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COAST AND GEODETIC SURVEY C&GS 33

The Tsunami of March 28, 1964, as Recorded at Tide Stations

Rockville, Md.
July 1967

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Alexander B. Trowbridge, Secretary

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Robert M. White, Administrator

COAST AND GEODETIC SURVEY
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ESSA TECHNICAL REPORT C&GS 33

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ABSTRACT

The tsunami generated by the Prince William Sound Earthquake of March 28, 1964 (G.M.T.), was the largest since the 1960 Chilean tsunami. Seiche action was damaging as far away as the Gulf of Mexico. This report contains 105 reproductions of tide curves showing the tsunami, and 8 curves showing oscillations induced by the long-period seismic waves—6 in the Gulf of Mexico and 2 at Arkansas damsites. A brief history of the Seismic Sea Wave Warning System [Tsunami Warning System since March 15, 1967] and a report of its operation during the tsunami warning action are included. Fatalities totaled 122, and over $104 million in damage resulted. These are tabulated together with detailed data on wave heights and arrival times at various stations throughout the Pacific.

INTRODUCTION

THE PRINCE WILLIAM SOUND EARTHQUAKE of 03:36:14.0 G.M.T., March 28, 1964, was one of the largest shocks ever recorded on the North American Continent. The epicenter was located at 61.04° N., 147.73° W., between Crescent Glacier and Unakwik Inlet. The magnitude, as determined by the U.S. Coast and Geodetic Survey, was 8.3 ± 0.33. This earthquake, in addition to generating a major tsunami of record size along much of the Pacific coast of North America, caused several local tsunamis which were responsible for locally heavy damage (table 1) in various arms and inlets of Prince William Sound. It also generated seiches in rivers, harbors, channels, lakes, and swimming pools as distant as the U.S. Gulf Coast States.

The major tsunami connected with the Prince William Sound Earthquake was generated by broad crustal warping along a northeast-southwest trending hinge line. This hinge line (1) runs roughly parallel to the southeast coast of Kodiak Island; (2) passes across Narrow Cape and seaward of Cape Chiniak; (3) turns toward the north and passes across the eastern portion of the Kenai Peninsula and the western portion of Prince William Sound; (4) swings east in the vicinity of the epicenter; and (5) passes just south of Valdez, terminating near the Copper River. South and east of this hinge zone, an area stretching from Kodiak Island to Kayak Island was uplifted as much as 50 feet according to U. S. Coast and Geodetic Survey bathymetric surveys. The seaward limits of the uplifted zone have not been definitely established, but the zone includes most of Prince William Sound and the continental shelf from Kayak Island to Sitkinak Island. The zone of uplift probably includes portions of the continental slope and may extend seaward as far as the Aleutian trench; it is roughly equivalent to the zone of aftershocks, as shown on figure 1. North and west of the hinge line, an area that includes most of Kodiak Island, Shelikof Strait, Cook Inlet, the Kenai Peninsula, and the Chugach Mountains subsided by amounts up to more than 7 feet.

The generating area of the major tsunami is roughly equivalent to the area of uplift and is shown in figure 2. This illustration is simplified and shows only the source of the first motion registered by tide gages outside this area. Within the generating area, the motion of the water was extremely complex and was further compounded by waves generated by local slides and, particularly within Prince William Sound, by complex local diffraction, refraction, and reflection patterns. If the assumption is made that all elevation changes that occurred during the earthquake happened instantaneously, the initial impulse given to the ocean is somewhat as shown in cross sections A-A' and A'-A" on figure 2.

LOCAL WAVES

In many of the harbors and bays along the south and east coast of the Kenai Peninsula and the northern shore of Prince William Sound, subaqueous landslides occurred and generated highly destructive local waves. The principal destructive local waves occurred at Seward, Valdez, and

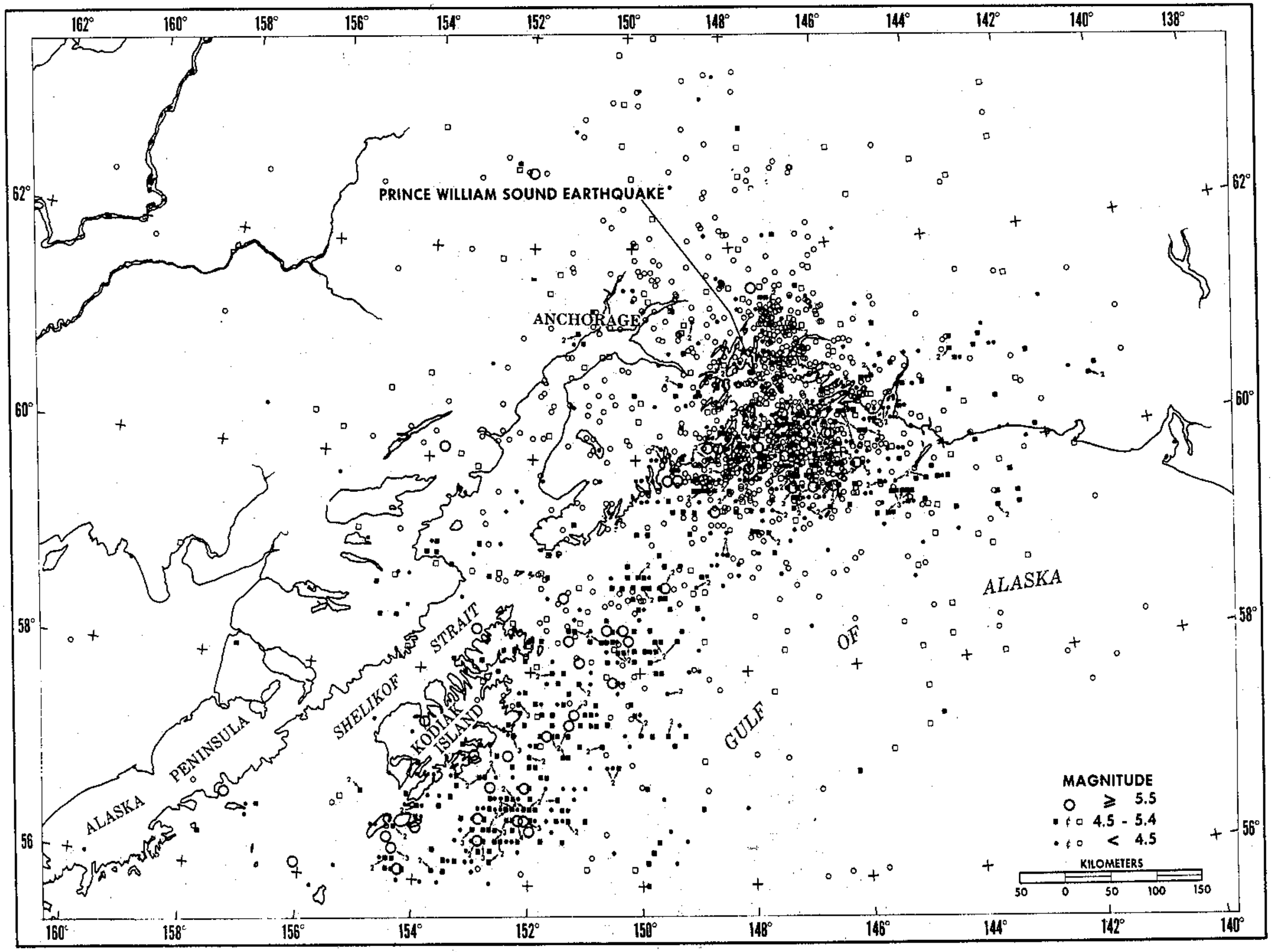

FIGURE 1.—The Prince William Sound Earthquake of March 28, 1964, epicenter and aftershock locations through December 31, 1965. The symbols ○, ■, and ● indicate aftershocks located by using teleseismic data. The symbols □ and ○ indicate aftershocks located by using data from the net of temporary seismograph stations installed after the March 28 earthquake.

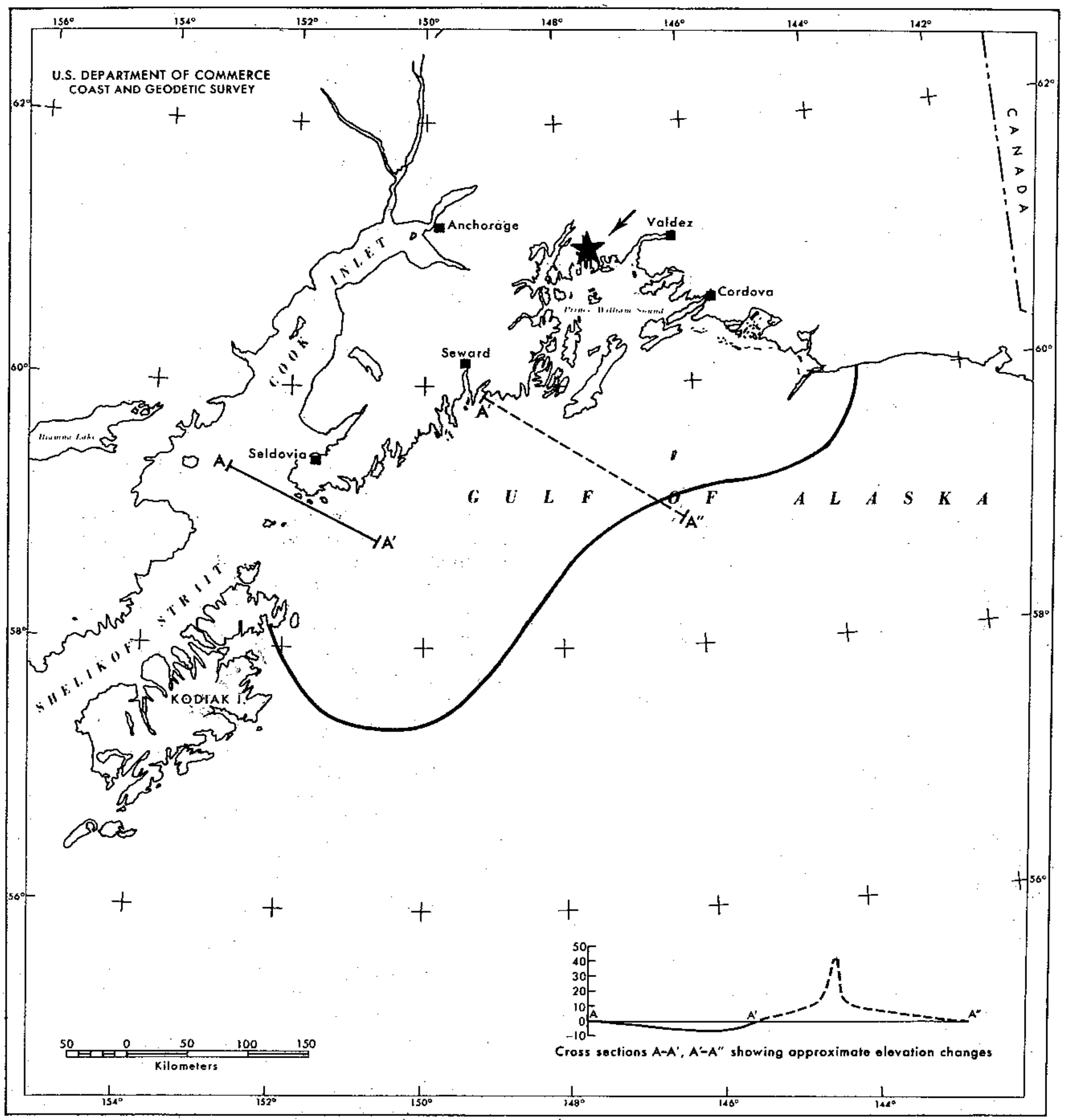

FIGURE 2.—Generation area of Prince William Sound tsunami.

Table 1.—Casualties and major damage due to the tsunami of March 28, 1964

Location	Casualties	Damage
		Dollars
Alaska		
Cape St. Elias	1	....
Chenega	23	100,000
Cordova	....	1,775,000[1]
Kaguyak	3	50,000
Kalsin Bay	6	....
Kodiak (City)	8	31,279,000[2] —(23,714,000 private; 7,565,000 public)
Kodiak Naval Station	....	10,300,000[2]
Old Harbor	1	150,000
Ouzinkie	....	500,000
Port Ashton	1	....
Port Nellie Juan	3	....
Point Nowell	1	....
Seldovia	....	500,000[1]
Seward	12	14,614,000[1]
Spruce Cape	3	....
Valdez	31	12,568,000[1] (8,453,000 private; 4,115,000 public); 15,000,000[2]
Whitshed	1	....
Whittier	13	10,000,000[2]
British Columbia, Canada		
Alberni-Port Alberni	....	10,000,000[4]
Hot Springs Cove	....	100,000
Zeballos	....	150,000
Oregon		
Cannon Beach	....	230,000[5]
Florence	....	50,000[5]
Newport	4	....
Seaside	....	276,000[5]
Waldport-Alsea	....	160,000[5]
California		
Crescent City	11	7,414,000[6]
Long Beach Harbor	....	100,000[6]
Los Angeles	....	175,000 to 275,000[6]
Marin County	....	1,000,000[6]
Noya Harbor	....	250,000 to 1,000,000[6]
Hawaii		
Hilo	....	15,000[7]
Maui	....	52,590[7]

[1]*Anchorage Daily News*, April 18, 1964.
[2]Tudor, 1964.
[3]*Daily Alaska Empire*, March 31, 1964.
[4]Civil Defense estimated damages of $5 million, excluding damage to heavy industry and private autos.
[5]Sandstrom, 1964.
[6]California Disaster Office, 1964.
[7]Stevenson, 1964.

Whittier. In this section, no attempt has been made to separate the damage caused by the earthquake from the damage caused by the landslides, the tsunamis, or both.

Seward

At Seward, a stretch of the waterfront about 3,500 feet long and as much as 300 feet wide, including all waterfront facilities from the Standard Oil Company dock north to the San Juan dock, slid into Resurrection Bay shortly after the earthquake started and while the shaking was still intense. These facilities included the Standard Oil docks and warehouses, the Army docks and warehouses, the City dock, the small-boat harbor, the San Juan dock, the cement plant, and the marine ways.

The slide drew water out from the shoreline and created one or two boillike disturbances at distances estimated from several hundred feet to perhaps one-half mile from the shore; from these disturbances waves spread in all directions. Oil from waterfront fuel storage tanks which had been ruptured by the earthquake immediately ignited, and the waves spread fire along the waterfront.

The ground which slid into Resurrection Bay was water-soaked alluvium. According to charts of the Seward harbor, the preearthquake offshore slope was between 30° and 35°. The instability of this slope under the earthquake-induced vibration was vividly demonstrated. The slide and the tsunami wiped out almost the entire economic foundation of Seward and caused 12 deaths (table 1).

The wave generated by the slide caused considerable damage to the railroad yards and reached a maximum height of about 30 feet at Lowell Point (Grantz, Plafker, and Kachadoorian, 1964). Approximately one-half hour later, a wave—probably the first of the major tsunami series—struck Seward, destroying the Alaska Railroad docks, washing out railroad and highway bridges, and piling railroad rolling stock into giant windrows of wreckage. It spread flaming petroleum over the waterfront, igniting the rolling stock, the electrical generation plant, and some residences. This wave also swept many dwellings from the vicinity of the small-boat harbor, and washed boats into the lagoon north of Seward and onto the tidal flats at the head of Resurrection Bay.

Valdez

Local waves were generated by slides in two separate areas of Port Valdez—one at the town of Valdez and the other near the mouth of Shoup Bay. The wave—generated near Shoup Bay by large submarine slides of portions of the terminal moraine that occupies the mouth of the bay—deposited driftwood at an elevation of 170 feet above lower low water near the site of the Cliff Mine, and splashed silt and sand as much as 220 feet above lower low water at the same place (Plafker and Mayo, 1965). Waves from this source washed the Middle Rock Light in Valdez Narrows off the 35-foot reinforced concrete pedestal on which it was mounted.

The town of Valdez was situated on the edge of an outwash delta consisting of unconsolidated silty sand and gravel. This delta lies at the head of the deep, steep-sided fiord of Port Valdez. Before the earthquake, the offshore slope of the delta face was approximately 15°. During the earthquake, the shaking caused failure of the unstable, water-saturated material, and a slice, approximately

4,000 feet long and 600 feet wide, slid into the sea and carried the dock area and portions of the town with it. The slide generated a wave which slammed into the waterfront within 2 to 3 minutes of the onset of the earthquake. In a report to the owners, the captain of the SS *Chena*, which was unloading cargo at the Valdez dock at the time of the earthquake, stated that his ship was raised about 30 feet and heeled over 50° to 70° by the initial wave. This wave demolished what was left of the waterfront facilities, caused the loss of the fishing fleet, and penetrated about 2 blocks into the town. Thirty-one people lost their lives in the slide and the subsequent waves (table 1).

Whittier

Slides of unconsolidated water-soaked alluvium around the head of Passage Canal generated waves that destroyed much of the Whittier waterfront before the earthquake ended.

According to witnesses, three waves struck Whittier, with the second one causing most of the damage. One of the waves, probably the same one that caused the major damage in Whittier, reached a height of 104 feet above lower low water (Plafker and Mayo, 1965). The waves destroyed two sawmills; the Union Oil Company tank farm, wharf and buildings; the Alaska Railroad depot; numerous frame dwellings; and the railroad ramp handling towers at the Army pier. They also caused great damage to the small-boat harbor. As at Seward and Valdez, fire broke out at the tank farm and contributed to the destruction. Thirteen people were killed at Whittier by the tsunami (table 1). After the locally generated waves dissipated, the tsunami did not reach above the extreme high water line.

Miscellaneous

Major waves were noted at other localities within Prince William Sound, minutes after the earthquake. Although the wave action at some of these places may have been generated locally, it is probable that most of the disturbances noted were caused by the tectonic warping and were part of the major tsunami. Due to the many islands, inlets, and passages in western Prince William Sound, the waves built to great heights and caused considerable damage in many places. At Chenega, where 23 people were killed, 19 of 20 houses were washed away, and the water reached a school, which was located 90 feet above sea level. At Port Nellie Juan, the dock was destroyed, and three lives were lost. In this general area, maximum heights reached by the tsunami ranged from 50 to 70 feet, although the maximum at Port Nellie Juan was much lower. At Point Nowell, a wave which reached about 40 feet above sea level washed away two cabins and killed their owner. Port Ashton sustained little damage, although one person was drowned.

In many Prince William Sound localities, the water reached the highest level close to the time of high tide which occurred between 1000 and 1100 G.M.T. At Cordova, the tsunami caused extensive damage to the docks and floated away some houses near the waterfront. Here, the maximum height reached by the tsunami was about 5 feet above the highest high-tide line. At Whitshed, near Cordova, 10 cabins were washed away; one person, who had returned to his cabin believing the danger had ended, was drowned.

THE SEISMIC SEA WAVE WARNING SYSTEM

History and Description

After the devastating Aleutian tsunami of April 1, 1946, military and civilian sources criticized the U. S. Coast and Geodetic Survey for the lack of warning in the Hawaiian Islands. The critics correctly pointed out that seismic waves from this earthquake were recorded at Honolulu and other observatories within minutes after the occurrence of the earthquake; and consequently, the tsunami could have been predicted. The error in this criticism lay in the fact that seismograph records were changed only once each day, and until the film records were developed, no knowledge of an earthquake occurrence was normally available. In addition, the great majority of underwater earthquakes does not cause tsunamis, and no arrangements were in effect to verify the existence of a tsunami through actual observation.

Another necessity for efficient operation of a warning system was the development of a method to determine quickly and accurately the amount of time between the occurrence of a tsunami-producing earthquake and the arrival of the waves in the Hawaiian Islands. This problem was solved by the preparation of a seismic sea wave traveltime chart for Honolulu in early 1947. This chart consists of a series of more or less concentric lines overprinted on a chart of the Pacific Ocean. The lines represent distances from Honolulu for each half hour and hour of the wave's traveltime. Traveltime to Honolulu is obtained by plotting the epicenter of an earthquake on the chart and noting its position with respect to the time lines. Given the time of the disturbance, the arrival time of the first sea wave at the Honolulu tide station becomes immediately available. The need for traveltime charts based on other tide stations became evident early in the operation of the Seismic Sea Wave Warning System (SSWWS). This need was based on two factors: (1) The necessity of estimating when the existence or absence of a wave could be observed at a particular tide station, and (2) the necessity of providing accurate estimates of tsunami arrival times to additional countries and

areas. Charts for all tide stations in the SSWWS were completed by 1950. Traveltime charts are prepared on a continuing basis for new tide stations that join the Warning System from time to time. Because the manual preparation of traveltime charts is a tedious, time-consuming task, a computer program is being developed to compute the charts.

Personnel in the U. S. Coast and Geodetic Survey, especially Comdr. E. B. Roberts, believed that the technical problems preventing the establishment of a workable seismic sea wave warning system could be overcome. Although the Coast Survey had no obligation under law to provide tsunami warnings, it saw the need for such warnings and had the scientific know-how and part of the organization necessary for such an undertaking. Furthermore, responsible officials in the Coast Survey considered themselves morally obligated to create and organize such a system. Consequently, under the direction of Comdr. E. B. Roberts, Comdr. C. K. Green, and Mr. W. B. Zerbe, work was initiated on the technical problems involved.

Because some tide stations in the SSWWS had relatively poor communications and because tide gages were normally checked only once a day, Comdr. Green designed a seismic sea wave detector which would be actuated so as to ring an alarm by the wave motion of a tsunami. The alarm, located where it would always be noticed by personnel at a tide station, insures an early warning that a tsunami has been generated, whether a request for tidal data has or has not been received at the tide station. Since the detector is normally actuated by the first part of the wave motion before the arrival of the destructive part, it can be used to sound an alarm locally for the post or community in which it is located. The first detector was installed at Honolulu for testing and adjustment in the fall of 1947. Subsequent detectors were installed at Hilo, Hawaii; Midway Island; and in the Aleutian Islands.

The acquisition of suitable seismographs and visible recording equipment was another problem which had to be solved. Photographic techniques were generally used by seismologists for recording earthquakes because they were simple, practical, and precise. Visible recording apparatus in existence in 1946 was generally unsatisfactory and of poor accuracy due to electronic problems. Various instrumental systems were tried, the most promising being that designed by Fred Keller, a New Kensington, Pa., scientist. In 1947 and 1948, equipment following his design was built and installed at Tucson, Ariz.; College, Alaska; and Honolulu, Hawaii. These installations were modified during the summer of 1950 by the addition of a highly stable, cathode-coupled, spilt-beam amplifier developed by R. M. Wilson and L. R. Burgess of the U. S. Coast and Geodetic Survey. This type of amplifier employs a galvanometer to react directly from a seismometer. A light beam reflected from a mirror on the galvanometer moves accordingly, and falls more or less intensely on a photocell. The output of the photocell actuates a pen recorder, and the record is continuously available for inspection. When a strong earthquake is recorded by these instruments, an alarm (audible, visible, or both), located where it is always noticeable, is tripped—thus insuring the prompt observation of all major earthquakes.

The collaboration of the Armed Forces and the Civil Aeronautics Administration (now the Federal Aviation Agency) was sought to establish a rapid, high-priority communications system. The first meeting relative to the formation of the communication network was held in the Navy Department on July 20, 1948, with representatives from the Office of the Chief of Naval Operations and the U. S. Coast and Geodetic Survey. Since it was obvious that it would be necessary to secure the cooperation of the Army, Air Force, and the Civil Aeronautics Administration to implement a warning system, a second meeting was held on August 12, 1948, to discuss a proposed communication plan for the seismic sea wave warning system. Attending this meeting were Maj. J. P. Moran and Capt. R. B. Moody, U. S. Air Force; Lt. K. B. Best, U. S. Army; Capt. D. M. Agnew and Capt. H. T. Orville, U. S. Navy; Mr. G. C. Pearson, Civil Aeronautics Administration; and Mr. W. B. Zerbe and Comdr. E. B. Roberts, U. S. Coast and Geodetic Survey. As the various armed services and the CAA were well aware of the need for a seismic sea wave warning system in the Pacific, the tentative plan was approved. Thus, the operation of the U.S. Coast and Geodetic Survey's Seismic Sea Wave Warning System in the Pacific began [Tsunami Warning System since March 15, 1967].

Initially, the Warning System consisted of the U. S. Coast and Geodetic Survey seismological observatories at College and Sitka, Alaska; Tucson, Ariz.; and Honolulu, Hawaii, and the following tide stations—Attu, Adak, Dutch Harbor, and Sitka, Alaska; Palmyra Island; Midway Island; Johnston Atoll; and Hilo and Honolulu, Hawaii. However, the Warning System began to expand almost immediately. By November 15, 1949, when the first edition of the *Communication Plan for the Seismic Sea Wave Warning System* was issued by the U.S. Coast and Geodetic Survey, seismological observatories at Berkeley and Pasadena, Calif., and Tokyo, Japan, and tide stations at Kodiak, Alaska; San Pedro and La Jolla, Calif.; Balboa, C. Z.; Canton Island; Apra Harbor, Guam; Koror Island; Kwajalein Atoll; Wake Island; and Pago Pago Harbor, American Samoa, had been added. Some seismological and tide stations have joined the SSWWS and others have left it over the years. At

the time of the Prince William Sound Earthquake, 15 seismological stations and 30 tide stations were participating. The list of active participants was as follows (see fig. 3 for location).

Seismological Stations

Honolulu, Hawaii (Operational Center of the SSWWS)	Manila, Republic of the Philippines
Apia, Western Samoa	Papeete, Tahiti
Berkeley, Calif.	Pasadena, Calif.
College, Alaska	Santiago, Chile
Guam, Mariana Islands	Sitka, Alaska
Hong Kong	Tokyo, Japan
Lima, Peru	Tucson, Ariz.
	Victoria, B. C., Canada

Tide Stations

Adak, Alaska	Legaspi, Republic of the Philippines
Apia, Western Samoa	Marcus Island
Attu, Alaska	Midway Island
Balboa, C. Z.	Nauru Atoll
Canton Island	Nawiliwili, Hawaii
Christmas Island	Pago Pago Harbor, American Samoa
Crescent City, Calif.	Papeete, Tahiti
Guam, Mariana Islands	San Pedro, Calif.
Hachinohe, Japan	Shimizu (Tosa), Japan
Hilo, Hawaii	Sitka, Alaska
Johnston Atoll	Suva, Fiji
Kodiak, Alaska	Tofino, B.C., Canada
Kwajalein Atoll, Marshall Islands	Unalaska, Alaska
La Jolla, Calif.	Valparaiso, Chile
La Punta, Callao, Peru	Wake Island

Initially, the SSWWS was to supply tsunami warning information to the civil authorities of the Hawaiian Islands and to the various military headquarters in the Hawaiian Islands for dissemination to military bases throughout the Pacific and to the U.S. Trust Territory of the Pacific Islands. Beginning on October 14, 1953, the warning information furnished to the civilian authorities of the Hawaiian Islands also was given to the Civil Defense Agencies of California, Oregon, and Washington. In June 1957, the Honolulu Observatory (HO) began supplying estimated arrival times for seismic sea waves on the coasts of these three states. The great destruction caused by the May 1960 Chilean tsunami caused a large number of countries and territories to join the Warning System in order to be protected from future tsunamis. Beginning in November 1960, warnings were supplied to Canada, Alaska, and Tahiti. Additional warning information was supplied to Japan, beginning in February and March 1961. Taiwan started receiving warnings in November 1961, and the Republic of the Philippines and the Fiji Islands in December 1961. During 1962, the HO began supplying warnings to Chile (March), Hong Kong (June), and New Zealand (July). Western Samoa began receiving warnings in January 1963, and American Samoa in November 1963.

The first test of the SSWWS came in connection with the Tonga Islands earthquake of September 8, 1948. Seismograph reports were obtained, and the epicenter of the earthquake was located. A traveltime of 6 hours and 35 minutes for the wave from the epicenter to Honolulu was predicted from the traveltime chart, and military and civilian agencies were alerted to stand by for a possible tsunami warning. As wave reports came in, it became evident that the wave would be small, and the alert was cancelled. Later, as predicted, the Honolulu tide-gage record showed that a 6-inch seismic sea wave had arrived.

Several small tsunamis were registered in various parts of the Pacific during the years 1949, 1950, and 1951, but no warnings were issued to the public as a result of the action by the Seismic Sea Wave Warning System. The extreme irregularity of earthquake occurrence was demonstrated in the years 1950 and 1951. In 1950, the Honolulu Observatory requested tide reports in connection with 26 earthquakes, but in 1951, there were only 3 such occasions.

