THE METEOROLOGY OF CYCLONE WINIFRED

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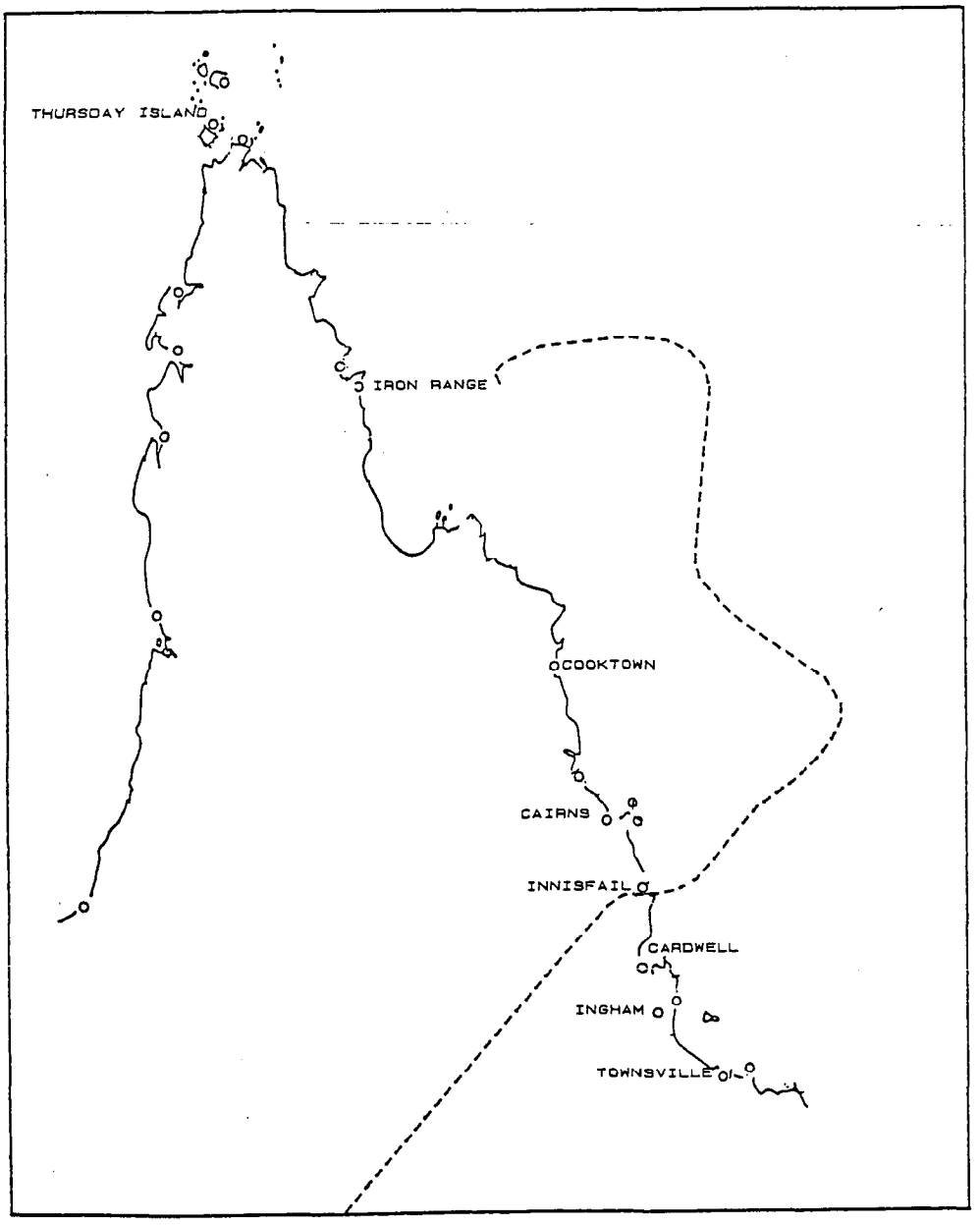
INTRODUCTION

Cyclone Winifred which crossed the North Queensland coast between Cairns and Townsville on February 1, 1986 was the first severe cyclone in 14 years to have a major impact on Australia's east coast. Winifred was therefore a severe test of community preparedness and public understanding of cyclones, as well as of the total warning process. In the hierarchy of severe tropical cyclones, Winifred was of moderate intensity, but relatively large in its area of impact.

