JAMES COOK CYCLONE STRUCTURAL TESTING STATION

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CHARACTERISTICS OF CYCLONE RISK TO DWELLINGS

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CHARACTERISTICS OF CYCLONE RISK TO DWELLINGS

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SUMMARY An engineering model of wind damage is used to investigate the characteristics of dwelling location, degree of exposure and the construction of strong houses. Differences between the risk characteristics of wind damage due to cyclones and thunderstorms are also noted. Finally, an assessment is made of the influence of errors that may occur in the input parameters of the damage model.

1 INTRODUCTION

In the wake of extreme damage in 1974 caused by floods in the city of Brisbane, and by cyclone Tracy on Darwin, the Federal Government proposed that a Natural Disaster Insurance Scheme be set up for Australia. In order to provide technical information for the insurance scheme, the Australian Department of Housing and Construction in co-operation with the CSIRO Division of Building Research undertook an investigation to assess the potential cyclone damage to dwellings in Australia.

This assessment was made through use of an engineer-model for wind damage. In the following section a brief description of the model will be given. Further details and the basis of the model may be obtained from a previous paper (Leceister et al. 1979). The purpose of this present paper is to use the model to obtain some idea of the characteristics of the damage risk due to cyclones.

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2 THE DAMAGE MODEL

The basic three components of the damage model are the characteristics of wind regime, the degree of exposure and the strength of dwellings. They were measured at nine important localities of the coastal regions of Australia at risk from cyclone damage. These localities are shown in Fig. 1.

The wind regimes for cyclones, specified in terms of regional basic wind velocities, are shown in Fig. 2. For any particular dwelling these winds are modified by the factors 1.02, 0.93 or 0.65, depending on whether the exposure of the dwelling corresponds to that defined as category 1, 2 or 3 (Standards Association of Australia 1975). All winds are defined in terms of the peak three-second gust.

The wind resistance of a dwelling is described in terms of a relationship between wind speed and damage. The damage is defined in terms of a damage index which in turn is defined as follows for damage to the building itself:

damage index = (repair cost)/
(initial cost of the building);

and for damage to contents:

damage index = (replacement cost)/
(initial cost of contents).

In these definitions the effects of post-disaster inflation are neglected and all costs refer to those expected for stable economic conditions.

The relationship between wind speed and damage for five basic dwelling structures, denoted by Types A-E, is defined according to Fig. 3 and Table 1. A summary of the distribution of these house types into the various exposures is given in Table 2, for the nine localities surveyed.

The information contained in Figs 2 and 3, and Tables 1 and 2, may be combined through a Monte Carlo technique to provide computer simulations of wind damage histories for each locality. It is these computer simulations that have been examined to assess the characteristics of cyclone risk.

3 CHARACTERISTICS OF CYCLONE RISK

3.1 The Average Risk

The annual risk, averaged over a long period of time, is a basic parameter in the discussion of risk characteristics. Table 3 shows this risk for the localities investigated. The wide range in the expected risks is to be noted.

3.2 Damaging Winds

The damage contribution by various wind speeds is shown in Fig. 4. It indicates that even winds having return periods as short as 100 years would be expected to cause a considerable amount of damage.

3.3 Effects of Exposure

Table 4 shows the large damage contribution to exposed houses, defined herein as houses located in terrain categories 1 and 2. Typically about 35 percent of the houses in a given locality are exposed, yet these sustain about 75 percent of the total damage incurred.

3.4 The Benefits of Strong Houses

In this context a strong house will be defined as one having a structure of Type C, D or E and the benefit will be defined as the difference between expected damage indices for the two cases of all houses being of Types A or C only. As shown in Fig. 5, the number of strong houses in each survey locality is roughly proportional to the expected benefits. However, it would be more rational for all houses to be strong ones in localities where the benefits exceed the additional construction costs involved. The difference between the construction costs for a weak and a strong house would be typically about 5-15 percent.

3.5 The National Damage Total

For insurance purposes it is convenient to consider the cyclone-prone areas of Australia to be made up of four coastal regions, designated Zones 1-4 and consisting roughly of the coasts of south Queensland, north Queensland, north Australia and north-west of Australia. The estimated annual damage index for these zones and their relative contribution to the national damage total is given in Table 5. The large contribution of Zone 1, arising from the large number of houses in Brisbane, is to be noted. This is unfortunate as there is considerable uncertainty involved in the derivation of the cyclone wind regimes for Brisbane.

