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Inundation of Whitianga town during the 1960 Chilean tsunami

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Table of contents

List of figures

List of photos

List of tables

List of maps

Dedication

This report is dedicated to the memory of our friend and colleague, the late Dr. Vernon Pickett (18 January 1951 - 7 May 2014).

- Brendan Morris and Jose Borrero

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Executive summary

This report combines written and verbal eyewitness reports with survey and modelling information to arrive at an estimated inundation area for the 1960 Chilean tsunami in Whitianga. This report has been completed as a part of the Eastern Coromandel Tsunami Strategy - an ongoing, multi-year project that works with communities on the eastern Coromandel Peninsula to identify and reduce the risks from tsunami events.

The study used a combination of both qualitative and quantitative approaches to determining inundation levels, including a review of existing historical written and verbal reports, on-site interviews with local eyewitnesses, a survey of a cliff-side marker of maximum inundation level and recent numerical modelling.

While historical written and verbal accounts provided a good general overview of inundation, recent eyewitness interviews provided a much greater level of detail on the location, extent and nature of inundation. On-site interviews included detailed descriptions of impacts around the harbour and Mill Road/Monk Street areas, and at the Taputapuatea Stream at the northern end of Buffalo Beach.

The on-site interviews identified a marker peg placed at the maximum inundation level at Pah Point immediately after the 1960 event. A survey of this marker enabled an estimation of the maximum possible water levels across Whitianga from the event.

With respect to numerical modelling, the use of the ComMIT tool and the MOST tsunami model is a significant improvement over the previous modelling efforts, because it allows for the direct investigation of realistic earthquake tsunami sources and the full solution of tsunami wave evolution from the source to the study site. This type of modelling has not been done previously. Six different source model 'Cases' were trialled for the 1960 Chilean earthquake in order to achieve a 'best-fit' to the observed effects at Whitianga. We conclude that modelling Cases 3 and 4 provide the best estimation of inundation around the Taputapuatea Stream. We also conclude that the modelling results do not match eyewitness reports as well around the Mill Road/Monk Street area, but we are able to rely on greater levels of eyewitness evidence in this area.

We are confident that the source models and bathymetry grids used in this study provide a robust characterisation of the effects of the 1960 tsunami in Whitianga. We also contend that the distributed slip source of Fujii and Satake (2012) (used in Cases 3 and 4) yields the overall best fit to the observed effects during the 1960 Chilean tsunami, and that the inundation results from Prasetya et al., 2009 significantly overstate the level of inundation along Buffalo Beach.

Based on all the evidence considered, we conclude that the 1960 Chilean tsunami surge most likely did not extensively or uniformly overtop the dune ridges parallel to Buffalo Beach and The Esplanade. Rather than dune overtopping, flooding behind the ridges occurred due to water surging through topographic lows in the ridges where streets cut through to the harbour in Whitianga town, and where the Taputapuatea Stream at the northern end of Buffalo Beach enters Mercury Bay. Once inundation began, flow paths followed established low points in watercourses along the swales (low points) behind the dune ridges.

This study has aided in verifying the ComMIT tool and MOST tsunami model, based primarily on eyewitness observations. This improves confidence in future inundation modelling from other tsunami sources and events at Whitianga, providing better information for emergency management and land use planning.

1 Purpose and expected outcomes

The purpose of this report is to confirm the extent of land inundation of the 1960 Chilean tsunami in Whitianga town, using a combination of eyewitness reports, survey information and modelling information.

The expected outcomes are to

- enhance the existing understanding of inundation effects of the 1960 Chilean tsunami event on Whitianga town
- provide further verification of recent modelling work to underpin future tsunami modelling
- raise awareness of the effects of tsunami inundation from distant tsunami events and the profile of tsunami hazard risk management within the Whitianga community.

It is anticipated that this report will also provide for a greater level of public awareness of the impacts of tsunami in Whitianga, and the need to prepare for these events.

2 Background

2.1 Importance of tsunami risk management

While the presence of tsunami hazards in New Zealand has been recognised for generations, the importance of identifying tsunami hazards and managing risks has increased dramatically in the past 10 years.

The 2004 South-east Asian tsunami event highlighted the risks from large plate boundary earthquakes, and resulted in over 200,000 deaths – primarily in Indonesia, Sri Lanka, India and Thailand. This event prompted the New Zealand Government, via the Ministry of Civil Defence & Emergency Management to assess national tsunami hazards and risks, and was the catalyst for ongoing development of tsunami hazard and risk management guidance resources. These developments prompted local authorities across New Zealand to either begin or expand work programmes aimed at identifying and managing tsunami tsunami risks.

Two distant tsunami events from Samoa (2009) and Chile (2010) reinforced the need for local and national response planning, and resulted in improvements to distant tsunami identification and response processes both locally and nationally.

The 2011 Japan (Tohuku) tsunami event has further reinforced the focus on tsunami risk management, and has resulted in significant changes in scientific understanding about the mechanisms of large plate boundary earthquakes and their tsunami-generation potential.

2.2 Coromandel East Coast tsunami hazards

The east coast of the North Island, including the Coromandel Peninsula, is at risk from tsunami hazards. The primary risks to the East Coromandel coast are from distant and regional source tsunami. Distant tsunami are generally caused by large earthquakes on the circum-Pacific subduction zones (see Figure 1) and have travel times (time from event to wave arrival on shore) of greater than 12 hours, while regional tsunami have travel times of between one and three hours. Studies indicate that the main source of distant tsunami is from South America, and that these are relatively frequent events – occurring about once every 50 to 100 years (Power el al., 2007). Distant source tsunami take 12-15 hours to reach New Zealand, providing time for evacuation of communities.

The primary regional source of tsunami is the Tonga-Kermadec (TK) Trench to the northeast of New Zealand. The TK Trench is the subduction zone between the Pacific and Australian plates and runs from the east coast of New Zealand's North Island northward to the Central South Pacific, southwest of Samoa (Figure 2). Like other subduction zones, powerful earthquakes along the TK Trench would be capable of producing very large tsunami. Maximum nearshore wave heights (peak to trough) of the order of 10 metres with runup in excess of 15 metres would not be unreasonable for this type of tsunami source. Of particular concern for New Zealand would be ruptures along the southern segments of the TK Trench south of 24˚ S latitude. Although the TK trench is not known to have produced such large events in recorded history, and the frequency of very large earthquakes along the TK plate boundary is unclear, evidence from tsunami deposits suggests that a very large event from a regional source last occurred in the 14th Century (McFadgen, 2007). Within the Waikato region, the risks from "regional" tsunami generated along the TK Trench have been recognised as being the single biggest risk to people in the region since 2004.

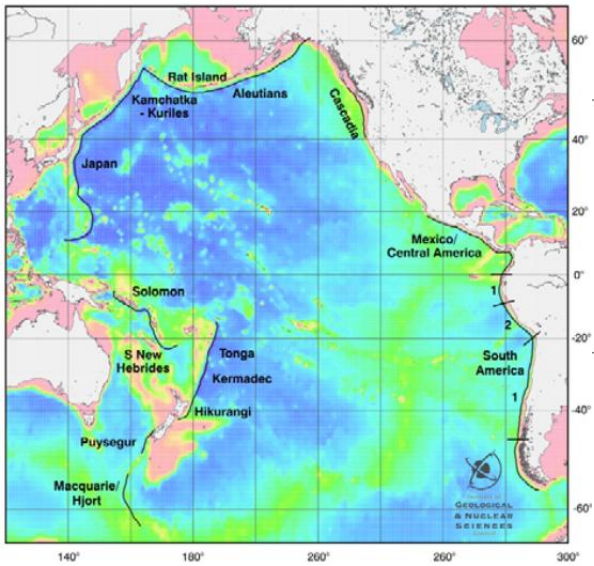


Figure 1: The circum-Pacific subductions zones that represent the majority of far field and regional tsunami source regions for New Zealand.

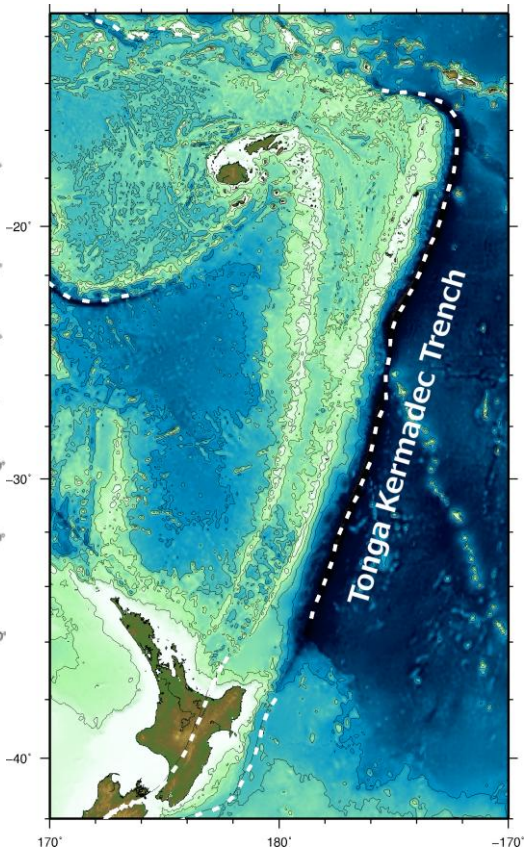


Figure 2: A close up view of the Tonga-Kermadec trench which extends from the east coast of New Zealand to Samoa.

2.3 The Eastern Coromandel Tsunami Strategy

The Waikato Regional Council and the Thames-Coromandel District Council are jointly managing the East Coast Tsunami Strategy. The strategy has been in progress since initial scientific work to identify tsunami hazards was undertaken between 2002 and 2006. The Eastern Coromandel Tsunami Strategy is an ongoing, multi-year project that works with communities on the eastern Coromandel coast to identify and reduce the risks from tsunami events.

Projects within each of the east coast communities have two strands:

1. To develop in collaboration with east coast communities, emergency plans to allow for the safe and timely evacuation of a community
2. To develop long-term planning strategies to ensure critical building and infrastructural assets are located away from high-risk tsunami zones.

Projects within each of the communities use on-going public education and engagement as an important part of the project.

2.4 Whitianga tsunami project

Tsunami risk mitigation work on the Coromandel east coast initially focussed on Whitianga, following scientific studies showing that Mercury Bay was at particular risk due to tsunami amplification effects within Mercury Bay.

The project began in 2008 with the production of a University of Waikato technical report on tsunami inundation in Whitianga, which became the basis for a community risk reduction process and production of a risk management plan. Public communication and consultation took place during 2011, and the Whitianga project is now in an ongoing risk management implementation phase.

Community work to identify and improve tsunami risk management in Whitianga has involved:

- Scientific/technical work: inundation modelling and mapping for maximum likely event, development of hazard zones to inform land-use planning
- Formation of local tsunami working group: consisting of community board, emergency services, community and staff representatives
- Communication with the community: development of summary report specific to the Whitianga community
- Presentation of information: via community open days, seeking feedback on hazards, risks and actions to improve risk management
- Consultation on the draft risk management proposal: the proposal was taken to the community for feedback, with a work programme based on realistic and achievable risk management actions
- Development of a risk mitigation proposal based on local community feedback and direction.

2.5 Benefits and use of this report

This report is a unique opportunity to bring together all existing historical information, recent eyewitness reports and the latest numerical modelling techniques to confirm the extent of inundation from an historical tsunami event. While the inundation from recent events can be easily surveyed and recorded, the ability to verify inundation from historical events is significantly more challenging.

The primary benefit from this report is the verification of the ComMIT tool and the MOST tsunami model, based primarily on eyewitness observations. Verification of the ComMIT tool and the MOST tsunami model means that inundation modelling of other

tsunami sources and events at Whitianga can be undertaken with confidence in the results, and may be used to better inform emergency evacuations and/or land use planning decisions in the future. In addition, modelling can be completed for a variety of tsunami sources and events for other east coast communities with the same level of confidence, providing better information for future risk management actions.

It is anticipated that this report will also provide for a greater level of public awareness of the impacts of tsunami in Whitianga, and the need to prepare for these events.

3 Methodology

This report was developed by using both qualitative and quantitative approaches to determining the inundation levels of the 1960 Chilean tsunami in Whitianga, including:

- Review of existing written and verbal historical accounts of the event in Whitianga
- Interviewing local eyewitnesses in Whitianga, including:
    - Marking up historical photos and contemporary maps
    - Visiting all known inundation sites around Whitianga with eyewitnesses
    - Viewing the inundation level marker at Pah Point, and observing inundation sites from the harbour
    - Photographing sites of interest
    - Obtaining relevant historical photos
- Survey of the inundation marker peg at Pah Point, plotting of the inundation level across Whitianga, and comparing the inundation level to both historical reports and recent eyewitness interviews
- Review of previous tsunami modelling, recent modelling of Chilean tsunami inundation and comparison of recent modelling to historical accounts and recent eyewitness interviews.

The results of existing historical accounts, recent eyewitness interviews, the survey and modelling were then collated to reach conclusions on the estimated level of inundation of the 1960 event.

4 Overview of 1960 Chilean earthquake and its effects on New Zealand

The great earthquake of 22 May 1960 centred near Valdivia in southern Chile remains the largest instrumentally recorded earthquake in history (Kanamori, 1977). While estimates of its magnitude vary from M_W 9.3 to 9.6 (Bilek, 2009, Fujii and Satake, 2012), it was undisputedly an extremely large earthquake with rupture extending for nearly 900 km along the subduction zone (Plafker and Savage, 1970, Barrientos and Ward, 1990). The earthquake produced a tsunami that affected the entire Pacific Ocean. Runup heights in the source region were in excess of 25 metres, with runup on the order of 6 metres observed in both Japan and Hawaii. Fatalities occurred in both Japan and Hawaii as a result of the tsunami.

The earthquake occurred at 19:11 UTC on May 22, 1960, corresponding to 7:11 am on 23 May in New Zealand. Travel time from the source region to New Zealand is on the order of 12.5 hours, implying first arrival along the New Zealand coast in the evening of 23 May, shortly before 8 pm. Given the time of year, the tsunami arrived after dark and most of the effects occurred overnight in the dark.

The tsunami was also observed throughout New Zealand, particularly at sites along the east coast such as Lyttelton, Otago Harbor, and Tauranga (Heath, 1976; De Lange and Healy, 1986; Bell et al., 2004). At all sites where the tsunami was recorded on tide gauge stations, the tsunami was observed as a leading elevation wave (see Heath

1976), i.e. the first motion of the water is positive. This observation makes sense given the earthquake source mechanism, which would produce uplift to the west of the South American mainland and subsidence on shore to the east.

Notable effects of the 1960 tsunami in New Zealand are described in de Lange and Healy (1986) and include the following:

- 2.8 metre surges in Tutukaka (Northland) causing flooding of roads and some minor damage to a bridge abutment;
- 0.6 metre surges in Auckland's Waitemata harbour;
- 1.2 metre bores in the Waimata River at Gisborne with surges continuing for days after tsunami arrival;
- Maximum water levels of 3.0-3.5 metres at Lyttelton Port causing damage to the electrical system.

However, New Zealand-wide, Whitianga suffered some of the strongest effects, as noted in de Lange and Healy (1986) and Bell et al. (2004). The effects at Whitianga are described in the next section.

