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AN ASSESSMENT OF THE ROLE OF INSURANCE AND STRUCTURAL MEASURES IN FLOOD MITIGATION PLANNING*

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There is no entirely satisfactory strategy to mitigate the risks associated with flooding. In Australia, reliance is usually placed on structural measures; however, an appraisal under different criteria highlights reasons for their inadequacy. Insurance is initially advocated as an alternative and appraised under similar criteria. It is shown to be a useful mitigation strategy, although somewhat limited in that it is merely a palliative to the flood problem. An alternative approach to flood mitigation is hypothesized which incorporates insurance as its base and utilizes other measures, particularly structural, where feasible. Such an approach is shown to effectively maximize the beneficial features of both insurance and structural measures. Problems relating to the workability of the scheme are subsequently analysed.

1 INTRODUCTION

Recent occurrences of flooding in Australia have highlighted the inadequacy of existing flood mitigation policy. Based ostensibly on a philosophy of containing the flood itself, it bears no consideration to residual risk and the creation of appropriate incentives for efficient floodplain management.

Given the assumption that society is averse to risk, there is justification in attempting to mitigate the risk. Two basic approaches may be adopted. One is to attempt to take some control over the hazard by the use of structural measures (e.g. levee banks, dams and channel improvements). Alternatively the burdens resulting from the occurrence of the hazard could be mitigated by non-structural measures (e.g. zoning ordinances, flood forecasting and warning systems, flood proofing, land use conversion, and insurance).

The most appropriate strategy for flood mitigation is uncertain. This paper attempts to clarify this uncertainty by first analysing each approach to determine whether either represents a socially desirable means of mitigation (section 2). An alternative strategy is postulated and investigated (section 3) on the hypothesis that neither basic approach achieves the desired end. The implications which can be drawn from the analysis are discussed in section 4.

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The method of analysis adopted in the paper is to evaluate the alternatives in terms of a multidimensional social welfare function [27, 51]. This approach is widely used for appraising water resource projects in the United States [77, 78, 79], and is now recommended by the Australian Government for use in this country [16]. The appropriate number of dimensions to the function can vary, although four are most frequently used: economic growth, social welfare, regional development and environmental quality.[1]

For exemplary purposes, structural measures in the general sense, are assumed to represent the first alternative. Insurance is used as an example of the latter approach, mainly because in theory at least, it, more than any other non-structural measure, is most likely to eliminate the risks associated with flooding. Moreover, there is evidence of an increasing public demand for insurance.[2]

A useful array of literature is available on each alternative. The role of structural measures in the flood mitigation context is relatively well documented [33, 40, 47, 61, 75, 82]. Most work on flood insurance has emanated from the United States [30, 31, 32, 41, 43, 47, 62, 74], where a dubiously successful flood insurance scheme operates under a Congressional Act [76].[3] In contrast, little direct work on flood insurance has been undertaken and published in Australia [25, 34].

2 EVALUATION OF MITIGATION ALTERNATIVES[4]

2.1 Economic Growth

When an investment causes the net value of the nation's output of goods and services to increase, that particular investment will make positive contributions to economic growth. The contribution of structural measures and insurance to this end is now reviewed.

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[1] Initial evaluation could be made with either of two underlying assumptions. The objectives will normally be specified, while the weights relevant to each may or may not be. For the purpose of this paper, weights are not specified, and each objective is considered of equal importance, although final decisions could be made with different emphasis on particular objectives. In evaluating a strategy, assessment is made in terms of the beneficial and adverse effects on each objective Included among the effects can be the opportunity costs of supporting one objective, *vis-a-vis* others [12]. The expression of effects does not require quantitative assessments, mainly because it is not always possible to do so for some objectives. The multidimensional approach therefore represents nothing more than a "consumer's" report of project effects for project selectors [46].

[2] This was noted several times in the press in 1974.

[3] Haveman [32] questions the success of the scheme.

[4] The theory, or "state of the art", is not well developed for welfare, regional and environmental quality objectives, and much of the argument in respect of these objectives may therefore be perceived as being merely observations, axioms or even asides.

Structural Measures

It is usual to determine an investment's contribution to economic growth by benefit-cost analysis [22, 55, 63, 69]. Positive contributions are assumed to be made if the ratio of discounted benefits to costs is in excess of one. Notwithstanding, the mechanics of benefit-cost analysis are often questioned [4, 8, 13, 26], with implications relating to the true contribution of that investment to economic growth, and the efficiency of resource allocation in a macro sense.[5] Moreover, some inherent characteristics of the structural measures themselves, and the nature of their provision, may impede an efficient allocation of micro resource units.

Consider first the mechanics of benefit-cost analysis. It is widely recognized that measurement errors in respect of benefits and costs, and the choice of discount rate, can seriously distort the true economic worth of a project. It is usual to include as benefits of a structural flood mitigation measure, the reduction in damages incurred with the implementation of the measure, and the value of productive output which would otherwise be foregone in the absence of the measure (the opportunity cost of inundated land). Conversely the costs relate to its construction, use and maintenance. Clearly the accuracy of estimates about the timing and magnitude of benefits and costs will influence the validity of the benefit-cost ratio. On the question of timing, accuracy will be difficult when there is variability in the annual net benefits of flood mitigation [34].