A rough estimate of the average national damage may be obtained by applying the figure of $53 per house given in Table 5 to 500 000 houses. This leads to an average annual risk of about $25 000 000.

3.6 Insurance Against Wind Damage

Because there is a wide range in the cyclone winds that occur at any particular locality, and because the wind resistance of houses has a damage threshold as shown in Fig. 3, there is a wide range in the damage that can occur during a 20-year period. This is illustrated by the information in Figs 6 and 7 and Table 6. The probabilities of sustaining damage at other levels than the average which was determined have been calculated. The figures show typical relationships for Brisbane while in Table 6 the risks, expressed as damage relative to the average, are tabulated for three probabilities for the nine locations. For example, for the buildings of Brisbane, there is 0.21 probability that no damage will occur, a 0.5 probability that the risk will not exceed 0.13 times the average, and a 0.05

probability that it will exceed 5.4 times the average. The wide range of possibilities makes it difficult to choose appropriate values for insurance premiums.

In this respect the characteristics of risk for cyclones differ from those of localized damaging winds such as those due to thunderstorms or tornadoes. To illustrate this, some risk characteristics for pseudo-thunderstorms are shown in Figs 6 and 7 and Table 6. In computing these risks it has been assumed that the wind regime relative to any particular dwelling is the same for both cyclones and pseudo-thunderstorms. However, whereas each cyclone is assumed to affect a complete locality, each thunderstorm is assumed to affect only one-tenth of a locality. Obviously it is also assumed that there are 10 times as many thunderstorms as cyclones. The computed risks show a considerably reduced range of possible damage for the pseudo-thunderstorms; and so for this type of risk it may be appropriate to relate insurance premiums directly to the average annual risk. Furthermore, it is to be noted that because the damage by thunderstorms is localized, these are less likely than cyclones to be associated with post-disaster inflation of the damage repair costs.

3.7 Effects of Errors in the Damage Model

Recent investigations have indicated that the damage model discussed in this paper probably overestimates the cyclone risk. Consequently it is of interest to assess the sensitivity of the model to the input parameters. Table 7 shows the annual risk computed for wind regimes that are reduced by 5 ms^{-1} from those shown in Fig. 2. A comparison between the risks shown in Tables 3 and 7 indicates that the damage due to this reduced wind regime is roughly 60 percent of the damage given by the original model. This large effect arising from small changes in wind speeds is also of interest in relation to current proposals to reduce wind damage by modifying tropical cyclones.

4 CONCLUSIONS

There is a wide range in the average annual risks at the various localities surveyed. Exposed houses contribute a great proportion of this risk. Based on the risk model used in this paper, the national damage total is estimated to be about $25 million. However, a small change in the risk model parameters, made in accordance with recent findings, would reduce this estimate to about $15 million. A large proportion of the national risk is attributed to Brisbane, because of the large number of houses there. The appropriate insurance risk for cyclones is difficult to assess because of the wide range of damage than can occur within any 20-year period.

Finally, it is recommended that all houses be built as strong houses in localities where the cyclone risk exceeds the additional construction costs of strong houses. Of the localities surveyed this would apply to Darwin, Hedland, Carnarvon and Roebourne Shire.

5 ACKNOWLEDGEMENTS

The authors are indebted to Ms Fran Young for processing the data discussed herein.

