CYCLONE TESTING STATION

DAMAGE IN THE PILBARA
CAUSED BY CYCLONES AMY AND DEAN

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TECHNICAL REPORT NO. 4

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Since the publication of this document in May some more accurate meteorological data has been made available to the Station by the Bureau of Meteorology.

1. The maximum wind gust recorded at Port Hedland Airport during Amy was 70 knots (130 km/h or 36 m/sec) rather than the 120 km/h quoted.

2. Dean crossed the coast about 20 nautical miles (37 km) east of Port Hedland. Therefore that town would have been just outside the radius of maximum winds. This implies that the barograph record shown in Figure 4 would not provide an accurate estimate of the minimum central pressure of the cyclone. The Bureau of Meteorology's latest estimate of the minimum central pressure at or shortly after landfall is 945 mb.

3. The Bureau has estimated a mean sea level minimum pressure of 932 mb for cyclone Amy. This minimum pressure is estimated to have occurred about four hours after Amy crossed the coast.

G.F. REARDON.

August, 1980.

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by

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James Cook Cyclone Structural Testing Station

1. INTRODUCTION

Tropical cyclones appear to be attracted to the Pilbara region of Western Australia. Figure 1 (Ref. 1) shows the tracks of a selection of most damaging cyclones for the years 1967-1978. At least five of these cyclones affected towns in the Pilbara region. During the first two months of 1980, five tropical cyclones developed in the Indian Ocean off the Western Australian coast. Two of these dissipated before making landfall, but the other three, cyclones, Amy, Dean and Enid, caused damage to buildings and other structures in the towns of Goldsworthy, Port Hedland and Shay Gap.

Cyclone Amy, which struck on January 10th 1980, caused considerable damage to the mining town of Goldsworthy, which is situated approximately 30 km from the nearest coastline. Three weeks later on February 1st cyclone Dean crossed the coast approximately 20 km east of Port Hedland.

On behalf of the Cyclone Structural Testing Station, the author visited Port Hedland and Goldsworthy early in February to inspect damage and to offer technical assistance in the reconstruction of some buildings. This report therefore deals only with the effects of cyclone Amy and Dean, cyclone Enid occurred later in February.

2. METEOROLOGICAL DATA

The Bureau of Meteorology maintains an office and weather recording instruments at Port Hedland aerodrome. This office tracked the two cyclones and issued statements on the position and intensity of each. Figure 2 shows the track of the two cyclones.

As can be seen from Figure 2, both cyclones made landfall east of Port Hedland. Amy crossed the coast approximately 140 km from Port Hedland and Dean crossed only 20 km from the city.

The effect of cyclone Amy was relatively small at Port Hedland, the maximum wind speed recorded was only 120 km per hour (33.3 metres/sec). However there was an anemometer at Goldsworthy which was in the path of the cyclone. This anemometer displayed 221 km/hr (61.4 m/s). The author does not know when the anemometer was last calibrated, and therefore how accurate this reading would be.

It is estimated that because the centre of cyclone Dean passed only 20 km from Port Hedland, the city would have been in the path of the wall of most destructive winds which surrounds the eye of a cyclone. The maximum wind gust recorded at the airport, 191 km/hr (43 m/s) would therefore have been a very good estimate of the peak gust of the cyclone. Similarly the barograph record showing a minimum of 962 mb would provide an accurate estimate of the minimum central pressure of the cyclone. Figure 3 shows the anemograph and Figure 4 shows the barograph for cyclone Dean. Some traces on these records have been touched up for reproduction in this document.

Cyclone Amy was a slow moving cyclone, travelling at speeds of 5 - 10 km/hr, but Dean was quite fast travelling at about 30 km/hr when it made landfall.

3 GOLDSWORTHY

3.1 General

The town of Goldsworthy was built by the company Goldsworthy Mining Limited to provide housing, offices and workshops for employees working at the mine. There are approximately 180 houses, 60 van sites and 12 blocks of units providing accommodation for single men, as well as the other buildings necessary for the running of a mine in a remote area. Presumably because of the remoteness of the area, and possibly because the town has a finite life, all the houses in Goldsworthy are transportable. Most were prefabricated in Adelaide and transported in two sections a distance of nearly 3000 km to the site. The two sections were then reassembled on site and some additional walls erected to complete the houses. The first houses were built at Goldsworthy in 1966 and the newest group were built in 1975.

