Anticipating Waves of Destruction – Preparing the New South Wales Tsunami Emergency Management State Plan

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Introduction

Tsunami can and have affected coastlines of Australia, including the NSW coast. The NSW State Emergency Service (SES) is now recognised as the combat agency for tsunami in NSW and is responsible for planning for tsunami and controlling tsunami response operations when they occur. This paper outlines the characteristics of tsunami and their possible affects on NSW and describes the emergency risk management planning work being undertaken by the SES for tsunami in NSW.

Characteristics of Tsunami

A tsunami is a series of ocean waves generated by a sudden displacement of large volumes of water. In the process of the sea level returning to equilibrium through a series of oscillations, waves are generated which propagate outwards from the source region. They may be caused by the vertical movement of the sea floor as a result of large earthquakes; submarine or coastal volcanic eruptions; meteor impacts; or coastal landslides either land based or submarine. Earthquakes have generated the majority of tsunami recorded on the Australian coast. However, not all earthquakes generate tsunami. To generate a tsunami, the fault where the earthquake occurs must be underneath or near the ocean, and cause vertical movement of the sea floor over a large area. Earthquakes are most common at plate boundaries where moving tectonic plates meet. Shallow focus earthquakes along subduction zones (where one tectonic plate is pushed under another) are responsible for most destructive tsunami experienced world wide.

Tsunami travel outward in all directions from their point of generation (but not necessarily with equal energy in every direction) and can strike coastal areas great distances from their source. Tsunami speed is dependent on water depth. In deep water and open ocean, tsunami can reach speeds of 800 kilometres per hour. Heights of tsunami in deep water are only slight and can go unnoticed. As a tsunami enters shallow water its speed decreases rapidly. This causes the wave length of the tsunami to decrease and the height of the wave to increase. It is important to note that despite these changes a tsunami's energy flux, which is dependent upon both its wave height and speed remains nearly constant. Energy begins to be lost once a tsunami begins to rush onshore. Some energy is reflected offshore, while shoreward propagating energy is lost through friction and turbulence.

Destruction from tsunami is the direct result of three factors: inundation, wave impact on structures, and erosion. Strong tsunami-induced currents can lead to the erosion of foundations and the collapse of bridges and sea walls. Floatation and drag forces can move buildings and over-turn vehicles. Tsunami associated wave forces can demolish buildings as a result of exposure to the initial turbulent front of the wave and the outflow of water back to the sea between tsunami surges. Considerable damage is also caused by the resultant floating debris, including boats, building materials, furniture and cars that can crash into buildings, piers, vehicles and people.

Tsunami magnitude at the coast is dependent upon the configuration of the coastline, shape of the ocean floor, reflection of waves, tides and wind waves. Narrow bays, inlets and estuaries may cause funnelling effects that enhance tsunami magnitude. Offshore reefs and shallows can act to reduce tsunami magnitude. The combination of these factors means that the flooding produced by a tsunami can vary greatly from place to place over a short distance.

A tsunami is not a single wave, but a series of waves. The time that elapses between the passage of successive wave crests at a given point is usually from 5 to 90 minutes. Oscillations of destructive proportions may continue for several hours, and several days may pass before the sea returns completely to its normal state. The first wave in the series may not be the largest. The approach of a tsunami may be preceded by abnormal ocean behaviour. Depending on whether the first part of the tsunami to reach the shore is a crest or a trough, it may appear as a rapidly rising or falling tide.

History of Tsunami in NSW

The NSW coast has experienced about 34 tsunami since European settlement, many of which have been too small to produce noticeable effects. The largest tsunami recorded in 1960 and 1868 were associated with tide gauge measurements of approximately one metre (Geoscience Australia, 1996). There has been no recorded loss of life or major damage recorded as a consequence of tsunami, although, some minor damage to boats and coastal infrastructure occurred as a result of the 1960 Chilean and 1868 Peruvian tsunami.

The 1960 tsunami was recorded along the entire NSW coast and appeared as a wildly fluctuating tidal level which went on for most of a day. The tsunami was generated as a consequence of a large submarine earthquake offshore of the Chilean coast (8.6 Richter Magnitude and 30km focus). The tsunami caused death and destruction throughout the Pacific Basin, with 5000 to 10000 deaths in Chile and a further 2200 deaths across the Pacific. The tsunami took only 17 hours to travel the 12670 kilometres between Chile and the NSW coast. The following newspaper extracts describe the consequences of the 1960 Chilean tsunami in Sydney and Newcastle.