Apart from errors in estimation, the magnitude of net benefits can be affected by the inclusion/exclusion of certain benefits and costs under efficiency criteria. The problems relating to the inclusion of secondary effects and externalities for example, have largely been overcome by the adoption of multiobjective appraisal techniques [46, 56, 72]. Likewise the problem of opportunity costs have been overcome with this technique.[6] Contention still remains, however, over the inclusion of land enhancement effects [47].[7] There is also the possibility of double counting when structural projects are designed to serve a range of purposes, e.g. flood mitigation, water supply, irrigation and power.

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[5] A necessary condition for an economically efficient allocation of resources is assumed to be a benefit-cost ratio in excess of one. But it is not a sufficient condition for the most efficient allocation, either in one particular location or spatially. In this latter sense, a large proportion of the mitigation work undertaken in New South Wales has been in coastal areas, as distinct from inland areas. The choice of one location in favour of another for a mitigation structure should depend on a comparison of the respective gains and losses with each alternative [20].

[6] For example, it is possible to determine the effect on efficiency, of achieving a certain level of security.

[7] Primarily these effects relate to land enhancement benefits which may be defined as the prevention of damages to development influenced by the particular measure, and the potential utilization of land more intensively, after the provision of the measure. Nonetheless, the net effect of land enhancement may be adverse. Richmond shows that in certain circumstances, farmers will be worse off financially by intensive development of a newly protected area [68]. These effects are distinct from development induced as a result of economic growth occurring without the implementation of the measure.

In respect of the question of the efficiency of micro-units locating on the floodplain, it is common for structural measures to be provided as public goods because of the failure of a competitive market to emerge for their supply and demand. Primarily the market fails because many are of an indivisible nature, and cannot be provided in individual units because of technological externalities [66]. Further it is not possible to subject beneficiaries to the "exclusion principle". This means that no pricing system has been successfully implemented which would make it possible to exclude those beneficiaries unwilling to pay in order to receive the direct benefits [31]. The benefits are accordingly provided at a zero or highly subsidized price to the beneficiaries, who may also receive windfall gains with the capitalization of mitigation benefits into property values.[8]

The provision of structural measures at less than their economic worth becomes a perverse incentive for inefficient activities to locate on the floodplain.[9] The incentive is amplified when the occupant perceives the protection offered to be absolute [81]. Other perverse incentives include the expectation of further publicly financed protection measures,[10] and the natural desire of society to provide relief and rehabilitate occupants affected by a hazard at less than the economic cost of that relief and rehabilitation.[11]

Insurance

Arrow [2] designates two ways of improving the allocation of resources under uncertainty. The first is public intervention with the government effectively able to adopt a neutral position with regard to risk. This is synonymous to the case for public provision of structural mitigation measures outlined in the previous section. The nature of the product however, rendered inducements to an inefficient allocation of resources on the floodplain.

The second means to improvement is the existence in sufficient variety of markets for contingent claims (insurance markets). In the case of flooding, a market for contingent claims which incorporates an annual occupancy charge (premium), will, in theory at least, allow the use of economic incentives to induce an efficient allocation of resources on the floodplain. A requirement for efficient location will be where the premium is at least equal to the full social costs of occupancy. These consist of the mean annual expected losses through flood damage together with loadings for administrative and transactions costs, and risk bearing.

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[8] An argument against competitive allocation is that benefits indirectly accrue to society as a whole. Beggs [10] for instance estimated significant costs to society in road closure due to flooding.

[9] These activities are inefficient in the sense that if required to pay for the mitigation benefits received, they could not feasibly locate.

[10] Krutilla [41] suggests a significant part of the increase in damage potential on urban flood plains in the United States has been in response to proposed future structural mitigation measures.

[11] For example, fodder is often dropped by air to flood affected stock, with the charge to the owner being far less than the actual cost of providing that relief. Government financed low interest loans are another form of subsidization.

Thus by resorting to the economic incentives of prices and charges, an insurance scheme will mean rational occupation is only possible if locational benefits exceed the locational costs inclusive of the insurance premium. Insurance should consequently offer significant benefits in terms of allocative efficiency. If it is optional, it will at least subject occupants to the "exclusion principle", while if mandatory, it will induce a more efficient and socially desirable distribution of resources.

An additional efficiency benefit of insurance is that it can allow risky activities to be undertaken. The ability to shift risks may be a deciding factor in an investment decision, where the investment is potentially feasible, yet where the investor himself may be unable to bear the risks of failure [2].

