

# **Tropical cyclone risk relevant to stabilization of the HMS Fowey archeological site**

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## **1. Introduction**

Stabilization of the HMS Fowey is susceptible to sediment movement caused by episodic weather events. Tropical cyclones are the most serious coastal hazards affecting south Florida. Two recent tropical cyclone events caused widespread damage to underwater resources in the south Florida region. The site of the wreck of the HMS Fowey was uncovered after the passage of Hurricane Andrew in 1992, yet received little damage from the recent passage of Tropical Storm Gordon in November of 1994. The wind fields of these two events are examined and the risk of future tropical cyclone activity in the areas is assessed using the National Hurricane Center's risk analysis program.

## **2. Hurricane Andrew and Tropical Storm Gordon**

The center of Hurricane Andrew passed the longitude of the HMS Fowey site at 0821 UTC, 24 August 1992; about 40 minutes before landfall and about 10 min after Air Force reconnaissance aircraft measured the highest flight level winds in the storm. The surface wind field of Andrew was reconstructed by Powell et al., (1995) and Powell and Houston (1995a) using all available wind data from the surface and adjusting flight level winds to the surface with a boundary layer model. The field of maximum 10 min surface (10 m) winds appropriate for oceanic exposure at the time of passage (Fig. 1) indicates that the site encountered the most destructive part of the storm, the eyewall. The wind units in Fig. 1 are  $\text{m s}^{-1}$ ; to convert to knots simply multiply by two. The calm part of the eye passed about 4 miles to the south but the winds at the Fowey site only decreased to  $15\text{--}20 \text{ m s}^{-1}$  as the eye passed. Swaths of meteorological quantities related to damage have been constructed by Powell and Houston (1995b). These fields (not shown) indicate that the Fowey site was located in the area receiving the maximum duration of > hurricane force ( $34 \text{ m s}^{-1}$ ) winds, on the order of two hours, and received  $>50 \text{ m s}^{-1}$  winds for a period on the order of one hour. Because of its proximity to the eye, the Fowey site received the eyewall winds on the west and east sides of the storm; this was associated with a wind direction shift of roughly 140-150 degrees. Initially northwest and north winds probably would have transported material offshore and southward; after the eye passed winds from the southeast would have assisted in additional sediment removal towards the north.

In contrast, Tropical Storm Gordon was a much weaker tropical cyclone passing far to the south

of the site on 17-19 November 1994 with maximum gusts rarely exceeding  $25 \text{ m s}^{-1}$  (50 kts). Gordon's erratic track (Fig. 2) is indicative of the complexity of tropical cyclone motion. Gordon was repeatedly influenced by large scale atmospheric flow features (upper level troughs and high pressure systems) that were themselves in motion. No one feature was sufficiently dominant to force Gordon along a given track for very long so Gordon meandered as each feature came and went. Gordon's wind field (Fig. 3 expressed in knots) was much weaker than Andrew and the peak winds were not really caused by Gordon alone, but by a strong pressure gradient that set up between Gordon and a high pressure cell in the Atlantic to the northeast of south Florida. This is typical of tropical storms; they are usually too weak to have a well defined symmetric wind field structure. As a result the peak winds occurred over south Florida, far from the center of the storm. Damage done to underwater resources was probably related to the long duration (2 days) of easterly winds near gale force (35 kts) or higher as Gordon passed to the south. The long duration of east winds allowed deep water waves to become fully developed and produced higher than average water levels for an extended period. Lack of sediment removal at the Fowey site may be related to it's location in relatively shallow water downwind of where the larger waves were breaking on the outer reefs.

### 3. Hurricane Risk Assessment at the Fowey Archeological Site

Risk was estimated through use of the National Hurricane Center risk analysis software (HURISK) as described by Neumann (1987). From 1886-1994, 59 tropical cyclones (32 hurricanes and 27 tropical storms) passed within 75 n miles of Legare Anchorage (Table 1, Fig. 4). During this period, Legare Anchorage was sufficiently close to nine greater-than-100 kt storms to have experienced the eyewall, including two storms in 1935 and one in 1933. One of the 1935 storms was the famous Florida Keys storm that destroyed Flagler's railroad and held the record for the lowest observed pressure in an Atlantic hurricane (until Gilbert in 1988). The information in Table 1 is taken from 6 hourly storm track data, hence the lack of consistency with the Andrew analysis described above. The mean occurrence date is September 24, with strong clustering (Fig. 5) of events over the twelve week period from mid-August through late October. The direction of approach is roughly bimodal, with one population approaching from the ESE, the other from the SW or SSW (Fig. 6).

(Fig. 7)

We find using a Poisson distribution that there is a 42% chance of at least one tropical cyclone event during any one year (where an event is defined as the circulation center passing through the 75 nautical mile circle); the probability of at least one event exceeds 90% in 5 years. The chances of multiple events over any 5 year period are as follows: at least 2 events, 75%; at least 3 events, 50%; at least 4 events, 30%, and at least 5 events, about 15%. Strength of the event is given by use of the Weibul function. Using the 75 (50) n mi radius (Fig. 8), we find a mean return period for category 1 or greater of 4 (6) years, category 2 or greater 7 (10) years, category 3 or greater 10 (15) years, category 4 or greater 17 (25) years, and category 5 or greater 35 (50) years. If we use a 20 nm radius typical of the radial distance of the eyewall from the center of a hurricanes circulation, the return period for a Category 1 or greater is 15 years, a category 2 or greater is 25 years, a category 3 or higher is 35 years, a category 4 or higher is 60 years, and a category 5 is 120 years. The return period for a direct hit of an Andrew-type storm (Category 4) at the Fowey site is on the order of 200 years.

#### 4. Conclusions

The greatest threat to the HMS Fowey archeological site appears to be from the passage of an intense (Category 2 or greater) hurricane eyewall. Risk analysis suggests that an eyewall passage from a category 2 or higher hurricane happens roughly every 25 years.

#### References

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Powell, M. D., S. H. Houston, and T. A. Reinhold, 1995a: Hurricane Andrew's Wind Field at Landfall in South Florida. Part I: Standardizing Measurements for Documentation of Surface Wind Fields. Submitted to *Weather and Forecasting*, 1995

