Submission to National Disaster Insurance Review

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I am an environmental and water engineer with a doctorate in ecological economics. I have been in professional life for 47 years, working mainly in the Asia-Pacific Region, in government, private and academic roles. My consultancy has specialised in, among other matters, advising on strategies for optimally reducing the social and economic losses on floodplains. I have undertaken or participated in the economic evaluations of losses from flooding in 16 floodplains in Australia, where each property in the floodplain was surveyed individually. In addition, my consultancy has assessed the economic benefits of flood-mitigation strategies in basin-wide studies for Sydney, Newcastle, Wollongong, Christchurch and Hanoi.

Since 1988, I have been advising insurance companies on the causes of inundation of properties. In all, I have undertaken or supervised the investigation of 1,000 or so such properties. More recently, I have been undertaking research into mediaeval water systems in South East Asia to see if their histories can provide lessons today. A *curriculum vitae* is attached at the end of this submission.

This submission will explain how the flood risk is much larger than the insurance industry seems to appreciate; that it is already paying for most of the losses; and that having Automatic Cover with Opt out may have a financial result that would be little different financially from an Automatic Flood Cover model, but with a larger social cost. It will discuss how communal resilience to the flood risk tends to decline, and how it would be in the interests of the insurance industry for it to become more pro-active in reducing the economic and social losses from floods.

1 The economics of flood insurance

Even where insurance companies have stated that they do not cover flood damages, I have observed over the years that they can end up paying for a significant proportion of the household losses. In 1989, we estimated from our company‟s own experience that insurance companies paid as much as half the losses to households, three-quarters of the losses to industry and 90% of floods from urban drains (Lustig and Haeusler, 1989: 14). Since then, the policies of some major insurers have been amended to include most urban flooding, and some rural riverine flooding (Irish, 2002: 114), and with one insurer all household flooding (Owide, 2002: 114), so that these proportions would be higher. It might also be noted that flood insurance is available for large commerce and industry, often at low or even zero premiums. It is difficult to understand how amending policies to include all flood losses might not be financially feasible.

It is instructive to compare what happens with Australia‟s household insurance with the situation in New Zealand, where flood cover is available to households [Issues Paper A4.1] and flooding conditions are not all that different. Bewick and Lustig (1989: 143) found that the flood losses per household in New Zealand were two to three times those in NSW. Part of the reason for this was that the NZ policies covered replacement of lost possessions rather than the indemnity value. Whatever the cause, full cover was clearly affordable by the New Zealand community.

It is arguable that flood insurance is also socially necessary. When one compares the social effects of flooding after the Sydney floods of 1986 and 1988 (Lustig and Haeusler, 1989: 7) with those in Invercargill, New Zealand (Luketina, 1986), the economic importance of flood insurance becomes clear. Sydney people suffered emotional stress, infections, arthritis, heart trouble, marriage breakups, alienation, disturbed behaviour and even premature death. Invercargill residents mostly experienced only stress from disruption to their normal lives.

The social impacts are economically substantial. Our surveys following the 1988 Sydney floods

showed that the householders usually regarded the social effects as worse than the financial losses they incurred. This implies that the economic cost of the social effects exceeded the economic costs of the financial losses. In addition, there are substantial monetary costs arising from the effects on health and the cohesion of the family. In other words, the economic cost of flood losses to households is significantly more than double the direct monetary cost of losses to property, and it is reasonable to posit a factor of three. The implication that it may be easy to recover from uninsured losses to contents [Issues Paper 5.5 and 13.7] for other than low income tenants [Issues Paper 5.6] is not readily supported by the known facts.

If flood insurance were universally available, this would substantially reduce the economic costs of the social affects. Thus, while non-financial social costs are monetarily uninsurable [Issues Paper 2.15, last sentence], the substantial reduction in social losses when there is flood cover means, in effect, that the most important social losses are insurable indirectly.

The Issues Paper has raised the problem of moral hazard, that flood insurance will remove many incentives for mitigating the losses [Issues Paper 3.13 and 11.3]. It is felt that this is no more an issue than with any other event covered by a home insurance policy. As it is, we found in our social surveys that householders normally respond emotionally to the entry of floodwaters as with an unlawful entry, an event that is covered by household policies. Moreover, a proportion of the potential losses would be of household items that have sentimental value, so even if there were discounted premiums, there would remain incentives to mitigate losses. A far greater problem is that the resident may simply fail to take such steps through denial of the hazard [Issues Paper 15.3].

Over several decades of dealing with the hydraulic aspects of insurance claims for water inundation, I have observed that both insureds and insurers understand the distinction between flood and storm poorly. In at least one case, the insurer‟s definitions have had different meanings to what was intended, and it may be that this insurer did not conform to Sections 35(2) and 37 of the Insurance Contracts Act by derogating from flood cover in a manner that was clear to the client. [It might also be noted that this insurer persisted with some flawed definitions after it was advised of these difficulties.]

While the definition of riverine flooding proposed in the *Clearing the Waters* report (Treasury, 2011: 5) might be thought to provide clarity, this would not eliminate the confusion as much as is hoped. According to that report (*op. cit*.: 3), it is proposed to distinguish between riverine flooding (Category B) and stormwater runoff (Category A), which is defined as localised flooding produced by short-duration storms. However, no explanation is provided for the meanings of „localised‟ or „short duration‟. Indeed, where similar concepts have been defined in the past, it has at times entailed hydrological and even meteorological analysis to know if a particular event was „flood‟ or „storm‟. Further, where both riverine flooding and stormwater runoff could impinge on a particular location, it might not be possible to determine how to classify a particular instance of inundation without professional help. This has been a major cause of delays in assessment [Issues Paper Chapter 16].

Even if maps of different types of flood risk were prepared as proposed (Treasury, 2011: 19, para. 86), it would either be “precise” and thus complex and not readily understood by lay people [Issues Paper 15.20 to 15.23]; or it would be simplistic and thus potentially misleading. Hydrology is an inexact Art, and the inaccuracies in hydrological assessments are inherently large, so that the reliability of flood maps showing the different categories of risk could be based on flawed foundations. It is thus not apparent how flood maps could help an insurer explain its derogation from flood cover clearly.

I have frequently encountered situations where, even though I would normally have classified an inundation as caused by „flood‟ rather than by „storm‟, I could not rule out the small chance that it

was otherwise, and so had to give the client the benefit of the doubt. Such situations have not been rare events. Most flood-prone residences are in areas of low to moderate flood risk [Issues Paper 2.3 and 2.10], and these are where flash flooding or stormwater runoff are liable to be the proximate cause of the losses. This is because storm runoff arrives quickly at a property, while with these higher properties, floods take time to rise to the level that causes inundation. Thus flood mapping to show insurability by its very nature could run counter to the requirement of the Insurance Contracts Act 1984 (ICA) for the insurer to show utmost good faith [Issues Paper 15.26].

A further complication is the proposed classification of flooding from short-duration meteorological events as storm. Most urban catchments are small, and their floods would normally result from short-duration events, however defined. Thus properties upstream would be covered under storm, while properties downstream subject to the same flood may not. Since it is difficult to underpin such an outcome with logic, the policy may fail the requirements in Secs 35(2) and 37 of the ICA to explain a derogation from flood cover clearly.