The benefits of insurance in the sense outlined may be constrained by the problems of "moral hazard" and adverse selection. The "moral hazard" problem occurs where the insurance policy itself alters the incentives of the insured, and therefore the probabilities on which the insurer has determined the premium rate [2, 3, 5, 64]. The outcome of the hazard will generally be a combination of two factors—unavoidable risk against which the insurer would be willing to insure, and human decision, a factor which he cannot quantify [70]. The "moral hazard" problem relates to this in two ways. Firstly, assuming the provision of insurance is competitive,[12] there may be motives for increased loss, in both the situation where the insured has absolute coverage, and that where he is overinsured.[13] In these circumstances, the insurer bears socially unnecessary costs. Were it possible for the insurer to quantify the human element, then premiums could be made to vary with it, and accurate loss probabilities calculated. In the second case, the availability of insurance, which compensates actual damages, may provide incentives discouraging the undertaking of individual flood damage reduction measures such as proofing.

To overcome this problem, any ability to adversely influence the outcome of the hazard needs to be removed from the control of the insured. This may be done in one of three ways. Firstly, insurers could refrain from risk-bearing. Secondly, they could resort to direct inspection and control to make sure the individual minimizes all losses under his control. This would add substantially to transactions costs. The third possibility is co-insurance where the insurer would compensate only some stated proportion of the loss. If the "moral hazard" problem is significant, this alternative seems the most acceptable, as it would alleviate the problem yet still allow partial risk shifting. It would also compensate for the risk aversion of the insurer himself.

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[12] In competitive equilibrium, the price of insurance will usually be uniform over the quantity bought, hence will not vary with the individual's expected loss [65]. In other words, excessive insurance purchases will not appreciably affect the premium per unit. The insured's behaviour is thus spread over all other insurance purchases, as the insurer does not know which customers have greater coverage than others.

[13] If the motives of the insured are to minimize loss, then the insurer has no real problem. To assist in minimizing loss, efficient flood warning and prediction devices will be necessary [11].

The problem of adverse selection in the theoretical sense is likewise related to the inability of the insurer to determine accurately, characteristics of the insured and therefore probabilities for premium determination [1, 65]. It will occur when the insurer holds an undue proportion of above average risks with subsequent claims for compensation being higher than expected. It is most likely to eventuate in the situation of competitive equilibrium and will be manifested if individuals have the freedom to buy or not to buy, to choose the amount and plan of insurance and to persist or discontinue as policy-holders. There is evidence that flood insurance would only be purchased spasmodically, particularly by those with low risks [70].[14]

2.2 Social Welfare

In analysing the likely impact of structural flood mitigation measures and insurance on this objective, the approach taken is to consider a broad range of factors affecting welfare: for example, contributions to the security of life and health; contributions to amenities such as recreational opportunities; and contributions to the stability of income.

Structural Measures

Structural measures aim to reduce the frequency of flooding, but not eliminate it. Protection is only afforded from a "design flood" of a specified magnitude, and as such, there will usually remain some probability of exceedance. Nonetheless, they can reduce the mean annual flood damages, if only because the variance of flooding is reduced.[15] Structural measures will therefore make a partial contribution to the security of life and stability of income, but will not remove the cost to society of immediate relief work.

Structural measures may also accrue welfare benefits in the provision of recreational opportunities, particularly in the case of multipurpose dams. This need not necessarily be the case however, for all structural measures. Irish and Burton [34] report a confrontation between the townspeople of Maclean on the lower Clarence River, and the local flood mitigation authority, on the grounds that proposed levee banks would interfere with existing recreational opportunities, as well as being aesthetically displeasing.

Insurance

The operation of an insurance scheme will not stop flood damages from occurring. Insurance will therefore offer no security benefits against loss of life or injury.

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[14] The hazard is often perceived as being repetitive and cyclical, so there is no need to worry about the event until just before the cycle is due to recommence. A second argument advanced is that a flood in year "t" reduces the probability of experiencing a flood in year "$t + 1$". Thus, for some time after the occurrence of a flood there is relative safety.

[15] This is borne out in work carried out by Richmond and Irish [69] in relation to a flood mitigation levee constructed at Singleton in New South Wales. The conclusion assumes that land enhancement effects are inconsequential.

Notwithstanding, the provision of insurance could contribute to social welfare in two ways. First, and most importantly, through its indemnification role, it can eliminate much of the risk associated with flooding—that is, damage and production losses. The magnitude of these losses is variable and may be described by a probability distribution about a mean.

For this assertion to hold, it is necessary to make two assumptions about the behaviour of the floodplain occupant under uncertainty [3]. It is assumed firstly that he acts to maximize the expected value of his utility function, where utility is represented by income less a random deduction for flood damages. Individuals are also assumed to be risk averse because the marginal utility of their income diminishes. It follows that an individual would prefer a certain income m, rather than one with a probability distribution about a mean m.

On the basis of these assumptions, an individual would increase his welfare if he could purchase insurance indemnifying him against flood losses, at a premium n equating to the mean annual damages. In practice the premium must be in excess of n as it will contain a loading for transaction costs and risk-bearing. But because the individual's risk aversion is assumed to exceed this loading, he will still purchase the policy.