Regular monthly tests to keep operating personnel familiar with the communication methods and requirements were begun early in 1949. These communication tests have been instrumental (1) in eliminating flaws which showed up in the SSWWS from time to time, and (2) in determining the most rapid and reliable communication routes.

The first major tsunami in the Pacific after the formation of the Warning System occurred in connection with the November 4, 1952, Kamchatka earthquake. Advance warnings provided to communities in the path of this tsunami resulted in a reduction of damage and no casualties. The March 9, 1957, Aleutian tsunami, the second major Pacific tsunami following the formation of the SSWWS, caused $3 million damage in the Hawaiian Islands, but once again, due to timely warning, there was no loss of life. The May 1960 Chilean tsunami pointed out a weakness in the Warning System. Although tsunami warnings were broadcast to the residents of the Hawaiian Islands well in advance of the arrival of the wave, 61 people were killed in Hilo, Hawaii, because they failed to heed the warnings.

The 1960 Chilean tsunami stimulated a sizable increase in basic research on tsunamis, and also caused a number of countries to request tsunami warnings from the HO. These requests necessitated the addition of tide and seismic stations to secure the coverage necessary to provide timely warnings.

Operations During the Tsunami

Eight minutes after the beginning of the Prince William Sound Earthquake, the seismic waves it generated reached Hawaii and triggered the alarm attached to the seismograph at the U.S. Coast and Geodetic Survey's Honolulu Observatory. The normal working day at the Observatory had ended,

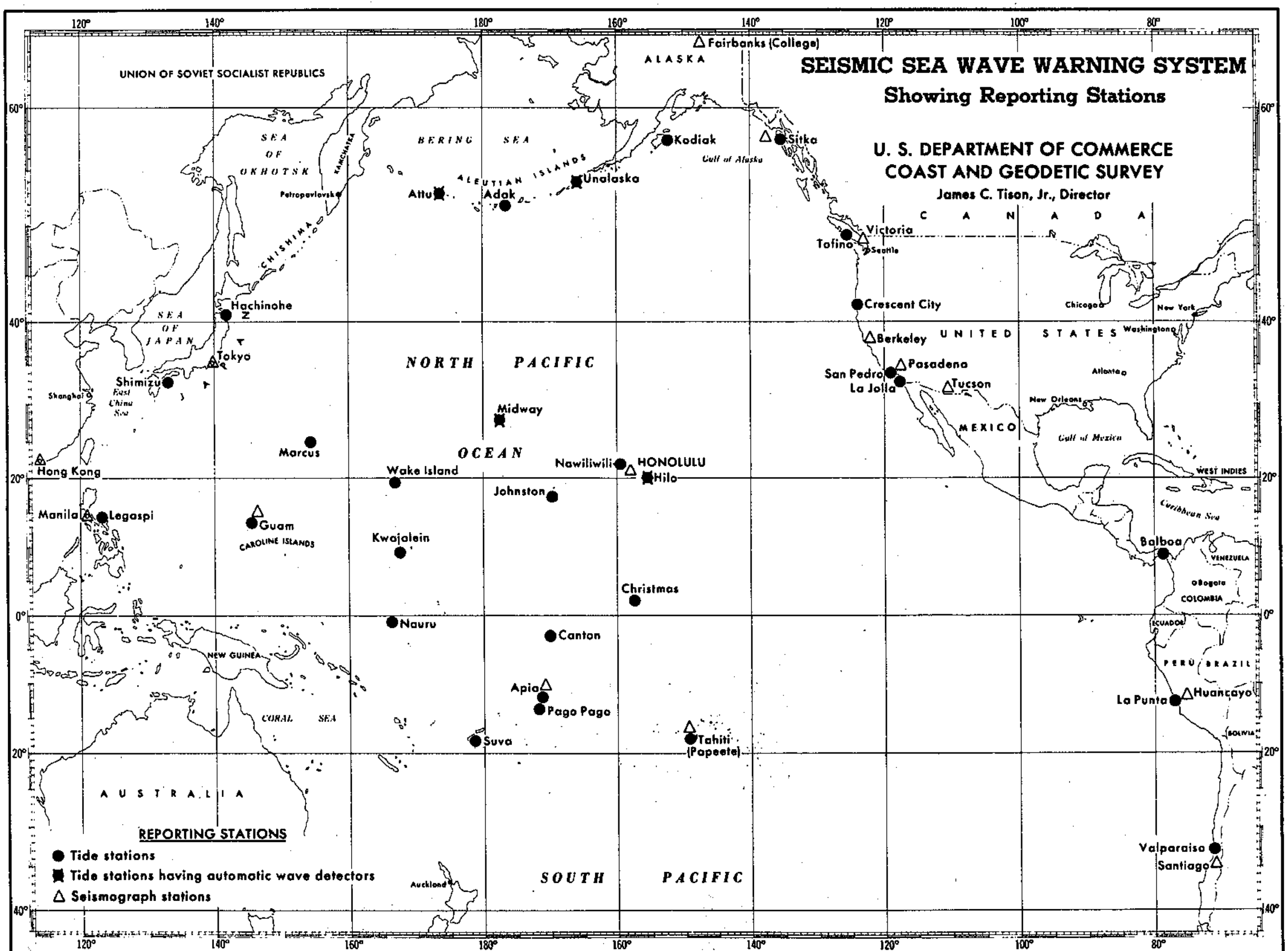

FIGURE 3.—Seismic Sea Wave Warning System showing locations of reporting stations.

and the personnel had returned to their quarters on the Observatory grounds for supper. The food was destined to go uneaten, however, since earthquakes and tsunamis do not respect normal working hours. With the sounding of the alarm, the SSWWS once again began its continuing task of locating major Pacific earthquakes and detecting tsunamis as soon as possible after their generation.

Although the staff at the Honolulu Observatory was not aware of it, the earthquake had destroyed the control tower at Anchorage International Airport, thus destroying a vital communication link through which flowed seismic reports from College and Sitka Observatories and tidal data from Kodiak, Sitka, and Unalaska. Kodiak and Sitka were able to utilize alternate routings, but the receipt of data from both locations was greatly delayed. Locally generated waves had already struck Seward, Valdez, and Whittier, and the wave front of the tsunami was approximately as shown in figure 4.

Action began immediately at the Honolulu Observatory, following the sounding of the alarm at 0344 (All times are Greenwich Mean Time (G.M.T.) unless otherwise noted). The photographic records were changed, the U.S. Coast and Geodetic Survey Honolulu District Officer and Hawaiian Civil Defense authorities were notified of the earthquake, and requests for seismic readings were sent to the various seismic observatories participating in the SSWWS. At 0419, the first seismic report came in, giving the *P* reading from the Manila Observatory. By 0452, enough information had been received to permit the HO to locate the earthquake epicenter at latitude 61°N., longitude 147 1/2°W., near Seward, Alaska. An advisory message was prepared and sent to all dissemination agencies in the Warning System at 0502. A second advisory was issued at 0530 by the HO, giving estimated arrival times of the tsunami at the various places in the Pacific for which predictions are made.

After the issuance of the initial advisory, the Honolulu Observatory attempted to obtain tide reports from stations near the epicenter. Requests for data were sent to Unalaska, Kodiak, Adak, Attu, and Sitka, Alaska; Tofino, British Columbia; and Crescent City, Calif. Unofficial reports had been received that a tsunami was approaching Kodiak. At 0509 and 0510, two messages were received from the Kodiak tide observer stating that an earthquake had been felt and that the tide gage had been damaged. At 0540, Commander in Chief, Pacific (CINCPAC) reported that Kodiak was evacuated. At 0555, the Kodiak tide observer reported: "EXPERIENCE SEISMIC SEA WAVE AT 280435Z WATER LEVEL 10-12 FEET ABOVE MSL. WILL ADVISE." Since the expected tide stage at that time was not known by the personnel at the HO, they had no information on which to base an estimate of the tsunami amplitude. Consequently, a decision was made to wait for amplification before a warning was issued. A further message arrived from Kodiak at 0611, and although most of the text had been lost in transmission, enough was received to cause the HO to begin preparing a tsunami warning message for all dissemination agencies in the SSWWS. The complete text of the 0611 message from Kodiak was received by the HO at 0630. It stated that the water rose to 15 to 20 feet above mean sea level in 10 minutes and then fell 15 to 18 feet below mean sea level in 22 minutes.

The Honolulu Observatory issued its tsunami warning bulletin at 0637, after two false starts occasioned by an incoming message and a garble in transmission.

Shortly after 0700, reports began arriving from other tide stations in the Warning System and from various coastal points giving information on wave action and heights. Requests for information were received and answered. At 1100, the Honolulu Observatory issued another bulletin to the dissemination agencies, listing a representative spread of maximum wave heights reported to the HO. The following is the official log of the HO for the Prince William Sound Earthquake.

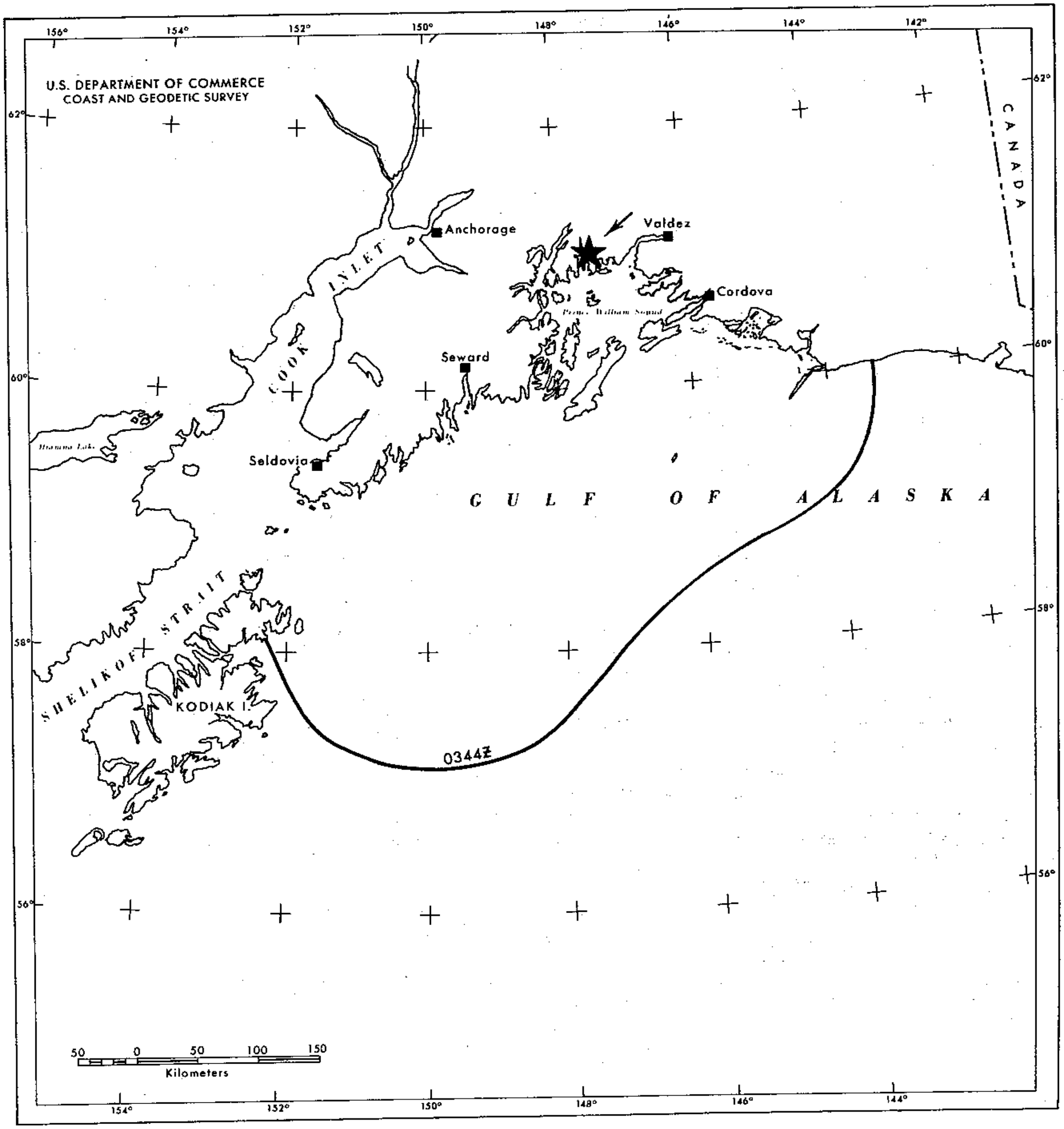

FIGURE 4.—The approximate tsunami wave front at 0344Z when the seismograph alarm was tripped at the Honolulu Observatory.

SEISMIC SEA WAVE WARNING LOG

Honolulu Observatory

G.M.T.	TO	FROM	EVENT OR REMARKS
0344			ALARM SOUNDED. NOTED LARGE EARTHQUAKE. SCALED P PHASE 034354. NO OTHER PHASES READABLE FROM VISIBLE RECORD.
0358			CHANGING PHOTO RECORDS.
0400	HDO	HO	ADVISED DISTRICT OFFICER OF EARTHQUAKE.
0401	MACDONALD	HO	ADVISED DR. GORDON MACDONALD, ACTING TSUNAMI ADVISOR, OF EARTHQUAKE.
0405	BUTCHART	HO	ADVISED COL. BUTCHART, VICE DIRECTOR C.D., OF EARTHQUAKE.
0407	HO	CINCPAC	CALLED FOR INFORMATION.
0413	COLLEGE SITKA PASADENA TUCSON BERKELEY	HO	REQUESTED IMMEDIATE READINGS EARTHQUAKE OF 0336Z.
0416	JMA TOKYO	HO	REQUESTED IMMEDIATE READINGS EARTHQUAKE OF 0336Z.
0418	GUAM OBS.	HO	REQUESTED IMMEDIATE READINGS EARTHQUAKE OF 0336Z.
0419	HO	MANILA	P 034813.
0423	HO	HONG KONG	P 034334 S 4755.
0425	HO	KUNIA	CALLED FOR INFORMATION.
0430	HO	PTO	TIDES OFFICER CALLED FOR INFORMATION.
0431	HO	GUAM	EP 034706.
0432	HO	FLEET WEA CENTRAL	REPORTED EARTHQUAKE TREMORS IN KODIAK FROM 0332Z TO 0340Z. KODIAK TIDE GAGE DAMAGED.
0433	HO	JMA	MATSUSHIRO P 034516. SAPPORO P 034428 S 5120. SENDAI P 034459. REQUEST YOUR READINGS.
0436	HO	FAA	REPORTED COMMUNICATION CABLES TO ALASKA BROKEN.
0438	HO	BERKELEY	P 034205.
0448	HO	TUCSON	IP 034328 ES 4932.
0449	JMA	HO	HON IP 034554.1. PRELIMINARY MAGNITUDE APPROX 8.
0452			DETERMINED EPICENTER AT 61 N, 147½ W, H = 033610. NEAR SEWARD, ALASKA, MAGNITUDE 8.
0454	HO	FAA	REPORTED INTERNATIONAL TOWER AT ANCHORAGE DEMOLISHED.
0459	HO	PASADENA	IP 034350Z.
0501	HO	COMBARPAC	TIDAL WAVE REPORTED HEADING FOR KODIAK.
0502	NAVCOMMSTA HONO AND FAA HONO FOR AIG 158	HO	ISSUED BULLETIN NO. 1 AS FOLLOWS: *THIS IS A TIDAL WAVE (SEISMIC SEA WAVE) ADVISORY. A SEVERE EARTHQUAKE HAS OCCURRED AT LAT 61 N LONG 147.5 W VICINITY*

G.M.T.	TO	FROM	EVENT OR REMARKS
0502			*OF SEWARD, ALASKA AT 0336Z 28 MARCH. IT IS NOT KNOWN REPEAT NOT KNOWN AT THIS TIME THAT A SEA WAVE HAS BEEN GENERATED. YOU WILL BE KEPT INFORMED AS FURTHER INFORMATION BECOMES AVAILABLE. IF A WAVE HAS BEEN GENERATED ITS ETA FOR THE HAWAIIAN ISLANDS (HONOLULU) IS 0900Z 28 MARCH.*
0508	CINCPAC	HO	ISSUED BULLETIN NO. 1.
0509	HONO POLICE	HO	ISSUED BULLETIN NO. 1.
0509	HO	KODIAK T.O.	TIDE GAGE DAMAGED BY FIRST TREMOR 280332Z. NO TRACE DUE DAMAGE. REPAIRS WILL BE COMPLETED 280800Z.
0510	HO	KODIAK T.O.	MODERATE EARTHQUAKE NEAR KODIAK 280332Z TO 280340Z. WILL ADVISE STAFF READINGS. TREMORS CONTINUING.
0511	W.B. DUTY FORECASTER	HO	ISSUED BULLETIN NO. 1.
0512	MACDONALD	HO	ISSUED BULLETIN NO. 1.
0515	KUNIA	HO	ISSUED BULLETIN NO. 1.
0517	HDO	HO	ISSUED BULLETIN NO. 1.
0530	NAVCOMMSTA HONO AND FAA HONO FOR AIG 158	HO	ISSUED BULLETIN NO. 2 AS FOLLOWS: *THIS IS A TIDAL WAVE (SEISMIC SEA WAVE) INFORMATION BULLETIN. DAMAGE TO COMMUNICATIONS TO ALASKA MAKES IT IMPOSSIBLE TO CONTACT TIDE OBSERVERS. IF A WAVE HAS BEEN GENERATED THE ETA'S ARE: ATTU 0745Z, ADAK 0700Z, DUTCH HARBOR 0630Z, KODIAK, 0530Z, SAMOA 1430Z, CANTON 1530Z, JOHNSTON 1100Z, MIDWAY 0845Z, WAKE 0930Z, KWAJALEIN 1430Z, GUAM 1315Z, TOKYO 1030Z, SITKA 0530Z, SAN PEDRO 0930Z, LA JOLLA 1000Z, BALBOA 2330Z, ACAPULCO 1300Z, CHRISTMAS 1230Z, CRESCENT CITY 0800Z, LEGASPI 1430Z, NEAH BAY 0730Z, SAN FRANCISCO 0915Z, TAHITI 1430Z, TOFINO B.C. 0730Z, VALPARAISO 2200Z, HONOLULU 0900Z, HUALEIN TAIWAN 1430Z, LA PUNTA 1900Z, MARCUS 1100Z, HONG KONG 1530Z, SHIMIZU 1130Z, HACHINOHE 1000Z. ALL TIMES ARE FOR 28 MARCH.*
0530	HO	KH6ESL	SHORT WAVE CONTACT WITH YAKATAGA, ALASKA.
0531	HO	HONOLULU	CHECKED OPERATION OF HONOLULU GAGE.
0539	UNALASKA T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0600Z AND 0700Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0700Z. ACK. RECEIPT OF THIS MSG. IMMED.
0540	HO	CINCPAC	REPORTED EVACUATION OF KODIAK.
0541	KODIAK T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0530Z AND 0630Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0630Z. ACK. RECEIPT OF THIS MSG. IMMED.
0543	ADAK T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0630Z AND 0730Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0730Z. ACK. RECEIPT OF THIS MSG. IMMED.

G.M.T.	TO	FROM	EVENT OR REMARKS
0544	ATTU T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0715Z AND 0815Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0815Z. ACK. RECEIPT OF THIS MSG. IMMED.
0548	HO	SITKA OBS.	IP 033759Z. STRONG LOCAL FELT AT SITKA. MADE SOME INSTRUMENTS INOPERATIVE.
0550	SITKA OBS.	HO	INSPECT TIDE RECORDS BETWEEN 0500Z AND 0600Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0600Z. ACK. RECEIPT OF THIS MSG. IMMED.
0552	CRESCENT CITY T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0730Z AND 0830Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0830Z. ACK. RECEIPT OF THIS MSG. IMMED.
0555	HO	KODIAK T.O.	EXPERIENCE SEISMIC SEA WAVE AT 280435Z. WATER LEVEL 10-12 FT. ABOVE MSL. WILL ADVISE.
0555	TOFINO T.O.	HO	INSPECT TIDE RECORDS BETWEEN 0700Z AND 0800Z. REPORT ANY UNUSUAL ACTIVITY IMMEDIATELY OR REPLY NEGATIVE AT 0800Z. ACK. RECEIPT OF THIS MSG. IMMED.
0558	CD	HO	ADVISED OF TIDAL ACTIVITY AT KODIAK.
0601	HO	WAKE	TIDAL WAVE (SEISMIC SEA WAVE) ADVISORY 280502Z RECEIVED 280530Z.
0602	HO	TAHITI	IP 034814.5.
0606	HO	WAKE	YOUR 280530Z RECEIVED 280551Z.
0610	HO	NPM	REQUEST RERUN OF BULLETIN NO. 2 TO AIG 158.
0611	HO	KODIAK T.O.	WATER LEVEL STARTED RISING AT 280435. ROSE 15.
0615	HO	FAA	REPORTED COMMUNICATIONS RESUMED WITH ANCHORAGE.
0618	CD	HO	ADVISED OF LATEST ACTIVITY AT KODIAK.
0620	AIG 158	HO	RERUN OF BULLETIN NO. 2.
0625	HO	MARINE PAPEETE	BULLETIN NO. 2 RECEIVED 280618Z.
0625	HO	AP	REPORTED 6 DEAD AT ANCHORAGE.
0630	HO	KODIAK	WATER LEVEL STARTED RISING AT 280435Z. ROSE 15-20 FT. ABOVE MSL BY 280445Z. EBB TIDE STARTED 280445Z. WATER LEVEL 15-18 FT. BELOW MSL AT 280507Z.
0635	HO	KODIAK	WATER LEVEL STARTED RISING AT 280435Z. ROSE 15.
0637	NAVCOMMSTA HONO AND FAA HONO FOR AIG 158	HO	ISSUED BULLETIN NO. 3 AS FOLLOWS: *THIS IS A TIDAL WAVE (SEISMIC SEA WAVE) WARNING. A SEVERE EARTHQUAKE HAS OCCURRED AT LAT 61 N LONG 147.5 W VICINITY OF SEWARD, ALASKA AT 0336Z 28 MAR. A SEA WAVE HAS BEEN GENERATED WHICH IS SPREADING OVER THE PACIFIC OCEAN. THE ETA OF THE FIRST WAVE AT OAHU IS 0900Z 28 MAR. THE INTENSITY CANNOT REPEAT CANNOT BE PREDICTED. HOWEVER THIS WAVE COULD CAUSE GREAT DAMAGE IN THE HAWAIIAN ISLANDS AND ELSEWHERE IN THE PACIFIC AREA. THE DANGER MAY LAST FOR SEVERAL HOURS. OTHER ETA INFORMATION IS AS FOLLOWS:* [SAME ETA'S AS THOSE LISTED IN ADVISORY BULLETIN ISSUED AT 0530].

G.M.T.	TO	FROM	EVENT OR REMARKS
0638	CINCPAC	HO	ISSUED BULLETIN NO. 3.
0638	KUNIA DUTY FORECASTER	HO	ISSUED BULLETIN NO. 3.
0640	CD	HO	ISSUED BULLETIN NO. 3.
0644	HAWSEAFRON	HO	ISSUED BULLETIN NO. 3.
0645	W.B. DUTY FORECASTER	HO	ISSUED BULLETIN NO. 3.
0646	HO	CANTON T.O.	YOUR 280502Z RECVD. STAFF READING NEGATIVE DISTURBANCE.
0648	HDO	HO	ISSUED BULLETIN NO. 3.
0646	HO	SITKA OBS.	IP 033759Z. STRONG LOCAL FELT. HAVE SOME INSTRUMENTS INOPERATIVE. STANDING BY TIDE GAGE.
0651	HO	ADAK T.O.	YOUR 280543Z RECVD. 280617Z.
0656	BALBOA T.O.	HO	CORRECT ETA 2000Z, REPEAT 2000Z.
0700	HO	FIJI POLICE SUVA	280530Z RECVD. BY FIJI POLICE SUVA AT 280638Z.
0701	HO	UNALASKA	5.2 AT 1929. 4.6 AT 1933.
0704	HO	WAKE	YOUR 280637Z RECVD. 280655Z.
1706	HO	ADAK T.O.	YOUR 280544Z RECVD. 280615Z.
0708	HO	KODIAK	SEA WAVES AT 0435Z 32 FT. AT 0540Z 35 FT. AT 0630Z 30 FT. SEAS DIMINISHING WATER RECEDING. EXPECT SIX MORE WAVES. NO EMERGENCY EXISTS.
0710	CD	HO	INFORMED OF LATEST TSUNAMI INFORMATION.
0711	HO	SITKA	UNUSUAL TIDAL ACTIVITY BEGAN 0510Z. FLUCTUATIONS LARGE. STILL OCCURRING.
0715	CD	HO	GAVE FOLLOWING ETA'S FOR HAWAIIAN ISLANDS: KAUAI 2215, OAHU 2300, MAUI 2300, HAWAII 2315, HST.
0725	HO	MARINE PAPEETE	YOUR BULLETIN NO. 3. RECVD. 280716Z.
0725	HO	KWAJALEIN	REQ. VERIFY ETA KWAJ AT 1430Z.
0730	HO	HVO	IP 28034403.6. REMAINING DATA OBSCURED.
0730	KWAJALEIN T.O.	HO	REVISED ETA 1200Z, REPEAT 1200Z.
0732	HO	CRESCENT CITY T.O.	NO DISTURBANCE AT 280705. WILL STAND BY.
0738	RAF	HO	ADVISED ETA FOR CHRISTMAS ISLAND.
0739	CD	HO	ADVISED OF LATEST INFORMATION.
0750	HO	FIJI POLICE SUVA	REF. 280637 RECVD. BY FIJI POLICE SUVA AT 280740Z.
0810	HO	KODIAK	HIGH WATER LEVELS REACHED 280435Z ABT 15 FT. ABV MSL. 280540Z HIGH WATER ABT 18 FT. ABV MSL. 280630Z ABT 16 FT. ABV MSL. 280644Z HIGH WATER ABT 6 FT. ABV.

G.M.T.	TO	FROM	EVENT OR REMARKS
			MSL. AMPLITUDE RAPIDLY DECREASING. TIDE GAGE INOPERATIVE SINCE 280332Z FURTHER COMMUNICATIONS PENDING RESTORATION MAJOR COMMUNICATION LINKS. 280715Z WAVE ACTION ONLY SLIGHT. APPEARS TO BE DAMPED OUT COMPLETELY.
0816	HO	TOFINO	YOUR 280555Z RECVD. 280709Z.
0822	HO	COAST GUARD	FOLLOWING INFORMATION ON WAVE HEIGHTS REPORTED BY COAST GUARD. BULL HARBOR, CANADA 12 FT. AT 0722Z; TOFINO 8 FT. AT 0710Z; CORDOVA 30 FT. HUMBOLDT BAY HIGH NOW.
0825	HO	CG	NAWILIWILI GAGE NORMAL AT 0821Z.
0826	HO	TOFINO	TOFINO OPERATION FIRST SURGE 0710Z REACHED PEAK OF 8 FT.
0830	CD	HO	REPORTED LATEST WAVE ACTIVITY.
0837	HO	CD	EXCHANGE OF INFORMATION.
0842	HO	SITKA	WATER ROLLED 16 FT. IN 30 MIN. JUST PRIOR TO 0700Z. FELL 9 FT. 0700/0745 NOW RISING FAST. WILL REPORT FURTHER.
0848	HO	ATTU	STAFF READING 2.2 AND 1.6. NEGATIVE UNUSUAL DISTURB.
0851	HO	ADAK	YOUR 280543Z RECVD. 280615Z. STAFF READING 4.8 NEGATIVE DISTURBANCE.
0851	HO	CG	NAWILIWILI GAGE RECORDED 1 FT. WAVE AT 0845Z.
0905	HO	JMA	REQUEST YOUR DATA OF TSUNAMI OBSERVATIONS. ESPECIALLY AT HAWAII IS. AND ALEUTIAN IS.
0911	HO	CG	3FT. WAVE REPORTED AT FRENCH FRIGATE SHOALS.
0915	HO	CD	FOLLOWING WAVE HEIGHTS REPORTED IN HAWAIIAN IS. KAHULUI, MAUI, 1 FT. OVER BRIDGE, ¼ MI. INLAND; HILO 6 FT. AT 1107Z; WAIALUA 4 FT.; LANIKAI 5 FT.
0917	HO	TAIPEI	TAP P 034718Z S 5630 TAU P 034723Z HWA P 034728Z S 5628 HEN P 034737Z.
0923	JMA	HO	WAVE HEIGHTS REPORTED BY VARIOUS MEDIA: KODIAK 30 FT., CORDOVA 30 FT., TOFINO 8 FT., CRESCENT CITY 12 FT., LOCAL WAVE HEIGHTS JUST BEGINNING TO BE RECORDED AT 28/0920Z. ACCURATE REPORTS FOR HAWAII WILL FOLLOW WHEN KNOWN.
0928	HO	KODIAK	QUAKE HAS GENERATED SEA WAVES AT IRREGULAR INTERVALS FROM 30 TO 35 FT.
0934	HO	CG	LATEST NAWILIWILI WAVE HEIGHTS.
0942	HO	CD	SECOND WAVE AT HILO 7¼ FT. SIXTH WAVE AT KAUAI 2½ FT.
0948	HO	CG	NAWILIWILI NOW EXPERIENCING DIMINISHING RECESSIONS AND WAVE ACTION. MAX. WAVE HEIGHT 3 FT.
0953	HO	CG	NO WAVE OBSERVED AT KURE ISLAND.