6 REFERENCES

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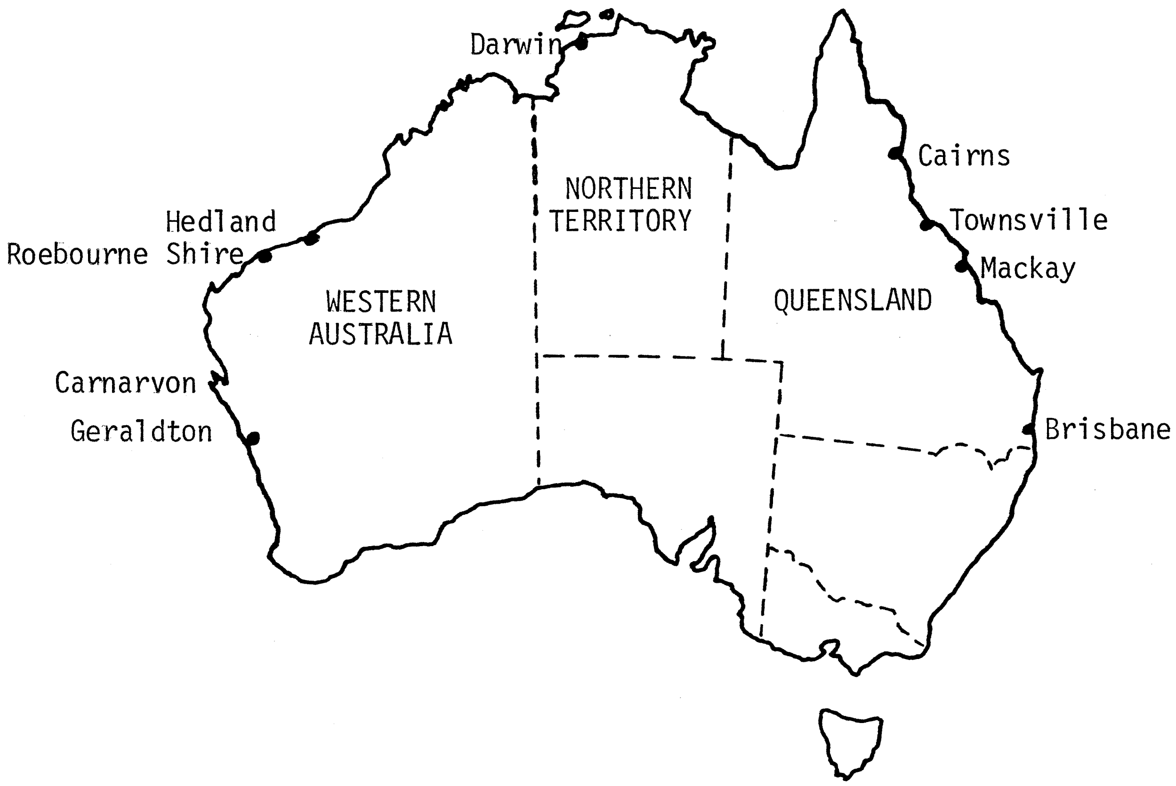


Figure 1: Location of risk survey

TABLE 1

CLASSIFICATION OF BASIC HOUSE STRUCTURES

(Leicester *et al.* 1979)

HOUSE STRUCTURE TYPE	WIND GUST VELOCITY (ms^{-1})	
	Minor Damage	Major Damage
A	35	45
B	40	50
C	45	60
D	50	70
E	∞	∞