A scheme of this nature should involve no social cost to the nation as it is actuarially based. Its benefits are reflected in the reduction of the risk associated with flood losses. It seems reasonable to conclude therefore that the non-existence of markets for the bearing of risks will reduce the welfare of those who wish to transfer risks to others at a specified price, as well as those who would find it profitable to carry the risk at that price. This conclusion fits the requirements of a movement towards Pareto optimality. If one person is made better off, without others being made worse off, then a movement towards Pareto optimality results. In an insurance contract, at least one party must be better off, while the other must remain at least as well, if not better, off.

Insurance is unlikely to completely eliminate risk, in that it will not usually compensate for the risk of incomplete or delayed recovery.[16] For a productive enterprise, this risk includes certain intangible losses, for example, the loss of customer goodwill because of the inability to maintain supplies. Hence reliance on insurance alone could be financially disastrous. A strategy of risk management as an adjunct to insurance, may, in many cases, overcome these problems.[17]

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[16] Nor would it compensate for risks to real estate values [54]. Values in certain areas of Brisbane affected by the 1974 floods, fell as a result of the flood.

[17] The emphasis with risk management is on the prevention of foreseeable "accidents" with insurance being relegated to a secondary compensatory role. A major function of risk management lies in the provision of contingency plans before the disaster actually occurs. A judicial risk management programme may also help to lower insurance premiums [14].

A second way in which flood insurance can contribute to welfare is that it will put cash in the hand of the affected reasonably quickly after the occurrence of the disaster. This will not alleviate the need for initial relief work, but may reduce the amount of public subsidization of rehabilitation effort.

2.3 Regional Development

In certain circumstances, the inclusion of this objective has been questioned. Freeman and Haveman [27] assert that it is only rightfully included if one region is considered more deserving than another.[18] Otherwise all benefits and costs would be included in the economic growth account. Back [9] criticizes its inclusion on the grounds that a knowledge base for estimating the contributions of water projects to regional development does not exist.

Notwithstanding Back's criticism, an attempt is made to analyse the contributions of the respective strategies to the objective, given the assumption that all regions are not considered equally deserving. Certainly many entries into the regional account could also enter the economic growth account. However, there may be certain primary benefits and costs which will accrue independently to the region and more importantly there are secondary benefits and costs accruing directly to the region.

Structural Measures

Direct benefits to the regional development account will accrue from structural measures if they are used as developmental incentives with the intention of influencing the location of people or economic activities so as to improve the interregional distribution of output and income. As an example, it may be socially desirable to provide flood protection, even if it does not contribute to national economic growth, because it would be in the interest of the region, and perhaps the nation as a whole, to encourage population and economic activities into the region for economic or even non-economic reasons [46].[19] The means to achieving such ends would be for governments to provide the measure either on a free or highly subsidized basis to the beneficiaries.

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[18] Moreover the effectiveness of an investment in water resources in providing regional benefits will depend significantly on the stage of development of the region. If it is at an advanced stage, the benefits should not be as great as if it were at a less advanced stage [17].

[19] Some writers have criticized benefits in this sense. Mera [59] implies maximizing aggregate output is more important than interregional equity, and that redistribution through development of this sort impedes the outcome of a competitive market, and therefore may result in a reduction in aggregate output. James [37] suggests that in water resource investments some of the costs will usually be paid by the poorest groups while some of the benefits accrue to the richest. This is contrary to a direct redistribution of income.

Other benefits may accrue as secondary effects. Included amongst these are the utilization of resources, including labour, which would otherwise have been either unemployed or underemployed.[20]

Regional benefits in the form of multiplier effects also are justifiable benefits. Multiplier effects can be gauged as the increased income resulting from the construction and operation of projects and other economic activities induced by the existence of the project. There may also be induced employment opportunities over and above those created by the project itself. Assuming the structural measure is provided as a public good, or at least at a price below the beneficiary's willingness to pay, it will in effect release private resources for investment in these associated activities [39]. These investments will be assisted by the existence of agglomeration and scale economies [45]. One firm's ability to locate in a particular area can generate economic activity that will attract other firms and people. This may be because they can benefit from the close location to the first firm, or because total activity has reached the level necessary for that firm to sustain profitable operation.

The costs to the regional development account from a structural measure are necessarily difficult to explicitly define. McColl and Throsby [52] define as broad categories some of the likely costs. These include the cost of resources supplied from the region itself, external diseconomies, the loss of assistance payments contributed from outside the region to previously unemployed or underemployed labour, and losses of net regional income from other activities displaced by the construction and operation of the project.

Insurance

The operation of a flood insurance scheme should only affect the regional account in one of two circumstances. First, if the availability of insurance is limited to selected regions, then it may offer a contribution as a development incentive aimed at improving the interregional distribution of output and income. In this sense, the availability of insurance may provide the incentive required to attract economic activity. The second instance is where the availability of insurance in selected regions at subsidized rates provides similar incentives for development. In this case efficient allocation may not necessarily result, although benefits would accrue with an improved distribution of interregional equity. If this were to happen, secondary and multiplier effects may also be pertinent benefits accruing to insurance.