Figure 1. Track of cyclone Winifred, from January 27, to February 6, 1986.



TRACK

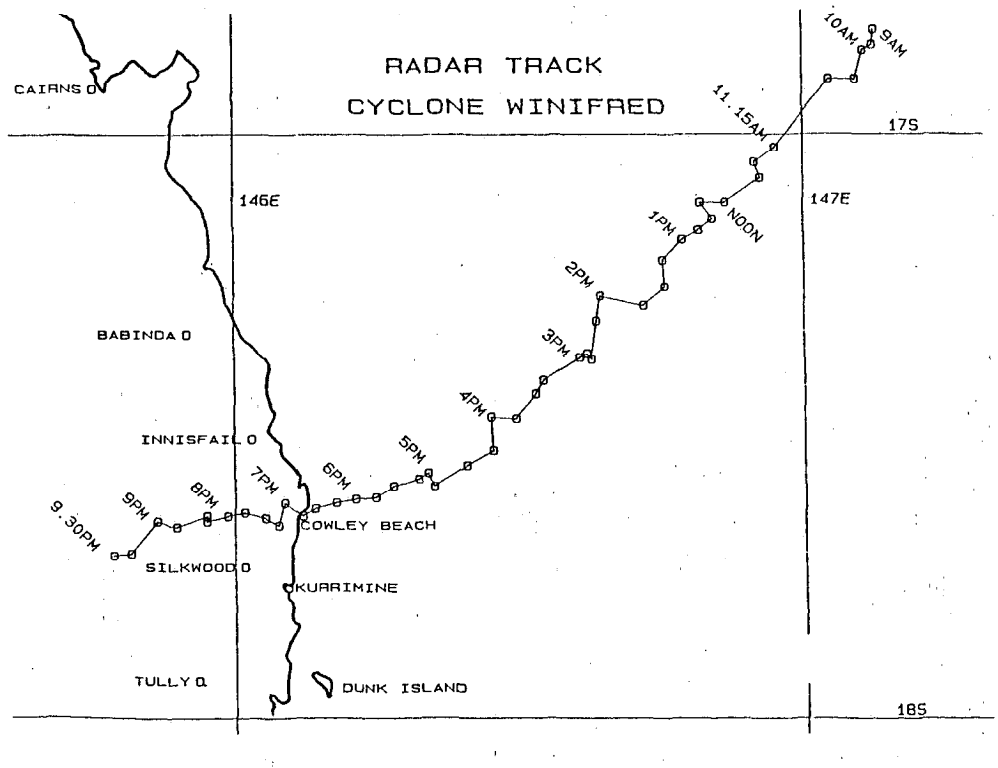
Cyclone Winifred developed from a tropical low, first identified on the afternoon of January 27, approximately 450 km north of Cairns. The low pressure system moved initially in an easterly direction and very slowly intensified. Early on the morning of January 29, the system changed course and commenced moving on a southerly track. By 0400 hrs on January 30 (Day 1), the low had developed into tropical cyclone Winifred with a central pressure of 995 millibars (mb).

Winifred continued to intensify, and underwent two major changes of direction before landfall, firstly from south to south-east on the evening of Day 1, and from south-east to south-west overnight on January 31, (Day 2). The centre temporarily turned from south-west to west-south-west just prior to landfall at 1845 hrs on February 1 (Day 3). Throughout its life prior to landfall, Winifred continued to intensify from its initial pressure of 995 mb to an estimated pressure of 957 mb on landfall. The cyclone weakened as it moved inland but continued to exist as a weakening depression until February 6 (Day 8). The track of the system is shown as Figure 1.

