How high was the storm surge from Tropical Cyclone Mahina?

North Queensland, 1899

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Introduction

Tropical Cyclone Mahina was the most intense tropical cyclone to cross the Australian coast in historical times. Its central pressure was recorded by barometer at 27 inches (914hPa) as the eye approached the coast at Bathurst Bay (*Figure 1*) at approximately 4.30 am on the 22nd March 1899 (Whittingham 1958). Over 300 persons lost their lives when a fleet of pearling luggers and schooners were wrecked and sunk by the phenomenal seas. One of the most interesting aspects of this event was the eyewitness report of a 43 foot (13m) surge at Ninian Bay adjacent to Barrow Point 30 km south of Bathurst Bay which extended inland for 2–3 miles (3–5 km). Constable Kenny, camped on a ridge fully 40 foot above sea level, was inundated to his waist by a 'tidal wave' (storm surge and associated ephemeral sea level rise) at his camp site some 0.5 miles (800m) inland at approximately 5 am (Anonymous 1899). This account suggests this surge was the largest ever recorded in Australia.

There is considerable departure between the size of this reported surge and the results of numerical models that determine the magnitude of surges based upon the storm characteristics and the local bathymetry. In this instance a number of numerical simulations of the Cyclone Mahina storm surge were undertaken using Hubbert et al. (1991) Australian real-time system for forecasting tropical storm surges (Callaghan 1993). No appreciable surge (<3m) was produced by the model. The Jelesnianski-Trajer nomogram technique, still widely used for forecasting surge heights by the Australian Bureau of Meteorology, also produced a surge height of 2-3m for Cyclone Mahina.

Because of these discrepancies, and because predictions of surge inundation during modern cyclone events are based upon these forecasting methods, it is important to verify the magnitude of the surge during Cyclone Mahina. Virtually all marine inundations either transport marine materials landward or leave erosional indicators in the coastal landscape. By recognising these 'fingerprints' it is possible to determine the magnitude of a past inundation event and its approximate age. We undertook a field survey of the area from Cape Melville to Ninian Bay to ascertain the heights of past storm surges in this region and determine if there is physical evidence of the extreme magnitude surge reported to have occurred during Cyclone Mahina. The results of this survey are presented here.

Heights of past surges in the Bathurst Bay region

Storm related marine inundation is the term adopted here to include storm surge, wave set up and wave run-up. Here we refer storm surge to mean a rise above normal water level resulting from a reduction in atmospheric pressure combined with the effects of surface wind stress. Wave set-up is a quasi-steady super-elevation of the sea-surface due to the onshore mass transport of water resulting from breaking waves. Wave run-up is the extent or height to which broken waves swash onto the land. Such inundations typically leave distinct markers in the coastal landscape. These include sedimentary deposits or debris lines of both ephemeral and longer-lived (century to millennia scale) materials. The former includes seaweed, coastal grasses and marine faunal carcases and the latter fragments of corals, shells and coarse-grained marine sands. Erosional indicators can also be produced during the inundation; these include small wave eroded scarps or terraces within unconsolidated coastal deposits such as raised gravel beaches or ridges as well as the general disturbance of terrestrial materials. The heights of these features can be surveyed to mean sea level or some other datum and materials within the deposit dated, usually using carbon dating, to give an approximate age of the event. In this manner a frequency/ magnitude record of pre-historic marine inundation events can be developed.

At Ninian Bay we surveyed four separate transects from the modern beach to approximately 30m above sea level. These