3.2 Cyclone Damage

It should be emphasized at this point that the author visited Goldsworthy four weeks after cyclone Amy struck. Therefore although most of the severe damage to buildings was still evident, minor damage had been repaired and the severely damaged sections of houses had been removed. This meant that a detailed investigation into the reasons for the damage could not readily be made. However as at least four houses that survived cyclone Amy were partially destroyed by cyclone Dean, the conclusions drawn for those houses are assumed to be applicable to similar houses that were damaged by the previous cyclone.

Immediately after cyclone Amy struck, company officials made a preliminary survey of the extent of the damage. The results of this survey with respect to housing are as follows:-

- 8% Destroyed or very seriously damaged
- 9% Unroofed
- 21% Partly unroofed
- 36% Lost some roof sheeting
- 26% No visible damage

Subsequently a more detailed survey was conducted and a list of damage to each house was made. The information from this survey has been classified into a more general grouping as suggested by Leicester and Reardon (Ref 2) and is given in Appendix 1, page 31.

3.2.1 Extensive damage

At least sixteen houses suffered extensive damage during cyclone Amy, and a further four during cyclone Dean. Such damage ususally meant loss of roof structure and loss of some walls. Figure 5 shows this kind of damage that occurred during cyclone Dean, but it probably epitomizes the damage that occurred in the previous cyclone. Figure 6 shows a closer view of the same house, in which construction details of the wall can be seen. The wall was obviously of panelized construction and was possibly relying on the plywood cladding to withstand uplift forces at roof level. No steel anchor rods were evident.

Figure 7 shows a group of extensively damaged houses in the worst hit part of the town. Two points are worth noting. First, all houses are of the same design and second, each suffered the loss of its long front wall and portions of the roof structure. (The dark walls in the photograph are actually internal walls exposed by the loss of an external wall and roof section.) Other houses exhibiting similar damage are shown in Figures 8 and 9. Enquiries about the construction of that type of house revealed that the rear sections of the house had been transported from Adelaide and the front wall added as on-site construction. It was therefore evident that the sections of house that had been transported were considerably stronger than those made on site. This was presumably because the transportable sections had been designed to withstand handling forces en route.

This hypothesis was supported by the failure of the style of house shown in Figure 10. The failure shown was typical for that type of house and again demonstrated that the section of house assembled by on-site labour was not as strong as the transportable sections.

Buildings and structures other than houses suffered approximately the same proportion of extensive damage as did the houses. However, the buildings that were extensively damaged were of domestic-type construction, namely blocks of units, school and police station. Only one structural steel frame was reported as being extensively damaged.

Approximately sixteen of the sixty caravans at Goldsworthy were destroyed by the winds. Figure 11 shows typical damage to a van that had broken away from its tie down cables and rolled. It is most likely that all vans were secured to concrete foundation pads by wire ropes.

3.2.2 Serious damage

As previously mentioned, the author was able only to inspect the extreme damage, serious and minor damage were being repaired at the time of the visit. The following comments are based upon the damage assessment compiled by Goldsworthy Mining Limited (GML) and upon a brief report by Rinaldi (Ref. 3), senior engineer of the Public Works Department, W.A., who visited the town a few days after the cyclone.

In the context of this report, serious damage has been defined as a combination of two or more of the following.

(a) loss of more than half roof cladding
(b) loss of some roof structure
(c) loss of some ceiling cladding
(d) damage to walls other than by missiles

This category would include the 30% of houses defined by GML as being unroofed or partly unroofed. It would therefore include most of the twenty three newest houses in the town. They were well constructed, having welded light gauge metal framing and incorporating anchor bolts. They were very similar to the type of house constructed at South Hedland. However every house had most of the metal roofing tiles blown off, which resulted in damage to ceiling cladding and to walls. Figure 12 shows the worst damaged house in this group.

A detailed inspection of the roofing revealed that it had been fastened with nails of a size smaller than is specified by the manufacturer. These nails had been pulled out of the battens during the cyclone.

