite appropriately reach different results. Different results are reached in this context because, among other things, different levels of accuracy are required for different purposes and because different assumptions are made about losses by groups with different objectives.

This paper, however, deals with the first point: the inherent, or apparently inherent complexities and inaccuracies in loss assessments. It does this because many of the sources of and reasons for lack of precision are not widely acknowledged. The paper first examines some implications of using an economic approach, including issues surrounding assessment of mitigation alternatives. The identification and measurement of losses is then discussed with the emphasis on the difficulties involved with indirect and intangible losses – the assumption that stage-damage curves are reliable is questioned; dealing with the underlying problems of uncertainty in flood frequency determinations and predictions about the future – both essential for cost-benefit analysis – is covered next; approaches to assessment follow, with comments on their dependence on accurate information and their robustness in the face of uncertainty; finally, the peculiarly Australian question of converting 'potential' into 'actual' loss estimates is examined. Flood loss assessment is used throughout to illustrate the issues.

What is an economic approach?

Poor quality assessments do not occur because the basic principles and procedures are unknown. In fact, the field of economic cost-benefit analysis was originally codified for assessing whether flood mitigation proposals were worthwhile in the U.S. *Flood Control Act* of 1936. The basic approach has been extended since and applied to most areas of government activity. As far as hazard mitigation is concerned, economic assessment has been extended the furthest in the U.K. and U.S. For decades, central government funds have been made available for flood works in the U.K. only if the proposals satisfy cost-benefit criteria following government guidelines. Assessments there have generally followed the detailed approach set out in handbooks prepared by Middlesex University's Flood Hazard Research Centre (Penning-Rowsell and Chatterton 1977; Parker, Green, and Thompson 1987; Penning-Rowsell et al. 1992). The National Academy of Sciences has published guidelines in the U.S., and FEMA is developing a comprehensive approach to *Natural Hazard Loss Estimation Methodology* or HAZUS (see www.fema.gov/hazus/fl_main.htm). The U.S. General Accounting Office sets out its criteria for an economic loss assessment in its review of losses from the attacks on the World Trade Centre (U.S. GAO 2002). In Australia, the approach has been widely, if erratically, used and was codified by Thompson and Handmer (1996). Recently, the Australian Bureau of Transport Economics has restated the principles of economic loss assessment and applied them in a national assessment, the *Economic Costs of Natural Disasters in Australia* (Bureau of Transport Economics 2001). These documents pay only limited attention to the gaps and limitations in loss assessments.

Economic versus financial losses

The principles of economics are different from those governing financial accounting in private-sector enterprises. However, few loss assessments satisfy the demands of either economics (Cochrane 1991) or financial accounting.

The objective of an economic analysis is to assess the impact of an event on the economy of the area selected for analysis (see Table 1). Such areas are usually large political jurisdictions, such as countries or states, with responsibility for economic management. Selection of other areas, such as a region or town, involves a large degree of judgment and acceptance that much of the economic activity flowing into and out of the area will not be captured. We are interested in the net economic cost of a disaster to the area. To calculate this net cost, all costs and benefits resulting from that event need to be identified and where possible quantified. Any social or environmental costs (known as intangibles, see below) must be identified and included in the economic analysis.

A financial analysis, on the other hand, is usually undertaken to assess the return or loss on an investment from the perspective of a commercial enterprise (Table 1). Commercial enterprises are interested in the impact of a disaster on their own profits rather than the impact on the economy. Some impacts not counted as a financial loss by a business affected by a disaster can be counted as losses to society. Such losses would generally include all intangible losses, much of the disruption caused by disaster, and losses to the residential and governmental sectors. Similarly, there are financial losses that are not economic losses. For example, one company may be forced to close following a disaster and thereby lose its sales market, but others may then reap the lost business, resulting in no net loss to the economy in question, apart from any extra costs incurred in transferring production. Similarly, tourists may cancel their trips to an area impacted by disaster, but holiday elsewhere in the same country or region – with no net loss to the economy. Such impacts depend on the structure and boundary of the economy under consideration.

Insurance assessments can produce estimates higher than those prepared using economic principles. This is because household insurance policies commonly provide 'new for old' replacement coverage for insured losses, whereas an economic analysis only counts the market or depreciated value of goods lost or damaged. This comment applies to household insurance policies; it does not apply to insurance for vehicles, commerce, etc. Depreciated value can be thought of as the actual market value. For example, most new cars or computers lose value dramatically with time, so that a five-year-old car might be worth half its new value.