2.4 Environmental Quality

The necessity to undertake environmental impact assessments has reinforced the importance of considering the physical and aesthetic

[20] The inclusion of such secondary benefits has been disputed in the past on the grounds that it was believed unemployment would not have existed in the absence of the project [46].

changes resulting from man's interaction with his environment.[21] Flood mitigation measures must be evaluated in this regard, with consideration given to minimizing the detrimental effects and encouraging, if possible, environmental enhancement in a positive optimizing sense [15]. In spite of this desire, it is questionable if a socially optimal environment can be defined because of variations in individual perceptions. This analysis is therefore limited to listing the beneficial and adverse impacts of the respective strategies on the environmental objective.

Environmental quality benefits are considered to be contributions resulting from the management, preservation, restoration or enhancement of any environmental characteristic of the particular location under study. Environmental quality costs are the deterioration of environmental characteristics.

Structural Measures

Two types of environmental impact resulting from structural measures can be identified; namely, construction and use impacts [21].

Direct construction impacts may be twofold. Most commonly they refer to any beneficial or adverse consequence resulting from physical changes in the environment, for example, the movement of earth and the clearing and removal of trees.

Additionally, direct construction impacts result from the irreversible commitment of resources which minimize or preclude the freedom of choice of future resource users. The alteration of an environment by a structural measure is often assumed to be irreversible, or one in perpetuity. In this sense, the freedom of choice for future resource users is restricted, and the ability of individuals to exhibit an option demand for visiting the preserved site at some future date is constrained [80].[22] The expected benefits associated with such an irreversible decision therefore need to be adjusted to reflect the loss of options it entails [7].

Indirect construction impacts are factors incidental to the purpose of the project—for example, increased evaporation rates, changes in river temperature, reduced stream flows, and changes in the existing ecology. This latter example is of particular importance. The ecologist is concerned with the preservation of natural environments. Two notions reflect their thinking [23]. Firstly, an environment is the healthier and the better the greater the variety of living species that are represented in a given area. The second argument refers to the extinction of species and the need to maintain adequate populations of them. The resulting

[21] For example, the New South Wales Government has recently passed legislation requiring environmental impact statements to be undertaken on any activity that is likely to come into conflict with the environment [60].

[22] The concept of option demand assumes that consumers will be willing to pay some amount, their "option value", for the right to consume a "commodity" at a future date. That "commodity" may refer to an unaltered environment. The summation of individual "option values" should influence the decision of whether or not to develop a site or preserve it in an unaltered form. The problem is developing a practical mechanism to charge non-users for their option.

impacts of structural measures may well be in conflict with these notions. Apart from damage caused to natural vegetation, the habitat for indigenous mammals and waterfowl can be destroyed or reduced, and breeding grounds and food supplies for economically important estuarine dwellers such as prawns and fish interfered with [18, 28].[23]

Use impacts are less identifiable than construction impacts. They reflect the environmental impact resulting from the use of the resource. For example, a dam may be constructed for flood mitigation purposes, and recreational development subsequently follows. Any environmental impact resulting from this development would seem a relevant effect in respect of this objective.

Insurance

Insurance offers a strategy which does not directly interfere with the existing natural environment. As such it is difficult to attribute adverse environmental effects to the strategy. Nonetheless, if some form of development in any way enhanced the environment, the amount of improvement would be a relevant opportunity cost to charge to insurance. Moreover, if the availability of insurance itself was an incentive to development, then any adverse environmental effect attributable to that development, would also be a relevant cost of insurance. If it is assumed that no incentives for development derive from insurance, then the benefits of insurance, in the sense of environmental preservation, will be the opportunity costs of development [24]. Benefits will accrue in the preservation and maintenance of existing ecological systems. Insurance will also avoid irreversible actions thereby preserving the freedom of choice for future resource users who may benefit more from preservation than alternative investments such as structural flood mitigation measures. Other benefits accrue to insurance in the form of option demands.

3 FUTURE FLOOD MITIGATION STRATEGIES

Proceeding under the assumption that society is sufficiently risk averse to display a positive demand for flood mitigation, in this section we consider the alternatives available to provide the most socially desirable policy for the future. The likely problems of introducing such a policy are also considered.

3.1 Alternative Policies

In the first instance, future flood mitigation planning might consider a choice between the two approaches analysed in this paper. On the other hand, it might consider an approach which, rather than requiring a choice between the two, combines them, and other non-structural measures into one unified strategy to mitigate the flood problem.

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[23] Sinden [73] argues somewhat conversely that the alteration of existing ecology is only an environmental cost if that ecology, or parts of it, are unique. If not, one merely has to travel a further distance to view similar ecological features.

3.1.1 Structures or Insurance?

The choice between these mitigation alternatives is not easily made. Ideally the choice should rest on a comparison of the net effects of each in relation to the predetermined criteria. However, unless trade-off ratios depicting the relative importance of each objective are specified, and the analysis made for the particular location for which mitigation is sought, it is not possible to be definitive about the most desirable strategy. Clearly, neither alternative is in consistent *rapport* with the stated criteria, and as the number of objectives increase, so would this form of variance. The choice is not made any easier with the benefits of insurance often not direct, and their magnitude not easily ascertainable.