The GML assessment refers repeatedly to "patent roofing material" having blown off resulting in both serious and minor damage. This is presumably the roof sheeting with "concealed clip type fixing" referred to by Rinaldi. As some brands of this type of roof sheeting are not recommended for use in cyclone areas it is not surprising that it did not perform satisfactorily.

A number of industrial and service buildings were seriously damaged insomuch as they lost a considerable amount of wall cladding and roof sheeting. In some instances roof structure was also damaged.

Rinaldi commented on the very poor performance of translucent sheeting and questioned its use in cyclone areas. The debris from these sheets had been cleaned up before the author's visit, but it is agreed that if a material cannot be made secure it should not be used in a cyclone prone area.

3.2.3 Minor damage

Minor damage includes such things as broken windows and wall cladding from missiles, and the loss of individual sheets of roofing or flashing. There was also a considerable amount of asbestos cement lining sucked off the eaves.

As previously mentioned the immediate survey by GML showed that 26% of houses had no visible damage. However, the detailed investigation listed only 13 of the 181 houses as being undamaged. As there were seven houses in one street which were not mentioned in the survey, they may have been undamaged. This would have resulted in a maximum of only 11% undamaged. It has been assumed that this figure represents a more accurate assessment of the minor damage.

3.3 Cyclone Resistance

The degree of cyclone resistance built into the houses varied, and it apparently increased as newer houses were built. This is to be expected, as the town was well established before cyclone Tracy devastated Darwin or cyclone Joan hit Port Hedland. Both events caused a significant increase in requirements for cyclone resistance for houses. As previously mentioned anchor rods were not evident in the wall shown in Figure 6, however other house designs did include them. Figure 13 shows their presence in a house that had a wall panel blown off. The steel rods extended from the roof panel through to the steel RSJ bearer, and were thus easily accessible for tightening. In some instances the detail at the top of the rods proved inadequate. Figure 14 shows this detail whereby a short section of steel angle was welded to the top of the rod. In theory this angle was to hold the roof panel in position, but in practice the flexing roof panel worked free of the angle as there was no positive fastening between the two.

Another type of hold down used was an overbatten located at each end of the house. Each steel overbatten was anchored to the concrete footing by means of a wire rope and turnbuckle at each end, as shown in Figure 15. Some of these turnbuckle hooks were opened by the forces generated on the house during the cyclone, Figure 16. This overbatten system of tie-down was used for the style of house shown in Figures 5 to 7.

As has already been stated, Figure 12 shows damage that occurred to one of the latest design of houses. Although each of the houses of this type suffered loss of roofing this was the only one that had considerable structural damage. The general lack of structural damage to this group of houses reinforces the argument that the newer houses, containing more cyclone resistant provisions, were better able to resist the severe wind forces.

4. PORT HEDLAND

4.1 General

The township of Port Hedland consists of two separate parts, the original port town and the new development of South Hedland, located some 5 km inland. The old section is a narrow strip of built-up area approximately 300 metres wide facing the Indian Ocean. At the back of this built-up area there are salt-pan flats.

South Hedland was built progressively during the early and mid-seventies. Most houses were designed and built to the most recent requirements for cyclone resistance. Therefore the town is looked upon by researchers as somewhat of a test area, whereby little if any damage should occur during cyclones whose maximum gust wind speed is approximately 55 m/s. As the measured maximum wind gust during cyclone Dean was 53 m/s it provided an ideal test for the buildings. The town of South Hedland performed almost exactly as would have been predicted insomuch as the cyclone caused very little damage to the houses. The damage that did occur, such as lifting of roofing or failure of transportable classrooms could readily be explained.

The original part of Port Hedland has many older houses that have experienced a number of cyclones. Many of these have been upgraded or patched up after having been damaged by previous cyclones. It was therefore not uncommon to observe two similar houses in the same area, one of which had been seriously damaged and the other was virtually unscathed. The latter one would have been upgraded after a previous cyclone.

As cyclone Dean made landfall about 20 km east of Port Hedland, the winds that hit the town were blowing across the land towards the sea. Although the land was generally flat with few trees, the speed of the wind would have been slightly less than had it been blowing off the sea.