RADAR TRACK

A radar surveillance was maintained by the Cairns Weather Service Office throughout Day 1 and Day 2. Photographs at half-hourly intervals of the plan position indicator (PPI) display which presents a plan view of the echoes from the rain associated with the cyclone were available from 1730 hrs on Day 2 until 1000 hrs on Day 3. From 1000 hrs until 2300 hrs on the Day 3, photographs were available at 15 minute intervals. The main radar features of a tropical cyclone are the eye, which is essentially an echo-free area; and the eye well echo, which surrounds the eye and is approximately circular or slightly elliptical in shape. When discernible features of a cyclone are available on radar, this provides the best means of determining the location of the system and the radar track of Winifred is shown as Figure 2.

Figure 2. Cyclone Winifred: radar track.



The centre of the system was taken to be the geometrical centre of the echo free area within the eye wall. Previous radar observations of tropical cyclones have often shown that the centre appears to move in an irregular fashion with sudden accelerations and deviations from a mean direction of movement, and in this regard Winifred was no exception.

EYE CHARACTERISTICS OF WINIFRED

A partial eye wall echo was discernible on the Cairns radar by 0700 hrs on Day 3 when the centre was located about 185 km from the radar. By 1300 hrs, with the centre 130 km from Cairns, the complete eye was visible and remained so until 2100 hrs, from which time the cyclone began to lose its identifiable radar features.

The radar eye of Winifred was large and mostly elliptical, having a mean diameter of 51 km at 1300 hrs. However, as the cyclone approached the coast, the eye diameter gradually decreased to 49 km by 1700 hrs when the eye well first touched the coast, and to 41 km as the centre of the eye crossed the coast. This decrease in diameter was in agreement with other evidence indicating that the cyclone continued to intensify until landfall at 1845 hrs.

PRESSURE PROFILE

Barograph traces are available from three localities which experienced the cyclone's eye. The centre of the eye passed within 15 km of Innisfail, where a corrected lowest central pressure of 963 mb was recorded. A copy of the trace is shown as Figure 3. The barograph was checked in the week following the cyclone and was found to be reading 2 mb high. At South Johnston, the lowest corrected pressure recorded was 958 mb. A copy of this trace is shown as Figure 4.

Figure 3. Cyclone Winifred: Barograph trace at Innisfail.