Table 1: Key elements of an economic approach to loss assessment, contrasted with the usual or financial approach.

Economic assessment is about:

- **All members of a defined society or economy, not individual firms;**
- **Economic efficiency for this defined economy, not components within it;**
- **Depreciated rather than replacement values;**
- **Counting all impacts on the economy, both positive and negative;**
- **Changes to economic activity as a result of the disaster in the defined economy.**
- **Avoiding double counting, by counting losses once* and by not counting losses made up later or by other businesses in the same economy.**

Economic assessment is NOT about:

- **Distributional affects;**
- **Commercial profit and loss.**

Use of economic approaches for assessing mitigation proposals

Mitigation measures are implemented to reduce disaster losses, and so the benefits of any disaster mitigation measure are assessed in terms of the losses expected to be avoided by introducing that measure. Economic assessment is one of a number of decision support tools for mitigation proposals. But in practice it is often used as the sole criterion for flood mitigation, especially in England and Wales, and for some projects funded by the U.S. federal government. Decision makers often ignore the limitations of an economic approach and proceed as if the results of an analysis were near perfect. Table 2 sets out some of the more common experiences with using an economic approach for assessing mitigation.

The type of loss and the type of mitigation measure determine how complex it is going to be to include it in an economic assessment. Mitigation measures that try to prevent the disaster, such as levees or dams that positively exclude floods from an otherwise flood-prone area or strict land use controls that exclude people from hazardous areas, are relatively easy to assess as they will prevent almost all of the losses which would otherwise have been expected. There are some caveats to this general picture. Of course, they will not prevent losses above their design level, but these can usually be calculated. If the measure is a structure such as a flood levee, normally some allowance should be made for the chance that it might fail. We could add that even this calculation would normally assume perfect maintenance, whereas this is far from the case, and maintenance costs and difficulties are almost always underestimated. Political neglect, other priorities, new knowledge and rising standards making the original design obsolete are just some of the reasons why maintenance difficulties are underestimated. Where measures are likely to increase exposure to the hazard, although at a reduced

* A key element here is the 'stocks and flows' issue whereby damage to a physical asset (stock) should not be counted as well as loss of profits generated by that asset (flows), on the basis that one is a reflection of the other. Rose and Lim (2002) review the issue. This is not dealt with here except to note that, in a world dominated by human capital, the issue may not be so clear cut.

Table 2: Some experience with economic assessment for disaster losses.

- **Decision makers ignore the limitations of economic assessment.**
- **Items for which market values are hard to establish, or which are contentious, are ignored.**
- **Poorer areas do badly – they are worth less, and protecting them gives less return for the investment – as economics generally ignores distributional effects.**
- **Assumptions about the future of land use, climate, and individual behavior are always rough estimates.**
- **Through the application of discount rates, the future is generally discounted at the same rate for everything: Is this appropriate?**
- **The time dimension and event sequencing are usually ignored.**

risk – such as levees encouraging new development in the newly protected areas – this should also be taken into account as possibly leading to higher loss than before if the levee is ever breached or over-topped. Mitigation measures may also create new hazards or transfer the problem elsewhere rather than eliminating it.

However, most disaster mitigation measures can only alter the outcome of the event by changing the pattern or amount of loss, rather than preventing (or nearly preventing) losses altogether. Assessment of measures that modify the disaster outcome, such as smaller scale building modifications including floodproofing or retrofitting for earthquake and cyclone protection, may appear simple to assess, but compliance with these requirements has to be estimated, and it may be very low.

A similar problem of estimating compliance arises with mitigation measures which rely on public or commercial response such as warning systems, flood management schemes, and other strategies open to interpretation and negotiation, including most land use regulations. These mitigation measures are easily specified on paper, but there is great uncertainty over how they work out in practice – and the economic outcome will depend on the reality of how well they work in the event of a disaster. The issue here is the gap between written regulations and the realities of implementation (e.g., between the assumptions about near-perfect warning message dissemination and the reality of patchy dissemination and slow response).