G.M.T.	TO	FROM	EVENT OR REMARKS
0954	HO	CG	NAWILIWILI 1½ FT. AT 0938Z.
1002	HO	HDO	1½ FT. WAVE REPORTED AT MIDWAY.
1009	HO	CD	THIRD WAVE AT HILO 1½ FT. FOURTH WAVE AT 1008Z 2FT. FOLLOWED BY NORMAL RECESSION.
1014	HO	CIVIL DEFENSE WELLINGTON	REQUIRE DETAILS OF WAVE HEIGHTS HONOLULU AND ELSEWHERE IF AVAILABLE.
1020	HO	HONOLULU T.O.	FIRST WAVE ACTIVITY AT 0855Z. 1½ FT.
1023	HO	KWAJALEIN	REQ. FURTHER INFO. TIDAL WAVE EFFECTS KWAJ.
1026	HO	CG	LATEST WAVE HEIGHTS NAWILIWILI.
1029	HO	SITKA	EXPECTED TIDE STAGE BETWEEN 0925 AND 0955. UNUSUAL TIDE ACTIVITIES CONTINUE.
1033	HO	HAWSEAFRON	MIDWAY EXPECTS 1 FT. AT 0847. SINCE 0900Z, HAVE STEADY 0.2 FT. TO 0.3 FT. SEICHE.
1040	HO	CD	4 FT. RISE AT HILO AT 1017. 7TH WAVE 3 FT. AT 1030.
1049	HO	CG	LATEST WAVE HEIGHTS AT NAWILIWILI.
1050	HO	WAKE	AT 1033Z RISE OF 0.8 [FT.] RECOMMENDED 1100Z FOR ALL CLEAR HAWAII.
1100	HO	CD	EIGHTH WAVE AT HILO 2.5 FT. RECOMMENDED 1100Z FOR ALL CLEAR HAWAII.
1100	NAVCOMMSTA HONO AND FAA HONO FOR AIG 158	HO	ISSUED BULLETIN NO. 4 AS FOLLOWS: *THIS IS A TIDAL WAVE (SEISMIC SEA WAVE) INFORMATION BULLETIN. THE LARGER WAVES HAVE APPARENTLY PASSED HAWAII. AN ALL CLEAR STATUS FOR HAWAII CAN BE ASSUMED AT 1100Z. ALL PARTICIPANTS IN THE SSWWS SHOULD ASSUME THE ALL CLEAR STATUS 2 HOURS AFTER THEIR PARTICULAR ETA UNLESS LOCAL CONDITIONS WARRANT THE CONTINUANCE OF THE ALERT STATUS. MAXIMUM WAVE HEIGHTS REPORTED BY VARIOUS MEDIA ARE: OAHU 8 FT., HAWAII 6 FT., KODIAK 30 FT., MIDWAY 1.5 FT., KAUAI 3 FT., CRESCENT CITY 12 FT., CORDOVA 30 FT., TOFINO 8 FT.*
1108	HO	TOFINO	0850Z DIAGRAM READ 16 FT. RUNOUT STARTED AT THIS POINT. THIS IS THE SECOND WAVE.
1111	HO	HONOLULU T.O.	FIFTH WAVE 2½ FT. PEAK TO PEAK. PERIODS OF ½ HOUR.
1122	HO	WAKE	YOUR 281100Z RECVD. 281112Z.
1123	HO	MARINE PAPEETE	RECVD. YOUR BULLETIN NO. 4. 281117Z.
1124	HO	RAF	REQUESTED INFO. ON CHRISTMAS ISLAND.
1126	HO	CG	LATEST WAVE HEIGHTS NAWILIWILI.
1134	HO	CINCPAC	REQUEST INFO. ON ALL CLEAR FOR ISLAND OF HAWAII.
1203	HO	ADAK	YOUR 280544Z RECVD. 280615Z. STAFF READING 4.2. SLIGHT DISTURBANCES.
1225	HO	JMA	TSUNAMI BEGAN AT 1020Z EASTERN COAST OF HOKKAIDO, AT 1038Z PACIFIC COAST OF NE HONSHU, ALL INITIAL MOTIONS ARE PUSH.

G.M.T.	TO	FROM	EVENT OR REMARKS
1226	HO	KWAJALEIN	NO UNUSUAL DISTURBANCES NOTED.
1230	HO	CINCPAC	AT SAN DIEGO 5 FT. RECESSION FOR 1 HOUR. THEN RETURN TO NORMAL. 10 FT. WAVE AND MINOR DAMAGE AT CATALINA ISLAND.
1252	HO	KWAJALEIN	SMALL DISTURBANCES TO TIDE RECORD BEGAN ABOUT 281230Z. WATER FELL 0.3 FT. WILL REPORT FURTHER.
1258	HO	TOFINO	FIRST WAVE AT 0710 DIAGRAM 15 FT. AT PEAK, SECOND WAVE AT 0850 DIAGRAM 16 FT. AT PEAK, THIRD WAVE PEAK AT 0955. NO READING. TIDE GAGE DAMAGED.
1306	HO	HONG KONG	REQ. EXPECTED INTENSITY AND REVISED ETA HONG KONG.
1306	HO	KWAJALEIN	WATER FELL 0.5. BEGAN RISE AT 281245Z.
1315	HONG KONG	HO	HO CANNOT PREDICT THE INTENSITY OF A TIDAL WAVE (SEISMIC SEA WAVE). ETA HONG KONG IS 28/1530Z BASED ON INFORMATION AVAILABLE.
1425	HO	NAVSTA GUAM	AT 291315Z NEGATIVE DISTURBANCES.
1428	HO	KWAJALEIN	RISE OF 1.3 BETWEEN 281345Z AND 281357Z. FELL 0.3 AT 281400Z. NOW RISING.
1613	HO	CIVIL DEFENSE WELLINGTON	CAN YOU ADVISE WAVE HEIGHT AT CANTON ISLAND.
1622	CIVIL DEF. WELLINGTON	HO	NO WAVE HEIGHT REPORT RECEIVED FROM CANTON ISLAND AS OF 1620Z. HO WILL SEND INFO. IF RECEIVED.
1743	HO	VALPARAISO	PLS. INFORM AS SOON AS POSSIBLE INTENSITY OF SEA WAVE AT HAWAIIAN IS.
1813	VALPARAISO	HO	SENT BULLETIN NO. 4.
1841	HO	VALPARAISO	YOUR MESSAGE 28/0600Z RECVD. 28/1240Z.
1923	HO	CHRISTMAS ISLAND	UNUSUAL DISTURBANCES OCCURRED 281130. RAISED TENTH OF A FOOT AND FELL THE SAME.
1927	HO	ADAK T.O.	TIDE IS 5 FT. NORMAL. ADAK IS NORMAL. SHEMYA IS NORMAL.
1932	HO	SAMOA	TIDAL ACTION COMMENCED AT 1400Z WITH SLIGHT RISE AND FALL. ROSE 6 IN. AT 1415Z FOR A PERIOD OF 6 MIN. FALL OF LESS THAN 6 IN. OVER A PERIOD OF 5 MIN. AT 1447Z.
2050	HO	CANTON	NO TIDAL WAVE ACTION OBSERVED AT CANTON, OBSERVATIONS STILL BEING TAKEN.
2143	HO	LA PUNTA	WAVE BEGAN 1910 TIDE RECORD SHOWS WATER ROSE 3 FT. IN 7 MIN. AND FELL 3.4 FT. IN 9 MIN. 2ND WAVE SAME HEIGHT AND SAME PERIOD. 3RD WAVE ROSE 3.6 FT. AND FELL 5 FT. IN 17 MIN.
2145	HO	SUVA T.O.	TIDE RECORD SHOWS WATER ROSE 0.6 FT. AND FELL 0.4 FT. IN 10 MIN. AT FOLLOWING TIMES: 281910Z, 281945Z, 282020Z. STILL IRREGULAR.

Not included in the above log are numerous calls for information from military officials, wire services, and the local press. All were advised of actions taken by the Honolulu Observatory.

Figures 4, 5, and 6 are included to show the approximate location of the initial tsunami wave front when the seismograph alarm was triggered at the HO, when the epicenter was determined, and when the tsunami warning was issued. The arrival time of the tsunami at selected stations is also shown on figure 6.

TSUNAMI EFFECTS

Alaska

Outside of the Prince William Sound area and Seward, the only Alaskan area to suffer heavy tsunami damage was the Kodiak Island group. At the Cape St. Elias Lighthouse, a member of the U.S. Coast Guard was drowned by the initial wave, and the other three men stationed there barely escaped. Beyond Cape St. Elias, damage in Alaska was limited to a dock which collapsed at Sitka, and there were minor disruptions of floats and log rafts at logging camps in the Ketchikan area. The nearest tide gage to the epicenter which survived the tsunami was at Yakutat. It recorded a maximum rise of 7.6 feet beginning at 1007, near the time of the predicted high tide. The Sitka tide gage recorded a 14.3-foot rise on the third wave of the tsunami beginning at 0624.

The Alaska Peninsula and the Aleutian Islands were shielded by the Kodiak Island group from the direct action of the tsunami. In Shelikof Strait, as in Cook Inlet, maximum amplitudes were on the order of 5 feet. Maximum amplitude in the Aleutian Islands, as recorded on tide gages, was under 3 feet.

The city of Kodiak and Kodiak Naval Station were the only places in Alaska which received advance warning of the tsunami. The U.S. Fleet Weather Central at Kodiak Naval Station, which participates in the Seismic Sea Wave Warning System by maintaining a tide station and by serving as a dissemination agency, provided this local warning.

The earthquake, strongly felt at the Fleet Weather Central, put the tide gage and all communication circuits available (except telephone) out of commission, and caused damage to the hangars, aprons, and ramps at the Naval Station. The damage was caused mainly by differential settlement of pile- and fill-supported structures.

At 0410, after a report of a 30-foot tsunami was received from Cape Chiniak, the Commanding Officer of the Fleet Weather Central, failing to reach the Naval Station Officer of the Day, called the Armed Forces Radio Station and had a warning broadcast. The broadcast resulted in an extremely smooth, orderly, prompt, and complete evacuation of the Naval Station and Federal Aviation Agency personnel on Woody Island. Reports indicate that the evacuation of the city of Kodiak was reasonably prompt, but it was not as complete or as well carried out. This difference was undoubtedly due to the better discipline of the military and government personnel and their dependents, and to the emergency procedures that had been prepared in advance for the Naval Station.

About 10 minutes after the warning was issued, the tsunami, similar in appearance to a swiftly rising flood, arrived at the Fleet Weather Central. By 0435, the first wave had crested at 22 feet above the tide staff zero, giving a rise of about 16 feet on the first wave. The highest crest in the tsunami reached about 30 feet above the tide staff zero, and the maximum amplitude (crest to trough) was about 35 feet.

The personnel at Fleet Weather Central continued to supply information of the tsunami to the Honolulu Observatory under extreme handicap. With all radio circuits in the tower building inoperative, a telephone message was passed to a remote Navy radio station for relay via Naval Communication Station San Francisco, giving information on the first crest. At 0447, all electric power in the tower was lost, due to flooding of the main power station. Auxiliary power was supplied at 0503, and an additional message was sent to the HO, giving more detail on the first wave. Since there was doubt about the delivery of the first two messages, a third message was sent over Coast Guard circuits at 0726, shortly after the Coast Guard Radio Station NOJ, located in the tower building, returned to operation and contacted Ketchikan. This message gave details on crest heights and arrival times.

The Kodiak Naval Station suffered heavy damage from the tsunami and minor damage from the earthquake. Estimates of approximately $10 million tsunami damage by Public Works, Kodiak Naval Station (Tudor, 1964) include complete destruction of the cargo dock and heavy damage to roads and bridges, the central powerplant and the Holiday Beach generator, the microwave installation, the runway ends and shoulders, the marginal pier, the public works maintenance shop, the hobby shop, and the bowling alley. Because of the advance warning, there were no military fatalities or serious injuries.

The tsunami caused 21 deaths in and near the city of Kodiak. These included 8 dead at Kodiak, 3 at Kaguyak, 6 at Kalsin Bay, 1 at Old Harbor, and 3 at Spruce Cape (Lowell, 1965). The low-lying areas of the Kodiak waterfront suffered extreme damage. All float docks in the area that were protected by breakwaters were broken up and cast ashore or were washed away. All wharves and piers on the waterfront were destroyed, except for the City dock. A preliminary Civil Defense survey listed 58 structures in a 5-block

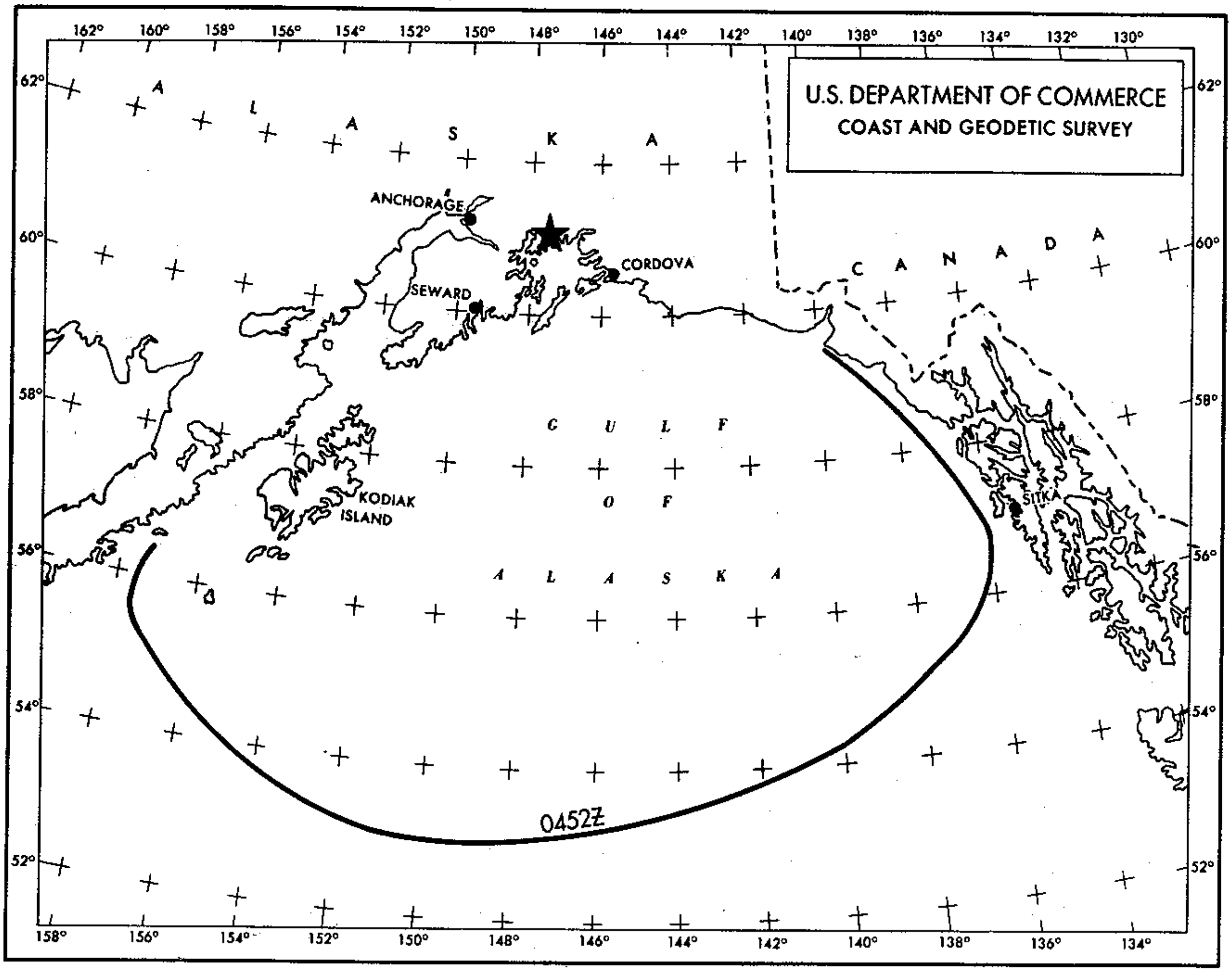

FIGURE 5.—The approximate tsunami wave front at 0452Z when the epicenter was determined.

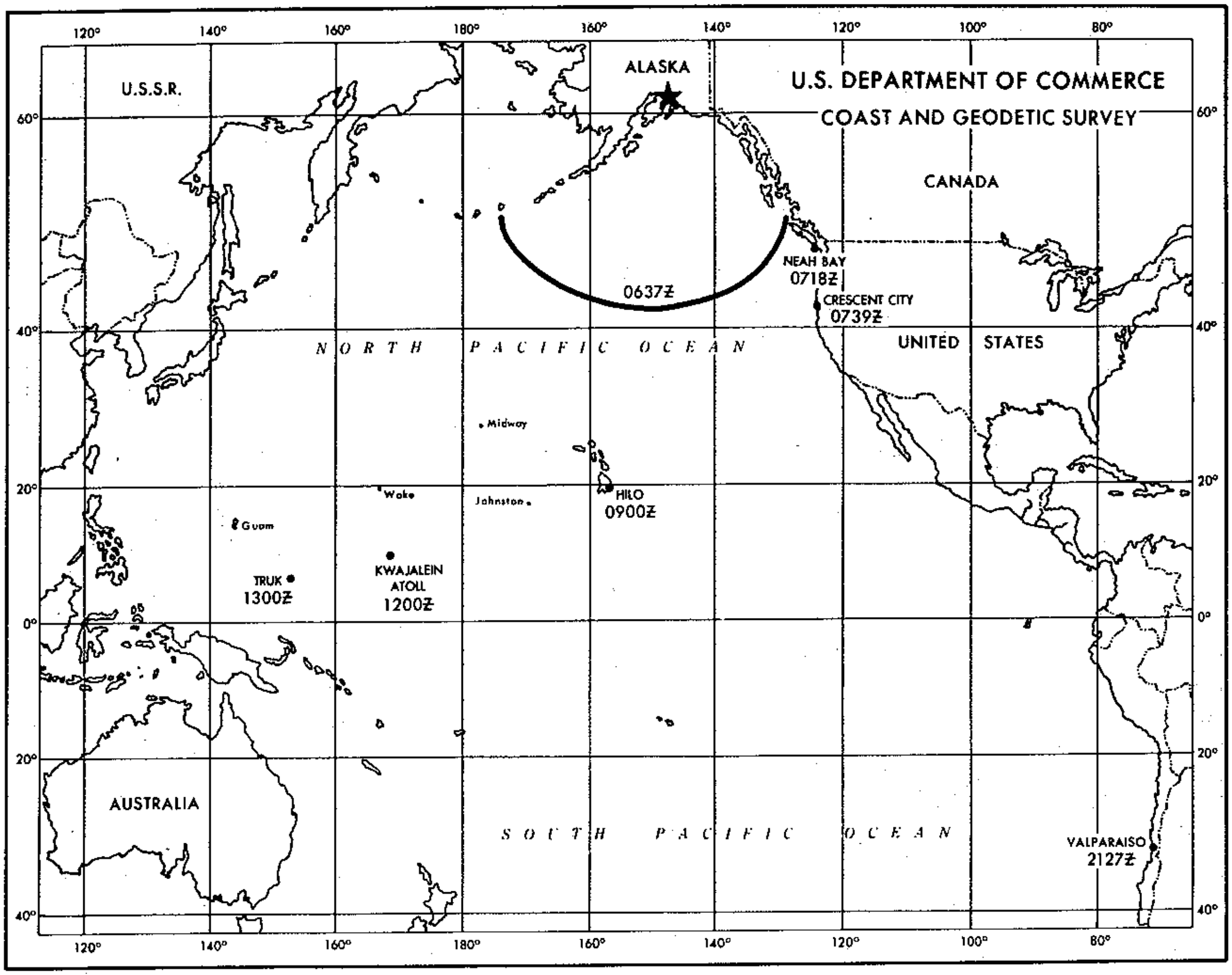

FIGURE 6.—The approximate tsunami wave front at 0637Z when the warning message was issued. The arrival times of the tsunami at selected stations are indicated.

section of the business district as demolished or so badly damaged as to make demolition necessary. Seven more structures in the same 5-block area were so badly damaged as to make their salvage questionable, and an additional 23 were damaged. Overall, Civil Defense estimated damage to Kodiak at $31,279,000 (Tudor, 1965). This includes damage of $2,165,000 to harbor facilities; $19,-346,000 to business and industry; $5,400,000 to public property; $2,440,000 to the fishing fleet; and $1,928,000 to dwellings. Comdr. Alfred Stroh, Civil Engineer Corps, U.S. Navy, reported 158 dwellings destroyed and 20 severely damaged (Stroh, 1964). The Alaska Division of Public Health (Preliminary report . . ., 1964) lists 71 business firms that were heavily damaged or destroyed.

The city of Kodiak was fortunate in that it had approximately 30 minutes of warning before the arrival of the first crest. The first wave was a gentle flood followed by a gradual ebb. The second wave advanced as a cresting 30-foot wall that thundered through the channel and pushed 50- to 100-ton boats over the breakwater as far as three blocks into the city.

Small villages in the area also suffered heavily. The 9 houses and the Russian Orthodox Church that comprised Kaguyak were swept away. All of the 35 homes in Old Harbor were floated from their foundations; however, 6 or 7 probably were salvageable. The old school and the new school suffered minor damage, and the church was undamaged. Ouzinkie had 5 houses, a grocery store, and a cannery destroyed. At Afognak, 4 homes, the community hall, and a grocery were washed away and destroyed. Several other homes moved on their foundations, and most of the 26 autos in the town sustained water damage.

Canada

Since the Canadian dissemination agency had withdrawn from the Seismic Sea Wave Warning System in July 1963, no official warning of the tsunami was provided to Canada. The earthquake, however, was felt in the Yukon Territory and northern British Columbia.

The tsunami struck the Canadian coast near the time of high tide. It was higher than any previously recorded in British Columbia. The earliest recorded arrival was 0533 at Tasu Sound. Damage was extensive and widespread, although the majority of the damage occurred at the twin cities of Alberni and Port Alberni. The highest wave reported in Canada was at Shields Bay, on the west coast of Graham Island. This crest was reported to be 17 feet above spring high water (32 feet above tidal datum), and the wave severely damaged a logging camp.

The twin cities of Alberni and Port Alberni are about 35 miles from the open ocean, near the head of the long and narrow Alberni Inlet. The tsunami period apparently matched the natural frequency of the inlet, causing amplification of the waves. According to the Port Alberni tide gage, the first wave arrived shortly before 0800 and swept into the towns, equaling the worst flooding conditions ever recorded there. The second crest was the highest of the series. It reached 20.9 feet above tidal datum, as determined from water marks on buildings. The period from the first to the second crest was approximately 97 minutes. The initial wave served to alert the inhabitants of the most heavily damaged areas of Alberni and Port Alberni. Many evacuated their houses, and almost all had dressed and were alert when the second wave arrived. As a consequence, there were no fatalities or serious injuries. Fifty-eight properties, including individual homes, stores, and multiple auto courts, were completely destroyed. In addition, 320 dwellings suffered damage, ranging from minor to severe. Six hundred ninety-four persons were driven from their homes until repairs or replacements could be made.

Damage near Alberni was centered on the low-lying areas along the north bank of the Somass River. Buildings not bolted to their foundations were swept inland as far as 1,000 feet. Log booms and boats in the inlet were carried high on shore causing heavy damage. Total damage in the Alberni-Port Alberni area, excluding damage to heavy industry and private autos, was about $5 million. The forest industries complex of MacMillan, Bleodel, and Powell River, Ltd., suffered much damage, but the amount was not made public.

An attempt to compute the natural period of Alberni Inlet was made, using the formula for a rectangular harbor open at one end,

$$T = 4\,l / \sqrt{gh},$$

where l is the length of the harbor, h the depth, and g the gravitational constant. In using this formula, the effects of the meandering path of the channel, the numerous constrictions in the channel, and the effects of friction were all neglected. The natural period of Alberni Inlet from Chup Point was 70 minutes, based on an average depth of 91 fathoms and a path length of 23 miles. The natural period of Trevor Channel and Alberni Inlet was computed as 110 minutes, based on an average depth of 82 fathoms and a path of 34 miles. It is probable that the 90- to 100-minute period, as recorded on the Port Alberni tide record, is the natural period of the 23-mile path.

Other locations also suffered major damage. The village of Hot Springs Cove had 16 of its 18 houses destroyed. At Zeballos, 30 homes were knocked from their foundations, and considerable damage to personal property was caused by silt and salt water. In the small logging community or Amai, where the tsunami caused considerable damage to 10 buildings, 37 people were made

homeless. The tsunami also destroyed the radio telephone communication system at Amai.

Washington

Some damage was done on Lake Union, Seattle, Wash., by seiching caused by the earthquake vibration. The disturbance caused minor damage to the gangway of the USCGS ship *Patton* and snapped a mooring line on the USCGS ship *Lester Jones*. Minor damage was also caused to several pleasure craft, houseboats, and floats which broke their moorings.

Of the four bulletins issued by the Honolulu Observatory during the tsunami, three were received by the Washington State Department of Civil Defense. At 0642, the second advisory was received, giving an estimated arrival time for Neah Bay of 0730. The warning was received at approximately 0713. By 0718, all coastal counties had been advised that the tsunami warning had been received. The final advisory was received by the Washington Civil Defense about 1130, at which time the coastal counties were advised that the emergency had ended. Damage in the State of Washington included the destruction of one small bridge at Copalis and one at Iron Springs, near Pacific Beach. A mile of ocean shore bulkhead was taken out at Moclips. Minor damage was reported to houses at Moclips and Pacific Beach; 4 mobile campers were overturned, and a sheriff's car was lost in the Ocean Shores and Pacific Beach area (Robinson, 1964 and 1966). The tsunami struck the outer coast of Washington between 0715 and 0755. Maximum heights were approximately 4 to 5 feet. The Neah Bay tide gage recorded a maximum wave of 4.7 feet.

Oregon

Reception times of the first two bulletins were not reported by the Oregon State Civil Defense Agency. The warning bulletin, filed at 0637, was received at 0700 and immediately disseminated to the coastal areas. U.S. Coast Guard stations along the coast reported that the initial wave arrived between 0730 and 0800. The only tide station in Oregon, that at Astoria, recorded a maximum wave of 2.4 feet. The Coast Guard stations reported much greater heights, ranging up to 14 feet at Umpqua River, 12 feet at Siuslaw River; and 10 to 11 1/2 feet at Nehalem River, Depoe Bay, Yaquina Bay, and Coos Bay.

The Oregon State Civil Defense Agency reported that four children who were camping with their parents on the beach near Newport were drowned. Damage estimates, supplied by Oregon State Civil Defense, are given below.

Bandon—Negligible.
Cannon Beach—City, $50,000; private, $180,000.
Chetco—Negligible.
Coos Bay—Negligible.
Depoe Bay—$5,000.
Florence—$50,000.
Port Orford—Negligible.
Rogue River—$3,000.
Seaside area—City, $41,000; private, $235,000.
Tillamook—Negligible.
Umpqua—$5,000.
Waldport-Alsea area—Port facilities, $145,000; private, $15,000.
Warrenton—Negligible.
Yaquina—$5,000.

Much of the damage in Oregon occurred away from the ocean front. For example, in Seaside (fig. 7), all damage occurred along the banks of the Necanicum River and Neawanna Creek. At the north end of town, the wave overflowed the banks of Neawanna Creek, damaging four trailer-houses and 10 to 12 houses, and washing out a railroad trestle over the creek. Along the Necanicum River, flooding occurred in the downtown section of Seaside in the area bounded by Broadway, Downing Street, Second Avenue, and the river. The Fourth Avenue Bridge was washed out, and the Avenue G Bridge was so badly damaged that it had to be closed. Logs and debris were scattered all over the low-lying areas.

Much the same pattern of damage occurred at Cannon Beach where the wave penetrated up Elk Creek, washing out the old Highway 101 bridge and damaging the new one.