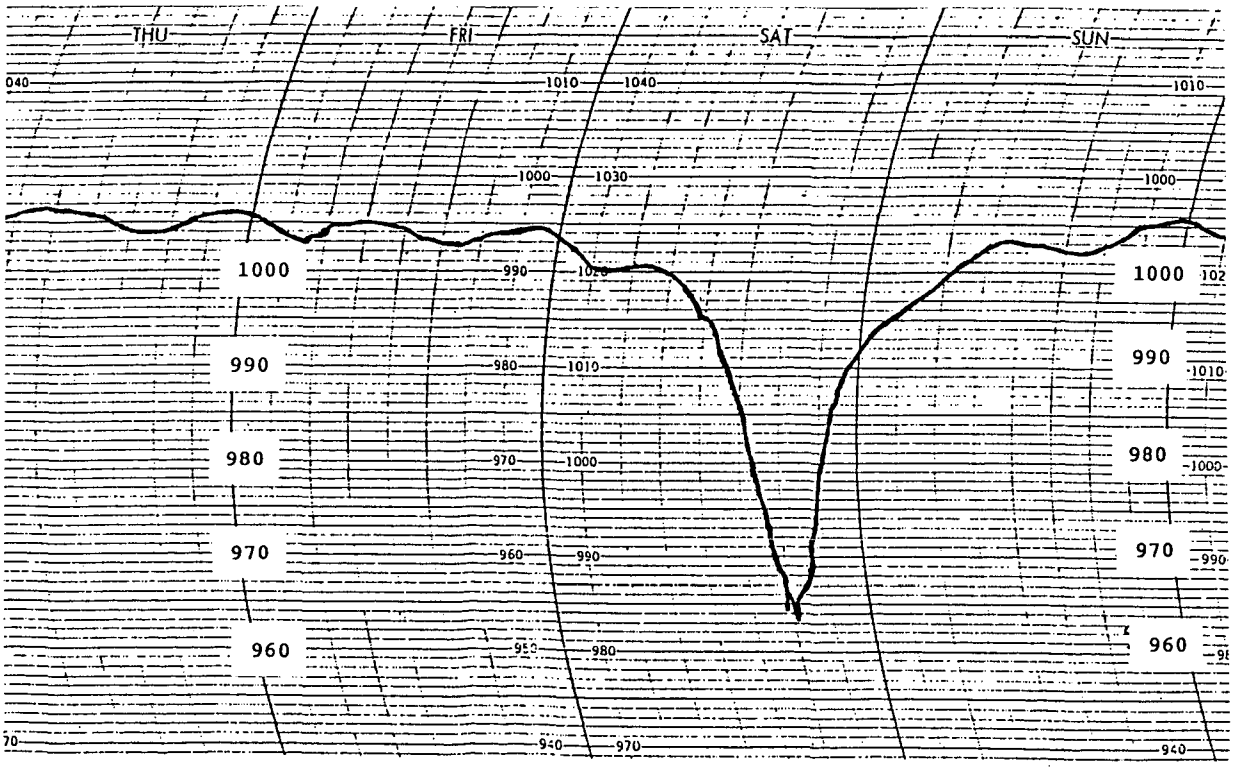
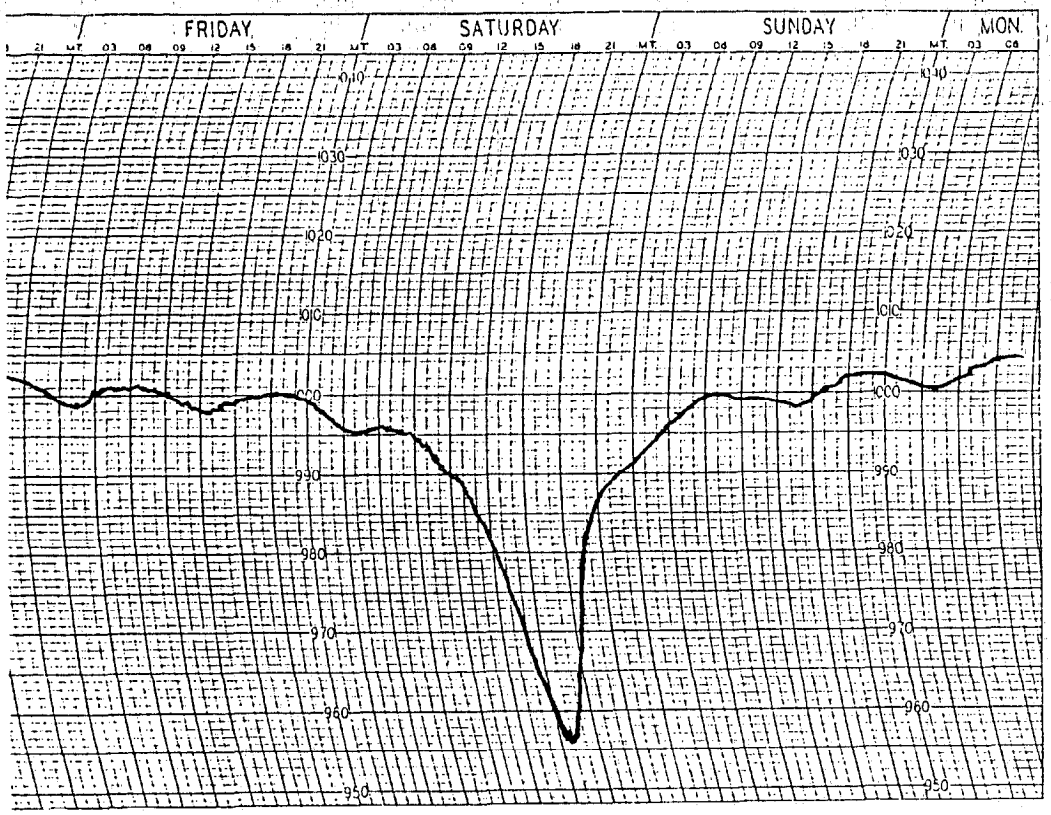