5 Impacts of 1960 Chilean tsunami on Whitianga town

5.1 Previously Published Accounts

Several authors have recounted the effects of the 1960 tsunami in Whitianga, including de Lange and Healy (1986) and Bell et al., (2004). In the Appendix of de Lange and Healy (1986) the following is written:

> *"WHITIANGA: Oscillations of 1.8 to 2.5 m were recorded. At the lowest ebb, the wreck of the Buffalo was exposed for about 20 minutes and attempts were made to salvage it. The returning surge damaged opposite Whitianga and swept 11 boats from their moorings. There were retrieved with some difficulty. At the peak, the waterfront road was under water and the airport and two or three houses were flooded."*

The Bell et al. (2004) account is a bit more detailed:

> *"11 boats were also swept away, but they were recovered. (Fraser database 1998). Worst hit in BOP and eastern Coromandel with repeated surges of up to 7 ft (2.1 m) (am May 24) Some launches alternately stranded and riding high at moorings, others broke away but were recovered. (Bay of Plenty Times May 24 1960) On May 24, boats broken away from moorings. No major damage, although rise was 6-8 ft above normal and 2 to 3 houses on beachfront were flooded. (Bay of Plenty Times May 25 1960) 11 small craft swept out to sea, gardens and airport hangar flooded, fish left floundering on shore road. Sea surged up river, swept over road and into foreshore gardens. The aerodrome was flooded and 3 aircraft moved to safety when water reached over the wheels. 11 small craft swept up river or out to sea rescued. Estimated that river ran out at 25 knots, a tugboat at full steam ahead went backwards. (Auckland Star May 24 1960) Sea swept over road, flooding foreshore gardens. Aerodrome flooded, water over wheels of aircraft in hangar. Later aircraft located 11 small boats swept out to sea, or up the river. Water running out of river at estimated 25 knots early a.m. May 24. (Evening Post May 24 1960) Surge reached several feet above high water at about 2100 (May 23). Boats broke adrift, were swept out or capsized. Resident described water a rapidly swirling river. Some boats recovered. Tide full at 17.55 (May 23) and the sound of surge against the tide could be heard [section of report missing, rest abandoned until rest of report obtained] (NZ Herald May 24 1960) Vessel hit bottom at Whitianga Wharf am May 24. Water surged up and down at 20-minute intervals. Buffalo wreck exposed. (NZ Herald May 25 1960)."*

While these accounts are important and useful for understanding the 1960 event, they are problematic for a few reasons. Firstly, in the first account the description of the wreck of the Buffalo being exposed, it is not mentioned that this occurred on 24 May, more than 12 hours after tsunami arrival. Also, the first account simply states that 'the airport was flooded'; for a contemporary reader, this would raise alarm given the present location of the Whitianga airport, however, in 1960, the 'aerodrome' as it was called was located very close to the shoreline along Buffalo Beach. While the second description mentions the aerodrome, it is not clarified where it was located at the time.

5.2 Eyewitness accounts

5.2.1 Historical

Howard Pascoe and Bruce Smith written accounts

Eyewitness accounts of the effects of the 1960 Chile tsunami in Whitianga were reproduced by Bell et al. (2004) who sourced a testimonial by H.W. Pasco and others from the New Zealand Nautical Almanac. An additional eyewitness account (Mr. Bruce Smith) was also provided for this study by staff at the Waikato Regional Council (Dr. Vernon Pickett, pers. comm.). These testimonies provide some insight in to the character of the tsunami inundation overnight from May 23 to May 24, 1960.

In his account of the event, Mr. Smith states that he first observed the tsunami effects around 9:30 pm on 23 May. At that time he stated that ***'the tide came in and out at a fast rate'***. After this initial observation, another vessel took Mr Smith out to his boat which was moored in the harbour. He noted multiple surges over the next hour as he worked to pump water out of the boat which was leaking due to damage sustained during the first hours of the tsunami. Around midnight he made the decision to beach the vessel if it broke free from its mooring. At 2:30 am, a strong incoming surge did just that, as it pushed the nose of his vessel underwater until the mooring line gave way. He momentarily lost control of his boat and was nearly thrown overboard, however he regained control and managed to beach the vessel on a town street ***'approximately 50 m from the Whitianga Pub's front door'***. This location was described in the Pascoe account as being ***'on to the road on the wharf side of Karena Creek'***.

The best description of the inundation comes from the Pascoe account which states that ***'the sea came up Monk Street to where the Power Station was and up to the Dairy Company front office steps'***, he also noted that there was inundation ***'into the old aerodrome hangar along the northern end of Buffalo Beach, where it wet crates of corrugated iron stored on the floor damaging them'***. Pascoe's account also gives some indication of the current speed when he states that a vessel he was handling was ***'doing 12 knots and going backwards'*** due to an incoming surge. He adds that they continued to move backwards for ***'20 minutes until the tide turned and swept us out through the entrance to safety'***. He also notes that ***'about 2 am on Tuesday morning […] seemed to be the worst time'***. The Pascoe account also describes the weather as ***'very fine'*** with ***'practically no wind or swell outside in the Bay'***.

The full text of both Howard Pascoe's and Bruce Smith's accounts are provided as Appendix 1 and Appendix 2 respectively.

Iain Lennox

The following written account of the effects of the 1960 Chilean tsunami is sourced from Te Ara Encyclopaedia of New Zealand[1]:

> *This ship, HMS Buffalo, was wrecked on the main beach at Whitianga, Coromandel, in July 1840. The wreck gave its name to Buffalo Beach but was largely forgotten – until May 1960. Iain Lennox, who was living there, recalls what happened when the tsunami arrived.*
>
> *What's your story?*
>
> *Contributed by Iain Lennox of Te Awamutu.*
>
> *I'd just got my old Vauxhall Velox ready for a local spray painter when the news came advising folk to prepare for a tsunami. In particular, to head for the hills. So – off came the paper I'd taped to the car windows, and off we went to the hills close by.*
>
> *When the time for the arrival of the tsunami had passed, we headed back into the village. We found that there hadn't been any big wave, but (and this was still happening), there were several extra high and low tides with only a short time in between them. The main beach at Whitianga is named Buffalo Beach, after a boat that was wrecked there. The tsunami effect exposed the remains of the wreck for the brief time of each low tide. So the wreck became of great interest to the locals.*
>
> *Also, the narrow gap where the ferry crossed the estuary opening from the wharf to Cooks Beach would normally have quite a flow with an ebbing tide (some 5–7 knots), but during this time it was almost like a cataract of water.*
>
> *In those days, with the tight import controls it was well nigh impossible for most Kiwis to buy a car, so it was quite a moving thing to see in a local's garage, a brand new Ford Consul. The water had come up as high as the window – the owner had not heeded the tsunami warning.*

Don Ross interview for Radio New Zealand

A radio interview on the impacts of the 1960 Chilean tsunami at Whitianga was recorded with former Whitianga Harbourmaster Don Ross in 1993. The audio recording is part of the Radio New Zealand "*When the siren goes*" collection – a six-part documentary series exploring a range of themes about disaster awareness.

In the interview, Mr. Ross describes many of the impacts of the rapid rise and fall of water similar to other witnesses. He states that when the water receded, it reduced the flow within the "river" (harbour) to the size of a small stream that you could almost walk across.

Of particular relevance to establishing the extent of inundation, he mentions the following points:

- That seaweed was washed into his back yard as a result of the tsunami
- That along Buffalo Beach Road, one resident alerted their neighbour to the fact that their goat was swimming around the pole it was tied to in the back yard
- That in some areas along Buffalo Beach road, the tsunami deposited fish (including sharks) and seaweed on the lawns.

The full sound recording is available from the Radio NZ sound archives, at:

[1] Refer to http://www.teara.govt.nz/en/tsunamis/5/3.

http://www.radionz.co.nz/collections/all-audio/audio/2538566/a-tsunami-in-whitianga-in-1960

5.2.2 Accounts from recent interviews

Overview

During initial development of the recent WRC Technical Report (2013/24) on tsunami inundation modelling in Whitianga and Tairua/Pauanui, the importance of verifying the model based on eyewitness reports and "ground-truthing" of the effects of the 1960 Chilean tsunami was recognised. An initial identification of eyewitness verification work required was developed by Dr. Jose Borrero in August 2012. Advice on eyewitness contacts was sought from TCDC staff in the Whitianga office.

In September 2012, Brendan Morris contacted Merv George, who recommended a number of local witnesses as potential interviewees. Following initial conversations with seven eyewitnesses, four eyewitnesses agreed to meet with Brendan Morris and Dr. Vernon Pickett to discuss and verify the extent of inundation – Walter Russell, Robin Lee, Ted Ramsbotham and Toby Morcom.

A brief conversation about inundation extent was held with Roly Chaney, who was working to help sandbag Albert Street on the night of the event to prevent flooding of houses. He stated that ankle-deep water got to at least #6 Albert Street – he was clearing a manhole cover there that kept filling with debris. He also stated that water crossed the road into Albert Street and Mill Road, and flooded basements of houses in that area.

Merv George and Mitch Pascoe (son of Howard Pascoe) both offered to assist as required, but noted that the other eyewitnesses would likely provide a more accurate account of events, since both Merv and Mitch were young children at the time.

Interviews with Walter Russell, Robin Lee, Ted Ramsbotham and Toby Morcom were held onsite on 19 November 2012, and detailed descriptions, maps and photos are provided below.

5.2.2.1 Interview #1: Robin Lee and Walter Russell – interview and mapping of inundation (Photos 1 and 2)

Robin Lee was first notified of the tsunami around 9pm. Robin was at home in Owen Street at this time. The engine of the "Three Kings" launch was revving loudly just after 9pm, and that alerted him. Robin describes the water as ripping in and out of the harbour.

Robin recalls that water reached the grass at the foot of Owen Street. It's now called Sleeman's Park. Normally that grass area did not go under water, and that night, "*it was well under*".

Howard Pascoe and Robin were looking after a launch at the time, and jumped into a dinghy and went out to the launch just after 9pm. At this time, the water was running into the harbour. The launch engine was around 160hp, and with full throttle into the current, they were unable to loosen the mooring rope to get it off the bollard, and had to wait until the tide turned.

Robin remembers that the vessel could do about 10 knots at full speed. The boat was freed once the tide turned, but the vessel was unable to head out of the harbour upon the arrival of another wave. Robin estimates that at full speed into the current, they were "*doing about 10 knots backwards*" against the current, and being washed back into the harbour.

Robin went down to the wharf, and noticed that during receding tides, the wharf piles were vibrating. Robin observed that the water worked like a pump – more water came in than was able to flow out, so that in the top of the harbour, water levels did not change much, with tides getting higher and higher over a period of 2-3 days.

Walter and Robin confirmed the locations of both the houses mentioned in Howard Pascoe's account – Mr. Merv George's and Mr. Don Ross'. They stated that both houses lie in a natural hollow – a swale in the dune ridge/swale system that underlies Whitianga. Water flowed between the sections where the garages were, as the garages were in the lowest lying parts of the properties. The swale goes right through town, past what was at that time the hospital in the middle of Buffalo Beach (now the site of the Whitianga Continuing Care rest home), and out as far as the Taputapuatea Stream (also known as Mother Brown's Creek) at the north end of Buffalo Beach. Walter confirms that this area was a natural swamp. The flow of water onto Don Ross's section was confirmed by Don Ross in his 1993 radio interview (refer to earlier section).

The archived report of Iain Lennox was discussed – that a neighbour's car was inundated up to the windows. Walter suggested that this report may have been referring to a car left in a garage behind Roly Smith's house, which was located on the foreshore at the corner of the Esplanade and Mill Road. Walter stated that there used to be a number of baches and garages behind this house, and that the area was very low-lying. Even today, the buildings in this area are approximately 1 metre below the road. This area has been subject to storm surge flooding since the tsunami event.

Jack Crawford's houses were also low-lying – and again, part of the same swale system. The swale turned into a swamp on the other side of Albert Street during rainfall events – as kids, they used to play in the swamp on rafts. The site of Jack Crawford's house is now a motel, and they have recently installed large sump holes to try and deal with day-to-day drainage issues.

Photo 1: The late Dr. Vernon Pickett (left) discusses inundation extent with Robin Lee (centre) and Walter Russell (bottom right).

Photo 2: The locations of inundation were discussed and mapped using both historical and contemporary photographs.

Photo 3: The levels of inundation in the town and locations of landmarks identified by Robin Lee and Walter Russell were mapped on this 1955 historical oblique photograph.

Bruce Packer's house was identified on Buffalo Beach Road. There were reports of a flounder being found on his deck due to the tsunami. Walter indicated that the foundations on Bruce Packer's house were very low to the ground. The site is now occupied by the Admiralty Lodge Motel.

Walter did not recall water flowing up Mill Road from the foreshore during the tsunami, but he has seen flows going up Mill Road as a result of storm surges.

The location of where the launch "Marlin" ended up after it was driven ashore was confirmed. The final resting place of the boat was slightly above the high tide line.

Robin and Walter confirmed that water inundated baches along Buffalo Beach Road near Taputapuatea Stream, and that at times, storm surges have reached these areas as well. The location of the wreck of the Buffalo was described as being around 125 m offshore from the old hospital building. Walter recalls the wreck being a hazard when surfing in Buffalo Bay, and Robin described the depth of the wreck being around 1 m deep at low tide.

The following day, surges came and went about every 20-30 minutes, and carried on for about 3 days. The Buffalo was uncovered during the first day, but Walter is not sure about the other days. The tide would rise almost to the level of the old wharf, but never came over it. Within 20 minutes, you could walk around it.

An overview of inundation sites identified is provided in Maps 1 and 2

5.2.2.2 Interview #2: Site inspection of Mill Street and Monk Street with Walter Russell

During this brief onsite interview, Walter Russell pointed out the following:

- The low-lying nature and flat gradient of Monk Street from the Mill Street intersection sloping gently towards the harbour
- The low-lying areas on the eastern side of Don Ross' section, and the connection of this low-lying area to the adjacent property on the Esplanade – the former residence of Merv George
- The low-lying area on the corner of the Esplanade and Mill Road near the foreshore (Roly Smith's house).

Walter was at the hotel on the evening of the tsunami, which was located at the edge of the harbour on the corner of Victoria Street and Blacksmith Lane. In the back of the hotel is a house which the owner lived in, and Walter noted that the water came up onto the front steps of the hotel (the steps being on the harbour side of the building).

With reference to Monk Street, Walter stated that the water reached the power station (which was situated at what is now 3 Monk Street), and that being the case, was likely to have reached the hall as well – probably via the gutters. Monk Street has a fairly low elevation (Photo 5).

Map 1: Recent aerial photograph of Whitianga showing tsunami inundation landmarks along Buffalo Beach identified by Robin Lee and Walter Russell.

Map 2:Recent aerial photograph of Whitianga town showing tsunami inundation landmarks identified by Robin Lee and Walter Russell.

The location of the old aircraft hangar was confirmed. The hangar site was located just above stream level, and was subject to occasional stream flooding.

Walter confirmed that from talking to Merv George, the water reached the steps on his house, but did not flow into the house. Walter estimates the depth to be around 20-30 cm. He also noted that the water likely flowed through to Don Ross' section as well, since this section is the continuation of the swale beyond Merv George's house (Photo 4).

Photo 4: The low-lying area (swale) on the eastern side of #6 Mill Street (Don Ross' house).

Photo 5: Looking down Mill Road towards the Esplanade from the corner of Mill Road and Monk Street.