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# HRD Surface Wind Analysis

## Hurricane Andrew 0821 UTC, 24 August 1992

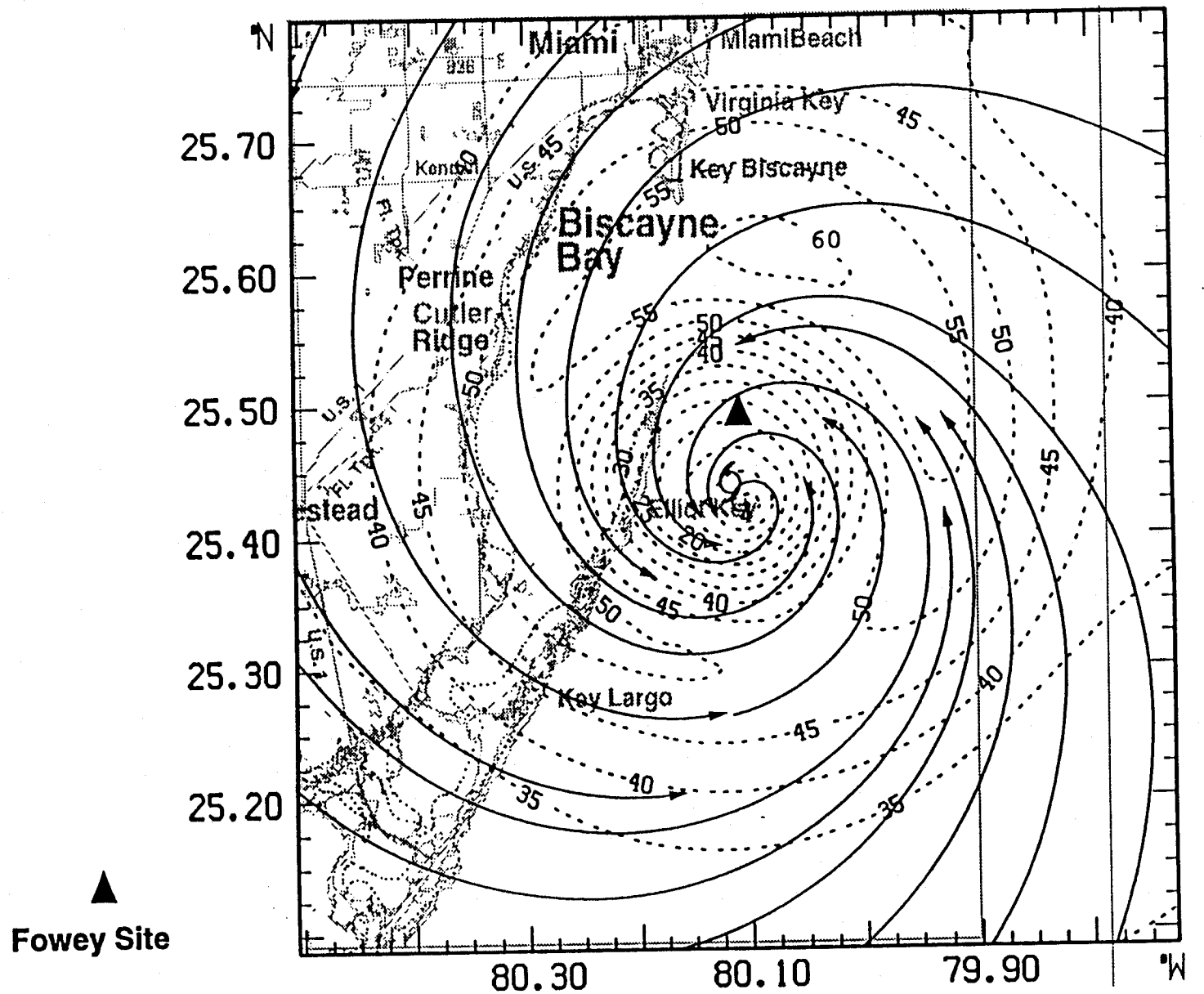
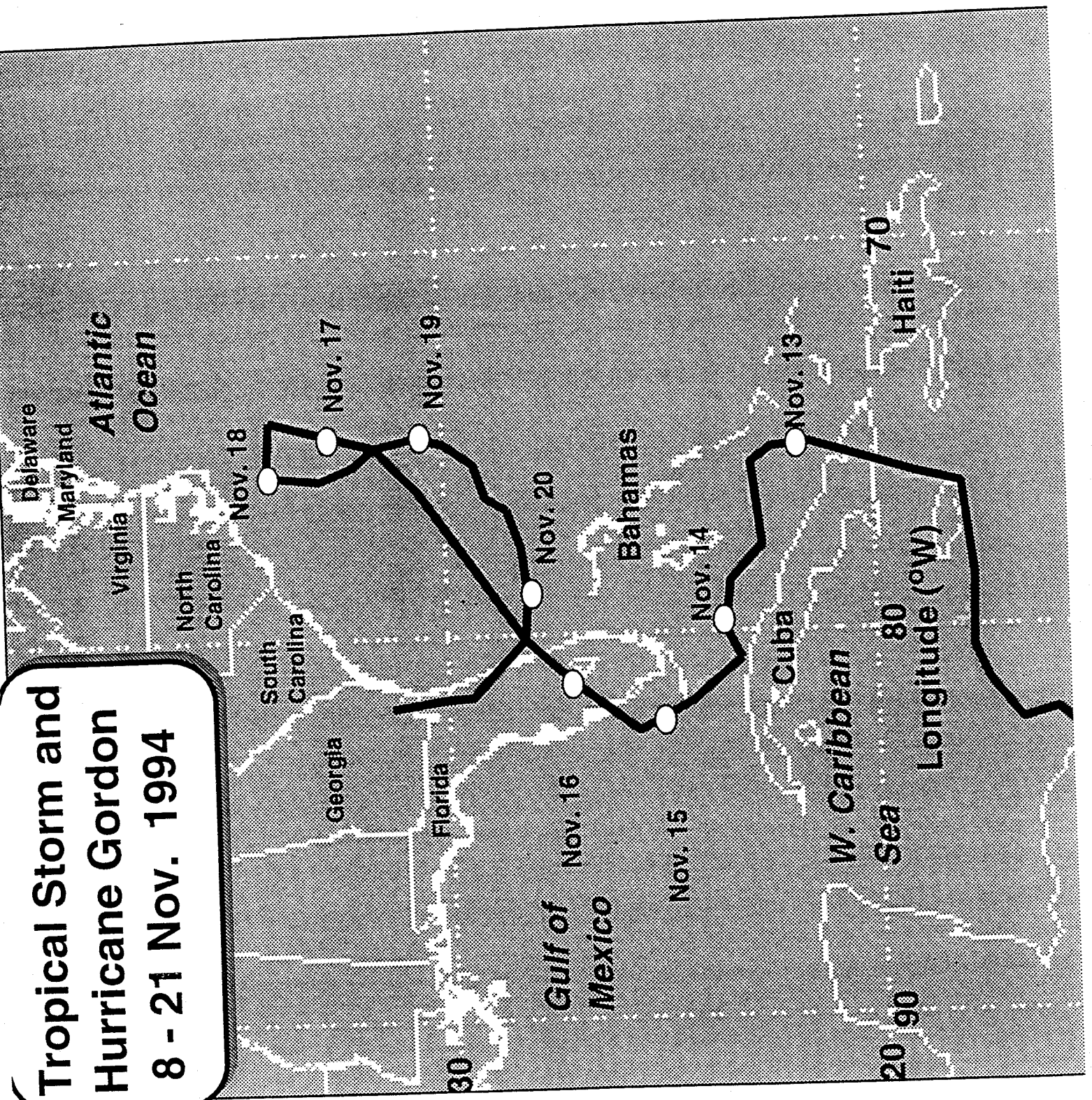


Fig. 1

Maximum 10 min wind ( $\text{m s}^{-1}$ ) for marine exposure at 10 m level

# **Tropical Storm and Hurricane Gordon 8 - 21 Nov. 1994**



Latitude (°N)