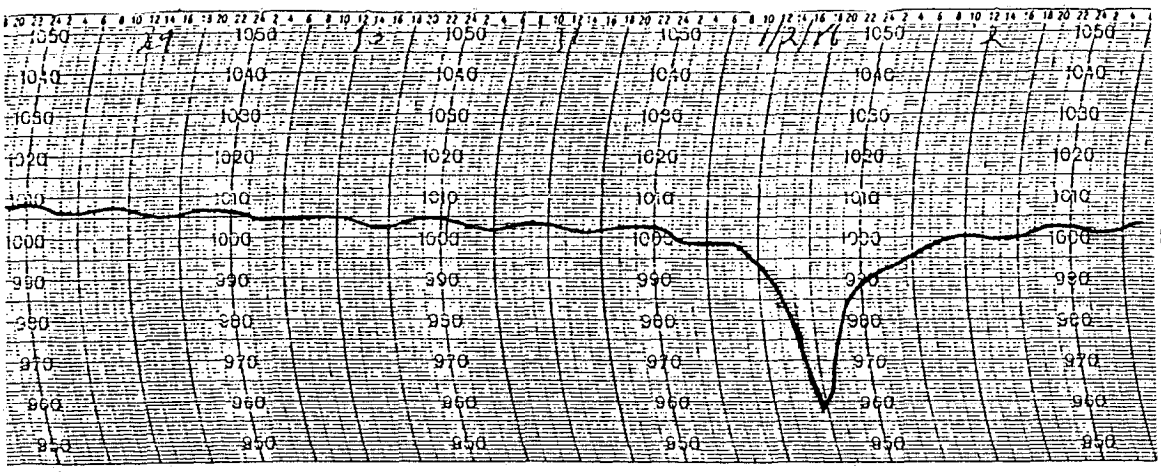