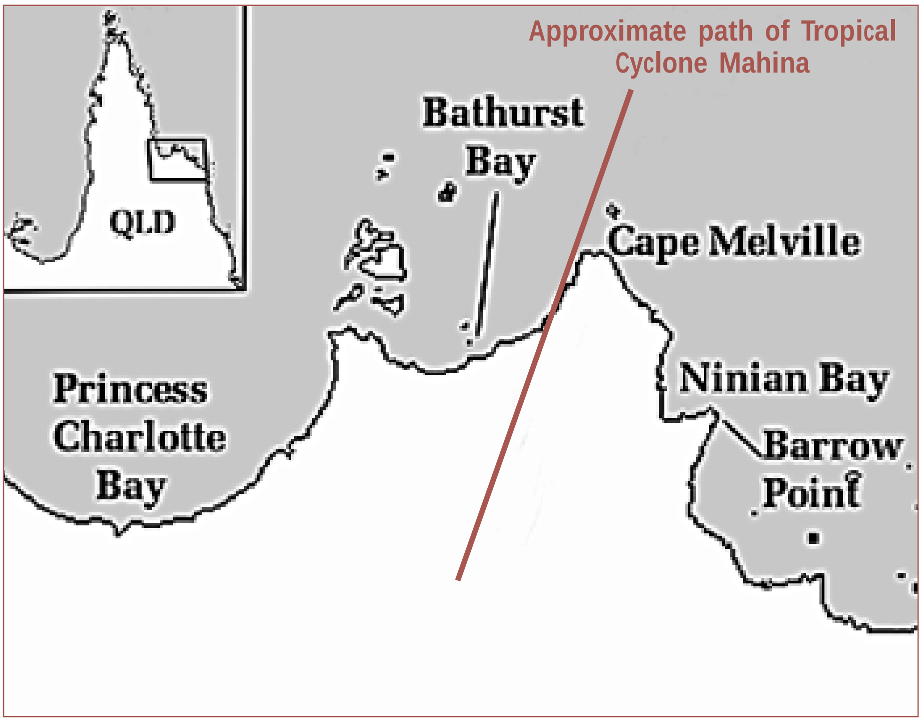

Figure 1: Location map

transects were located at the eastern and western ends of Ninian Bay and extended over the rocky headlands at these locations. The other transects were located within the central portion of the bay and extended onto a 20m high aeolian sand ridge that runs parallel to the shore approximately 1 km inland. Other transects were also undertaken along the crest and seaward flank of this sand ridge for approximately 500m towards its western end. Further transects, perpendicular to the coast, were also surveyed on the rocky headlands and promontories both bounding and within Ninian Bay. A similar procedure was undertaken at Cape Melville in the vicinity of the Outridge monument and along the coast west of Cape Melville for approximately 5 km. Along each of these transects a thorough search was undertaken for marine inundation deposits.

No evidence for marine inundation events was discovered above approximately 3–5m HAT. Below this level abundant deposits of marine shell, coral, pumice and wave transported sands were evident. At the eastern end of Ninian Bay these deposits extend up to the base of the granite slopes 2–3m HAT. No marine carbonates or sands were found amongst the granites or within the narrow valleys that extend into the backing range of hills. Weathered material derived from the granites (Gruss) and littering the gentle granite slopes above 3m HAT also showed no signs of disturbance. A similar situation occurs at the western end of Ninian Bay. Here shells and fragments of shells were found within crevasses of the folded strata of the headland up to a height of approximately 4–5m HAT. Above this height no other marine carbonates or sands were located except within a small midden (shells deposited by Aborigines after eating the contents) towards the crest of the headland. The sands that comprise the bulk of this midden are fine-grained and hence appear to have an aeolian origin.

Shells on the sand ridge behind Ninian Bay as well as those behind a small lagoon at the rear of the main barrier were found at a height of approximately 10–15m HAT. These shells displayed clear anthropological associations having a concentrated spatial distribution, a limited number of species (predominantly of the genus Anadara) of uniformly large size and no indication of littoral scaring suggesting they were alive at the time of deposition. The absence of coral, pumice or wave emplaced sand that discount the possibility of midden associations was found at any site.

A similar situation was observed at Cape Melville. Here small blocks and fragments of coral along with marine shells and coarse-grained marine sands occur to a height of approximately 3 m HAT. These deposits are in the form of a series of beach ridges that extend parallel to the coast for hundreds of metres to over one kilometre. These beach ridges were no doubt deposited during cyclonic events and represent the elevation to which the most extreme storm related marine inundations have reached in recent geological time. No other fragments of shell, coral or wave emplaced sands were found extending to elevations above the level of these beach ridges. Reports of large coral blocks located close to and at higher elevations than the Outridge memorial located approximately 600m inland were not substantiated. Only locally derived terrestrial sediments from the granite hills behind surround this memorial.