Fig. 2

**Tropical Storm Gordon 14 Nov. 1994 1900 UTC**  
**Maximum Sustained 10 min mean winds (kts) at 10 m**

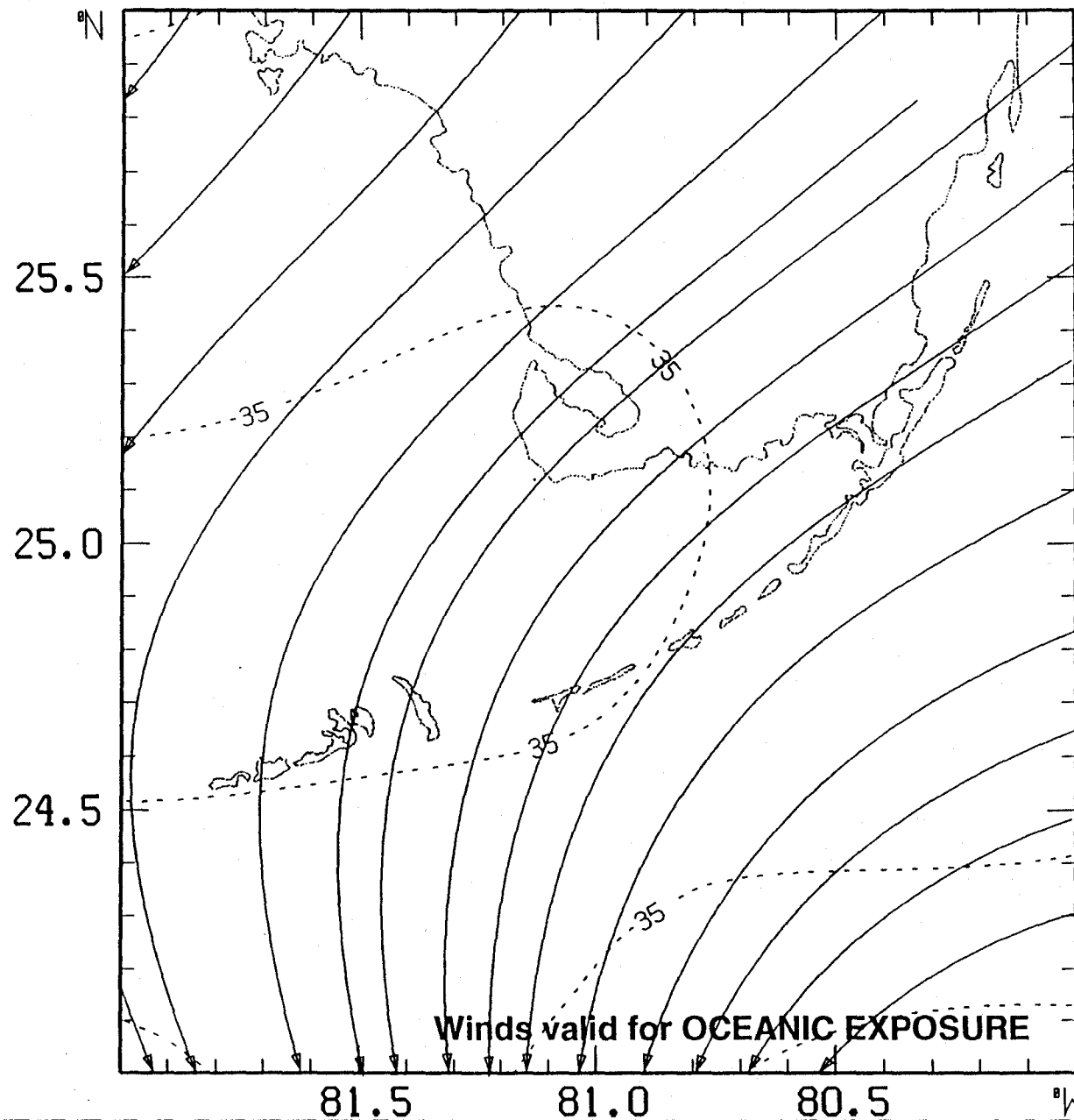
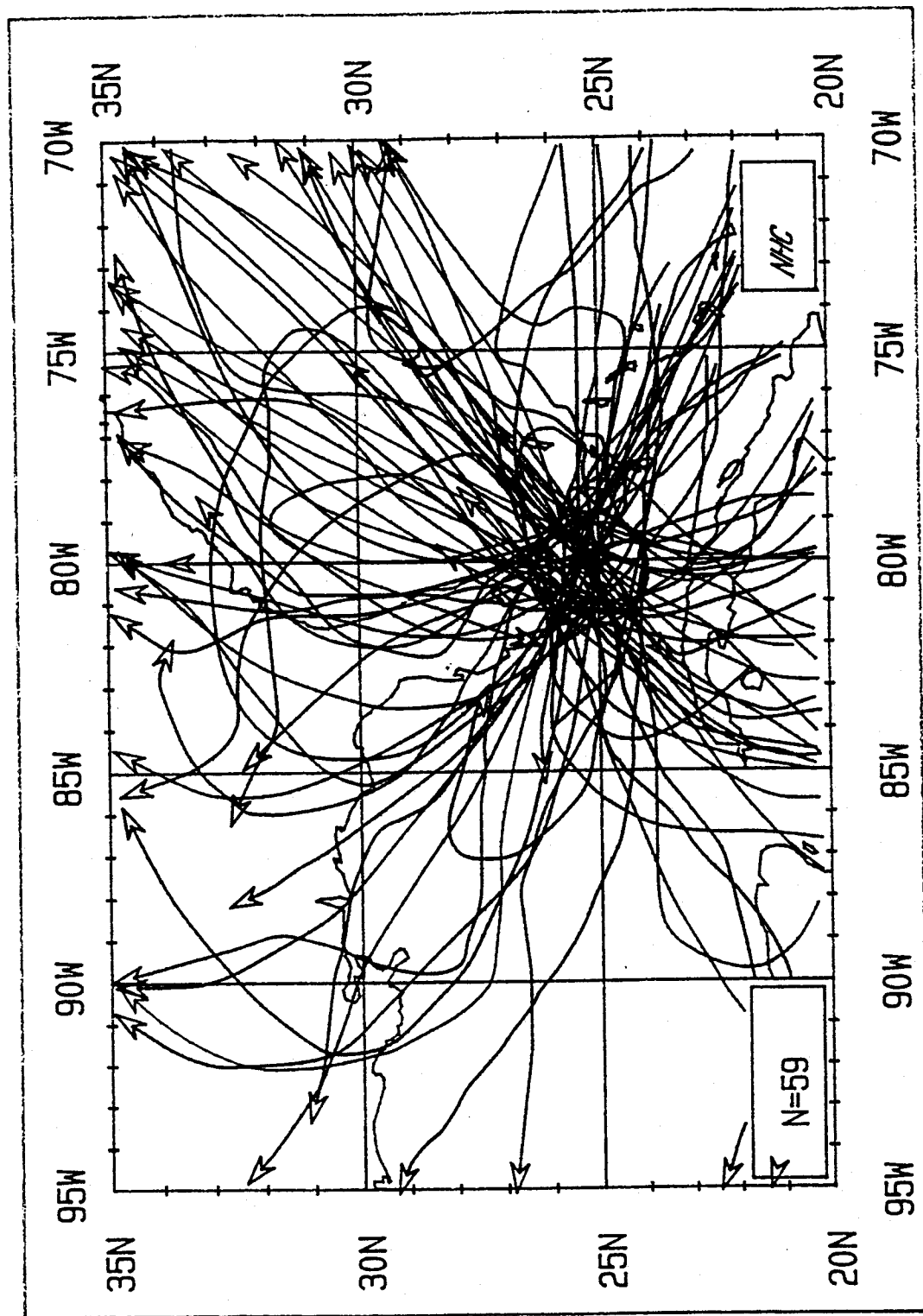