California

The first advisory bulletin issued by the Honolulu Observatory was received by the California Disaster Office (CDO) at 0536. The second advisory was received at 0644 and disseminated via the State Department of Justice Teletype System to all sheriffs, chiefs of police, and civil defense directors of coastal counties and cities at 0703. The California Disaster Office received the warning at 0713 and relayed it to the coastal counties and cities at 0725. Some discrepancy exists in these reported dissemination times, since all coastal jurisdictions reporting stated that bulletin number 2 was received at 0708, and the warning bulletin was received at 0750.

The tsunami reached record heights along the coast of northern California and was disastrous at Crescent City. The large amplitude of the waves at Crescent City was probably due to focusing caused by bottom topography. J. A. Roberts and Chen-Wu Chien (1964) have ascribed this focusing primarily to the topography in the vicinity of Cobb Seamount, approximately 400 miles northwest of Crescent City, and have prepared refraction diagrams to illustrate this.

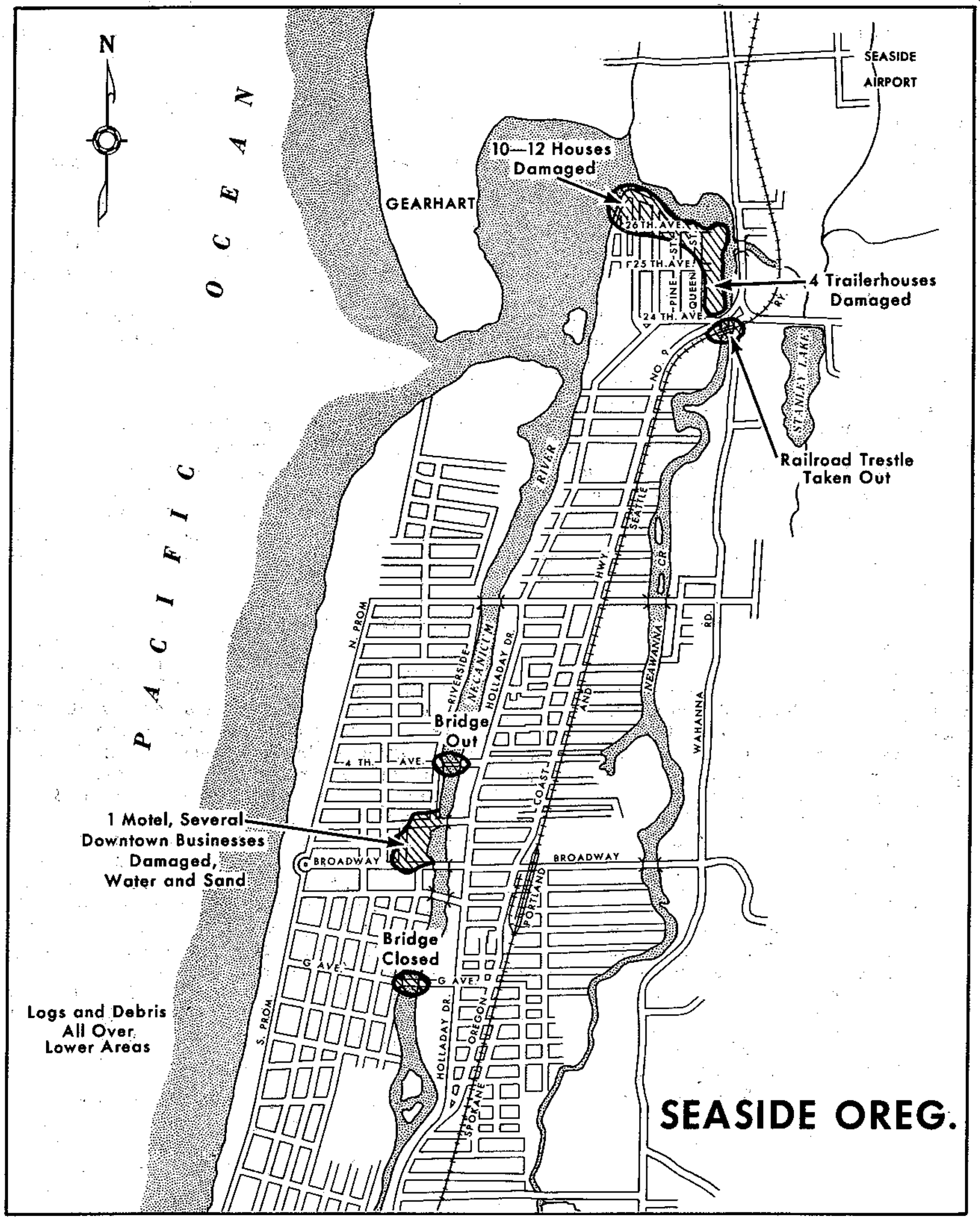

FIGURE 7.—The location of major tsunami damages in Seaside, Oregon.

California had a longer time to prepare for the onslaught of the tsunami than the other Pacific Coast States, but due to much larger wave amplitudes and lack of proper response and knowledge among the public, the death and damage totals were much greater than any other place, except Alaska. The California Disaster Office reported 11 killed and 35 injured in Crescent City, and between $7,939,000 and $8,789,000 damage in the State. An additional $1 million in Marin County, which was not included in the CDO estimate, brought the total damage in California to almost $10 million.

At Crescent City where the bulk of the damage occurred, the county sheriff immediately contacted county and city civil defense authorities upon receipt of the advisory at 0708. The low-lying and coastal areas were warned, and evacuation began immediately. Evacuation was reasonably prompt, but not complete. The first two waves caused minor flooding in the business district, and many people returned to the area to clean up their places of business, since past experience showed that Crescent City normally experienced one or two surges with minor flooding during a tsunami. This premature return to the evacuation area was the cause of most of the fatalities. The third and fourth waves caused most of the destruction and the casualties; they caught the people who returned to the area after the second wave, and others who had failed to evacuate. Seven people, including the owner and his wife, returned to the Long Branch Tavern to remove the money from the building. Since everything appeared normal, they stopped to have a beer and were also trapped by the third wave. Five of the seven were drowned when the boat in which they were attempting to escape was sucked into Elk Creek by the recession and was smashed against the steel grating of the bridge over the mouth of the creek.

Approximately 30 blocks were devastated in Crescent City. The California Disaster Office reported damage (excerpted from a report of the California Department of General Services) as follows:

- 54 residences, total loss.
- 13 residences, major damage.
- 24 residences, minor damage.
- 21 commercial fishing boats, lost (sunk or beached).
- 12 house trailers, total loss.
- 172 business houses, severely damaged or destroyed.

Estimated cost to replace and repair:

Public property	$473,000
Private utilities	68,000
Private property	6,873,000
Total estimated cost	$7,414,000

The streets of Crescent City were strewn with rubble from demolished buildings, and logs which were swept in from the beaches. Automobiles were heaped in scattered piles, and stock from damaged stores was scattered throughout the area. The third wave picked up a gasoline tank truck parked at the Texaco station and slammed it through the garage door of the Nickols' Pontiac Building. An electrical junction box just inside the door was knocked loose by the impact, and a fire started. The fire destroyed the building and spread back to the Texaco tank farm which burned for 3 days.

The greatest height reached by the tsunami at Crescent City was 20.70 feet above mean sea level. This height was determined from the water marks on the flag pole near the Harbor Masters office at Citizens dock.

Crescent City was not the only place where the inhabitants placed themselves in jeopardy. Newspapers estimated that 10,000 people jammed beach areas at San Francisco to watch the tsunami arrive. In San Diego, an attempt was made to evacuate the beach areas, but curious citizens created a problem. Had large amplitude waves struck these places, the casualty lists would have been much greater.

Reaction by county and city civil defense organizations varied considerably. In Humboldt County, the second advisory issued by the Honolulu Observatory was received at 0708 at the county sheriff's office. All agencies were mobilized by 0718, evacuation of all persons in danger areas was completed by 0740, and road blocks were established under the direction of the sheriff's office to guarantee and enforce against any return to the threatened area. In Marin County, internal weaknesses in the county disaster organization were emphasized in reports submitted by cities and districts. San Francisco attempted to evacuate ocean beaches immediately upon receipt of the advisory, but as noted above, efforts were unsuccessful. Los Angeles County made no attempt to evacuate waterfront areas.

The tsunami did not spare other areas of the California coast. Mendocino County reported that approximately 100 fishing boats in Noyo Harbor suffered damage with 10 being sunk. A dredge in the harbor was carried upstream about one-fourth mile and grounded on a sandbar. Estimates of the damage ranged from $250,000 to $1 million. In Marin County, approximately $1 million worth of damage was done to small boats and berthing facilities, mostly in Loch Lomond Harbor in San Rafael. Los Angeles County Civil Defense reported $100,000 to $200,000 damage to six small-boat slips, pilings, and the Union Oil Company fuel dock; $75,000 damage due to scouring action on the harbor sides in Los Angeles County Harbor; and 8 docks wth a value of $100,000 destroyed in Long Beach Harbor. Only

negligible damage was reported elsewhere in the State.

Hawaii

At 0401, the Honolulu Observatory notified the Assistant Tsunami Advisor to the State of Hawaii that a major earthquake had occurred. The same information was provided the Civil Defense Vice Director at 0405. The Vice Director passed the information to the Director, key staff members, and the civil defense administrators in all counties. At 0425, Civil Defense activated its emergency operating center. At 0643, following receipt of the tsunami warning from the HO, the decision was made to sound all coastal sirens and to activate the Civ-Alert Radio Broadcast System. At 0700, the sirens and the Civ-Alert System were activated simultaneously in all counties. The sirens were sounded again at 0800 and 0830, and the Civ-Alert System remained continuously active after 0700. Evacuation was fairly complete, and no casualties resulted from the tsunami. The earliest recorded arrival was 0833, at Nawiliwili.

Damage was light in Hawaii, although wave heights in excess of 12.5 feet were recorded at Hilo, and waves in excess of 11.0 feet were recorded at Kahului. In Hilo, four restaurants and a residence were flooded near the head of Reeds Bay. The highest of the flooded restaurants had a floor approximately 6 feet above sea level. This floor was flooded to a depth of 1 foot. The west end of the Waiakea Bridge over the Wailoa River was partially undermined, and the sidewalk, collapsed, creating a hole approximately 9 by 10 feet. Civil Defense estimated the total damage to be $15,000.

Considerable damage was reported from Maui where Civil Defense reported estimated damages of $52,590. The major damage was limited to facilities at Kahului Harbor, and all damage resulting mainly from flooding, was restricted to the immediate waterfront area. The Kahului Railroad Company, which suffered the majority of the tsunami damage, reported damage occurred primarily to freight and to the wooden supports of concrete piers. The complete listing of the damage on Maui is given below.

Aloha Bar and Restaurant	$50
Camp 1 Beach, Spreckelsville	600
Full Gospel Church	500
Kahului Railroad Company	42,500
Kaiser Permanente Cement	60
Agrifino Cortez, Kualapuu	100
Maui Frontier Restaurant	4,000
Maui Savings and Loan Company	100
Standard Oil Company	1,000
State and County	1,620
Ulupalakua Cold Storage	1,060
Y. Hata and Company	1,000
Total damage	$52,590

Chile

The warning issued by the Honolulu Observatory was received by the Departamento de Nacegación e Hidrografía in Valparaiso at 1210. By 1440, all maritime authorities along the Chilean coast had been alerted and supplied with estimated arrival times of the tsunami.

Since time was available, the Departamento de Navegación e Hidrografía instructed its tide observers to install 5-meter staffs and make photographs of the maximum and minimum sea-level oscillations to provide more exact records of wave amplitudes than those provided by the tide gages. Maximum amplitudes reported were 11.3 feet at Valparaiso and 16.4 feet at Huasco.

Because beaches and harbors were cleared, there were no deaths or injuries resulting from the tsunami. Slight damage was done at Iquique, Coquimbo, Huasco, and San Vincente, primarily to shipping.

Miscellaneous

Reports received from other dissemination agencies in the Warning System indicate that the response to the warning was adequate and timely. No damage was reported by any of the dissemination agencies, except as noted above. A report was received from Honiara in the Solomon Islands indicating that a boat had been beached there by the tsunami.

SEICHES ON THE GULF COAST

Immediate reports were received of seiche action in rivers, lakes, bayous, and protected harbors and waterways all along the Louisiana coast and along the Texas coast as far west as Freeport. These surges commenced between 30 and 40 minutes after the earthquake, or about the time the Love and Rayleigh waves from the earthquake were passing through the area.

McGarr (1965) derived an analytical expression for the effect of seismic surface waves on a water channel of width L and depth H and used it to compute a theoretical marigram. He compared this with an actual marigram recorded in a channel at Freeport. His study indicates that the horizontal component of motion of the seismic surface waves is the primary cause of seiches generated in channels by teleseisms. Donn (1964) computed the fundamental periods for several profiles across the waterways in the vicinity of the Freeport tide gage and found the periods to be close to those of the seismic surface waves. It is probable that resonance, or near resonance, between the seismic surface waves and either the fundamental period or some low harmonic of the seiches, occurred all along the Gulf Coast States, wherever disturbances were reported.

In view of the fact that both Donn and McGarr consider the amplitude of the Rayleigh waves to

have exceeded 10 centimeters, it is interesting to note that the bridge tender at the Woodland Highway Bridge over the Algiers Canal, just east of New Orleans, reported that he felt sharp, well-defined shakes on the bridge. His report is the only account of actual motion felt in the Gulf States.

Damage, although generally minor, was widespread along the Gulf Coast. The area in which damage was reported extended from the Lake Borgne, La., area on the east to Houston, Tex., on the west, and as far inland as Baton Rouge, La. The seiche action was recorded on tide gages along the coast from Port Isabel, Tex., to Key West, Fla. The seiche was also recorded on water-level recorders at Blakely Dam and Narrows Dam near Hot Springs, Ark. Although newspapers reported that 5-foot drops and corresponding rises were noted at oil rigs in the Gulf of Mexico, the only tide gage maintained by the Coast and Geodetic Survey on an oil rig showed no disturbance. This tide gage was on Humble Oil Platform "A", Grand Isle, La.

Damage reported near Golden Meadow and Galliano, La., included flooding along both sides of Bayou Lafourche. A number of boats in the same vicinity broke loose, and several sank or were washed ashore. One large oyster vessel broke loose and crashed into a bayou-side store.

The Headquarters of the 8th Naval District at New Orleans reported a sudden rise of 1 1/2 feet in the Mississippi River, causing vessels at the wharf to surge, mooring lines to break, and other minor damage. An 83-foot U.S. Coast Guard cutter, a barge, and a boat parted their mooring lines in the Industrial Canal. In the Harvey Canal, across the Mississippi River from New Orleans, a large number of barges were set adrift by a surge that had an amplitude of about 2 1/2 feet.

At the Port Allen Lock on the Morgan City-Port Allen Waterway, damage estimated at $3,200 was suffered by the landing pier and mooring dock. Near Denham Springs on the Amite River, a recession of 5 feet was followed by surges which damaged boathouses, ramps, and boats.

At Amelia Landing, east of Morgan City, La., waves of approximately 4 1/2 feet were reported. At the intersection of Bayous Long and Milhomme, 8 miles north of Morgan City, the Army Corps of Engineers lost one small boat when it was crushed between a quarterboat and a tree on the bank by a 4-foot wave. Another boat was damaged.

The Commander of the Texas Group, Atlantic Reserve Fleet, located at Orange, Tex., reported such minor damage as parted mooring wires, bent brows, and parted shore-power connections. Also, two dock bollards pulled loose. He also reported that three 10,000-ton commercial vessels broke loose from moorings in Houston, Tex., due to the seiche.

Other reports indicated that numerous boats and barges broke loose along the Texas coast, and that damage to a marine sales and service facility at Beaumont amounted to thousands of dollars.

TIDE GAGE DATA

The U.S. Coast and Geodetic Survey has published reports based on tide records of the tsunamis of April 1, 1946; November 4, 1952; March 9, 1957; and May 22, 1960. This paper provides observational data on the fifth major tsunami of recent years.

The earthquake of March 28, 1964, and the resulting tsunami caused more damage than any of the other four, except the May 22, 1960, disturbance. In 1964, damage in the United States exceeded the total for the other four disturbances.

A further comparison of the five tsunamis is through the amplitude of the greatest wave recorded for each. In table 2, statistics are given on maximum waves (rise or fall) recorded at several tide stations which were in operation during at least two of the tsunamis. Where the maximum wave exceeded the gage limit (indicated by + in the table), the figures may be misleading. For example, Hilo, Hawaii, was devastated in 1960, although the height indicated is only 9.6+ feet. The 1964 height, however, was 12.5+ feet, and Hilo suffered only minor flooding.

This report presents the data gathered through an examination of tide curves from 106 stations in the Pacific Ocean area. Statistical information is presented primarily in table 4; it includes certain data relative to the time and height of the initial and maximum waves. In relation to the data compiled in table 4, there are 105 prints of tide curves showing the arrival and initial stages of the tsunami which may be studied for variations in wave period, amplitude, etc., for many locations. The Marcus Island tide curve is not reproduced, since the tsunami cannot be distinguished on it. The 105 tide curves, a map locating the 106 tide stations, and tables 4 and 5 appear in the appendix to this paper. As elsewhere in the report, Greenwich Mean Time is used.

Data included in table 4 and the accompanying tide curves illustrate some of the difficulties encountered in analyzing the tide curves, since interpretation of the various statistics is often subjective. In the majority of cases, the initial disturbance is clearly defined, but for other stations, it is obscure and not well determined. This is due, at least in part, to one or more of the following factors: Screening effects of continental masses or island groups between the source and the tide gage; location of the tide gage in an area protected from the action of the open ocean; poor response of the tide gage to waves of tsunami periods; and masking of the tsunami effects by a large tidal range, local seiche action, or both.

Table 2.—Maximum recorded rise or fall

Station	1946	1952	1957	1960	1964
	Feet	*Feet*	*Feet*	*Feet*	*Feet*
Massacre Bay, Alaska	....	8.0	3.8	11.0+	2.8
Sweeper Cove, Alaska	....	6.9	....	7.0+	1.9
Yakutat, Alaska	....	1.8	2.2	5.2	7.6
Sitka, Alaska	2.6	1.5	2.6	3.0	14.3
Prince Rupert, British Columbia, Canada	....	....	....	0.4	8.9
Tofino, British Columbia, Canada	1.9	2.0	....	4.6	8.1
Neah Bay, Wash.	1.2	1.5	1.0	2.4	4.7
Crescent City, Calif.	5.9	6.8	4.3	10.9	13.0+
San Francisco, Calif.	1.7	3.5	1.7	2.9	7.4
Santa Monica, Calif.	....	3.6	3.0	9.1+	6.5
Los Angeles, Calif.	2.5	2.0	2.1	5.0	3.2
La Jolla, Calif.	1.4	0.8	2.0	3.3	2.2
San Diego, Calif.	1.2	2.3	1.5	4.6	3.7
Ensenada, Mexico	....	....	3.4	8.1	7.8+
Salina Cruz, Mexico	....	4.0	1.2	5.2	2.8
La Libertad, Ecuador	....	6.2	3.5	6.3	4.2
La Punta, Peru	....	6.4	0.9	7.2	6.4
Antofagasta, Chile	5.9	4.7	3.0	4.6	3.3
Valparaiso, Chile	5.0	5.9	6.7	5.6	6.2
Talcahuano, Chile	....	12.0+	4.6	16.6	5.4
Hilo, Hawaii	....	7.9	8.9	9.6+	12.5+
Honolulu, Hawaii	4.1	4.4	3.2	5.5+	2.7
Midway Island	....	6.6	2.7	2.0	0.9
Johnston Atoll	....	1.4	0.7	3.4	1.0
Pago Pago Harbor, American Samoa	....	6.0	1.4	5.2	1.3
Wake Island	....	1.7	2.4	3.3	0.5
Ft. Denison, Sydney Harbour, Australia	....	....	....	2.7	1.0
Coffs Harbour, New South Wales, Australia	....	....	....	3.3	0.2
Miyako Jima, Japan	....	....	....	10.2	1.1
Aburatsu, Japan	....	....	....	6.6	2.4
Shimizu (Tosa), Japan	....	....	....	8.9	1.8
Kushimoto, Japan	....	....	....	10.5	2.6
Toba Ko, Japan	....	....	....	5.9	0.8
Mera, Japan	....	....	....	7.9	1.9
Hanasaki, Japan	....	....	....	8.2	2.2

Table 5, lists (1) the time the seichelike action began at six typical Gulf Coast tide stations and at two Arkansas damsite water-level recorders and (2) the maximum amplitudes reached. Within the limits of the timing accuracy of the gages, it appears that the beginning of the recorded disturbances coincided with the arrival at the station of the seismic surface waves. Table 5 is accompanied by six prints of tide curves and two of water-level recordings showing the disturbance.

Wave Travel

Wave-travel data are given in table 3 for stations where the initial arrival time of the tsunami is fairly well determined. Since the epicenter of the earthquake was on land, distances are measured from a point with coordinates 60° N., 147° W. Distances of wave travel are computed for the great-circle arc from this point to the tide station. In almost all cases, the great-circle route is shorter than the actual path traveled by the initial wave. The great-circle routes from this point to most stations on the west coast of North and South America intersect the continents. Because of greater ocean depths, longer routes may provide earlier arrival than the great-circle route, even where there is no intervening land mass or island group. Since wave speed varies during the travel period and the traveltime to each station is the only factor that is fairly well determined, the computed speed is an average for the distance from the source to the tide stations. These computed speeds are generally less than the actual velocity, since the true travel distances for the wave are greater than the computed distances.

Because tsunami wave lengths (distance between successive crests) are very much longer than the oceanic depths over which they travel, their speed is controlled by the water depth and is computed by the shallow-water wave formula $S = \sqrt{gd}$, where d is the water depth, and g is the acceleration due to gravity. For computing speed in knots with the depth in fathoms, this equations becomes $S = 8.23 \sqrt{d}$.

Wave Period and Wave Length

Wave period for a tsunami is difficult to determine, and the wide variation in this time interval for the stations given in table 4 will illustrate the confusion encountered. The period between the first and second wave crests, as recorded, varies from 7 minutes to 2 hours. The deep-ocean period of the tsunami is almost impossible to determine from records of coastal tide stations, although the majority of the energy of the tsunami was probably contained in a single wave formed by drainage from the uplifted portion of the Gulf of Alaska. The natural period of the local basin, harbor, or shelf area should be evident shortly after the arrival of the initial wave. However, interference caused by refracted or reflected arrivals commences and is indicated on the tide curve quite early; this confuses the identity of the true period.

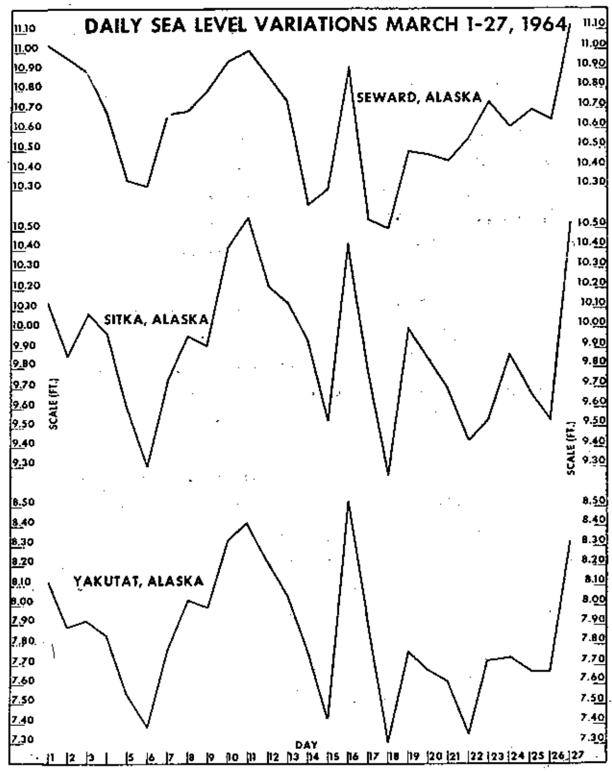

FIGURE 8.—Daily variations in sea level for March 1964.

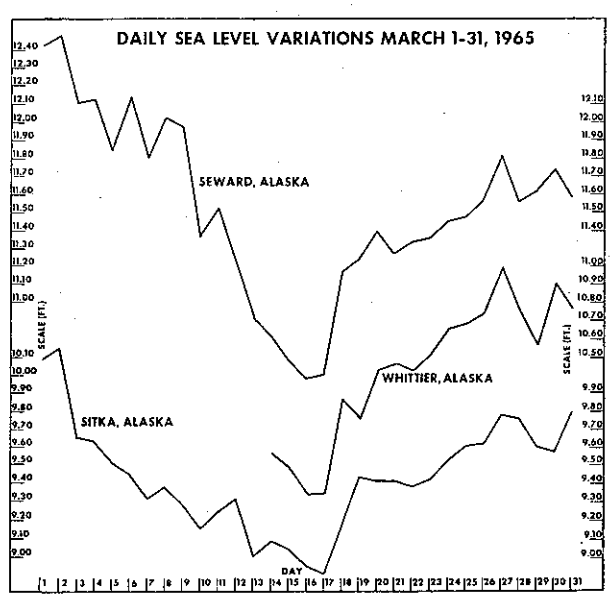

FIGURE 9.—Daily variations in sea level for March 1965.

Table 3.—Wave travel

[Station numbers are identical with those in table 3. Locations are on figure 11. Distances are measured from a point with coordinates 60°N. and 147°W.]

Tide station	Great-circle distance	Time		Average speed
	Nautical miles	*Hours*	*Minutes*	*Knots*
1. Massacre Bay, Attu, Alaska	1,365	3	51	355
2. Sweeper Cove, Adak, Alaska	1,098	3	24	323
3. Unalaska, Alaska	733	2	30	293
4. Yakutat, Alaska	222	1	24	159
5. Sitka, Alaska	405	1	30	270
7. Ketchikan, Alaska	564	2	49	200
9. Tasu Sound, Canada	658	1	57	337
14. Tofino, Canada	973	3	24	286
23. Neah Bay, Wash	1,042	3	42	282
26. Astoria (Tongue Pt.), Oreg	1,165	4	20	269
27. Crescent City, Calif	1,380	4	03	341
28. San Francisco (Presidio), Calif.*	1,626	5	06	319
30. Avila, Calif.*	1,805	5	08	352
31. Rincon Island, Calif.*	1,877	5	41	330
32. Santa Monica, Calif.*	1,917	5	39	339
33. Los Angeles (Berth 60), Calif.*	1,937	5	48	334
34. Alamitos Bay, Calif.*	1,939	6	00	323
35. Newport Bay, Calif.*	1,952	5	50	335
36. La Jolla, Calif.*	2,006	5	48	346
37. San Diego, Calif.*	2,015	6	14	323
38. Ensenada, B.C., Mexico*	2,074	6	06	340
39. La Paz, B.C., Mexico	2,635	8	51	298
42. Mazatlán, Sin., Mexico*	2,782	8	24	331
43. Manzanillo, Mexico*	3,056	8	39	353
44. Acapulco, Gro., Mexico	3,286	9	29	347
45. Salina Cruz, Oax., Mexico*	3,447	10	34	326
46. San Jose, Guatemala*	3,685	11	16	327
47. Acajutla, El Salvador*	3,730	11	42	319
49. Corinto, Nicaragua*	3,862	12	24	311
50. Puntarenas, Costa Rica*	4,061	12	47	318
51. Quepos, Costa Rica*	4,109	12	24	331
52. Puerto Armuelles, Panama*	4,206	12	48	329
54. Bahia Solano, Colombia*	4,470	14	09	316
57. San Cristobal, Galapagos Island, Ecuador*	4,510	12	51	351
58. La Libertad, Ecuador*	4,816	14	33	331
59. Talara, Peru*	4,932	14	20	344
60. La Punta (Callao), Peru*	5,442	15	35	349
61. San Juan, Peru*	5,672	15	54	357
62. Matarani, Peru*	5,843	16	21	357
63. Arica, Chile*	5,970	16	54	353
64. Antofagasta, Chile*	6,237	17	03	366
65. Caldera, Chile*	6,403	17	19	370
66. Valparaiso, Chile*	6,689	17	51	375
67. Talcahuano, Chile*	6,839	18	39	367
68. Corral, Chile*	6,991	19	03	367

Table 3.—Wave travel—Con.

[Station numbers are identical with those in table 3. Locations are on figure 11. Distances are measured from a point with coordinates 60°N. and 147°W.]