5.2.2.3 Interview #3: On-water inspection of the sites of significance around Whitianga Harbour with Walter Russell

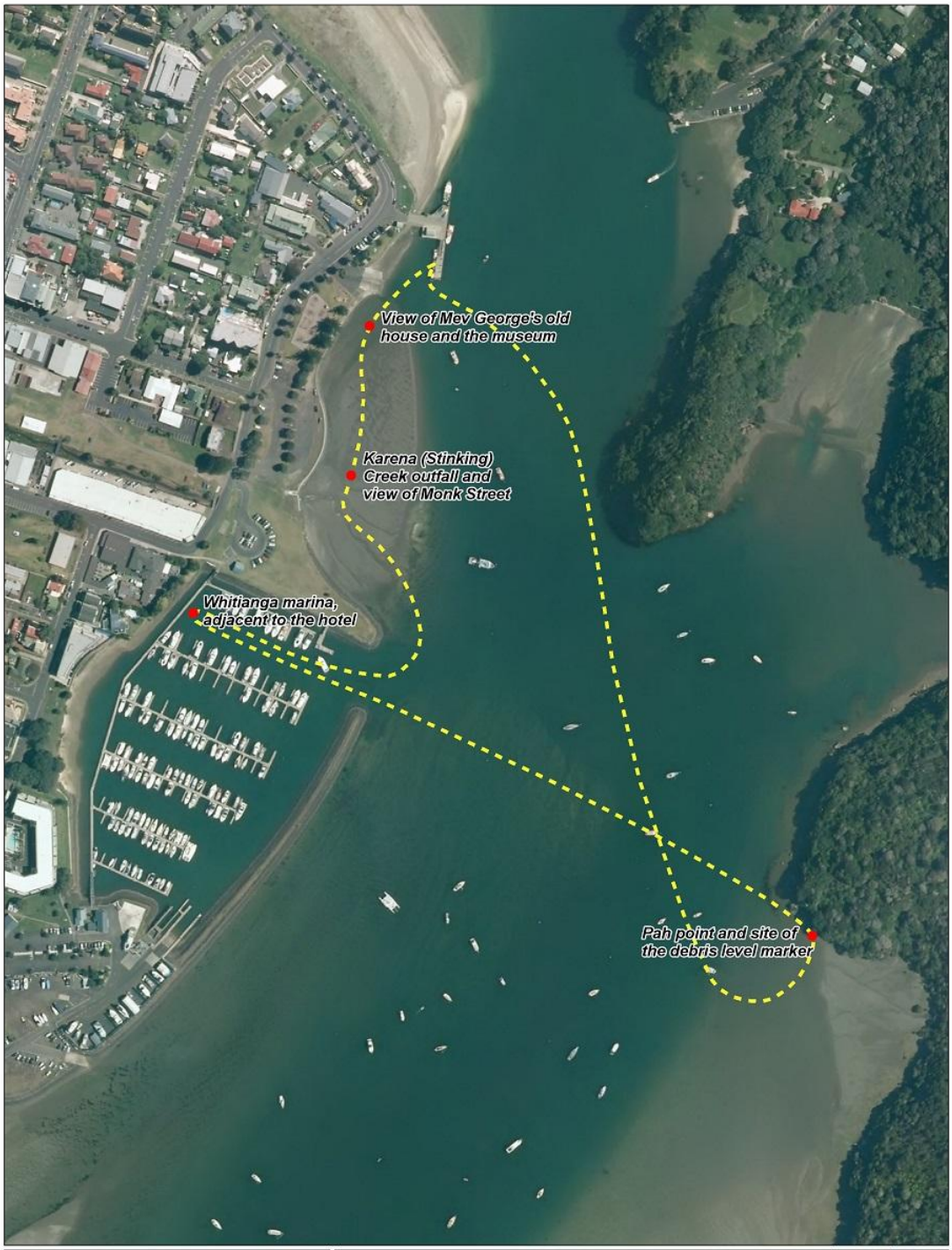
A brief on-water inspection of sites of significance in the Whitianga harbour was undertaken, as shown in Map 3 below.

Marker peg at Pah Point (Photos 6 and 7)
Howard Pascoe's account of the tsunami states that "***Robin Lee and I carved a mark in the sandstone cliff where the dust was washed off and a distinct line could be seen along the cliff some 4ft. above the highest spring tide***".

Walter explained that the marker peg was driven into the cliff a few days after the event at the high tide level – on the other side of the harbour. The original peg is suffering wear and tear, but is still intact. There are signs of cliff erosion around the peg. The level of the peg is roughly 1m above the high tide mark.

Following inspection of the peg, Walter gave an explanation of the level of inundation at the hotel. The original floor level of the hotel has not changed since the event.

Observation of the hotel from the marina indicated that projection of a similar water level to that indicated by the peg across the harbour would approximate inundation up to just below the hotel floor level – or inundation of the steps in front of the hotel as reported (Photo 8).



Map 3: Route of harbour inspection with Walter Russell.

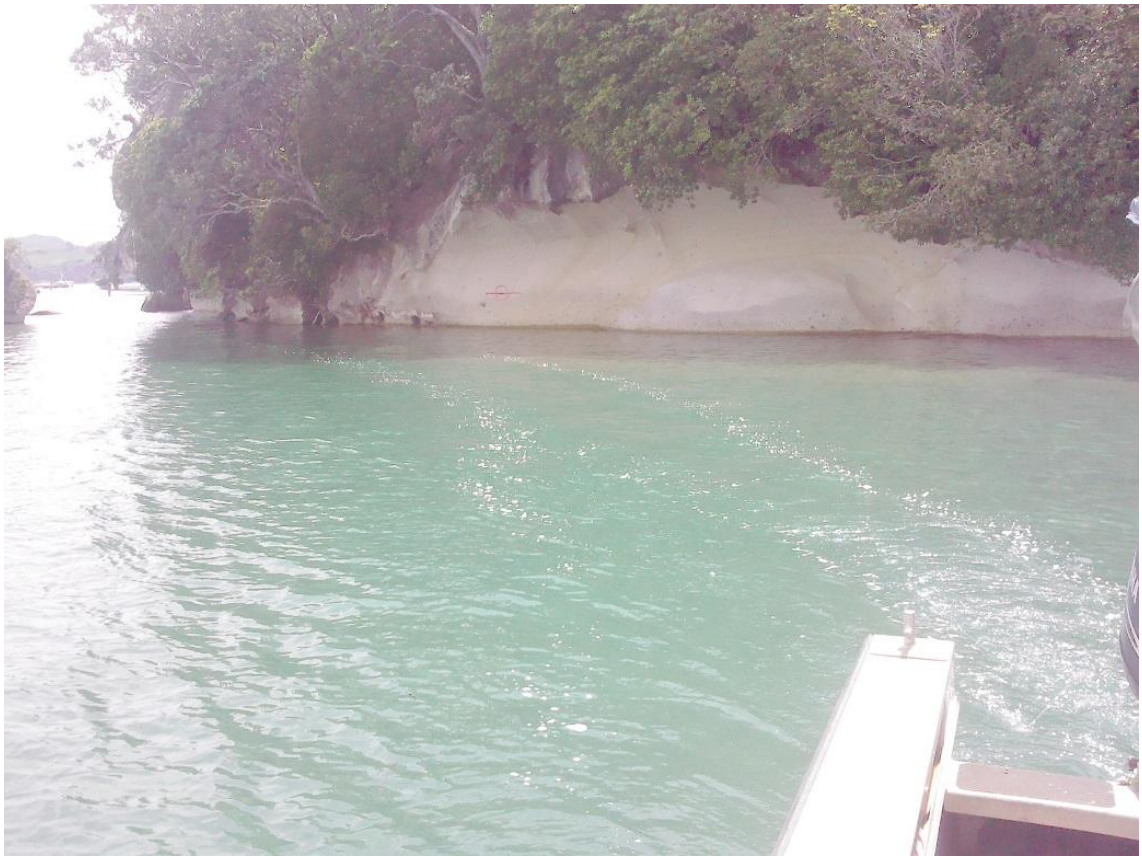


Photo 6: Looking towards the marker peg site showing maximum inundation level at Pah Point.

Photo 7: Walter Russell showing the site of the maximum inundation level at Pah Point. The original marker peg is in the middle of the circle.

Photo 8: The Whitianga Hotel taken from the marina, showing the approximate level of inundation as described by eyewitnesses (level of the original steps).

Photo 9: Looking north up Monk Street from the harbour.

An inspection of the area in front of Monk Street was made from the harbour (Photo 9). On-water observation suggests that a water level that inundated the hotel steps would

likely have flowed up Monk Street, since the foreshore at the end of Monk Street seems to be at a lower level than where the steps would have been. On-water observation of the site where Merv George's house was located indicates that inundation from the harbour almost certainly would have occurred.

Interview #4: Driving along the Esplanade and Buffalo Beach Road with Walter Russell

As previously mentioned, Walter is unclear whether there was overtopping of water into Mill Road from the sea, but has seen water overtopping the dunes and flowing down Mill Road towards Monk Street during storm surge events since the tsunami. Since Mill Road slopes away from Buffalo Bay, water that overtops from the ocean drains down the gutters in Mill Road and out through Monk Street towards the harbour. The water that does overtop the dunes has a tendency to pond, due to the fact that the drainage is into sand – the water cannot get away (Photo 10).

Photo 10: House at the corner of Mill Street and the Esplanade – a low-lying area subject to ponding and storm surge.

It is common to get 500 mm of water ponding behind the Esplanade – one example being at the Anchorage Motel, 22/23 The Esplanade. The Esplanade (then Buffalo Beach Road) rises as you move north along towards Eyre Street, with the gradient of Eyre Street falling inland away from Buffalo Beach Road. Walter pointed out the low-lying swamp area that is now covered by Oceans Resort Whitianga, and continues north towards the old hospital and Whitianga Continuing Care. The swamp was known to him as Mrs Eyre's swamp – the original owner of the farm in this area.

Driving north from Whitianga Continuing Care down Buffalo Beach Road, there is a pronounced fall in Buffalo Beach Road down towards the Taputapuatea Stream. At Jackman Road, there are two large stormwater pumps to deal with issues that arise from poor drainage.

Walter stated that further down Buffalo Beach Road, the water reached what is now Admiralty Lodge – adjacent the mouth of the Taputapuatea Stream on Buffalo Beach Road.

The location of the old aircraft hangar was confirmed – it was situated just above stream level in front of the houses that have been built there. The level of the hangar floor was confirmed as being similar to the small stream access road that runs to the stream, adjacent to Buffalo Beach Road by the bridge (Photo 11).

Photo 11: Site of the old aircraft hangar adjacent to Taputapuatea Stream on Buffalo Beach Road, showing the stream access road.

Interview #5: Ted Ramsbotham, outside the town hall on Monk Street

Ted's father was playing badminton in the town hall that evening. One of the players observed that water had flowed up to the hall door (Photo 12), so they followed the water down to the wharf. Ted states that people then walked around the wharf once the tide went out, and followed the water back up Monk Street.

On the second occasion, the water reached the Fire Station door, which was located next to the hall (slightly less inundation). The water then receded again, but this time people were unable to walk around the wharf, due to the erosion of sand and consequent water depth.

Photo 12: View from the north-east corner of Mill Road and Monk Street looking towards the old Volunteer Fire Brigade Building and town hall.

Photo 13: View from the north-east corner of Mill Road and Monk Street looking south along Monk Street towards the harbour.

The barge that had come down from Auckland that night to do channel maintenance in the harbour remained offshore in Buffalo Bay, and returned to Auckland the following day. The barge was unable to enter the harbour. Moorings were left exposed by the tsunami – some of which had not been seen for 30-40 years.

Bruce Smith drove the Marlin onshore near Karena (Stinking) Creek in order to get the boat out of danger.

Photo 14: View of the harbour from the wharf taken on the morning of 24 May 1960. On the upper right, the Marlin is seen resting ashore near Karena Creek and the hotel (photo courtesy Ted Ramsbotham).

Ted describes the movement of water in and out of the harbour by its impacts at the wharf. The water went flat half way up the wharf piles on the change of tide. The water flowed quickly upstream until the water was coming up through the floorboards on the wharf, then began to flow quickly out. There was a lag between the flow of water and the height of water on the piles, with the water level rising on the piles even as the water began to flow out of the harbour. Once in full flow out of the harbour, the water level dropped to half way along the wharf piles before dropping quickly to the bottom of the piles, and then returning to the half-way point as water began to flow in.

The water was flowing so fast that the wharf piles were shaking, and the noise of shells against the piles was deafening.

Ted describes the scene in the morning as "*rubbish everywhere in Buffalo Bay*". There were numerous logs in Buffalo Bay. The tide rose and fell every 20 minutes for two days. It took about a month before the tides came right. Fortunately, the sea was calm.

Ted stated that water overflowed into Albert Street across Buffalo Beach Road - much like an overflowing hand basin.

In the northern beach area, the water flowed through the camping ground, into Ohuka Creek (adjacent to Ohuka Beach to the north of Taputapuatea Stream), and then back into Buffalo Bay.

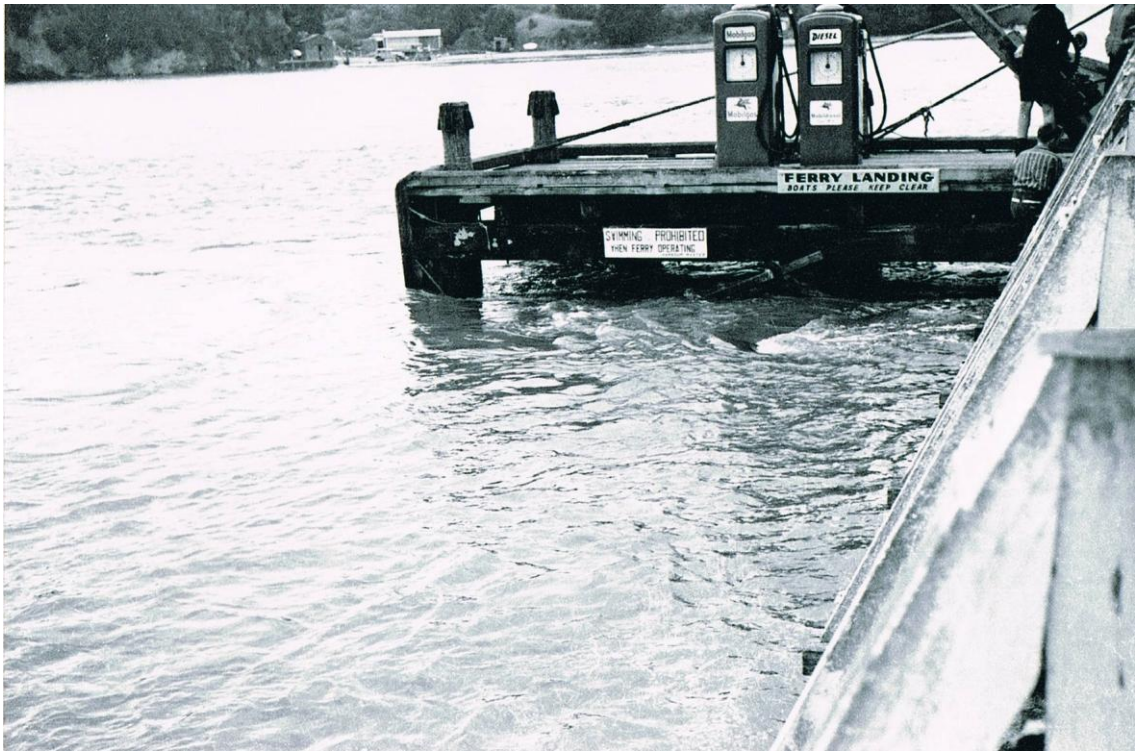


Photo 15: View of the wharf at the top of the tidal range taken on the morning of May 24 1960 (photo courtesy Ted Ramsbotham).

Photo 16: View of the wharf at the bottom of the tidal range taken on the morning of May 24 1960 (photo courtesy Ted Ramsbotham).

Ted noted that when the properties around the lower end of Taputapuatea Stream were originally surveyed, that the survey pegs used to go underwater in some storm surge events. He noted that one property developer had to re-survey and mark the sections following one such storm surge event.

Ted confirmed the inundation of the airstrip hangar.

Interview #6: Toby Morcom, outside the town hall on Monk Street

Toby was playing badminton at the hall that evening, and got word from one of the players that unusual events were happening at the wharf. He went down to the wharf to observe, and noticed that the tide was rising and falling about every 20 minutes. The tide was going out faster and falling lower than any neap or spring low tide – at least one metre lower. At high tide, it was at least a metre higher than the highest tides. When Toby left the wharf around 11.00 pm, the surging incoming tide was almost overtopping the wharf where the two bollards are shown in Photo 15, and the spray was flying over the top of the fuel pumps, while the whole wharf was shuddering.

Toby reported that he had left his car parked at Ferry landing (visible in the background of Photo 15) the previous night. He went across the harbour to check on his car on the morning of 24 May, and found that the water level had inundated the vehicle to a depth of at least a metre – the tide mark being on the middle of the back seats of the vehicle, or about 50 mm below the bottom of the car windows. Toby estimates that this level was around 1.5m higher than the highest tide levels at Ferry Landing.

