Surviving a Tsunami:

Lessons from Chile, Hawaii, and Japan

Eyewitness accounts of the Pacific Ocean tsunami associated with the giant Chilean earthquakes in 1960 and 2010

Information on the 2014 edition

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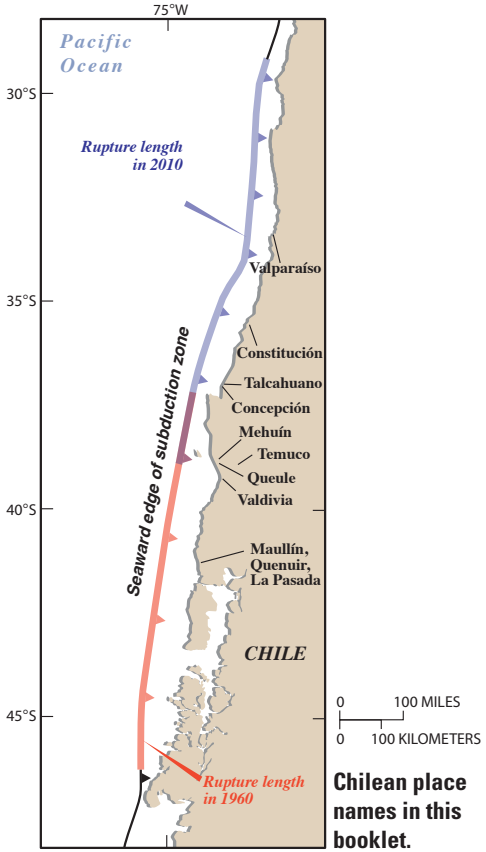
After the 2010 Chile Tsunami, the International Tsunami Information Center (ITIC) was asked to update the booklet to add information on historical and potential tsunami sources off South America, Middle America, and in the Caribbean. In addition, lessons learned from the 2010 tsunami were included in this booklet which was published in Spanish by UNESCO IOC in 2012.

Original new content, compiled by the International Tsunami Information Center, (www.tsunamiwave.info) is summarized on page 2. The new content, not included in USGS Circular 1218, is found on pages 2, 3, 4, 5, 6, 7, 10, 12, 13 and 19.

The booklet was translated back into English in 2014 by the International Tsunami Information Center.



Chilean place names in this booklet.

Information on the original edition

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Information on the 2010 additions

The Spanish booklet was updated as a rapid response after the 27 February 2010 Chile earthquake and tsunami. The Explora program, the UNESCO's DIPECHO project and the School of Ocean Sciences of the Pontificia Universidad Católica de Valparaíso used this booklet to promote appropriate actions using the lessons learned from both the 1960 and 2010 events.

The new and original content was based on the 2010 interviews with survivors conducted by the "Geomarinos" group of the School of Ocean Sciences.

Newly-collected photographs on the front and back covers from the 1960 event were added.

Design modifications in 2010 made by Annette De Vásquez.

Front cover caption:

People observing the first waves from the 22 May 1960 tsunami safely from higher ground, Puerto Saavedra, Chile.
See p. 7

Surviving a Tsunami: Lessons From Chile, Hawaii, and Japan

Original edition compiled by Brian F. Atwater[1], Marco Cisternas V.[2], Joanne Bourgeois[3], Walter C. Dudley[4], James W. Hendley II[1] and Peter H. Stauffer[1].
Additions to the original made in 2010 by Marco Cisternas V.[2], Mabel Keller[5] and Giovana Santillán[6].
Additions to the original made in 2012 by Laura Kong[7] and Nicolás Arcos[7].

This 2012 version was been translated and published in Spanish with financing by the European Commission. Project: "Communities resilient to earthquakes and tsunamis in Puerto Plata (Dominican Republic)".

Humanitarian Aid and Civil Protection

Empowered lives. Resilient nations.

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United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

In 2014, Spanish portions were translated into English by the International Tsunami Information Center, and the booklet printed with financing from the U.S. National Oceanic and Atmospheric Administration (NOAA) Tsunami Program. This edition will be updated in French and Spanish.

National Oceanic and Atmospheric Administration

International Tsunami Information Center

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CONTENTS

Surviving a Tsunami—
Lessons From Chile, Hawaii, and Japan

Introduction

This book contains true stories that illustrate how to survive—and how not to survive—a tsunami. It is meant for people who live, work, or play along coasts that tsunamis may strike. Such coasts surround most of the Pacific Ocean but also include some coastal areas of the Atlantic and Indian Oceans and Mediterranean seas.

Although many people used to call tsunamis "tidal waves," they are not related to tides but are rather a series of waves, or "wave trains," usually caused by changes in the level of the sea floor during earthquakes. Tsunamis have also been caused by the eruption of coastal and island volcanoes, submarine landslides, and oceanic impacts of large meteorites. During the 26 December 2004 Indian Ocean Tsunami that killed 227,000, tsunamis reached heights 50.6 meters (166 feet) above sea level in Sumatra, Indonesia. In the 2011 Japan Tsunami that killed 17,000, waves reached 38.9 meters (127.6 feet) above sea level and flooded kilometers inland.

The stories in this book were selected from interviews with people who survived a Pacific Ocean tsunami in 1960 as well as the 2010 Chilean earthquake and tsunami. Many of these people contended with the waves near their source, along the coast of Chile. Others faced the tsunami many hours later in Hawaii and Japan. Most of the original interviews in Circular 1218 were done decades later in the 1980s and 1990s. The new accounts included in this publication (p. 7 and 8) were compiled between 2009 and 2010 (p. 3, 5, 6, 7, 12, 13 and 19). Also new to this edition is information regarding earthquake sources that can generate tsunamis in Central America and South America, including the Caribbean (p. 4).

The stories provide a mixed bag of lessons about tsunami survival. Some illustrate actions that reliably saved lives—heeding natural warnings, abandoning belongings, and going promptly to high ground and staying there until the tsunami is really over. Others describe taking refuge in buildings or trees or floating on debris—tactics that had mixed results and can be recommended only as desperate actions for people trapped on low ground.

Almost 50 years later, Juan Peña, from Puerto Saavedra (right), provides details about the earthquake and tsunami of 1960 to Diego Muñoz. In January 2010, both are seated on the town's pier, which was built to minimize coastal erosion caused by the 0.9 meter (3 foot) drop in elevation that occurred during the 1960 earthquake.

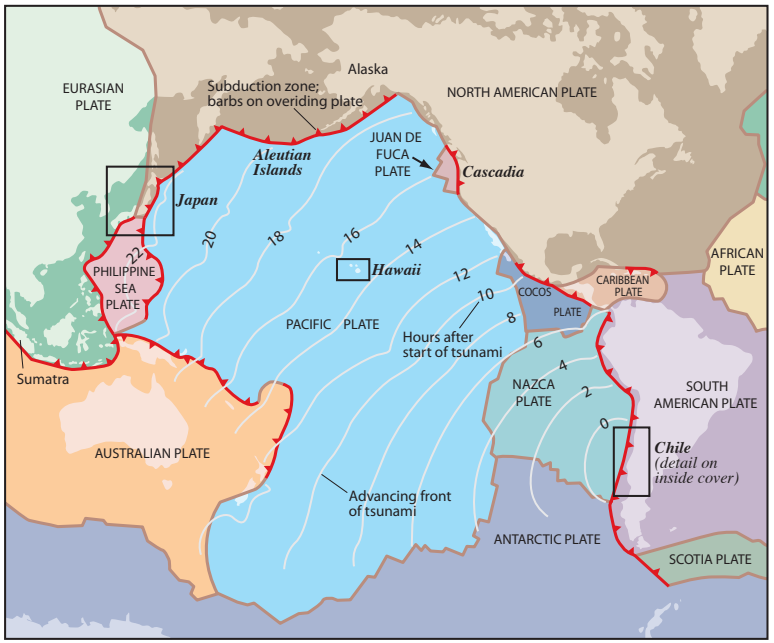
The Great Chilean Earthquakes and Tsunamis of 1960 and 2010

Most of the stories refer to the tsunami of 22 May 1960 in south-central Chile. This tsunami, which travelled across the Pacific Ocean, was generated by the largest earthquake ever measured, the 1960 Chilean mainshock of magnitude 9.5. In Chile, the earthquake and the tsunami that followed took more than 2,000 lives and caused property damage estimated at 550 million USD (1960 dollars). From Chile, the tsunami radiated outward, killing 61 people in Hawaii and 139 people in Japan, and at least 23 in the Philippines. Damage was estimated at 24 million USD in Hawaii, 50 million USD in Japan and 0.5 million USD in the Philippines.

On 27 February 2010, nearly 50 years after the 1960 event, the region was struck again. A magnitude 8.8 earthquake and local tsunami caused 30 billion USD in damage and economic loss along a 700 kilometers (430 miles) length of Chilean coast in the Valparaiso-Concepción/Talcahuano area. 521 people lost their lives, and 1.8 million people were affected. More than 370,000 homes, 2013 schools, 79 hospitals and 4,200 boats were damaged or destroyed. The earthquake ranked as the 6th largest since 1900.

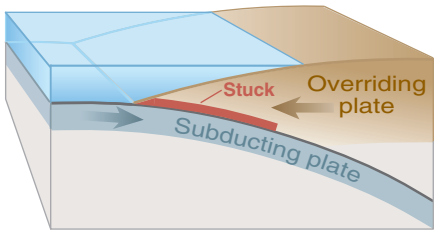
The 1960 and 2010 Chilean earthquakes ruptured fault zones along which slabs of sea floor are descending, or "subducting," beneath the adjacent South American continent. Such "subduction zones" are formed where two tectonic plates of the Earth's outer shell meet. Earthquakes occur when the fault ruptures, suddenly releasing built-up energy. During the 22 May 1960 giant earthquake, the South American Plate's western margin lurched as much as 20 meters (60 feet) relative to the subducting Nazca Plate, over an area 1000 kilometers (600 miles) long and more than 160 kilometers (100 miles) wide.

Like Chile, many other areas are located near subduction zones capable of producing earthquakes which generate tsunamis. Central America and Mexico (see map p.4) and Cascadia (see map to right) are among the areas vulnerable to tsunamis. The Cascadia Subduction Zone produced an earthquake setting off a tsunami in 1700 that crossed the Pacific hitting Japan 10 hours later, resulting in two deaths in Nakaminato, Japan. Since 1700, the Pacific Northwest of North America has been quiet so people must look elsewhere for guidance about tsunami survival.



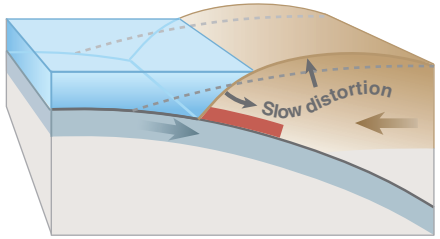
The 1960 Chilean tsunami radiated outward from a subduction zone along the coast of Chile. Its waves reached Hawaii in 15 hours and Japan in 22 hours.

