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Developing an effective tsunami warning system: lessons from the 1960 Chile earthquake tsunami for New Zealand coastal communities

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Abstract The magnitude 9.5 earthquake on 22 May 1960 in southern Chile was the largest instrumentally recorded earthquake in the 20th century. It generated a tsunami that swept the shores of Chile and radiated out across the Pacific, with the major loss of life in Chile and, despite warnings being issued, in both Hawai'i and Japan. The absence of a Pacific-wide tsunami warning system at the time meant that the tsunami struck New Zealand without an official warning being issued. Fortunately, there was no loss of life despite widespread damage to coastal facilities. A large aftershock occurred in Chile 3 days later (25 May) and fears about a tsunami from this event resulted in the broadcasting of a nationwide warning on radio in New Zealand. Newspapers of the day reported that thousands of people around the country were evacuated, making this the largest and most widespread evacuation in New Zealand's history. Almost the entire population of Whitianga, Waihi Beach, Whakatane, Ohope, and Opotiki were moved to high ground for several hours and, in many other communities, people self-evacuated from coastal fringes. After the event, there was much discussion in the newspapers of the

need to improve both warnings and public awareness of the hazard, and of the appropriate response to warnings. Over the 40 years from 1960 up to the 26 December 2004 Indian Ocean tsunami, public awareness of New Zealand's tsunami risk and preparedness had waned. Since 2004, the renewed focus on tsunami has built on a range of improvements in emergency management policies and practices, and the lessons identified from the event paved the way for a number of new initiatives to get underway to enhance the New Zealand's tsunami warning capacity and capability.

Keywords tsunami; public response; warnings; 1960

INTRODUCTION

With a magnitude estimated to be about 9.5 (Kanamori 1977), the earthquake on 22 May 1960 at 19.11 UT (Universal Time; 07.11 NZST 23 May) in southern Chile was the largest instrumentally recorded earthquake in the 20th century. It generated a tsunami that swept the shores of Chile and radiated out across the Pacific (ITDB/PAC 2004) (Fig. 1). There was major loss of life in Chile (about 800 from the tsunami) and, despite warnings being issued, in both Hawai'i (61 deaths) and Japan (199 deaths).

According to the Integrated Tsunami DataBase (ITDB/PAC 2004), the 1960 earthquake caused a large local tsunami with a maximum recorded run-up in Chile of 25 m. The tsunami resulted in US\$550 million (US\$3.6 billion in 2005 values) in damage in Chile. Another US\$24 million (US\$158 million in 2005 values) in damage occurred in Hawai'i, and about US\$500 000 to US\$1 million (US\$3.3–6.6 million in 2005 values) in damage on the United States west coast. In Japan, the waves were more than 6 m high, causing US\$50 million (\$US330 million in 2005 values) in damage.

The absence of a Pacific-wide tsunami warning system at the time meant that the tsunami struck New Zealand without an official warning being issued. Fortunately, there was no loss of life. However, there was widespread damage to coastal facilities.

The first waves of the tsunami arrived in the late evening of 23 May 1960, unobserved by most people. Nevertheless, the lives of several people in Hawke's Bay, Gisborne, and Banks Peninsula were endangered, although no-one was seriously injured. The tsunami caused considerable minor damage to houses, boats, shops, wharves, jetties, port facilities, and boatsheds. Peak run-up heights ranged from 0.5 to 4 m throughout the east coast and at some places on the west coast of both the North and South Islands of New Zealand. The Chatham Islands, 1000 km to the east of Christchurch, were also strongly affected. The largest run-ups observed in New Zealand were in Gisborne (about 3.5 m), Napier (about 4 m), around Banks Peninsula (about 3 m), and in the Chatham Islands (about 3.5 m).

The Earthquake and War Damage Commission received 69 claims from the 1960 tsunami, from Whangarei to the mouth of the Catlins River, with the greatest number coming from the Banks Peninsula and central Hawke's Bay (EQC 1961). Total losses recorded were £5549 (about \$193 000 in 2006 values) (EQC unpubl. files). These figures probably do not reflect the total losses but the real figure is likely to be modest nevertheless. The impact of the tsunami was actually reduced by some of the largest waves occurring within an hour or two of low tide over a significant part of the coast (G. Downes pers. comm. 2006, unpubl. New Zealand Tsunami Database). After the initial tsunami, a large aftershock occurred in Chile and fears about a tsunami from this event resulted in the broadcasting of a nationwide tsunami warning on 26 May 1960.