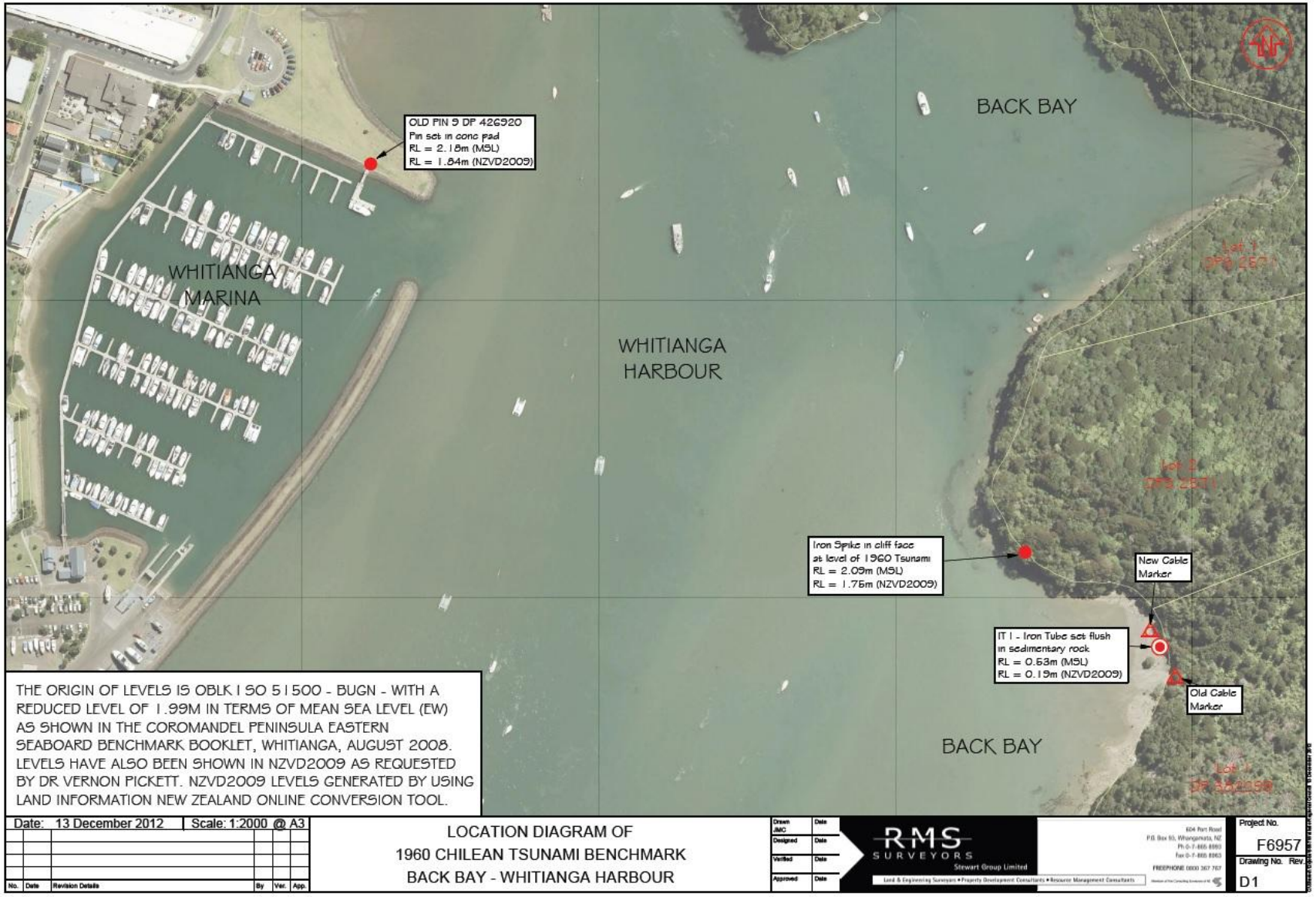
Once the car was dealt with, he had the problem of tending to his launch – a 25 foot vessel. The vessel was tied to a mooring just off Ferry Landing, and had dragged its mooring up as far as Quarry Point. Toby reports being stuck in the dingy on the way to retrieve the vessel due to rapidly falling tides, and gathering a dozen good-sized Snapper that were flapping around in the mud against the telephone cable. He raised the vessel mooring, and attempted to get out of the harbour on the outgoing tide, but was unable to do so as the water came back into the harbour, and the boat at full speed was unable to make way against the incoming current. He dropped the mooring approximately 300 m past the wharf, and waited until the water receded again, before proceeding out of the harbour around cemetery point, and into Flaxmill Bay.

Toby stated that the water overtopped the foreshore at the end of Mill Road. After overtopping, the water ran down Mill Road towards Monk Street. He recalls that the volumes of water were small coming down Mill Road – about 300 mm deep in some places. Toby was unable to say how fast the water was flowing – he could only see where the water had been. He observed that the water appeared to move down Mill Road into Monk Street, and then flowed back towards the harbour. He did not observe whether the water had reached either the fire station or the hall. He confirmed that there is a natural low lying area near the foreshore on the corner of Mill Road and the Esplanade, and he would not be surprised if water flowed from the foreshore into this area.

5.3 Survey of post-tsunami debris line inundation level

5.3.1 Overview

In November 2012, Waikato Regional Council requested a survey to determine the level of the spike placed in the cliff at Pah Point, and relate this to Waikato Regional Council level datum within Whitianga town. The request was for the survey to meet a standard of +/- 0.01 m vertically (or better if possible) and +/- 0.02 m horizontally, with heights reduced to both Moturiki Vertical Datum 1953 and NZ Vertical Datum 2009, and horizontal coordinates to be provided in terms of both NZMG and NZTM. The survey of the marker peg at Pah Point was completed in December 2012 by RMS Surveyors (Map 4).



Map 4: Survey Photo Plan.

5.3.2 Survey results

Map 4 shows that the inundation level reached at Pah Point in 1960 was 2.09 m above MSL.

Map 4 shows a photo plan of the location of the iron spike and reduced levels in terms of MSL and NZ Vertical Datum 2009. Waikato Regional Council Datum and Auckland Vertical Datum are the same, with Datum 0 at MSL.

5.3.3 Survey interpretation

To better illustrate the potential extents of the 1960 tsunami if it were to occur today, we plotted the 2.09 m water level onto Waikato Regional Council's Digital Elevation Model of Whitianga. The results shown in Map 5 illustrate what areas of the town could potentially be affected if a similar tsunami event were to occur today.

It is important to note that Map 5 is not a reconstruction of the 1960 inundation extents, but is rather a representation of the maximum water level attained in the Whitianga area in 1960 superimposed on contemporary topography. This figure uses a 'bath tub' approach, i.e. simply marking as 'inundated' any areas that lie below 2.09 m that are hydraulically connected to the sea. Therefore this map likely over estimates the potential inundation from a real event, since the landward incursion of flood waters would be reduced by friction and turbulence in real tsunami flows.

The following observations can be made about the inundation in Map 5 in relation to the eyewitness reports:

Northern end of Buffalo Beach

- Supports eyewitness reports of flooding of the aircraft hangar at Taputapuatea Stream and inundation of properties along Buffalo Beach Road
- Suggests that flooding of properties along Buffalo Beach Road was due to direct inundation in the location of the stream, and potentially due to back flow to the south parallel to the shore
- Supports reports of seaweed and fish being found on properties on Buffalo Beach Road and a goat swimming in the back yard of one of the properties.

Mill Road/Monk Street area

Supports reports of eyewitness inundation reports in the following areas:

- Mill Road along the entire length
- Monk Street up to at least the old power station and the Town Hall
- Through the low area (swale) located around 6 Mill Road (Don Ross' house) - including through onto Merv George's property, and reports of seaweed being found in the yard of 6 Mill Road
- Inundation up to the front steps of the Dairy Company office (now museum) on the harbour
- The low areas (swales) behind the Esplanade - including the Esplanade end of Mill Road
- Inundation up to about 6 Albert Street, but not beyond this point, and no flow of water from Albert Street around into Monk Street

Marina area

- Inundation up to the steps of the Hotel and to the end of Owen Street.

Map 5: Inundation area for uniform water level rise of 2.09m – equivalent to the level measured at Pah Point in 1960.

5.4 Whitianga town inundation modelling

Bell et al., (2004), Roulston et al., (2007) and Prasetya et al. (2008) presented numerical model results of tsunami hydrodynamics in Whitianga and the greater Coromandel Peninsula region. The Bell et al. (2004) study did not provide any detailed results for specific coastal communities, but rather focussed on the overall amplification of highly idealised tsunami waves affecting the area. They used a sinusoidal boundary condition as input to a coarse model grid covering the entire Bay of Plenty from East Cape to Great Barrier Island and showed that Mercury Bay is susceptible to resonance for incident waves with a 75-minute period.

The Roulston et al. (2007) (unpublished draft) report conducted some detailed inundation modelling for a generic 'South American Tsunami' source, but not for the 1960 tsunami specifically. Their results predicted small scale inundation for this scenario along the Buffalo Beach foreshore with some strong current speed modelled for the entrance to Whitianga Harbour. The effects are smaller, but of a similar scale to what were reported from the 1960 event in Whitianga.

The Prasetya et al. (2008) study used more detailed bathymetry and topography grids to explicitly model tsunami inundation in Whitianga. An important result from the Prasetya et al. (2008) study was the recognition of the importance of the source data for developing an accurate terrain model. They described the effect of terrain models derived from ground-striking and non-ground-striking LiDAR source data on tsunami inundation and showed the differences in the resulting inundation patterns. However, the Prasetya et al. (2008) study was deficient in its modelling accuracy relative to the 1960 event in that their results (shown in **Error! Reference source not found.** 12) significantly overstate the inundation that was actually observed.

For this report, we expand on the tsunami inundation modelling conducted by Borrero (2013) as part of the Waikato Regional Council's efforts to produce tsunami hazard and evacuation maps for the region's most tsunami-prone communities located on the Coromandel Peninsula. Among other things, the Borrero (2013) report aimed to revise and update efforts to model the inundation at Whitianga caused by the 1960 tsunami conducted by Prasetya et al. (2008).

The numerical modelling presented in this study was carried out using the Community Model Interface for Tsunamis (ComMIT) numerical modelling tool. The ComMIT model interface was developed by the United States government National Oceanic and Atmospheric Administration's (NOAA) Centre for Tsunami Research (NCTR) following the December 26, 2004 Indian Ocean tsunami as a way to efficiently distribute assessment capabilities amongst tsunami prone countries. The hydrodynamic calculations contained within ComMIT are based on the MOST (Method Of Splitting Tsunami) algorithm developed by Titov and Synolakis (1995, 1998).

The backbone of the ComMIT system is a database of pre-computed deep water propagation results for tsunami generated by unit displacements on fault plane segments (100 x 50 km) positioned along the world's subduction zones. Currently, there are 1,691 pre-computed unit source propagation model runs covering the world's oceans included in the propagation database (Figure 3). Using linear superposition, the deep ocean tsunami propagation results from more complex faulting scenarios can be created by scaling and/or combining the pre-computed propagation results from a number of unit sources (Titov et al., 2012). The resulting trans-oceanic tsunami propagation results are then used as boundary inputs for a series of nested near shore grids covering a coastline of interest (Figure 4). The nested model propagates the tsunami to shore computing wave height, velocity and overland inundation.

The use of the ComMIT tool and the MOST tsunami model is a significant improvement over the previous modelling efforts described above, mostly because it allows for the direct investigation of realistic earthquake tsunami sources and the full solution of

tsunami wave evolution from the source to the study site – a type of modelling that was not done in either of the previous modelling reports.

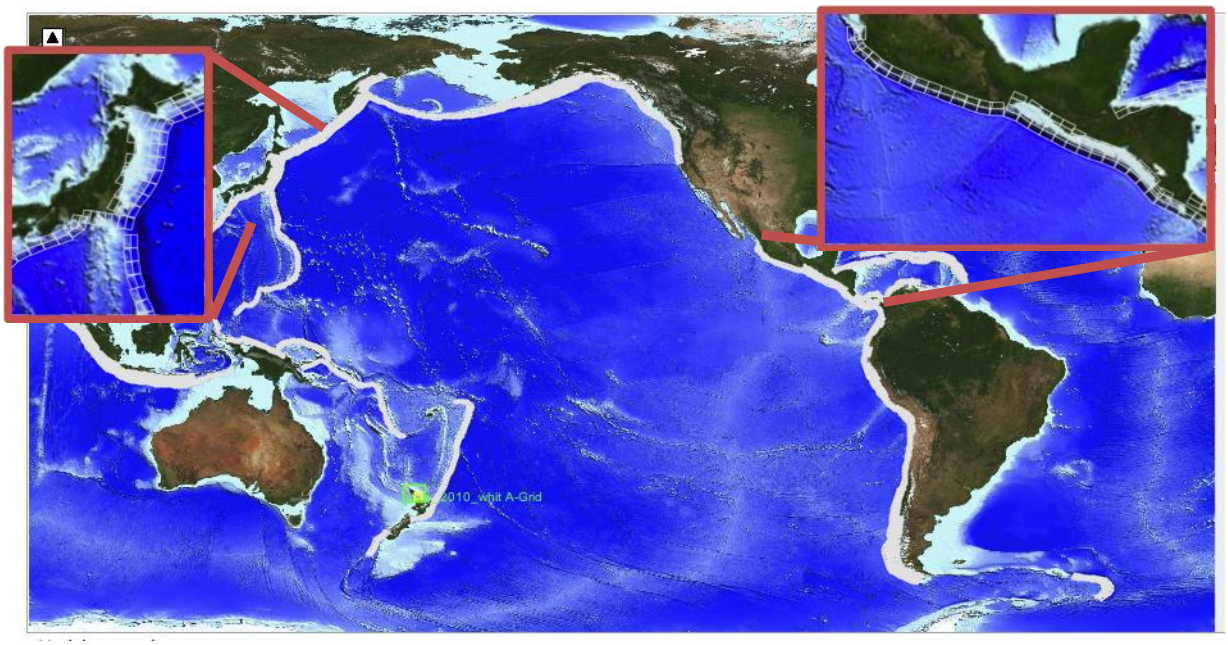


Figure 3: The ComMIT propagation model database for tsunamis in the world's oceans. Insets show the details of the source zone discretization in to rectangular sub-faults.

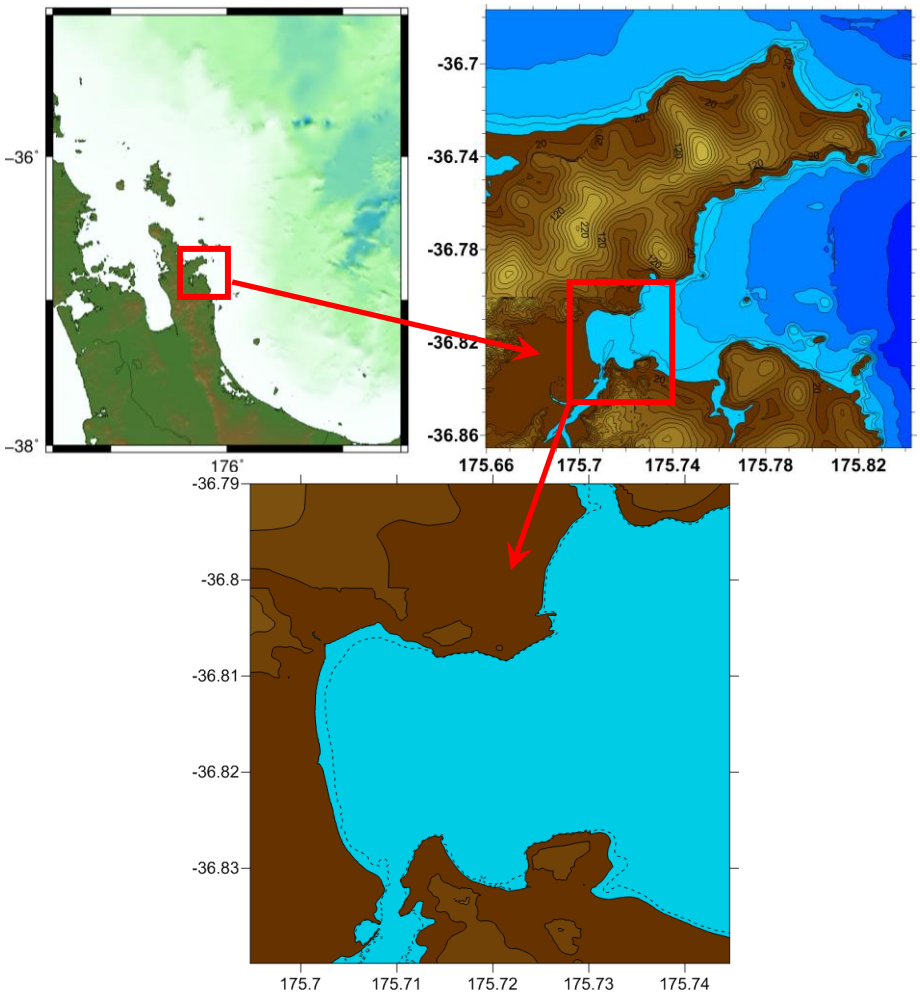


Figure 4: Inshore numerical modelling grids covering Whitianga.