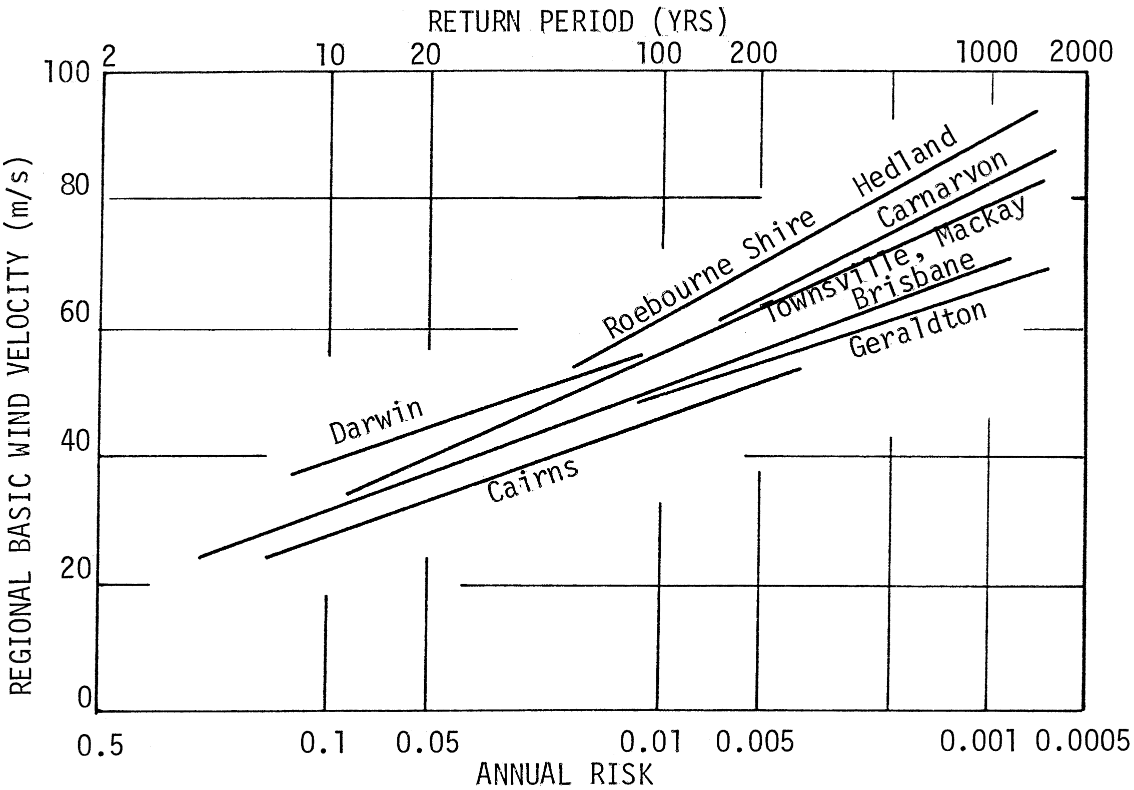


Figure 2: Regional basic wind regimes (after Leicester et al. 1979)

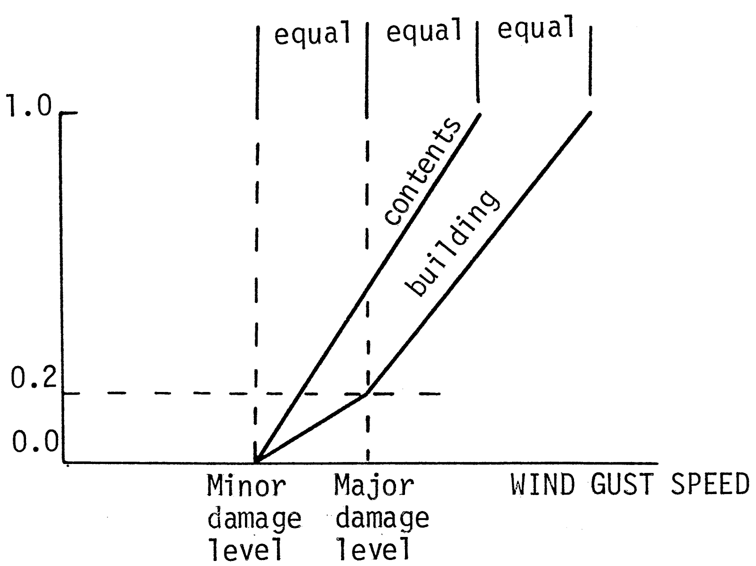


Figure 3: Relationship between wind speed and damage (after Leicester et al. 1979)

TABLE 2

SUMMARY OF TERRAIN CATEGORY AND HOUSE STRUCTURE TYPE (Leicester *et al.* 1979)

LOCATION	TERRAIN CATEGORY	HOUSE STRUCTURE TYPE (%)				
		A	B	C	D	E
Geraldton	1	2	5	4	0	0
	2	2	6	5	0	0
	3	35	41	0	0	0
Carnarvon	1	0	2	2	1	0
	2	4	18	20	6	0
	3	12	23	10	2	0
Roebourne Shire	1	0	1	8	19	3
	2	0	2	11	25	3
	3	0	0	10	18	0
Hedland	1	0	0	3	8	0
	2	0	0	9	32	3
	3	0	0	10	32	3
Darwin	1	0	2	3	3	2
	2	0	4	6	7	3
	3	2	23	12	21	12
Cairns	1	1	2	1	1	0
	2	2	7	8	2	0
	3	33	40	2	1	0
Townsville	1	1	1	2	1	0
	2	2	5	7	1	0
	3	33	40	2	5	0
Mackay	1	1	2	2	1	0
	2	2	8	9	3	0
	3	26	38	6	2	0
Brisbane	1	1	1	0	0	0
	2	2	5	1	0	0
	3	66	24	0	0	0

TABLE 3

EXPECTED DAMAGE
(Leicester et al. 1979)