TSUNAMI—A SERIES OF WAVES, OR "WAVE TRAINS," USUALLY CAUSED BY A SEISMIC SHIFT OF THE SEA FLOOR



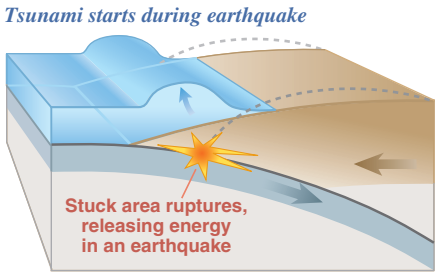
Vertical Slice Through a Subduction Zone

One of the many tectonic plates that make up Earth's outer shell descends, or "subducts," under an adjacent plate. This kind of boundary between plates is called a "subduction zone." When the plates move suddenly in an area where they are usually stuck, an earthquake happens.



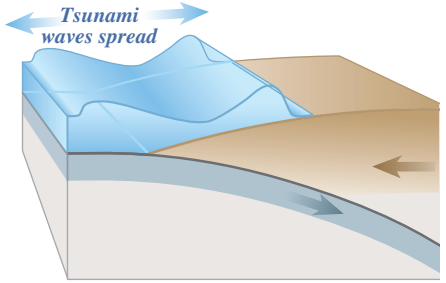
A. Between Earthquakes

Stuck to the subducting plate, the overriding plate gets squeezed. Its leading edge is dragged downward, while an area behind bulges upward. This movement goes on for decades or centuries, slowly building up stress.



B. During an Earthquake

An earthquake along a subduction zone happens when the leading edge of the overriding plate breaks free and springs seaward, raising the sea floor and the water above it. This uplift starts a tsunami. Meanwhile, the bulge behind the leading edge collapses, thinning the plate and lowering coastal areas.



C. Minutes Later

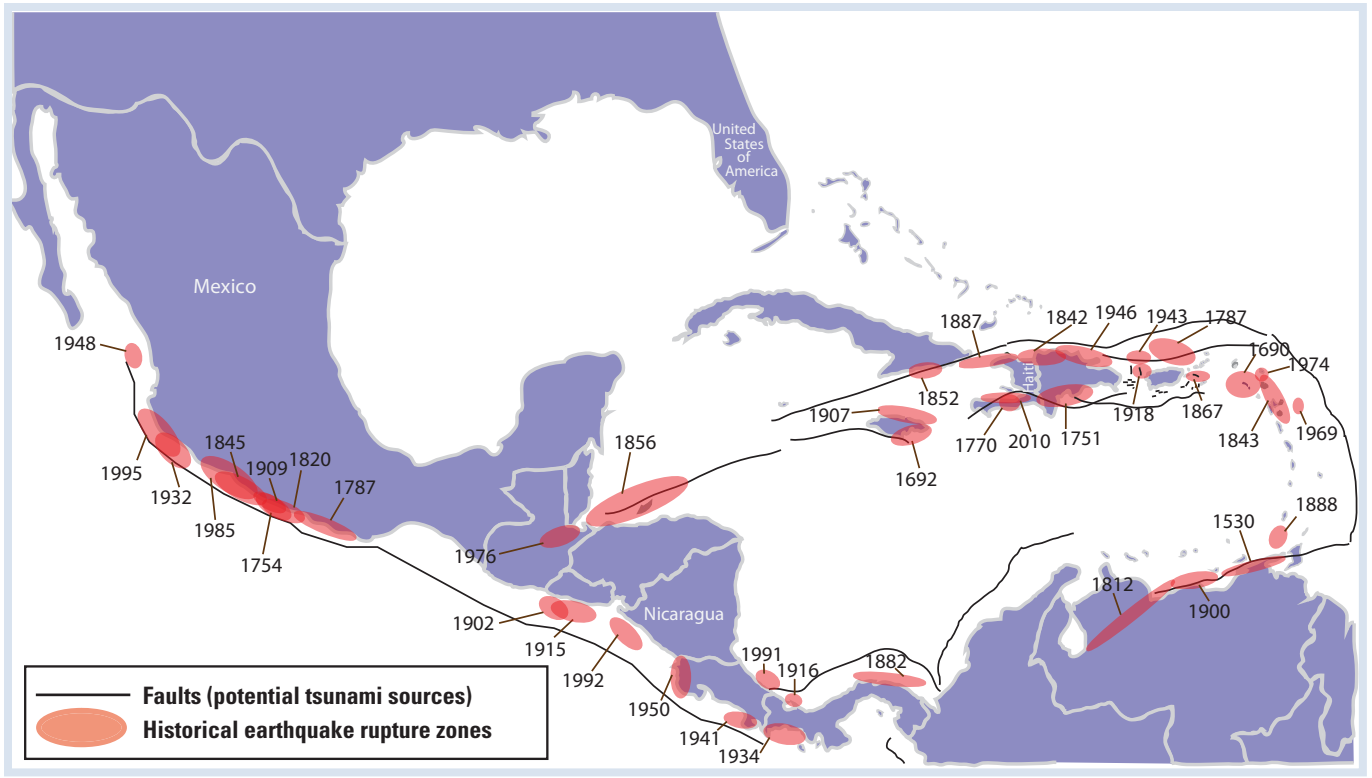
Part of the tsunami races toward nearby land, growing taller as it comes in to shore. Another part heads across the ocean toward distant shores.

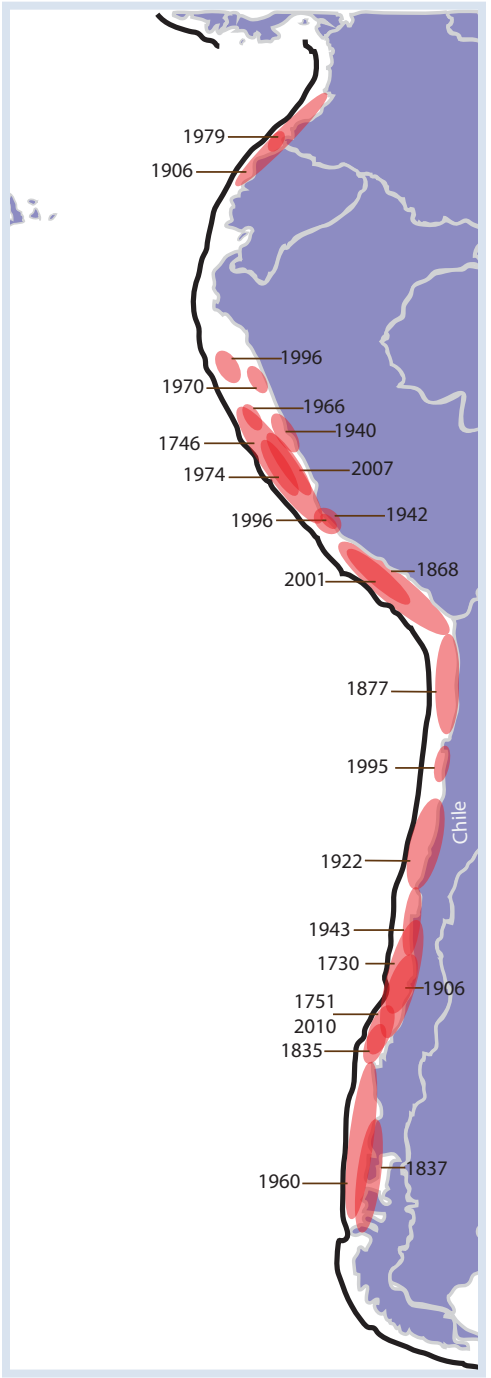
Historical and Potential Tsunami Sources

Many of the world's shorelines are in the proximity of subduction zones that produce tsunamis. In the Americas, much of the Pacific coast between Alaska and southernmost Chile, and the coasts and islands countries in the Caribbean are vulnerable to tsunamis. In these regions, tsunamis are typically generated by earthquake faulting and, to a lesser extent, by landslides and volcanic eruptions.

Destructive tsunamis produced by subduction zones occur so infrequently that the few centuries we have of written history do not tell us the full story about the tsunami hazards that these zones pose. This is why the extent of the losses from the tsunamis in Sumatra, Indonesia, in 2004 and in Tohoku, Japan, in 2011 was so unexpected. The maps on this page are thus providing an incomplete picture of tsunami hazards since they summarize occurrences only from the past several hundred years. A more complete picture of the expected hazard requires tsunami histories that extend thousands of years into the past.

Right: Historical earthquakes magnitude 7.0+. Because recurrence intervals of giant earthquakes can be very long (100s to perhaps 1,000 or more years), use of only written records may result in the underestimation of a region's tsunami potential.





Many Will Survive the Earthquake

In coastal areas, the largest subduction zone earthquake may kill fewer people than the tsunami that follows.

José Argomedo survived the 1960 Chile earthquake, which he initially mistook for nuclear war.

Mr. Argomedo was 22 years old and living on a farm outside Maullín, Chile, where he got news of the world from his radio. Early in May 1960, the big news was the tension between the United States and the Soviet Union—a Soviet missile had downed an American spy plane.

On 18 May, the Soviet leader, Nikita Khruschev, suggested treating the United States like a cat that had stolen cream. "Wouldn't it be better," he said, "to take the American aggressors by the scruff of the neck also and give them a little shaking?"

A few days later, on the afternoon of 22 May, while out riding his horse, Mr. Argomedo felt more than a little shaking. As the ground beneath him shook hard for several minutes, he got down from his horse. Mr. Argomedo thought the Cold War had turned hot. However, like everyone else in the area of Maullín, Quenuir, and La Pasada (see photo, p. 17), he was actually living through a magnitude 9.5 earthquake, the largest ever measured.

Mr. Argomedo was on high ground during the hours that followed the earthquake. However, many other residents of the area were not, and 122 were killed by the ensuing tsunami.

Past earthquakes provide lessons for future generations. In the decades that followed, new building codes were passed so that stronger earthquake-resistant structures were built. In coastal Chile, lessons from the 1960 earthquake included going to high ground upon feeling a strong earthquake. This lesson also saved lives in 2010, when the tsunami associated with a Chilean earthquake of magnitude 8.8 took only 156 lives in Chile.

Many houses in Maullín, Chile, withstood the magnitude 9.5 Chile earthquake of 22 May 1960. The ensuing tsunami caused most of the damage shown in this photo, taken between 23 May and 3 June 1960.

