BUREAU OF METEOROLOGY

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In reply please quote
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Detective Senior Constable Stewart Gray
NSW Water Police
Wharf 25, Harris Street
PYRMONT NSW 2009

Dear Detective Senior Constable Gray,

On 18 June 1999 Mr Bruce Neal, the Bureau's Assistant Director (Services), wrote to you regarding further projects being undertaken by the Bureau as input to our final report on the meteorological aspects of the race, and also in response to questions you asked at the meeting in April with Mr Pat Sullivan, the Bureau's Regional Director for NSW. I am now able to submit this additional information for use by the Coroner in his inquiry into the 1998 Sydney to Hobart Yacht Race.

I also feel that it may be of some use to you if I also provide comment regarding the CYCA's Report of the 1998 Sydney Hobart Race Review Committee as it makes some important recommendations concerning weather related matters.

As you are aware, the Bureau's view is that in issuing its first "Storm Warning" at 2pm on Saturday 26 December 1998, the fleet, Race organisers and the media were given unambiguous warning that the Bureau's expectations were for dangerous wind and sea conditions to develop over the Race area the following day. This warning, the most severe possible for these latitudes, gave the fleet at least 18 hours notice before the storm occurred.

Since the event there has been considerable public discussion about how the sailors interpreted the forecasts and warnings and about the adequacy of the service provided by the Bureau. This has caused the Bureau much concern as the forecasts and services we have provided in the past have been based on strict adherence to international standards and conventions in the use of terms to describe weather conditions at sea. In the light of this experience we have approached the CYCA directly with a view to our working closely together to improve the communication and understanding of meteorological information by the yachting community. We also recognise that we will need to work closely with the media on this issue.

Report of the 1998 Sydney Hobart Race Review Committee

On 2 June 1999 the CYCA released the Report by the Race Review Committee into the running of the 1998 Sydney to Hobart yacht race. Several findings and recommendations were related to weather services, and the Bureau's attitude to these is at Attachment A.

Definitions and Terminology

Wind speeds at sea are measured (or forecast) as the average wind over10 minutes, and given in nautical miles per hour (knots). Over open waters, wind gusts can be expected to be up to 40% greater than the 10-minute average speed.

Shelter is often sought in the lee of an island or other landfall. Inshore, the average wind speed is substantially reduced on a lee shore. However, in the lee of a very rugged coast wind gusts and squalls can in the extreme reach twice the 10-minute average wind speed.

Sea and swell wave heights are measured as the vertical distance between a trough and the following crest. By international convention, the measure of sea state is the *significant wave height*, defined as the average height of the highest one third of all the waves past a point over a given time interval. It includes the combined effect of the swell and wind driven sea waves. This is close to the average height of the waves as estimated by an experienced observer.

The relationship between the significant wave height and the maximum wave height will depend on the time interval of the wave-measuring period. The most likely maximum wave height is about 1.7 times the significant wave height as measured over a half hour interval and almost twice the significant wave height when measured over a three hour interval.

In the analysis of the raw data from a Waverider buoy, a 30 minute interval will estimate adequately the significant wave height, but if the maximum wave height measured is also to be quoted in a collective of coastal reports broadcast to mariners, wave measurements over a three hour interval is preferred.

Separate Studies

As detailed in Mr Neal's letter of 18 June 1999, the Bureau has undertaken further studies in the following areas:

(a) A study of wind observations from Wilsons Promontory lighthouse

The Bureau has investigated the effect of the topography of Wilsons Promontory, how representative the Bureau's observing station at the Promontory is of wind flow in nearby areas of Bass Strait, and the role it plays in forecasting weather in the Strait.

It has found that the disruption to the airflow caused by the irregular shape of the Promontory should extend at the most, to the order of 40 to 50 km beyond the Promontory. At the present time this "area of influence" around the Promontory can only be estimated using physically based mathematical scaling techniques. A more detailed analysis would require that fluid dynamic modelling be undertaken, either of a theoretical nature using complex numerical simulations, or physical nature using scale models in a fluid dynamic laboratory. Such a study is outside the current expertise and scope of the Bureau's research centre and, if considered necessary, will need to be carried out by another research group.