A factor which helped to minimize the amount of damage caused by cyclone Dean was the collection of all outside rubbish before the cyclone struck, thus minimizing the likelihood of flying debris. Special collections of outside household rubbish are always made during the early warning phase of the cyclone alert; thus potential missiles such as spare roof sheeting, empty drums and the like are removed.

4.2 Cyclone Damage

The damage at South Hedland was negligible. The author observed only three instances of damage, one in which many of the lightweight roof tiles were stripped off the roof of a house (Figure 17), damage to the roof and walls of a transportable classroom Figure 18 and loss of roof sheeting from an industrial building. There may have been other minor damage, but there was no evidence of serious damage.

Serious damage did occur in the older parts of Port Hedland. One newspaper report listed eight houses as being unroofed, 16 as being partly unroofed and 30 others as being damaged. It also stated that more than 20 vans at the caravan park were demolished. General opinion at Port Hedland was that the speed of movement of the cyclone, stated by the Bureau of Meteorology as being 29 km/hr, helped many buildings survive. Because the cyclone was moving so rapidly, the buildings were not subjected to a very long period of buffeting.

As most of the damage occurred in the older part of Port Hedland, the rest of this section will relate to that area.

4.2.1 Extensive damage.

The author inspected one of four houses that suffered extensive damage, Figure 19. The figure shows that two external walls at the corner of the house were blown out. This probably occurred after part of the roof structure had been lifted off, and thus the lateral restraint at the top of the walls was removed. At least half of the roof sheeting and supporting roof structure were blown off. The house was of an older style of construction, but it had been upgraded in strength by the addition of external steel bars attached to some studs. These steel bars are visible in Figure 19.

4.2.2 Serious damage

Most of the damage that occurred in Port Hedland could be classified as serious damage. It consisted of roof cladding and roof structure being blown off. This was more common than having the cladding only blow off. Figures 20, 21 and 22 illustrate three different examples of this type of failure.

The roof cladding and battens shown in Figure 20 were blown off the flats in the background. The cladding came from the rear half of one of the buildings where it extended from the ridge to the box gutter, thereby covering part of the unlined carport area. While the cladding had been firmly attached to the battens with screws and large washers, the battens had been fastened to the rafters with only one nail per crossover. This obviously constituted the weakness which caused failure.

Figure 21 illustrates the same type of failure. In this case the entire roof structure was blown off the house. The hip ended roof was lifted as a unit and deposited in the yard. The number of fasteners securing the cladding to its battens gave a strength far in excess of that of the fasteners securing the roof framing to the wall framing, thus failure occurred at that joint. It appears that this house had been part of a program of upgrading after a previous cyclone as it is unlikely that the number and type of fasteners securing the roof sheeting would have been used in the original construction. The short sheets of roofing indicate that they are original.

Figure 22 shows portion of the roof structure that blew off a house. In this case the roofing was secured to the battens by clips, the battens were attached to the rafters with framing anchors, but it appeared that the rafters were only nailed to the wall framing. At the ridge the rafters were only skew nailed into the ridge board, Figure 23.

Figure 24 shows another house that was seriously damaged. The entire roof structure was blown off the house. Cyclone anchor rods had been installed in the house after cyclone Joan in 1975. The author was unable to investigate this house further.

4.2.3 Minor damage

In this context the term minor damage relates to structural damage to the cladding of houses. It is readily acknowledged that although the loss of only a few sheets of roofing or a few roof tiles can be classified as minor damage, the associated entry of rain may cause damage worth many times the cost of replacement of the roofing.

Figures 25, 26 and 28 illustrate minor damage. Figure 25 shows one of a group of four units that were damaged in a similar way. Part of the roof sheeting on the leeward slope was removed.

In Figure 26, the house on the left had its roof sheeting peeled back at the eaves. The eaves were unlined and the peeling process was arrested by an over-batten located on top of the sheeting above the wall line. Over-battens can be seen on the undamaged house on the right.

There were very few tiled roofs in Port Hedland, however, one model complex had a very large roof area of tiles that had been nailed to the battens. Each eaves tile was also screwed to the fascia as shown in Figure 27. The roof had been sarked. Only about four small groups of tiles were lifted during the cyclone. Some ridge capping was also blown off.