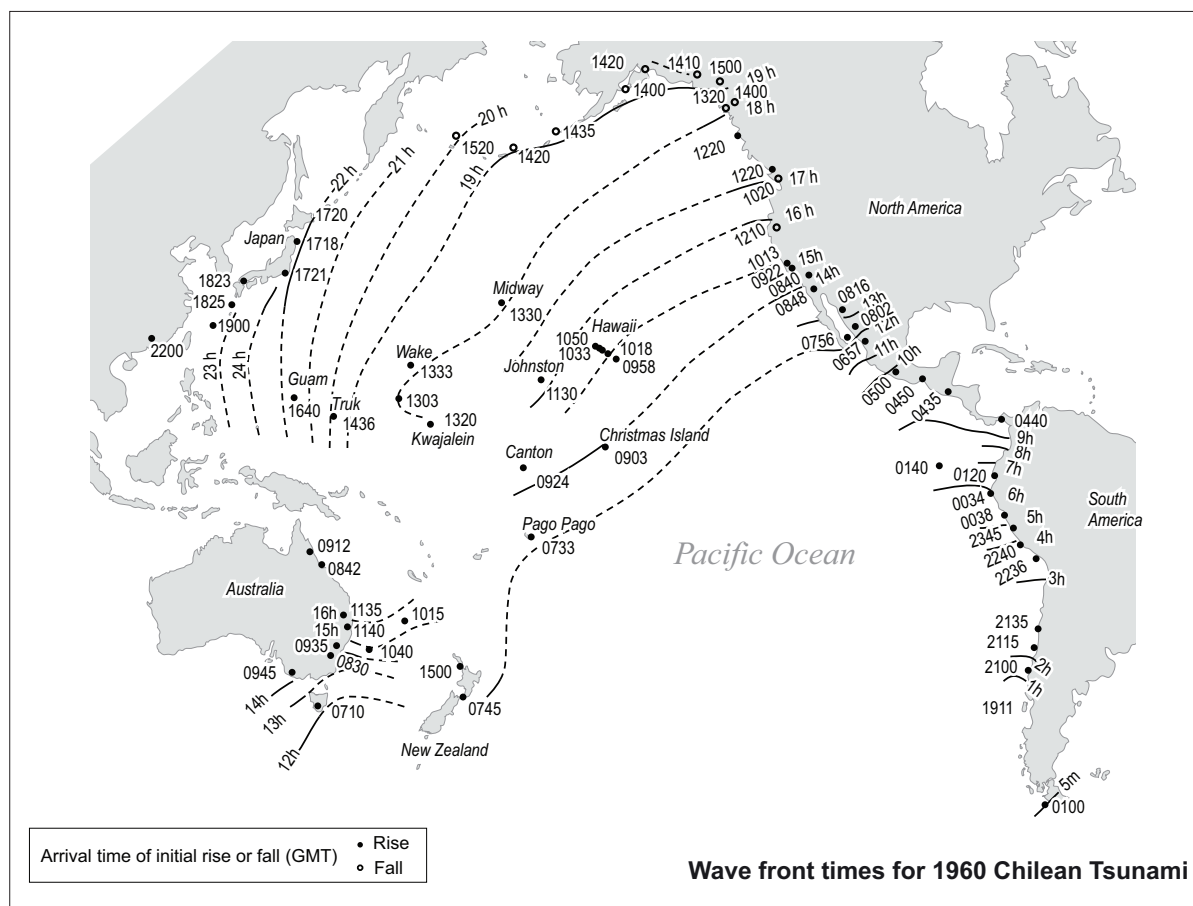


Fig. 1 Travel-time map for the 1960 tsunami (modified from de Lange 1998; data from NOAA).

This paper specifically focuses on the public and organisational response to the 26 May 1960 tsunami warning and discusses the methods of alert, the issue of “non-response” to warnings, the impact on utilities, post-tsunami public debate, and developing improved tsunami warnings since 1960. This discussion provides an analysis of public and government reactions to tsunami warnings and response, and looks at the lessons identified from the 1960 event.

METHOD

The principle method of data collection for the 1960 tsunami impact and evacuation story was a comprehensive analysis of articles in 38 newspapers (listed in Appendix 1) in print across New Zealand in May–June 1960. A systematic content analysis of the themes arising from the newspaper articles was undertaken. In addition, interviews were conducted between November 2004 and December 2007 with 18 eyewitnesses of the 1960 tsunami and who were evacuated. Oral accounts were collected from Akaroa (2), Blenheim, Christchurch (2), Lyttelton, Napier (2), Okains Bay, Opotiki, Paroa, Pigeon Bay, Te Awanga, and Whitianga (5).

THE 1960 TSUNAMI WARNINGS

After the initial tsunami, a large aftershock occurred in Chile (probably M7.5, 25 May 0834 UT listed in ITDB/PAC 2004), and fears about a tsunami from this event resulted in the broadcasting of a nationwide warning on radio in New Zealand. The sequence of events is as

follows: a warning was received from Honolulu by the Air Department in Wellington at 11.43 a.m. (NZST) on 26 May that “a fresh, disastrous earthquake in Chile” had occurred and that a tsunami could possibly reach New Zealand within an hour (*Otago Daily Times*, 27 May 1960). It was reported that “the appropriate departments and authorities were immediately notified, including the Marine Department, the Police, harbour masters, and the Government Emergency Organisation” (*Otago Daily Times*, 27 May 1960). The Marine Department issued a warning at 12.40 p.m. stating “our information does not say whether a wave has in fact been generated, nor what its intensity would be, if a wave has been generated by this earthquake it can be expected to pass through the New Zealand-Fiji area in about an hour’s time” (*The Evening Post*, 26 May 1960). Around 1 p.m., the Police broadcast warnings throughout New Zealand (*Northern Advocate*, 26 May 1960).