Zeckhauser [83] has made an attempt to provide guidelines for the choice between PIP goods, (of which a flood mitigation structure is an example), and insurance.[24] His analysis suffers in that it only relates to efficiency criteria, and makes the dubious assumption that the PIP good provides absolute protection. The method involves determining the amount an individual would pay (option value) for the right to consume at zero cost, the service of the PIP good. If the aggregate of option values exceeds the cost of the PIP good, then there is justification for its provision on that basis. For a risk averse person, his option value will normally exceed the benefits from the PIP good; that is, the elimination of flooding. Even so the benefits will not necessarily exceed the costs of the structural measure, so in some situations the option value can be less than the cost of the measure. In this sense insurance would be the more attractive alternative provided the risk related premium, inclusive of loadings, was less than the cost of the PIP good.

3.1.2 A Unified Strategy to Mitigate the Flood Problem

An argument can be established for a flood mitigation strategy which aims to eliminate the likelihood of a flood occurring, and therefore the risk which would normally be associated with flooding. Structural measures are the only means which purport to reduce flooding, however, as shown in the analysis, rarely will they eliminate flooding. Further, it may not always be feasible to provide structural measures as they may not adequately meet the appraisal criteria established for the investment.

Since some amount of risk exists either in the presence of structural measures, or in their absence, we have suggested the desirability of mitigating that risk. Insurance is shown to be a most useful strategy to accomplish this end. But it is insidious to recognize insurance as the only useful strategy. Certainly, it is likely to be the most complete non-structural strategy, but other non-structural measures can be useful adjuncts. For example, zoning can delineate areas of potential risk; flood warning systems may facilitate the attempts by occupants to

[24] A PIP good may be defined as a probabilistic individual preference good. It refers to a good for which individuals cannot accurately state their estimated likely future demand for its use.

minimize loss; and individual preventive activities such as proofing and land use conversion can be useful strategies to reduce risk.[25] An optimal mitigation strategy will *a priori* most likely include a mix of the alternative strategies. With these aims in mind it is possible to devise a unified strategy which endeavours to eliminate where possible the flood itself, and otherwise remove any residual risk. Such a strategy will utilize both structural and non-structural measures.[26]

The postulated strategy requires in the first instance the operation of a mandatory flood insurance scheme with premiums equating to the mean annual expected damages, plus contributions to administrative and transactions costs, and a loading to cover the cost of risk-bearing. Where other mitigation measures, either structural or non-structural, have already been undertaken, the premium should still include each category of cost.

If a new structural or non-structural measure, or incremental increases to them, can provide positive net benefits in respect of the evaluation criteria, this should reduce the risks and therefore the premium.[27] If the extent of the premium reduction were such that it equalled the net benefits to flood mitigation of the new measure, then from the point of view of the insured, it would be desirable for the measure to be undertaken. Further, a proportion of the premium reduction would be applied toward the cost of the structural measure.

As new occupants come to a floodplain, they should be charged a premium equal to the residual damage potential, together with the normal loadings [41]. *Ceteris paribus*, this is less than that paid by occupants locating before the structural measures were undertaken. With time, further degrees of structural or non-structural protection may be justified, and again premiums could be appropriately adjusted.

Under this approach to floodplain management, efficient development of the floodplain is encouraged, and the residual risk of flood losses is removed. In effect therefore, the strategy maximizes the beneficial aspects of both measures in respect of the evaluation criteria, and minimizes the adverse effects. It adds flexibility to mitigation policy in that alternatives to insurance will only be undertaken if they can satisfactorily comply with the objectives.

The scheme charges all occupants a risk related premium on their insurance at all times. It is necessary though that an equitable cost-sharing arrangement be also determined in the provision of structural measures. This is not likely to be a problem if the cost share was some

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[25] Ramasamy and Sinden [67] show that under certain assumptions, altering land use to flood tolerant poplar production will provide returns to the investment in excess of structural mitigation measures.

[26] Attempts have been made to develop means to ascertain an optimum combination of structural and non-structural measures. For example, James [35, 36, 38] has developed a model to determine the least cost combination of the measures. But the model is inadequate because it is directed only toward satisfying the basic efficiency criterion.

[27] For example, as structural measures are subject to economies of scale, their implementation may not be warranted until the damage potential has increased to a significant magnitude.

proportion of the premium reduction. But, a significant problem would emerge if there were not consensus amongst all beneficiaries about decisions on structural measures.

The proposal obviously depends largely on the ability to successfully operate a flood insurance scheme. A number of important questions can be asked of such a scheme; is it necessary for the scheme to be mandatory; will it need to operate on a public basis; how can premiums which accurately reflect risk be determined; is there justification to subsidize the premiums of existing occupants; and finally, how would low cost-sharing requirements for structural measures affect the insurance scheme? The implications of these problems are considered in the following section.

3.2 Some Likely Problems in the Development of a Flood Insurance Scheme

3.2.1 Mandatory Versus Optional Insurance?

The essence of the above proposal is the enrolling of all floodplain occupants in the scheme, and charging them for the full cost of their occupancy. This will necessarily require insurance to operate in a mandatory framework.