The author did not observe any cases of domestic windows having blown in, as screens were often used to protect them. Figure 17 shows solid plywood screens used to protect windows. There was one case of a large shop window having been blown in, Figure 28. It is believed that the damage was not caused by flying debris.

5. OTHER PILBARA TOWNS

The two cyclones also caused damage to other communities in the Pilbara region. Cyclone Amy battered the aboriginal settlement at Strelley Station, and cyclone Dean caused damage at Marble Bar. Newspaper reports from Marble Bar tell of at least three houses that had their roofs blown off and of severe damage to school buildings and to shops.

The author inpsected three new houses at the Strelley pumping station between Port Hedland and Goldsworthy. The houses had been completed but were unoccupied. One house lost portion of its roof structure as shown in Figure 29. Again the roof structure was lifted off the walls, with the roof sheeting remaining securely fastened to the battens. It is unusual to see a hip end blown off in this fashion because damage to such houses usually occurs over the main roof area.

6. COMMENTS ON REPAIRING HOUSES

When repairing or upgrading existing houses, there is always a difficulty in deciding how much should be done. It is obvious from the damage shown in Figure 21 that a program of strengthening the hold-down of roof cladding can be nullified if the roof structure is not adequately fastened to the walls. In any program of upgrading older houses or of repairing the roofs of damaged houses, it is strongly recommended that a thorough inspection be made of the fastenings between roof battens and rafters, between rafters wall plates and between rafters and ridge beams. It would be uneconomical to strengthen the fastening of the cladding if the structure itself was still understrength.

Mention has been made of upgrading older houses by the addition of steel angle over-battens which were held down by flat steel bars fastened to the studs. A threaded rod was welded to the top of the flat bar and passed through the roofing and over-batten, allowing the system to be tightened. The house shown in Figure 19 had been strengthened in this way, but to no avail.

Whilst the initial cause of failure of that house could not be pinpointed there was one obvious weakness in the system. The holes in the steel over-batten had been cut with a torch, not drilled, thereby leaving an excessive clearance around the rod. It is quite possible that some holes were large enough to allow the nut to pass through, this being prevented only by the washer. The washer may have been sufficiently strong to resist construction forces but not to resist the pressure of cyclone winds, therefore the whole upgrading system was nullified.

It is considered good practice to brace roof trusses in the plane of the roof. Light gauge metal strap can be used to achieve this, as shown in Figure 30, a roof being upgraded. However metal strap is always difficult to tighten. The method of tightening by twisting may be satisfactory if it is done correctly. A close examination of the spiral of the straps in the figure shows that the tightening was achieved by fastening each end of the strap and rotating the centre. As the diagonal straps have not been fastened to any intermediate trusses, they will start to unwind and become loose as soon as any tension is applied. This technique is useless as a bracing medium. It is quite disconcerting to see such a basic principle of mechanics being misused in this way.

6. CONCLUSIONS

The housing at Goldsworthy did not perform well as nearly 90% of it was damaged in some way. The sections of house that were built in a factory and transported to the site proved to be much stronger than the sections that were erected on site. This was presumably because they were built to withstand forces generated during transportation. Most industrial buildings at Goldsworthy were not damaged structurally, but many lost a considerable amount of cladding, including nearly every sheet of translucent material.

The maximum wind gust measured during cyclone Dean was nearly the theoretical design gust speed for houses. The fact that there was very little damage is South Hedland deomonstrates that houses can be designed and built to withstand cyclone winds. Such houses do not have to be exorbitantly expensive, nor look like bomb shelters.

Both cyclones demonstrated the need for sufficient fasteners to be provided in the roof structure. The strength of the fastening system holding roof cladding to roof structure has been improved in recent years to the extent where it is now stronger than many fastening systems used in roof construction.

However the structural integrity of roofing systems is still dependent upon the use of the correct type of fastening. One roofing system in the area suffered extensive damage because a fastener was used which was smaller than that recommended by the roofing manufacturer.

Despite the provision of tie-down cables, about 20% of the caravans in both Goldsworthy and Port Hedland were destroyed. This amount of damage is too great for the wind speeds involved. As caravans are a popular form of dwelling in the tropics, more attention should be given to making them secure during high winds.