Estimating the economic benefits of disaster mitigation is wholly dependent on predictions of the future. Yet, as with predicting the level of compliance with regulations, predicting the future through forecasting land uses, commodity prices, and environmental conditions is itself hazardous and prone to uncertainty. Assuming that it will be the same as the present is a typical and perhaps necessary approach, but one which is usually incorrect.

Implications of using an economic approach

Economic loss assessment counts the losses to the local economy as well as the benefits. Even if we could assess losses perfectly – and we cannot – we would still be faced with the problem of identifying and then estimating the benefits (or offsetting payments) resulting from the disaster for the area of assessment. This is particularly important within a regional context, because postdisaster insurance and aid funds that flow into the area may partly offset the tangible losses suffered – something that is unusual at the national level. Joe Scanlon (1988) is one of the few hazard researchers to document the benefits offsetting some disaster losses. Note that dollar benefits are normally offset against dollar losses only. Intangible losses are not included in this part of the analysis. Normally, attention could be given only to the major flows of funds into the region that are clearly a result of the event under assessment. This can generally be assessed fairly easily after an actual event, but poses difficulties when hypothetical events are being assessed. Table 3 shows the impact of including benefits for a region of North Queensland, Australia. In this case study the losses were estimated at $245.1 million (Australian dollars [ED.: $138 million U.S]), but benefits to the region in the form of insurance payments and government aid (both from outside the region) amounted to $141.9 million ($80 million U.S.), for a resultant net loss of $123.2 million ($69 million U.S.) – half the original estimate. This net loss is borne by the region defined for the analysis. However, the loss to the nation would be the full amount of $245.1 million as benefits to the region are simply transfers within the national economy. (Even this statement needs qualification, as business gains outside the region would need to be deducted from the loss estimate for a national perspective.) The U.S. General Accounting Office highlights the importance of offsetting payments in its report on the World Trade Center attacks. The New York City Partnership estimates the losses to the city at 83 billion U.S. dollars, offset by insurance, federal government aid, and increased economic activity worth about 67 billion dollars, to give a net loss to the city of some 16 billion (quoted in U.S. GAO 2002).

Defining and measuring loss

The economic framework for disaster loss assessment possess a number of measurement challenges including determination of the spatial and temporal boundaries of the analysis. Within this framework, the assessment of flood losses is based on a number of conventional or agreed approaches, each of which carries assumptions

Table 3: Total economic cost of the January 1998 floods to north Queensland: Implications of including benefits.
(Figures are in Australian dollars [AUD].
NDRA refers to the Australian Natural Disaster Relief Arrangements.)

Loss type	Losses to region ($m)	Benefits to region NDRA ($m)	Insurance ($m)	Total ($m)	Total economic loss ($m)
Totals AUD ($U.S.)	245.1 (138.1)	52.56 (29.6)	69.35 (39.1)	121.91 (68.7)	123.19 (69.4)

and its own set of uncertainties and measurement problems. This section examines: how losses are normally classified; stage-damage curves which have been a key tool for flood loss assessment; the geophysical information underlying cost-benefit analysis; and issues of exposure and vulnerability.

Types of loss

Losses are conventionally classified as either direct or indirect. These are the major categories of loss, which can be further subdivided into tangibles and nonmarket impacts – or intangibles – according to whether or not the loss can be easily valued in dollars. Table 4 contains examples. In practice, the two types of tangible losses are distinguished from intangible losses, giving three overall loss categories: direct, indirect, and intangible. These three categories represent increasing levels of uncertainty and measurement difficulty. Uncertainty will also increase with the scale of the event. This is because indirect and intangible losses are likely to be larger, as a percentage of the total loss, as the size of the impact increases – with the result that losses from large-scale events will likely be underestimated (research cited in U.S. NAS 1999, p. 15). The U.S. GAO follows this classification of direct/indirect losses but does not have a separate category for intangibles. For an examination of other approaches to defining direct and indirect losses, see Rose and Lim (2002).