What is more, one can rarely know how intense the rainfall was at the site after the event, since the nearest pluviometer (an instrument for recording rainfall intensity) will normally be kilometres away, where the pattern of rainfall will have been different. So it is entirely possible—albeit unlikely—that there was a period of very intense local precipitation—much larger than what was recorded at the pluviometer—resulting in so much runoff that it was able to enter the client‟s house.

Finally, the proposed arbitrary distinction between „flood‟ and „storm‟ can have perverse effects. Stormwater runoff is more likely to enter a house that is low on the ground than one next door where the floor is raised. In such a case, the stormwater could enter the low house before the floodwaters arrived, and the losses should be covered by an insurance policy. The raised house would escape the stormwater, but could then be inundated by the flood, and the losses may not be covered under the same form of insurance policy. Such an outcome would defy common sense and run counter to the objective of encouraging the homeowner to attempt to manage the risk [Issues Paper 2.14].

To sum up, having Automatic Flood Cover with Opt Out may end up with a result that might not be all that different financially from a simple Automatic Flood Cover model, but it would have a larger social cost. It may also lead to insurers having difficulties with conforming to Sections 13, 35 and 37 of the ICA.

2 Enhancing the role of the insurance industry in sustaining the flood-risk management system

It could be beneficial to the insurance industry were it to become more pro-active in ensuring a sustainable floodplain management system. This would be particularly beneficial if the Automatic Flood cover were adopted. This is because a sustainable flood-risk management system would need to be designed in recognition of the following trends and features: -

- *Insurance companies have a large and growing stake in having a sustainable emergency management system*.

- *The awareness of the flood risk in a community inevitably declines with time since the last flood*, and flood-prone households are liable to be unprepared for the next big flood, if they are only passive recipients of information on the hazard (Dufty, 2008: 6, Attorney-General's Department, 2009: 57). Insurance companies providing flood cover could help provide incentives to residents of the floodplain to prepare for the flood hazard.

- *The decline in flood awareness results in reduced political pressures for maintaining the preparedness of the flood-prone community*. There is thus an appreciable risk that public resources available for sustaining communal resilience will be small by the time of the next large flood. To counter this, the insurance industry could be empowered to apply countervailing political pressures for funding to maintain the emergency management network. It may even be feasible for the insurance industry—the sector with the greatest financial stake—to provide some of the modest funding needed for the secretariats of the local Flood Risk Management Committees. In this way, it could be assured of having a large and continuing say in the sustainability and enhancement of the local emergency management systems.

These points will be now be explained in more detail.

2.1 Insurance companies have a large and growing stake in having a sustainable emergency management system

Floodplains are flat, easy to settle and productive, thus tending to attract pressures for intense development. From a strict monetary sense, this is quite rational, since the material benefits from exploiting these areas on average normally outweigh the material losses to a significant degree. Indeed, in the experience of most occupiers of floodplains, the losses from flooding are normally minor.

This impression is often reinforced by infrastructure such as levees and dams, designed to mitigate flood losses. However, most flood-mitigating works are generally designed to protect assets from floods only up to the level of the 1%AEP (annual exceedance probability) event, since it is rarely judged economical to install infrastructure that mitigates losses from higher floods. [Floods lower than the 1%AEP level will henceforth be referred to as „Small Floods".] Floods can have flows up to roughly ten times those of a 1% AEP flood, so the cost of protecting against floods higher than the 1%AEP level [hereafter „Large Floods"] will often be substantial, and hard to justify for an event that people might never see in their lifetimes.

Yet when one estimates the monetary losses from floods on a floodplain, one finds that on average about half the losses from floods are from Large Floods, as illustrated in Figure 1, so that when flood-mitigating infrastructure is installed, it only eliminates the risk from Small Floods—addressing only half the problem. Yet the reduction in risk encourages renewed development in the floodplain, and when the inevitable Large Flood does come, the losses will be greater than before, so that installing flood-mitigating infrastructure need not result in significant long-term reductions in flood losses [Issues Paper 10.5 to 10.7]. Thus while it is correct that only a small proportion of homes are exposed to high or very high risk [Issues Paper 2.8], it does not follow that losses from Large Floods are of less consequence to the community—and hence to the insurers—than those from Small Floods.

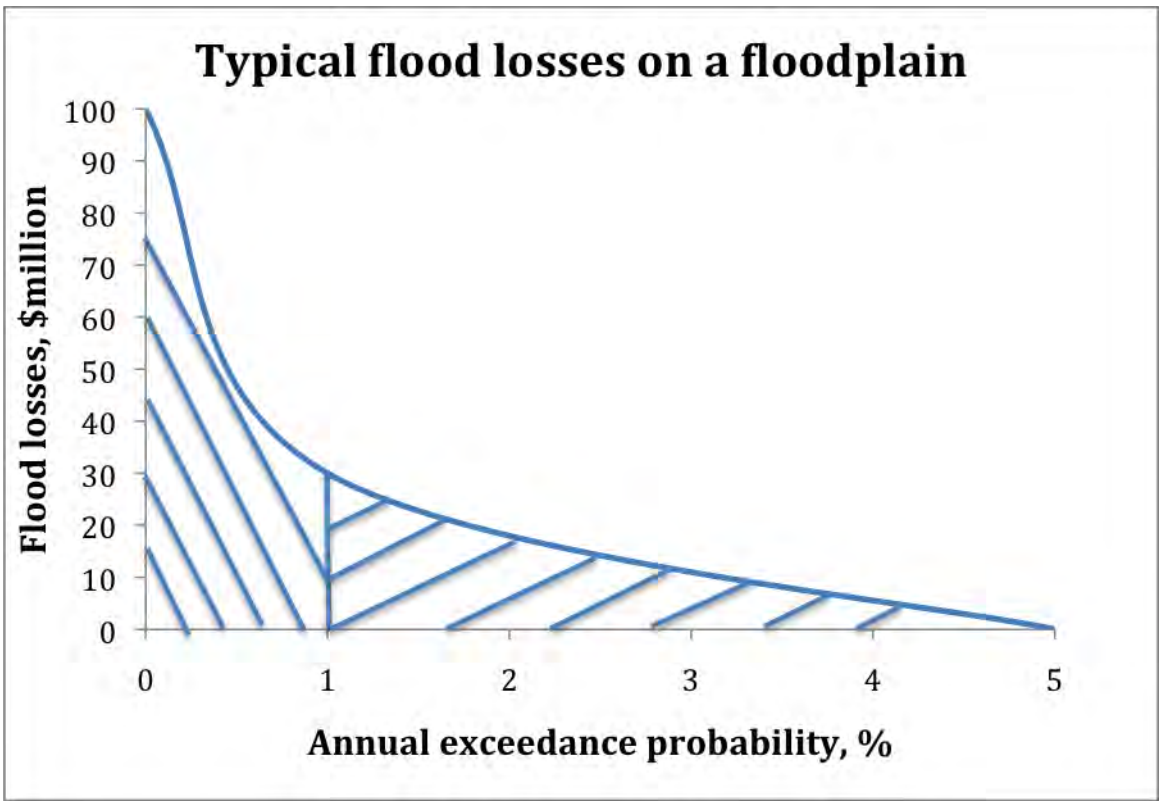

Figure 1 Typical plot of flood losses against AEP. Average annual losses are proportional to the area under the curve. The area for floods lower than the 1% level (on the left) is about the same as for floods greater than the 1% level (on the right).