LOCALITY	AVERAGE ANNUAL DAMAGE INDEX (%)	
	Buildings Only	Contents Only
Geraldton	0.15	0.30
Carnarvon	0.37	0.66
Roebourne Shre	0.31	0.60
Hedland	0.19	0.39
Darwin	0.15	0.32
Cairns	0.08	0.15
Townsville	0.23	0.43
Mackay	0.26	0.48
Brisbane	0.13	0.26

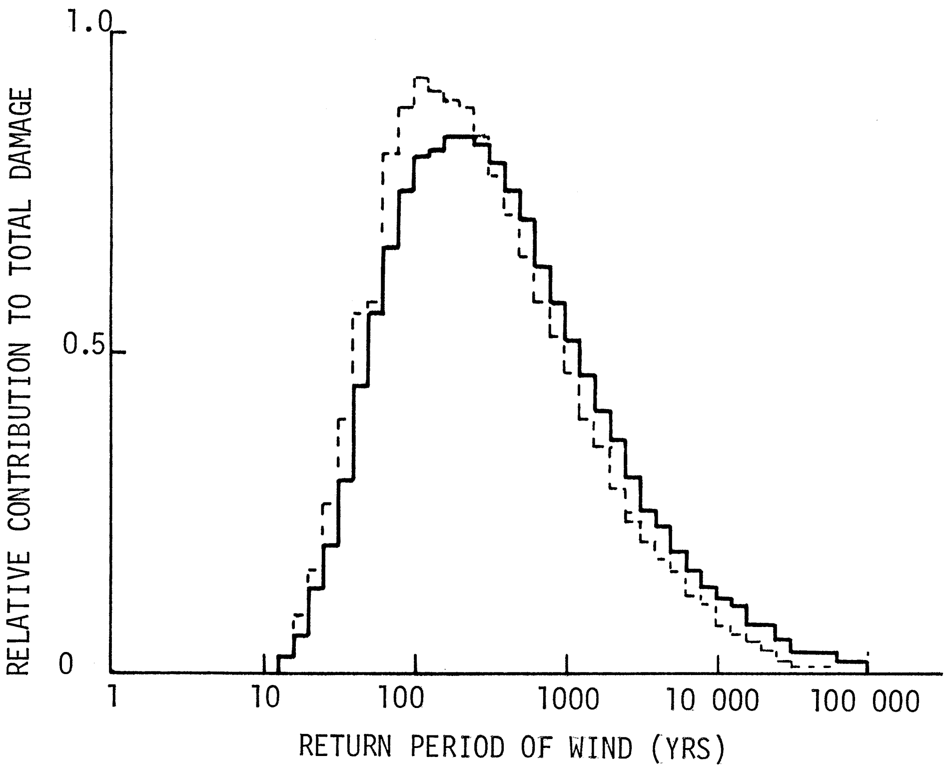


Figure 4: Damage contributions by various wind speeds (average of all survey locations) (after Leicester et al. 1979)

TABLE 4

DAMAGE TO EXPOSED HOUSES

LOCALITY	EXPOSURE RATIO*	DAMAGE CONTRIBUTION**	
		Buildings	Contents
Geraldton	0.24	0.82	0.80
Carnarvon	0.53	0.86	0.84
Roebourne Shire	0.66	0.97	0.96
Hedland	0.52	0.93	0.92
Darwin	0.25	0.89	0.75
Cairns	0.24	0.73	0.70
Townsville	0.20	0.59	0.64
Mackay	0.28	0.69	0.67
Brisbane	0.10	0.51	0.48

*Exposure Ratio = (no. of exposed buildings)/(total no. of buildings)