- **Direct losses** result from contact with floodwater, wind, etc. They are generally the most visible, often represent the largest loss component, and are the easiest to assess. Nevertheless, a wide range of loss estimates is still possible because of different assumptions about the condition of the assets before the disaster and, as with all types of loss, because of different approaches to measurement and variations in the resources and skill used in the assessment.
- **Indirect losses** arise as a consequence of the impact of the hazard. They reflect disruption to economic and other activity within the area of analysis, which flow from the effects of flooding, wind, or fire, etc. – hence the term 'indirect.' Indirect losses are more complex to evaluate, particularly because of the need to avoid double counting losses which have already been assessed as direct losses or which are already counted elsewhere in the analysis. Indirect losses to commerce may be made up by other enterprises within the area of analysis or by the same enterprise over a reasonable time period. Not surprisingly, the application of economic principles such as the need to determine the spatial and temporal dimensions of the analysis has the most impact in dealing with indirect loss assessment – generally reducing the estimates.
- **Intangible losses** is a catchall term that identifies direct and indirect impacts for which there is no commonly agreed method of evaluation and not normally a market. They include lives, health, memorabilia, ecological damages, destruction of community life, cultural artefacts, and loss of leisure. Research shows that people often value the intangible losses from a flooded home – principally loss of memorabilia, stress, and resultant ill health – as at least as great as their tangible dollar losses (Heinz 2000). Yet, most studies relegate intangibles to little better than footnote status. The National Academy of Sciences Framework for loss estimation (U.S. NAS 1999, p. 15) states that intangible losses "may sometimes be greater than the losses of direct physical destruction." But on the same page it advises that loss assessors should "Focus on direct losses, as they are easier to objectively measure" (ibid.). Lives lost are an exception to this general picture. The Australian Bureau of Transport Economics uses a value of $1.3 million Australian ($732,000 U.S.) per life (BTE 2001). Assessments of losses from the World Trade Center attacks used a foregone earnings approach to value lives at about $5 million U.S. each (U.S. GAO 2002). One problem with the U.S. approach is that the lives of high income earners have greater value than those on lower incomes. In summary, there is usually great uncertainty over the identification of intangibles and their valuation, with the result that losses are typically seriously undervalued.

Identifying losses is challenging, especially for those of an indirect and intangible nature. Although there appears to be reasonable consensus over the appropriate approach to measurement for most direct losses, this apparent agreement disguises much variation in practice, in particular over how the damaged item is valued. Stage-damage curves, the basic method of assessing direct flood losses to dwellings, are reviewed below. There is now doubt about their real value.

Are stage-damage curves worth the effort?

Stage- (or depth-) damage curves represent the relationship between expected loss and varying depths of flood water. These are typically used for assessing loss to housing and other structures where the stage or depth refers to depth of water inside a building and the damage refers to the damage expected from that depth of water. They have been the fundamental element of flood loss assessment.

The basic expectation from flooding is that deeper water will result in greater loss. At floor level, floor coverings will be damaged, and there may be losses to furniture and other items normally kept at floor level. At two or three metres of water inside a single storey building, all contents will be lost, and the structure itself may be endangered. Modern building techniques and furnishings, as well as contemporary furnishings and contents, may be making the stage-damage concept less relevant. Curves may disguise enormous variation in individual cases and uncertainty about their true value (Blong 2002).

There are two methods for developing stage-damage curves:

- Firstly, they can be compiled from loss measured following flooding; Stage-damage curves can be based on actual loss data collected after a flood using a single event or an amalgam of events. The U.S. curves employed by the Corps of Engineers are drawn up this way (USACE 1996), as are most Australian stage-damage curves.
- Secondly, the curves can be constructed synthetically. Synthetic stage-damage curves are produced from detailed inventories of typical property contents for different types of property; the height above floor level each item is normally kept, classified by the potential loss if flooded. This is the method used by the U.K.'s Flood Hazard Research Centre, where the items are also depreciated so that the loss reflects the economic loss rather than the replacement cost of the flooded items (Penning-Rowsell and Chatterton 1977). In practice, each item is assumed to be halfway through its economic life. Structural damage is derived from estimates of the cost of repairing the damage caused by flooding to building fabric for each building type.

Both methods are based on an averaging approach (explained below in 'Implications for Approaches to Loss Assessment') and assumptions regarding the validity of the transfer of loss estimates from one situation to another. Stage-damage curve values are very sensitive to flood water depth, yet this is frequently known only approximately. The curves only assess direct losses to small structures and their contents. No matter how much effort is put into them, large elements of direct loss must be assessed in other ways. In most cases, overall assessment results will depend on how indirect and intangible losses are handled.