SYDNEY HARBOUR IN CHAOS FROM QUAKE WAVE

SYDNEY. — Tidal waves generated by the earthquakes in Chile smashed into the New South Wales coastline yesterday.

AIR PILOT SEES BEACH DISAPPEAR

MELBOURNE. — Salmon spotting pilot Dick Ritchie yesterday saw Three-Mile Beach, Wilson's Promontory, "disappear"

(Hobart Mercury, 25/5/1960)

"Freak currents tore away moored boats and upset shipping. The huge tide tore from their moorings about 30 launches and small craft and two barges at the Spit: Swirled the barges in among drifting launches, overturning several of them and damaging others: Smashed one of the barges into the Spit Bridge. Set adrift 800 logs from moorings at Balmain shipping yard, which were then swept down the Parramatta River. Swept away a strip 100 yards by 60 yards from Clontarf Reserve Point Park and exposed a high tension submarine cable: In one tense moment a 30ft. fishing trawler sank in Throsby Creek near Newcastle. Eight launches were ripped from their moorings in Throsby Creek and swept half a mile into Newcastle Harbour." (Brisbane Courier Mail, 25/5/1960)

"We were being towed from Gore Bay to Pyrmont and became almost stationary in White Bay when we struck an eight knot current"... "Suddenly the freakish current turned and we were swept under the Glebe Island Bridge in a flash." (Hobart Mercury, 25/5/1960)

The 1868 tsunami was caused by a large submarine earthquake (8.5 Richter magnitude) centered offshore of the coast of Peru in the Peru-Chile trench. The following newspaper extract describe the effects of the tsunami in Sydney harbour.

"An extraordinary tidal disturbance has been experienced here this morning since about half past 6 o'clock – the vessels at the coal shoots broke from their moorings, one nearly loosing her masts; the sand bank was suddenly uncovered to the extent of a foot, and was rapidly covered again." And "The extraordinary phenomenon which took place this morning, and continues, is termed by nautical men a volcanic wave. At 8.30, the vessels in the harbour were thrown into great confusion. The Alexander broke from her moorings and had to anchor in the stream. The Planter was shaken so much by the action of the tides that the captain expected his masts to fall. The ship Lucibelle, 1000 tons, was swung round four times, although a strong ebb tide was running; and the vessels in harbour swung round in all directions. The tide ran down sometimes at a rate of 12 knots, the same as if there was a strong fresh in the river."(Sydney Morning Herald, 17/8/1868)

The historical record is useful when assessing the tsunami risk, but is critically flawed by its short length of just over 210 years. Surely many more tsunami occurred before European settlement? Paleo-tsunami researchers have speculated that larger tsunami have impacted upon the NSW coast before European settlement measuring tens of metres (Bryant and Nott, 2001; Bryant and Young 1996; Bryant, Young and Price, 1992). Other researchers, however, have disputed the likely tsunami magnitudes discussed in these findings (Dominey-Howes, per comm, 2005) and caution has been advised when interpreting such pre-historic events (Davidson and Rynn, 1998).

Sources of Tsunami

The sources of historical tsunami vary and are classified as either; local, regional or distant, depending on the distance of their generation from the coastline of impact.

Local tsunami (also classified as near-field) are generated close to the affected coast. They provide little to no warning time, hence communities at-risk are reliant upon observing environmental signals such as strong ground shaking or abnormal ocean behaviour in order to undertake required response actions. No local tsunami have been observed since European settlement, though evidence indicating the existence of previous submarine landslides prior to European settlement has been found on the continental shelf offshore of the NSW coast (Jenkins and Keene, 1992). These landslides may have generated tsunami prior to European settlement.

Regional tsunami are those generated within the Australian region of the South West Pacific. Potential regional tsunami sources are located in subduction zones along the Indian-Australian and Pacific tectonic plate boundary which runs through Macquarie Island, New Zealand, Tonga, Vanuatu, Papua New Guinea, the Solomon Islands and the Kermandec Islands. Travel time from these locations to the NSW coast varies but is in the order of several hours.

Distant tsunami (also classified as far-field) are generated far away from the affected coastline. NSW may be affected by tsunami generated as far away as North America, South America, Antarctica and Asia. Warning times for distant tsunami vary according to the location of their source, and can be from many hours to almost a day. Distant tsunami may affect the entire NSW coast.