Public and organisational response to the 26 May 1960 warning

The warning resulted in the evacuation of many east coast towns in both the North and South Island (Fig. 2). Table 1 presents a summary of known information on the communities evacuated. Much of the observed behaviour is consistent with public response to warnings from a range of other hazard events (Tierney et al. 2001; DRSS 2006).

The decision to evacuate appears to have been made at a local level by local police, and little national consistency is apparent. In many other communities, people from coastal fringes were merely advised to move inland. However, special attention was given to many schools in low-lying coastal areas, with many closing, and the children sent home or to higher ground.

Methods of alert

A range of methods to alert communities were reported. Radio broadcasts were commonly reported “at frequent intervals during the afternoon” in coastal communities throughout New Zealand (*The Times* (Palmerston North), 27 May 1960). However, in some communities, such as Blenheim, it was reported that as no local radio station existed at the time, the community had to rely on telephones for alerting the public (*Marlborough Express*, 27 May 1960).

Local police played a key role in most communities that chose to evacuate. For example, in Kaikoura “low lying areas [were] evacuated very rapidly by the Police” (*The Press*, 27 May 1960; *Marlborough Express*, 26 and 27 May 1960; *The Kaikoura Star*, 30 May 1960). In Whakatane, “the Police and a traffic officer maintained order in the borough streets and advised people lining the waterfront to move to higher ground” (*Evening Post*, 27 May 1960), and in Napier, transport officers directed traffic away from the main road along Marine Parade beach (*NZ Herald*, 27 May 1960). In a number of locations, police and traffic officers set up road blocks to limit access to evacuated areas. However, in other coastal areas, police chose not to pass on warnings. *The Press* (Christchurch) reported “Neither the Otago Education Board nor the Otago High Schools Board, controlling authorities of most of Dunedin’s schools, received a direct warning about the tidal wave... The Dunedin Police, which received first advice about the wave, also did not communicate with organisations such as the Dunedin City Corporation, the St. John Ambulance Association and the Dunedin Metropolitan Fire Brigade.” (*The Press*, 28 May 1960). The police chief was reported as saying: “At that stage it was not ‘considered’ advisable to get in touch with other organisations and it was not necessary to do so.” (*The Press*, 28 May 1960).

Post Office staff also had a key role in alerting people in several communities (see Table 1). For example, the *Taranaki Herald* reported “three members of the New Plymouth chief



Fig. 2 Location map of evacuated communities on 26 May 1960.

post office staff had a busy afternoon yesterday. They rang every government office in New Plymouth with a warning that tidal waves were approaching New Zealand. But this unusual message caused little alarm among the city's civil servants. Some of the elderly residents of New Plymouth were, however, perturbed by the frequent broadcast flashes about the waves." (*Taranaki Herald*, 27 May 1960). In many locations, staff members were kept busy with overloaded switchboards as residents of the affected communities tried to get more information. This is an issue that is likely to recur in any large-scale disaster as, despite large advances in telecommunication technology since 1960, it is still likely that key contact centres would be overloaded in an emergency.

Table 1 Summary of information on evacuated towns on the afternoon of 26 May 1960.