Figure 4. Cyclone Winifred: Barograph trace at South Johnstone.



The centre of the eye passed within a few kilometres of the Joint Tropical Trials and Research Establishment (JTTRE) at Cowley Beach. This station was equipped with a barograph and a synchrotac anemometer. A copy of the barograph trace from Cowley Beach is shown as Figure 5. The lowest central pressure recorded was 958 mb just before 1800 hrs on the Day 3. It is interesting to note that the lowest central pressure occurred approximately one hour before the geometrical centres of the eye was closest to Cowley Beach, suggesting that the pressure centre and the geometrical centre of the eye did not coincide. Pressure values extracted from the trace at Cowley Beach have also been plotted on Figure 6 to allow simultaneous examination of the wind and pressure field at that station.

Figure 5. Cyclone Winifred: Barograph trace at Cowley Beach.

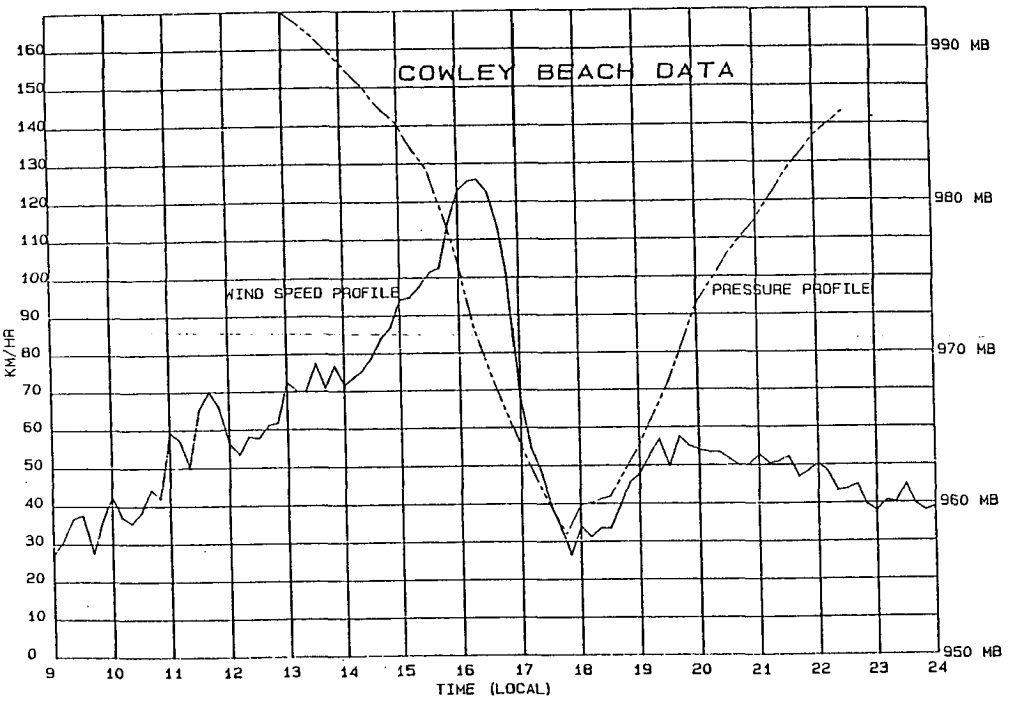


WINDS

The anemometer at Cowley Beach provided 10 minute wind run data in kilometres for each 10 minute period of the day. These data yield the most accurate and detailed description of the windfield associated with Winifred and 10 minute mean winds in kilometres/hour (km/hr) are plotted as Figure 6.

JTTRE have advised that the anemometer does not record 10 minute wind run values between about 21 and 25.5 km; that is, any value of 21 km would be higher, but no higher than 25.5 km. The highest 10 minute wind run recorded was 21 km, which converts to a mean wind of 126 km/hr. Based on the mean wind speed profile shown in Figure 6, it is considered unlikely that this value would have been higher, and 126 km/hr has been accepted as the maximum mean 10 minute wind.

Figure 6. Cyclone Winifred: Wind speed and pressure data - Cowley Beach.



To arrive at an estimate of the peak two to three second gust, it is necessary to apply an approximate gust factor to the mean wind. The major consideration in selecting a gust factor is the surface roughness. The strongest mean winds at Cowley Beach occurred between 1600 hrs and 1630 hrs when the wind direction was south-south-easterly. This indicates that the mean wind was essentially an off water wind and a gust factor of 1.4 would be appropriate. This gives a maximum gust of 176 km/hr.

Remarkably strong winds were recorded as far north as Cairns in the westerly wind regime north of the cyclone centre. The effect of mountainous terrain was clearly evident at Cairns Airport where north-westerly wind gusts to 119 km/hr were recorded while the mean winds were averaging only 45 to 55 km/hr. With such mountainous terrain along the far north tropical coast, large local variations in wind gusts would be expected.

GRADIENT WIND PROFILE

The availability of pressure data from the barograph at Cowley Beach, and the accurate location of the cyclone centre from radar observations enable calculation of the gradient wind profile near the eye. The results of these calculations are shown in Table 1. for the south-south-east wind regime before the passage of the cyclone centre. The gradient wind level is the level at which the wind is not affected by the frictional influence of the earth's surface and is usually about 1 000 m above the surface. In the table, $\triangle$**P** represents the pressure drop during the time that the cyclone approached a distance $\triangle$**R**, **R** is the distance from Cowley Beach, and **Vg** is the gradient wind.

Table 1. Gradient wind profile - cyclone Winifred.

Time (EST)	$\triangle$P (mb)	$\triangle$R (km)	R (km)	Vg (km/hr)
1400 - 1430 hrs	2.0	8.3	56.9	120
1416 - 1445 hrs	2.1	9.3	52.3	111
1430 - 1500 hrs	2.0	8.2	47.6	110
1445 - 1515 hrs	2.6	8.2	43.9	122
1500 - 1530 hrs	3.1	8.7	39.5	123
1515 - 1545 hrs	4.3	9.6	35.2	130
1530 - 1615 hrs	7.4	5.7	26.5	195
1600 - 1630 hrs	7.0	6.1	24.1	175
1615 - 1645 hrs	5.4	7.4	20.4	128
1630 - 1700 hrs	5.0	7.4	16.7	111
1645 - 1715 hrs	4.6	7.2	13.0	96
1700 - 1730 hrs	4.0	6.9	9.5	78

Inspection of the figures in Table 1 indicates that the radius of maximum winds was approximately 27 km. Estimates of the radius of maximum wind using the mean wind speed profile shown in Figure 6, and the speed of the cyclone indicates that this is a realistic assessment. Table 1 also indicates that maximum winds should have been experienced at Cowley Beach at about 1600 hrs which is in close agreement with recorded data.