**Fig. 3**

**NOAA Hurricane Research Division Surface Wind Analysis System**

# TROPICAL CYCLONES (1886-1994) PASSING WITHIN 75 N.MI. OF LEGARE ANCHOR

| STORM INDEX NUMBER | STORM NAME | YEAR | MONTH | DAY (GMT) | STORM NUMBER FOR YEAR | MAXIMUM WIND (KTS) NEAR STORM CNTR AT CLOSEST PT. OF APPROACH | CLOSEST POINT OF APPROACH (CPA) N.MI. | STORM HEADING (DEGS) AT CPA | STORM FORWARD SPEED AT CPA (KTS) |
|--------------------|------------|------|-------|-----------|-----------------------|---------------------------------------------------------------|---------------------------------------|-----------------------------|----------------------------------|
| 1                  | 1886       | 1886 | 1     | 1         | 1                     | 1                                                             | 1                                     | 1                           | 1                                |
| 2                  | 1887       | 1887 | 2     | 2         | 2                     | 2                                                             | 2                                     | 2                           | 2                                |
| 3                  | 1888       | 1888 | 3     | 3         | 3                     | 3                                                             | 3                                     | 3                           | 3                                |
| 4                  | 1889       | 1889 | 4     | 4         | 4                     | 4                                                             | 4                                     | 4                           | 4                                |
| 5                  | 1890       | 1890 | 5     | 5         | 5                     | 5                                                             | 5                                     | 5                           | 5                                |
| 6                  | 1891       | 1891 | 6     | 6         | 6                     | 6                                                             | 6                                     | 6                           | 6                                |
| 7                  | 1892       | 1892 | 7     | 7         | 7                     | 7                                                             | 7                                     | 7                           | 7                                |
| 8                  | 1893       | 1893 | 8     | 8         | 8                     | 8                                                             | 8                                     | 8                           | 8                                |
| 9                  | 1894       | 1894 | 9     | 9         | 9                     | 9                                                             | 9                                     | 9                           | 9                                |
| 10                 | 1895       | 1895 | 10    | 10        | 10                    | 10                                                            | 10                                    | 10                          | 10                               |
| 11                 | 1896       | 1896 | 11    | 11        | 11                    | 11                                                            | 11                                    | 11                          | 11                               |
| 12                 | 1897       | 1897 | 12    | 12        | 12                    | 12                                                            | 12                                    | 12                          | 12                               |
| 13                 | 1898       | 1898 | 1     | 1         | 13                    | 13                                                            | 13                                    | 13                          | 13                               |
| 14                 | 1899       | 1899 | 2     | 2         | 14                    | 14                                                            | 14                                    | 14                          | 14                               |
| 15                 | 1900       | 1900 | 3     | 3         | 15                    | 15                                                            | 15                                    | 15                          | 15                               |
| 16                 | 1901       | 1901 | 4     | 4         | 16                    | 16                                                            | 16                                    | 16                          | 16                               |
| 17                 | 1902       | 1902 | 5     | 5         | 17                    | 17                                                            | 17                                    | 17                          | 17                               |
| 18                 | 1903       | 1903 | 6     | 6         | 18                    | 18                                                            | 18                                    | 18                          | 18                               |
| 19                 | 1904       | 1904 | 7     | 7         | 19                    | 19                                                            | 19                                    | 19                          | 19                               |
| 20                 | 1905       | 1905 | 8     | 8         | 20                    | 20                                                            | 20                                    | 20                          | 20                               |
| 21                 | 1906       | 1906 | 9     | 9         | 21                    | 21                                                            | 21                                    | 21                          | 21                               |
| 22                 | 1907       | 1907 | 10    | 10        | 22                    | 22                                                            | 22                                    | 22                          | 22                               |
| 23                 | 1908       | 1908 | 11    | 11        | 23                    | 23                                                            | 23                                    | 23                          | 23                               |
| 24                 | 1909       | 1909 | 12    | 12        | 24                    | 24                                                            | 24                                    | 24                          | 24                               |
| 25                 | 1910       | 1910 | 1     | 1         | 25                    | 25                                                            | 25                                    | 25                          | 25                               |
| 26                 | 1911       | 1911 | 2     | 2         | 26                    | 26                                                            | 26                                    | 26                          | 26                               |
| 27                 | 1912       | 1912 | 3     | 3         | 27                    | 27                                                            | 27                                    | 27                          | 27                               |
| 28                 | 1913       | 1913 | 4     | 4         | 28                    | 28                                                            | 28                                    | 28                          | 28                               |
| 29                 | 1914       | 1914 | 5     | 5         | 29                    | 29                                                            | 29                                    | 29                          | 29                               |
| 30                 | 1915       | 1915 | 6     | 6         | 30                    | 30                                                            | 30                                    | 30                          | 30                               |
| 31                 | 1916       | 1916 | 7     | 7         | 31                    | 31                                                            | 31                                    | 31                          | 31                               |
| 32                 | 1917       | 1917 | 8     | 8         | 32                    | 32                                                            | 32                                    | 32                          | 32                               |
| 33                 | 1918       | 1918 | 9     | 9         | 33                    | 33                                                            | 33                                    | 33                          | 33                               |
| 34                 | 1919       | 1919 | 10    | 10        | 34                    | 34                                                            | 34                                    | 34                          | 34                               |
| 35                 | 1920       | 1920 | 11    | 11        | 35                    | 35                                                            | 35                                    | 35                          | 35                               |
| 36                 | 1921       | 1921 | 12    | 12        | 36                    | 36                                                            | 36                                    | 36                          | 36                               |
| 37                 | 1922       | 1922 | 1     | 1         | 37                    | 37                                                            | 37                                    | 37                          | 37                               |
| 38                 | 1923       | 1923 | 2     | 2         | 38                    | 38                                                            | 38                                    | 38                          | 38                               |
| 39                 | 1924       | 1924 | 3     | 3         | 39                    | 39                                                            | 39                                    | 39                          | 39                               |
| 40                 | 1925       | 1925 | 4     | 4         | 40                    | 40                                                            | 40                                    | 40                          | 40                               |
| 41                 | 1926       | 1926 | 5     | 5         | 41                    | 41                                                            | 41                                    | 41                          | 41                               |
| 42                 | 1927       | 1927 | 6     | 6         | 42                    | 42                                                            | 42                                    | 42                          | 42                               |
| 43                 | 1928       | 1928 | 7     | 7         | 43                    | 43                                                            | 43                                    | 43                          | 43                               |
| 44                 | 1929       | 1929 | 8     | 8         | 44                    | 44                                                            | 44                                    | 44                          | 44                               |
| 45                 | 1930       | 1930 | 9     | 9         | 45                    | 45                                                            | 45                                    | 45                          | 45                               |
| 46                 | 1931       | 1931 | 10    | 10        | 46                    | 46                                                            | 46                                    | 46                          | 46                               |
| 47                 | 1932       | 1932 | 11    | 11        | 47                    | 47                                                            | 47                                    | 47                          | 47                               |
| 48                 | 1933       | 1933 | 12    | 12        | 48                    | 48                                                            | 48                                    | 48                          | 48                               |
| 49                 | 1934       | 1934 | 1     | 1         | 49                    | 49                                                            | 49                                    | 49                          | 49                               |