Why is it necessary to enrol all floodplain occupants? For a flood insurance scheme to operate viably it will need a sufficiently broad distribution of risks over a number of independent floodplains so as to eliminate the need for expensive reinsurance. The nature of flooding makes losses interdependent on any one floodplain, and in a flood situation, claims for compensation could be expected from most occupants. This is not conducive to the viability of insurance for a single floodplain.

The success of the scheme depends on having a fund of sufficient magnitude to meet future claims.[28] A mandatory scheme would ensure a continuity of demand for insurance, and thereby eliminate the real likelihood of a spasmodic demand for coverage.[29]

A mandatory scheme will also reduce administrative and transactions costs associated with the sale of insurance as a result of economies of scale. Examples of insurance with high administrative and transactions costs are usually found in non-mandatory schemes. The cost of risk-bearing per unit of insurance will also be substantially lowered.

It will be necessary to offset against these benefits the cost of eliminating the freedom of choice of floodplain occupants. For a person not averse to risk, this could be significant.

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[28] Schaake and Fiering [71] estimated the mean annual flood damages to residences in the United States to be $130 million with a standard deviation of $110 million. With claims of this magnitude, an initial reserve fund of approximately $600 million would be required. Upon simulating the fund, they show it could operate for 50 years with only a 5 per cent probability of achieving a negative balance in any one year.

[29] *See* footnote 14.

3.2.2 Public Provision of Insurance

A case exists for the public provision of a good or service where a competitive market has failed to emerge for its supply and demand [3]. In this sense, a valid case can be established for the public provision of flood insurance, particularly if it is to be mandatory.

A number of arguments are commonly put forward for the failure of a competitive market to emerge. The first is that transactions costs are excessive.[30] A case for public provision therefore rests on the ability of the government to reduce the transactions costs. Certainly if the scheme were mandatory, and publicly run, then economies of scale should result in transactions costs being lowered.

Alternatively, availability of insurance in the private market may be non-optimal because of the absence of perfect information on the competitive outcome [1, 6, 65]. The absence is manifested in the problems of "moral hazard" and adverse selection. Public provision is one means of alleviating these problems.

In competitive equilibrium it is suggested the price of insurance does not vary with the quantity bought, although the probability of loss will vary directly. An individual insurer cannot determine exactly the total quantity the insured has bought. Instead he is only aware of the quantity he has sold to the insured.

We have suggested the price should rise to match the expected risk. If an insurer attempts to do this, the insured would only rationally purchase the maximum units he can at the lower price from that insurer. In these circumstances the insured may purchase in total more insurance than is necessary to match the risk. The problem is exaggerated by sellers themselves, who will also conceal sales [65].

Public provision of insurance can therefore represent a Pareto optimal improvement over competitive equilibrium simply in the sense that if the Government were the sole seller, then it would have information on total purchases. They could either enforce limits on coverage or adjust premiums so as to minimize the effects of the two problems.

3.2.3 Establishment of Premium Rates

Throughout this paper, we have stressed that for insurance to derive maximum benefits, premiums must reflect risk together with the normal loadings. This involves assessing damage potential, which necessarily will need to be made on an individual property basis. Although difficulties may exist in making assessment, a more pronounced problem may be developing a relatively inexpensive method of doing so [42].

The need for estimates to be made on an individual property basis is a consequence of many factors. For example, it is not reasonable to charge a uniform rate to specific types of property, regardless of its location on a floodplain, as this would lead to an adverse selection problem—the low risk property would effectively subsidize the high

[30] Lees and Rice [44] suggest that buyer's costs, as well as seller's, may be a reason for the absence of insurance.

risk property. There may also be variations between specific types of property—the quality of the structure and floor elevations are but some. The setting of rates must also reflect the level of individual preventive activity. If an individual undertakes flood proofing of his property, risk is reduced.

Kunreuther and Sheaffer [42] have proposed a sequential method for computing insurance premiums for individual properties. The steps are: compute a depth/damage relationship for the property; compute a flood height/frequency relationship; construct area wide flood conditions; and finally, relate the individual property to the flood conditions. It is thence a relatively easy procedure to calculate a premium. A method of this sort is certainly useful particularly for residential structures, but it is by no means a perfect proposal.

As an example, when determining the depth damage relationships, no simple means exists to account for variance in the relationships over time. The value of damage to a warehouse depends on what is stored at the time of flooding. Assessment of agricultural damages is difficult because of the variability of damageable components in both type and price [53]. The duration of inundation is also a critical factor for agricultural damages.

Due to limited information on flood flows, errors of estimate can be made in determining depth/damage and flood height/frequency relationships. This may well be a significant problem in Australia. Another source of bias in determining these relationships can come from the use of finite increments of stage [29].