Evacuated towns	Extent		Notes and references
	○ partial	● full	
Auckland	○		Tamaki Drive residents told to remove cars. Switchboards jammed/overwhelmed. Schools in low lying areas evacuated (e.g., Panmure area and other areas on the Hauraki Gulf estuary) (<i>NZ Herald</i> 27/5/60, <i>Danniverke Evening News</i> 27/5/60, <i>The Northland Times</i> 26/5/60, <i>The Nelson Evening Mail</i> 26/5/60, <i>The Southland Times</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>Wanganui Herald</i> 26/5/60). People lunching in the wharf area urged to leave and school children in low-lying areas to be dismissed (<i>ODT</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60). Hundreds of people defied police and lined roads around the harbour (<i>Taranaki Herald</i> 26/5/60).
Blenheim	○		Wairau Pa near the Wairau River mouth was evacuated, school children in Blenheim were sent home (<i>ODT</i> 27/5/60, <i>Ashburton Guardian</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Bluff	○		Most residents of Fortrose, Riverton and some of Bluff moved out of the townships. Police evacuated Oreti Beach residents (near Invercargill) (<i>The Southland Times</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Christchurch	○		Port of Lyttelton closed (first time in 110 year history), train traffic suspended (also <i>ODT</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60). Schools at Sumner and other places northward evacuated. Residents of Redcliffs and Sumner fled to higher ground (<i>The Press</i> 26/5/60, 27/5/60, <i>ODT</i> 27/5/60, <i>Ashburton Guardian</i> 27/5/60, <i>Danniverke Evening News</i> 27/5/60, <i>The Northland Times</i> 26/5/60, <i>The Nelson Evening Mail</i> 26/5/60, <i>Taranaki Herald</i> 26/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>Wanganui Herald</i> 26/5/60).
Dunedin	○		“Some people left their jobs, took children from schools and travelled to the high suburbs. Others drove to the beaches or waited on the wharves—disaster. ... Some schools closed—Port Chalmers, Tainui and others—and many parents called on schools on the flat to take their children away”. (<i>NZ Herald</i> 26/5/60).
Gisborne	○		“Patients removed from hospital, shops and schools were closed and women and children lined hillsides above some East Coast townships yesterday afternoon, following the tidal wave warning.” (<i>The Northland Times</i> 27/5/60). Residents alerted at Tologa Bay, Tokomaru Bay and Te Araroa. Post office and many shops shut—Cook Hospital removed mothers and babies from maternity hospital. Beach camp evacuated (<i>Wairoa Star</i> 27/5/60).
Granity	○		Granity school was evacuated (<i>Marlborough Express</i> 26/5/60, <i>Wanganui Herald</i> 26/5/60).
Greymouth	○		Paroa school near Greymouth was evacuated (<i>Marlborough Express</i> 26/5/60, <i>Wanganui Herald</i> 26/5/60). Harbour board took precautions (<i>Taranaki Herald</i> 26/5/60).
Hokitika	○		“Precautions were also being taken in the Westport, Karamea and Hokitika Schools” (<i>The Ashburton Guardian</i> 25/5/60).
Kaikoura	●		“Untried emergency precautions went into perfect action on Thursday afternoon when the tidal wave warning was given, and all concerned must be given great credit for the smoothness of the evacuation of the pupils of the Kaikoura District High School and the warning given to people living and working in West and East Ends and other areas.” (<i>The Kaikoura Star</i> 30/5/60). “At Kaikoura within minutes of the siren sounding the alarm, residents of the township and school children were up on the hill overlooking the sea, and in an area of safety.” (<i>ODT</i> 27/5/60).
Karamea	○		Karamea school was evacuated (<i>Marlborough Express</i> 26/5/60, <i>Wanganui Herald</i> 26/5/60).

Table 1 (continued)

Evacuated towns	Extent ○ partial ● full	Notes and references
Kawerau	○	Two schools evacuated and many residents also went to higher ground (15 miles from coast but worried about the river) (<i>NZ Herald</i> 27/5/60, <i>The Press</i> 27/5/60, <i>Marlborough Express</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Leigh	○	“More than 200 people, including school children, gathered on high land overlooking the wharf” (<i>NZ Herald</i> 27/5/60, <i>ODT</i> 27/5/60).
Napier	○	Transport officials directed traffic away from Marine Parade. Schools on the flat cleared (<i>NZ Herald</i> 27/5/60, <i>ODT</i> 27/5/60, <i>The Nelson Evening Mail</i> 26/5/60, <i>Taranaki Herald</i> 26/5/60, <i>Wairoa Star</i> 27/5/60, <i>Wanganui Herald</i> 26/5/60).
New Plymouth	○	“Three members of the New Plymouth chief post office staff had a busy afternoon yesterday. They rang every government office in New Plymouth with a warning that tidal waves were approaching New Zealand. But this unusual message caused little alarm among the city’s civil servants. Some of the elderly residents of New Plymouth were, however, perturbed by the frequent broadcast flashes about the waves.” (<i>Taranaki Herald</i> 27/5/60).
Ohope	●	Most residents abandoned their homes (<i>BOP Beacon</i> 27/5/60).
Opotiki	●	Between 400–500 residents as well as school children went to higher ground (<i>The Press</i> 27/5/60, <i>ODT</i> 27/5/60, <i>Marlborough Express</i> 27/5/60). “At Opotiki, on the other hand, there was little alarm and, in fact, a number of residents continued line fishing along the coast”. (<i>BOP Beacon</i> 27/5/60).
Oreti Beach	●	Most residents of Fortrose, Riverton and some of Bluff moved out of the townships. Police evacuated Oreti Beach residents (near Invercargill) (<i>The Southland Times</i> 27/5/560, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Orewa	○	Students taken to hills. Shops at Orewa closed. Switchboard jammed with calls (<i>NZ Herald</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Pareora	●	“For almost two hours this afternoon, the only sign of life in the township...was two fowls scratching in the dirt.” Freezing works and township evacuated (<i>The Press</i> 27/5/60, <i>ODT</i> 27/5/60, <i>Wairoa Star</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Picton	○	Many workers left work—boats put out in Picton. (<i>Marlborough Express</i> 26/5/60).
Riverton	●	Most residents of Fortrose, Riverton and some of Bluff moved out of the townships. Police evacuated Oreti Beach residents (near Invercargill) (<i>The Southland Times</i> 27/5/560, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Taipa	○	“The Taipa District High School was evacuated and staff and pupils went to the hill between Taipa and Cable Bay for the afternoon. There was some activity in waterfront houses in Mangonui.” (<i>Northland Age</i> 27/5/60).
Te Awanga	○	“Many people moved on to rooftops. Several residents piled drums filled with sand and shingle on their lawns to break the force of any large waves” (<i>NZ Herald</i> 27/5/60).
Timaru	○	“Thousands lined the cliffs above Caroline Bay for nearly two hours...much of the business and industrial activity came to a halt.” (<i>NZ Herald</i> 27/5/60).
Waihi Beach	●	Whakatane, Whitianga, Mercury Bay (from warning from Post Office), Whangamata and Waihi Beach evacuated. (<i>NZ Herald</i> 27/5/60, <i>The Press</i> 27/5/60, <i>The Southland Times</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60). Post Office and seaside homes evacuated (<i>NZ Herald</i> 27/5/60, <i>Taranaki Herald</i> 26/5/60).