To confirm that the winds measured at Wilsons Promontory are unrepresentative of the winds over the nearby areas of Bass Strait, the Bureau performed a study which compared wind observations from Wilsons Promontory with other coastal sites in the Bass Strait region. Details of this study are discussed at Attachment B. The study examined the hypothesis that Wilsons Promontory is no different to other coastal observing sites in the vicinity of Bass strait.

The outcome of the study was that Wilsons Promontory observations are statistically speaking quite different from other observations in the area. It showed that for the long term records for the Bass Strait area, Wilsons Promontory has reported the highest incidence of winds above 30 knots, with 16.4% of all its observations over 30 knots. Cape Grim located on top of a 93m bluff on the northwestern tip of Tasmania was second ranked with 9.1% and Kingfish B third with 7.9%. Wilsons Promontory reported winds over 40 knots on 5% of occasions, which is about five times as frequently as the next windiest location, Cape Grim. For winds over 50 knots this ratio increased to more than 6 times. Most of the Bureau stations have not reported winds in excess of 60 knots. Moreover, on occasions when wind speeds of more than 40 knots were reported at the Promontory, a significantly large proportion of stations elsewhere in the Strait reported wind speeds less than 35 knots. The Bureau's scientists are of the view that the high incidence of strong winds at Wilsons Promontory is directly attributable to orographic forcing of the wind field at that location.

(b) An evaluation of anemometers used to measure winds from yachts

In order to be able to utilise the observations from yachts which competed in the 1998 race (in the re-analysis of the event and modelling studies), the Bureau needed to ascertain the accuracy of masthead anemometers of the type typically used by racing yachts. To this end, a report on the calibration and behaviour of masthead anemometers was undertaken by the Australian Regional Instrument Centre, Observations and Engineering Branch, of the Bureau. A copy of *Instrument Report 653* is at Attachment C.

The study tested 3 masthead anemometers, from different manufacturers, and found that there was a high *uncertainty of measurement* with only one sample conforming to the Australian Standard (AS 2923) and Bureau specifications for a robust anemometer suitable for network use under controlled conditions. One of the samples did not satisfy threshold start speed of accuracy specifications. Other findings include:

- A data logger that could not record wind observations above 50 knots;
- An anemometer that could not withstand wind speeds beyond 80 knots;
- Problems with smoothing and filtering of data by the data loggers and control units;
- The anemometers are largely unaffected by roll position, but each has a unique response to pitch angle that increases the uncertainty in the wind speed measurement; and
- The accuracy may be affected by the vertical orientation of the rotor, by about 14% of the true wind speed and as much as 100% for low wind speeds (under 10 knots).

Given these findings, the uncertainty in any wind measurement on a boat under any wind conditions is likely to be greater than 10% of the true wind. The study also indicates that observations in wind conditions like those of the 1998 Race, even from well maintained anemometers, could be highly unreliable.

(c) Estimates of wave heights from the police helicopter

This study was not progressed largely as a result of the use by the Bureau of alternative reports of sea state from a wide range of sources including yachts competing in the Race, other shipping in the area, and satellite observations.

(d) An explanation of numerical prediction and the numerical models used by the Bureau

This explanation, supplied in full at Attachment D:

- includes a schematic description of how computer forecasting models operate;
- explains some of their limitations and capabilities; and
- provides charts from the various models which were available to the forecasters through to Boxing Day (26 December 1998).

To further illustrate the limitations and capabilities of numerical simulation of atmospheric and oceanic phenomena I have also included as Attachment E, part of a draft post-race research study performed by the Bureau of Meteorology Research Centre using high resolution weather and surface wave prediction models which are currently being developed by the Bureau. To assist in understanding of how numerical models were used to simulate the development of the storm, I have also organised for an animated presentation of the modelled event to be provided to you.