Tide station	Great-circle distance	Time		Average speed
	Nautical miles	*Hours*	*Minutes*	*Knots*
70. Bahia Esperanza, Palmer Peninsula, Antarctica	8,445	22	34	374
71. Argentine Islands, Antarctica	8,368	21	49	384
72. Christmas Island	3,515	7	45	454
73. Hilo, Hawaii Island, Hawaii	2,441	5	24	452
74. Kahului, Maui Island, Hawaii	2,380	5	11	459
75. Mokuoloe Island, Oahu Island, Hawaii	2,359	5	09	458
76. Honolulu, Oahu Island, Hawaii	2,368	5	17	448
77. Nawiliwili, Kauai Island, Hawaii	2,342	4	57	473
78. Midway Islands	2,271	4	51	468
79. Johnston Atoll	2,773	6	03	458
80. Canton Island, Phoenix Islands	3,944	8	39	456
81. Pago Pago Harbor, American Samoa	4,602	10	15	449
82. Lyttelton, New Zealand	6,524	18	34	351
85. Fort Denison, Sydney Harbour, Australia	6,397	17	09	373
86. Camp Cove, Sydney Harbour, Australia	6,394	16	54	378
88. Rabaul, New Britain	4,778	11	49	404
89. Moen Island, Truk Islands, Caroline Islands	4,165	9	24	443
90. Kwajalein Atoll, Marshall Islands	3,682	8	24	438
91. Eniwetok Atoll	3,673	8	09	451
92. Wake Island	3,138	6	45	465
94. Apra Harbor, Guam, Mariana Islands	4,058	9	12	441
97. Aburatsu, Japan	3,536	10	27	338
100. Toba Ko, Japan	3,235	11	24	284
102. Ofunato, Japan	2,874	7	04	406
103. Hanasaki, Japan	2,569	6	39	386
104. Yuzhno Kurilsk, Kuril Islands	2,540	6	24	397
106. Petropavlovsk, Siberia, U.S.S.R	1,793	5	34	322

*The great-circle lines from this point to stations on the west coast of North and South America intersect the continents. Therefore, the true wave-travel distances are greater than the computed distances. Computed speeds are similarly distorted and are less than their real values.

Other Features

The tsunami was highly directional, being focused by the shape of the generating area and the surrounding land masses toward the south and southeast. Maximum wave heights in the Aleutians and Japan, except at Ofunato, were under 3 feet. Chilean stations, on the other hand, generally had maximums in excess of 6 feet.

The tide gage maintained by the U.S. Coast and Geodetic Survey at Seward, Alaska, was destroyed by the earthquake and tsunami. However, the wreckage of the gage and the tide house was later found on the deck of a tanker which had been tied up at the dock where the tide gage was installed. The tide record was salvaged, and although it did not show the tsunami, an analysis was made to extract available water level information. Figures 8 and 9 show the daily sea level variations for the months of March 1964 and 1965 for Seward and two other Alaskan tide stations. The values for each day are the mean of the hourly heights for the date. The dates for these three stations are based on local (+10 hours) time. The value for March 27, 1964, is based on data to 1800 hours.

No unusual variations in sea level were found to have occurred prior to the earthquake. The con-

trol stations were deliberately chosen outside of the area of crustal deformation; however, all three stations show the same direction and order of variation. The magnitude of the variation prior to the earthquake did not exceed the maximum variations noted on other days.

REGIONAL TSUNAMI WARNING SYSTEMS

Since the Honolulu Observatory is unable to provide warnings to areas close to the source of a tsunami, regional tsunami warning systems are being organized by the U.S. Coast and Geodetic Survey. These regional systems are designed to provide tsunami warnings on the basis of seismic data alone, within 15 minutes of the occurrence of any large earthquake in the area they are protecting. The warnings normally will be based solely on the fact that an earthquake with a magnitude great enough to generate a tsunami has occurred in an area where tsunami generation is possible. The first regional system is designed to provide warning information for Alaska and the Aleutian Islands. Its headquarters will be at the Palmer Observatory, Palmer, Alaska.

Seismic data for the system will be provided by a tripartite network of seismographs, with remote recording at the Palmer Observatory. Short-period seismographs will be installed at two outposts—Palmer West and Palmer South—approximately 25 and 28 miles, respectively, from the Palmer Observatory. In addition, data will be telemetered to Palmer from short-period seismographs at the Adak, College, and Sitka Observatories. All telemetered seismic data and the data from the short-period seismographs at Palmer will be recorded on helicorders, thus providing the personnel at Palmer with instantaneous visual readout of seismic data from six locations, three at Palmer and one each at Adak, College, and Sitka.

Since the Adak and Sitka Observatories will have limited warning responsibility in their immediate areas, expanded seismic capabilities are being provided at these two locations. At Sitka, a short-period vertical seismometer is being installed on Biorka Island, and the data will be telemetered to the Sitka Observatory. Adak will have a small tripartite network with legs 1 to 2 miles long. In addition, Adak will have telemetered tide data available from Shemya.

Palmer, as the center of the Alaska Tsunami Warning Center, will have an extensive communication network (fig. 10). The basic network will be supplied by the Defense Communication Agency (DCA) and supplemented by facilities of the FAA and Office of Civil Defense.

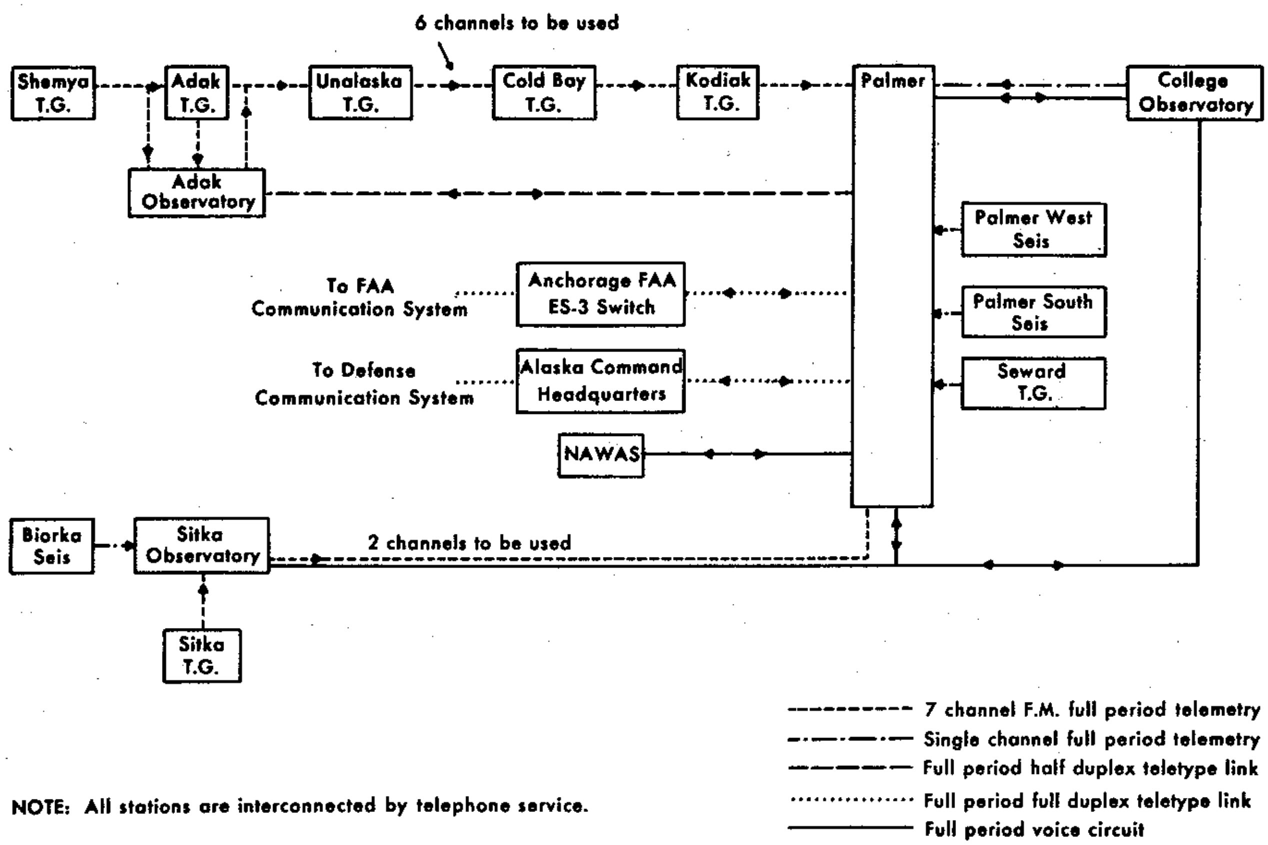

FIGURE 10.—The Alaska Seismic Sea Wave Warning System Communication Network.

One circuit will bring seismic data to Palmer from Adak, and tide data from Shemya, Adak, Unalaska, Cold Bay, and Kodiak. Bridging facilities at Adak will permit the Adak Observatory to monitor Shemya tide data transmitted on this circuit. A second circuit will be used to bring seismic and tide data from Sitka to Palmer (Future plans call for the transmission of tide data from Yakutat on this circuit as well). Palmer also will have a continuous record of Seward tide data, and an additional circuit will be used to telemeter seismic data from College to Palmer.

A full-time voice circuit will connect the observatories at Palmer, Sitka, and College. A full-time teletype circuit will link Palmer and Adak. In addition, the Palmer Observatory will have teletype circuits into the FAA ES-3 switch at Anchorage and the Defense Communications System.

The primary means for disseminating watch and warning information to the people of Alaska will be through the National Warning System (NAWAS) which is being extended to the Palmer Observatory.

It is anticipated that a similar regional system will be developed for Western United States. The Honolulu Observatory would serve as a regional warning center in the event of a major earthquake in the Hawaiian Islands.

ACKNOWLEDGMENTS

Tide observers are responsible for the original records reproduced in this report. Services of these individuals and local organizations cooperating in maintenance of tide stations and furnishing records used in this report are greatly appreciated. Special acknowledgment is extended to the following organizations in other countries for providing tide records and pertinent information, thus permitting a more complete coverage of the region affected.

Departamento de Navegación e Hidrografía de la Armada, Chile;

Canadian Hydrographic Service;

Inter-American Geodetic Survey and the several countries in Central and South America which regularly furnish tide records to this Bureau;

Instituto de Geofisica, Universidad Nacional de Mexico;

The Royal Observatory, Hong Kong;

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Earthquake Research Institute, University of Tokyo, Japan;

Oceanographic Institute, Wellington, New Zealand;

Naval Hydrographic Office, Taiwan, Republic of China;

Naval Hydrographic Service, Australia;

Bureau of Mineral Resources, Geology and Geophysics, Australia;

Institute of Aeroclimatology, U.S.S.R.;

National Institute of Oceanography, England; and

Servicío de Hidrografía Naval Secretaría de Marina, Argentina.

Special thanks are due also to the many civil defense organizations and dissemination agencies that participated in the Seismic Sea Wave Warning System and submitted reports on the tsunami in their respective areas.

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Appendix

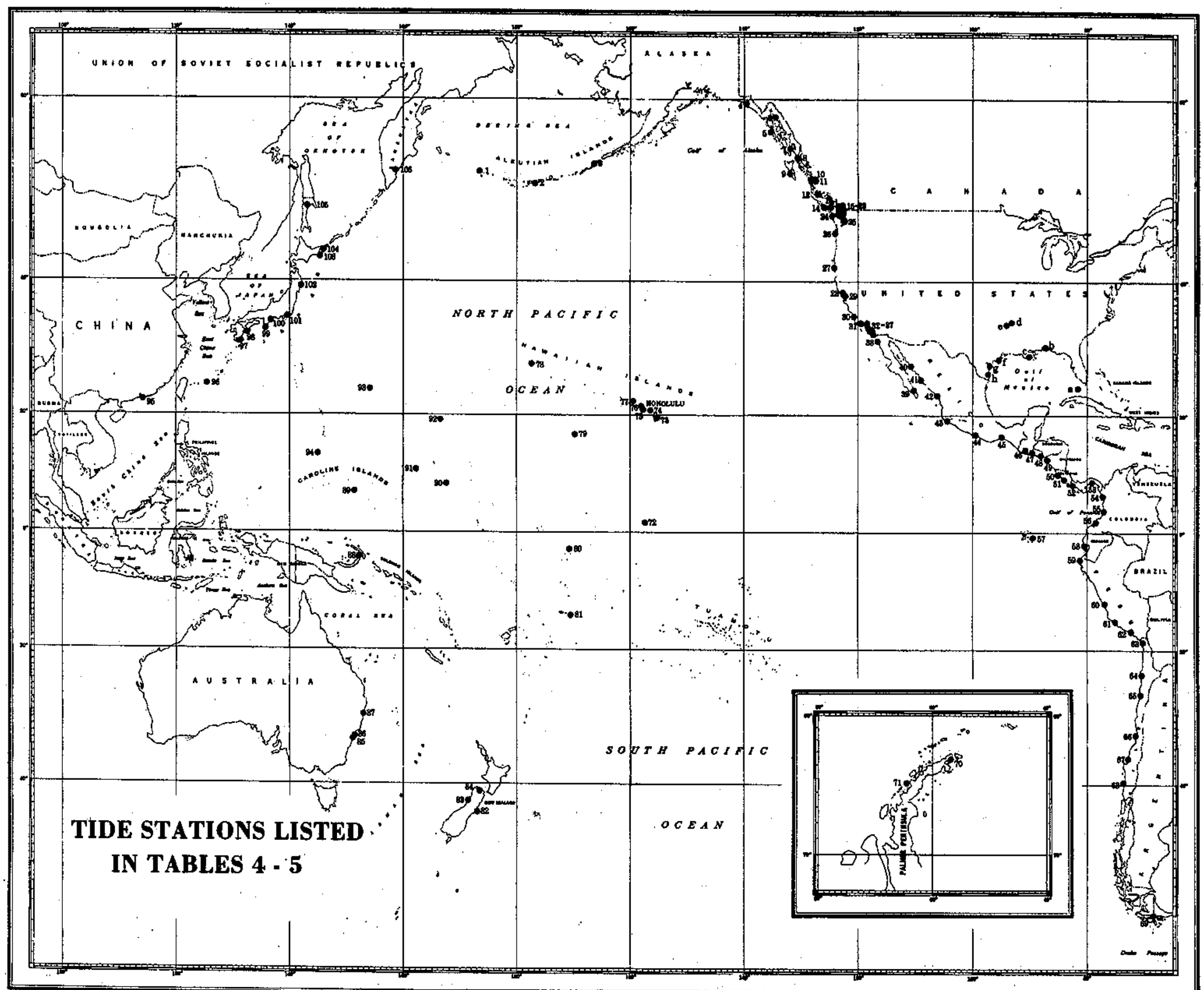


FIGURE 11.—Locations of tide stations.

Table 4.—The tsunami of March 28, 1964, as recorded by tide gages

[Earthquake epicenter 61.04°N., 147.73°W., on coast of northern Prince William Sound, Alaska. Wave generating area is shown on figure 2; station locations are on figure 11. Symbols are defined at the end of this table. All times are Greenwich Mean Time.]

Tide station	Latitude		Longitude		Initial wave						Maximum rise or fall				
					Time of arrival			Period 1st to 2nd crest	Initial rise	Following fall	Time of beginning			Duration	Height
	° North	'	° West	'	*Day*	*Hour*	*Minute*	*Minute*	*Feet*	*Feet*	*Day*	*Hour*	*Minute*	*Minute*	*Feet*
1. Massacre Bay, Attu, Alaska.....	52	50	186	48	28	07	27	72	0.7	1.0	28	19	46	14R	2.8
2. Sweeper Cove, Adak, Alaska....	51	51	176	39	28	07	00f	54	0.6	0.8	29	04	17	21F	1.9
3. Unalaska, Alaska..................	53	53	166	32	28	06	06	36	0.3	1.0	28	15	15	13R	2.6
4. Yakutat, Alaska....................	59	33	139	44	28	05	00	7	4.6	2.8	28	10	07	23R	7.6
5. Sitka, Alaska	57	03	135	20	28	05	06	50	5.8	11.6	28	06	24	35R	14.3
6. Juneau, Alaska	58	18	134	25	28	06	49	81	2.7	7.5	28	07	22	32F	7.5
7. Ketchikan, Alaska.................	55	21	131	39	28	06	25	29	1.6	1.2	28	09	22	30R	3.7
8. Prince Rupert, Canada...........	54	19	130	20	28	06	52	92	1.4	5.8	28	08	12	56R	8.9
9. Tasu Sound, Canada	52	45	132	01	28	05	33	70	2.9	6.3	28	05	52	22F	6.3
10. Bella Bella, Canada	52	10	128	08	28	06	53	39	3.2	6.3	28	07	24	20F	6.3
11. Ocean Falls, Canada	52	21	127	41	28	08	00	32	7.2	12.5	28	08	25	15F	12.5
12. Alert Bay, Canada.................	50	35	126	56	28	07	39	29	3.8	5.7	28	07	53	18F	5.7
13. Port Alberni, Canada.............	49	14	124	49	28	08	00	87 (est.)	.....	....	.....	.....	....	17+F	....
14. Tofino, Canada.....................	49	09	125	55	28	07	00	20	3.4	5.1	28	08	50	24F	8.1
15. Pitt Lake, Canada	49	26	122	31	28	12	00	g	.....	....	.....	.....	....	....	....
16. Point Atkinson, Canada	49	20	123	15	28	09	07	90	0.3	0.7	28	12	50	52R	0.8
17. Vancouver, Canada	49	17	123	07	28	09	20	120	0.2	0.5	28	11	05	45R	0.6
18. Fraser North Arm, Canada	49	12	123	05	28	10	15	g	.....	....	....	.....	....	....	....
19. New Westminister, Canada......	49	12	122	54	28	10	30	g	.....	....	....	.....	....	....	....
20. Steveston, Canada.................	49	07	123	12	28	09	45	g	.....	....	....	.....	....	....	....
21. Fulford Harbor, Canada..........	48	46	123	27	28	08	35	40	1.3	1.4	28	13	53	22R	2.0
22. Victoria, Canada	48	25	123	24	28	08	02	50	2.2	4.8	28	08	18	39F	4.8
23. Neah Bay, Wash.	48	22	124	37	28	07	18	22	2.9	2.4	28	08	44	21R	4.7
24. Friday Harbor, Wash.	48	33	123	00	28	08	30	19	0.8	0.2	28	09	50	60R	2.3
25. Seattle, Wash.	47	36	122	20	28	09	12	48	0.4	0.3	28	11	39	20F	0.8
26. Astoria (Tongue Pt.), Oreg.	46	13	123	46	28	07	56	20	1.7	1.3	28	09	44	9R	2.4
27. Crescent City, Calif.............	41	45	124	12	28	07	39	29	4.8+	13.0+	I	I	I	....	....

28. San Francisco, (Presidio) Calif.	37	48	122	28	28	08	42	39	2.3	3.9	28	09	35	24F	7.4
29. Alameda (NAS), Calif.	37	46	122	18	28	09	06	42	1.5	2.5	28	09	57	24F	5.4
30. Avila Beach, Calif.	35	10	120	44	28	08	44	15	4.4	5.0	28	10	00b	14F	10.4+
31. Rincon Island, Calif.	34	21	119	26	28	09	17	37	2.4	4.1	28	11	33b	22F	5.9+
32. Santa Monica, Calif.	34	00	118	30	28	09	15	39	2.5	4.2	28	11	20	15R	6.5
33. Los Angeles (Berth 60), Calif.	33	43	118	16	28	09	24	27	0.5	0.4	28	10	08	24F	3.2
34. Alamitos Bay, Calif.	33	45	118	07	28	09	36	37	1.7	2.8	28	09	56	24F	2.8
35. Newport Bay, Calif.	33	36	117	54	28	09	26	24	1.0	1.3	28	10	06	14F	1.8
36. La Jolla, Calif.	32	52	117	15	28	09	24	33	1.9	2.2	28	09	36	16F	2.2
37. San Diego, Calif.	32	43	117	10	28	09	50	9	0.7	0.4	28	11	31	27R	3.7
38. Ensenada, Baja California, Mexico	31	51	116	38	28	09	42	46	4.7	7.8+	28	09	52	18F	7.8+
39. La Paz, Baja California Sur, Mexico	24	10	110	19	28	12	27	39	0.3	0.3	30	05	39	42F	1.8
40. Guaymas, Sonora, Mexico	27	55	110	54	28	12	30	180	0.2	0.3	28	14	00	60F	0.3
41. Topolobampo, Sinaloa, Mexico	25	37	109	03	28	11	59	....	.....	S	.....	.....	....	....	0.1
42. Mazatlán, Sinaloa, Mexico	23	11	106	26	28	12	00	38	0.6	0.5	28	22	56	22F	1.6
43. Manzanillo, Colima, Mexico	19	03	104	20	28	12	15	31	1.3	2.4	29	07	20	6R	3.9
44. Acapulco, Guerrero, Mexico	16	51	99	55	28	13	05	30	0.8	1.2	29	04	09	13F	3.5
45. Salina Cruz, Oaxaca, Mexico	16	10	95	12	28	14	10	31	0.8	1.0	29	02	07	10R	2.8
46. San José, Guatemala	13	55	90	50	28	14	52	48	0.4	0.3	29	03	00	18F	0.6
47. Acajutla, El Salvador	13	35	89	51	28	15	18	48	0.5	0.3	29	22	15	17F	1.0
48. La Union, El Salvador	13	20	87	49	c	c	c	....	.....	S	.....	.....	....	....	....
49. Corinto, Nicaragua	12	28	87	12	28	16	00	g	0.1	0.1	.....	.....	....	....	....
50. Puntarenas, Costa Rica	09	58	84	50	28	16	23	42	0.2	0.3	29	03	50	7R	1.0
51. Quepos, Costa Rica	09	24	84	10	28	16	00	g	0.3	0.2	29	05	17	8F	1.5
52. Puerto Armuelles, Panama	08	16	82	52	28	16	24	g	0.2	0.1	29	01	12	7F	0.6
53. Naos Island, C. Z.	08	55	79	32	c	c	c	....	.....	S	.....	.....	....	....	....
54. Bahia Solano, Colombia	06	14	77	24	28	17	45	11	0.2	0.1	29	02	54	5F	1.2
55. Buenaventura, Colombia	03	54	77	05	....	......	......	....	.....	S	.....	.....	....	....	....
56. Tumaco, Colombia	01	50	78	44	c	c	c	....	.....	....	29	03	31	15R	0.3
	South		*West*												
57. San Cristobal, Galapagos Islands, Ecuador	00	54	89	37	28	16	27	14	1.7	2.7	28	17	18	6R	3.8
58. La Libertad, Ecuador	02	13	80	55	28	18	09	23	0.7	0.9	28	19	49	8R	4.2
59. Talara, Peru	04	35	81	17	28	17	56	15	1.8	2.9	28	19	03	6F	3.5
60. La Punta Callao, Peru	12	03	77	09	28	19	11	16	2.0	2.3	28	21	09	12R	6.4
61. San Juan, Peru	15	21	75	09	28	19	30	16	2.0	3.9	28	19	40	10F	3.9
62. Matarani, Peru	17	00	72	07	28	19	57	12	0.9	1.2	29	04	22	4R	2.9

See footnotes at end of table.

Table 4.—The tsunami of March 28, 1964, as recorded by tide gages—Con.

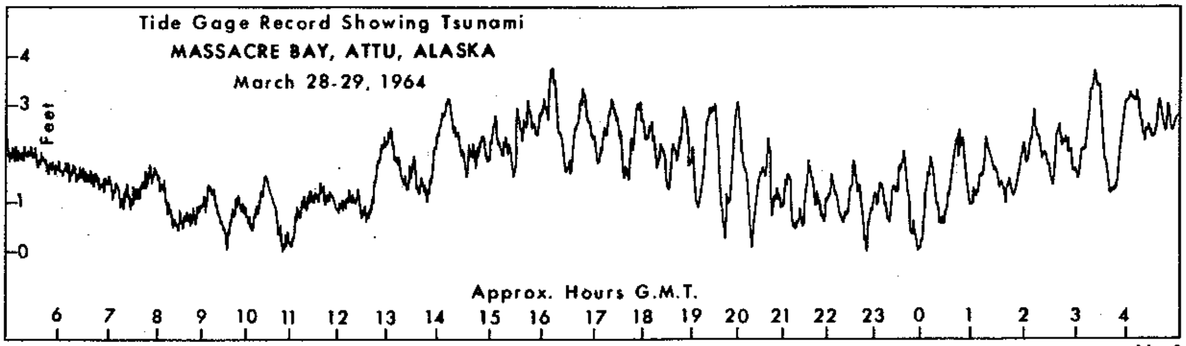
Earthquake epicenter 61.4°N., 147.73°W., on coast of northern Prince William Sound, Alaska. Wave generating area is shown on figure 2; station locations are on figure 11. Symbols are defined at the end of this table. All times are Greenwich Mean Time.

Tide station	Latitude		Longitude		Initial wave						Maximum rise or fall				
					Time of arrival			Period 1st to 2nd crest	Initial rise	Following fall	Time of beginning			Duration	Height
	°	'	°	'	*Day*	*Hour*	*Minute*	*Minute*	*Feet*	*Feet*	*Day*	*Hour*	*Minute*	*Minute*	*Feet*
	South		*West*												
63. Arica, Chile	18	28	70	20	28	20	30	15	1.4	1.3	29	05	09	10R	7.0
64. Antofagasta, Chile	23	39	70	25	28	20	39	19	1.5	1.7	28	23	09	6F	3.3
65. Caldera, Chile	27	04	70	50	28	20	55	19	2.4	4.1	I	I	I	....	....
66. Valparaiso, Chile	33	02	71	38	28	21	27	31	2.8	3.8	28	22	52	14R	6.2
67. Talcahuano, Chile	36	42	73	06	28	22	15	12	2.3	1.0	29	00	00	6R	5.4
68. Corral, Chile	39	52	73	26	28	22	39	27	4.3	6.3	28	22	54	20F	6.3
69. Ushuaia, Tierra del Fuego, Argentina	54	49	68	13	c	c	c	....	.....	....	29	03	03	36F	0.8
70. Bahia Esperanza, Palmer Peninsula, Antarctica	63	24	57	00	29	02	10	g	0.1	0.1	.....	......	......	....	0.2
71. Argentine Islands, Palmer Peninsula, Antarctica	65	15	64	16	29	01	25	17	1.9	1.0	29	03	40	9F	3.2
	North		*West*												
72. Christmas Island	01	59	157	29	28	11	21	12	0.3	0.1	28	11	21	13R	0.3
73. Hilo, Hawaii Island, Hawaii	19	44	155	03	28	09	00	19	5.7	11.3+	28	09	22	8R	12.5+
74. Kahului, Maui Island, Hawaii	20	54	156	28	28	08	47	23	6.8	11.0+	28	09 to 10	00a 00	R 12 F	11.0+
75. Mokuoloe Island, Oahu Island, Hawaii	21	26	157	48	28	08	45	57	1.0	1.1	28	11	51	46R	1.9
76. Honolulu, Oahu Island, Hawaii	21	18	157	52	28	08	53	21	1.5	2.6	28	10	04	16F	2.7
77. Nawiliwili, Kauai Island, Hawaii	21	57	159	21	28	08	33	13	1.2	2.4	28	08	46	7F	2.4
78. Midway Island	28	13	177	22	28	08	27	15	0.2	0.1	28	08	51	7F	0.9
79. Johnston Atoll	16	45	169	31	28	09	39	26	0.9	1.0	28	10	02	18F	1.0
	South		*West*												
80. Canton Island, Phoenix Islands	02	48	171	43	28	12	15	24	0.2	0.1	28	12	15	19R	0.2
81. Pago Pago Harbor, American Samoa	14	17	170	41	28	13	51	20	0.4	0.3	29	12	34	7R	1.3

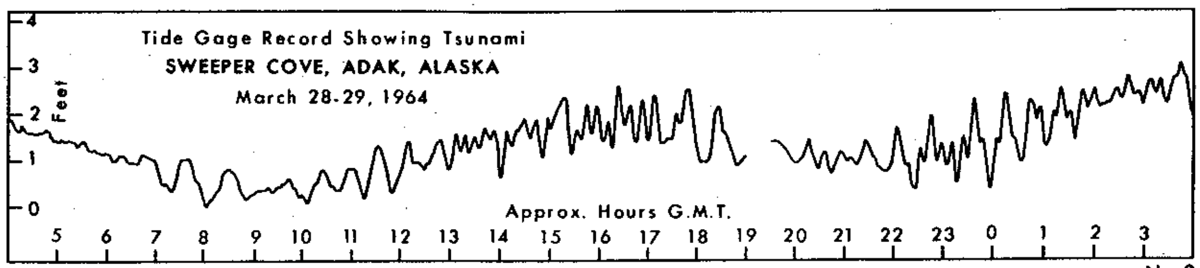
	South		*East*												
82. Lyttelton, New Zealand	43	37	172	43	28	22	10	12	0.2	0.2	29	06	00	40F	4.1
83. Greymouth, New Zealand	42	26	171	13	c	c	c	....	.....	....	29	05	27	20R	1.2
84. Nelson, New Zealand	41	16	173	16	c	c	c	....	.....	....	I	I	I	....	....
85. Fort Denison, Sydney Harbour, Australia	33	51	151	14	28	20	45	33	0.1	0.1	29	02	52	33R	1.0
86. Camp Cove, Sydney Harbour, Australia	33	48	151	16	28	20	30	g	0.1	0.1	29	04	50	17R	0.6
87. Coffs Harbour, Australia	30	18	153	09	c	c	c	....	.....	....	......	.....	......	....	0.2
88. Rabaul, New Britain Island	04	12	152	12	28	15	25	30	0.3	0.3	29	03	24	15F	2.0
	North		*East*												
89. Moen Island, Truk Islands, Caroline Islands	07	27	151	51	28	13	00	33	0.3	0.1	28	17	50	25F	0.6
90. Kwajalein Atoll, Marshall Islands	08	44	167	44	28	12	00	41	0.6	0.6	28	13	39	18R	1.0
91. Eniwetok Atoll, Marshall Islands	11	22	162	21	28	11	45	....	0.1	0.1		S		....	....
92. Wake Island	19	17	166	37	28	10	21	15	0.5	0.5	28	10	21	14R	0.5
93. Marcus Island	24	17	153	58	c	c	c	g	.....	....	......	.....	......	....	....
94. Apra Harbor, Guam, Mariana Islands	13	26	144	39	28	12	48	42	0.2	0.3	28	20	15	24R	0.4
95. Hong Kong	22	18	114	10	c	c	c	....	.....	....	......	.....	......	....	0.1
96. Miyako Jima, Japan	24	48	125	17	c	c	c	....	.....	....	28	22	13	17R	1.1
97. Aburatsu, Japan	31	35	131	25	28	14	03	23	0.4	0.5	29	04	43	12F	2.4
98. Shimizu (Tosa), Japan	32	47	132	58	c	c	c	....	.....	....	28	20	40	11R	1.8
99. Kushimoto, Japan	33	28	135	46	c	c	c	....	.....	....	29	11	58	8F	2.6
100. Toba Ko, Japan	34	29	136	51	28	15	00	g	0.2	0.2	28	21	45	13R	0.8
101. Mera, Japan	34	55	139	50	c	c	c	....	.....	....	29	03	00	10R	1.9
102. Ofunato, Japan	39	04	141	43	28	10	40	40	0.5	0.5	28	21	20	23F	4.5
103. Hanasaki, Japan	43	17	145	35	28	10	15	g	0.3	0.1	30	01	00	25F	2.2
104. Yuzhno Kurilsk, Kuril Islands, U.S.S.R.	44	00	145	30	28	10	00	45	0.3	0.5	30	01	40	18R	2.5
105. Poronaysk, Sakhalin Islands, U.S.S.R.	49	12	143	05	c	c	c	....	.....	....	29	18	03	58R	1.1
106. Petropavlovsk, Siberia, U.S.S.R.	53	01	158	39	28	09	10	g	0.1	0.1	......	.....	......	....	0.1

I—Incomplete record.
S--Only slight evidence on record.
+--Gage limit exceeded.
R—Rise.
F—Fall.

a--Four waves exceeded gage limit.
b—Small part of record missing.
c--Arrival time indefinite.
f—Initial oscillation was a fall.
g--Indeterminate.