Our model of the 1960 Chile earthquake is based on research recently published by Fujii and Satake (2012) who determined a detailed slip distribution for this earthquake based on the analysis of far-field tide gauge recordings in conjunction with estimates of crustal deformation in the near field. We also looked at similarly sized earthquakes with uniform amounts of co-seismic slip applied over the entire fault plane. The fault segments used in the tsunami source characterization are indicated in Figure 5. In total we trialled six different source models for the 1960 Chile earthquake. The slip amounts applied to each fault segment in each case are listed in Table 1, and the resulting computed sea floor deformations are shown in Figure 6.

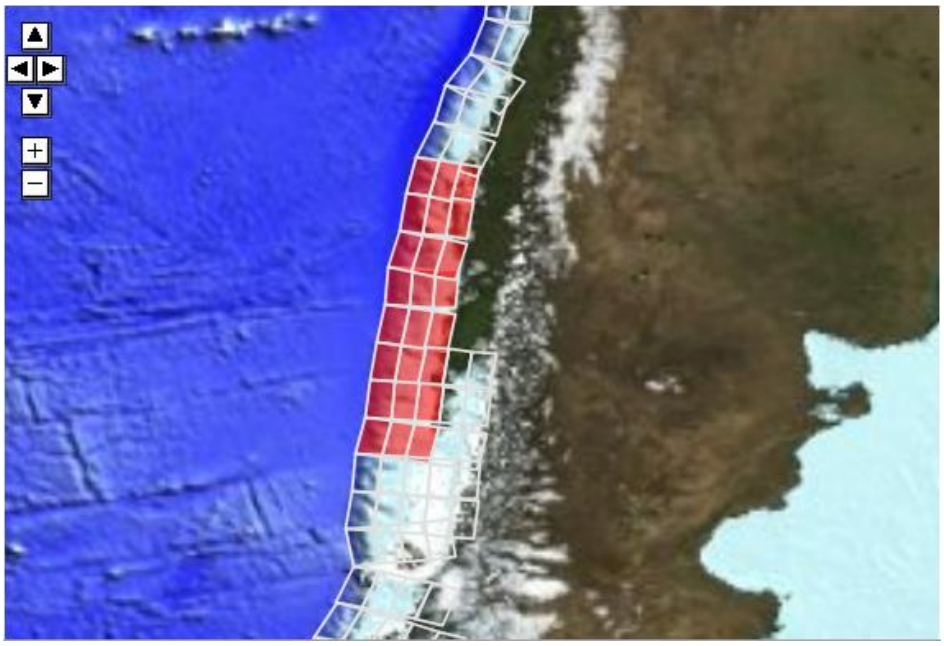


Figure 5: Unit source segments used to define the 1960 Chilean Earthquake suite of events.

Table 1 Slip (in m) applied to each of the 27 sub-faults indicated in Figure 5 for version 1-6 of the 1960 Chilean earthquake.

case 1			**case 2**			**case 3**		
17.5	17.5	17.5	20.8	20.8	20.8	4.2	10.8	1.0
17.5	17.5	17.5	20.8	20.8	20.8	5.5	30.1	17.5
17.5	17.5	17.5	20.8	20.8	20.8	2.3	25.9	9.4
17.5	17.5	17.5	20.8	20.8	20.8	4.1	24.7	9.6
17.5	17.5	17.5	20.8	20.8	20.8	6.5	27.4	5.5
17.5	17.5	17.5	20.8	20.8	20.8	21.4	14.8	5.1
17.5	17.5	17.5	20.8	20.8	20.8	12.8	18.1	4.6
17.5	17.5	17.5	20.8	20.8	20.8	3.1	17.1	2.3
case 4			**case 5**			**case 6**		
5.0	12.9	1.2	2.8	17.8	1.2	3.7	12.9	2.7
6.6	36.1	21.0	4.9	20.5	5.5	7.8	29.6	11.3
2.8	31.1	11.3	5.0	21.7	6.2	25.7	36.1	21.0
4.9	29.6	11.5	6.6	31.1	6.6	15.3	32.9	11.5
7.8	32.9	6.6	15.3	32.9	11.5	6.6	31.1	6.6
25.7	17.8	6.2	25.7	36.1	21.0	5.0	21.7	6.2
15.3	21.7	5.5	7.8	29.6	11.3	4.9	20.5	5.5
3.7	20.5	2.7	3.7	12.9	2.7	2.8	17.8	1.2

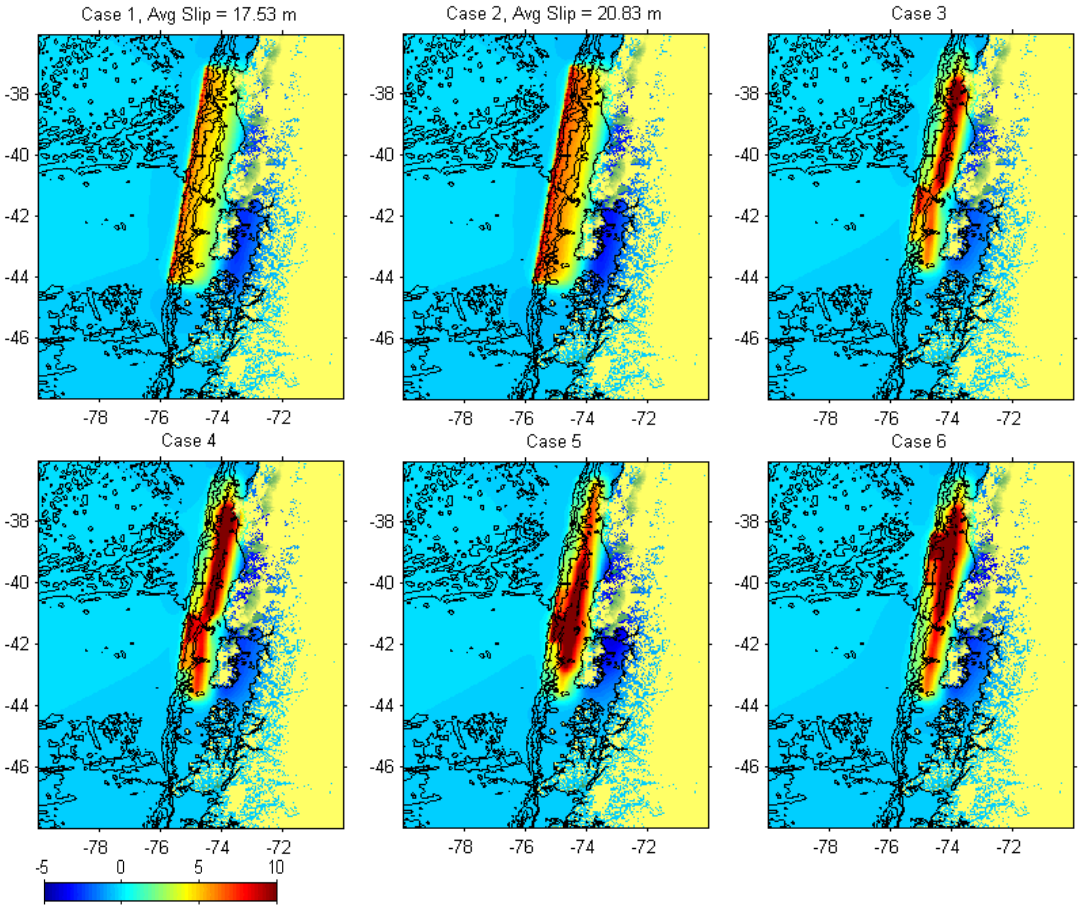


Figure 6: Six representations of the co seismic deformation associated with the 1960 Chilean earthquake. Case 1 – average slip 17.5 m; Case 2 – average slip 20.8 m; Case 3 – Fujii and Satake (2012) source; Case 4 – Fujii and Satake (2012) slip distribution increased by 20%, concentrated to south; Case 6 - Fujii and Satake (2012) slip distribution increased by 20%, concentrated to north.

5.4.1 Comparing Model Results to Eyewitness Accounts

The results from the six different source models at the Whitianga tide gauge are shown in Figures 7 and 8. In Figure 7 we first show the predicted tidal water level that day in relation to the earthquake origin time, the tsunami first arrival and to the timing of the strongest effects as described by eyewitnesses. In the second panel we show the six different simulated water level time series superimposed on one figure. The six individual water level time series are then shown in Figure 8.

Since no instrumental recordings of the tsunami are available for the 1960 tsunami in Whitianga, we must rely on eyewitness accounts to provide some insight into the character of the tsunami surges and to validate our numerical models. Prior to this study, the most widely quoted eyewitness account of the 1960 tsunami in Whitianga was that of H.W. Pascoe and others (reproduced in Bell et al., 2004) who sourced the testimonial from the New Zealand Nautical Almanac. An additional eyewitness account by Mr. Bruce Smith was also available. These accounts are reproduced in full in Appendices 1 and 2.

In his account of the event, Mr. Smith states that he first observed the tsunami effects around 9:30 pm on May 23. At that time he stated that ***'the tide came in and out at a fast rate'***. After this initial observation, another vessel took Mr Smith out to his boat, which was moored in the harbour. He noted multiple surges over the next hour as he worked to pump water out of the boat, which was leaking due to damage sustained during the first hours of the tsunami. Around midnight he made the decision to beach the vessel if it broke free from its mooring. At 2:30 am, a strong incoming surge did just that, as it pushed the nose of his vessel underwater until the mooring line gave way. He

momentarily lost control of his boat and was nearly thrown overboard, however he regained control and managed to beach the vessel on a town street ***'approximately 50 m from the Whitianga Pub's front door'***. This location was described in the Pascoe account as being ***'on to the road on the wharf side of Karena Creek'***.

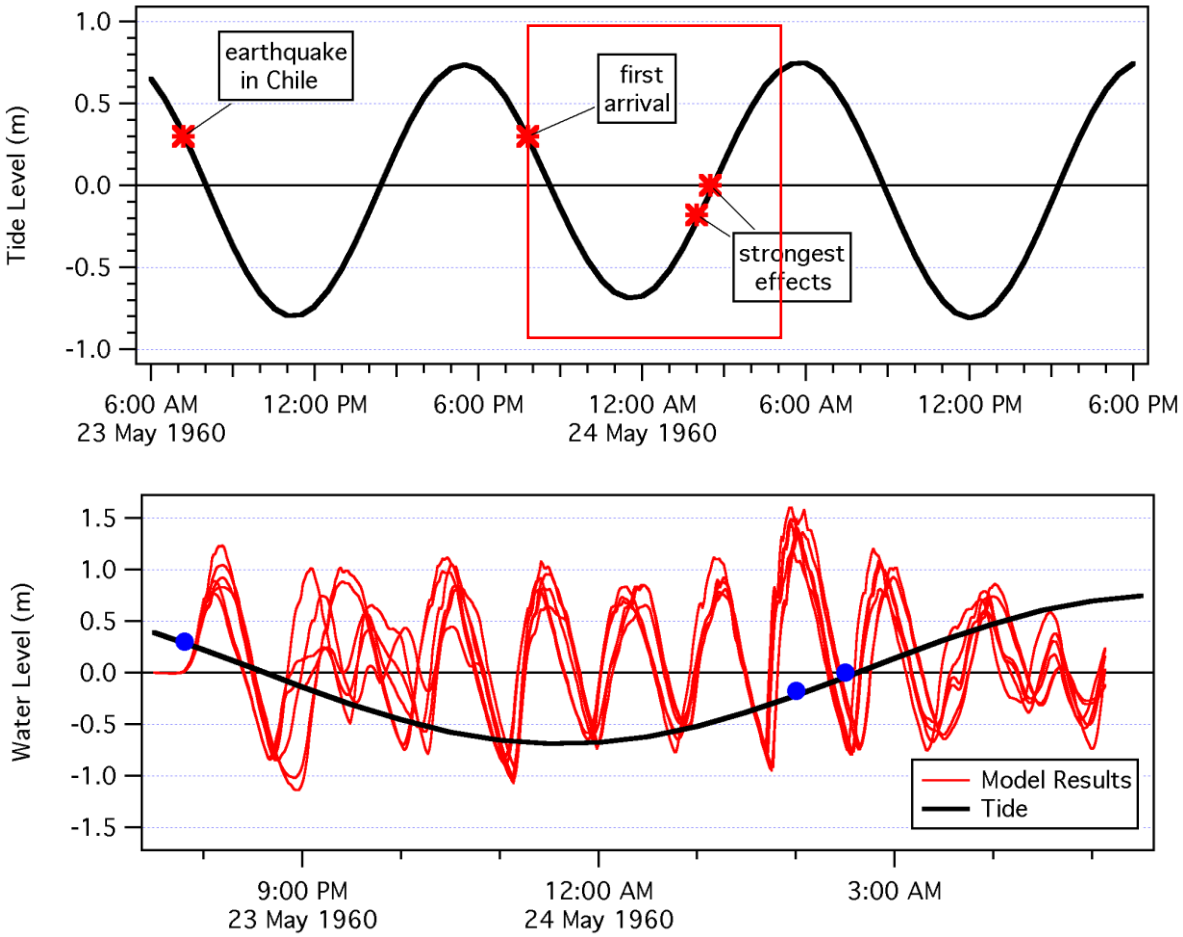


Figure 7: (top) The predicted tide on the day the 1960 Chile tsunami affected Whitianga. Important times are marked and noted. (bottom) Model results (red) for the six source models compared to the predicted tide level. (black) Blue dots indicate the modelled arrival time and the times when the witnesses observed the worst effects.

The best description of the inundation comes from the Pascoe account which states that ***'the sea came up Monk Street to where the Power Station was and up to the Dairy Company front office steps'***, he also noted that there was inundation ***'into the old aerodrome hangar along the northern end of Buffalo Beach, where it wet crates of corrugated iron stored on the floor damaging them'***. Pascoe's account also gives some indication of the current speed when he states that a vessel he was handling was ***'doing 12 knots and going backwards'*** due to an incoming surge. He adds that they continued to move backwards for ***'20 minutes until the tide turned and swept us out through the entrance to safety'***. He also notes that ***'about 2 am on Tuesday morning [...] seemed to be the worst time'***. The Pascoe account also describes the weather as ***'very fine'*** with '***practically no wind or swell outside in the Bay'***.

Mr. Smith's account of multiple surges around 9:30 pm matches most closely with the model results for Case 3 and Case 4 (see Figure 8). We note that Cases 3 and 4 were based on an earthquake slip distribution that had been rigorously constrained by far field tide gauge data and near field geodetic data (Fujii and Satake, 2012) with Case 4 being the same as Case 3, just with slip increased by 20%. The uniform slip source models (Case 1 and 2) produce results, which appear to have more regular oscillations and less apparent higher frequency component. Cases 5 and 6, which concentrated

the slip either to the south or the north of the fault plane, do contain some higher frequency signals, however, neither one has this high frequency feature around 9 pm as noted by Mr. Smith. We also note that the model results are consistent with the observation by the two witnesses that the largest and strongest surges happened around 2 am on May 24. This effect can be seen in the results from all of the source models (Figure 7 and Figure 8).