The problem of strengthening older houses has still not been solved.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. SOUTHERN, R.L. "The Nature of Tropical Cyclones", Design for Tropical Cyclones, James Cook University, Townsville, September 1978.
2. LEICESTER, R.H. and G.F. REARDON. "A Statistical Analysis of the Structural Damage by Cyclone Tracy", Civil Engineering Transactions, I.E.Aust. Vol. CE18 No. 2, 1976.
3. RINALDI, B. "Brief Interim Report on Damage to Goldsworthy by Cyclone Amy", Public Works Department, Western Australia.

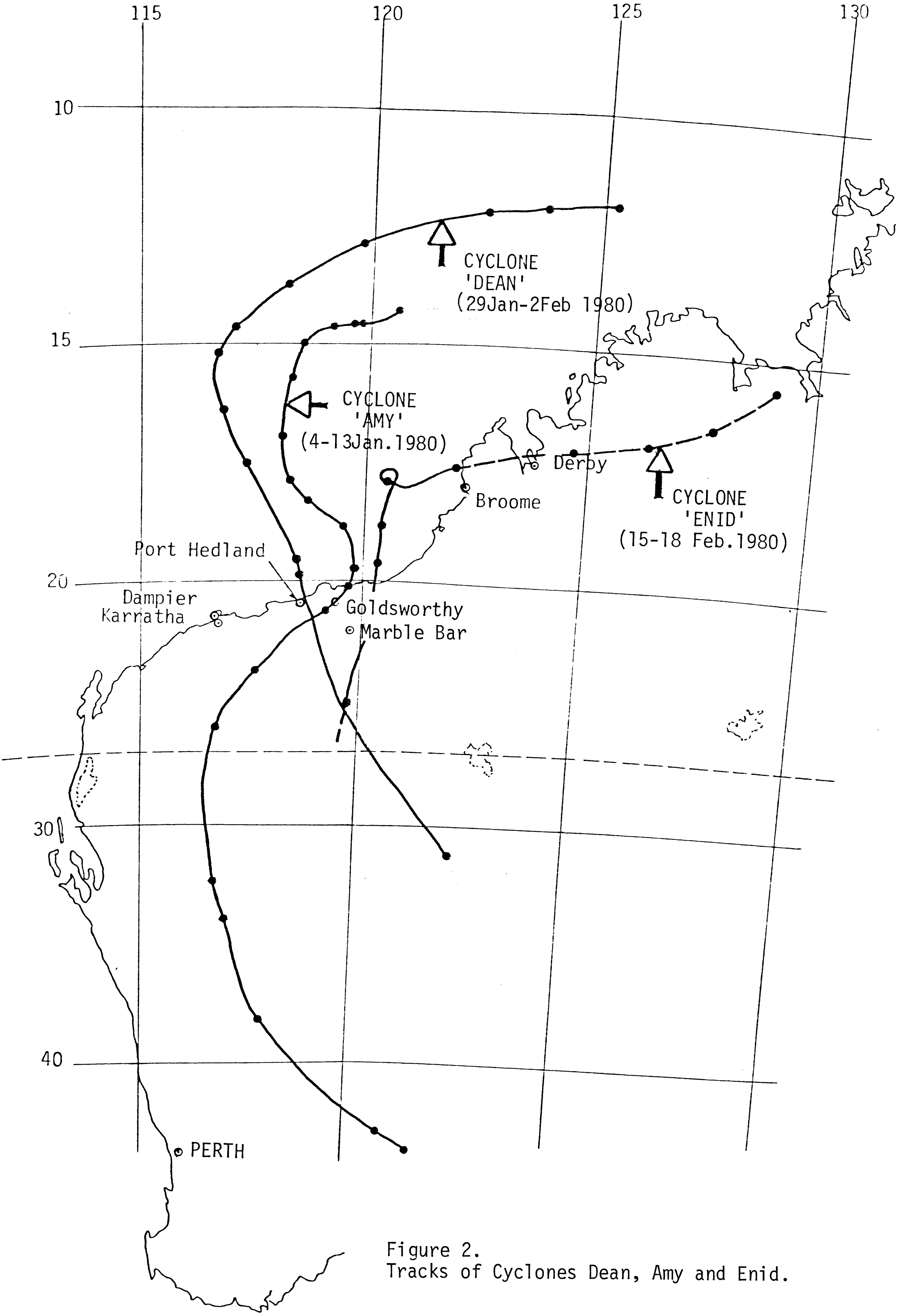

Figure 2.
Tracks of Cyclones Dean, Amy and Enid.