No.1



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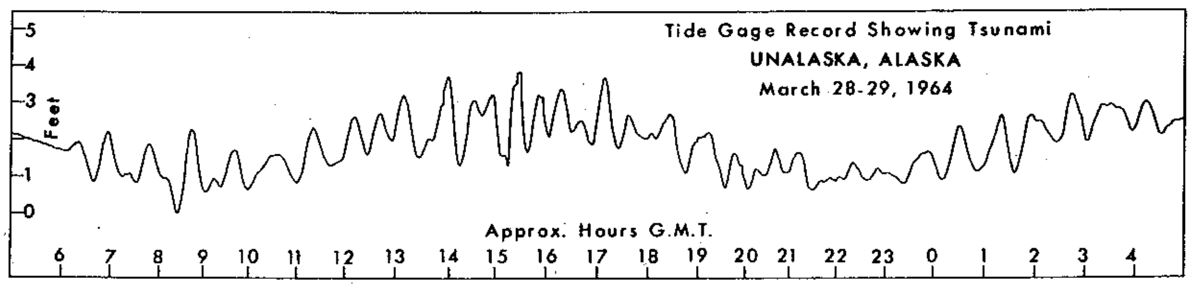
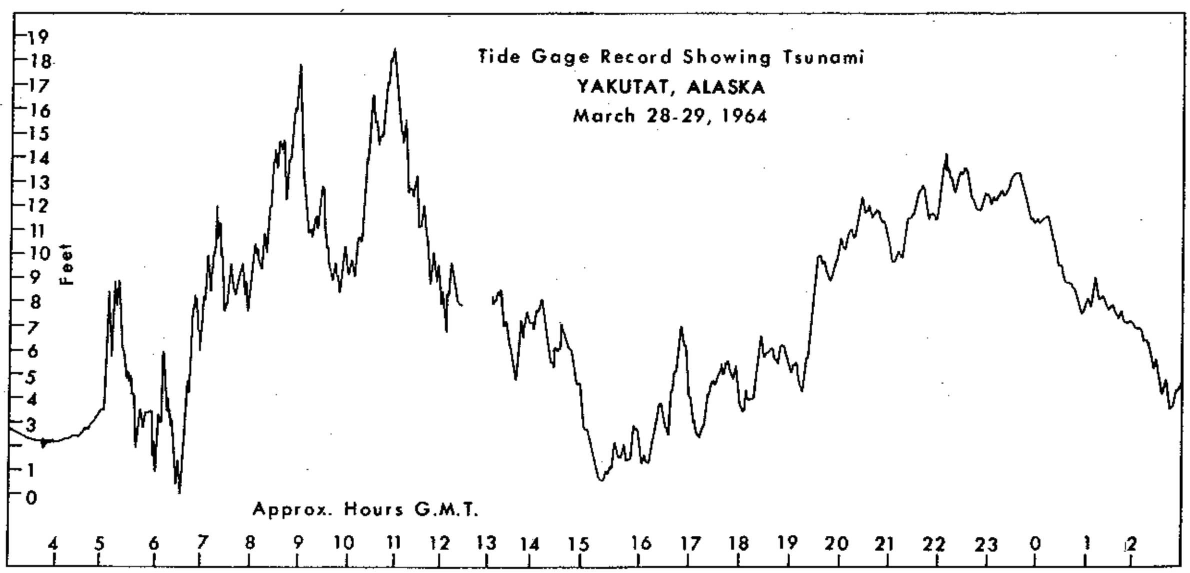


No.3



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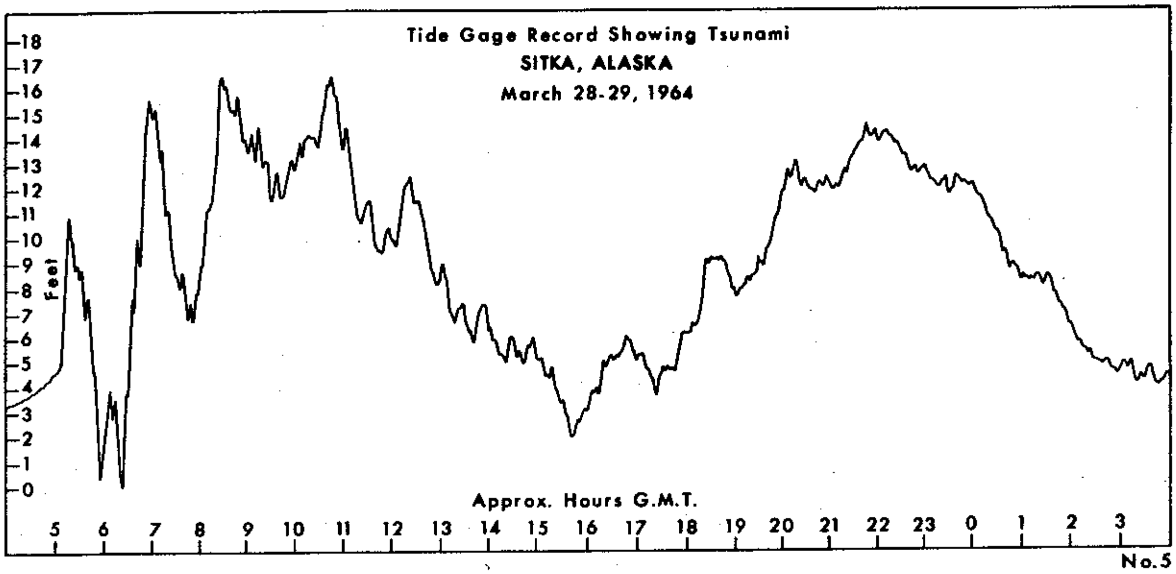
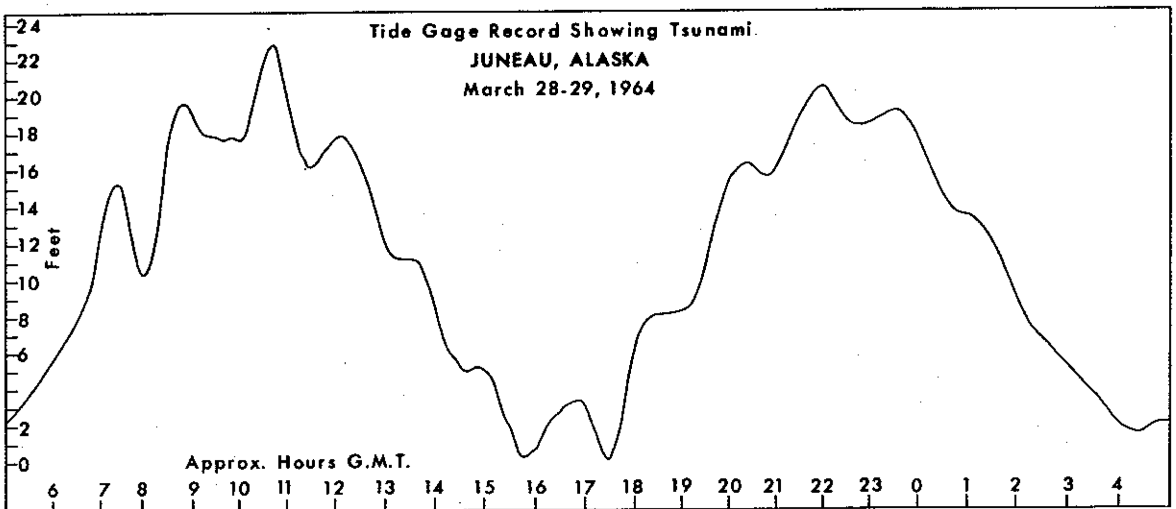
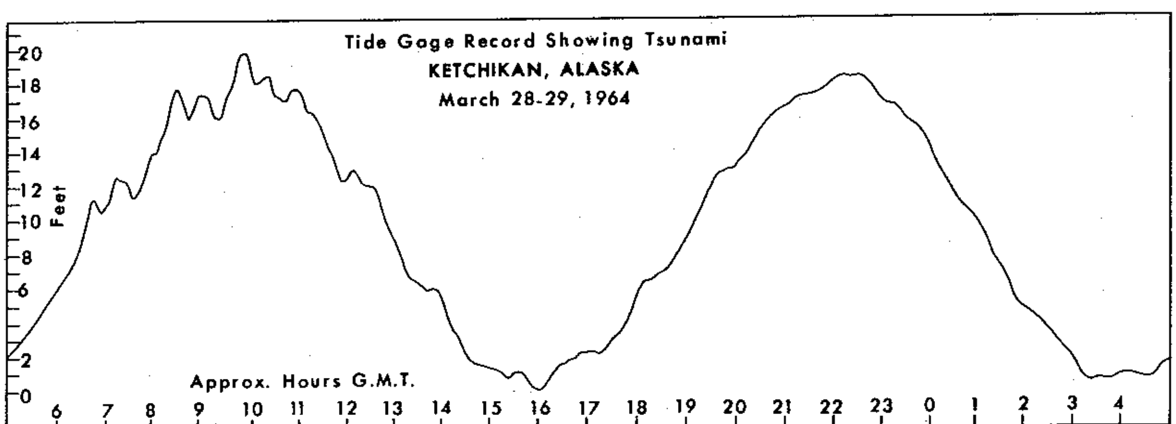

Tide Gage Record Showing Tsunami
SITKA, ALASKA
March 28-29, 1964
Feet
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3

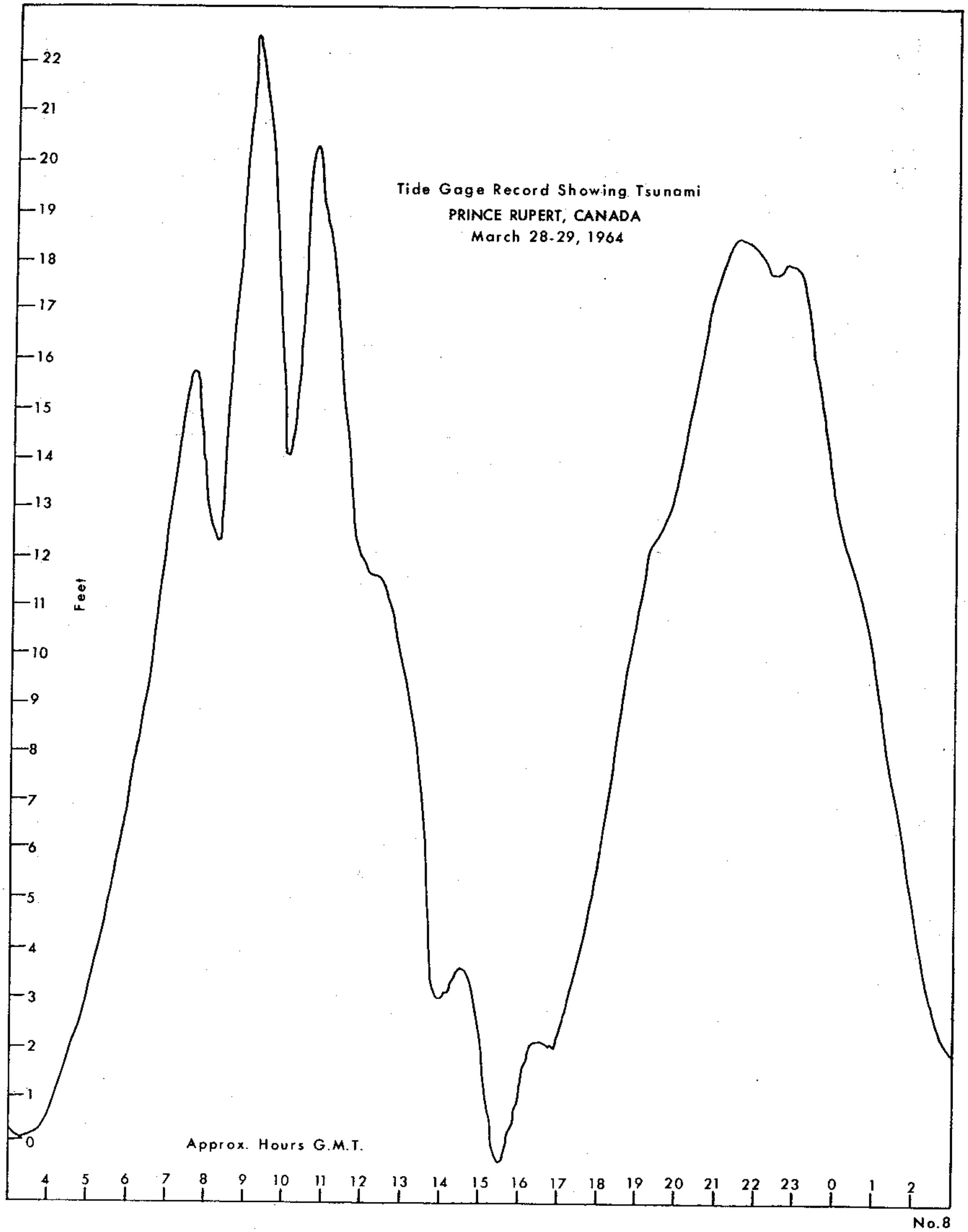
No.5

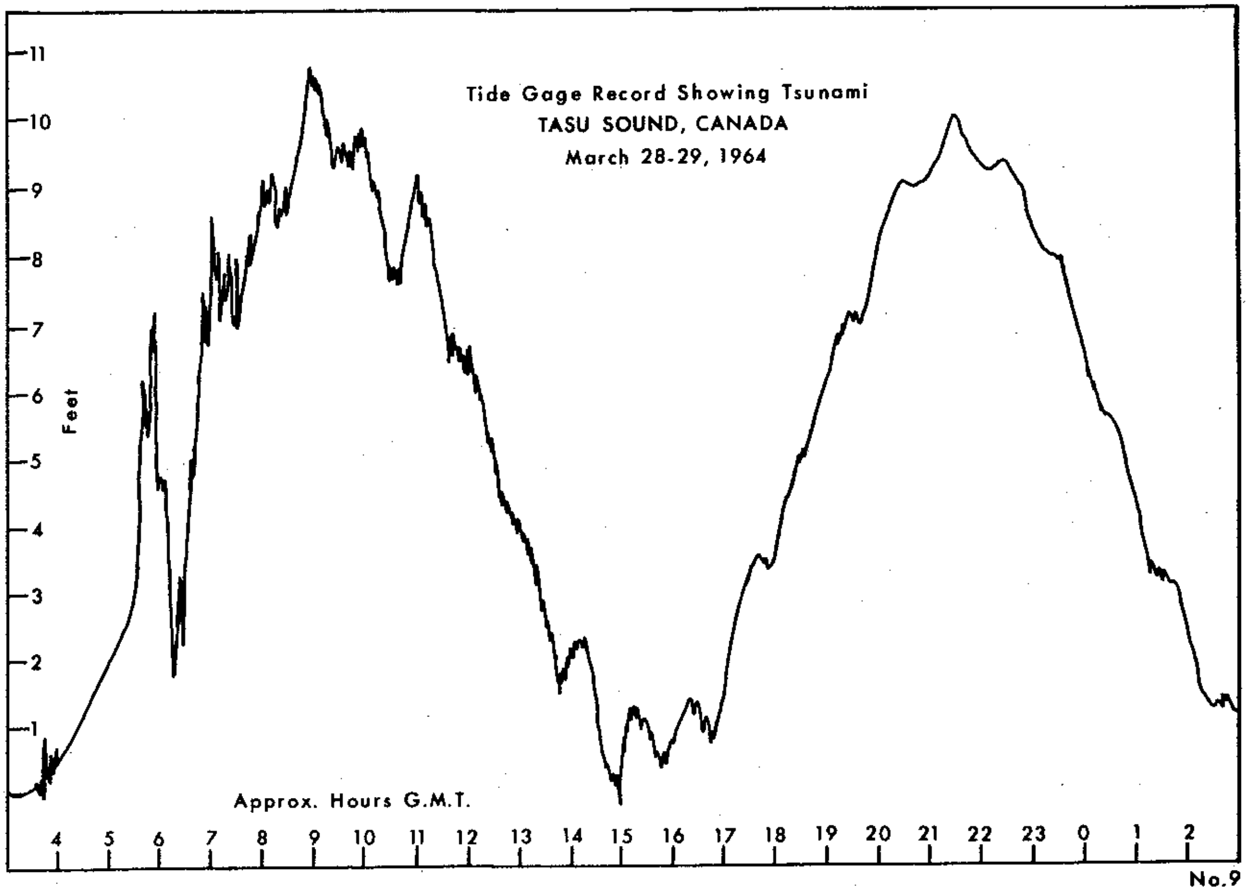

Tide Gage Record Showing Tsunami
JUNEAU, ALASKA
March 28-29, 1964
Feet
24
22
20
18
16
14
12
10
8
6
2
0
Approx. Hours G.M.T.
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4

No.6

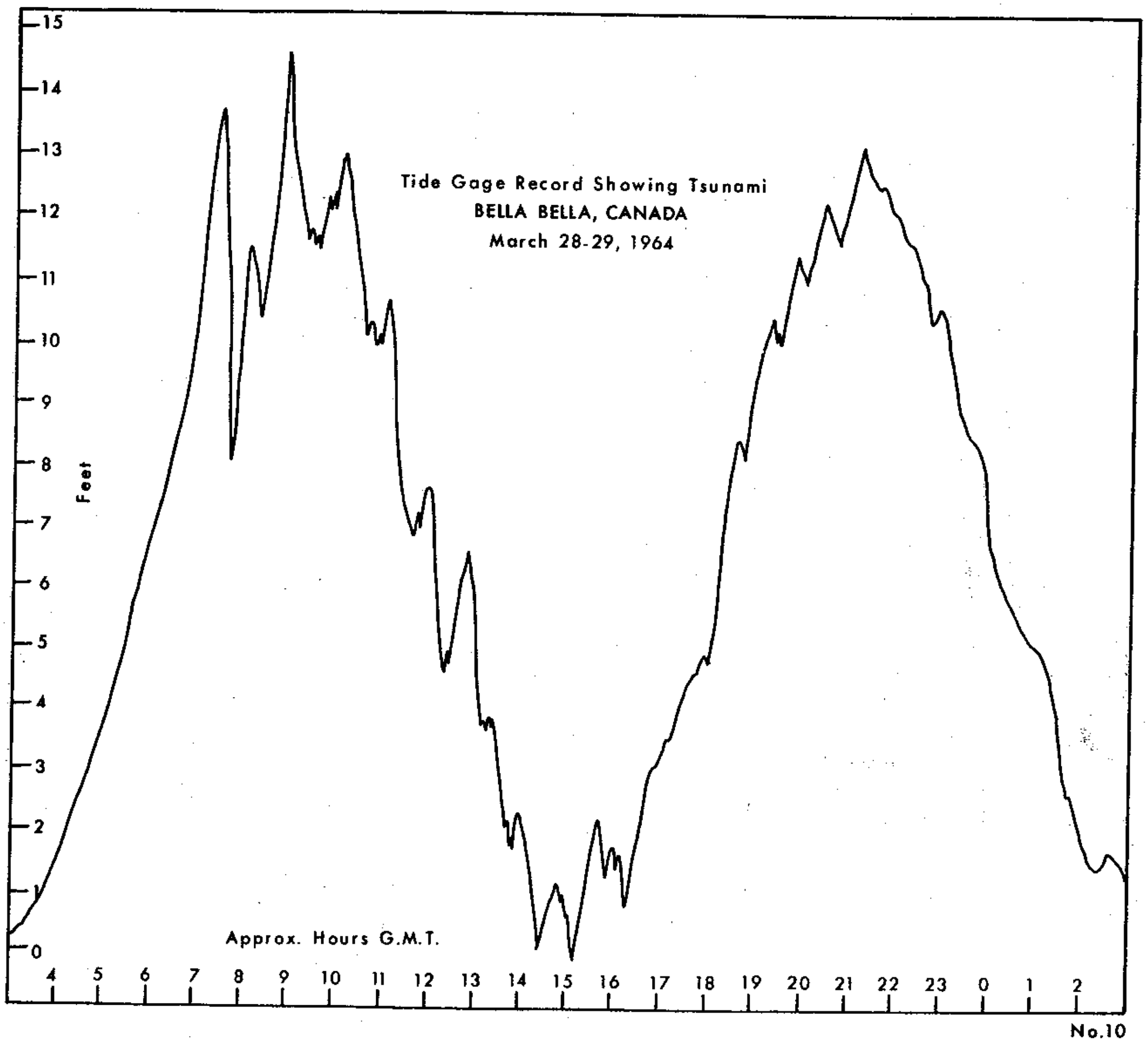

Tide Gage Record Showing Tsunami
KETCHIKAN, ALASKA
March 28-29, 1964
Feet
20
18
16
14
12
10
8
6
2
0
Approx. Hours G.M.T.
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4

No.7

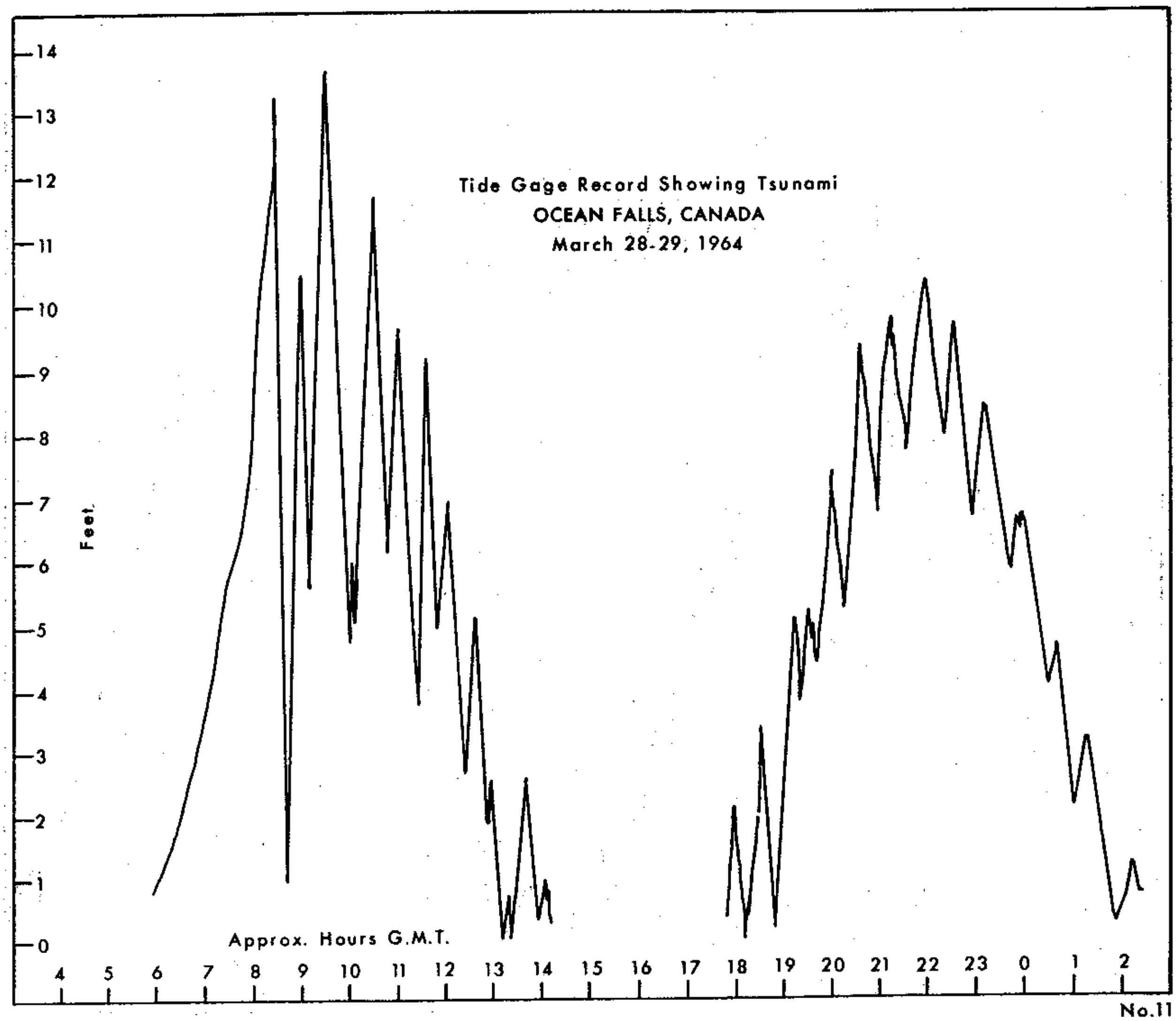

Tide Gage Record Showing Tsunami
PRINCE RUPERT, CANADA
March 28-29, 1964
Feet
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.8