Table 1 (continued)

Evacuated towns	Extent		Notes and references
	○ partial	● full	
Wellington	○		Several schools took the precaution of moving children to higher ground shortly after 1 p.m. The children were later sent home.” (<i>Evening Post</i> 27/5/60). “Fire and ambulance services in Wellington evacuated their headquarters and ‘stood to’ at high vantage points in the city to be prepared for any emergency.” (<i>The Times</i> (Palmerston North) 27/5/60).
Whakatane		●	“Residents of Whakatane looked from the hills down on their nearly-deserted town yesterday after the tidal wave warning. Shops and offices closed: schools were evacuated and the telephone exchange was worked by a skeleton staff. Hundreds of cars caused the biggest traffic bottleneck of the Bay of Plenty as motorists flocked to the higher ground to the east of the town. Cars three and four abreast blocked the Whakatane-Ohope highway. It was several hours before order was restored. School children, escorted by teachers, swarmed over the hillsides, and residents without vehicles hurried to higher ground to cram every vantage point for any sign of the advancing wave. Many without cars were taken to the hills by neighbours, who organised a taxi service. Meanwhile, the Police and a traffic officer maintained order in the borough streets and advised people lining the waterfront to move to higher ground.” (<i>Evening Post</i> 27/5/60).
Whangamata		●	Whakatane, Whitianga, Mercury Bay (from warning from Post Office), Whangamata and Waihi Beach evacuated. (<i>NZ Herald</i> 27/5/60, <i>The Press</i> 27/5/60, <i>The Southland Times</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60). Evacuated within 1/2 hour of the warning. About 120 children and 300 adults evacuated by cars, trucks and buses (<i>NZ Herald</i> 26/5/60, <i>ODT</i> 27/5/60, <i>Taranaki Herald</i> 26/5/60, <i>The Southland Times</i> 27/5/60).
Whangaparoa	○		Students taken to hills. Switchboard jammed with calls (<i>NZ Herald</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).
Whitanga		●	Whakatane, Whitianga, Mercury Bay (from warning from Post Office), Whangamata and Waihi Beach evacuated. (<i>NZ Herald</i> 27/5/60, <i>The Press</i> 27/5/60, <i>The Southland Times</i> 27/5/60, <i>The Wanganui Chronicle</i> 27/5/60, <i>The Times</i> (Palmerston North) 27/5/60).

In addition to radio and telephone communication and the police response, sirens were used in at least two communities to warn the public. In Kaikoura, it was reported that “within minutes of the siren sounding the alarm, residents of the township and school children were up on the hill overlooking the sea, and in an area of safety.” (*Otago Daily Times*, 27 May 1960). Furthermore, in Whitianga the “fire alarm sounded three times” (*NZ Herald*, 27 May 1960).

The wide range of alert methods used was a product of both the lack of any formal response system at the time and also the warning environment that existed. Research into alerting options (Sorenson 2000; Leonard et al. 2006) frequently highlights the need for multiple methods.

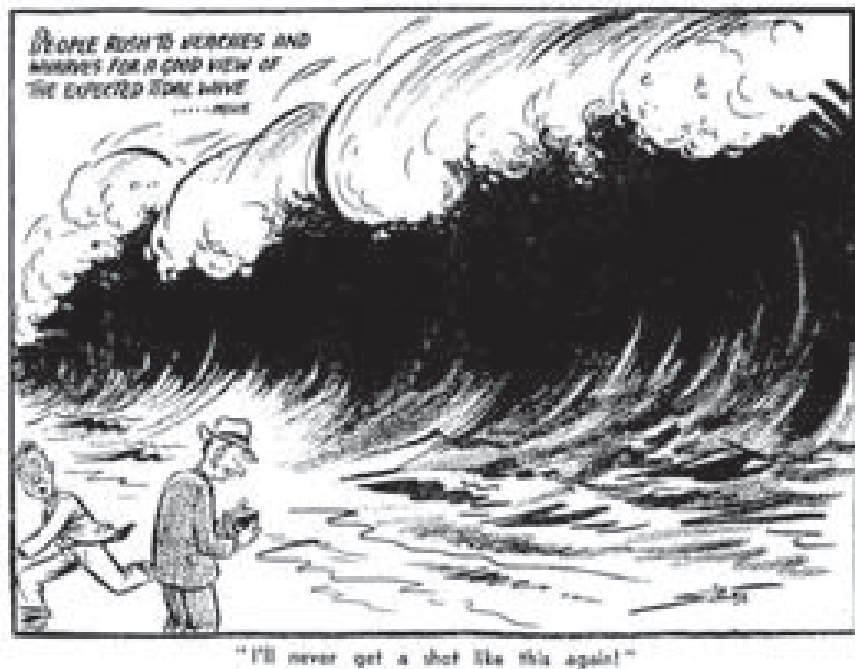
Non-response to warnings and tsunami “sightseeing”