Exposure and vulnerability

In the definitions employed in this paper and drawn from Emergency Management Australia (EMA 2000), exposure refers to people, assets, and activities threatened or potentially threatened by flooding, and vulnerability refers to the susceptibility to harm by flooding of what is exposed and its ability to recover. Assessment of exposure is reasonably straightforward within the rather severe limits of flood hydrology and hydraulics, as set out below, and the quality and reliability of the needed datasets (see, for example, Granger, 2002). As well, the number of people and activities actually exposed may be dependent on many circumstantial factors. However, assessment of vulnerability is much more complex. There is no general agreement on what constitutes vulnerability or on how it should be measured. Although there are many publications suggesting various approaches, most of these either use surrogates or employ indicators for which the evidence is often contested. Physical scientists

Table 4: Types of loss and measurement. (Uncertainty in both identification and valuation increases from the top left to the lower right of the table.)

Can the lost item be bought and sold for dollars?	Direct Loss Loss from direct contact with flood water.	Indirect Loss No contact – loss as a consequence of flood water.
Yes – Tangible	For example, buildings and contents, cars, livestock, crops, infrastructure.	For example, disruption to transport, etc. Loss of value added in commerce and business interruption where not made up elsewhere. Legal costs associated with lawsuits
No – Intangible	For example, lives and injuries. Loss of memorabilia. Damage to cultural or heritage sites. Ecological damage.	For example, stress and anxiety. Disruption to living. Loss of community. Loss of nonuse values for cultural and environmental sites and collections.

may assess vulnerability in terms of building safety, for example; other disciplines will employ livelihood security, wealth, gender, and so on. For our purposes here, it is sufficient to highlight that the concept and measurement are contested and that vulnerability is often specific to the situation and circumstance. At the present state of knowledge, measurement is expensive and of limited use for economic assessment due to its lack of stability through time. In addition, there is an important policy issue. Those of high vulnerability are likely to be less wealthy with fewer assets. A standard economic assessment would judge such people worthy of little flood mitigation investment relative to richer groups. This may not be a satisfactory social or political outcome.

The geophysical dimension

Knowledge about flood water extent and other characteristics is usually important for loss assessment of a single flood event. The survey and synthetic methods in particular depend on having accurate flood information. Where cost-benefit analysis is to be undertaken, additional information is needed. Knowledge of the flood frequency and magnitude relationship for the area being assessed is essential for estimating average annual damages (AAD) and for projecting losses into the future as required for cost-benefit analysis. Underlying the frequency-magnitude concept are many assumptions, including a stationary or stable climate. In addition, there is often uncertainty about the precise extent and attributes of the hazard, such as a storm or flood: where did it go, how strong was the water flow, how long did it last, what contaminants were in the water, and so on? Where flood water remains high for weeks, or where the contaminant may remain indefinitely, indirect and intangible losses may be much larger than direct losses even in the absence of deaths. However, existing standard methods do not assess this properly or even properly acknowledge the potential impacts.

To assess the magnitude of relatively rare events like the one percent flood takes a long, stable record. This is an important underlying assumption of both flood record analysis and flood damage assessment. But there is good evidence that the flood-producing aspects of climate are variable over periods of decades (for eastern Australia, see Smith and Greenaway 1983; for New Zealand, see McKerchar and Pearson 2001). In addition, in some areas short-term variability – also referred to as reliability – may be enormous. Arid areas exhibit this characteristic dramatically, where long periods of no flow may be followed by extensive flooding. McMahon, Finlayson, and Haines (1992) show that streamflow and therefore flooding in Australia and southern Africa varies greatly over the short-term – in addition to the longer-term variability mentioned above. On top of this, it is now generally recognised that climate change may have significant impacts on flood frequency and magnitude (Handmer, Penning-Rowsell, and Tapsell 1999).

The effects of land-use change on runoff adds further uncertainty to frequency/magnitude calculations. For all their apparent precision and the attention paid to the flood record, calculations of rare floods are abstract and sit within very wide confidence bands. It is also quite possible that climate change will affect the shape of the frequency/magnitude distribution. There appear to be two possibilities here. One possibility is that the rarer or more extreme events, such as the 1:100 flood or even rarer events, will be affected disproportionately. At other locations, the whole magnitude/frequency relationship may shift, so that floods of all severities will change. Such shifts will have a profound effect on the calculated annual average damage as smaller and medium-sized events are more important since they occur much more often and thereby normally contribute a greater proportion of the average damage. This shift has been documented from historical flood data; for example, Smith and Greenaway (1983) have shown that in southeastern Australia the flood frequency/magnitude regime has shifted, with a dramatic increase in flood damages.