It falls then to other techniques for mitigating losses from Large Floods, such as improving communal preparedness and warning systems and insurance. However as will be explained below, improving preparedness is inherently difficult to sustain, particularly for floods above the 1%AEP level. If flood insurance does become more accessible [Issues Paper 2.38], its design will need to take as much account of Large Floods as Small Floods, since it will be a major mechanism for addressing these losses.

(It might be noted that Figure 1, which is consistent with the results of all studies that I have been involved with, is quite different from what is depicted in Andrews et al (2008: Figure 2.2 and Tables 2.1 and 2.2), where the annual average losses from floods greater than the 1%AEP level are estimated to be very low. There may be several reasons for this. One is that the data for that paper was taken from records and reports of the Insurance Council of Australia. This data was for floods between 1970 and 2006, and it is quite likely that there were few floods higher than the 1%AEP level during that time. As well, the report relies on the work of Leigh and Gissing (2006), which largely considered only properties below the 1% level. Finally, as will be discussed below, many of the properties that were flooded would have been paid under storm and not recorded as flood.)

2.2 The awareness of the flood risk in a community inevitably declines with time since the last flood

Flood-prone communities tend to become less prepared for a flood over time following the previous event. If people or those close to them have experienced a flood, they are far more likely to prepare for the next one, and studies have shown that their losses are less than before (Schiff, 1977: 233, Lustig and Haeusler, 1989: 5). But as they die or move out, their replacements will mostly be unprepared for—if not unaware of—the hazard [Issues Paper 15.1]. Consequently, a first estimate of the decrease of communal awareness over time might be given by the turnover of the population. This is taken to be as illustrated in Figure 2, based on Equation A.2 in Appendix A. It allows for an

average population turnover for Australia of 23% over 5 years (ABS, 2010), where people changed to a residence in a different suburb or region. It ignores those people who may have moved into or out of a floodplain within the same suburb or region. Even with this conservative assumption, only about half the population who experienced the last flood will still be there 10 years later.

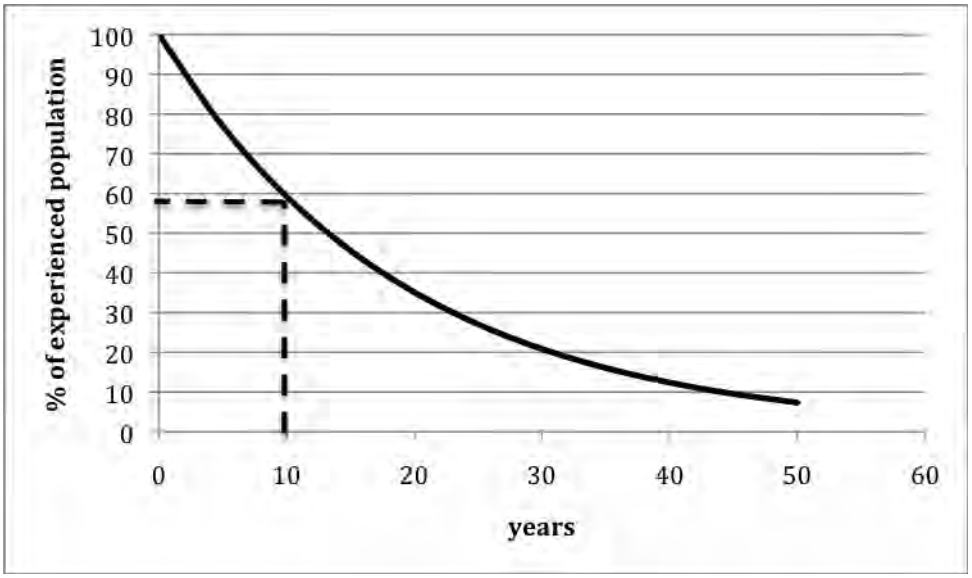

Figure 2 First estimate of decline in awareness of the flood hazard in an Australian community.

Even if people do observe a flood in their area but are unaffected because the flood does not reach them, they will tend to assume that they are likely to be safe from floods. This is because people tend to attribute favourable outcomes from risky circumstances to skill, and unfavourable outcomes to bad luck (Langer, 1975). Therefore, many of those who are flood prone, yet have been above a previous flood, may convince themselves that they are clever enough to have acquired a house above "the flood level". Typically, people may say that "floods come up to here", and resist the idea that larger floods will come (Slovic et al., 1984: 184). Thus, the expected communal awareness of large floods is likely to be small, as illustrated in Figure 3. This curve is a plot of Equation A.5 of Appendix A, calculated for Australia's turnover of population mentioned above. This indicates, for example, that on average perhaps no more than 14% of households would remain aware of the risks posed by a 1%AEP flood when it arrives. For larger floods, the likely percentage would be lower. While the interest in flood insurance would rise immediately after a flood [Issues Paper 2.38], it would fall to a negligible amount a short period later.

This low perception of the risk from Large Floods results in the political pressures for flood-risk management efforts being directed towards Small Floods. It is rare for resources to be allocated in an economically efficient manner, so that communal resources directed to managing the risk from Large Floods are equal to those for Small Floods. One cause of this is that few flood-risk management studies undertake economic evaluations of strategies for mitigating the losses from these large floods.

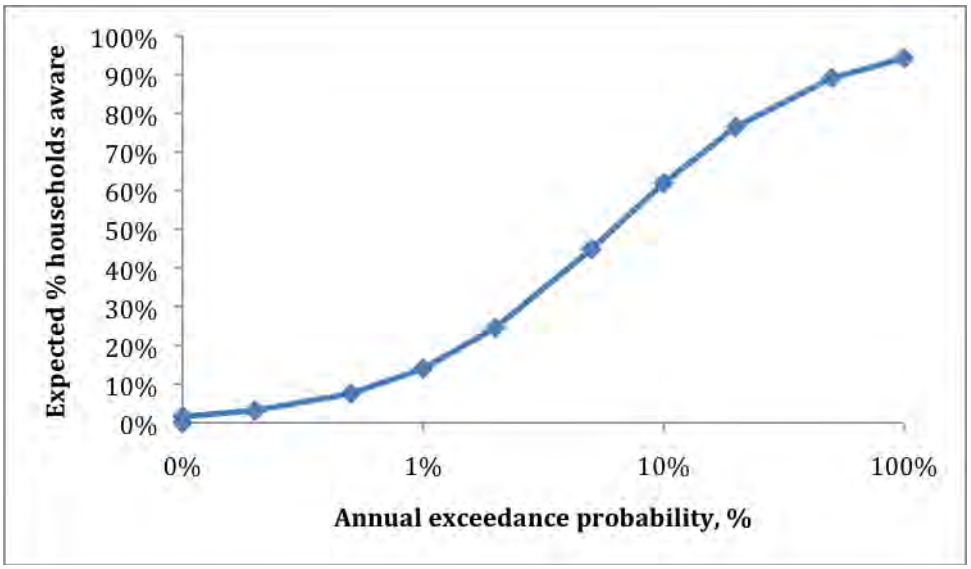

Figure 3 Expected awareness of community versus AEP

A further reason that Figure 2 is too conservative is that there are powerful psychological barriers that make it difficult to maintain resilience in a floodplain. These stem from the fact that it is important for mental health that we feel in control of our lives (Langer, 1977). Feeling helpless can be debilitating, and can even lead to death (Rodin and Langer, 1977: 900-2). Studies show that mental and physical stress can be more readily coped with if the subjects have a sense of control (Langer, 1983). This does not mean that they *are* in control, merely that they *perceive* they are in control.