Along with those members of the public who did evacuate to safe areas, there are also widespread newspaper reports of people ignoring the warnings. For example, the *Marlborough Express* reported that “in many seaside settlements, the residents, while warned of impending danger through the Police and in radio broadcasts, chose to remain where they were. ... Seaside residents who declined to leave their homes had in most cases however, taken precaution to plan an evacuation route.” (*Marlborough Express*, 27 May 1960).

Fig. 3 People gathering at Napier wharf observe the expected tsunami on the afternoon of 26 May 1960 following the police warning. (Photo courtesy of Russell Spiller, Batchelors Studio, Napier.)



Fig. 4 Cartoon from *Otago Daily Times* 28 May 1960. (Reproduced with copyright permission from *Otago Daily Times* 28 April 2006.)



In addition, pictures in many newspapers (Fig. 3, 4) show crowds waiting on or near the shore for the approaching tsunami. In Napier it was reported that “the effect of the warning, which was broadcast at frequent intervals during the afternoon, was to drive people towards the beaches rather than away from them. All afternoon seafronts at Marine Parade and Westshore were thronged with larger numbers of people than usual at this time of year” (*The Times* (Palmerston North), 27 May 1960), and in Wellington “The many people who flocked down to the waterfront and beaches yesterday did so in considerable danger as the water would have risen with considerable rapidity said a spokesman” (*Evening Post*, 27 May 1960). Fear that tsunami tourists could affect community response has commonly been expressed by residents in other susceptible areas since 1960 (Johnston et al. 2005).

In other communities “sightseers” chose safer locations. For example, “thousands lined the cliffs above Caroline Bay, Timaru, for nearly two hours yesterday afternoon ... cars were double and triple parked for some time, and much of the business and industrial activity in the city came to a halt.” (*Otago Daily Times*, 27 May 1960). In Whakatane, “residents ... looked from the hills down on their nearly-deserted town yesterday after the tidal wave warning. Hundreds of cars caused the biggest traffic bottleneck of the Bay of Plenty as motorists flocked to the higher ground to the east of the town. Cars three and four abreast blocked the Whakatane-Ohope highway. It was several hours before order was restored. School children, escorted by teachers, swarmed over the hillsides, and residents without vehicles hurried to higher ground to cram every vantage point for any sign of the advancing wave. Many without cars were taken to the hills by neighbors, who organized a taxi service. Meanwhile, the Police and a traffic officer maintained order in the borough streets and advised people lining the waterfront to move to higher ground.” (*Evening Post*, 27 May 1960).

The observations of the 1960 warning response are consistent with the extensive research on emergent groups and convergent behaviour in disaster and the pre-disaster warning phases (Dynes 1970; Stalling 1984; Tierney et al. 2001). In the case of tsunami warnings, the phenomena of concurrent evacuations, non-response, and convergent behaviours was also observed in Hawai‘i in 1960 (Lachman et al. 1961).

Impacts on utilities

As ports were one of the first groups to be alerted in the 1960 event, most took immediate precautions and warned vessels and ground staff. For example, the Lyttelton Harbourmaster advised “masters of vessels in the port to be on alert, gave an order that all unauthorized personal be ordered off the waterfront and instructed that moveable gear belonging to the harbor board, such as mobile cranes, be taken up to higher ground” (*Taranaki Herald*, 26 May 1960). In Tauranga, it was reported that following a warning from the port authority “two freighters and a tanker at Mount Maunganui Wharf and one at Tauranga strengthened their moorings” (*Taranaki Herald*, 26 May 1960). Small boat owners also took precautions in many coastal locations. It was reported that in Picton, “most of the pleasure fleet left for the Queen Charlotte Sounds” (*Otago Daily Times*, 27 May 1960).

Rail services were suspended in at least two areas: “The Railways Department in Christchurch ordered its coastal services to a halt. The Picton to Christchurch rail-car was stopped for one hour 55 minutes at Kowhai, south of Kaikoura, and the Christchurch to Picton rail-car was stopped at Clarence for one hour 50 minutes. The rail-car crews were told over the department’s train control telephone system to stop at the nearest high point. Two goods trains, which were scheduled to leave Christchurch between 2 p.m. and 3 p.m were also held.” (*The Press*, 27 May 1960).

A range of responses by other utility providers was also reported, from closure of telephone exchanges to, in one example, the cutting of electricity supplies (e.g., “At Mercury Bay the power was cut off and the telephone exchange closed.” (Riddle 1996, p. 194; *The Southland Times*, 27 May 1960).