Implications for approaches to assessment

How does all this uncertainty – in the economic approach, the underlying geophysical and demographic data, and the identification and measurement of damage – affect the various approaches to loss assessment? The variety of assessment methods used worldwide today can be categorised into three general types which range from very detailed postdisaster surveys attempting to calculate precise losses through to rapid estimates. They are known here as the averaging, synthetic, and survey approaches (Table 5). In practice, some combination of approaches would normally be used; for example, surveys are the most appropriate method for assessing losses to large businesses most infrastructure, and intangibles. The implications for each approach are considered below.

1. *The averaging approach* sets out an average loss per impacted dwelling, with average values for business premises based on the area of the structure. It does this by drawing on preexisting data. This average loss is applied to every flooded structure in the area being assessed. In the Australian state of Victoria, percentage figures for indirects and indexes for intangible losses are also used (Read, Sturgess, and Associates 2000). The averaging approach has the advantage of great simplicity and relatively low resource requirements compared with other approaches. It makes no pretence at precision in individual cases and does not rely on accurate flood depth information – although for cost-benefit analysis frequency/magnitude information is needed. The averaging approach also suggests considerable

evenhandedness, with one outcome being that the loss potential of poorer areas will be valued much the same as wealthy areas. However, the approach may under- or overvalue indirect and intangible losses. It also treats very serious and dangerous flood hazards the same as shallow flooding that results in little damage and poses little threat to safety. With refinement, the approach may be able to overcome these problems.

2. The *synthetic* approach involves a detailed assessment based on preexisting databases covering a range of building types and contents. Losses are based on assumptions regarding the age and condition of the items and the effect of the hazard, and are often developed theoretically or synthetically – as opposed to being based on experience. The synthetic approach is probably the most flexible and currently most widely used of the three approaches. It can make use of a variety of existing computer packages with their own stage-damage curves for calculating direct losses for the residences and small shops. However, the extensive use and availability of calculation packages disguises considerable debate over the accuracy of the stage-damage curves and resulting figures. The accuracy of the synthetic method depends, therefore, on the reliability of the available datasets including the detailed characteristics of the flood or floods in question. One argument is that the inaccuracies in this approach make no difference when it is applied to large areas – this argument can be made for the averaging approach, too, but that approach involves much less effort.
3. A *survey or historical* approach involves using surveys after the event being assessed to establish actual losses. The approach depends on surveys to ascertain the extent of the loss. Often this will involve taking a sample of households or enterprises and generalising the results to the affected population. Where a substantial number of properties are involved, a more sophisticated analysis is usually attempted, and stage-damage curves may be constructed for different activities and structure types. The curves produced in this way are based on a *sample* of affected properties and are used to estimate losses for all affected properties. The accuracy of the results depends, among other things, on rigorous sampling and careful survey design.

No matter how much effort goes into the rigor of this approach, historical loss assessment provides results that define the losses experienced at one point in time, given the community's preparedness, length of warning, and other unique attributes of the flood. This fact – and the wide variations in survey and sampling quality and in the elapsed time between the flood event and survey – greatly reduce the utility of the approach for comparative purposes.

'Actual' versus 'potential' losses?

Loss data collected after an event will be – or at least will appear to be – the losses actually experienced. In Australia such loss estimates are known as *'actual'* losses. They (purport to) take account of the unique features of the event, the warning system, people's experience with the hazard, and their preparedness. Questionnaire surveys typically provide this type of estimate. The synthetic approaches for flood loss estimation developed in the U.K., the U.S., and Australia, as well as the averaging approach, cannot reflect the unique attributes of each event and of the people involved. Instead, they provide what are known in Australia as *'potential'* losses. Generally, these are the

Table 5: Summary review of basic eements of the three approaches to loss assessment.