Heed Natural Warnings

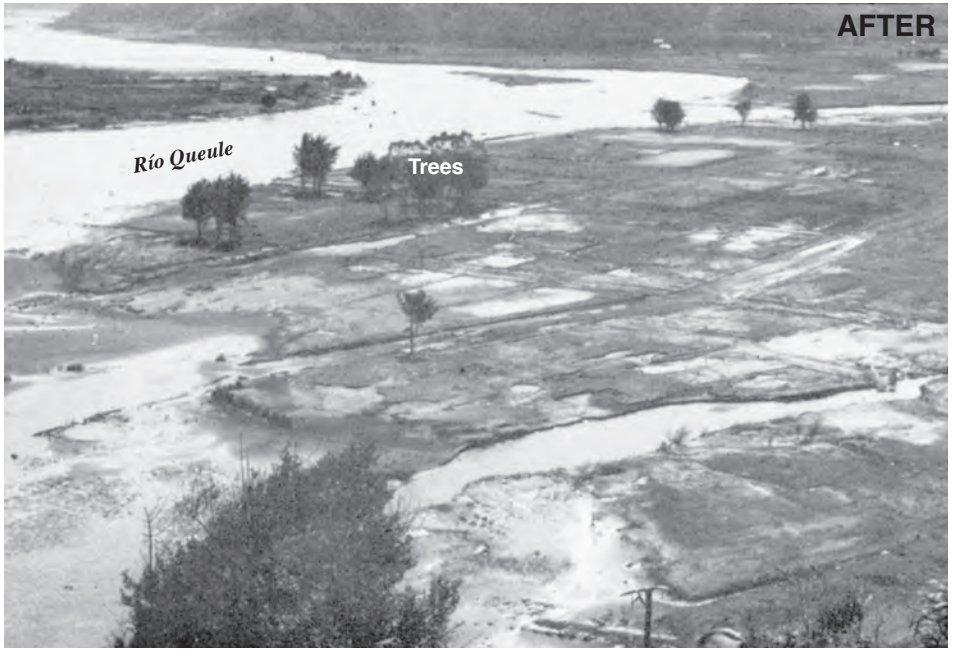
An earthquake may serve as a warning that a tsunami is coming, and so may a rapid fall or rise in coastal waters.

On Sunday, 22 May 1960, Jovita Riquelme took her 5-year-old daughter to Mass in Queule, Chile (see map on the inside front cover). During Mass, the priest talked about earthquakes. A swarm of quakes as large as magnitude 8 had occurred 160 kilometers (100 miles) to the north the previous day.

Later that Sunday, the magnitude 9.5 mainshock of the 1960 Chile earthquake rocked the region. After the shaking ended, many people from Queule decided to head to nearby hills. From their stories it is not known why they chose to do this, but their only known warning was the minutes of shaking or, perhaps, changes in the level of the Río Queule or the nearby Pacific Ocean (see also stories on p. 10, 13, 14).

Heeding natural warnings by going to high ground probably saved hundreds of lives in Queule. However, Mrs. Riquelme's family remained at their house on low ground near the Río Queule. The tsunami that followed the earthquake caught the Riquelme family there. During the confusion caused by the waves, Mrs. Riquelme lost her daughter, and her husband was badly injured. Her husband died of his injuries, and the body of her daughter was found 3 days after the tsunami.

Not far to the north of Queule, Vitalia Llanquimán lived outside the village of Mehuín. Soon after the earthquake shaking stopped, a man on horseback told her that the sea had receded from shore. At first, Mrs. Llanquimán was not alarmed by this news, but her husband took it as a warning that the sea, when it came back, might surge inland. Carrying their two youngest children, the couple hurried up a nearby hill, where they safely remained during the tsunami. The majority of people that survived the 2010 tsunami did so because they recognized the tsunami's natural warnings signs, such as sudden sea level changes and shaking of the earth.



Though 0.62 kilometers (1 mile) from the sea, most of Queule, Chile, was overrun and washed away by the tsunami that followed the 1960 Chile earthquake. Many residents of Queule fled to the safety of high ground soon after the earthquake, but Jovita Riquelme lost her daughter and husband to the tsunami because the family remained at their house on low ground near the Río Queule. From the height of debris tangled in the branches of trees that remained standing after the 1960 tsunami, Wolfgang Weischet, then a geographer at the Universidad Austral de Chile in nearby Valdivia, estimated that water from the tsunami was as much as 3.96 meters (13 feet) deep in Queule. Mr. Weischet took these before and after photos.

Take Oral Traditions into Account

In regions with a long oral history, such as Chile's Araucanía region, the experiences of elders can help save lives.

Although Puerto Saavedra was devastated by the 1960 tsunami, few people died in large part because they recognized the natural warning signs and remembered their oral traditions. In a nearby field, a worker, Martín Huaracán, remembers receiving the first warning sign. This first warning sign was shaking of the earth and it occurred in the morning of the day before the tsunami.

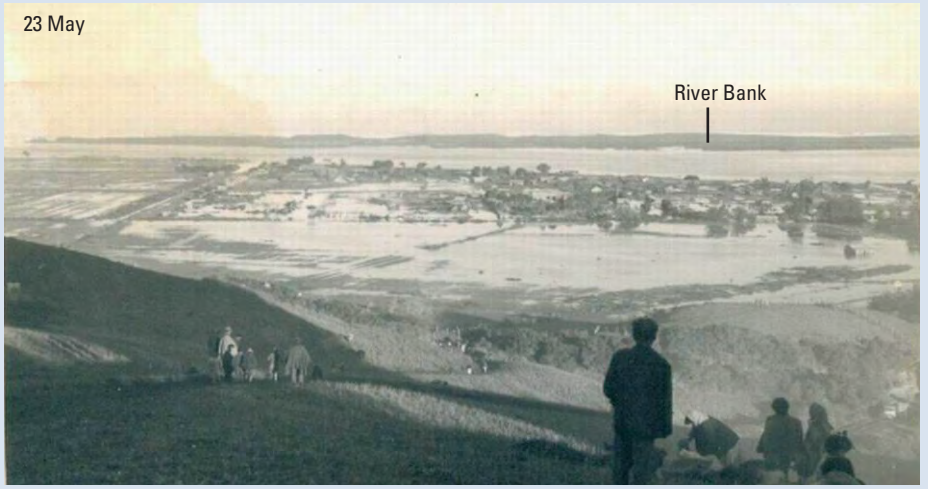
Mr. Huaracán was referring to the magnitude 8 earthquake on Saturday, 21 May 1960 (see p. 6). The earth shook intermittently throughout the day. The next afternoon (22 May), the great earthquake occurred. As the earth rolled, people could not stand and everything fell, including the fences and animals. Mr. Huaracán tried to stand by placing a foot against the fence, but decided it was best to lie on the ground.

The river provided the second warning sign. The river's waters began to withdraw unusually away from the shore. Mr. Huaracán received the third and last warning sign from elderly neighbors. They told him their ancestors said to go to high ground following the two prior warning signs. Thus, Mr. Huaracán decided to immediately head for higher ground. At that exact moment, the landowner, Mr. Henríquez, passed by with a truck filled with people. They picked up Mr. Huaracán and headed towards the hills. From there, Mr. Huaracán and other survivors would safely observe the tsunami as it swept away the town.

Today, Mr. Huaracán has no doubts that the tsunami was a greater catastrophe than the earthquake. He is very grateful for the advice from his neighbors.

Similarly, many residents of coastal villages survived the 2010 tsunami due to experiences of past events, or to stories of those that survived past tsunamis.

Mr. Martín Huaracán explains to the interviewer, Carlos Pineda, how he survived the earthquake and tsunami in Puerto Saavedra. Natural warning signs and recommendations from elderly neighbors saved his life.



The Puerto Saavedra community members, perhaps Mr. Huaracán among them, gather on a hill to observe the arrival of one of the first tsunami waves in 1960 (above). In this image, the Imperial River's bank (the black line) was open to the south of the town, allowing the tsunami wave (the clear line) to funnel toward the town. The following morning (below), the residents are still on high ground while the town remained inundated.

Beware of an Unusual Withdrawal of the Water

After an earthquake, you may see changes in the sea's behavior. Don't let curiosity get the best of you, move quickly to high ground as a tsunami may have been generated.

Curiosity almost cost Denis García his life. At the age of 26, Mr. García lived with his family in Corral, an active port near Valdivia (Chile). Immediately following the 1960 earthquake, he searched for his family in Corral Bajo, a neighborhood located almost at sea level.

He did not find his family, as they were safe on high ground. However, he observed the sea's unusual behavior, and it piqued his curiosity. Corral Bay was completely dry, something he had never seen before. Mr. García decisively headed toward the coast.

Today, we know the sea's withdrawal following an earthquake signals a tsunami's arrival. He was so focused on the exposed sea floor that he did not notice the great wave, 12 meters (40 feet) high, that was approaching. Although he tried to runaway, the wave caught him and dragged him toward the bay.

Denis García, 75 years old, lucidly remembers how his curiosity almost cost him his life. Shocked at finding Corral Bay dry following the 1960 earthquake, he did not notice the approaching 12 meter (40 foot) wave.

Despite Mr. García having spent his entire life next to the sea, he did not know how to swim. He clung to nearby floating debris and managed to stay afloat for hours.

Just when he was losing hope, the captain of a German boat came across him. Later, Mr. García would learn this was Walter Nordman, a World War II veteran. Mr. Nordman, an experienced swimmer, was saving his own life but still saved Denis. Both managed to climb onto the roof of a house that floated by (see p. 17).

Corral Bajo was completely destroyed by the 1960 tsunami waves that almost took Denis García's life.

By nightfall, the currents had taken both survivors to the coast, where they were finally rescued. Eager to find his family, Mr. García left immediately to search for them. Even today, he regrets not being able to thank the captain for saving his life. He never saw him again.

Corral Bay seen from Niebla. Soon after the 1960 earthquake, the bay's waters began to withdraw, leaving the sea floor exposed (above). This phenomenon, a tsunami warning sign, captured Denis García's attention. Below is a view of the same area in May 2009. A fishing boat, bottom right, serves as a scale.

Expect Many Waves

The next wave may be bigger, and the tsunami may last for hours.