| 50                 | 1935       | 1935 | 2     | 2         | 50                    | 50                                                            | 50                                    | 50                          | 50                               |
| 51                 | 1936       | 1936 | 3     | 3         | 51                    | 51                                                            | 51                                    | 51                          | 51                               |
| 52                 | 1937       | 1937 | 4     | 4         | 52                    | 52                                                            | 52                                    | 52                          | 52                               |
| 53                 | 1938       | 1938 | 5     | 5         | 53                    | 53                                                            | 53                                    | 53                          | 53                               |
| 54                 | 1939       | 1939 | 6     | 6         | 54                    | 54                                                            | 54                                    | 54                          | 54                               |
| 55                 | 1940       | 1940 | 7     | 7         | 55                    | 55                                                            | 55                                    | 55                          | 55                               |
| 56                 | 1941       | 1941 | 8     | 8         | 56                    | 56                                                            | 56                                    | 56                          | 56                               |
| 57                 | 1942       | 1942 | 9     | 9         | 57                    | 57                                                            | 57                                    | 57                          | 57                               |
| 58                 | 1943       | 1943 | 10    | 10        | 58                    | 58                                                            | 58                                    | 58                          | 58                               |
| 59                 | 1944       | 1944 | 11    | 11        | 59                    | 59                                                            | 59                                    | 59                          | 59                               |
| 60                 | 1945       | 1945 | 12    | 12        | 60                    | 60                                                            | 60                                    | 60                          | 60                               |
| 61                 | 1946       | 1946 | 1     | 1         | 61                    | 61                                                            | 61                                    | 61                          | 61                               |
| 62                 | 1947       | 1947 | 2     | 2         | 62                    | 62                                                            | 62                                    | 62                          | 62                               |
| 63                 | 1948       | 1948 | 3     | 3         | 63                    | 63                                                            | 63                                    | 63                          | 63                               |
| 64                 | 1949       | 1949 | 4     | 4         | 64                    | 64                                                            | 64                                    | 64                          | 64                               |
| 65                 | 1950       | 1950 | 5     | 5         | 65                    | 65                                                            | 65                                    | 65                          | 65                               |
| 66                 | 1951       | 1951 | 6     | 6         | 66                    | 66                                                            | 66                                    | 66                          | 66                               |
| 67                 | 1952       | 1952 | 7     | 7         | 67                    | 67                                                            | 67                                    | 67                          | 67                               |
| 68                 | 1953       | 1953 | 8     | 8         | 68                    | 68                                                            | 68                                    | 68                          | 68                               |
| 69                 | 1954       | 1954 | 9     | 9         | 69                    | 69                                                            | 69                                    | 69                          | 69                               |
| 70                 | 1955       | 1955 | 10    | 10        | 70                    | 70                                                            | 70                                    | 70                          | 70                               |
| 71                 | 1956       | 1956 | 11    | 11        | 71                    | 71                                                            | 71                                    | 71                          | 71                               |
| 72                 | 1957       | 1957 | 12    | 12        | 72                    | 72                                                            | 72                                    | 72                          | 72                               |
| 73                 | 1958       | 1958 | 1     | 1         | 73                    | 73                                                            | 73                                    | 73                          | 73                               |
| 74                 | 1959       | 1959 | 2     | 2         | 74                    | 74                                                            | 74                                    | 74                          | 74                               |
| 75                 | 1960       | 1960 | 3     | 3         | 75                    | 75                                                            | 75                                    | 75                          | 75                               |
| 76                 | 1961       | 1961 | 4     | 4         | 76                    | 76                                                            | 76                                    | 76                          | 76                               |
| 77                 | 1962       | 1962 | 5     | 5         | 77                    | 77                                                            | 77                                    | 77                          | 77                               |
| 78                 | 1963       | 1963 | 6     | 6         | 78                    | 78                                                            | 78                                    | 78                          | 78                               |
| 79                 | 1964       | 1964 | 7     | 7         | 79                    | 79                                                            | 79                                    | 79                          | 79                               |
| 80                 | 1965       | 1965 | 8     | 8         | 80                    | 80                                                            | 80                                    | 80                          | 80                               |
| 81                 | 1966       | 1966 | 9     | 9         | 81                    | 81                                                            | 81                                    | 81                          | 81                               |
| 82                 | 1967       | 1967 | 10    | 10        | 82                    | 82                                                            | 82                                    | 82                          | 82                               |
| 83                 | 1968       | 1968 | 11    | 11        | 83                    | 83                                                            | 83                                    | 83                          | 83                               |
| 84                 | 1969       | 1969 | 12    | 12        | 84                    | 84                                                            | 84                                    | 84                          | 84                               |
| 85                 | 1970       | 1970 | 1     | 1         | 85                    | 85                                                            | 85                                    | 85                          | 85                               |
| 86                 | 1971       | 1971 | 2     | 2         | 86                    | 86                                                            | 86                                    | 86                          | 86                               |
| 87                 | 1972       | 1972 | 3     | 3         | 87                    | 87                                                            | 87                                    | 87                          | 87                               |
| 88                 | 1973       | 1973 | 4     | 4         | 88                    | 88                                                            | 88                                    | 88                          | 88                               |
| 89                 | 1974       | 1974 | 5     | 5         | 89                    | 89                                                            | 89                                    | 89                          | 89                               |
| 90                 | 1975       | 1975 | 6     | 6         | 90                    | 90                                                            | 90                                    | 90                          | 90                               |
| 91                 | 1976       | 1976 | 7     | 7         | 91                    | 91                                                            | 91                                    | 91                          | 91                               |
| 92                 | 1977       | 1977 | 8     | 8         | 92                    | 92                                                            | 92                                    | 92                          | 92                               |
| 93                 | 1978       | 1978 | 9     | 9         | 93                    | 93                                                            | 93                                    | 93                          | 93                               |
| 94                 | 1979       | 1979 | 10    | 10        | 94                    | 94                                                            | 94                                    | 94                          | 94                               |
| 95                 | 1980       | 1980 | 11    | 11        | 95                    | 95                                                            | 95                                    | 95                          | 95                               |
| 96                 | 1981       | 1981 | 12    | 12        | 96                    | 96                                                            | 96                                    | 96                          | 96                               |
| 97                 | 1982       | 1982 | 1     | 1         | 97                    | 97                                                            | 97                                    | 97                          | 97                               |
| 98                 | 1983       | 1983 | 2     | 2         | 98                    | 98                                                            | 98                                    | 98                          | 98                               |
| 99                 | 1984       | 1984 | 3     | 3         | 99                    | 99                                                            | 99                                    | 99                          | 99                               |
| 100                | 1985       | 1985 | 4     | 4         | 100                   | 100                                                           | 100                                   | 100                         | 100                              |