**Damage Contribution = (damage to exposed buildings)/(total damage)

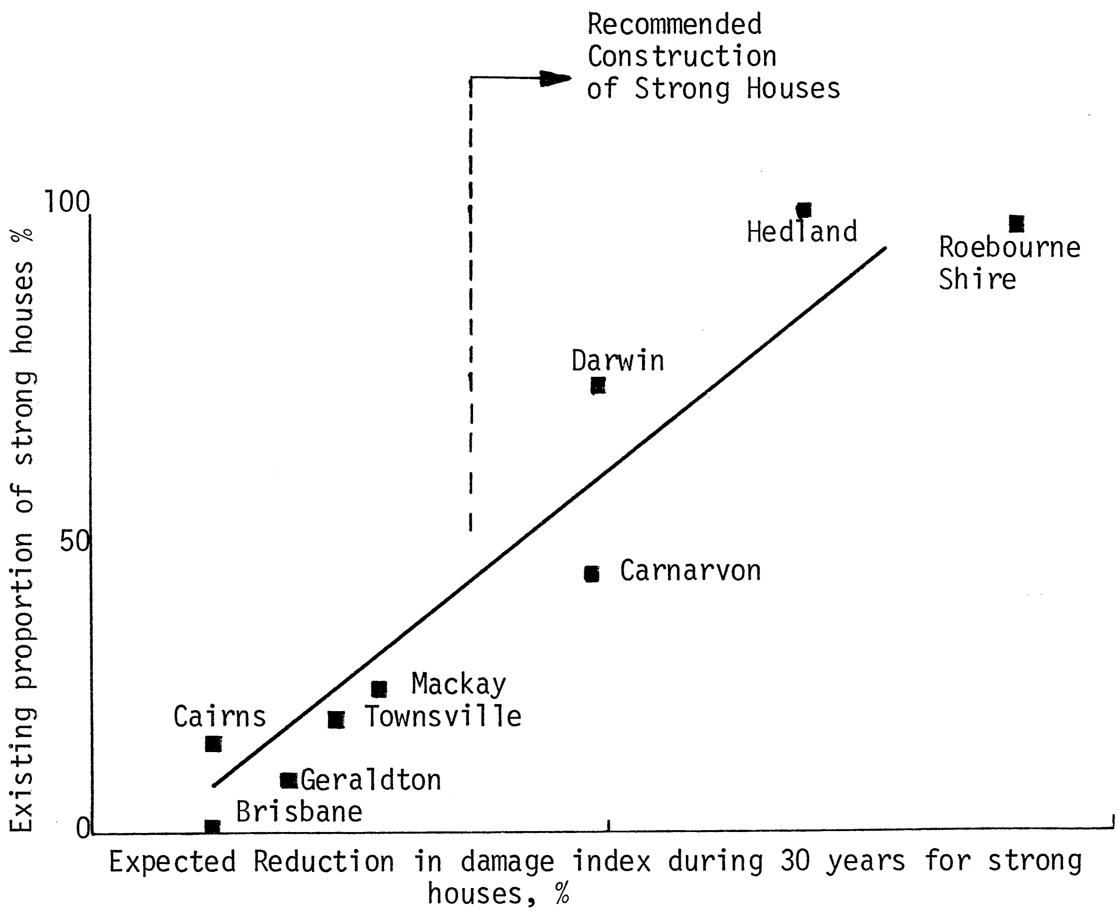


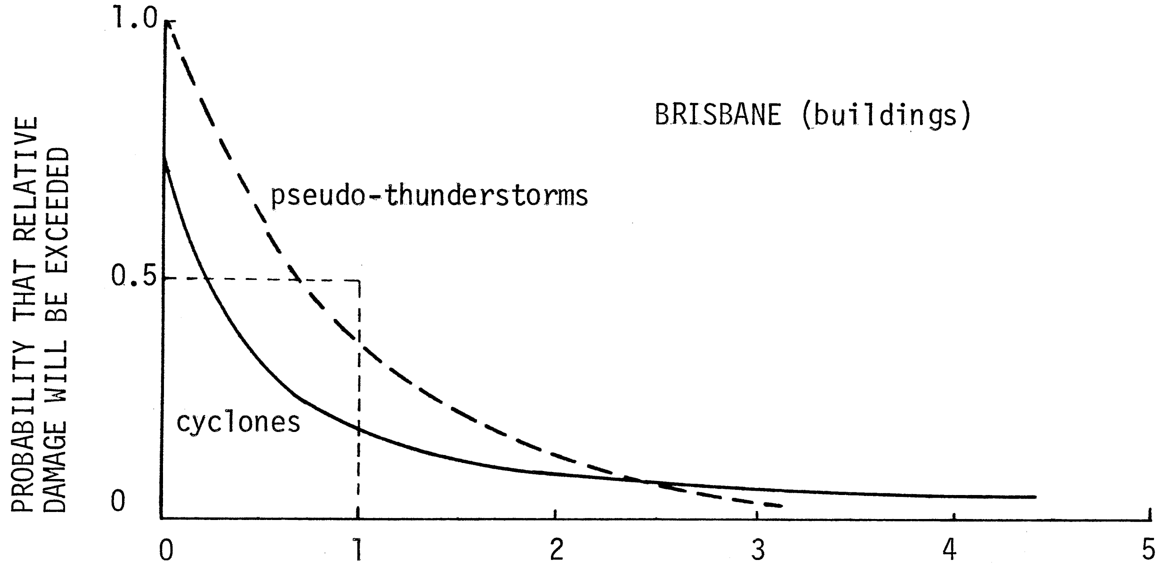
Figure 5: Relationship between the benefit and the number of strong houses. (after Leicester et al. 1979).