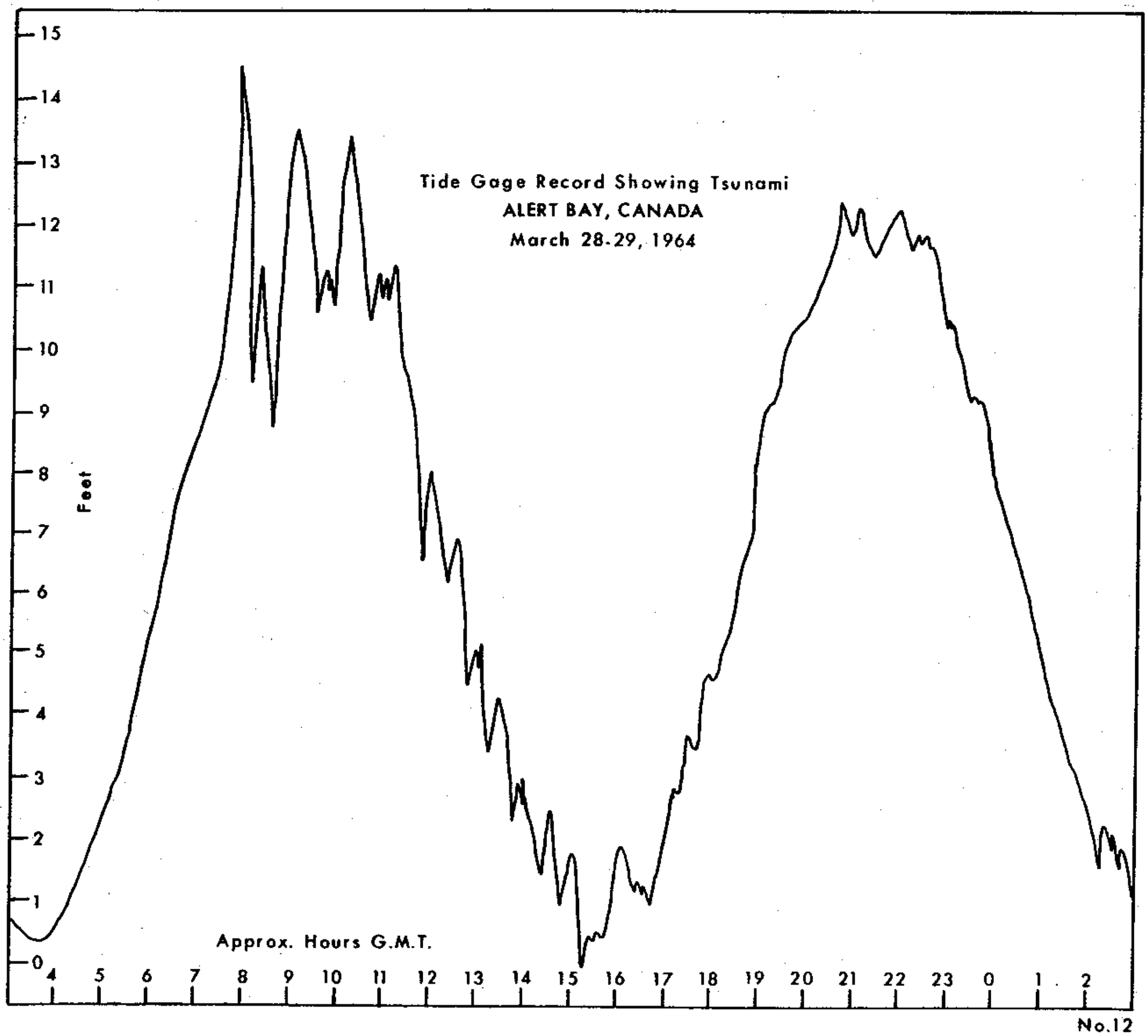
Tide Gage Record Showing Tsunami
TASU SOUND, CANADA
March 28-29, 1964
Feet
11
10
9
8
7
6
5
4
3
2
1
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.9

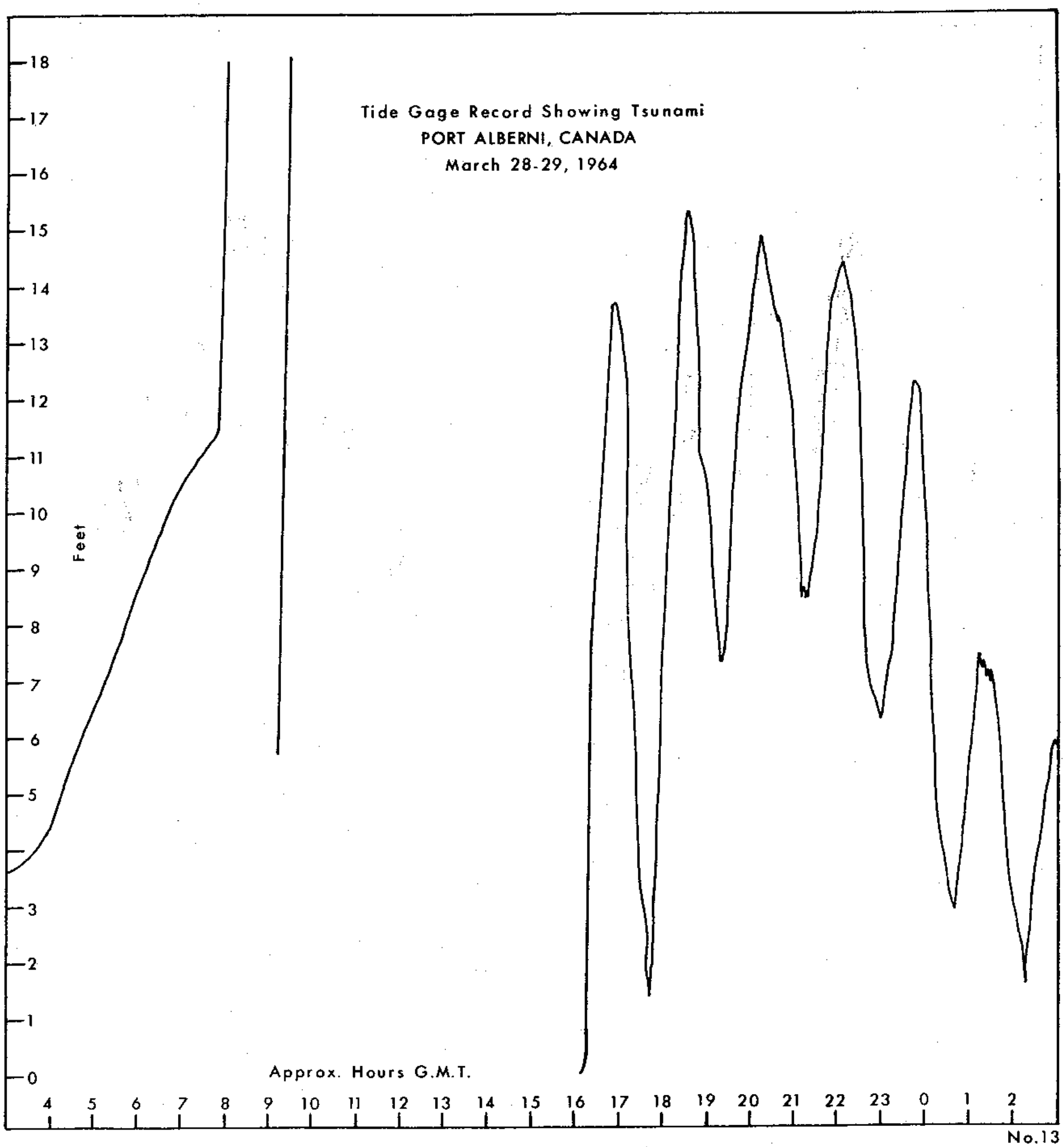


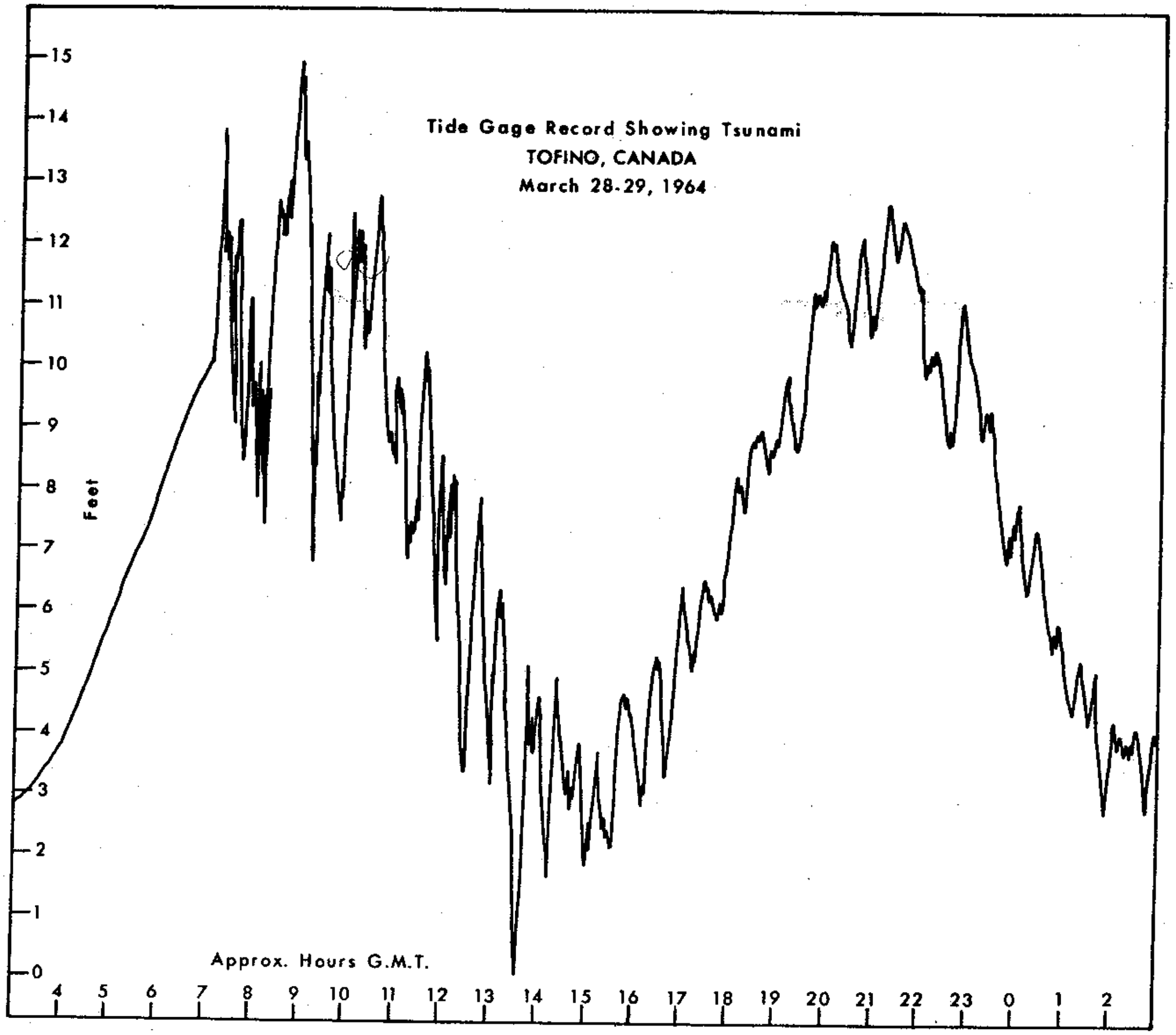
Tide Gage Record Showing Tsunami
BELLA BELLA, CANADA
March 28-29, 1964
Feet
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.10



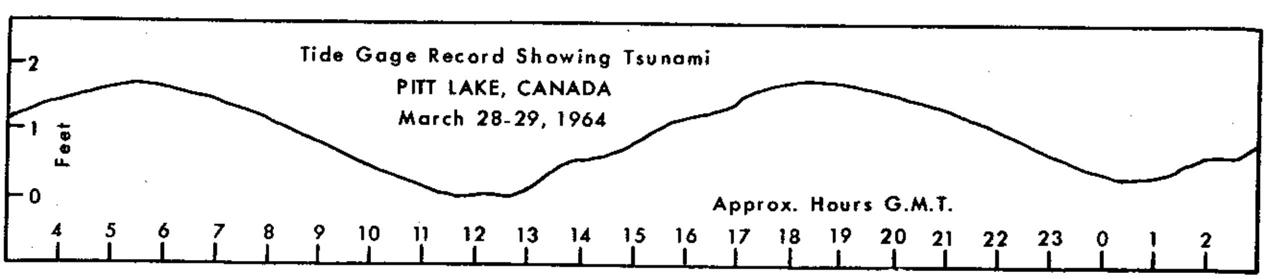
Tide Gage Record Showing Tsunami
OCEAN FALLS, CANADA
March 28-29, 1964
Feet
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.11


Tide Gage Record Showing Tsunami
ALERT BAY, CANADA
March 28-29, 1964
Feet
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.12

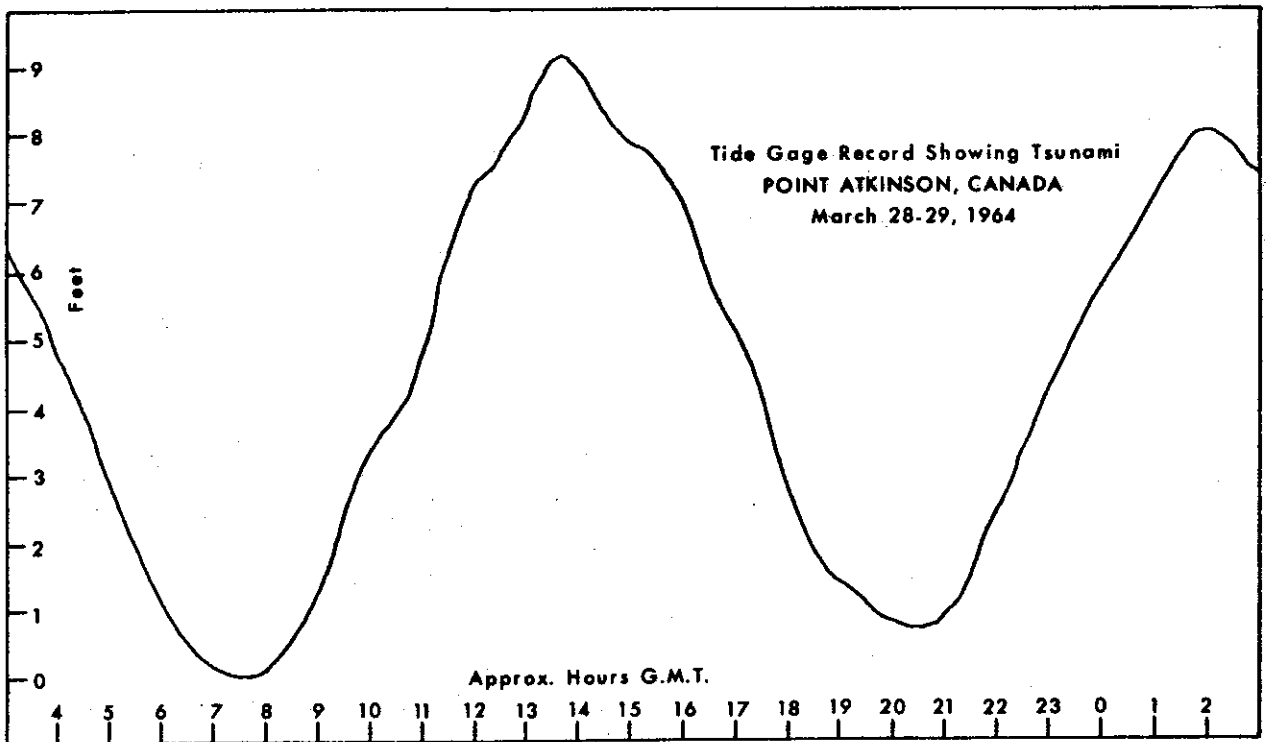

Tide Gage Record Showing Tsunami
PORT ALBERNI, CANADA
March 28-29, 1964
Feet
18
17
16
15
14
13
12
11
10
9
8
7
6
5
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.13


Tide Gage Record Showing Tsunami
TOFINO, CANADA
March 28-29, 1964
Feet
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
1
2

No.14

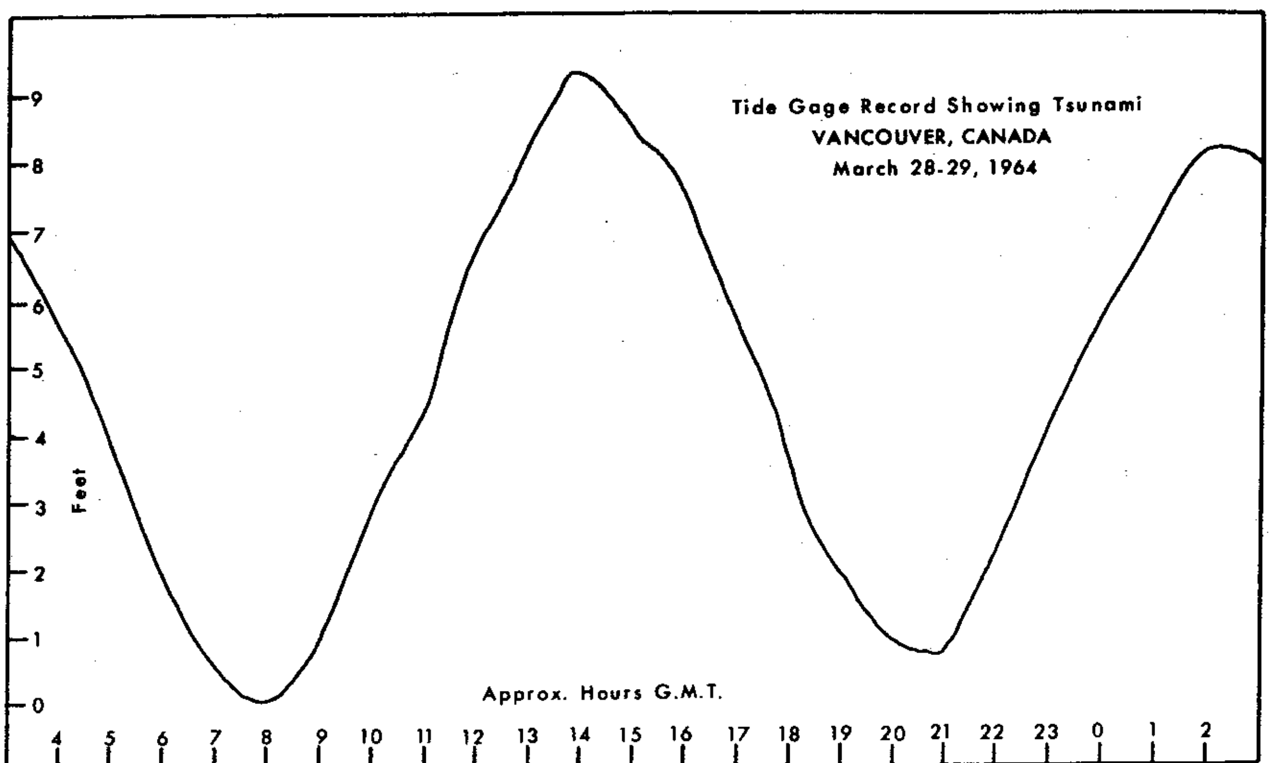

Tide Gage Record Showing Tsunami
PITT LAKE, CANADA
March 28-29, 1964
Feet
2
1
0
Approx. Hours G.M.T.
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
0
1
2

No.15



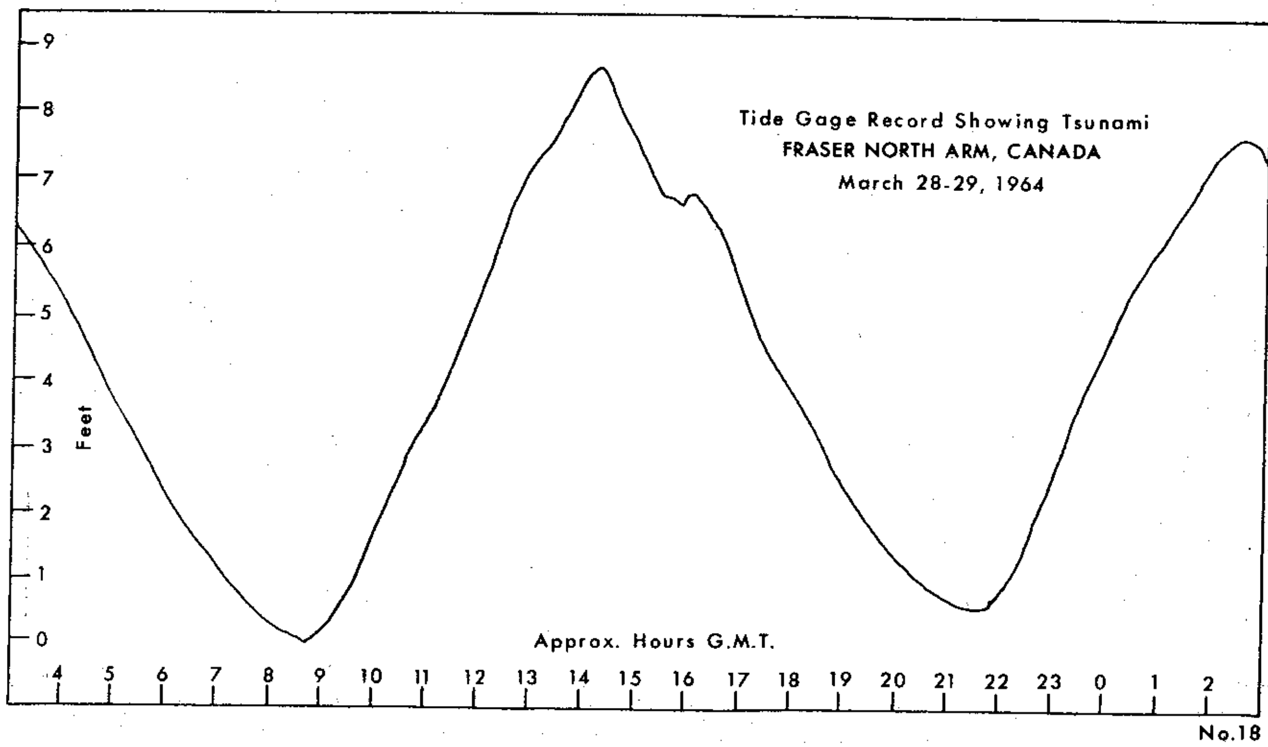
Tide Gage Record Showing Tsunami
POINT ATKINSON, CANADA
March 28-29, 1964
Feet
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2

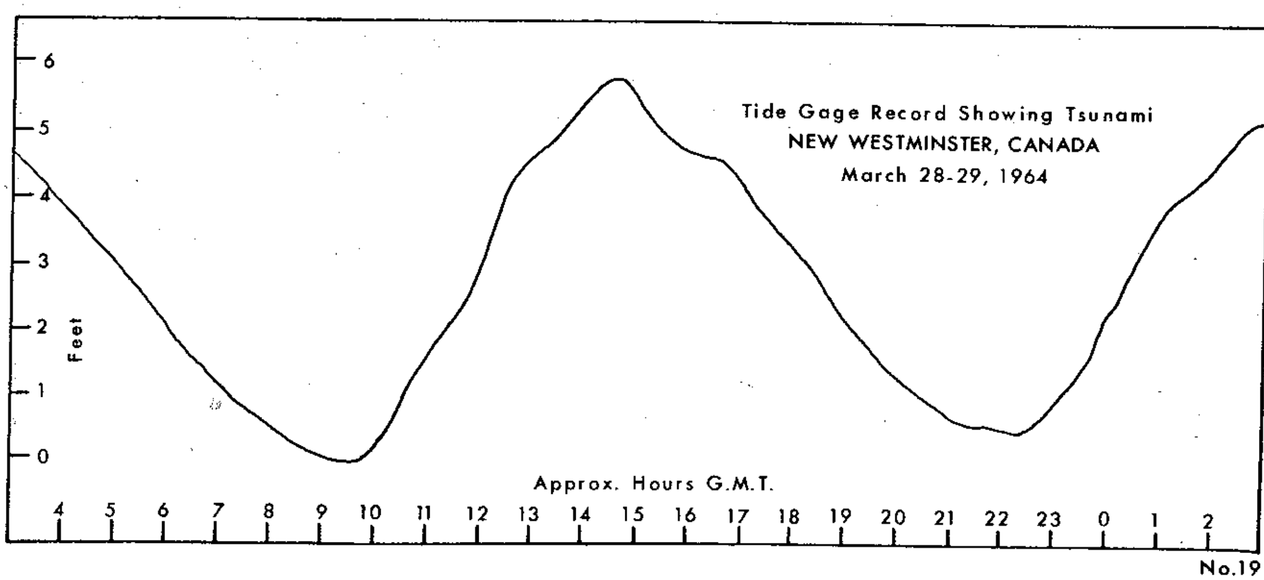
No.16

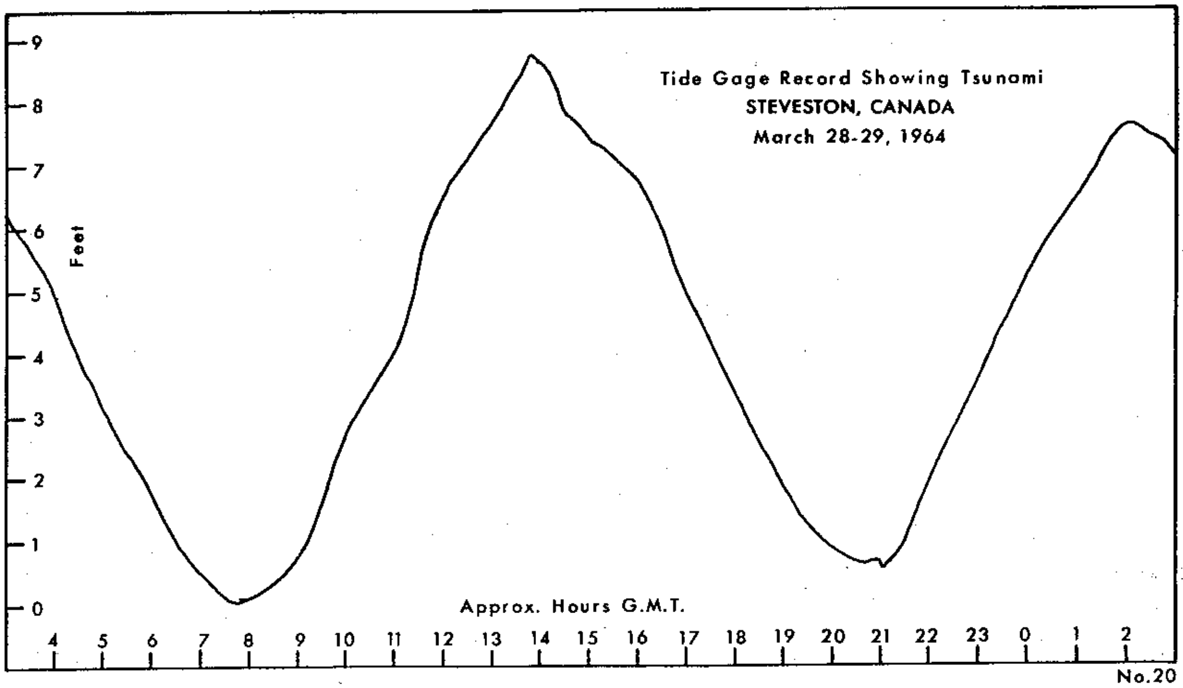


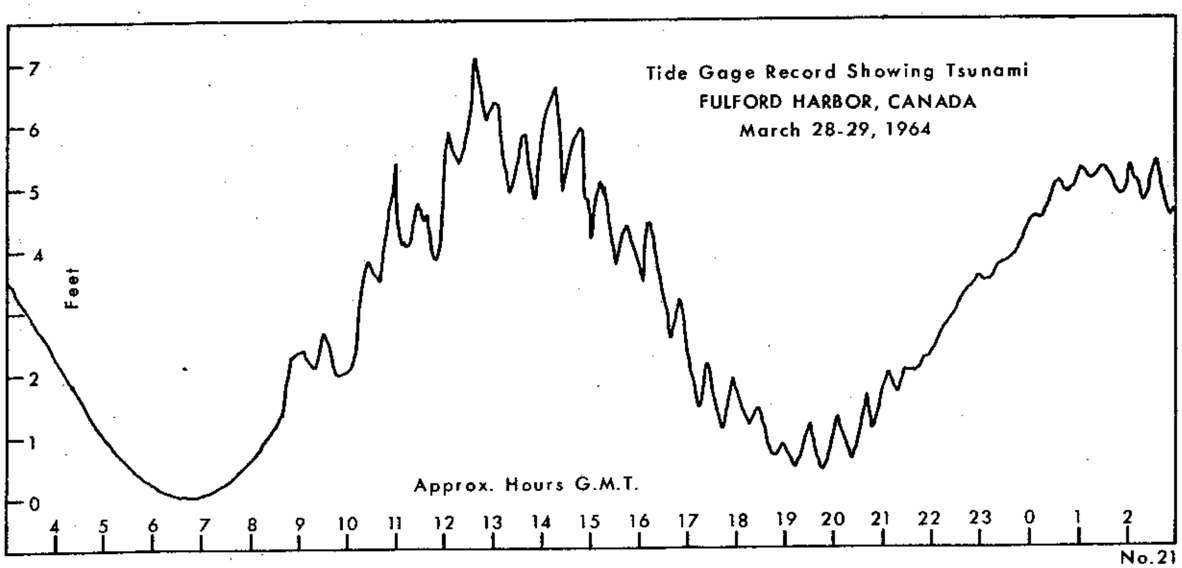
Tide Gage Record Showing Tsunami
VANCOUVER, CANADA
March 28-29, 1964
Feet
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2