| 101                | 1986       | 1986 | 5     | 5         | 101                   | 101                                                           | 101                                   | 101                         | 101                              |
| 102                | 1987       | 1987 | 6     | 6         | 102                   | 102                                                           | 102                                   | 102                         | 102                              |
| 103                | 1988       | 1988 | 7     | 7         | 103                   | 103                                                           | 103                                   | 103                         | 103                              |
| 104                | 1989       | 1989 | 8     | 8         | 104                   | 104                                                           | 104                                   | 104                         | 104                              |
| 105                | 1990       | 1990 | 9     | 9         | 105                   | 105                                                           | 105                                   | 105                         | 105                              |
| 106                | 1991       | 1991 | 10    | 10        | 106                   | 106                                                           | 106                                   | 106                         | 106                              |
| 107                | 1992       | 1992 | 11    | 11        | 107                   | 107                                                           | 107                                   | 107                         | 107                              |
| 108                | 1993       | 1993 | 12    | 12        | 108                   | 108                                                           | 108                                   | 108                         | 108                              |
| 109                | 1994       | 1994 | 1     | 1         | 109                   | 109                                                           | 109                                   | 109                         | 109                              |
| 110                | 1995       | 1995 | 2     | 2         | 110                   | 110                                                           | 110                                   | 110                         | 110                              |
| 111                | 1996       | 1996 | 3     | 3         | 111                   | 111                                                           | 111                                   | 111                         | 111                              |
| 112                | 1997       | 1997 | 4     | 4         | 112                   | 112                                                           | 112                                   | 112                         | 112                              |
| 113                | 1998       | 1998 | 5     | 5         | 113                   | 113                                                           | 113                                   | 113                         | 113                              |
| 114                | 1999       | 1999 | 6     | 6         | 114                   | 114                                                           | 114                                   | 114                         | 114                              |
| 115                | 2000       | 2000 | 7     | 7         | 115                   | 115                                                           | 115                                   | 115                         | 115                              |
| 116                | 2001       | 2001 | 8     | 8         | 116                   | 116                                                           | 116                                   | 116                         | 116                              |
| 117                | 2002       | 2002 | 9     | 9         | 117                   | 117                                                           | 117                                   | 117                         | 117                              |
| 118                | 2003       | 2003 | 10    | 10        | 118                   | 118                                                           | 118                                   | 118                         | 118                              |
| 119                | 2004       | 2004 | 11    | 11        | 119                   | 119                                                           | 119                                   | 119                         | 119                              |
| 120                | 2005       | 2005 | 12    | 12        | 120                   | 120                                                           | 120                                   | 120                         | 120                              |
| 121                | 2006       | 2006 | 1     | 1         | 121                   | 121                                                           | 121                                   | 121                         | 121                              |
| 122                | 2007       | 2007 | 2     | 2         | 122                   | 122                                                           | 122                                   | 122                         | 122                              |
| 123                | 2008       | 2008 | 3     | 3         | 123                   | 123                                                           | 123                                   | 123                         | 123                              |
| 124                | 2009       | 2009 | 4     | 4         | 124                   | 124                                                           | 124                                   | 124                         | 124                              |
| 125                | 2010       | 2010 | 5     | 5         | 125                   | 125                                                           | 125                                   | 125                         | 125                              |
| 126                | 2011       | 2011 | 6     | 6         | 126                   | 126                                                           | 126                                   | 126                         | 126                              |
| 127                | 2012       | 2012 | 7     | 7         | 127                   | 127                                                           | 127                                   | 127                         | 127                              |
| 128                | 2013       | 2013 | 8     | 8         | 128                   | 128                                                           | 128                                   | 128                         | 128                              |
| 129                | 2014       | 2014 | 9     | 9         | 129                   | 129                                                           | 129                                   | 129                         | 129                              |
| 130                | 2015       | 2015 | 10    | 10        | 130                   | 130                                                           | 130                                   | 130                         | 130                              |
| 131                | 2016       | 2016 | 11    | 11        | 131                   | 131                                                           | 131                                   | 131                         | 131                              |
| 132                | 2017       | 2017 | 12    | 12        | 132                   | 132                                                           | 132                                   | 132                         | 132                              |
| 133                | 2018       | 2018 | 1     | 1         | 133                   | 133                                                           | 133                                   | 133                         | 133                              |
| 134                | 2019       | 2019 | 2     | 2         | 134                   | 134                                                           | 134                                   | 134                         | 134                              |
| 135                | 2020       | 2020 | 3     | 3         | 135                   | 135                                                           | 135                                   | 135                         | 135                              |
| 136                | 2021       | 2021 | 4     | 4         | 136                   | 136                                                           | 136                                   | 136                         | 136                              |
| 137                | 2022       | 2022 | 5     | 5         | 137                   | 137                                                           | 137                                   | 137                         | 137                              |
| 138                | 2023       | 2023 | 6     | 6         | 138                   | 138                                                           | 138                                   | 138                         | 138                              |
| 139                | 2024       | 2024 | 7     | 7         | 139                   | 139                                                           | 139                                   | 139                         | 139                              |
| 140                | 2025       | 2025 | 8     | 8         | 140                   | 140                                                           | 140                                   | 140                         | 140                              |
| 141                | 2026       | 2026 | 9     | 9         | 141                   | 141                                                           | 141                                   | 141                         | 141                              |
| 142                | 2027       | 2027 | 10    | 10        | 142                   | 142                                                           | 142                                   | 142                         | 142                              |
| 143                | 2028       | 2028 | 11    | 11        | 143                   | 143                                                           | 143                                   | 143                         | 143                              |
| 144                | 2029       | 2029 | 12    | 12        | 144                   | 144                                                           | 144                                   | 144                         | 144                              |
| 145                | 2030       | 2030 | 1     | 1         | 145                   | 145                                                           | 145                                   | 145                         | 145                              |
| 146                | 2031       | 2031 | 2     | 2         | 146                   | 146                                                           | 146                                   | 146                         | 146                              |
| 147                | 2032       | 2032 | 3     | 3         | 147                   | 147                                                           | 147                                   | 147                         | 147                              |
| 148                | 2033       | 2033 | 4     | 4         | 148                   | 148                                                           | 148                                   | 148                         | 148                              |
| 149                | 2034       | 2034 | 5     | 5         | 149                   | 149                                                           | 149                                   | 149                         | 149                              |
| 150                | 2035       | 2035 | 6     | 6         | 150                   | 150                                                           | 150                                   | 150                         | 150                              |
| 151                | 2036       | 2036 | 7     | 7         | 151                   | 151                                                           | 151                                   | 151                         | 151                              |
| 152                | 2037       | 2037 | 8     | 8         | 15                    |                                                               |                                       |                             |                                  |