For example, if people are simply informed that their house it is in a hazardous location, this may threaten their sense of control, if they feel they cannot eliminate the hazard. The only way they might then feel they can retain a sense of control is to deny the problem. [To appreciate how we might behave in such a situation, let us envisage that we have almost completed a large project. Then a newly recruited young graduate points out a fatal flaw. What is our reaction?]

I have frequently observed—immediately after a flood—people telling themselves that it couldn"t happen again. It is a source of frustration for floodplain managers who provide the community with information about a hazard to see it mostly ignored. This is one reason that the preparedness of a community will often decline even more rapidly than shown in Figure 2. To illustrate, following the 1974 floods in Brisbane, the price of houses on the floodplain dropped. They were back to "normal" two years later. Among people purchasing a home, there are not just those who are unaware of the flood risk [Issues Paper 2.18], there are also many who, for a range of psychological imperatives will deny or rationalise away the flood risk. An analogous example of this can be seen from the findings of Miransky and Langer (1978: 404), that people in New York apartments who believed their neighbourhood was unsafe used their locks *less* than those who perceived their neighbourhoods as safe. The writers suggested that the more apprehensive subjects might be trying to distance themselves from negative events. It is not always appreciated that people act not so much to minimise losses, but to minimise distress (Green, 1990: 46). This means that they will only start to reduce losses if they *perceive* that this is the most effective strategy for minimising distress and restoring control.

To sum up, there is only a weak correlation between awareness and behaviour. People may be aware of a hazard, but they can underestimate the risk (Saarinen, 1990: 281). This tendency can be found among floodplain-management experts, not just lay people (1990: 283). [The proportion of flood experts living in flood-prone areas may be an interesting number.]

In light of these considerations, it is suggested that an indicative curve such as in Figure 4 may be more realistic than that taken from Figure 2. [A more "accurate" depiction would depend on the hydrological and topographic characteristics of a particular floodplain, the geographic distribution of housing, the floor levels, and the population turnover.] Likewise, the curve of Figure 3 is probably too optimistic. It follows too, that if equity is an important criterion in the design of a national disaster insurance scheme, there should be no option for people to decline flood cover [Issues Paper 2.33-2.37]. Many people will find it psychologically challenging to appreciate that flood insurance is an important strategy for reducing future distress, and they may choose to opt out of flood cover in order to reduce their present distress [Issues Paper 15.3 to 15.5].

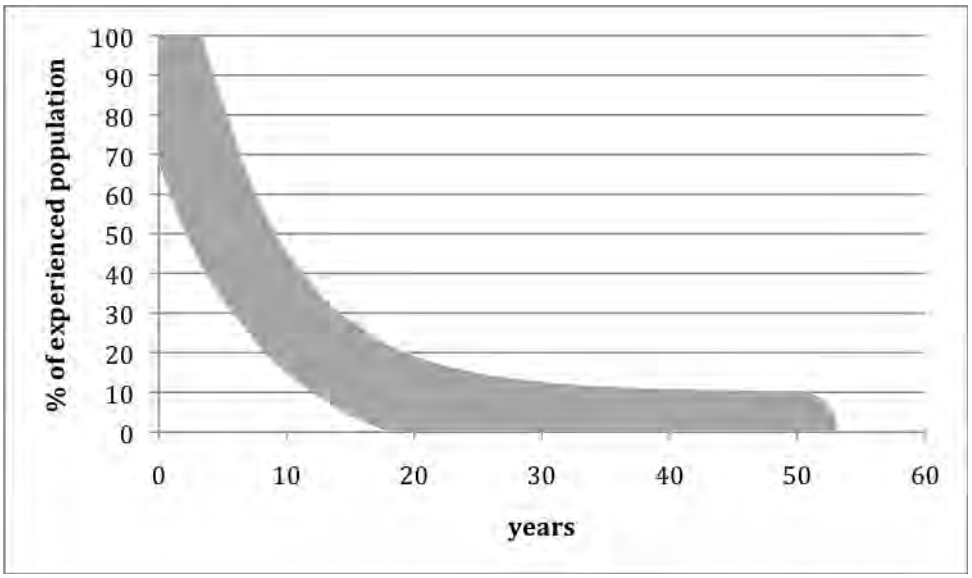

Figure 4 Modified estimate of decline of communal awareness of the flood hazard in an Australian community.

2.3 The decline in flood awareness results in reduced political pressures for maintaining the preparedness of the flood-prone community

One of the few strategies for mitigating losses from Large Floods is through emergency services. However, it would be prudent for insurers not to rely heavily on their effectiveness when setting premiums. Emergency-management systems are invariably made up of several government and non-government organizations.

As well, the people in an agency turn over through promotions, transfers and resignations, so that the experiences gained during the last disastrous event become less readily available. The longer the period, the less will be the appreciation by the emergency workers of the pitfalls in carrying out their duties and liaising with other organizations on a particular floodplain. For example, during investigations of the effectiveness of flood warning systems in northeast Victoria in the 1993 flood, I was told that the role of the SES was to combat floods, but not to warn (SKM, 1995: 31).

Unless there is very thorough training, the inexperienced replacements are unlikely to appreciate fully how they should work with others within the particular floodplain-management system. As a result, two inexperienced members of two cooperating organisations may have different understandings of who should do what, so that some tasks may be done inappropriately or left undone before, during and after the next flood. For example, a council flood-mitigation engineer may carefully design a retarding basin to reduce the flooding downstream, and then a council road engineer may carefully build a road above the flood level, restricting the flow of water into the retarding basin.

Figure 5 indicates that with an average 5-year turnover of staff and only four organisations in a flood-warning system (there can be more), the chances of coordination without too many mistakes could become small within a few years. Three curves are shown, labelled Optimistic, Moderate and Pessimistic. The assumptions made in deriving this figure were that an experienced member of staff would have a 95%, 90% or 85% chance respectively of not making a serious error, while a trained but inexperienced person would have an 85%, 80% or 75% chance; and that at time zero, all key personnel were experienced. The equation used for these curves is B.2 from Appendix B. A spreadsheet computing the graphs in this submission (other than Figure 1) can be provided, to allow the effects of alternative assumptions to be checked.

As it is, since it is unlikely for Large Floods to recur in less than 10 years, it can be expected that there will be negligibly few key personnel who will be experienced at the next event. This difficulty is compounded by the problems of coordination of government agencies even at the best of times. Yet coordination during an emergency is highly likely to encounter situations with little time for delicacy and subtlety.