TABLE 5

REGIONAL DAMAGE CONTRIBUTIONS

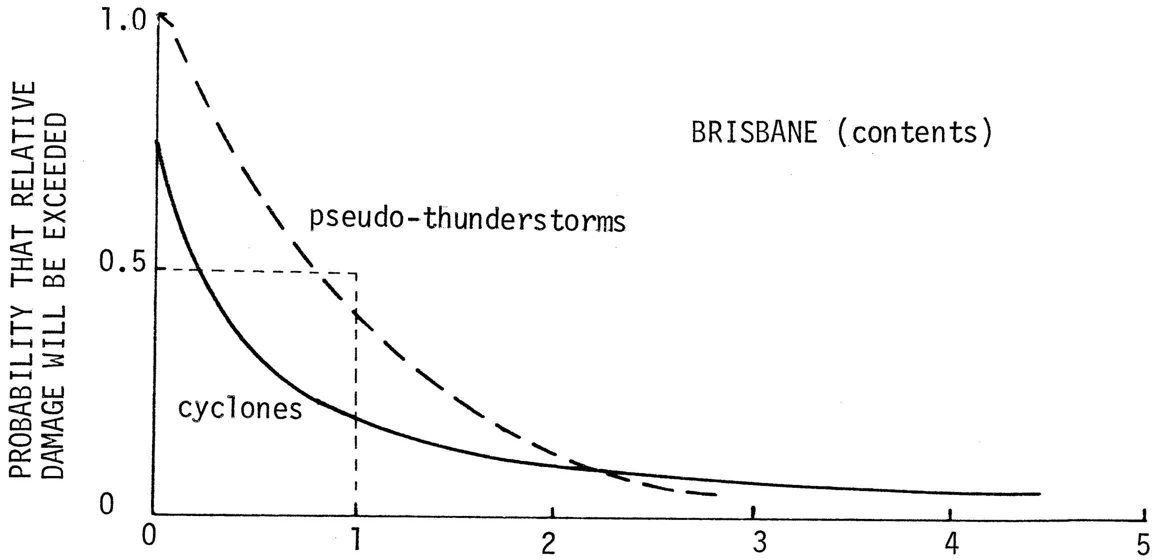
AREA	TYPICAL CITY	PROPORTION OF HOUSES (%)	ANNUAL DAMAGE INDEX (%)		ANNUAL LOSS PER HOUSE*	CONTRIBUTION TO NATIONAL DAMAGE TOTAL	
			Building	Contents		Per House	Per-centage
ZONE 1	Brisbane	76	0.14	0.27	$49	$37	71
ZONE 2	Townsville	20	0.18	0.34	$62	$12	23
ZONE 3	Darwin	1.5	0.16	0.33	$57	$ 1	2
ZONE 4	Hedland	2.5	0.24	0.44	$82	$ 2	4
		100				$52	100

*House value taken to be $25 000 for the building and $5 000 for the contents



RELATIVE DAMAGE = $\frac{\text{DAMAGE}}{\text{EXPECTED AVERAGE DAMAGE}}$

Figure 6: Risk of damage to buildings in Brisbane for a 20 year period.



RELATIVE DAMAGE = $\frac{\text{DAMAGE}}{\text{EXPECTED AVERAGE DAMAGE}}$

Figure 7: Risk of damage to contents of dwellings in Brisbane for a 20 year period.

TABLE 7

EXPECTED DAMAGE COMPUTED FOR REDUCED WIND REGIME

LOCALITY	AVERAGE ANNUAL DAMAGE INDEX (%)	
	Buildings Only	Contents Only
Geraldton	0.07	0.15
Carnarvon	0.24	0.42
Roebourne Shire	0.21	0.41
Hedland	0.13	0.27
Darwin	0.08	0.17
Cairns	0.04	0.08
Townsville	0.14	0.26
Mackay	0.16	0.29
Brisbane	0.06	0.14