Loss Assessment Approach	Direct Loss Houses/Small Business	Commerce, Farming (>1000m³)	Infrastructure	Indirect Loss	Intangible Loss
I Averaging	Average loss per flooded structure	Average loss per m² for types of enterprise & surveys	Average $ Per km of road and surveys*	Examine $ flow and use surveys % of direct	Identify types and magnitude. Surveys
II Synthetic	Standard stage-damage curves for types of property.	Stage-damage curves applied to m³ for different types of business	Stage-damage and average loss per km depending on type of infrastructure	Examine cash flow and use surveys.	Identify types and magnitude. Surveys
III Survey (based on sampling)	Surveys – new stage-damage curves.	Surveys.	Surveys.	Surveys.	Surveys.

* Much public infrastructure does not generate income directly, so future revenue cannot be used to assess loss nor is its social benefit necessarily related directly to the infrastructure cost.

maximum losses likely to occur in a given event. Potential losses are averages in the sense that they do not take account of the unique features of the event or of the affected population. It is worth observing that most U.S. and Australian stage-damage curves have been constructed from an amalgam of postflood event loss assessments and therefore reflect a mix of actual losses, including insurance losses – although they do not reflect the unique features of any one event. The U.K. curves have been synthesised as described earlier and represent pure potential loss.

Many of those assessing flood losses in Australia have adjusted potential losses so that they are closer to 'actual' losses, typically taking into account local experience, preparedness, and warning time. In Australia more or less standard ratios are often used for conversion of potential to actual losses (e.g., see Read, Sturgess, and Associates 2000; Handmer et al. 2002). Application of these ratios makes a major difference to the resulting damage estimate, reducing it by 60 percent for a flood experienced community with at least twelve hours of warning time. However, the ratios are based on a few data points from predominantly rural locations and were developed many years ago as indicative or preliminary (Smith 1981).

In addition to serious questions about the validity of the ratios, there are a number of practical and policy problems with this approach:

- the use of 'actual' losses may be discriminatory against those who take action to reduce their losses, as it will reduce the amount deemed worth spending on mitigation in their communities;
- 'actual' losses may discriminate systematically against poorer sections of the community, because their actual tangible losses may be very low – although intangibles may be very high – with the result that it will not be worth investing in mitigation;
- the 'actual' loss estimates are unstable as people move or as circumstances change – yet in cost-benefit analyses estimates are projected decades into the future; and
- it is not easy to estimate the ratio between actual and potential losses for different flood prone communities.

In any case, we may be fooling ourselves that we can measure 'actual' losses with precision. The implication is that, at the present state of knowledge, estimates of 'actual' losses may not be valid. Instead, it may be more appropriate to think of potential losses under different circumstances.

Conclusion – accept averages

There are significant uncertainties at every step in the loss assessment process, whether the intent is to produce economically sound estimates or not. Some of these uncertainties may be essentially irreducible, and, even if this eventually proves not to be the case as our knowledge expands, key steps require judgments – some of an overtly political nature. These uncertainties are not merely features of loss assessment, they are also inherent in the limits to our knowledge of climate and extreme events, and of people and economies. The apparent accuracy of assessments conducted immediately after a disaster may make them unsuitable for comparative purposes, as the precise impact of each disaster is contingent on an almost infinite range of situational factors which will vary over time and space.

The implications for loss assessment procedures everywhere are, in summary:

- exact loss estimates do not exist, and it is important to appreciate that disaster losses can only be estimated;
- the assessment process involves judgment, and efforts should go into refining this judgment process rather than simply attempting to achieve 'exact' loss values;
- training will increase expertise, which is essential for the application of an approach based on the principles of economics, but will not eliminate uncertainty;
- as intangible and indirect losses are difficult to identify and assess, are often the major part of the total loss, and are frequently ignored because of measurement difficulties, special effort should be devoted to these loss categories; and
- the approaches used should be examined for systematic or inherent biases.

These limitations support the development and adoption of an averaging approach. The emphasis here is on achieving a transparent and consistent approach that enables comparisons between areas and alternative strategies for risk management, rather than to pursue increasing accuracy which may be an illusion anyway. The approach should not be overly sensitive to minor changes in the dimensions of the hazard under consideration – as this will usually be an area of considerable uncertainty. The approach should nevertheless aim for a reasonable and achievable degree of accuracy and replicability. Consistency and replicability enables confidence with comparisons between areas, as well as between mitigation options – the normal reason for the assessment.

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