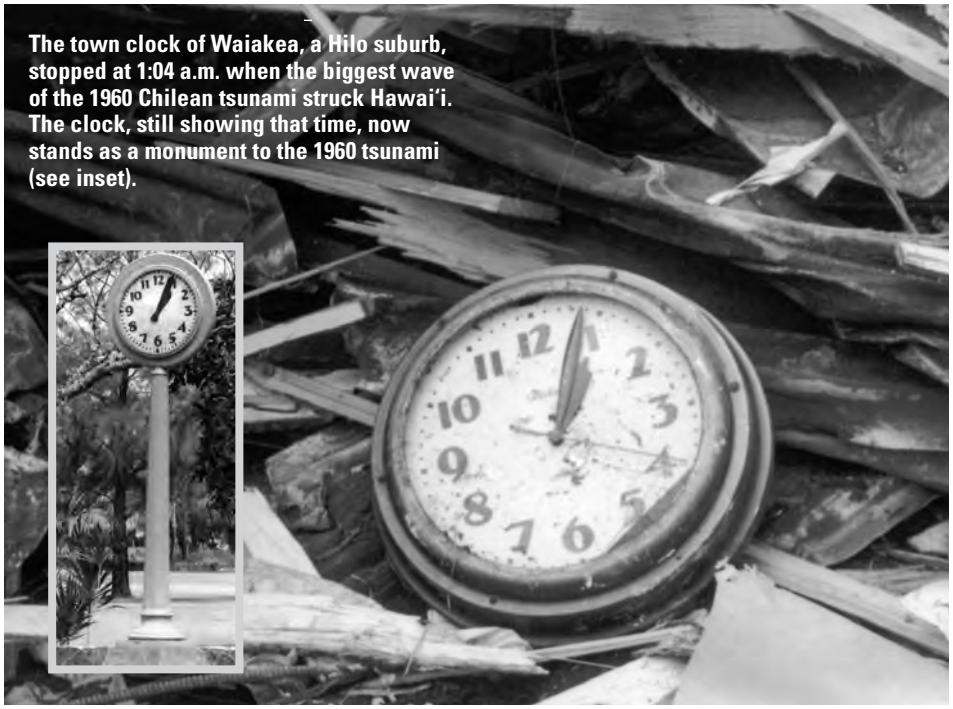
Just after 10 p.m. on 22 May 1960, seismologist Dr. Jerry Eaton and four companions assembled at the U.S. Geological Survey's Hawaiian Volcano Observatory on the Island of Hawai'i. Gathering cameras, notebooks, flashlights, and steel measuring tapes, they piled into a Ford station wagon for the 48.28 kilometer (30 mile) ride down to Hilo. There they hoped to measure the 1960 Chilean tsunami, which was expected to arrive at about midnight.

The men had good reason to measure this tsunami. Hawai'i had been struck in the past by deadly tsunamis, including ones from Chile in 1837 and 1877 and one from the Aleutian Islands in 1946 that in Hilo alone killed 98 people. Measurements of past tsunamis are commonly used to help identify areas at risk from future tsunamis. Measurements had been made in Hawaii of Aleutian tsunamis, but little was known about the heights of tsunamis from Chile.

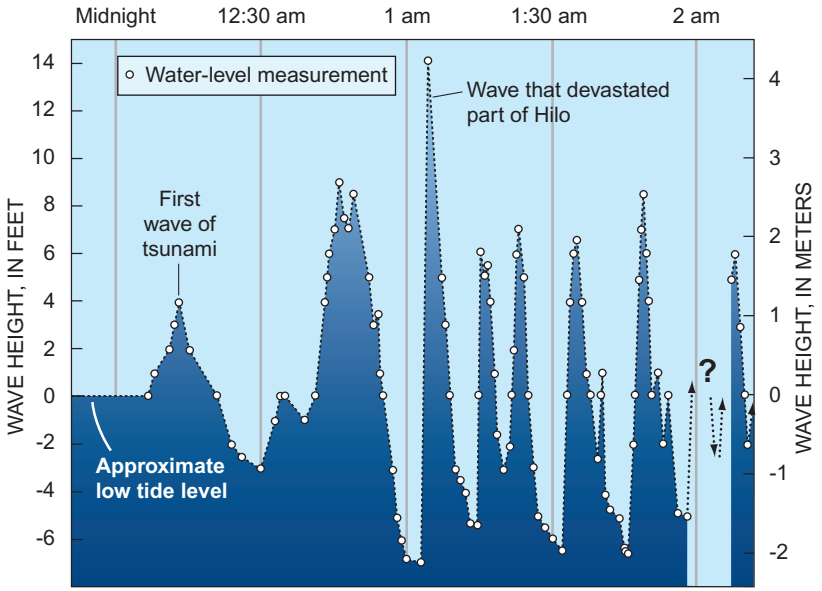
In Hilo, Dr. Eaton and his companions stopped to clear their plans with the police and then drove to the Wailuku River Bridge, on the shore of Hilo Bay (see map on p. 12). They knew that the 1946 Aleutian tsunami had destroyed the bridge there. The men set up an observation post on the new bridge and began measuring the water level beneath it. Just in case, they also planned their own evacuation route, a short sprint to high ground.

Just after midnight, the water under the bridge rose to 1.2 meters (4 feet) above normal—the first wave of the tsunami had arrived. At 12:46 a.m., the second wave washed under the bridge at a level 2.7 meters (9 feet) above normal. By 1:00 a.m., the water beneath the bridge had dropped to 2.1 meters (7 feet) below normal. Dr. Eaton recalls that they then heard an ominous noise, a faint rumble like a distant train, that came from the darkness far out in Hilo Bay. Two minutes later, they began to see the source of the noise, a pale wall of tumbling water, caught in the dim lights of Hilo. The wave grew in height as it moved steadily toward the city, and the noise became deafening.

By 1:04 a.m., the men on the bridge realized that they should run the tens of meters (few hundred feet) to high ground. Turning around, they watched the 6-meter-high (20-foot-high), nearly vertical front of the wave hit the bridge, and water splashed high into the air. After this wave had passed and they thought it was safe, Dr. Eaton and his companions returned to the bridge and continued to record the water level during several more waves of the tsunami (see diagram below).



The town clock of Waiakea, a Hilo suburb, stopped at 1:04 a.m. when the biggest wave of the 1960 Chilean tsunami struck Hawai'i. The clock, still showing that time, now stands as a monument to the 1960 tsunami (see inset).



TSUNAMI OF MAY 23, 1960, ON THE ISLAND OF HAWAII

The 1960 Chile earthquake produced a series of tsunami waves that crossed the Pacific Ocean. This record shows measurements of water levels beneath the Wailuku River Bridge made by seismologist Dr. Jerry Eaton and his companions during the first few hours of the tsunami in Hilo, Hawaii.

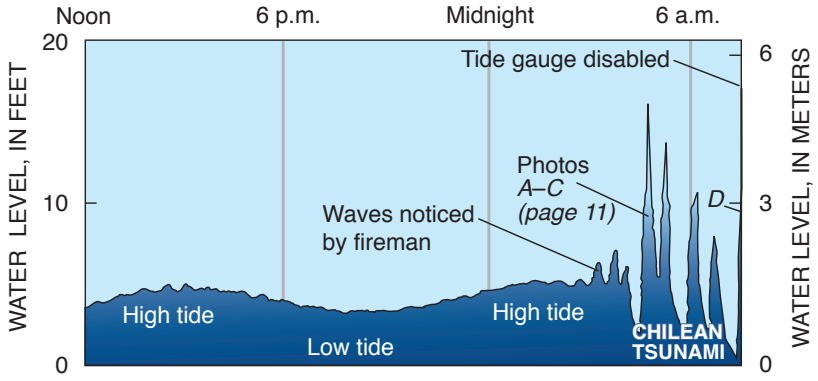
Head for High Ground and Stay There

Move uphill or at least inland, away from the coast.

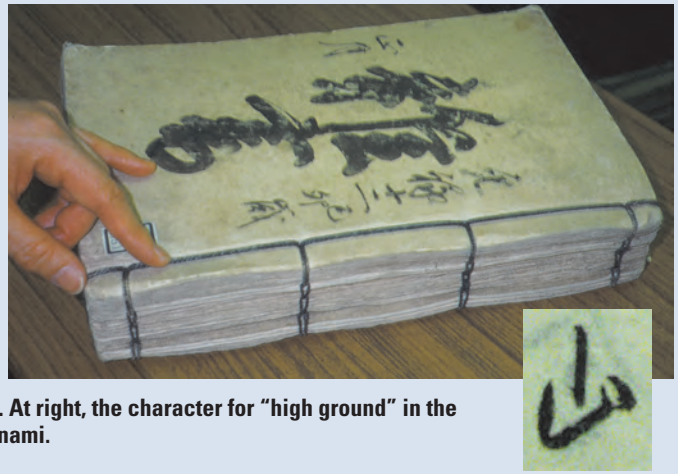
Going to high ground and staying there helped save lives during the 1960 Chilean tsunami, not only in Chile but also in Onagawa, Japan. Damaging waves in Onagawa, some of which carried battering rams of floating wood, reached heights of 4 meters (14 feet). Such waves kept arriving for several hours. Elsewhere in Japan, the tsunami killed 139 people, but in Onagawa no one died, probably because many people there went to high ground. Some residents arrived there by 4:45 a.m., as the first large wave entered town. They had been alerted by fireman Kimura Kunio. Mr. Kimura, on early morning watch beside the town's harbor, had noticed unusual motion of the water.

The 1960 tsunami was not the first South American tsunami to impact Japan. Tsunamis generated in Peru and Chile impacted the Japanese in 1586, 1687, 1730, 1751, 1837, 1868 and 1877.

Endo Fukuei (left, in 1999) recalls the fireman's warning that spurred citizens of Onagawa, Japan, toward high ground as the 1960 Chilean tsunami reached the town's harbor. Some residents gathered on a hillside as the first large wave poured into town (photos A-C at, p. 11). Almost 3 hours later, crowds remained on this hillside as another wave arrived (photo D, p. 11). Waves shown in the photos were recorded by a tide gauge in the Onagawa harbor (see below).



Tide-Gauge Record for 23 and 24 May 1960, at Onagawa, Japan



In Miyako, Japan, north of Onagawa, people went to high ground to escape the 1700 Cascadia tsunami (see p.3). Their flight is reported in this book of government records from 1700. The same records say that in Miyako this tsunami destroyed 13 houses, set off a fire that burned 20 more, and caused authorities to issue rice to 159 people. At right, the character for "high ground" in the entry about the 1700 tsunami.

People in Miyako, Japan, also went to high ground to escape the 1960 Chilean tsunami. Takanohashi Go (right), outside his family's grocery store in 1999, recalls the 1960 tsunami with fireman Yamazaki Toshio. As a middle-school student, Mr. Takanohashi ran uphill and escaped the tsunami's waves as they reached the store.


4:40 a.m.
Front of first large wave
Front of
train station
A


4:50 a.m.
Window pushed in
Debris in
swirling water
C


4:45 a.m.
Window still intact
Train station
B


7:30 a.m.
Window gone
Front of new wave
Water line from 4:55 a.m.
D

Heed Official Warnings

Play it safe, even if warnings seem ambiguous or you think the danger has passed.

There was plenty of time for evacuation in Hilo, Hawaii, as the Chilean tsunami raced across the Pacific Ocean on 22 May 1960. At 6:47 p.m. Hawaiian time, the U.S. Coast and Geodetic Survey (now the Pacific Tsunami Warning Center) issued an official warning that waves were expected to reach Hilo at about midnight. Around 8:30 p.m., coastal sirens in Hilo sounded and continued to sound intermittently for 20 minutes.