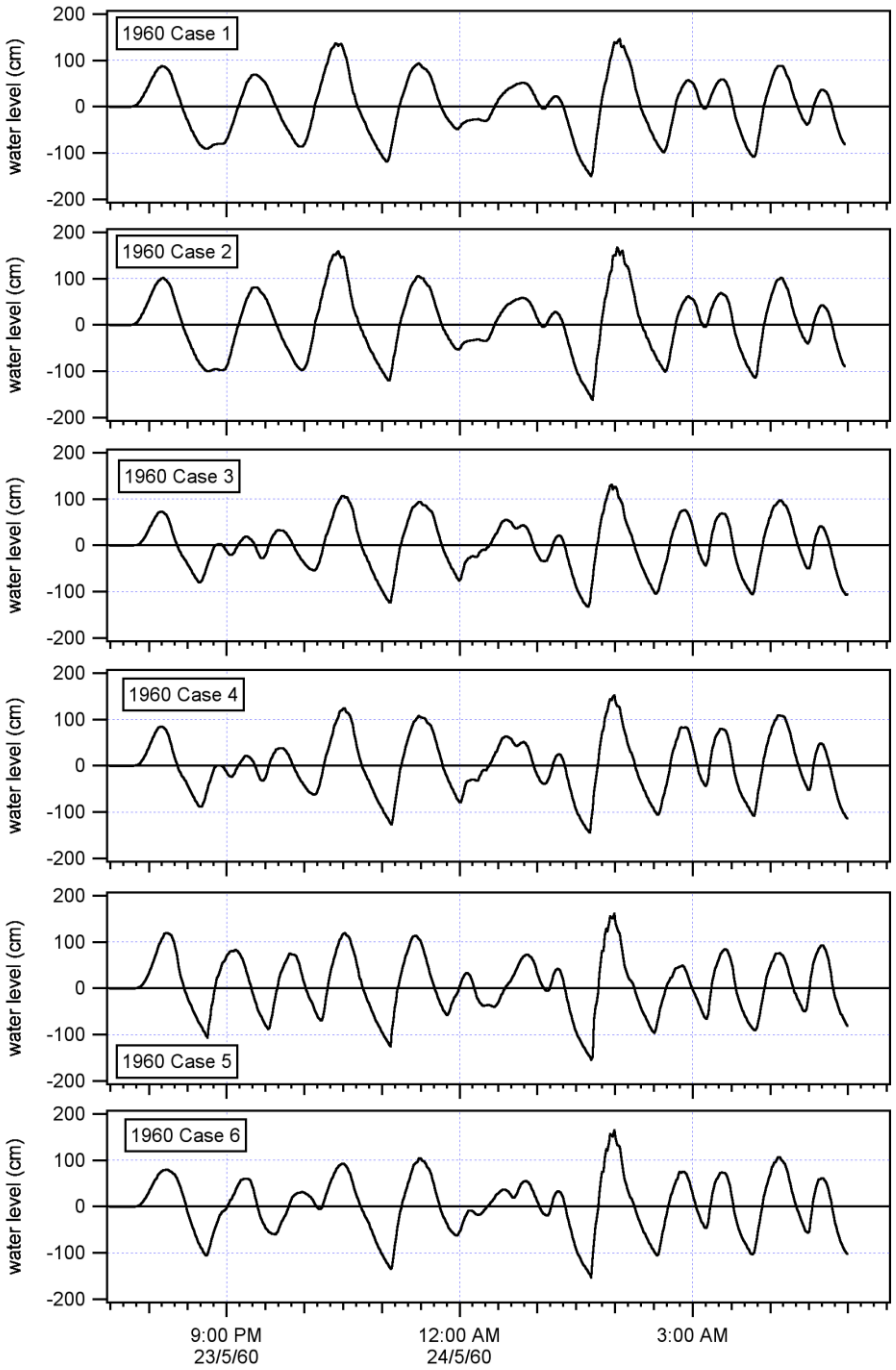


Figure 8: Time series of computed water levels at the present location of the Whitianga tide gauge for the six different 1960 Chilean tsunami source models.

5.4.2 Qualitative Comparison of Modelled Inundation to Historical Accounts

We use the eyewitness accounts described in Section 5.2.2 as additional calibration constraints for the modelling. Based on these interviews, several locations were marked on aerial imagery and compared to the modelling results (refer to Photo 3 and Maps 1 and 2 in section 5.2.2).

We then compare the descriptions of the inundation against four different model results and selected results are shown in Figures 9 to 11. For this comparison, we use the inundation results from Cases 3, 4 and 6, as well as a variant of Case 3 that reduces the bed friction setting used in the model. Cases 3 and 4 were chosen as they best represent the descriptions of the wave activity described in the previous section. Case 6 is used as an end member since it produces the overall largest modelled wave heights and inundation extents. We also test the effect of the friction setting on Case 3 to see if reducing the friction results in higher levels of inundation.

In Figure 9 we see that each of the four cases fits more or less with the witness accounts along the northern section of Buffalo Beach. At the site of the old aerodrome hangar, a small amount of inundation was reported. Also in that area, there were reports of a flounder fish discovered on the porch of a house. If we compare to the model results, we see that the case with the smallest predicted inundation (Case 3) shows the area around the hanger as being inundated as well inundation at the location of the flounder sighting. For Case 3 run with a lower frictions setting, the degree of inundation in those areas is somewhat greater but still consistent with the observations.

Along the Whitianga waterfront however, the model results do not match the descriptions as well (Figures 10 and 11). At the shoreline at the foot of Monk Street, the model predicts maximum wave amplitudes of less than 2 m, which is the minimum necessary to achieve the levels of inundation described by the witnesses. Indeed, results from Case 3 and Case 4 are deficient in their predicted levels of inundation. We obtain a better match to the witness accounts when either the friction is lowered in the model (Case 3 f2) or the slip amount of the source mechanism used to initialise the model is increased and concentrated to the north (Case 6, see Figure 6). The greatest degree of inundation in the town centre is seen with Case 6, which uses the 20% additional slip at the source concentrated in to one area. However, this model over-predicts the inundation along Buffalo Beach.

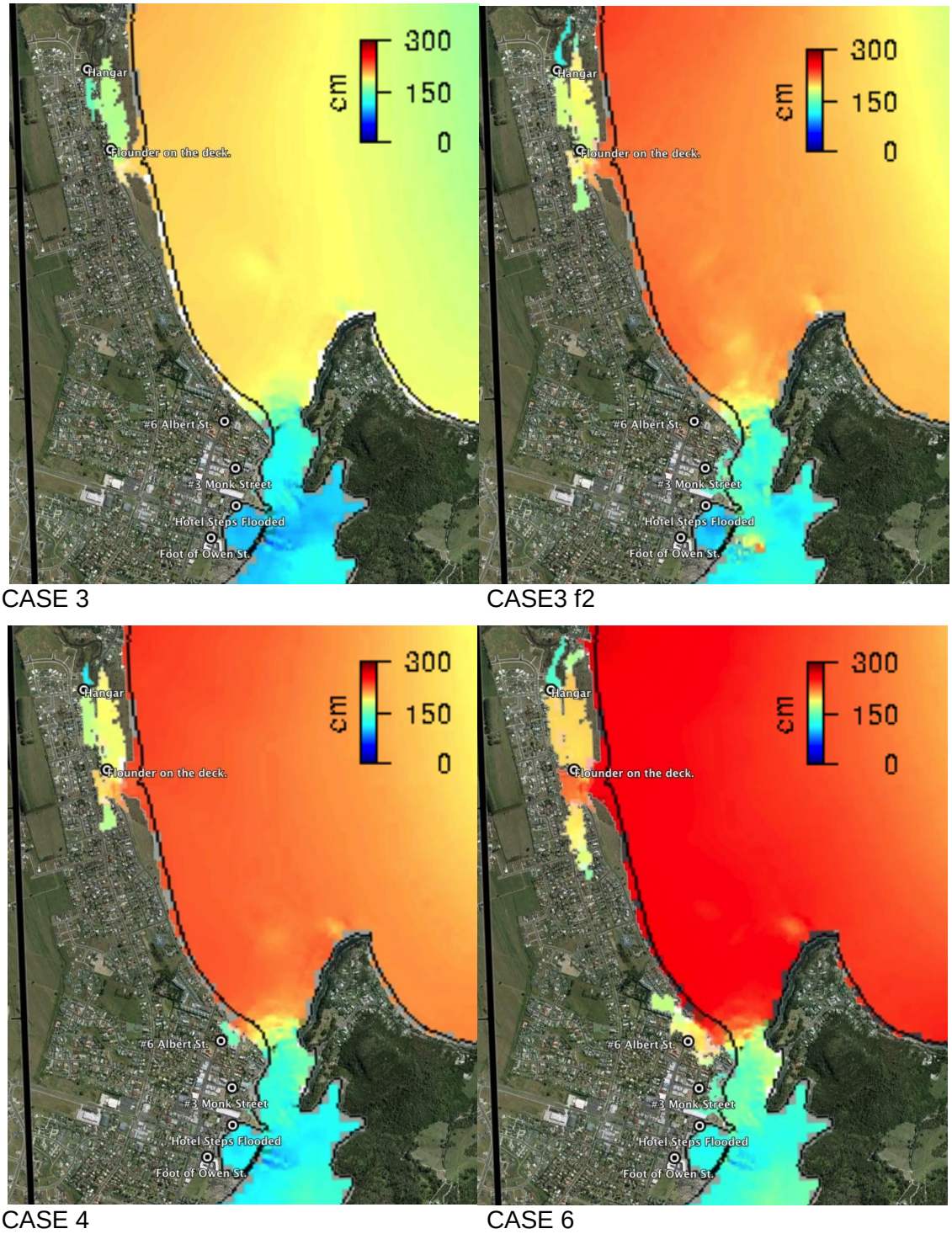
While both cases 3 and 4 replicated the observed inundation along Buffalo Beach, the cases with the higher friction (n = 0.03) did not yield sufficient inundation along the town waterfront. Reducing the friction factor on Case 3 to n = 0.021, increased the inundation in this area but may still slightly underestimate of the total inundation distance at the waterfront. Case 6 on the other hand produces more inundation along the waterfront, however it may be overstating the inundation along Buffalo Beach and the beach area just west of the harbour entrance.

Based on these results we are confident that the source models and bathymetry grids used in this study provide a robust characterization of the effects of the 1960 tsunami in Whitianga. We also contend that the distributed slip source of Fujii and Satake (2012) (used in Cases 3 and 4) yields the overall best fit to the observed effects during the 1960 Chilean tsunami.

This is supported by:

- The high frequency oscillations which occurred around 9:30 pm and are reproduced in the model
- The largest and strongest tsunami surges occurring around 2:30 am which are reproduced in the model, and
- The extent of inundation predicted along Buffalo beach.

We further suggest that the inundation modelling of Prasetya et al. (2008) over predicts the inundation from the 1960 event. Their results (Figure 12) show large-scale inundation across the front of Buffalo Beach reaching an elevation of ~3 m, the occurrence of which is not supported by historical accounts.



CASE 3 CASE3 f2

CASE 4 CASE 6

Figure 9: Comparison of Model results to areas that were wetted by the 1960 tsunami surges.

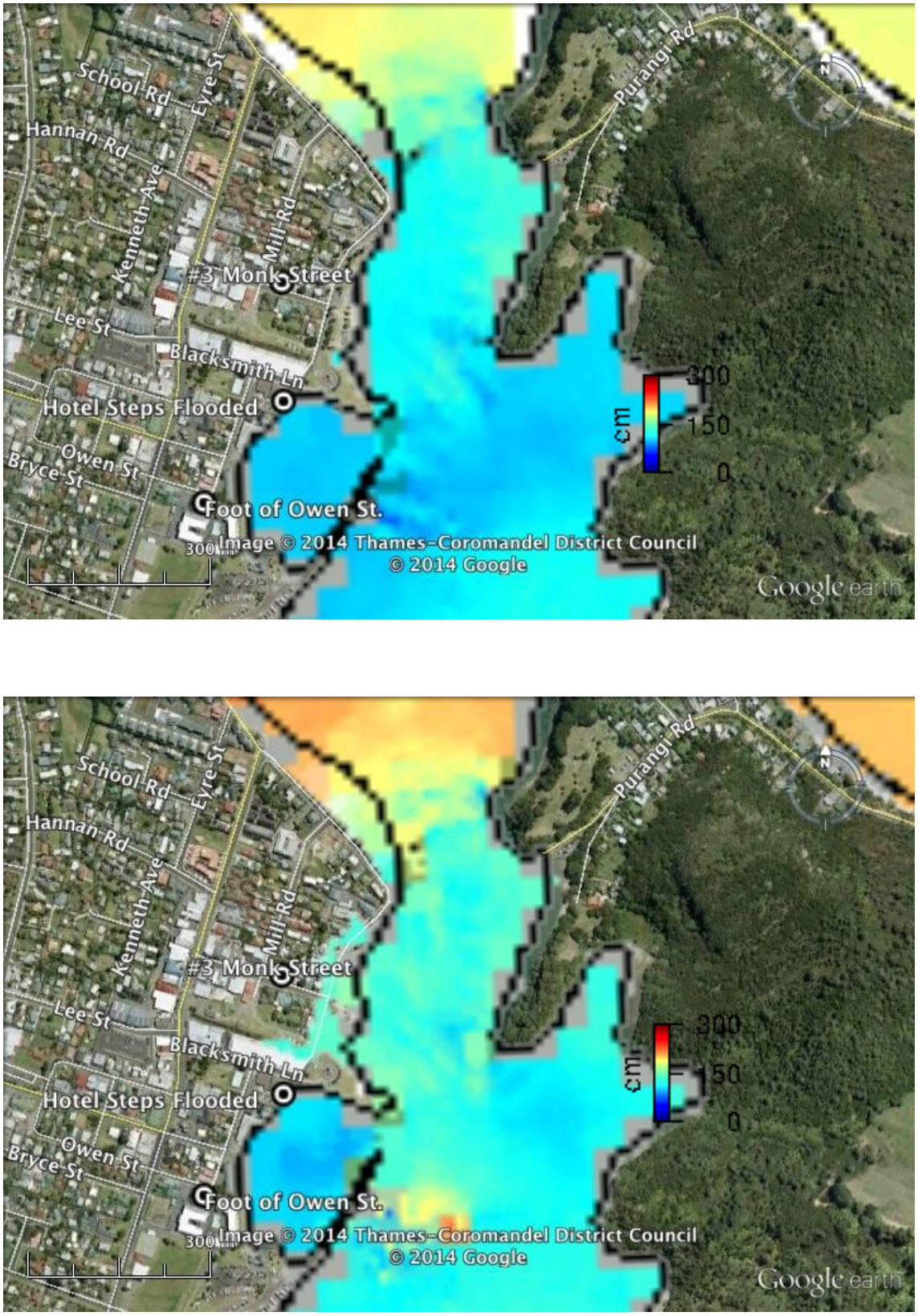


Figure 10: Close up of the inundation results at the Whitianga waterfront for Case 3 (top) and Case 3 f2 (bottom).