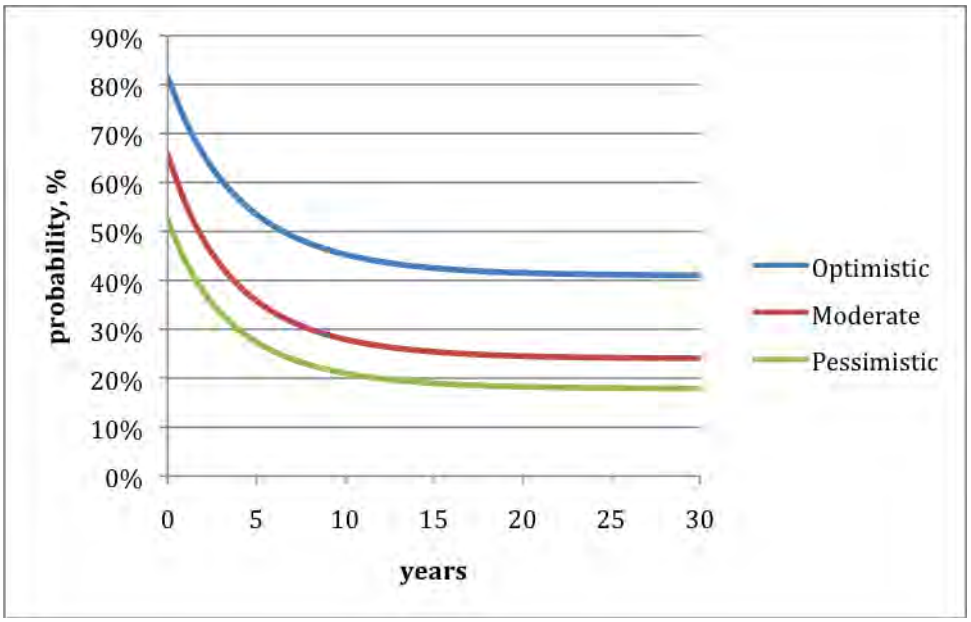

Figure 5 Theoretical decrease in probability of no serious errors within a local emergency management network

As time lengthens since the last event, the risk of an emergency agency being diverted from preparing for the next event increases, and funding diverts to areas where political pressures are greater. If this tendency cannot be resisted—and key emergency-management agencies are rarely politically powerful—the capacity of the agency declines. It is suggested that while strong efforts should be made to improve communication and coordination, we would do well to recognise, in designing a sustainable floodplain-management system, that coordination of flood-risk management has an appreciable risk of breaking down.

For these reasons, it is in the interests of insurers of flood-prone properties that there is continuing pressure to ensure that the various agencies in the emergency-management system remain prepared and coordinated. If the source of this pressure were the insurance industry, it would have the advantage that it was independent of government and that it had a continuing interest in sustaining its effectiveness.

3 Preparedness of commercial, industrial enterprises and government agencies

Commercial, industrial enterprises and public agencies are far less inhibited psychologically from

preparing for flooding than households when informed of the hazard. Some support for this was found following the Sydney floods of 1986 (Smith et al., 1990: 21). This is because businesses and public bodies tend to be less emotionally involved. Their decisions to locate on the floodplain stem mainly from financial considerations, and when businesses are aware of the risks of flood losses, these are generally treated as simply an additional financial consideration, possibly addressed by taking out flood insurance.

Since the financial losses from these sectors of the community are often greater than those suffered by households, it would make good economic sense to ensure that businesses are regularly informed of the risks and advised of strategies for reducing losses, particularly if flood insurance for business is to become more accessible [Issues Paper Chapter 7].

Conclusions

- The insurance industry may not fully appreciate that its liability for losses from flooding is large and growing, and that it already pays for most of it.

- Having Automatic Flood Cover is economically the most efficient option of those put forward in the Issues Paper.

- The benefits of universally available household flood insurance could be twofold: a substantial reduction in the economic cost of social losses; and enlisting a powerful group, insurers, with a continuing stake in sustaining communal resilience: in return for requiring the insurance industry to make flood insurance universally available to households, it should be invited to become a member of all flood-risk management committees. To enhance its interests and influence, the industry could be asked to fund the modest cost of the secretariats of these committees.

- The monetary losses to commerce and industry often exceed those incurred by households. As this is often covered by insurance, emergency management systems should be designed to facilitate insurers providing incentives to their clients to reduce their potential losses.

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APPENDIX A Decrease in community awareness of hazard with time

(I am indebted to Jim Irish, of the North China University of Water Engineering and Hydropower for this derivation. A version of this derivation was presented in SKM (1995).)

It is assumed that, unless there are sustainable measures to maintain preparedness, people will only apprehend the severity of the hazard if they have experienced it. Thus as people move out of the hazardous zone or die, their replacements will tend not to keep alive the communal awareness of the possible disaster.

Let m be the annual proportion of the community, which does not move out of the hazardous zone. Then if M is given by

$$m = e^{-M} \text{ or}$$

$$M = -\ln m \qquad \text{(A.1)}$$

and t is the time since the last disaster, then the proportion of the community that remains aware after time t is

$$m = e^{-Mt} \qquad \text{(A.2)}$$

Let t_D be the time from one disaster to the next. The proportion of aware members of the community that remain a year later is, on average

$$\frac{e^{-Mt_D}}{t_D} \qquad \text{(A.3)}$$

The probability of the period between disasters being t_D is

$$pe^{-pt_D}.\Delta t_D \qquad \text{(A.4)}$$

where p is the annual exceedance probability (AEP) of the hazardous event in any one year, and Δt_D is a convenient time interval. So the expected proportion of the community remaining aware for a given AEP is

$$\lim_{\Delta t_D \to 0} \sum_{t_D=0}^{\infty} \frac{e^{-Mt_D}}{t_D} .t_D.pe^{-pt_D}.\Delta t_D$$

As $\Delta t_D \to 0$, this expression becomes

$$\int_0^{\infty} e^{-Mt_D} pe^{-pt_D}.dt_D$$

$$= \frac{p}{p+M} \qquad \text{(A.5)}$$

APPENDIX B Decrease in effectiveness of a multi-agency emergency management network with time

(I am indebted to Jim Irish, of the North China University of Water Engineering and Hydropower for this derivation. A version of this derivation was presented in SKM (1995).)

Assume that an organisation involved in disaster mitigation turns its key personnel over on average every T_p years.

Assume too, that if a key person is experienced, their chance of not making a crucial error is M_e. Alternatively, if the officer is trained but inexperienced for a flood of this magnitude, the probability becomes M_{tr}.

Then if t_D is the time from the last to the next disaster, the probability P of there being an experienced person in charge is

$$e^{\frac{-t_D}{T_p}}$$

Likewise, the probability of there being only a trained, inexperienced person in charge is

$$1 - e^{\frac{-t_D}{T_p}}$$

So the probability of there being no serious mistake during an event at time t_D is

$$M_e.e^{\frac{-t_D}{T_p}} + M_{tr}(1 - e^{\frac{-t_D}{T_p}})$$

$$= M_{tr} + (M_e - M_{tr})e^{\frac{-t_D}{T_p}} \qquad \text{(B.1)}$$

If there are n such organisations with similar characteristics, the probability of no serious error becomes

$$P_n = \left\{ M_{tr} + (M_e - M_{tr})e^{\frac{-t_D}{T_p}} \right\}^n \qquad \text{(B.2)}$$

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ACADEMIC QUALIFICATIONS:

Bachelor of Science (Maths), Sydney University, 1963
Bachelor of Engineering (Hons 1) (Civil), Sydney University, 1965
Master of Engineering Science (Water Engineering), University of N.S.W., 1970
Doctor of Philosophy (Ecological Economics), University of N.S.W., 1984

PROFESSIONAL AFFILIATIONS:

Fellow, Institution of Engineers, Australia
Member, Australian Water Association.
Member, International Society for Ecological Economics
Honorary Research Associate, Department of Archaeology, University of Sydney, 2000-present.

CAREER & SPECIALISED COMPETENCE:

Forty-seven years experience in consulting, government and academic work in Australia, N.Z., Asia, Oceania, Europe and Africa: particular experience in economics of total watercycle management and natural disasters, ecological economics, on-site wastewater management, water engineering, environmental management and archaeology of water engineering.