TROPICAL CYCLONES PASSING WITHIN 75 N.M. OF LESAGE ANCHOR 1886-1994

CHART 2

BEETLE LOCATION MOVED TO 28.2N, 80.2W

Fig 4

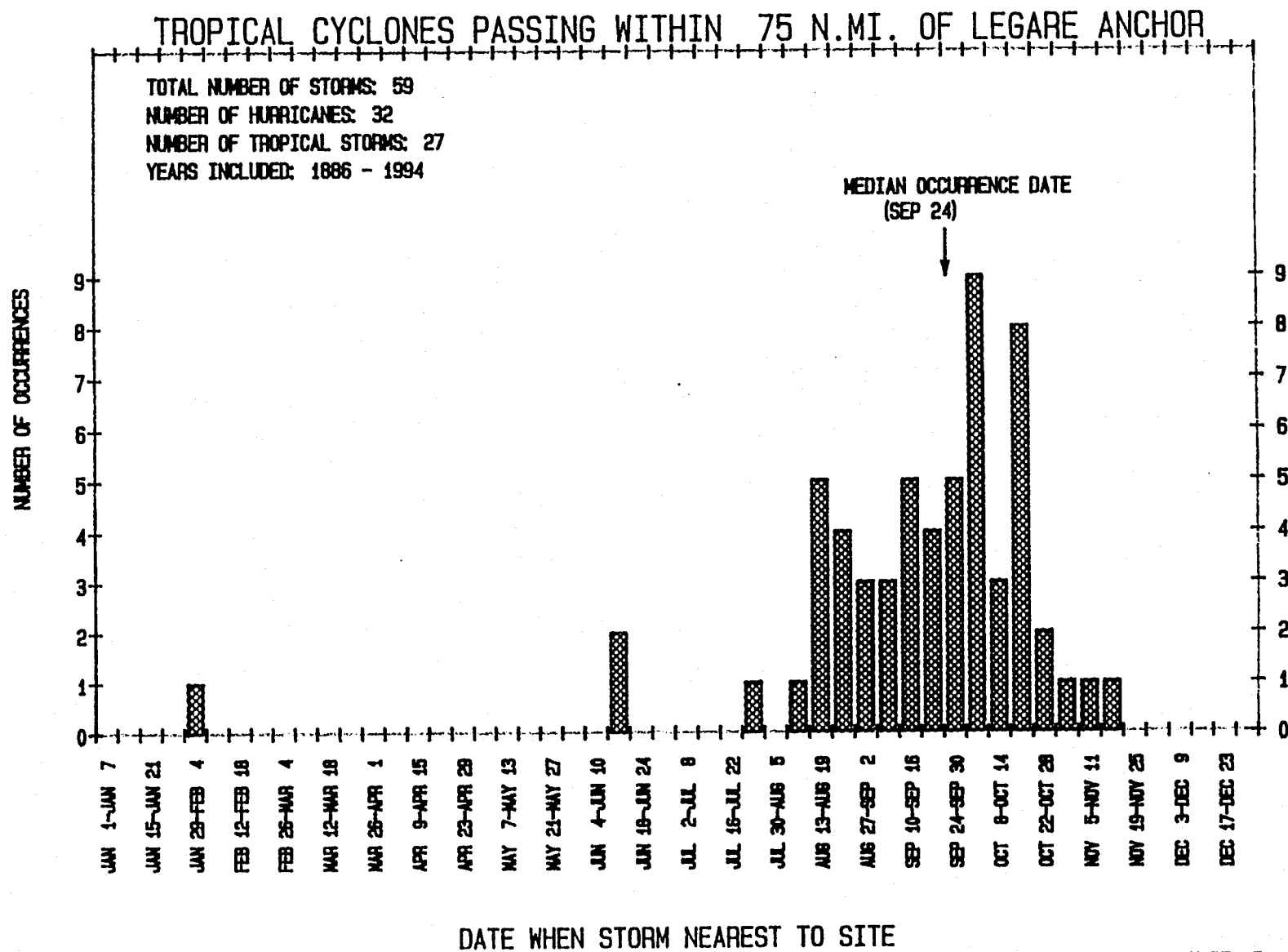


CHART 5