The impacts on utilities observed in the 1960 tsunami highlight the role and linkage of community infrastructure in the functioning of communities. These systems (e.g., roads, communications, water, and electricity supply) are often complex and interdependent (Johnston et al. 2006), and their disruption can affect warning dissemination, evacuations, and response

and recovery following a tsunami. While the specific characteristics of the 1960 event (e.g., it coinciding with low tide) may have muted the economic consequences at the time, it will be important to extrapolate the potential economic consequences from this event that could present should a similar-sized event occur, both with respect to the shorter and longer term implications that could arise (e.g., time to rebuild essential infrastructure such as ports and rail lines).

POST-TSUNAMI PUBLIC DEBATE

There was much discussion in the newspapers following the 1960 tsunami and subsequent tsunami alert about the need to improve both warning systems and public awareness. These were directed at both national and local arrangements. Examples of such comments included:

- “New Zealand reacted well on the whole to the possibility of tidal wave disaster ... Yesterday’s alert had distressing gaps which luckily did not matter. While Kaikoura was evacuated, while trains came to a standstill, while Lyttelton was organised to a high degree and every small boat owner in Christchurch rushed to protect his craft, this district of Monks Bay [near Christchurch], most vulnerable to attack, went placidly about its business.” (*The Press*, 30 May 1960).
- “Deficiencies in the national organization for emergencies were ‘glaring’ during the recent tidal disturbances and were now being ‘cleared up’.” (*The Press*, 2 June 1960).
- “Tidal waves could have resulted in real shambles—If the tidal wave had smashed on to Invercargill, Bluff, or other Southland coastal towns people would have been left to their own resources, without assistance for hours, perhaps days, because of the lack of an adequate emergency organization.” (*The Southland Times*, 27 May 1960).
- “...This country is ill-prepared to meet this type of emergency.” (*Wairarapa Times-Age*, 27 May 1960).
- “...and emergency precaution scheme, which had operated in Masterton a few years ago, had fallen by the way, mainly because there had been no cause to put it into effect.” (*Wairarapa Times-Age*, 28 May 1960).

DISCUSSION

Developing improved tsunami warnings since 1960

In 1949, the Pacific Tsunami Warning Center (PTWC) was established in Hawai‘i, to provide warnings of Pacific-wide tsunami to Hawai‘i and all other US interests in the Pacific. At the time of the 1960 tsunami, New Zealand and many other Pacific countries were not connected to the PTWC. In the weeks following the May 1960 events, newspapers reported that discussions were taking place between the Marine Department and other government departments “with a view to exploring the possibility of an advanced warning system for tidal waves around New Zealand” (*The Evening Post*, 26 May 1960). As a result of this event, arrangements were made for New Zealand to receive warnings from the PTWC. Formal arrangements were established in 1965 when the PTWC assumed responsibility as the operator of the Tsunami Warning System in the Pacific.

Following the 1960 tsunami, a range of management tools were made available in New Zealand. These included wave-travel-time maps (Gilmour 1964a, 1967) and public education resources (Gilmour 1964b). In addition, councils developed a range of local arrangements for the receipt and dissemination of tsunami warnings issued by national authorities. However, apart from minor alerts, these have never been tested to the level seen in 1960.

On a broader level within New Zealand, there has been a significant change in emergency management arrangements since 1960. The most recent legislation, the Civil Defence Emergency Management Act 2002 (CDEM Act) requires that a risk management approach be taken when dealing with hazards. As part of the comprehensive approach to civil defence emergency management (CDEM), all hazards, not only natural hazards, must be taken into consideration. The primary goal for communities is to be self-reliant and resilient. Communities should aim to reduce the likely impact from, prepare for, and be able to respond effectively to emergency events on their own. To encourage this, regional co-operation and co-ordination are paramount and form one of the cornerstones of the Act. In parallel, technological advances have increased our ability to detect and transmit warnings.

However, in the last 40 years, up to the 26 December 2004 Indian Ocean tsunami, public awareness of New Zealand's tsunami risk and preparedness waned (Johnston et al. 2003; Webb 2005). This is despite New Zealand's continued participation in PTWC and its governing body, the IOC International Co-Ordination Group for The Tsunami Warning System in the Pacific (now known as ICG/PTWS). New Zealand's vulnerability to tsunami damage has increased by at least an order of magnitude over the same period, due to increasing coastal development.

The rapid drop-off of public understanding of, and policy support for, hazard issues has been observed following other natural hazards events, such as earthquakes and flooding (Lindell & Perry 1992). For example, in California, both Turner et al. (1986) and Dooley et al. (1992) found that earthquake events led to an increase in residents concerns but this declined over time. In New Zealand, along with the 1960 tsunami, this has been observed in the context of earthquakes (Britton 1981) and flooding (Ericksen 1986). Also, in 2003, a national survey of people living in, and visiting, 42 coastal communities around New Zealand was conducted in order to determine people's awareness and perceptions of natural hazards, and their preparedness to deal with them. Knowledge of tsunami risk and preparedness was low (Johnston et al. 2003). However, in 2006, a repeat survey was conducted in a sub-set (9) of those communities to determine if awareness and preparedness of tsunami had increased following the Indian Ocean tsunami. Awareness was found to have increased significantly following the 2004 event (Du Bois 2007; Pishief 2007). Interestingly, interviews conducted between 2004 and 2007 with people who remember the 1960 tsunami and subsequent evacuation revealed that most had no memory of the time separation between the 22–23 May 1960 tsunami and the 26 May 1960 evacuations. Most people had merged the two events and recount that the main 1960 tsunami led to an evacuation but that there was little impact.