STORM SURGE

When a tropical cyclone crosses or closely approaches a coastline, there is a resultant rise in mean water level above that expected from astronomical tides alone, and this rise in water level is called a storm surge. The abnormal rise in level is caused principally by wind stress on the water surface and the effects of atmospheric pressure reduction. A storm tide is defined as the summation of the storm surge and the astronomical tide. Storm tide is the absolute water level above a stated datum.

The Bureau of Meteorology has responsibility for the production and dissemination of quantitative storm tide warnings to the State Counter Disaster Organisation. Warnings are issued only if the predicted storm tide height exceeds the Highest Astronomical Tide (HAT) at the locations under threat. Qualitative advices of storm threat are included in tropical cyclone warnings which contain landfall or near-landfall predictions.

Throughout Saturday, storm tide gauges at Cairns, Mourilyan, Clump Point, Cardwell and Lucinda were interrogated at regular intervals to monitor tide levels.

Levels at all centres were above predicted astronomical tides throughout the day. With a radius to the region of maximum winds of 27 km at landfall, the peak storm surge would have occurred near the Clump Point to South Mission Beach area. The maximum storm surge recorded at Clump Point was 1.6 m, approximately 0.2 m below the highest astronomical tide. Cardwell recorded a maximum surge of 1.2 m. Using tide heights obtained from interrogation of the gauges and additional data provided by the Beach Protection Authority, plots of actual tides, predicted astronomical tides and storm surge for various centres are shown as Figures 7 to 9.

Figure 7. Cyclone Winifred: Storm tide data - Clump Point.

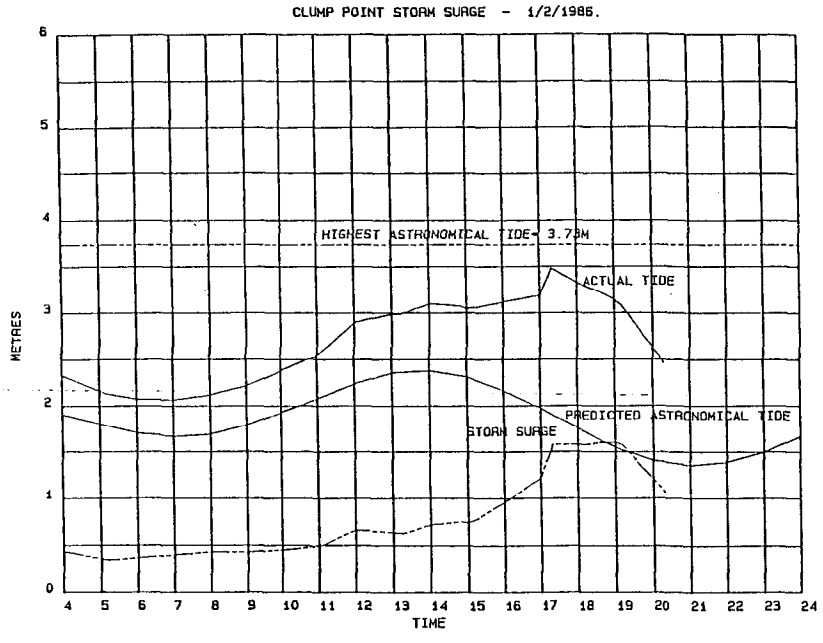


Figure 8. Cyclone Winifred: Storm tide data - Cardwell.