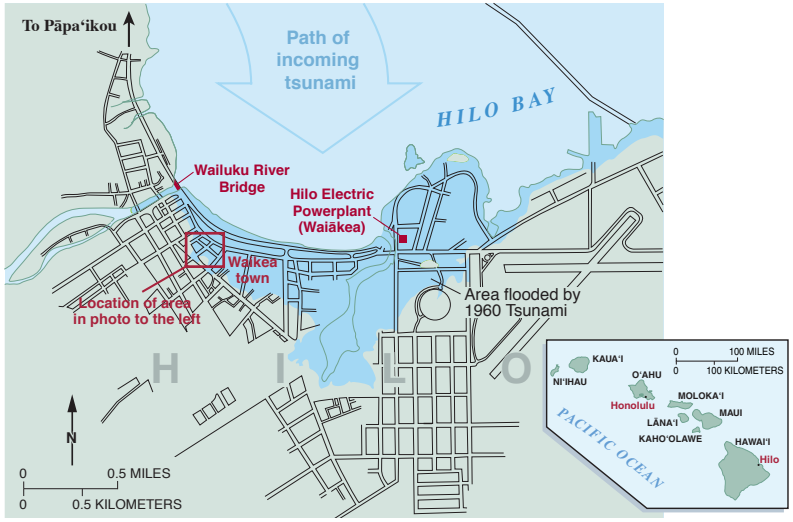
When the first wave, less than a meter (a few feet) high, arrived just after midnight, hundreds of people were still at home on low ground in Hilo. Others, thinking that the danger had passed, returned to Hilo before the highest wave of the tsunami struck at 1:04 a.m. on 23 May (see diagram on p. 9). One of those who came back too soon was 16-year-old Carol Brown.

Carol was at her family's house on low ground in Hilo when the warning sirens sounded. Carol's parents took valuables to a relative's house in Pāpa'ikou, a few miles northwest of Hilo, while Carol and her brother Ernest checked on a niece who was babysitting outside of town.

Later, Carol and Ernest returned to Hilo after hearing on the radio that tsunami waves had already come into town and were only 2.1 meters (7 feet) high. On the way back, they met a police officer who told them that the danger had passed. Carol and Ernest went to a sister's house in a low part of town. Around 1:00 a.m., they began to hear a low rumbling noise that soon became louder and was accompanied by sounds of crashing and crunching. Moments later, a wall of water hit the house, floating it off its foundation. When the house came to rest, Hilo was dark because the powerplant had been knocked out by the same wave.

Carol and her family survived the 1960 Chilean tsunami without serious injury. However, 61 other people in Hilo died and another 282 were badly hurt. These losses occurred, in part, because the warning sirens in Hilo on the evening of 22 May 1960, were interpreted differently by different people. Although nearly everyone heard the sirens, only about a third of them thought it was a signal to evacuate without further notice. Most thought it was only a preliminary warning to be followed later by an evacuation signal. Others in Hilo were unsure of how seriously to take the warnings, because several previous alerts had been followed by tsunamis that did little damage. The 1960 tsunami killed 61 persons in Hilo and caused 191 million USD in damage. Deadly Chilean tsunamis also hit Hilo in 1837 and 1877.

For the 2010 Chile tsunami, the Pacific Tsunami Warning Center issued a Tsunami Warning for the Pacific. In Hawaii, citizens heeded the advice and evacuated coastal areas. Damage exceeded 50 million USD to small harbors and beachside hotels, but no one died and no one was hurt.



In Hilo, Hawaii, although warning sirens sounded more than 3 hours before the first waves arrived, the meaning of these signals was not clear. Among those who evacuated in response was 16-year-old Carol Brown (wearing white dress in photo at right with her family in Pāpa'ikou). However, after hearing of small first waves and that the danger had passed, many people, including Carol and her brother Ernest, returned to homes in Hilo, only to be caught by the largest tsunami wave. The next morning revealed the destruction of Waikea town, where many locals had lived.

Abandon Belongings

Save your life, not your possessions.

Like everyone else in Maullín, Chile, Ramón Atala survived the 1960 Chile earthquake. However, he lost his life while trying to save something from the tsunami that followed.

Mr. Atala was Maullín's most prosperous merchant. Outside of town, he owned a barn and a plantation of Monterey pine. In town, he owned a pier and at least one large building and also had private quarters in a waterfront warehouse.

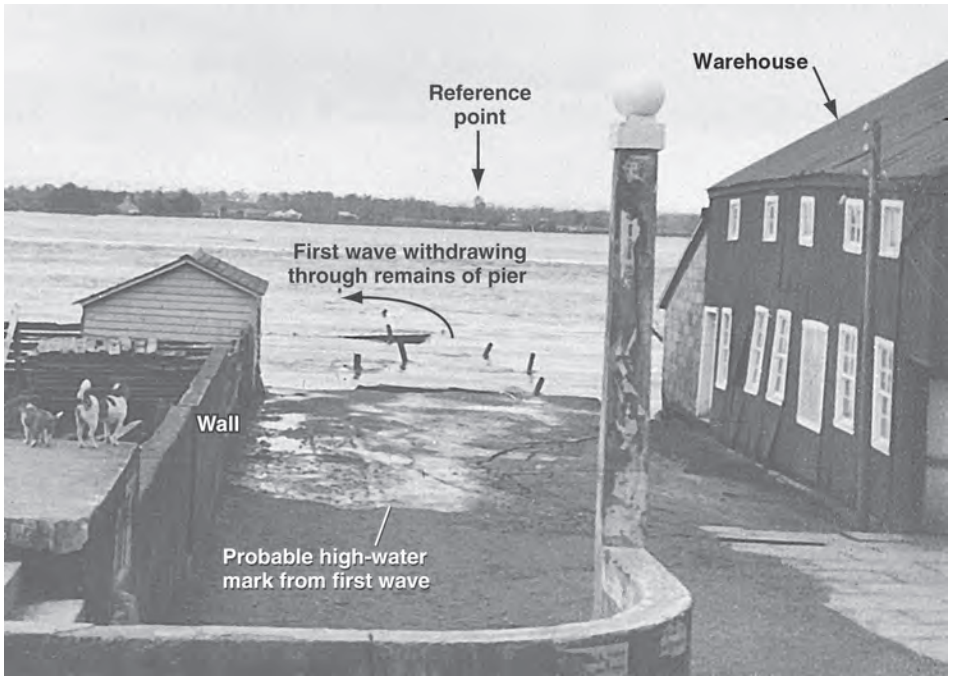
According to Nabih Soza, a fellow merchant, Mr. Atala entered this warehouse between the first and second waves of the tsunami that struck Maullín. Mr. Atala was probably trapped in the warehouse when the second wave of the tsunami washed the building away. His son, Eduardo, said that afterward his father was among the missing and that his body was never found.

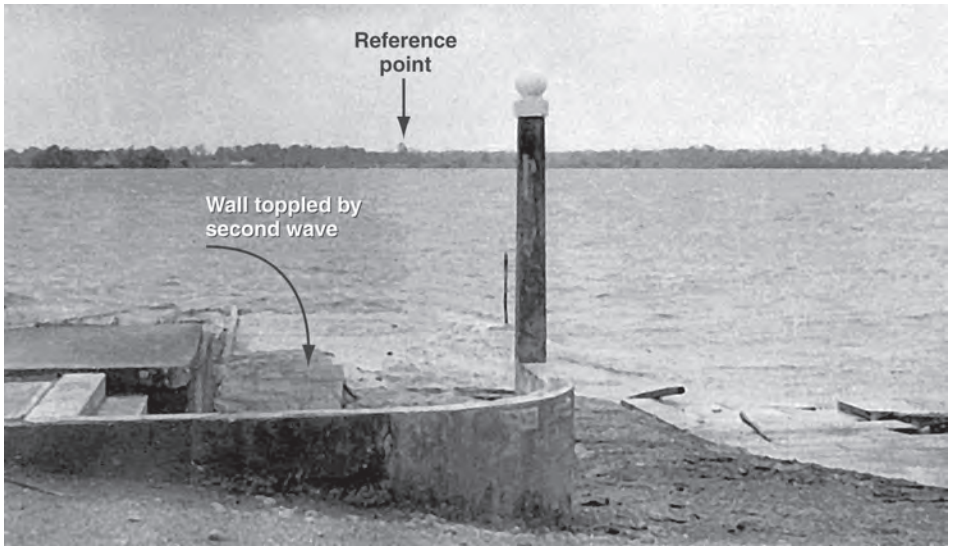
Some residents of the town say that Mr. Atala was briefly restrained outside the warehouse by his wife, who grabbed his hair before he finally broke away. Many in the town, spinning a cautionary tale about a wealthy man, say he entered the warehouse to rescue money.

Even as Mr. Atala was being carried off by the second wave, his barn outside of Maullín was providing a refuge for some 20 people, saving their lives from the tsunami (see story, p.15).

In 2010, a resident of Constitución (see map, inside cover) was in his riverfront home. Made of reinforced concrete, the house survived the magnitude 8.8 earthquake. After the earthquake, the man wisely evacuated to a safe zone. Upon returning, he found his house had been destroyed by the tsunami, and fish and debris had been left behind by the waves on what remained of his third floor.

Nabih Soza, at his store in 1989, remembers Ramón Atala, a fellow merchant in Maullín, Chile. Mr. Atala entered a warehouse in the town between the first and second waves of the 1960 Chilean tsunami.





Photographs taken during the tsunami show the warehouse as the first wave withdrew (top) and a similar view after the second wave washed the warehouse away (bottom).

Don't Count on the Roads

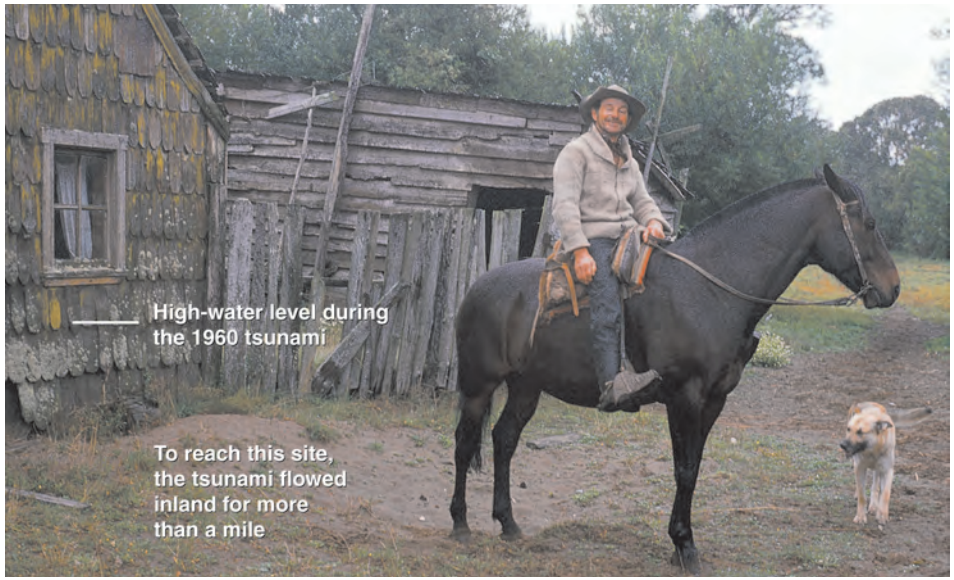
When fleeing a tsunami caused by a nearby earthquake, you may find roads broken or blocked.