PROFESSIONAL ACTIVITIES:

Engineers Australia: Founding Chairman, Environmental Engineering Panel, Sydney Division 1984-6; member sub-committee on environmental education, 1985-1989; Convenor, Seminar on Environmental Impact Assessment, 1987; publicity officer, 1987-89; Convenor Environmental Ethics Sub-Committee, 1989. Representative on Standards Australia/Standards New Zealand Committees WS-13-1 On-site Domestic Wastewater Management 2005-present. Representative on Standards Australia Committee WS-013-06 Domestic Greywater Treatment Systems 2010-present.

Australian Water Association: Representative on Standards Australia/Standards New Zealand Committees WS/13/1 On-Site Domestic Wastewater Management 1995-2000; WS/13/15 Waterless Composting Toilets 1995-2001 (Acting Chairman, 2001); WS/13/4 Aerated Wastewater Treatment Systems 2001; WS/13 Septic Tanks 1995-1998; Committee Member, National On-site Systems Interest Group (NOSSIG) 1997-2001.

NSW Department of Health: Member, Composting Toilet Performance Criteria Working Group 1995.

RedR Australia: Registered Engineer for Disaster Relief 1999-2008.

Department of Local Government: Representative on Technical Advisory Panel for On-site Sewage Management representing the Nature Conservation Council 1999-2001.

VOLUNTARY ACTIVITIES:

Deputy Chairperson, Traffic, Kensington-Kingsford Precinct Committee, 2000-2005. Precinct Representative, Randwick/Sydney Councils Flood Risk Management Committee, 2006-present.

LANGUAGES:

German - Good; French – Good; Japanese, Indonesian, Vietnamese, Khmer, Chinese - Conversational.

PERTINENT PROFESSIONAL EXPERIENCE:

1982-Present: ENVIRONMENTAL MANAGEMENT PTY. LTD.
Managing Director

Economic, Environmental & Water Studies

- Research Associate, Department of Archaeology, University of Sydney – Investigating the history of the water levels in the Dian Lakes of Kunming, Yunnan, China for the last 10,000 years, 2008 - present.
- Research Associate, Department of Archaeology, University of Sydney – Investigating the water-management systems of past settlements in Myanmar, 2006-2007.
- South Brighton Spit, Christchurch – advice on stability of tidal inlet and risk of coastal erosion (NZ Cashflow Control), 2002-2003.
- Water Sensitive Urban Design, Baulkham Hills, NSW - Design of a residential subdivision on a remnant farm in an urban catchment to improve the sustainability of the watercourse, to increase the biodiversity of the riverine zone, to mitigate the flooding and pollution downstream, and to enhance the residential amenity, 2001-2009.
- Team Leader - Water, Greater Angkor Project (Department of Archaeology, University of Sydney; École Française d'Extrême Orient; and APSARA, Royal Kingdom of Cambodia). Advising on the history of Central Angkor's water system and its consequences, 1999-2007.
- Environmental Specialist, Refugee Camps, Albania (United Nations High Commissioner for Refugees) Developing Environmental Guidelines for and rehabilitating tented refugee camps and refugee-affected areas, 1999.
- Papamoa Coastal Hazard Zones, New Zealand, Advice on economic and technical adequacy of procedures used for zoning coastal hazards, 1998-2002.
- NSW Floodplain Management Manual (Department of Land and Water Conservation, NSW) Incorporating the concept of ecologically sustainable development into the revised manual, 1996-7.
- Opotiki Healthcare Centre, New Zealand (in association with the Grafton Group, Auckland) Economic and social benefits of a controversial replacement of a flood-free hospital with a flood-prone healthcare centre, 1996.
- Ourimbah Creek Salinity Intrusion (FAI Insurance) Investigation of cause of intrusion of salt water over weir in Ourimbah Creek, 1992-4.
- Duck Creek Flood Mitigation (Water Board) Review of Environmental Factors for pruning of mangroves, 1992-3.
- Local Government and Resource Management Law Reform Program (New Zealand Local Government Association) Advice on feasibility of limitations on liability of local government for flood losses, 1990.
- Coastal Erosion Management (Coastal Council of NSW): Advising on social surveys to evaluate coastal residents' perceptions and apprehensions of the hazards of living very near to the coast, 1983.

Sustainable Water-Disaster Management

- Kiama 2011 (A&G) advice on the causes of inundation of property.
- Goulburn & Bigga 2010 (Elders, A&G) advice on the causes of inundation of property following floods.
- Ulmurra, 2009 (ARGIS) advice on causes of inundation of a property.
- Tamworth & Nundle, 2009 (NRMA, QBE) advice on the causes of inundation of property.
- Hunter Valley & Lake Macquarie, 2007 & 2008 (Allianz, CGU, Freeman McMurrick, Lumley, QBE, Western QBE) advice on the causes of inundation of property.
- Helensburgh, 2007 (Allianz) advice on the causes of inundation of property.

- Berry, 2005 (Allianz) advice on the causes of inundation of property.
- Appletree Street, Wingham (private clients) Representation in Land and Environment Court for Development Applications on flood-prone land, 2003.
- Edgewood Estate, Woonona – advice on flooding nuisance caused by residential developer (Mr Bugs Pest Control), 2002-2003.
- Gateway Island Development Plan – Independent Risk Management Assessment (North East Catchmant Management Authority and Wodonga City Council) Investigation of feasibility of residential, commercial and tourist development within the floodplain of the Murray River, 2001.
- Trial Bay Tourist Park Flood Risk Management Study, 2001.
- Macleay River Floods, March 2001 (Fortis, AAMI, CGU) Advice on causes of inundation of property, 2001.
- Wollongong Floods, August 1998 (QBE and Western QBE) Advice on legal causes of flood losses at Wollongong, 2001-2002.
- Namoi Valley Floods, November 2000 (Western QBE, NRMA) Advice on causes of inundation of property, 2000-2001.
- Hampton Court, Lansdowne Advice on legal liability for approving residential development in swampy ground, 2000-2004.
- Wollongong Floods, August 1998 (private clients) Advice on legal liability of Wollongong Council for the flood losses at Wollongong, 1998-2000.
- Flood Insurance Pilot study on feasibility of developing a scheme for flood insurance, 1998-1999.
- Wollongong Floods, August 1998 (NRMA Insurance, QBE, WQBE, Australian Alliance, and others) Advice on causes of inundation of property, 1998-2000.
- Townsville Floods, January 1998 (Insurance Enquiries and Complaints, General Insurance Panel) Technical Advisor to Panel at Hearing, 1998.
- Sea-Dyke Upgrading North Viet Nam (United Nations Development Program and World Food Programme) Evaluating the sustainability of the maintenance program for sea and estuarine dykes and developing a manual for estimating the average annual maintenance, 1998.
- Sydney Floods April 1998 (NRMA Insurance, GIO Insurance) Advice on causes of inundation of property, 1998.
- Townsville Floods January 1998 (Insurance Council of Australia, NRMA Insurance, CIC Insurance, Commercial Union, Munich Reinsurance) Advice on causes of inundation of property, 1998.
- Pegasus Bay New Town Development New Zealand (Pegasus Bay Coastal Estates) Economic, planning and technical oversight of water-disaster planning and environmental risk management, 1997-1999.
- Coffs Harbour Flood November 23 1996 (NRMA Insurance) Reports on flooding of clients' houses, 1997.
- Lismore Flood Mitigation (Lismore City Council) Evaluation of social and economic effects of preferred floodplain management options (in association with Sinclair Knight and Partners), 1997-1999.
- NSW Floodplain Management Manual (Department of Land and Water Conservation, NSW) Incorporating the concept of ecologically sustainable development into the revised manual, 1996-7.
- Waikanae Floodplain Management Plan (Wellington Regional Council, NZ) Advice on developing a sustainable floodplain management plan, 1996-97.
- Pakistan Assessment of Performance of Flood-Restoration Works (Asian Development Bank) Assistance with Project Evaluation Review of works following large floods in the Indus Basin, 1996.
- Ourimbah Creek Floodplain Management Plan (for Wyong Shire Council in association with ACER Wargon Chapman), 1994.