The following main points result from the post-event diagnostic study:

- The broadscale meteorological environment prior to the development of the intense but small scale low pressure system could be well-explained by classic mid-latitude meteorological theory relating to amplifying low pressure trough concepts;

- The secondary cyclogenesis (formation and intensification of the small, intense low pressure system) was extremely unusual, but could be explained using diagnostic techniques applied to very high resolution numerical forecast fields. The exact forcing mechanism for such cyclogenesis has not been described for Australian storms before;

- The pre-existing low in the Tasman Sea provided a source of warm, moist air which preconditioned the atmosphere over Bass Strait to enable the rapid development of the small, intense low pressure system;

- The high winds experienced were generated as a result of a narrow (approximately 50 km wide) band of winds up to 60 knots about 500m above the sea (called a *low-level jet* by meteorologists), which was oriented west-east across Bass Strait and to the east of longitude 148°E. This band of winds developed during the early hours of 27 December, strengthened and progressed rapidly eastwards to impact directly on the main body of the fleet as it tracked into waters south of latitude 37°S during the day;

- As the surface wind field responded to the intense, short-lived low level jet, waves of 5 m to 6 m significant wave height developed off Gabo Island during the early afternoon of 27 December. During the afternoon and evening of 27 December, waves of between 7 m and 8m significant wave height were generated in a band running north-east from about

100km east of Gabo Island. This band persisted into the morning of 28 December, as it moved eastwards into the Tasman Sea and began to dissipate;

- Only with very high resolution numerical models running in real time, coupled with an accurate starting analysis of the surface wind and pressure fields, could the detailed development of such a low pressure system and its associated sea wave field be forecast.

Most Likely Wind and Sea Conditions Experienced

To provide an assessment of the most likely conditions experienced by the fleet during the critical period on Sunday 27 December 1998, the Bureau has obtained as many observations as possible from yachts, the race Relay Vessel *Young Endeavour* and merchant shipping in the area at the time. This information has been used in the detailed manual re-analyses as well as the computer model studies of both the atmospheric and oceanographic conditions.

A study of wind and wave conditions at the Kingfish B platform during the storm was commissioned to provide insight on how unusual the conditions experienced in Bass Strait were. On the basis of study of wave conditions at the Kingfish B platform, the storm (as experienced at Kingfish B) can be characterised as a one in eight to ten years event. This infers that the storm was of a relatively unusual, but not highly unusual, intensity for that part of Bass Strait.

Crews who competed in the 1998 Race were surveyed by the CYCA on a range of areas related to the Race and their participation in it, including their observations or impressions of wind and wave conditions encountered at the height of the storm. The Bureau has analysed the responses to these questions which were provided by the CYCA. On the question of the wind speed encountered during the storm, the mean response for average speed[1] reported (from the 94 yachts that responded) was 56.4 knots, and the mean of maximum gusts[2] reported (from the 88 yachts that responded) was 67.8 knots. On the question of the wave heights encountered during the storm, the mean response for average wave height[3] reported (from the 99 yachts that responded) was 9.4 m, and the mean of maximum wave height[4] reported (from the 96 yachts that responded) was 13.9 m.

Taking into account all known and inferred environmental data to hand, the Bureau estimates that the most likely highest winds experienced by the competing yachts at the height of the storm were in the range from 50 to 60 knots. In particular, on the basis of the modelling studies, and taking into account the well known gustiness of winds, it was likely that gusts and squalls of around 70 to 80 knots would have been experienced in the band of high winds extending eastwards out of mid-Bass Strait, east of Kingfish B, as the storm developed during the afternoon of 27 December and the rain squalls mixed winds from the low-level jet down to the surface.

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[1]CYCA Survey Q.33 "During the storm what was the average wind speed and direction recorded on your yacht?"

[2]CYCA Survey Q.34 "What was the strongest wind gust and direction recorded on your yacht?"

[3]CYCA Survey Q.35 "In your opinion what was the average height of waves during the Storm?"

[4]CYCA Survey Q.36 "In your opinion what was the biggest wave you encountered?"

Taking into account observations from yachts, merchant ships, satellites and the results of the post-event modelling study, the highest significant wave heights generated by the storm would have developed in response to the development, intensification and movement of the narrow west-east oriented jet of surface winds during the second half of 27 December. The highest significant wave heights experienced would have been in the range 7 m to 8 m, in a band oriented south-west to north-east off Gabo Island which developed during the second half of 27 December. On the basis that peak wave heights would have been around 1.9 times the significant wave heights achieved during the storm, extreme wave heights (heights for one-in-1000 waves) were most likely to have been in the range 13 m to 15 m.

Yours sincerely,

G. Love
Deputy Director (Services)

8 December 1999