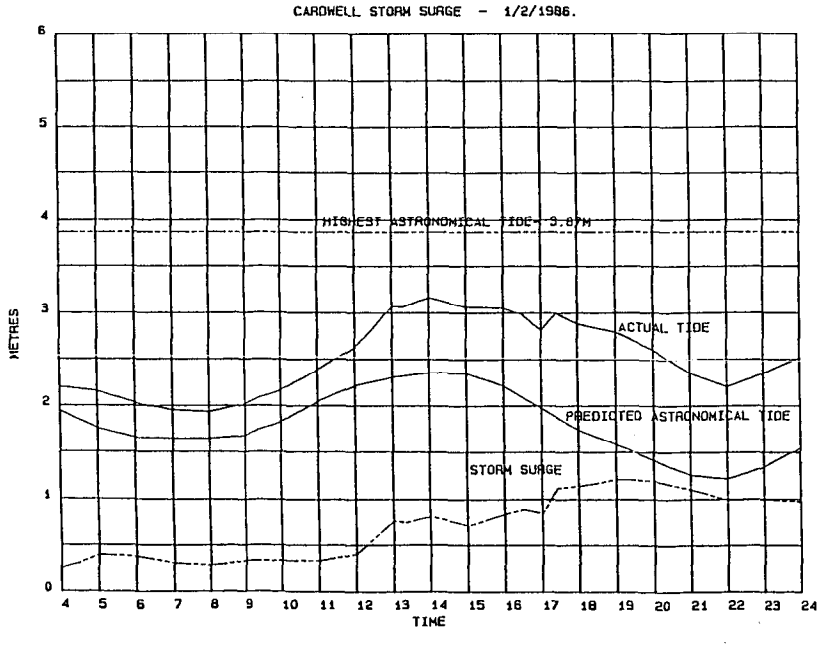
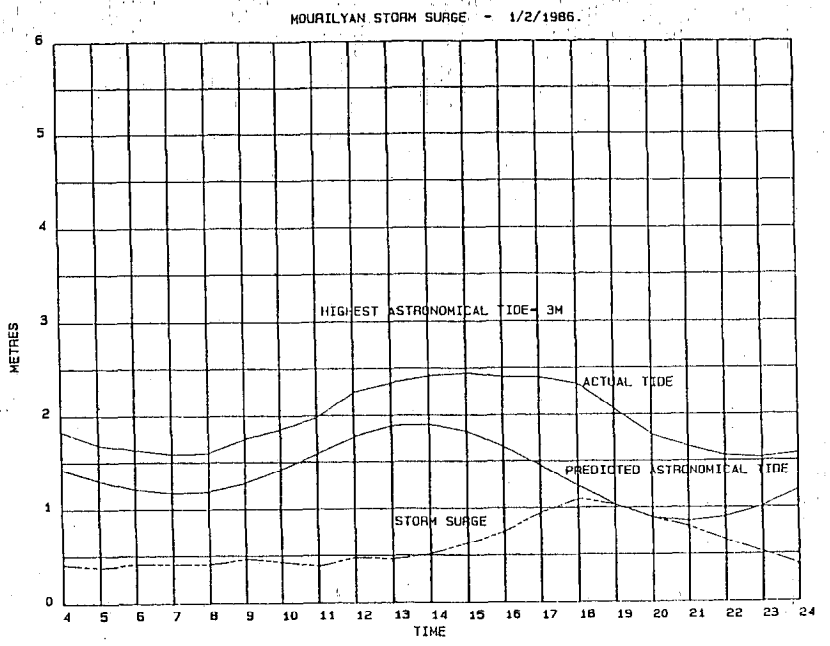


Figure 9. Cyclone Winifred: Storm tide data - Mourilyan.



RAINFALL AND FLOODING

Coastal catchments on the far north tropical coast were generally saturated by heavy rainfall associated with the developing low several days before Winifred made landfall. Between Day 1 and Day 7, totals of over 100 mm were recorded over much of the far north tropical coast and in some inland areas, whilst totals exceeding 500 mm occurred in some coastal areas particularly over the Tully, Herbert and Johnston River catchments. Major flooding resulted in the Tully and Herbert Rivers with river levels approaching record levels.