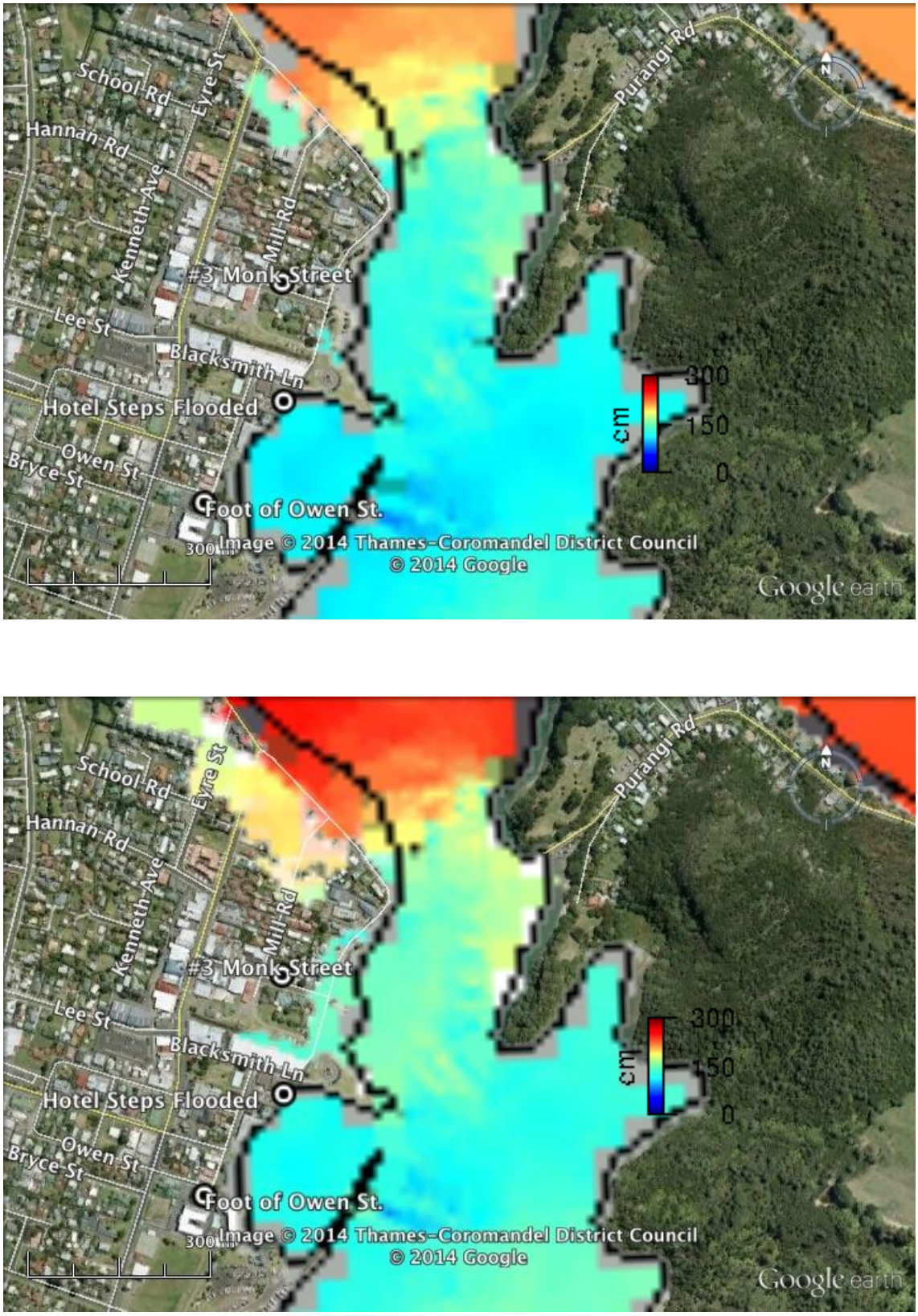


Figure 11: Close up of the inundation results at the Whitianga waterfront for Case 4 (top) and Case 6 (bottom).

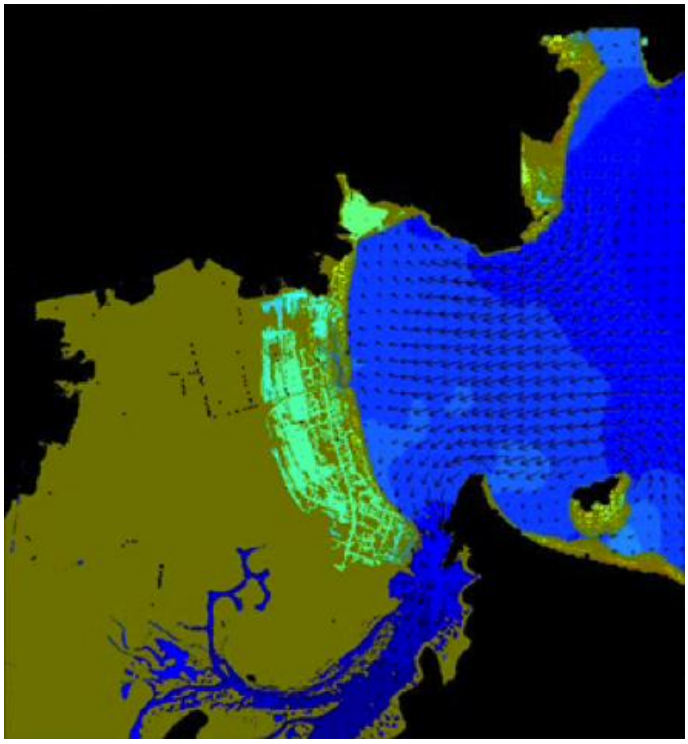


Figure 12: Inundation results from Prasetya et al., 2009 for the 1960 Chilean tsunami in Whitianga which significantly overstate the level of inundation along Buffalo beach.

6 Conclusions on the extent of 1960 Chilean tsunami inundation in Whitianga

We have used a combination of written and verbal eyewitness reports, survey and modelling information to arrive at an estimated inundation area for the 1960 Chilean tsunami, as shown in Map 6.

Based on all the evidence considered, we conclude that the 1960 Chilean tsunami surge likely did not extensively or uniformly overtop the dune ridges parallel to Buffalo Beach and The Esplanade. Rather than dune overtopping, flooding behind the ridges occurred due to water surging through topographic lows in the ridges where streets cut through to the harbour in Whitianga town, and where the Taputapuatea Stream at the northern end of Buffalo Beach enters Mercury Bay. Once inundation began, flow paths followed established low points in watercourses along the swales (low points) behind the dune ridges.

The evidence we have used to reach the following conclusions on estimated inundation extent in Whitianga town and at the northern end of Buffalo Beach is:

Whitianga town:

- We rely primarily on eyewitness evidence supported by the survey information
- All eyewitnesses interviewed reported inundation to the town hall along Monk Street, and inundation along Mill Road
- The Pascoe account supports inundation to the Dairy Company office steps (now the Museum) and inundation of properties through to the harbour adjacent to 6 Mill Road
- We are unclear whether dune overtopping occurred along The Esplanade, as there are conflicting eyewitness reports, and the modelling results are variable between Cases 3 and 3 f2 (no inundation) and Cases 4 and 6 (inundation).

Northern end of Buffalo Beach:

- We rely primarily on modelling results, supported by eyewitness evidence
- Modelling results for Cases 3 and 4 suggest that inundation around the stream entrance flooded properties along Buffalo Beach Road, flowed into the swale behind the foredunes and inundated the location of the old aircraft hangar
- Modelling results are supported by eyewitness evidence of inundation of the aircraft hangar and seaweed on the front lawns as described by Howard Pascoe, and reporting of fish/seaweed on lawns and a goat swimming in a backyard by Don Ross.

Map 6: Estimated inundation area of the 1960 Chilean tsunami.

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Appendix 1: Howard Pascoe's written account

RECOLLECTIONS OF A TIDAL WAVE BY H.W. PASCOE 1960.

The disastrous earthquakes in Chile which occured in 1960, and the resulting sea waves spreading havoc and destruction round the Pacific, have focused the attention of the whole world on one of natures most terrifying weapons - the Tsunami. Commonly called a tidal wave, the Tsunami gets its name from the Japanese, literally it means a "harbour wave" which appears to be not unreasonable when it is realised that these waves affect harbours and bays much more than they do ships at sea.

EXTRACT FROM NEW ZEALAND NAUTICAL ALMANAC

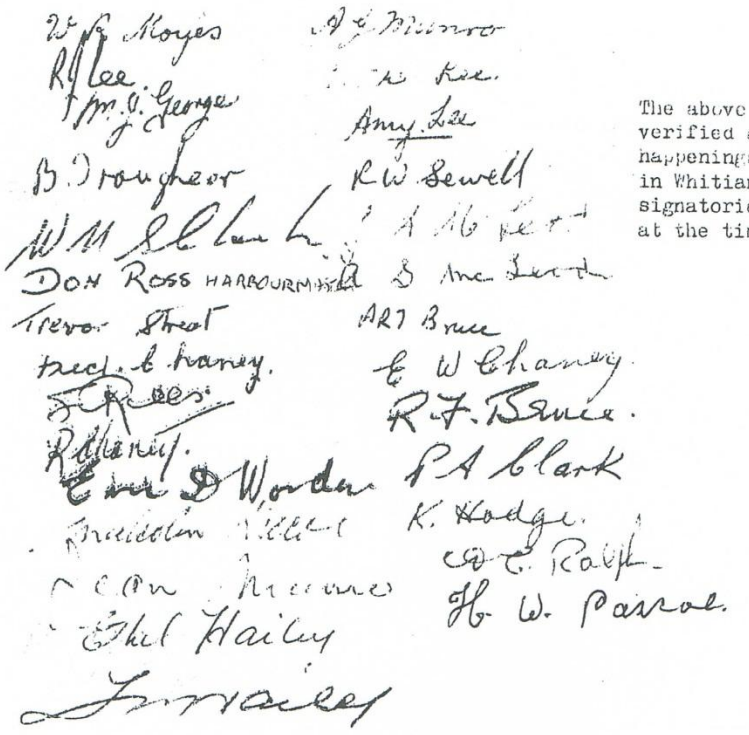
Mercury Bay is an East Coast bay shaped like a funnel, about 5½ miles wide and 8½ miles deep closing down to the river mouth and is very sensitive to big easterly waves and oceanic disturbances. Such as seismic waves as were caused by the Chilian earthquake. On Monday the 23rd of May 1960 at 9pm. the first of the tidal waves arrived and the water in the channel fell so people could walk outside the wharf at the north end, 20 minutes later it had returned to cover the road by the wharf. This it proceeded to do for the next four days. We were getting a tide every 40 minutes. The fishing boats that were moored in the channel between the wharf and the hotel were boarded by their owners,who walked out while they were high and dry and waited for the next outgoing rush of water that took them out to sea to safety. When i took the boat i was looking after the "Atlanta", 40ft. long and powered by a 180 hp G.M. into the stream we were doing 12 knots and going backwards trying to get out of the river. This we did for 20 minutes until the tide turned and swept us out through the entrance to safety. All this was going on in the early hours of Tuesday morning in the dark, a most terrifying experience.
One 28ft. fishing boat the "Mermaid" broke her mooring and was swept up into the mangroves about 2 miles up the river. Another the 34ft. "Marlin" tore the bollard out of the foredeck and was swept up on to the road on the wharf side of Karena Creek where she remained for over a week until she was pulled down and refloated. On the Thursday May 26th at midday a message came through to the Whitianga Police that rocks on Norfolk Island were being swept off the cliffs 40ft. up so Sgt. Mat. Andrews gave the orders to sound the siren for the evacuation of the town. Some folk going up on to the high ground on Davis Point and others going to the high ground behind the aerodrome, where some remained all night and others returning home again about night fall. Just above Pah Point by the cable marker , Robin Lee and i carved a mark in the sandstone cliff where the dust was washed off and a distinct line could be seen along the cliff some 4ft. above the highest spring tide. We estimated from that to where the tide went out was approximately 19ft., all this in 20 minutes. The rush of water when coming in was in excess of 12 knots and would be half as much again going out, which makes it something like 18 knots.
A big flat rock on Pah Point known as Schnapper Rock which people used to fish off, at about high water mark was about 20ft. x 10ft. x 6ft. deep and weighing in excess of 30 tons was swept away and has'nt been located since. The tide was coming and going so fast it was leaving quite big fish stranded and flapping, which could be heard at night and many were caught by residents in the daytime.
The sea came up Monk Street to where the Power Station was and up to the Dairy Company front office steps, also up to Mr. Merv Georges and Mr. Don Ross's houses. Also on to the front lawns of houses and into the old aerodrome hanger along at the northern end of Buffalo Beach, where it wet crates of corrugated iron stored on the floor damaging them. Also the old wreck of H.M.S. Buffalo was left high and dry. Mr. Alf Simpson hitched a Bulldozer on to it and pulled pieces off, which are now in the local Museum.I also watched a small trawler type of boat the "Three Kings" which was owned by Mr. Lee Rydes and powered by a 150 hp Hercules Diesel and capable of about 10 knots,

battling against a rush of water and a wave about 2' 6" high and going backwards and losing ground as she tried to get out to the open sea, which she did after about 20 minutes. This was about 2am on Tuesday morning which seemed to be the worst time. It went all day like that and on the Wednesday it seemed to be calming down, which it did from then on getting slower in its flow of water. It was Saturday before it had come back to anything like normal.
On the river that Tuesday morning were the vessels:-

Caroline	Gilbert Rivas	Norma	Bill Clark
Three Kings	Les Rides	Marlin	Rowley Smith
Ronomor	Bert Chaney	Oronga	Lloyd Palmer
Lady May	Jack Ralph	Tuna Eke	Teddy Brentnall
Atlanta	Howard McAdill	Ngaire	Connie Vivian Simons

Ngaire an ex whale chaser and used for game fishing was a very fast launch and even she could not head that lot off.
There were quite a few people on the river that Tuesday morning in dinghies and smaller boats trying to get them to safety.
I have mentioned the height the water rose each time the tide came in and another alarming thing was how far it went back each time it went out. This large movement of water travelling at such speed back and forth cut all the sandbanks and shell banks in the harbour right down to the black mud. It made quite a smell days later, the reason i think, was all the pipis and shell fish that had been disturbed had died. Some of these shell banks were between 2 and 3 feet high and were on the flats on the western side of the harbour out from the Hotel from Kerena Creek South. The one on the edge of the channel out off the football field being over 400 yards long and about 3 feet high, it was levelled right off and is still like that after 26 years. The others have reformed again in practically the same places but do not seem to be quite so high as they were before, but given time i think they will reform. The telephone cable was destroyed and dragged allover the place, some lengths of it finishing up the harbour.
I can find bits of it laying in the mud even now. The 6" x 6" x 15ft post with a white triangle on top that marked where the cable crossed the harbour, stood on one of these high shell banks near low water mark. This bank was covered in white shell and the tide covering it only on spring tides. Neap tides not covering it. This went in the waves too. Nothing being left. On the 26th of May the Kaimarama School and Mercury Bay Schools closed because of the warning from Norfolk Island and the pupils were evacuated to the hills for two days.
I often think back about it all and thank God that this all took place on a week of very fine weather, of practically no wind or swell outside in the Bay and nobody was drowned.

In conclusion the attached statement by Howard W. Pascoe was verified by the residents listed below. Which is only available as a copy of the original.



The above statement has been verified as a true record of th happenings of 23rd May 1960 in Whitianga River by the signatories who were residents at the time

Re-printed on 22/3/2001 by Mrs. Linda Reade from the original statement, at the request of Mr. Don Ross who was the Whitianga Harbourmaster at that time.

Appendix 2: Bruce Smith's written account

Bruce Smith's recall of the Whitianga "Tidal Wave" 23rd May 1960

I will now endeavour to describe an event which has been with me for 50 years. I feel it may help me to get something off my chest, by putting pen to paper. The events are as clear to me today as they were then; it was a life threatening event for me at the age of 22. I was bullet proof, or so I thought.

Other writings and recordings of this event are correct, but mostly deal with figures and facts not personal experiences, nor the emotional behaviour of many of the locals.

This is how it was for me.

It was a Monday night; we were playing badminton at the local hall. Molly Norman went home early, to return soon after with the news that there was a tidal wave, directing her story to the Morcom brothers Toby and Keith, as they had to cross the river to go home. We thought she was joking, so carried on playing. Toby said that we had better check it out just in case, so we packed up the badminton gear at about 9.30pm and went down to the wharf. Utter amazement and a feeling that I was dreaming came over me; we gazed at the boats floating up and down the river past the wharf. The tide came in and out at a fast rate, with Jim Butterworth's boat "The Foam," harmlessly going with the flow, at that stage, up and down the river, with her mooring still attached. From the then ferry boat landing on the northern end of the wharf, I jumped onto a shell bank and had dry feet. Ten minutes later the water was lapping the very top of the wharf. The "Marlin" our 35ft fishing boat, was still on its moorings, but seemed to be in some distress. Being moored 100 meters upstream from the wharf, I could make out in part light that she was following the Back Eddy, and when her mooring chain pulled her up, she put her nose into the swift flowing current and away she went with the ferocious speed of the current, only to be pulled up when the chain became taught again. This caused The Marlin to rock and roll violently, as if she had been grabbed by the scruff of the neck and had the shit shaken out of her.