Appendix 1

Table A1 shows a scale of damage level devised by Leicester and Reardon to compare the performance of different types of buildings in Darwin after that city was devastated by cyclone Tracy. The scale was designed to cope with the extensive damage that occurred in Darwin, and to be the basis of a simple system of categorization for statistical purposes. The *damage repair index* gives an indication of the structural performance of buildings. It is defined as follows

$$\text{damage repair index} = \frac{\text{cost for repair of damage}}{\text{initial cost of building}}$$

The indices given in Table 1 were established for a low set asbestos cement clad house, but should apply for any low set house of framed construction having board cladding.

TABLE A1

DEFINITION OF DAMAGE LEVEL
FOR LOW SET HOUSES

Damage Class	Worst Damage Feature	Damage Repair Index
1	Negligible	0.00
2	Missile damage to cladding or windows	0.05
3	Loss of half roof sheeting	0.10
4	Loss of all roof sheeting	0.15
5	Loss of roof structure	0.20
6	Loss of half walls	0.60
7	Loss of all walls	0.90

Because the town of Goldsworthy is so small and most houses were affected by Cyclone Amy the damage repair index was used to obtain an estimate of total damage to the housing. The event also provided an opportunity to gauge the general usefulness of the damage scale.

As previously mentioned, the author arrived in Goldsworthy three weeks after cyclone Amy damaged the town, thus a survey of damage using the classification given in Table A1 was not possible. However Goldsworthy

Mining Limited kindly made available details of their own estimates of damage to each house, and this has been used to classify the damage. Table A2 shows the classification of 180 dwellings. Caravans were not included in the survey.

TABLE A2

CLASSIFICATION OF DAMAGED HOUSES

Damage Class	Worst Damage Feature	Number of Houses	Percentage of All Houses
1	Negligible	69	38
2	Missile damage to cladding or windows	43	24
3	Loss of half roof sheeting	36	20
4	Loss of all roof sheeting	7	4
5	Loss of roof structure	8	4
6	Loss of half walls	7	4
7	Loss of all walls	10	6

An average damage repair index of 0.12 can be calculated from the information given in Tables Al and A2. This can be compared with values calculated by Leicester and Reardon for Darwin houses of 0.23 for low set asbestos cement clad houses, and 0.21 for low set brick houses. This means that the overall damage to houses in Goldsworthy was approximately half of that which occurred to similar houses in Darwin.

In comparing the results of Table A2 with those issued by GML, quoted on page 3 of this report, the following points should be noted.

(a) The percentages given in Table A2 should be taken as indications of the extent of damage rather than absolute values, because some difficulty was encountered in transposing damage descriptions supplied by GML into appropriate classes.

(b) The total percentage of houses in the lower two categories of each set of results, which could be called minor damage, is 62%

(c) GML quotes 8% of houses destroyed or very seriously damaged. This compares well with the total of Classes 6 and 7 of Table A2, 10%.

(d) If the remaining 28% of houses, listed as Classes 3, 4 and 5 actually should have been classified in Class 5, the calculated damage repair index is increased to 0.14.

Regarding the usefulness of the classification scale, the following comments are offered.

(a) The scale is most useful if the damage is surveyed in accordance with the headings recommended.

(b) The GML survey demonstrated the tendency to classify in terms of roof damage, even if damage to walls is more serious.

(c) If the survey is not conducted in accordance with the recommended headings, care must be taken to be consistent in the terminology used, eg. "minor damage", "roof damage". The GML survey reports 30% of houses were unroofed or partly unroofed, whereas the author *using the same data* states only 4% of houses lost roof structure. The discrepancy must be due to looseness of terminology.

(d) Some guidance should be given to users of the damage classification scale to assist them in identifying the worst damage feature when a number of different types occur.