3.2.4 Selective Subsidization of Insurance Premiums

An argument may exist for the subsidization of the premiums of existing floodplain occupants.[31]

Subsidizing insurance involves altering the normal pricing techniques so as to make insurance available to certain classes of buyer at rates that are less than the true actuarial costs. Thus a two-priced scheme for insurance will effectively subsidize some classes of insureds, and penalize others. A situation of this type is not synonymous with normal loss sharing principles which are the very essence of insurance. Under a subsidized scheme, the favoured class does not produce enough premiums to cover the losses, expenses and profit arising out of, and allocable to that class. In this sense then, insurance is sold below what is believed to be the expected cost for the class. The resulting deficiency therefore has to be borne ultimately by the penalized class.

Can subsidization be justified in the case of flood insurance? On efficiency grounds the answer may be yes, given the assumption that existing occupants located in ignorance of the flood hazard, and that there were no effective public safeguards against occupancy. Only if

[31] The Act to establish the flood insurance scheme operative in the United States [76], provides for those already located on the floodplain and wishing to purchase insurance, to do so at a subsidized rate. Future occupants would be required to pay the full actuarial premium.

a mandatory scheme were operative, would an adequate public safeguard against the risk exist. In this case new investments would be forced to consider the risk before being undertaken. Inefficient existing investments could not improve their efficiency unless relocated [50]. But, it may not be desirable if the social cost of transferring those resources exceeded the expected benefits of a more efficient allocation. If however, the effective subsidy exceeded the social cost of transferring the resources, then the subsidy would act as a disincentive to the movement of resources which could be justified.

On welfare grounds it is difficult to assess the desirability of subsidized insurance. In making assessment, it is required to know whether the subsidization results in a movement toward, or away from, a Pareto optimal position. That is, does the subsidizing of one insured class, and the effectual penalizing of another class by discriminatory pricing, increase the combined social welfare of both classes?

A subsidy may be seen as a type of quasi-welfare payment to the subsidized class [48]. Where a transfer payment is involved, it could be argued that if one member of the so-called penalized class would prefer the absence of the subsidy, then its existence alone would reflect a movement away from a Pareto optimal position. But in no way can we assume the benefits to the subsidized class are greater than the detriment to the penalized class, and that some compensatory allocation could alter this position.

The argument for and against subsidized insurance will only be valid if the scheme is mandatory. Under an optional scheme, no occupant is required to purchase insurance. In this case, no form of subsidization can be considered as holding because of the options open to the individual.

3.2.5 Cost-Sharing Arrangements

The primary objective of cost-sharing is that the adopted strategies should support and promote the wise and efficient use of floodplains [49, 50, 57, 58]. For structural mitigation measures the cost-share would ideally be based on the association rule.[32] However, under the proposal in this paper it must be related to the reduction in flood insurance premiums. The specific share should represent the proportion that premium reductions bear to the total benefits arising from the project [50].[33]

If insurance premiums were risk related, insurance itself would effectively offer a 100 per cent cost-sharing agreement. If not, the availability of insurance may be a disincentive to the undertaking of other preventive activities. On the other hand, structural measures are

[32] The association rule requires local beneficiaries to be charged a percentage of the cost-share equal to the ratio of marginal local benefits to marginal national benefits computed at the nationally efficient scale of output [57, 58].

[33] If it is possible to estimate non-insurable damages, their reduction should be added to the premium reduction to determine the cost-share.

usually provided at a negligible or nominal cost-share to the beneficiary. This would act as a constraint on the adoption of insurance, if it were optional.

4 CONCLUSIONS

This study does not contend to provide final judgement on an optimal flood mitigation strategy. Inferences have been made about reasons for the inadequacy of existing policy based largely on structural measures, and aimed at containing the flood. Consideration has also been given to the likely effects of insurance as an alternative non-structural measure. While the implications are more general than specific, some qualifications may be necessary in the sense that theory behind the assessment criteria, with the exception of economic growth is not well developed. Nonetheless it is hoped that the comments will induce further work into firstly, the value of alternative mitigation measures; and secondly, the desirability of strategies for mitigation which incorporate both structural and non-structural alternatives.

The philosophy adopted in the paper is that, unless policy initiatives are otherwise, there is no justification for individuals to locate on a floodplain unless they are prepared to meet the full costs of their occupancy inclusive of the expected damages from flooding. If the assumption holds that occupants are risk averse, then it is rational for them to take initiatives to minimize the risk. Insurance provides a strategy which can largely eliminate risk, however, it must be considered only a long-term palliative in the sense that the effective level of risk will remain unchanged over time. If the occupant desires to permanently reduce the level of risk then measures must be undertaken to reduce the number and/or magnitude of floods. If structural measures can be justified in respect of appraisal criteria, then they can be undertaken, providing the beneficiaries meet the cost of their provision.

The benefits of insurance in respect of the objectives of flood mitigation planning, render it a strategy which could well form the basis of future mitigation policy. The method of application of insurance is questionable. Consideration needs to be given to whether flood insurance would operate as an individual entity, or in view of the undoubted similarity of flooding to other natural disasters, whether it should operate in the form of a disaster fund [19]. Moreover, it would be necessary to simulate a fund to determine the likely magnitude and extent of insurance parameters and requirements.

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