The Skipper of the "Ngaire", Connie Symonds was on her boat and also one of the few boats left in the harbour. The others had all headed out to sea to escape the in and out suction of the river. Connie could see me on the wharf so called out, "*I'll pick you up on the beach as the next wave comes in, you will need someone to help you on The "Marlin." I said to my mate Norm will you come and help. His reply was "I'm not a boatman I wouldn't go out there in a million years"* Connie nudged The "Ngaire" onto the sandbank and I jumped on the bow. She reversed out and dropped me off at The "Marlin". We did this manoeuvre while the tide was momentarily slack. Rowley (My father) was in Auckland having a corneal graft operation. He had made an extra good job of having a mooring block so big and strong that it couldn't be dragged or broken. As soon as I had thanked Connie for dropping me off, I was alone. I sensed an unusual experience – absolute airiness. No wind, just the noise of swift current and stranded fish flapping for their lives on the sandbanks, until the next surge came, then they were gone, to be washed up somewhere else. The punishment that The"Marlin" had had, caused it to wrench the planking up "forard" and some of the corking had popped out of the gap between the planks. She was taking water onboard and leaking like a sieve. I started the motor and got the bilge pump going, just to keep pace with the leaking. I used buckets to bail out the excess.

After about an hour, I had most of the water under control, when all of a sudden I was saying to myself. What is happening?
What am I doing here?
What am I going to do? This was about midnight. I looked ashore and there were a few cars with their lights on in my direction. I figured there was someone out there caring for my safety. At this stage I had my first pump of adrenalin. I could not release the chain single handed off the bollard to freedom, - was it going to be freedom? I got to thinking, if I was free I couldn't go to sea with a leaking boat and would I run out of petrol to keep the engine and pump going. I concluded that staying put was the best thing for now, but if I did get free, I would drive The "Marlin" straight ashore and beach her. The car lights were still on the foreshore, I did have some moral support.

It all happened at 2.30am

The tide was coming in faster than ever; I could see the rough water through the light on the wharf. The surge was so strong; I had the motor in gear at full speed ahead. The nose of The "Marlin" dipped further into the oncoming surge and She was screwing like a corkscrew. The stern was lifting out of the water so far, the propeller was having little effect. I had a massive pump of adrenalin as something gave way. The bow of the boat reared into the air like a bucking bronco, the propeller cut in and I was full steam ahead, going sideways heading for the shoreline. Bang. I went ashore on the pipi bank. I scrambled onto the deck to throw an anchor out, when the boat did a double action as another surge wave hit.

The experience of the next few seconds proved to be the most chilling of my life; I know and have always known how close I came to losing my life that night. I was 22, a fit rugby player, years of sports, including boxing, all of which gave me reflexes and strength, (plus the adrenaline was pumping!) Add fate to the mix. I survived the ordeal.

Somehow, just in time, I managed to grab the rail as we lurched into deep water as the tide rapidly rose.

If I had not grabbed the rail, I would have fallen backwards into the water and rolled under the boat.

Back to the helm and full speed again. I finally ended up about 3 meters off the sealed road by Carena Creek (Stinking Creek) and only about 50 meters from the Whitianga Pub's front door. People were yelling for a rope to tie to the palm trees. When I went forward, still dressed in my badminton gear with the rope, I noticed the bollard was missing and 2 planks had pulled out of the quarter deck. The "Marlin" was at peace lying on her side; she gave me a wink and said

"Well done Bruce."

According to experts, under the circumstances I did the right thing. The only other boat on her mooring at 2.30am was The "Mermaid" as her Skipper; Witty Oxley was out of town. The "Mermaid" was found the next day, high and dry on Mangrove Island with very little damage done. At that stage the 2.30 surge was the biggest and strongest by far.

The local Police phoned warnings to all boat owners; however our family never received that call. The Smith family was not aware. As I said before all of the other launches headed out to sea, where they rafted up and waited, many of them didn't come back to their moorings in the river for several days. Neil Chaney had a close encounter in Flaxmill Bay, which I will refer to later.

THE DAY AFTER THE NIGHT BEFORE

The sun rose as usual with many towns' folk not knowing what went on the previous night. When they saw no boats in the river and The Marlin just 3m off the sealed road, they realized the enormity of the tidal wave. At that stage the radio stations were being up dated as to the areas affected and when to expect the next big one. The most affected places were coastal river, estuaries where the water was sucked in which was what happened in the Whitianga River. People, who were living on beachfront areas, merely experienced an extra large high tide. In the Whangapoua harbour, acres and acres of mussel beds were covered with sand which was washed off the northwest end of Matarangi beach.

As far south as Napier was affected, and in the Ahuriri Harbour the foot bridge was washed away, and West Shore kids had the day off school. The cause of the tidal wave (Tsunami) was due to huge volcanic eruptions of the coast of Chile, which was thousands of miles away and happened days before it reached the east coast of the North Island. It came across the Pacific Ocean and no doubt lost a lot of its initial intensity.

On Tuesday morning, the radio reported that there was a huge surge expected to hit Whitianga at 8pm, exactly 24 hours after the 1st wave hit on Monday evening. My plan was to replace the caulking of the planks up forard and give it a coat of red lead paint to stop any leaking, and as a temporary patch up. I thought that if I could dig a big trench in the sand beside the high side of The Marlin, I could get a dozen or so men to help push The Marlin into the hole of water to refloat her and put her on an even keel. It was easy getting the manpower, but not as easy to get the bull dozer. I had previously worked for Alfred Simpson driving his TD6, he was my first call and straight away said *"help yourself come and get it."* Alf's house was on the corner of Buffalo Beach Road and Jackman Ave, so I had to walk the tractor along the grassed sand dunes and along past the hospital. As I drove past the hospital, Alf appeared from off the beach and told me to bring the tractor down onto the beach as he was about to start work on salvaging the "Buffalo" (so he said with tongue in cheek). The tide was still surging in and out, not as severely as the previous night. As the surge went out Alfred said walk the tractor down to the sight where the Buffalo lay exposed high and dry, but the surge came in again and moved at the same rate that the bulldozer could go. We did this several times and agreed it was a hopeless task. My image of the Buffalo was part of the ship lying on its side facing approximately east west. The outer planking had rotted off leaving about a dozen large ribs exposed for a length of approximately 60feet. Quite a find of historic value, as the HMZ Buffalo was wrecked on the beach on the 27th July 1840, hence the name Buffalo Beach. The HMZ Buffalo had brought a load of convicts to Australia and was calling at Whitianga for a return load of spare Kauri spars and logs. The tidal waves' actions had uncovered the wreck off the sand and it wasn't long after that it was covered in sand again. I took some bearings that would give you a general area as to its location. Running in a Nth East and Sth West directions to the SW were the changing sheds in front of the hospital to the Nth East it was centered. It is approximately 125m from the high water mark.

Incidentally the changing sheds have been demolished but were 50m to the east of the present changing sheds of 2005.
After that bit of excitement, I continued walking the tractor along to Carena Creek where I proceeded to dig a big trench beside The Marlin. It was deep enough. Soon it filled with water from the creek and the mini surges. It was all going to happen at 8pm, so after an early tea we returned at 7.30 to take up our positions. 8pm came, no change in tide, 8.30pm came, nothing, 9pm – nothing and at 10pm we decided to call it a day as still nothing happened, it was a false alarm. I had a good sleep that night and wondered what Wednesday would bring. It was a day for the local people to express themselves in many ways. Everybody remembers the tidal wave. There were the explorers wandering about to see what had been changed by the wave, the pipi banks were stripped of pipis and the sand had been washed out to sea. The HMS Buffalo had been exposed, and then covered again by the sand and the tide.

Then there was one of the town characters, Jimmy Hawkswood, dressed in seaman's jersey and captain's hat plus a lifejacket, riding his bike around the town, visiting anyone who would listen to the update of what was going on. I was digging another trench just in case, when Jimmy told me, if I hear the siren go three times it was notice to evacuate the township, as it was reported that there was a huge wave and it was predicted to engulf the whole town. The custom was to sound the siren once only at midday. I was on the bulldozer and at exactly 11.45am the siren sounded once, everybody stood still, sounded twice, still standing still - our minds were busy- it was all a bit unreal. Then it sounded for the third time.

This was it.

We had to get out of town as best we could with what we could, rather a daunting reality. People did not rush. They went about their business slightly stunned. I left the bulldozer, went home and told my Mother Gladys and my little sister Margaret we were heading out of town. They weren't aware what the three sirens were for but thought something must be up. We took a suitcase of clothes each. Gladys packed up all of her important accounting book work, Margaret got the budgie and cage, and I let my two dogs off for a run before putting them in the back of the Ute along with the rest of our treasures. We headed for the hills on Pat Lee's farm just south of Kaimarama.

Other people went to the top of Brophys Hill, some up to Slaughter House Rd. Horses were ridden out of town; this was a very puzzling time for everyone. The boats were still out at sea.

There were our neighbours, Louis and Hilda Lowe who had been there all their lives and weren't going anywhere. Howard Clark and his wife Bertha also stayed put. There was a group of locals who used the opportunity to frequent the local pub and help themselves to free grog, mostly from the top shelf.

Diane Smith was 10yrs old, she thought the whole event was exciting, jumping on the back of her Dad's (Boy Smith) truck with a lot of locals who didn't have transport and heading off to the safety of Davis's Hill. As Diane recalls the dogs were howling as the siren went off. As Don Ross was heading out of town he felt sad and helpless, he had taken his family to safety the previous day to Browne's farm at Coroglen. Walter Russell recalls the sound of an express train as the surges went in and out. Colleen Hudson's adventurous catching of Mrs. Bruce's cats, putting them in a sugar- bag and taking them to safety. She was badly scratched and beside herself, as she thought

she was running out of time. Bill Clarke somehow came ashore from his boat to claim and take his infamous Black Marlin from the pub to safety. The hotel proprietor took all cash registers from the pub before leaving town.

How would you feel if your home, your livelihood and your possessions were going to be destroyed? As it was, we all waited in anticipation listening to the radio reports. It was a false alarm, nothing eventuated and by 4.30pm we all started to come back to town. The boats started to come back 4-5 days later to what was left of their moorings and the town returned to near normal. Rowley returned a few days later and in no time we had The Marlin in a cradle and with the help of the bulldozer sledged her down to low tide. At high tide she was afloat ready for business. The mooring and chain was retrieved with the bollard and the 2 planks still attached. The bollard was replaced into new planking on the quarterdeck.

There were no lives lost during this tidal wave experience. However, there was one very close encounter with 'Davy Jones's Locker' for Neil Chaney aged 20. He went out to sea with his father on The Ronomoor to raft-up with the other boats in Flaxmill Bay, where they stayed.

Bob Troughear from The Caroline was on The Ronomoor for the evening, so Neil's task was to row Bob back to the Caroline, by that time it was pitch black. It was about 2.30.m. As Bob got out of the dinghy to board his boat, a massive surge tipped it over, throwing Neil into the water. He was wearing heavy gumboots. Neil could not hold onto the boat, and slipped under the water, the gumboots dragging him down. Bob threw a rope across the upturned dingy and by some miracle Neil surfaced as the rope landed by his hand. He held the rope as Bob pulled him in. This was a close escape. He nearly drowned. The dinghy was retrieved the next day, five miles away, just inside Centre Island. Neil recalls that he thought he was heading for Davy Jones Locker, but thanks to Bob's quick thinking, he lived to tell the story.

Appendix 3: Photo locations around Whitianga

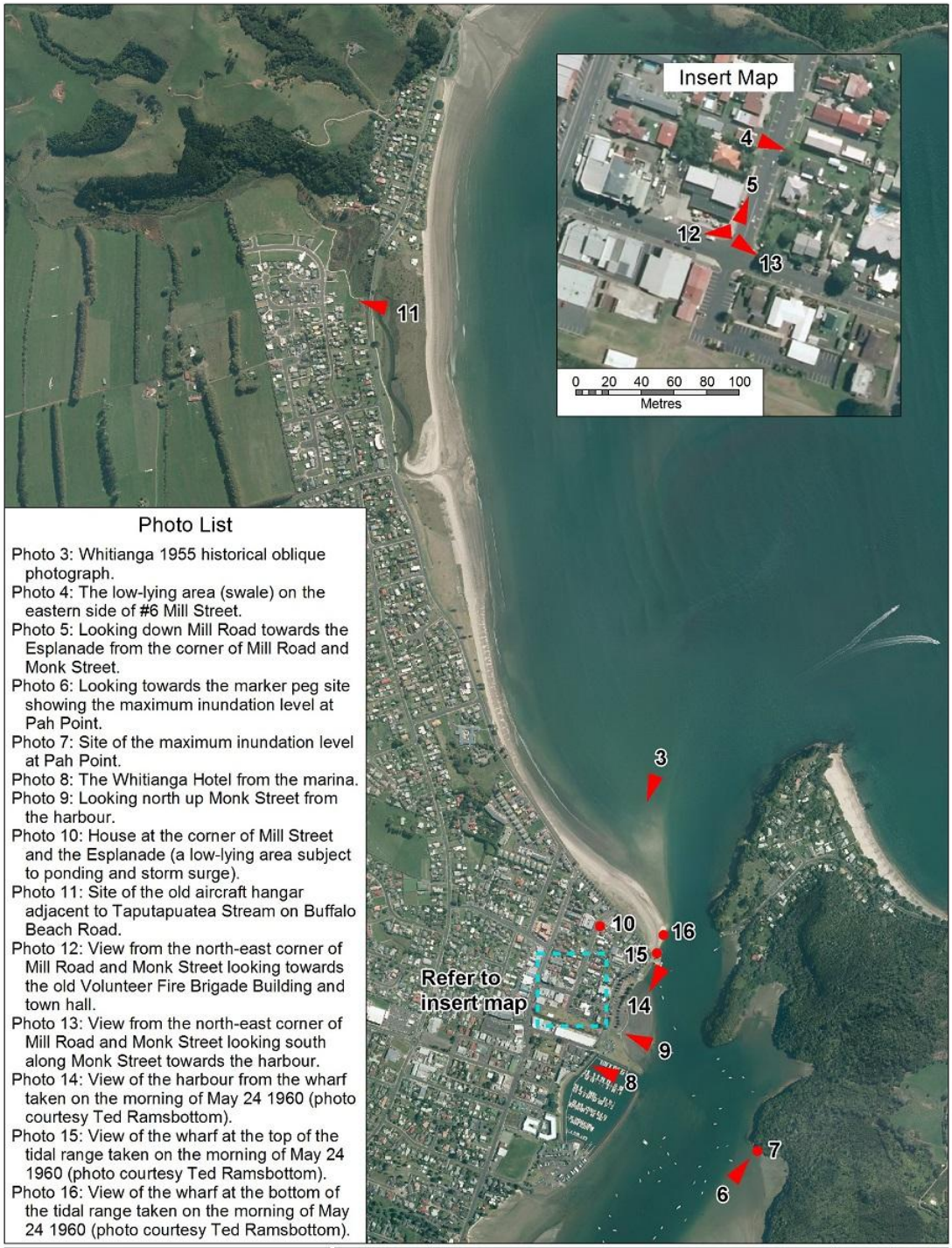


Photo List

Photo 3: Whitianga 1955 historical oblique photograph.
Photo 4: The low-lying area (swale) on the eastern side of #6 Mill Street.
Photo 5: Looking down Mill Road towards the Esplanade from the corner of Mill Road and Monk Street.
Photo 6: Looking towards the marker peg site showing the maximum inundation level at Pah Point.
Photo 7: Site of the maximum inundation level at Pah Point.
Photo 8: The Whitianga Hotel from the marina.
Photo 9: Looking north up Monk Street from the harbour.
Photo 10: House at the corner of Mill Street and the Esplanade (a low-lying area subject to ponding and storm surge).
Photo 11: Site of the old aircraft hangar adjacent to Taputapuatea Stream on Buffalo Beach Road.
Photo 12: View from the north-east corner of Mill Road and Monk Street looking towards the old Volunteer Fire Brigade Building and town hall.
Photo 13: View from the north-east corner of Mill Road and Monk Street looking south along Monk Street towards the harbour.
Photo 14: View of the harbour from the wharf taken on the morning of May 24 1960 (photo courtesy Ted Ramsbottom).
Photo 15: View of the wharf at the top of the tidal range taken on the morning of May 24 1960 (photo courtesy Ted Ramsbottom).
Photo 16: View of the wharf at the bottom of the tidal range taken on the morning of May 24 1960 (photo courtesy Ted Ramsbottom).

Map 4: Photo Locations Around Whitianga

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SCALE 0 200 400 600 800 1000 Metres

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