- Sea-Dyke Upgrading Central Viet Nam (United Nations Development Program) Development of a sustainable scheme for local asset management of sea and estuarine dykes, 1994-96.
- Water-disaster mitigation in Viet Nam (United Nations Development Program) Chief Technical Writer for International Consultation on Viet Nam's Strategy and Action Plan, and Technical Writer of Update and Policy on Sustainable Water-Disaster Mitigation, 1994-5.
- Flood-Warning Services for Northeast Victoria (Flood Warning Consultative Committee, Victoria) Review of effectiveness during floods of October 1993, and sustainable improvement of warning system, 1994-5.
- Woronora River Floodplain Management Plan (for Sutherland Shire Council in association with ACER Wargon Chapman), 1994-5.
- Coastal Flash-Flood Warning Study (NSW Public Works) Assessment of wider benefits of system studied earlier, 1994-96.
- Waimakariri River South Arm (Canterbury Golf International) Advice on locating a golf course, hotel and residences in a floodway, 1994-98.
- Handbook for preparing emergency loans (Asian Development Bank) Preparing handbook for rapid assessments of emergency rehabilitation projects after disasters, 1994-96.
- Sanctuary Point Floodplain Management Study (Shoalhaven City Council) Preparation of Floodplain Management Plan, 1992.
- Water-disaster mitigation in Vietnam (United Nations Department of Humanitarian Affairs) Team leader of international consultants and national experts preparing a Strategy and Action Plan, 1992-4.
- Darling Mills Retarding Basin (Upper-Parramatta River Catchment Trust) Re-evaluation of benefits of proposed retarding basin, 1992-3.
- Hanoi Dyke (Asian Development Bank) Economic, social and environmental evaluation of feasibility of upgrading, 1992-3.
- Song Chu and North Nghe An Irrigation Projects Viet Nam (Asian Development Bank) Economic evaluation of benefits of upgrading irrigation structures which were at risk of failure, 1992-3.
- Sheas Creek Catchment Management Study (The Water Board) Economic and social evaluation of flood-mitigation strategies, 1992-3.
- Red River Delta and Central Coast Vietnam (United Nations Development Program) Economic and social evaluations of flood-mitigation strategies, 1992.
- Darling Mills Creek (Upper Parramatta River Catchment Trust) Economic and social evaluation of flood-mitigation strategies. (in association with Bewsher Consulting), 1991-2.
- St. Georges Basin Flooding Survey (Shoalhaven City Council) Survey of effects of floods of 1991, 1991-2.
- Rose Bay Catchment Management Study (The Water Board) Evaluation of social and economic effects of floodplain mangement options (in association with Patterson Britton.), 1991
- Lismore Flood Mitigation (Lismore City Council) Evaluation of social and economic effects of a range of floodplain management options (in association with Sinclair Knight and Partners), 1991-5.
- Flood Mitigation Nowra (Shoalhaven City Council) Formulation of criteria for development on floodplain, 1992.
- Social and economic evaluation of floodplain management strategies (The Water Board) In-house workshop for senior stormwater engineers, 1992.
- Coastal Flash Flood Warning Study (Public Works Department) Evaluation of social and economic benefits of a flash flood warning system for the Wollongong - Newcastle - Sydney region (in association with ISMES), 1991-2.
- Cup and Saucer Creek Catchment Management Study (The Water Board) Evaluation of social and economic effects of flooding (in association with the Water Board's Stormwater Drainage Section), 1991.

- Cooks River Catchment Management Study (The Water Board) Evaluation of social and economic effects of flooding (in association with Binnie & Partners.), 1991.
- Burns Creek Catchment Management Study (The Water Board) Evaluation of social and economic effects of flooding (in association with Kinhill Engineers Pty. Ltd.), 1991.
- Sanitation Drainage and Flood Mitigation Study for the Kaleerwe-Kavule Area Kampala Uganda (Church of Uganda and Auckland Diocese of Anglican Church), 1990.
- Parramatta Floodplain Management (Upper Parramatta River Catchment Trust) Evaluation of economic effects of flooding of CBD, 1990.
- Floodplain Development Nowra (Theo Mavromattes) Advice on flood-resistant designs for housing, 1990.
- Penkivil Street Waverley Catchment Management Plan (The Water Board) Evaluation of social and economic effects of flooding (in association with Dames & Moore), 1990.
- Raglan St. Manly Catchment Management Plan (The Water Board) Evaluation of social and economic effects of flooding and environmental planning (in association with Binnie & Partners), 1990.
- Whites Creek Leichhardt Catchment Management Plan (The Water Board) Evaluation of social and economic effects of flooding (in association with Gutteridge Haskins & Davey), 1990.
- Shoalhaven River Bank Protection (Shoalhaven City Council) Vegetative stabilisation of river bank adjacent to Australian Pulp and Paper Mill's factory, 1990.
- Ettymalong Creek Flood Damages (Gosford City Council) Estimation of flood damages caused by development on a swamp, 1990-1.
- Waimakariri River Floodplain Management Plan (Canterbury Regional Council, New Zealand) Technical Adviser, 1989-90.
- Hutt River Flood Control Scheme Review (Wellington Regional Council, New Zealand) Technical Adviser, 1989.
- Lismore Floodplain Management (Lismore City Council) Survey of economic effects of flooding on commercial establishments in Lismore in April 1989.
- Floodplain Management Bankstown (GEC Projects) Advice on means of mitigating losses from flooding, 1989.
- Floodplain Management Nowra (Shoalhaven Milling Company) Advice on future development to mitigate flood losses, 1988.
- Flood Mitigation Nowra (Shoalhaven City Council) Report on potential for flood damage and means of mitigating losses for new urban development, 1988.
- Sydney Floods 1988 (Public Works Department) Reevaluation of losses in Georges River along the same lines as for the study following the flood of August, 1986 (1988-9).
- Sydney-Newcastle Floods 1988 & 1989 (NRMA Insurance) Report on flooding of clients' houses, 1988-9.
- Lismore Floodplain Management (Lismore City Council) Advice on strategies for staged programme of flood mitigation for Lismore, 1988.
- Blacktown Creek Flooding (NRMA Insurance) Report on flood damage in Blacktown Creek and means of mitigating losses, 1988.
- Floodplain Management (Ministry of Works and Development, N.Z.) Advice on formulation of new practices and procedures for floodplain management in New Zealand, 1988-9.
- Flood Insurance (National Roads and Motorists' Association) Advice on appropriate policies and practices for assessing flood damage. Advice on the feasibility of flood insurance. Assessment of flood damage claims, 1988-9.
- Sydney Floods Study (Public Works Department and Department of Water Resources) Evaluation of economic losses, social impacts, efficacy of warning and emergency systems in floods of August, 1986 and

assessment of losses in other floods. Derivation of empirical relationships for assessing future losses elsewhere in Australia, 1986-8.