Discussion

The heights of marine deposits at Cape Melville and Ninian Bay suggests that the majority, if not all, storm related marine inundations have only extended to a maximum elevation of 3–5m HAT in recent geological history (up to 6,000 yrs B.P.). This result stands in stark contrast to the report of the 13m inundation at Ninian Bay in 1899. A number of reasons may account for this apparent discrepancy. First, the 13m inundation may not have deposited any material above 3–5m HAT, especially in areas fronted by extensive stands of vegetation. Often storm surges, by themselves, represent a reasonably passive rise in sea level and their transporting capacity may be minimal because of their inherent low forward velocity. Waves on top of the surge and other associated currents are usually responsible for transporting marine materials landward. In this case, and at locations between 0.5 and 1 km inland from the coast, current velocities within the water column may have only been sufficient to have transported materials up to approximately 3–5m HAT. Above this elevation vegetation and other obstacles may have inhibited the fluid flow such that the water column was largely devoid of suspended materials except for light organics such as leaves and other flotsam. Such materials may have decomposed over the last century and hence no longer mark the elevation to which the inundation extended.

This explanation, however, is unlikely to account for the lack of wave transported material above 5 m on headlands and rocky promontories; at these locations there is little to inhibit the velocity of waves on top of a surge. Ninian Bay was in the left forward quadrant of Cyclone Mahina. The phenomenal seas of a severe category 5 cyclone in this quadrant could be expected to transport at least small fragments of shell and sand up to elevations well in excess of the height of the actual storm surge on headlands. This is especially so considering that on steeply fronted coasts wave run-up can be as much as 5 times wave height at the shore (Camfield 1980, Synolakis 1987). At these locations wave transported deposits could be expected to remain within crevasses and cracks in the rock for considerable time even under continued tropical rainfall conditions.

Another possibility is that Constable Kenny's interpretation of the surge may have been confused and then reported in the Outridge document. Constable Kenny may not have been camped as high above sea level as has been presumed. He arrived at the camp site at night (6pm) (Anonymous 1899) and during the mayhem of the cyclone before day break the next morning he may not have fully appreciated the exact elevation of his camp. It is also possible that Kenny's camp was inundated by wave run-up and not strictly surge although this may seem unlikely if he was camped 0.5 mile inland as suggested in the Outridge report (Anonymous 1899). Alternatively, Kenny's camp may have been inundated by a peak in terrestrial flood waters or a combination of marine surge and terrestrial run off which may have given the appearance of a 'tidal wave'.

The significance of wave run-up and at times its apparent confusion with the surge component of marine inundation is not to be underestimated. The Outridge report (Anonymous 1899) for example was not the only document to comment upon the height of the surge. Whittingham (1959) reports a verbal account of 13 'porpoises' were found after the storm some 50 feet (15m) above sea level, up a cliff, on Flinders Island near Bathurst Bay. This at first would appear to support the claim of a 43 foot (13m) surge at Ninian Bay. However, due to run-up, transportation and deposition of animals and debris can occur well above the depth of water at the shore. A 3m wave at the shore for example, supported by at least 3.5m of surge, is possible at this location and under these conditions according to wave forecasting curves (Komar 1976). Waves of this magnitude could theoretically transport objects (of a certain size and mass) up to 21m above normal sea level (3.5m surge +3m wave +15m run-up). This is especially the case where waves impinge upon a steep coastal topography for here the run-up values are significantly greater than on gently sloping shores (Camfield 1980, Synolakis 1987). If 'porpoises' were deposited at 50 feet (15m) a.s.l. on a cliffed section of Flinders Island then it would only require a 2–3m wave and near equivalent surge for this to be achieved.

Conclusion

There is little doubt that severe category 5 Cyclone Mahina struck the Bathurst Bay region on the morning of 22nd March 1899. However, the absence of marine deposits above 3–5 m HAT suggests that marine inundations have not exceeded this elevation in this region over recent geological history. These results agree closely with the results of numerical models of the storm surge associated with Cyclone Mahina. However, these models do not take into account wave run-up. While it is possible that wave run-up in some locations may have reached significantly higher elevations as Cyclone Mahina approached and crossed the coast the absence of marine deposits above 5m HAT generally suggests otherwise.

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