The Tsunami Risk in NSW

All low-lying areas that are close to the ocean or to estuaries could experience tsunami inundation. The hazard magnitude for tsunami threatening NSW is difficult to assess. The magnitude is likely to vary along the coast due to various offshore and coastal features. However, due to a lack of offshore data, no detailed tsunami hazard assessments have been conducted to assess what areas may be exposed to the greatest hazard. The information available from the short history of tsunami occurrence and lack of detailed modelling also makes it difficult to estimate magnitude-frequency relationships for tsunami.

Davidson & Rynn (1998) in their assessment of tsunami risk in Australia recognised the high risk along the NSW coast. Initial estimates made by the SES using 2001 census information suggest that 250,000 people live within 500 metres of the NSW coast and estuaries and below the 10 metre AHD contour. This estimate rises to some 330,000 people when considering people living within one kilometre of the NSW coast and estuaries and below the 10 metre AHD contour. Approximately 20% of the population potentially at-risk of tsunami is over the age of 65, which is greater than the state-wide average of 13%.

Vulnerability to tsunami is greatest between the Shoalhaven coast and the Newcastle coast, reflecting the high population density in this area. This vulnerability is expected to increase as a consequence of expanding coastal development in response to; continuing population growth, population ageing and the coastal retirement trend. Vulnerability is also seasonal and peaks during the summer months, especially during school holidays from December through to the end of January.

Both marine and land based elements are vulnerable to tsunami. It is likely that all significant tsunami (i.e. those that are noticeable) will affect marine based risk groups, whilst larger tsunami are required to cause damage to land based elements. It is therefore important to distinguish between them. Table 1 (below) lists examples of land and marine based elements that are vulnerable to tsunami.

Marine Based Elements	Land Based Elements
• Boats and their crew • Beach users, including swimmers, surfers, sunbathers, and fishers • Divers and snorkelers • Aquaculture industries • Submarine power, telecommunications, fuel and water supply lines • People and facilities in ports, harbours and marinas • Sewerage outfalls	• People and property in caravan parks and camping areas in low-lying coastal areas or on floodplains in tidal river areas • Coastal infrastructure including roads, bridges, power, water, gas, sewerage and telecommunications • Residential, commercial and industrial buildings and their occupants in low-lying coastal areas or on floodplains in tidal river areas • Motorists and vehicles on low-lying coastal roads • Low-lying coastal farmland including animals and crops. • Institutions such as schools and hospitals located in low-lying coastal areas.

Table 1 Examples of land and marine based elements at risk of tsunami.

Large tsunami striking the NSW coast have the potential to damage or destroy buildings and coastal infrastructure, wash ships ashore and threaten the lives of people living and working in coastal areas. Tsunami may also generate secondary hazards of fire and hazardous materials. Indirect affects may include loss of essential services, communication failures, supply shortages, traffic disruption, isolation of urban areas, loss of agricultural productivity, business disruption, social effects and disease.

Community Awareness

Tsunami have often been described as the forgotten hazard in Australia (Rynn, 1994). The Asian Tsunami of December 26, 2004 may have created an awareness of tsunami risk across NSW, but this awareness must be considered general and probably short term and does not address issues which may be specific to NSW coastal communities. As the years pass without further noticeable tsunami, awareness levels will surely decrease. Community education campaigns in coastal communities will be needed to enhance awareness levels and deliver risk information specific to individual coastal communities. To achieve this outcome the SES intends to develop and deliver education programs in partnership with other agencies.

Planning for Tsunami

In the light of the above background discussion it is appropriate to look at the task of undertaking emergency risk management planning for tsunami in NSW.

Some arrangements for managing responses to a tsunami have existed in the NSW State Flood Plan for a number of years. The logic behind this inclusion is that in its behaviour and consequences, a tsunami closely resembles a flood. The State Flood Plan is the principal document for establishing the framework within which flood emergency management is undertaken in NSW. The reference in the State Flood Plan is, however, not particularly detailed and furthermore, is not well supported by complementary tsunami-specific arrangements in other plans such as; SES Division and Local Flood Plans, or State, District and Local Disaster Plans (DISPLANs). In particular, some District and Local DISPLANs note that a response to a tsunami event would be controlled by the Emergency Operations Controller. This contradicts the State DISPLAN and the State Flood Plan which both recognise that SES controllers will control the response to floods at their respective level of operation (i.e. local, division and state).