Minutes after the 1960 Chile earthquake, René Maldonado rode his horse on the road from Maullín, Chile (see locations on photo, p. 17). During the ride, Mr. Maldonado's horse had to jump newly formed cracks in the road. The weakened road was soon severed by the waves of the tsunami that followed the earthquake, leaving channels too wide even for a horse to jump.

Not all people in the area fleeing the earthquake and the tsunami were as lucky as Mr. Maldonado. Some had their routes of escape severed by tsunami waves (see story, p. 15).

Shaking from the 1960 earthquake not only damaged roads but also caused landslides. In addition to blocking roads, landslides caused by the quake dammed the Río San Pedro in the foothills of the Andes about 64 kilometers (40 miles) east of the city of Valdivia, Chile. Later failure of this landslide dam unleashed a flood that covered parts of the city (see map on inside cover).

Similarly, the 2010 earthquake impacted roads, bridges and railways. For instance, in Concepción, the four bridges that cross the BioBío River were structurally damaged by soil liquefaction due to shaking.



At right, Mr. Maldonado poses on horseback in 1989 beside his 1960 home. Below, a photo from 1960 shows a main street in Valdivia, Chile, that was damaged when shaking from the earthquake caused land to spread toward the adjacent river.

The 1960 Chile earthquake cracked a road near Maullín, Chile, used minutes later by René Maldonado. This road was soon cut by the waves of the tsunami that followed the quake.

The 2010 Chile earthquake caused bridge slab sections in Tubul to collapse leaving the roadway unpassable.

Go to an Upper Floor or Roof of a Building

Only if trapped and unable to reach high ground, go to an upper story of a sturdy building or get on its roof.

The family of José Navarro, farming on a low peninsula near Maullín, Chile, had only one quick route to high ground after the 1960 Chile earthquake. The route was eastward along an unpaved road, across a bridge over a tidal stream, to uplands called Chuyaquén. Although a neighbor quickly took that route, the Navarro family stayed in their home, beside another tidal stream (see photo at lower right).

Some minutes after the earthquake, the Navarro family saw the waters of the stream recede. Never before had they seen so much of the streambed exposed. By then, the first wave of the tsunami that followed the quake was approaching but still out of view to the west (see locations on photo, p.17).

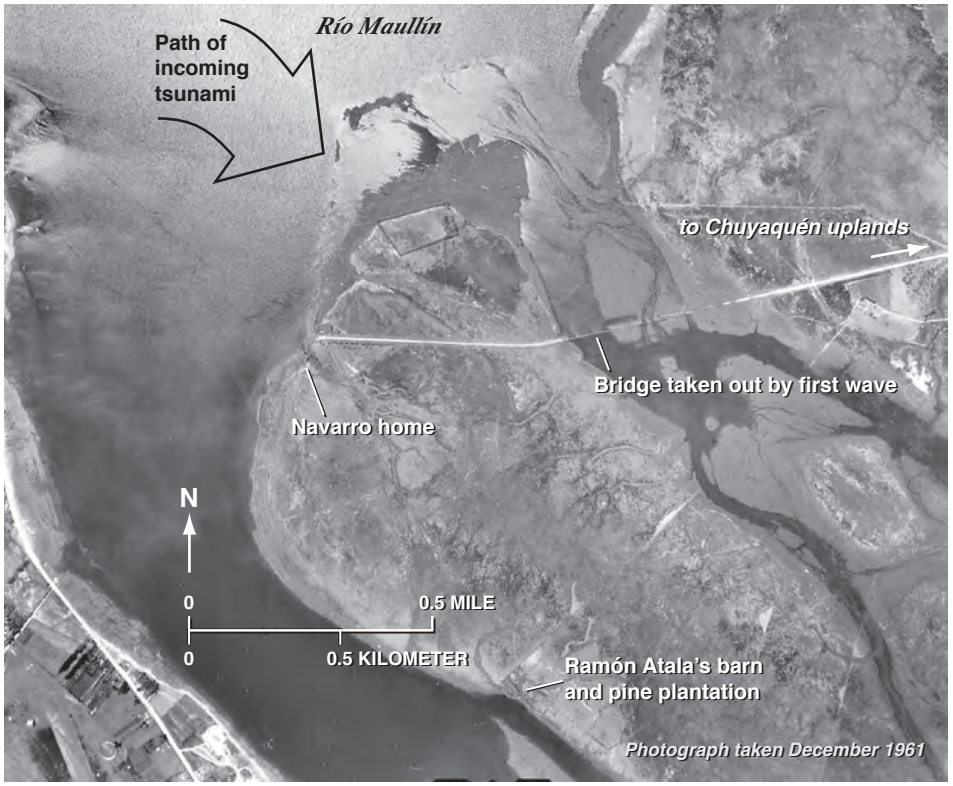
Only when they saw a low wall of water less than 1.6 kilometers (a mile) away did the Navarros head for high ground. The family needed to cover 0.8 kilometers (half a mile) just to reach the bridge that their neighbor had used. They got far enough to see the first tsunami wave destroy it in front of them.

As the first wave receded, they looked for something to climb. Nothing near them stood more than a meter (few feet) high, except for their 9-year-old apple trees and several windbreaks of cypress. Three quarters of a mile to the south, however, was a barn. This was among the properties of Ramón Atala, who was about to be carried away by the second wave in Maullín (see story, p. 13).

Although Mr. Navarro's wife and children headed for the barn, Mr. Navarro did not go with them. He thought he'd retrieve a few things from the family house. However, when he heard shouts from the direction of Maullín, he took them as a warning of a second wave and went directly to the barn.

The second wave reached the barn just as Mr. Navarro joined his family there. Along with 14 others, the Navarro family spent the night in the loft of Ramón Atala's barn, safe above the tsunami waters that ran beneath them.

Mrs. and Mr. Navarro, joined by a daughter, stand for a 1989 photo on the porch of their post-tsunami home on high ground near Maullín, Chile. The 1960 Chilean tsunami destroyed their former home, which was located on low ground by a tidal stream. Photo at right shows reference points for their flight to safety during the first two waves of the tsunami.



Climb a Tree

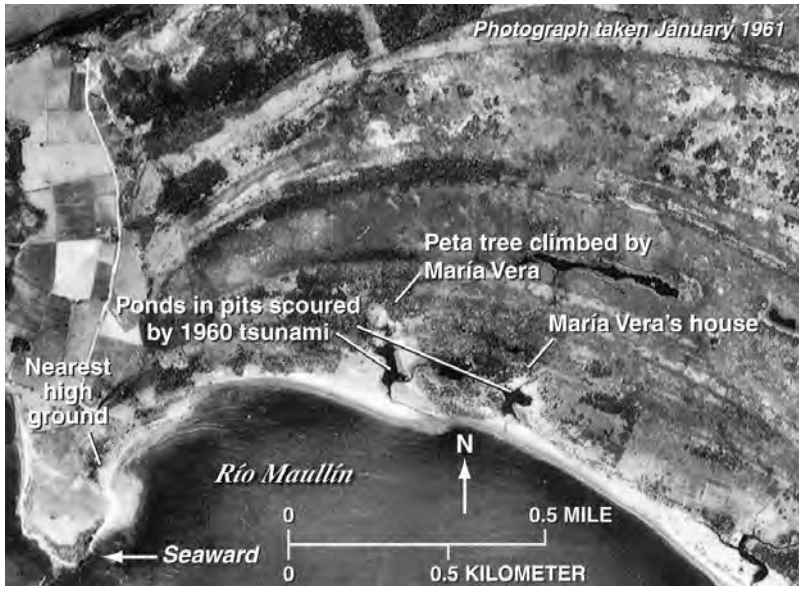
As a last resort, climb up a strong tree if trapped on low ground.

At least a dozen people near Maullín, Chile, survived the 1960 Chilean tsunami by climbing trees (see locations on photo, p. 17). However, others perished when the trees they climbed were toppled by the tsunami (see story, p. 17).

Ramón Ramírez, 15 years old at the time of the tsunami, survived by climbing into the branches of a cypress tree (photo at right) on a plain west of Maullín. While Mr. Ramírez stayed safely in the cypress, the waters of the tsunami swirled about the tree. The water crested at 4.6 meters (15 feet) above sea level, reaching about a meter (several feet) above the tree's base.

In nearby Quenuir, at the mouth of the Río Maullín, Estalino Hernández climbed an arrayán tree to escape the tsunami's waves. While he clung to the tree, the waters of the tsunami rose to his waist. Not far away, the onrushing water covered land 9.2 meters (30 feet) above sea level. Although Mr. Hernández survived the tsunami, he lost his 13-year-old son to the waves. Quenuir had 104 other victims, most of whom took to boats just after the earthquake and were caught by the first wave of the tsunami.

Inland from Quenuir, a pregnant María Vera and eight others climbed a peta tree on a low plain north of the Río Maullín (photo below). Throughout the night, water surged beneath them, scouring sandy ground nearby.



María Vera, pregnant and over a half mile from high ground, escaped the 1960 Chilean tsunami by climbing a peta tree outside of Quenuir, Chile. Ramón Ramírez (at right, in 1989) stands beside the cypress tree in which he safely stayed while the waters of the tsunami swirled about its base.