- Bankstown Square Shopping Centre (Civil and Civic): Advice on preparing submission to Council to vary its flood policy for this shopping centre, 1983.
- Grafton Flooding (Clarence River County Council): Redetermination of appropriate flood-frequency distribution for Grafton, 1982-3.
- Grafton Flood Mitigation (Clarence River County Council): Social and economic effects of an augmented levee system to protect South Grafton, 1982-4.

1982-83: Completed doctorate in environmental economics and environmental management.

1981-82: SINCLAIR KNIGHT & PARTNERS
Project Manager, Water Engineering Section: Economic Evaluation of Flood Mitigation Proposals (Department of Environment and Planning): Setting out a manual of procedures for evaluating the economic (cost-benefit) effects of flooding, and of the various options for mitigating these effects.

1979-81: NEXUS ENVIRONMENTAL STUDIES
Senior Environmental Engineer, engaged primarily on studies and planning for proposed oil shale mines in Queensland.

1976-69: UNIVERSITY OF N.S.W.
Doctoral Research Fellow, and tutor in multi-objective planning and systems engineering.

1972-76: PUBLIC WORKS DEPARTMENT, W.A.
Resident Engineer, in charge of Engineering Research Station, investigating hydraulic and geomechanical problems.

1965-72: PUBLIC WORKS DEPARTMENT, N.S.W.

1967-72 Hydraulics and Soils Laboratory, second in charge from 1968. Also responsible for a range of hydraulic and structural model studies.

1965-67 Assistant to Resident Engineer, Hume Reservoir, investigation of and construction for improvements to security of dam.

PERTINENT PUBLICATIONS

- Aeolian-induced cyclic meandering of an ephemeral deltaic river mouth 3rd Australian Conference on Coastal Engineering, Institution of Engineers, Australia, 1978.
- A systems approach to environmental engineering and planning. T.L. Lustig and R.N.Hirst, Conference on the Marine Environment Townsville 1981, Institution of Engineers, Australia.
- Tangible urban flood damage: an outline manual D.I. Smith, T.L. Lustig and J.W. Handmer, 2nd National Local Government Engineering Conference, Brisbane, 1983. Reprinted in Yip, Y.H. and Low, K.S. (Eds.) Urbanization and ecodevelopment with special reference to Kuala Lumpur. Institute of Advanced Studies, University of Malaya, Kuala Lumpur, 1985.
- Multiple-objective water resources planning: two opposing views on objectives T.L. Lustig and D.T. Howell, Hydrology and Water Resources Symposium, Hobart, 1983.
- An approach to assessing the effectiveness of urban floodplain management in Australia D.I. Smith, J.W. Handmer and T.L. Lustig Hydrology and Water Resources Symposium, 1986, Brisbane.
- Estimating actual from potential flood damages, and assessing alternative floodplain management strategies. T.L. Lustig, J.W. Handmer and D.I. Smith Hydrology and Water Resources Symposium, 1986, Brisbane.
- Assessing intangible flood damages for evaluating urban floodplain management options. J.W. Handmer, T.L. Lustig and D.I. Smith, Hydrology and Water Resources Symposium, 1986, Brisbane.
- The Sydney Floods of 1986 - losses, payouts and the future. D.I. Smith, M.A. Greenaway, J.W. Handmer and T.L. Lustig, 27th Annual Conference of Flood Mitigation Authorities of New South Wales. Penrith, 1986.

- The Sydney Flood Warning System, August, 1986. J.W. Handmer, M.A. Greenaway, T.L. Lustig and D.I. Smith, 27th Annual Conference of Flood Mitigation Authorities of New South Wales. Penrith, 1986.
- The Sydney Floods of 1986: Warnings, Damages, Policy and the Future. J.W. Handmer, D.I. Smith and T.L. Lustig, Hydrology and Water Resources Symposium, 1988, Canberra.
- Losses and Lessons from the Sydney Floods of August, 1986. T.L. Lustig, D.I. Smith, J.W. Handmer and M.A. Greenaway, CRES, ANU, Canberra, 1990.
- Social and Economic Effects of Floods T.L. Lustig and T.M. Haeusler, 29th Annual Conference of Flood Mitigation Authorities, Batemans Bay, 1989.
- Environmental education for engineers: an Australian viewpoint. Co-author as member of Environmental Education Subcommittee of Environmental Engineering Panel of Sydney Division of Institution of Engineers. Reprinted in The Environmentalist 9, 3, 197-200.
- Floodplain Management in New South Wales and New Zealand: lessons from a study of similarities and differences. T.L. Lustig and D. Bewick. Hydrology and Water Resources Symposium, 1989, Christchurch.
- Flood Insurance - A Social Blessing? 30th Annual Conference of Flood Mitigation Authorities, Wollongong, 1990.
- The applicability of the New South Wales Floodplain Development Manual to Kampala, Uganda. 31st Annual Conference of Flood Mitigation Authorities, Port Macquarie, 1991.
- A method for the rapid assessment of the economic benefits of strategies for mitigating floods with limited data: the case of North and Central Vietnam, in Vietnam: Proceedings of the International Workshop on Flood Mitigation, Emergency Preparedness and Flood Disaster Management, 22-25 June, 1992. Hànôi. UNDP and Socialist Republic of Vietnam.
- Editor. Vietnam: Proceedings of the International Workshop on Flood Mitigation, Emergency Preparedness and Flood Disaster Management, 22-25 June, 1992. Hanoi. UNDP, UNDRO and Socialist Republic of Vietnam.
- Strategy and Action Plan for mitigating water disasters in Viet Nam Lustig, T.L., Glemarec, Y., Solomatine, N., Silver, M., and Aamodt, T. (1993) UNDP, UNDHA and Socialist Republic of Vietnam, Hanoi.
- J.L. Irish and T.L. Lustig (1993) Economic evaluation of coastal protection strategies. 11th Australasian Conference on Coastal and Ocean Engineering, Townsville. Inst. Eng. Aust., Canberra.
- Chief Technical Writer, A Review of the disaster-related activities of the Asian Development Bank: an economic perspective, by G. Hecker, International Conference on the International Decade for Natural Disaster Reduction, Yokohama, 1994.
- Benefits of a Flash-flood warning system for the Sydney-Newcastle-Wollongong Region: Progress Report. 34th Annual Flood Mitigation Conference, Inverell, N.S.W., 1994.
- Proceedings of International Consultation on Strategy and Action Plan for Mitigating Water Disasters in Viet Nam. Hanoi, 1994, Chief Technical Writer.
- First Update of the Strategy and Action Plan for Mitigating Water Disasters in Viet Nam. UNDP, UNDHA and Socialist Republic of Vietnam, Hanoi (1995), Chief Technical Writer.
- Managing disasters sustainably in developing countries, in Vlasta Molak, Fundamentals of Risk Analysis and Risk Management. Lewis Publishers, NY, 1996.
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- Lustig, T. Linking downstream to upstream in landscape archaeology: some South East Asian examples. EURASSEA, Berlin 2010 (submitted for publication).