To clarify this situation in anticipation of the need to undertake more detailed planning the SES, in 2003, made representations to the peak emergency management committee in NSW, the State Emergency Management Committee (SEMC). In December 2003 the SEMC endorsed the combat agency status of the SES in respect of tsunami and recommended that the SES undertake the required detailed planning.

The development of the NSW Tsunami Emergency Management State Plan (TEMSP) by the SES began in early 2004, prior to the Asian tsunami of the 26th of December. It has been an inevitable consequence of that event that the priority for tsunami research and planning has been emphasised. The first draft of the TEMSP was presented at the SEMC meeting held in March 2005. This followed extensive investigation and consultation by the planning staff of the SES with all agencies listed in the plan. In particular, it was essential that the authors of plan had a full and detailed understanding of the nature of tsunami and of the current capabilities and limitations of tsunami detection and warning systems.

It was in the process of undertaking the required research that it became apparent that there are significant gaps in the knowledge base for tsunami world-wide and especially in the Australian context. There are differences of opinion within the scientific community about the evidence for past tsunami events and the likelihood and magnitude of tsunami in the future. The most difficult challenge for those involved in the response planning is that there is little or no information available by way of tsunami prediction for actual events.

In the current state of tsunami warning system development for example, there is little prospect of the SES being given any quantitative prediction of tsunami magnitude for a detected tsunami. In addition, as discussed earlier in this paper, there has been no detailed tsunami hazard modelling undertaken along the NSW coast. This makes the task of identifying potential areas of inundation and of designing and operating a public warning service aimed at evacuation of at-risk communities extremely difficult.

To put this limitation into some perspective, imagining the situation where a flood is known to be developing on a large and heavily populated floodplain. Despite being told that the flood is on its way, how could the community and the emergency service sector prepare, if there was no information provided about the anticipated depth of flooding. Fortunately in the case of floods this is not the situation and the Australian Government Bureau of Meteorology is able to provide a high quality flood prediction service which underpins the emergency risk management arrangements. A similar capability must ultimately be available for tsunami if that is both technically and economically possible.

Following the acceptance by the SEMC, in March 2005, of the first draft of the TEMSP as a basis for continuing development, a second round of consultation with all agencies listed in the plan commenced. In this second round, detailed work was undertaken to sharpen the warning arrangements with a particular focus on marine-based risk groups. This focus recognises that land-based tsunami risk communities are reasonably well served by a range of existing warning options, many of which have been devised for the flood and storm context. A second draft of the TEMSP has been prepared and was released for internal comment at the June 2nd 2005 SEMC meeting. The aim is to have the final plan ready for endorsement by the SEMC at their September 2005 meeting.

It should be noted that the TEMSP is comprehensive in scope and deals with; education, warning, evacuation, rescue, and recovery. The plan accounts for all possible tsunami magnitudes and generating mechanisms. As with all NSW emergency management plans, the TEMSP works from an assumption that agency responsibilities should focus on those activities for which they are naturally best suited by virtue of their usual business orientation. Put simply this means; fire & HAZMAT managed by fire & HAZMAT specialists, rescue managed by rescue specialists, health managed by health specialists, warning and evacuation managed by warning and evacuation specialists, etc.

The TEMSP identifies that the following specific emergency management functions may be required:

- Tsunami detection and notification
- Warning dissemination
- Evacuation of at-risk residents
- Protection and pre-deployment of resources
- Restriction of access to areas likely to be affected
- Management of waterways
- Reconnaissance of areas likely to be affected
- Search and rescue following the impact of a damaging tsunami
- Damage control to prevent further damage to damaged buildings
- Fire and HAZMAT management
- Media management
- Information management
- Resupply of isolated communities and properties
- Disaster victim identification and registration
- Health care, provided by a wide range of health services to treat affected communities.
- Management of energy and utilities
- Transport management
- Communications management
- Management of animals
- Property protection

Conclusion

In short, the primary focus of the TEMSP is to maximise the capacity of emergency services in NSW to combat tsunami, in particular to enhance the ability to warn and evacuate people at-risk. Community education programs will be aimed at developing understanding of the tsunami risk posed to communities and empowering people to take appropriate action in response to a tsunami.

The priority of any emergency response will be to the safeguarding of human life. Initially priority will be given to the warning and evacuation of persons at risk of tsunami. Once a tsunami has struck priority will shift to the search for and rescue of persons who have been trapped or injured and the activation of recovery arrangements.

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