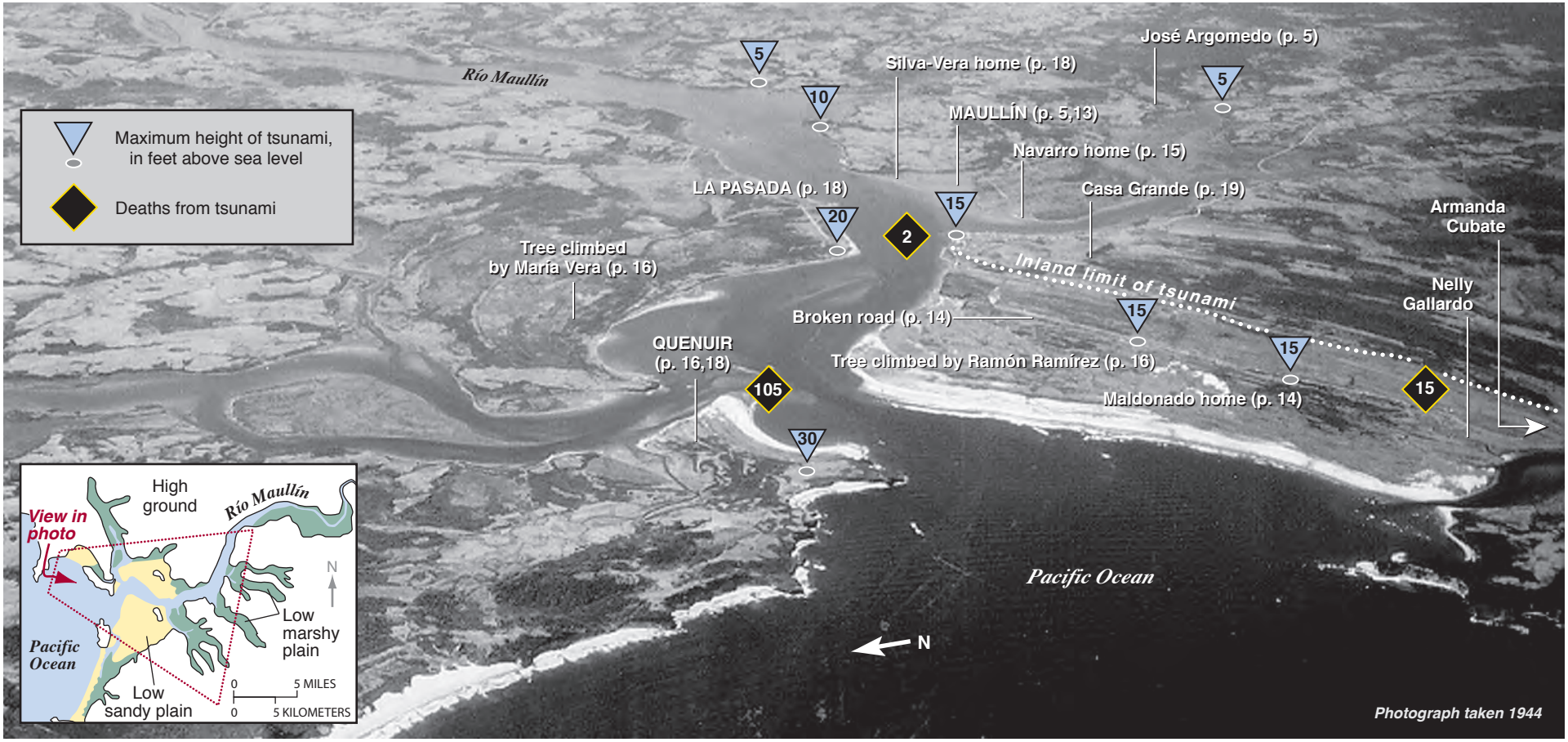
Climb onto Something that Floats

If swept up by a tsunami, look for something to use as a raft.

Drifting wood saved Nelly Gallardo during the 1960 tsunami. The parent earthquake struck while she was near the shore west of Maullín, Chile.

Soon after the shaking stopped, Ms. Gallardo headed inland on low ground, where waters of the first wave reached her knees. Turning back toward the shore to check on her house, she soon met the second wave, which swept her off her feet and defeated her attempts to swim. The next thing she recalls is a floating pole. It was a wooden rail, of the kind used for tying up horses, and Ms. Gallardo struggled to ride it. After a few hours, at dusk, currents carried the rail and rider into an arrayán tree. The tree's branches held Ms. Gallardo and two others through the night.

The roof of her family house served as a life raft for Armanda Cubate, her 4-year-old nephew Nelson, and five others. The house, on low ground west of Maullín, withstood the 1960 earthquake. The house also withstood the first two waves of the tsunami that followed the quake, but the third wave swept it away. This wave also toppled a nearby tree that Ms. Cubate's father had climbed to escape the tsunami. Both he and Ms. Cubate's mother drowned in the tsunami. Survivors on the roof later pulled the mother's body from the water.



As marked on this 1944 photo of the mouth of the Río Maullín, Chile, the 1960 Chilean tsunami flowed 3.2 kilometers (2 miles) inland from the beach at right foreground. In much of this flooded area, the tsunami reached a height of 4.6 meters (15 feet) above sea level. After being swept up by the tsunami, Nelly Gallardo floated on a wooden rail and Armanda Cubate took refuge on a roof (see far right in above photo). They survived the tsunami, but 15 other people near them died.

Expect the Waves to Leave Debris

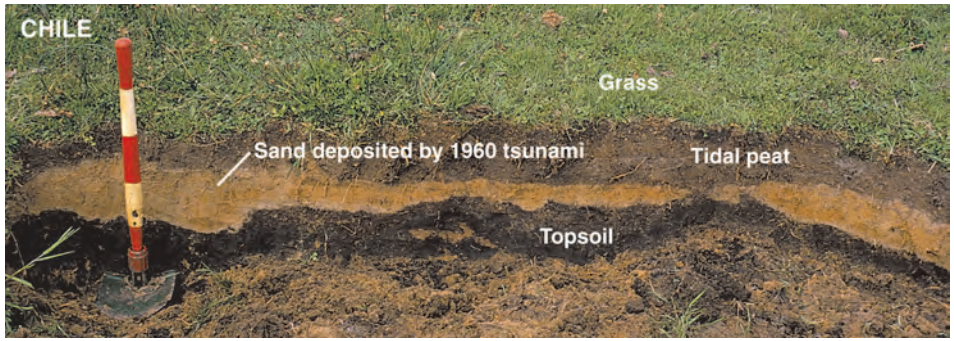
A tsunami will leave behind sand, the remains of houses, and bodies.

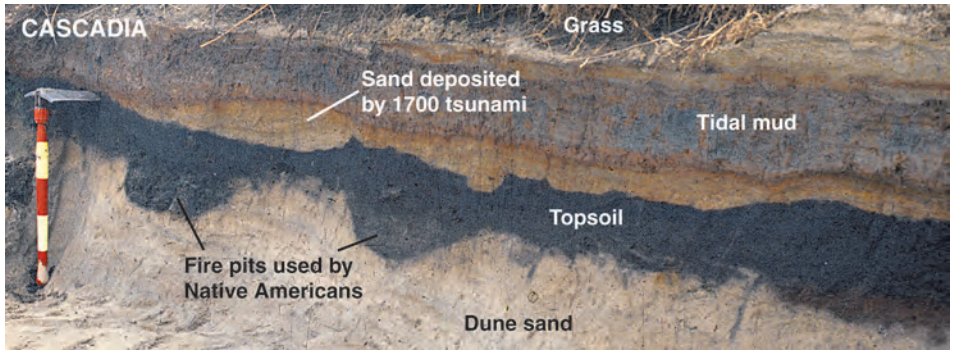
El maremoto fue tan grande que hasta los muertos sacó de sus tumbas ("The tsunami was so big that it even took the dead from their graves"). This saying comes from Quenuir, Chile, a village at the mouth of the Río Maullín (see locations on photo, p. 17). The tsunami that followed the 1960 Chile earthquake killed 105 people from Quenuir—a quarter of the village's population. In addition to this loss of the living, Quenuir lost many of its dead. The village cemetery was located on sandy ground that the tsunami washed away. Debris from the cemetery came to rest more than 4.8 kilometers (3 miles) upriver. There, just outside La Pasada, Tulio Ruiz found crosses and a full casket.

The 1960 tsunami also deposited sand along the Río Maullín, some of it on land owned by Juan Vera. He and his wife, María Isolina Silva, lived on low ground 3.2 kilometers (2 miles) east of Maullín. The 1960 earthquake found Mrs. Silva at home and her husband on a nearby hillside. Their house collapsed, but Mrs. Silva escaped and soon joined her husband on high ground. Together they watched the tsunami overrun their fields and carry away the remains of their house. The next day, Mr. Vera found a layer of sand several inches thick on much of the land the tsunami had overrun.

Many houses were carried inland by the 1960 tsunami. After fleeing to high ground near Queule, more than 160 kilometers (100 miles) north of Maullín, Filberto Henríquez saw houses floating away from the town. He recalls that some of the houses, with their stoves still smoking, looked like ships. Remains of houses from Queule ended up as much as a mile inland (according to a report by Wolfgang Weischet; see p. 6), but Margarita Liempí's house was deposited intact; even her drinking glasses were unbroken.

At Mehuín, near Queule, Jacinto Reyes buried some of the tsunami victims. Among them were the parents of two girls who were found in blackberry bushes, scratched but alive. Not all the tsunami victims were found quickly. About 10 days after the tsunami, Mr. Reyes happened upon bodies stuck in sand and being eaten by birds.





The 1960 Chilean tsunami deposited a sand layer on fields owned by Juan Vera near Maullín, Chile. When this picture of Mr. Vera was taken in 1989, the sand layer was still visible in a streambank (upper right photo, see map, inside cover, for location). A similar sand layer from the 1700 Cascadia tsunami covers the remains of a Native American fishing camp exposed in a bank of Oregon's Salmon River (lower right photo; see map, page 3, for location).

Expect Quakes to Uplift or Lower Coastal Land

A large earthquake can lower nearby coastal areas, allowing tidal water to flood them.

The 1960 Chile earthquake not only triggered a tsunami that killed Ramón Atala (see story, p. 13), but it also changed his Monterey pine plantation outside of Maullín, Chile, into a salt marsh. The pines, grown for timber, covered low ground around Mr. Atala's barn (see story, p. 15). During the earthquake, this land was lowered. Because tides were then able to inundate the plantation, the ground became too wet and salty for the trees to survive.

What happened to Mr. Atala's plantation happened at many places along Chile's coast. When a 966-km-long (600-mile-long) stretch of the South American tectonic plate was thinned during the 1960 earthquake, nearby land was lowered as much as 8 feet (see diagram B, p. 3). The sea was then able to cover coastal pastures, farms, and forests.