There has been a major shift in public expectations regarding emergency response in the decades since the 1960 event. Despite growing emergency management emphasis on public hazard education, a trend towards increasing the transfer of responsibility from people to societal institutions has been apparent in the literature (Gregg et al. 2004, 2007; Paton et al. 2005).

In the aftermath of the 26 December 2004 Indian Ocean tsunami, the New Zealand Government initiated a review of the country's tsunami risk and levels of preparedness. As a result, two reports were published in December 2005. The first summarised the current state of

knowledge of tsunami (Berryman 2005) and the second reviewed the current arrangements for tsunami warnings (Webb 2005). The reports highlighted New Zealand's tsunami risk and the need for the entire New Zealand emergency management sector to understand the complexities of emergency response planning to an event.

A range of land-use planning tools are available to reduce tsunami risk (Burby et al. 2000; Eisner 2005). In theory, all tsunami risk can be mitigated through land-use planning. However, because of a public desire to populate coastal areas, and because of the relatively long return period of damaging tsunami, regulations and land-use planning are in reality unlikely to provide effective mitigation for the entire risk.

An effective integrated warning system is required to address the residual risk. This has been split into five components (Webb 2005; Leonard et al. 2008): (1) effective early warning systems; (2) planning; (3) co-operation, discussion, and communication; (4) public education; and (5) exercises. Over the past 3 years (since late 2005), several government agencies have been working together to address the issues raised by the 2005 review. Improved tsunami warning systems and warning protocols have been initiated by the Ministry of Civil Defence Emergency Management (MCDEM), GNS Science, and other partner organisations; tsunami signage standards and evacuation planning guidelines have been developed (TWGSS 2007; MCDEM 2008); and an improved national and local exercising of the above arrangements has also taken place.

CONCLUSIONS

The public response to the 1960 tsunami provides some clear insights into a range of emergency management and public education issues that need to be addressed. When the consequences of this event are mapped onto contemporary community characteristics, emergency management agencies can have a valuable planning tool at their disposal.

The 1960 tsunami led to a number of significant changes in the way tsunami were managed in New Zealand. The most notable was New Zealand's membership in the Pacific tsunami warnings system. Despite the improved national warning systems, the public awareness of New Zealand's tsunami risk and preparedness waned between 1960 and 2004. In addition, New Zealand had lagged behind other countries in developing and implementing a range of tsunami-specific mitigation measures in this period (e.g., evacuation mapping and signage, hazard zoning, public education, warning systems) (e.g., USA National Tsunami Program, Bernard 2005).

The 2004 Indian Ocean tsunami significantly changed the effort given to tsunami preparation in New Zealand, and we have seen a significant improvement in both the political and policy support for tsunami risk management, and the human and financial resources to allow the establishment of a range of mitigation measures.

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Appendix 1 May to July 1960 newspapers reviewed.

<i>Ashburton Guardian</i>	<i>Taranaki Herald</i>
<i>Bay of Plenty Beacon</i>	<i>Taumarunui Press</i>
<i>Bay of Plenty Times</i>	<i>Te Awamutu Courier</i>
<i>Brooklyn News</i>	<i>Te Puke Times</i>
<i>Central Hawkes Bay Press</i>	<i>Thames Star</i>
<i>Dannevirke Evening News</i>	<i>The Akaroa Mail</i>
<i>Ellesmere Guardian</i>	<i>The Auckland Star</i>
<i>Evening Post</i>	<i>The Franklin Times</i>
<i>Evening Star</i>	<i>The Lyttelton Times</i>
<i>Hawkes Bay Herald</i>	<i>The Marlborough Express</i>
<i>Kaikoura Star</i>	<i>The Northland Times</i>
<i>Levin Chronicle</i>	<i>The Press</i>
<i>Morrinsville Star</i>	<i>The Southland Daily News</i>
<i>Mount News</i>	<i>The Southland News</i>
<i>Nelson Evening Mail</i>	<i>The Star</i>
<i>New Zealand Herald</i>	<i>The Taupo Times</i>
<i>Northern Advocate</i>	<i>The Timaru Herald</i>
<i>Oamaru Mail</i>	<i>The Times (Palmerston Nth)</i>
<i>Oamaru Times</i>	<i>The Wairoa Star</i>
<i>Otago Daily Times</i>	<i>The Wanganui Chronicle</i>
<i>Otago Witness</i>	<i>The Weekly Press</i>
<i>Putaruru Press</i>	<i>Wairarapa Times-Age (Masterton)</i>
<i>Rodney & Otamatea Times</i>	<i>Wanganui Herald</i>
<i>South Auckland Courier</i>	<i>West Coast Times</i>