Fig. 5

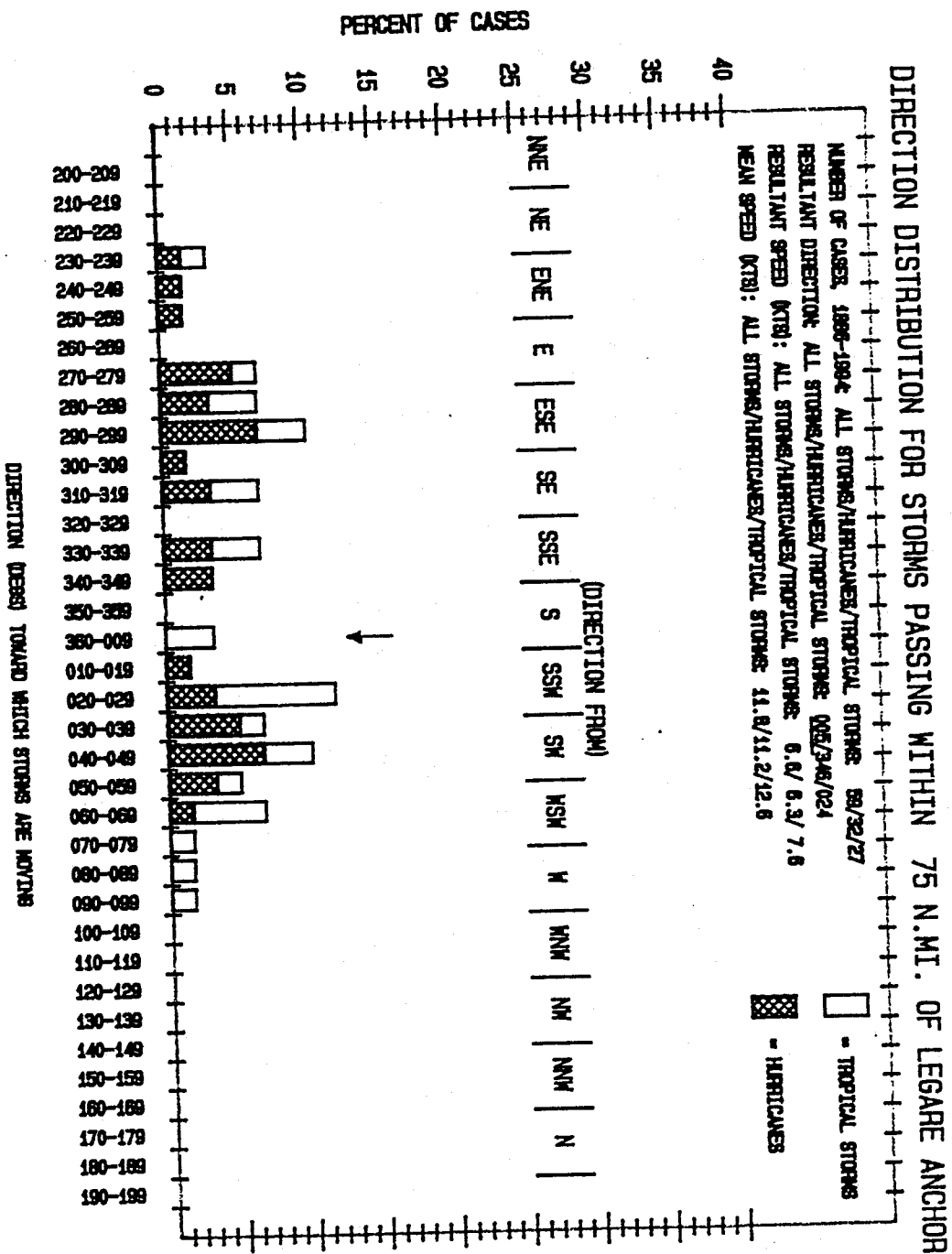


CHART 6

Fig. 6

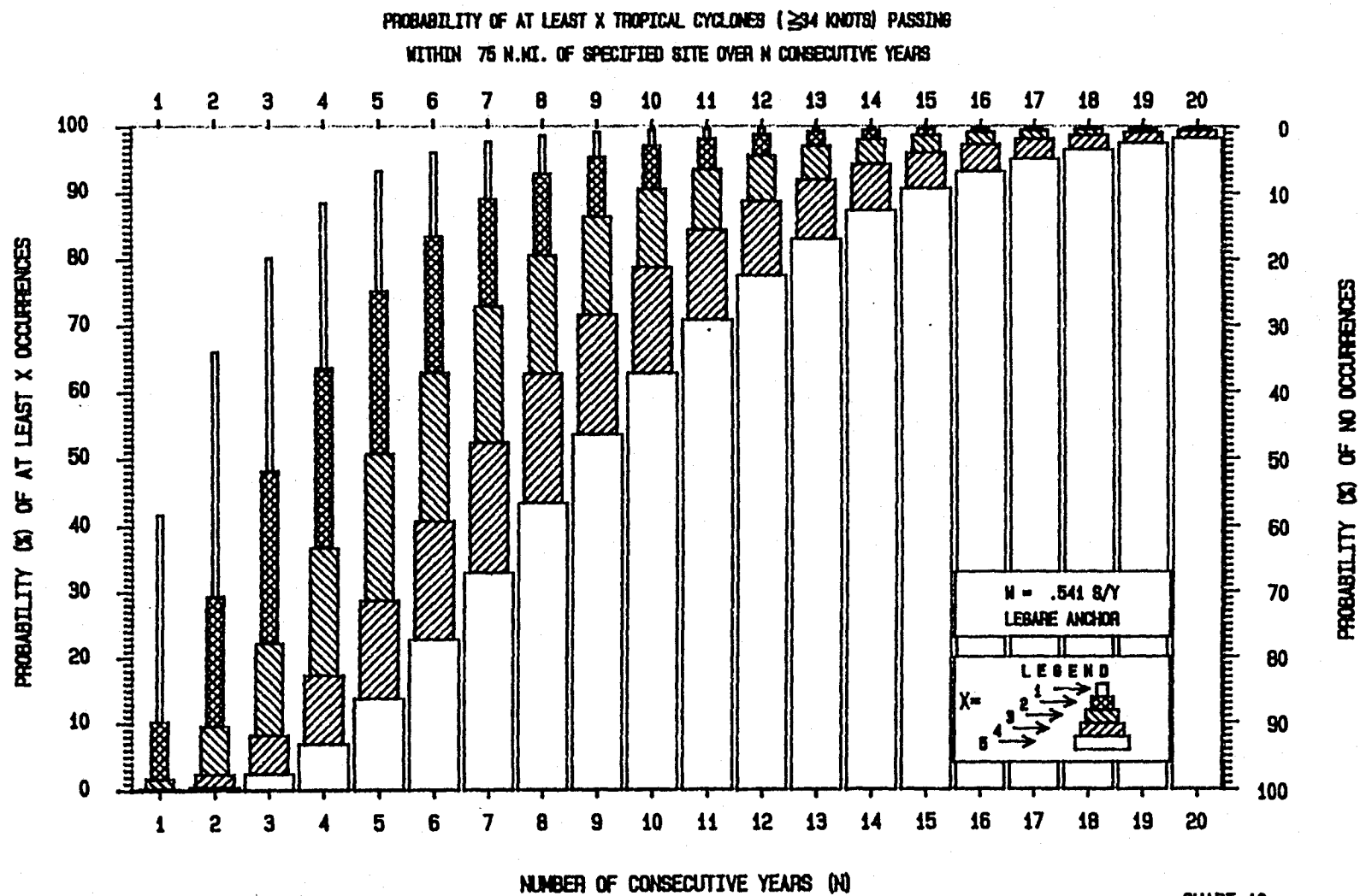


CHART 10

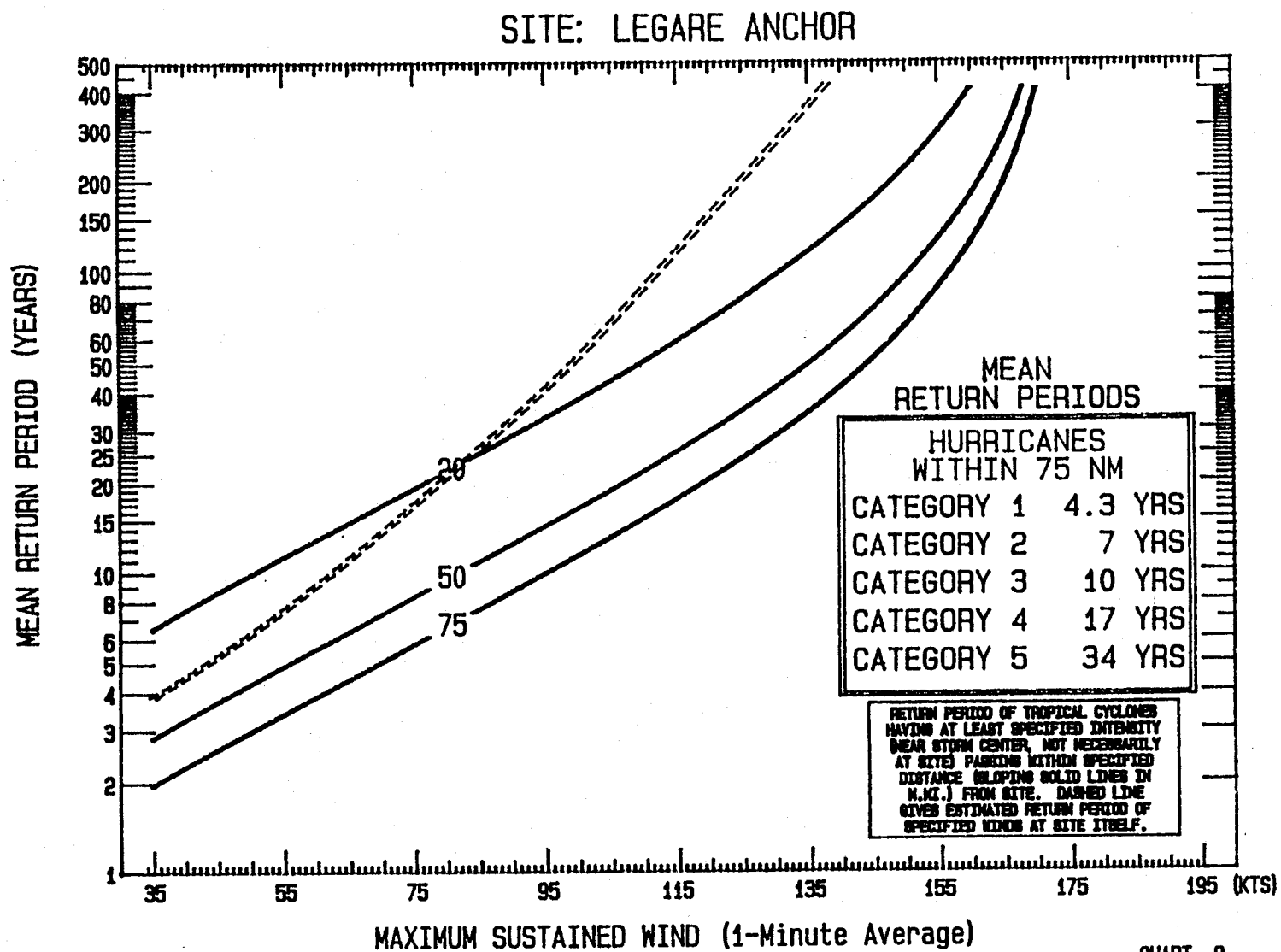


CHART 9

Fig. 8