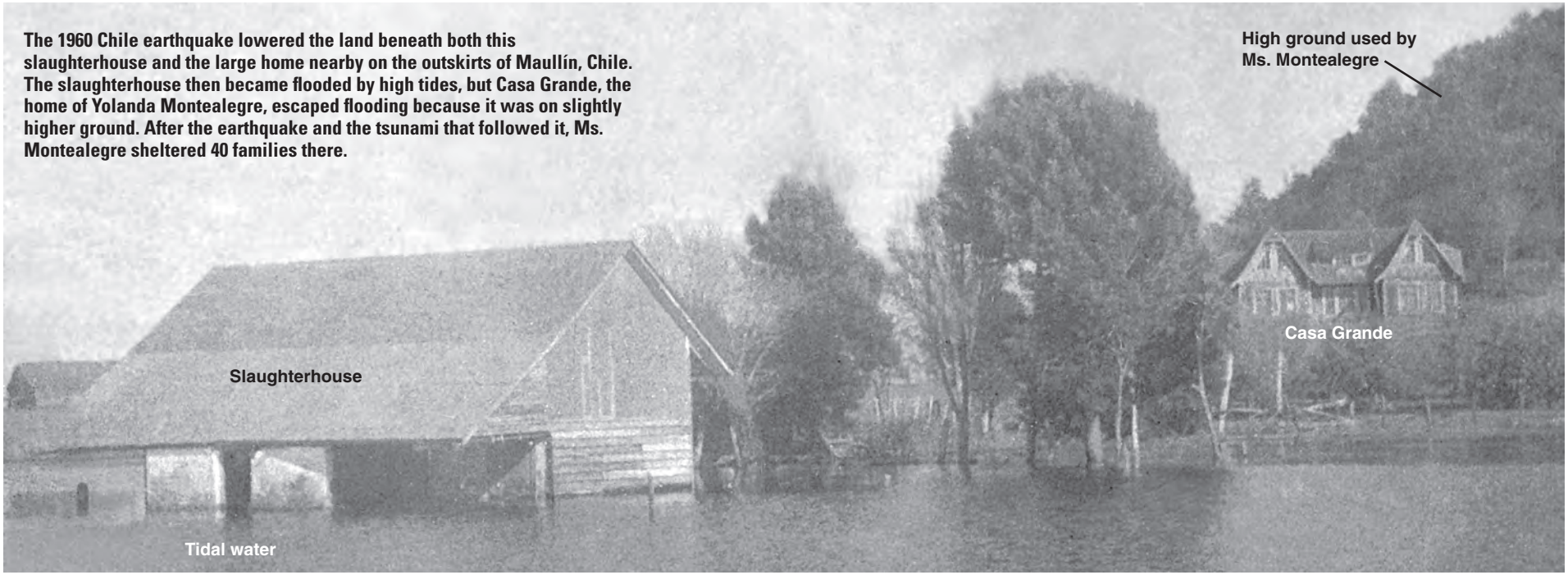
The 2010 magnitude 8.8 Chile earthquake resulted in 0.9-2.1 meters (3-7 feet) uplift in the south, and 0.5 meter (1.5 feet) of subsidence, or lowering, in the northern part of the affected coast. On the southern coasts of Arauco Peninsula and Isla Santa María, the uplift left shells and seaweed permanently dry (see photo).

At Isla Santa María (above), rising of the coast during the 2010 earthquake stranded coralline algae (white), mussels and seaweed.

Expect Company

Shelter your neighbors.

In the first weeks after the 1960 Chile earthquake and tsunami, Yolanda Montealegre provided shelter for 40 families in Casa Grande, her large home on the outskirts of Maullín, Chile (see locations on photo, p. 17). Ms. Montealegre left her house minutes after the earthquake and reached high ground in time to watch the arrival of the second wave of the tsunami that followed the quake. The next morning, she found Casa Grande in good shape, its ground floor dry. The families she soon took in were among the estimated 1 million Chileans left temporarily homeless by the earthquake and tsunami.



The 1960 Chile earthquake lowered the land beneath both this slaughterhouse and the large home nearby on the outskirts of Maullín, Chile. The slaughterhouse then became flooded by high tides, but Casa Grande, the home of Yolanda Montealegre, escaped flooding because it was on slightly higher ground. After the earthquake and the tsunami that followed it, Ms. Montealegre sheltered 40 families there.

Credits and Sources

People Interviewed

Listed alphabetically by father's last name. Numerals give age in 1960, omitted if age not recorded. Bold type denotes people named in this booklet or shown in one of its photographs.

Maullín, Quenuir, and La Pasada, Chile

Ricardo Águila (34), Juan Águila (36), Carlos Andrade (12), **José Argomedo Hernández** (22), José Asencio Cárcamo (45), Elisa Asencio Téllez (19), **Eduardo Atala B.** (42), Reinaldo Cárcamo (52), Hernán Cárcamo Gómez (33), Víctor Chávez Villegas (56), **Armanda Cubate** (38), Nelson H. Cubate O. (4), **Palmira Estrada Estrada** (27), **Nelly Gallardo** (23), René García Silva (39), Hermógenes Gómez Rival, Adelina Gómez Rival (44), Felisa del Rosario Hernández Paredes (39), **Estalino Hernández** (54), Gaspar Hernández, Tulio Hernández, René Leichtle Krebs (43), **René Maldonado** (30), Alejandrino Mancilla, Antonio Segundo Mancilla (22), Bernarda Mancilla S. (23), **Yolanda Montealegre Mücke** (40), Rodrigo Morales, Fidel Navarro (50), Oscar Navarro Navarro (34), **José Miguel Navarro Silva** (44), Enoc Ojeda (20), José B. Ojeda Muñoz (40), Julia Paredes Toledo (54), **Ramón Ramírez Solís** (15), Braulio Reyes, Jorge Ruiz (34), **Tulio C. Ruiz** (23), José Rupertino Sánchez Gallardo (15), René Serón (36), **María Isolina Silva** (29), Domitila Solís (50), Pedro Soto (62), **Nabih Soza** (23), Gastón Ezequiel Toledo Arria (22), José Elizardo Torralbo (27), **María Vera** (42), Guillermina Vera Mancilla (39), **Juan Vera Mancilla** (34), father of Ángela Vera Reyes.

Valdivia, Puerto Saavedra, Mehuín and Queule, Chile

Denis García (75), Erna Espinosa, Elsira Flores, **Filiberto Henríquez Jaramillo** (32), **Martín Huaracán**, Hernán Liempí (11), **Margarita Liempí** (18), **Vitalia Llanquimán**, Mr. & Mrs. Moraga, Gilberto Nahuelpán Liempí (25), Daniel Nahuelpán Rumillanca (32), **Juan Peña**, Alberto Perón Antilco (23), **Jacinto Reyes Reyes** (54), **Jovita Riquelme** (45), Alejandro Villagrán Rojas (25), Andrea de Mehuín, Erasmo de Mehuín (23), Diodema de Mehuín (35).

Onagawa and Miyako, Japan

Endō Fukuei (40), Moriai Miya (40), Moriai Mutsuhara (22), **Takanohashi Gō** (12), Yamasaki Nori (26), **Yamazaki Toshio**, Kimura Tsuneo (28)**.**

Hilo (Hawái)

Carol D. Brown (16) and **Jerry P. Eaton** (33).

Book Preparation

Interviews (C, Chile; J, Japan)

Brian F. Atwater (C, J), Joanne Bourgeois (C), José Ulloa Cortés (C), Marco A. Cisternas Vega (C), Héctor Jiménez Núñez (C), Marcelo López Bermedo (C), Carlos Pineda (C), Musumi Satoko (J), Mary Ann Reinhart (C), Adriana Sandoval Lagos (C), Tsuji Yoshinobu (J), Ueda Kazue (J) and David K. Yamaguchi (J).

Interviews (Hawaii)

Adapted from stories of tsunami survivors in Tsunami! by Walter C. Dudley and Min Lee, 1998 (University of Hawaii Press), and supplemented with 1999 interviews done by Walter C. Dudley, Peter H. Stauffer, and James W. Hendley II.

Photographs, Maps and Figures

Marco A. Cisternas Vega (p. 8, 19), Escuela de Arquitectura y Diseño de la Pontificia Universidad Católica de Valparaíso, Chile (p. 7, cover), Fuerza Aérea de Chile, Servicio Aerofotogramétrico (p. 15, image 16019), Honolulu Advertiser (p. 12), Ilustre Municipalidad de Maullín (p. 5, 13, 19), Diego Muñoz (p. 8), Pacific Tsunami Museum (p. 9, 12), Saint-Amand (1963; p. 6 y 14), Hellmuth Sievers (p. 8), Universidad de Tokio (p. 10, 11) y U.S. Defense Mapping Agency (p. 16, image 503-333; p. 17, image 552.R.13), UNESCO/ Daniel Melnick (p. 14), Constanza Vallejos (p. 2), A. Yamauchi (p. 14), María Carolina Zúñiga (p. 7), ITIC (p. 4), USGS (p. 3, 9, 10).

Critical Reviews

Sally Atwater, Sergio Barrientos, Susan Beck, Eddie Bernard, Jan Bono, Steven R. Brantley, Gary Brown, George Crawford, Lori Dengler, Paula Dunbar, Rich Eisner, Stephanie Fritts, Imamura Fumihiko, Eric Geist, Helen Gibbons, Frank González, Dick Hagemeyer, T.J. Harmon, Víctor Huérfano, Chris Jonientz-Trisler, Hal Mofjeld, Alan Nelson, Dave Oppenheimer, Jim Phipps, George Priest, Christa Rabenold, Peter Stauffer, Uri ten Brink, Barbara Thurman, Vasily Titov, John Vollmer, Christa von Hillebrandt-Andrade.

Other assistance

Mario Pino (Universidad Austral de Chile); Carolina Villagrán and Sergio Barrientos (Universidad de Chile); Maullín Gracilaria research team (Universidad Austral de Chile). Isoda Hisako, Kishimoto Kiyo and Satake Kenji (Geological Survey of Japan); Murakami Yoshikanei, Satō Hiroshi and Watanabe Tokie (University of Tokyo, Earthquake Research Institute); Abe Motomu (Town of Onagawa) and Ota Yoko.

For Additional Information

1960 Chilean earthquake and tsunami

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Tsunami-hazard information on the World Wide Web

http://www.ioc-tsunami.org
http://www.ngdc.noaa.gov/hazard/tsu.shtml
http://www.tsunamiwave.info
http://www.tsunami.gov

In interviews several decades later, people in Chile, Hawaii, and Japan recall the tsunami caused by a magnitude 9.5 earthquake that struck Chile in 1960. Their accounts contain lessons on surviving a tsunami:

- Many will survive the earthquake
- Heed natural warnings
- Take oral traditions into account
- Beware of an unusual withdrawal of the water
- Expect many waves
- Head for high ground and stay there
- Heed official warnings
- Abandon belongings
- Don't count on the roads
- Go to an upper floor or roof of a building
- Climb a tree
- Climb onto something that floats
- Expect the waves to leave debris
- Expect quakes to uplift or lower coastal land
- Expect company

The majority of this booklet is from United States Geological Survey (USGS) Circular 1218 and material that is free for public use. Circular 1218 can be found at the following webpage: http://pubs.usgs.gov/circ/c1218/

The booklet was updated to include the survivor experiences from the magnitude 8.8 earthquake and tsunami that struck Chile in 2010.

ITIC International Tsunami Information Center — www.tsunamiwave.info

Pontificia Universidad Católica de Valparaíso

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Intergovernmental Oceanographic Commission

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