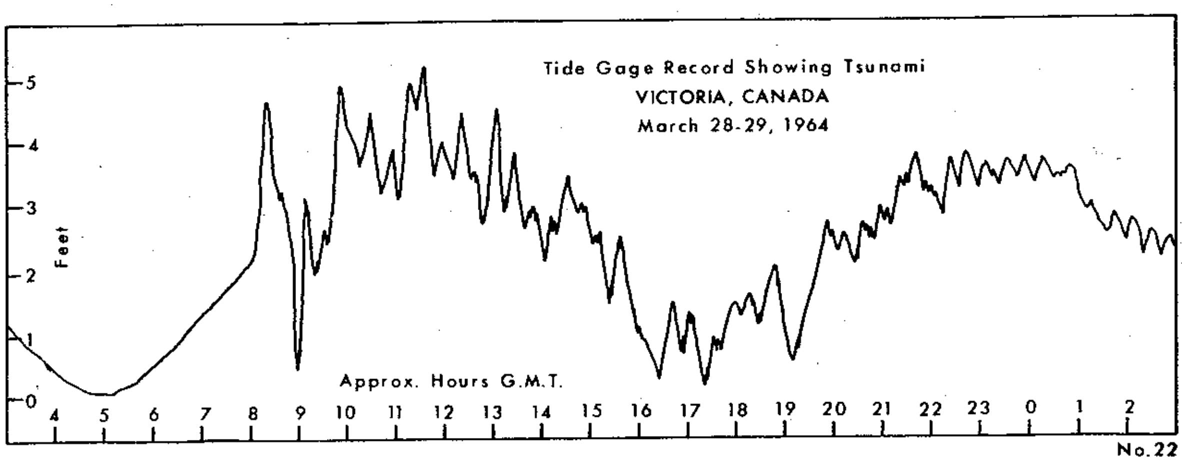
No.17

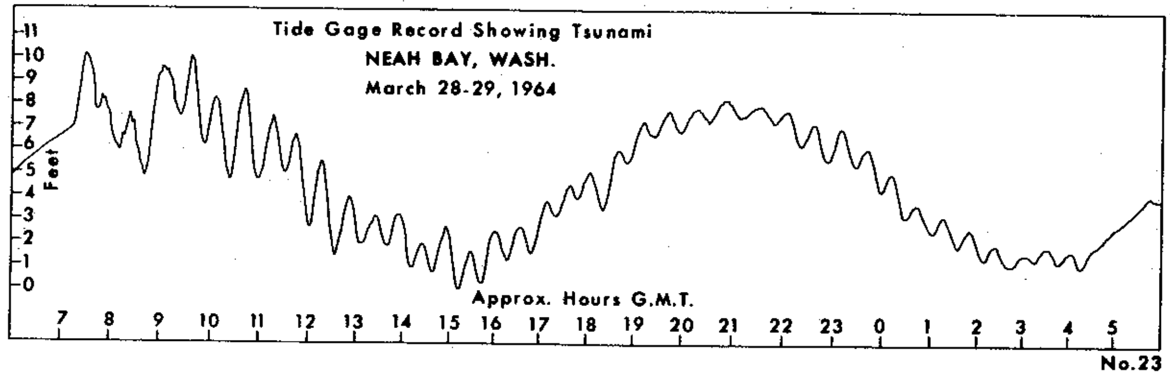

Tide Gage Record Showing Tsunami
FRASER NORTH ARM, CANADA
March 28-29, 1964
9
8
7
6
5
4
3
2
1
0
Feet
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.18

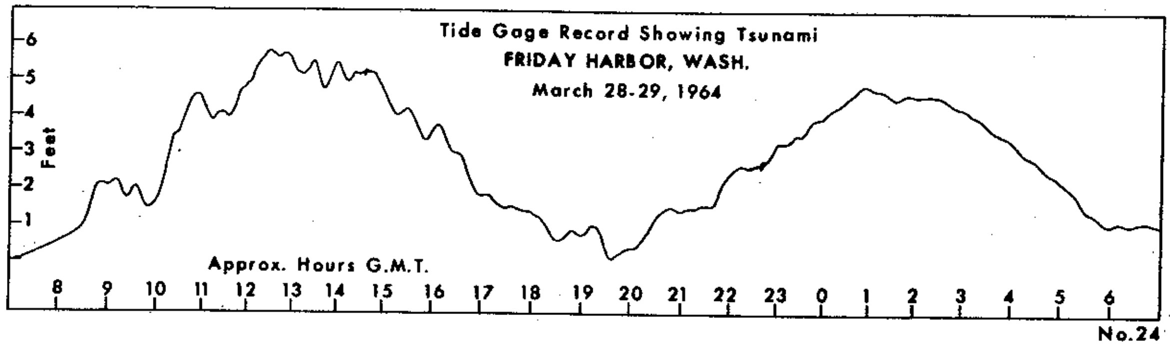

Tide Gage Record Showing Tsunami
NEW WESTMINSTER, CANADA
March 28-29, 1964
6
5
4
3
2
1
0
Feet
Approx. Hours G.M.T.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
No.19

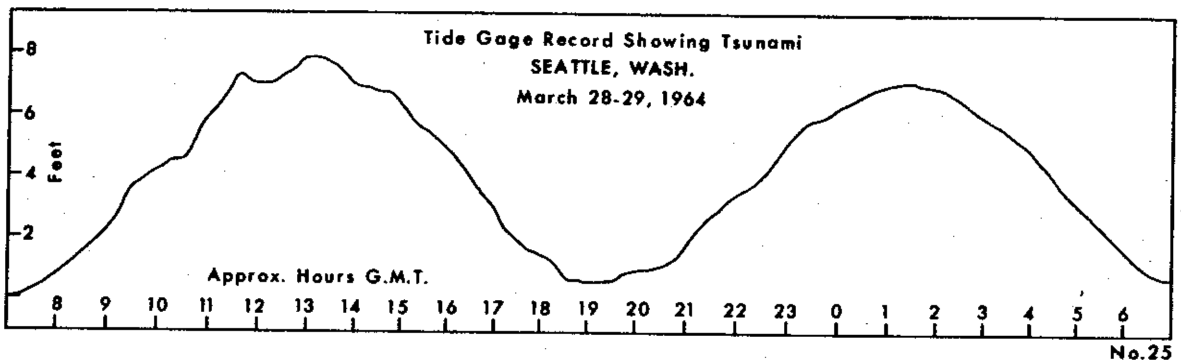

Tide Gage Record Showing Tsunami
STEVESTON, CANADA
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.20

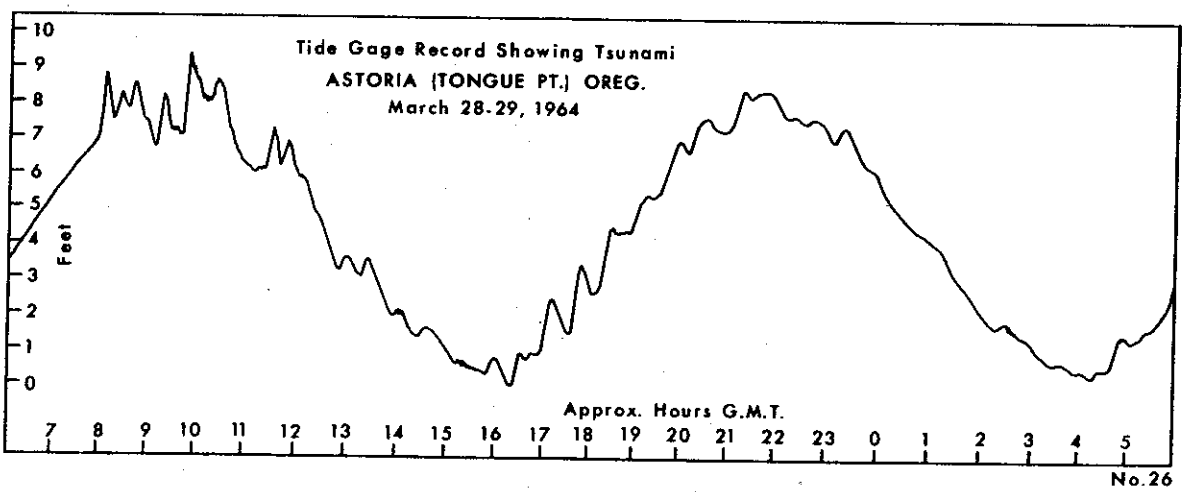

Tide Gage Record Showing Tsunami
FULFORD HARBOR, CANADA
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.21

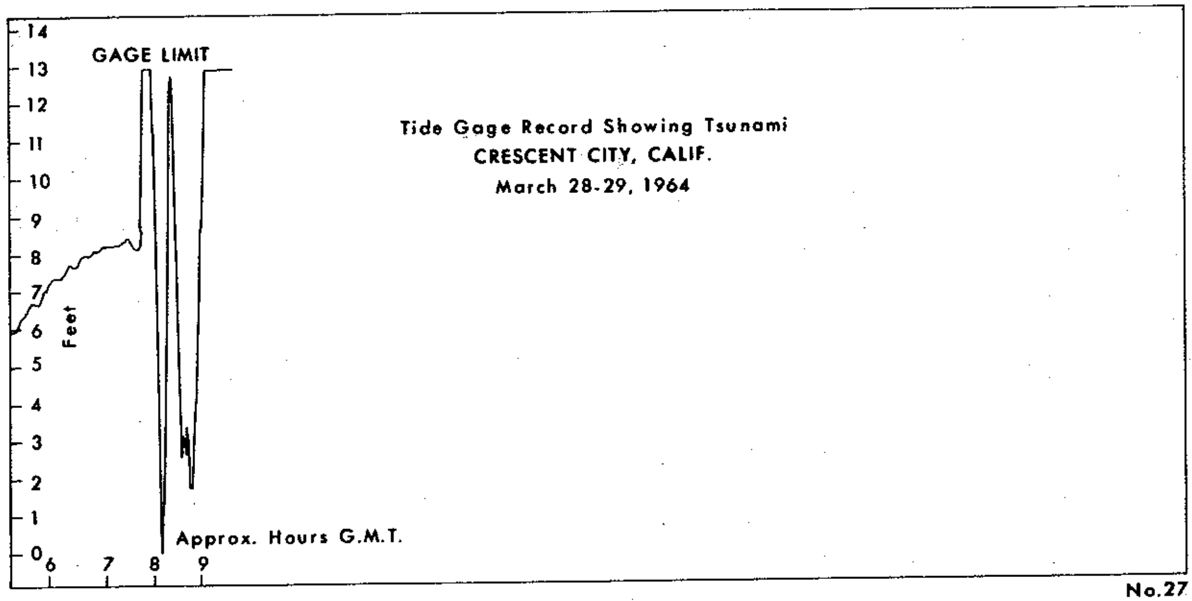

Tide Gage Record Showing Tsunami
VICTORIA, CANADA
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.22


Tide Gage Record Showing Tsunami
NEAH BAY, WASH.
March 28-29, 1964
Feet
11
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5
No.23


Tide Gage Record Showing Tsunami
FRIDAY HARBOR, WASH.
March 28-29, 1964
Feet
6
5
4
3
2
1
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.24


Tide Gage Record Showing Tsunami
SEATTLE, WASH.
March 28-29, 1964
Feet
8
6
4
2
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.25


Tide Gage Record Showing Tsunami
ASTORIA (TONGUE PT.) OREG.
March 28-29, 1964
Feet
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5
No.26



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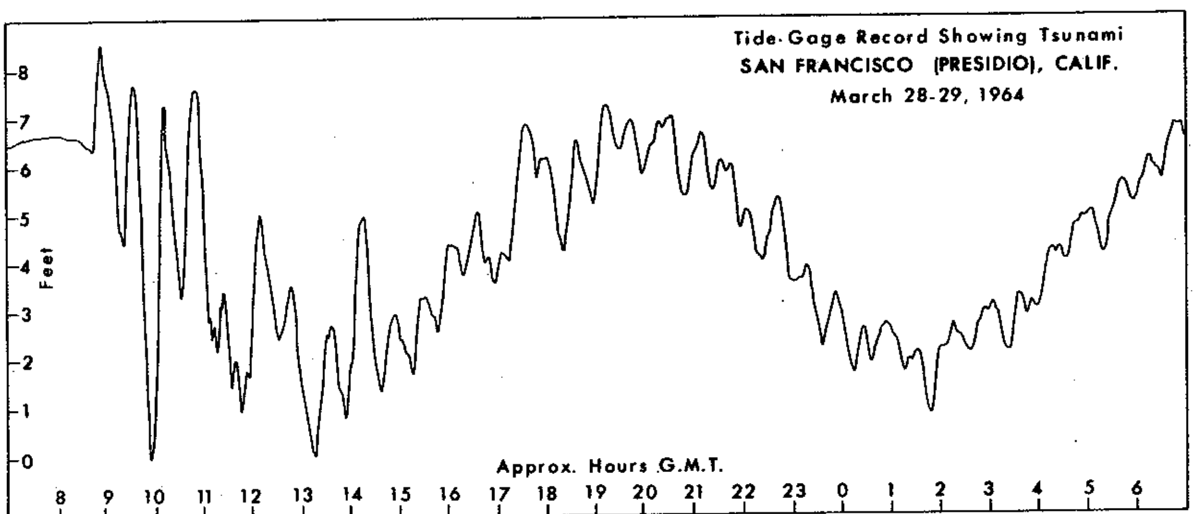

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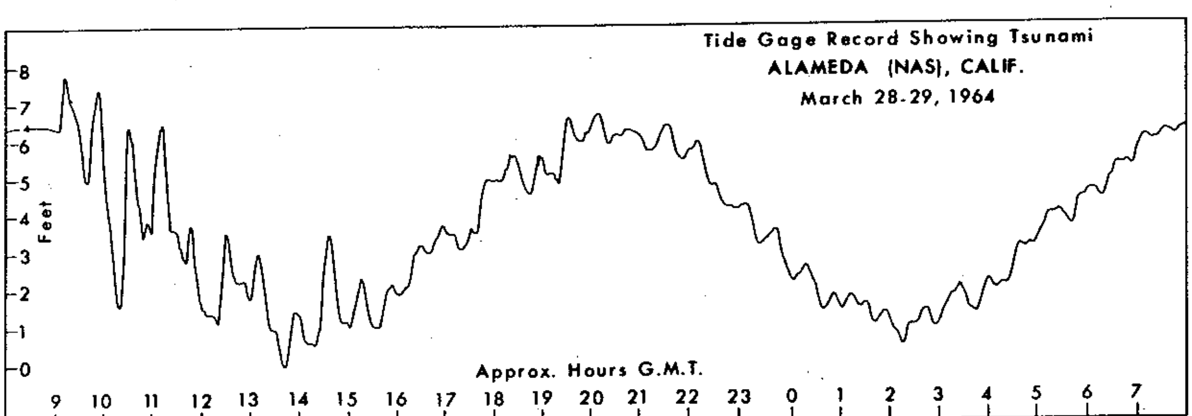

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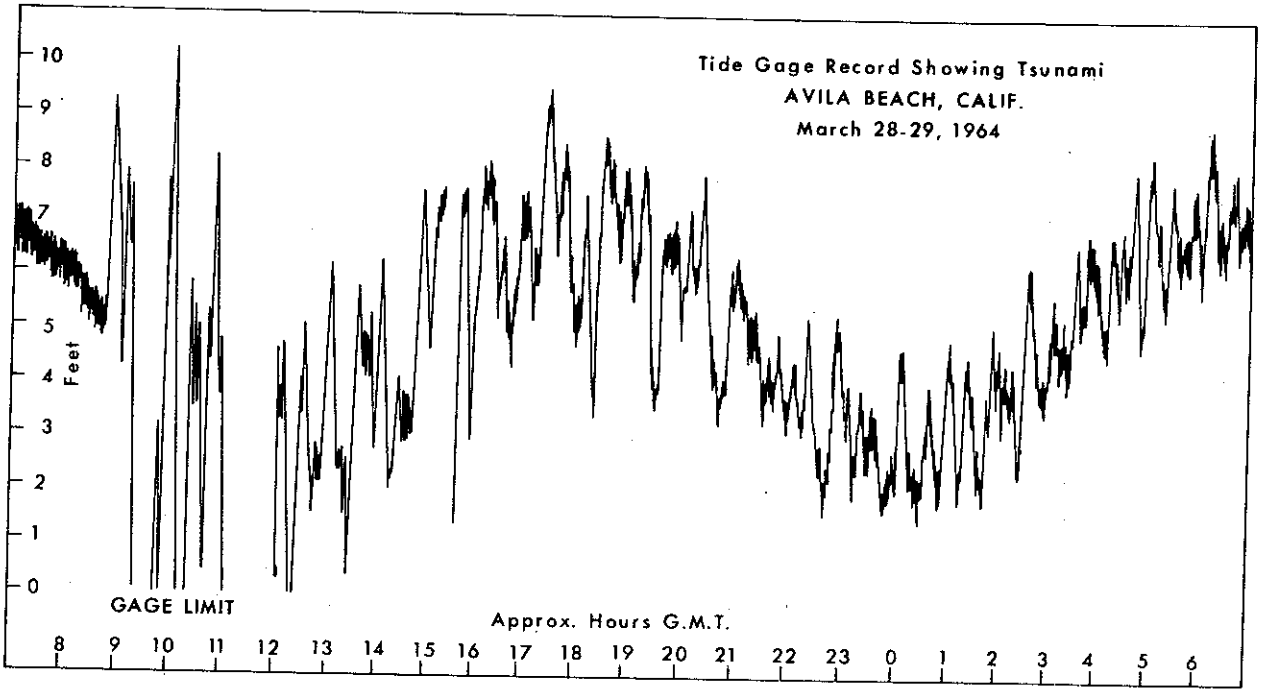
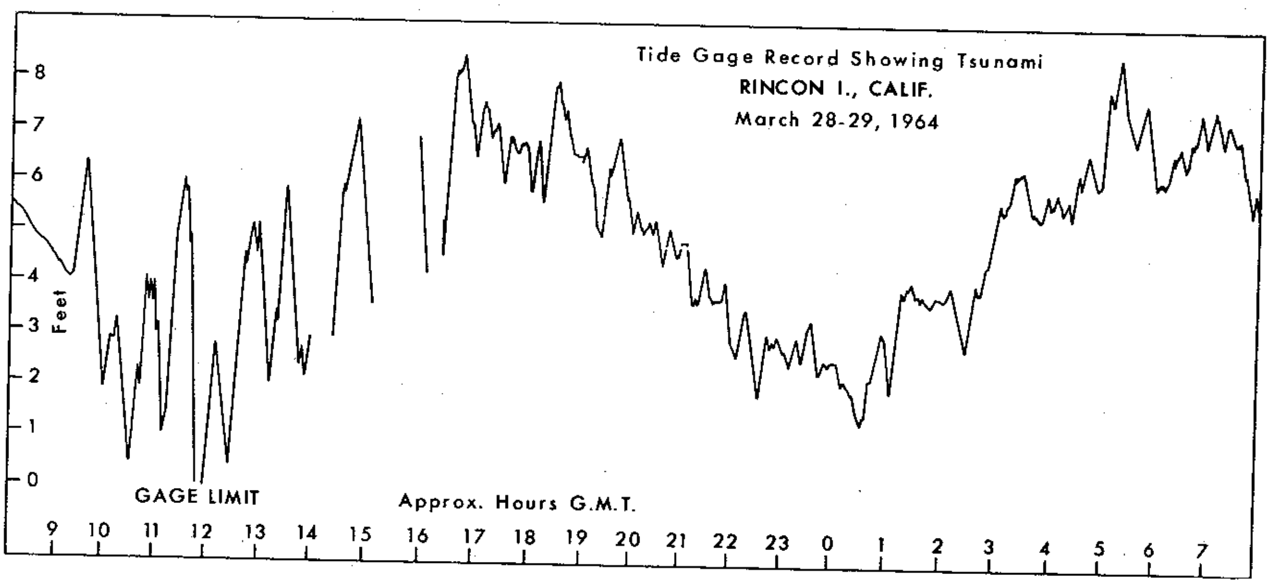
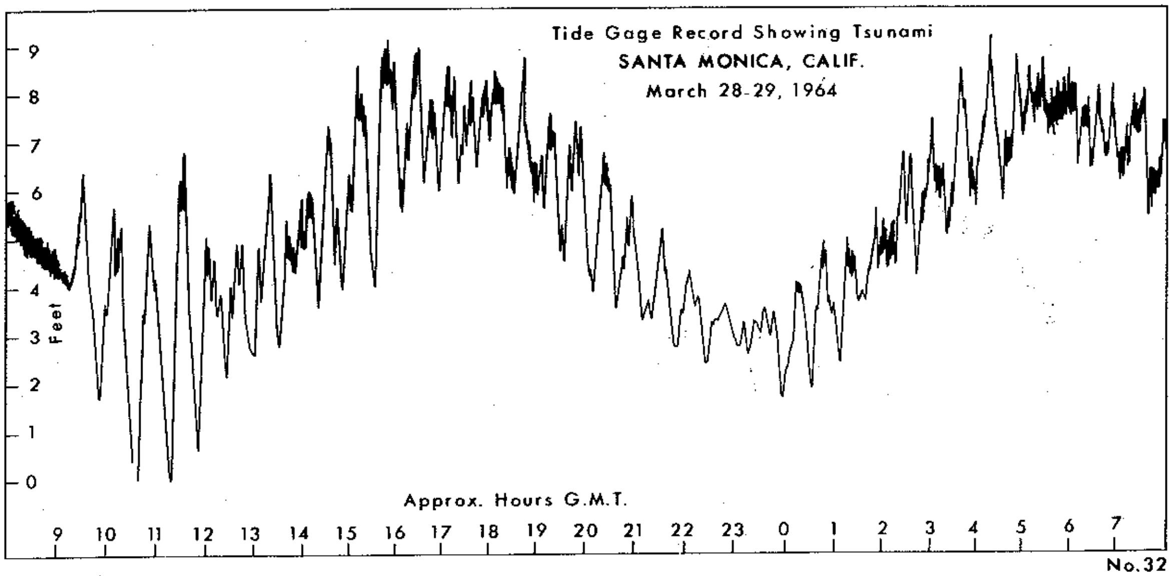
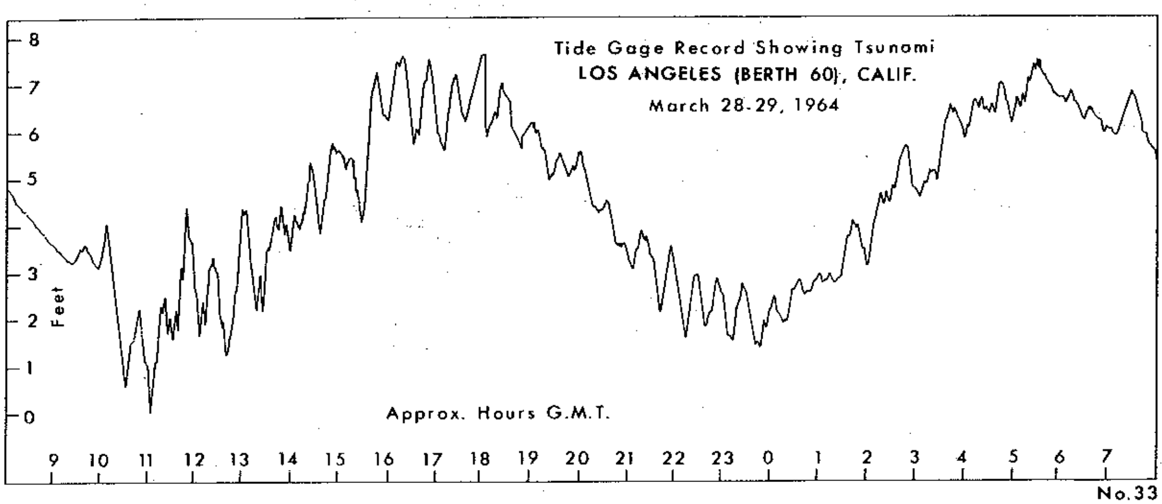

Tide Gage Record Showing Tsunami
AVILA BEACH, CALIF.
March 28-29, 1964
10
9
8
7
5
4
3
2
1
0
Feet
GAGE LIMIT
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6

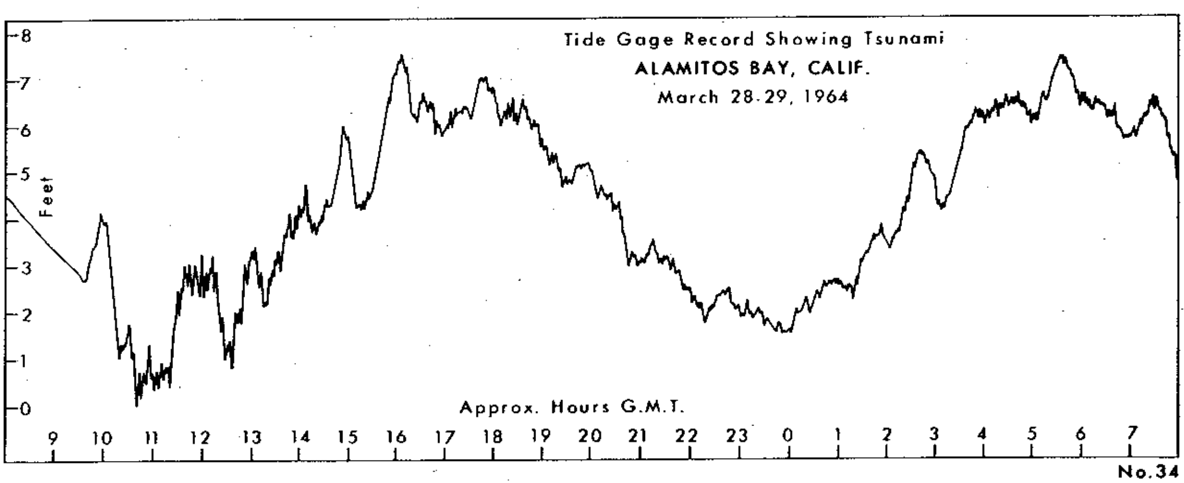
No.30

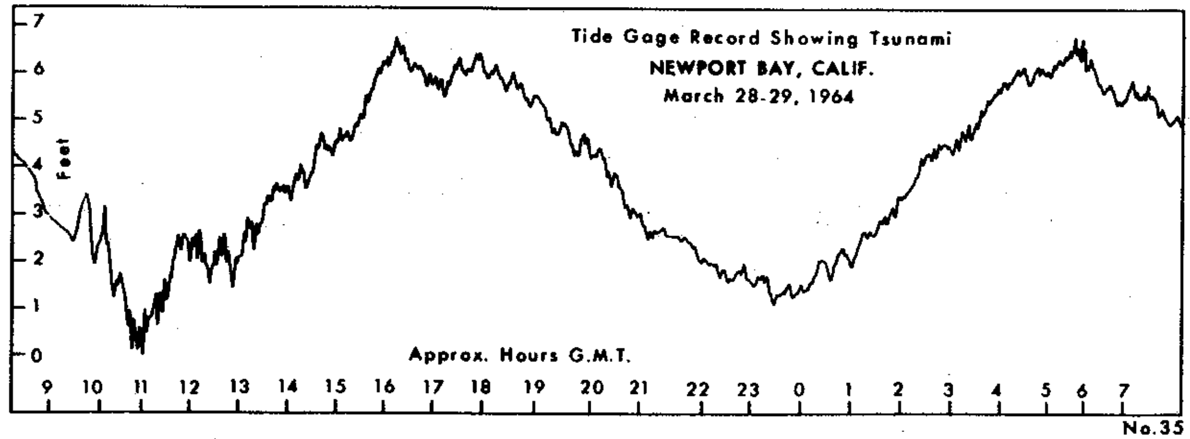

Tide Gage Record Showing Tsunami
RINCON I., CALIF.
March 28-29, 1964
8
7
6
4
3
2
1
0
Feet
GAGE LIMIT
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7

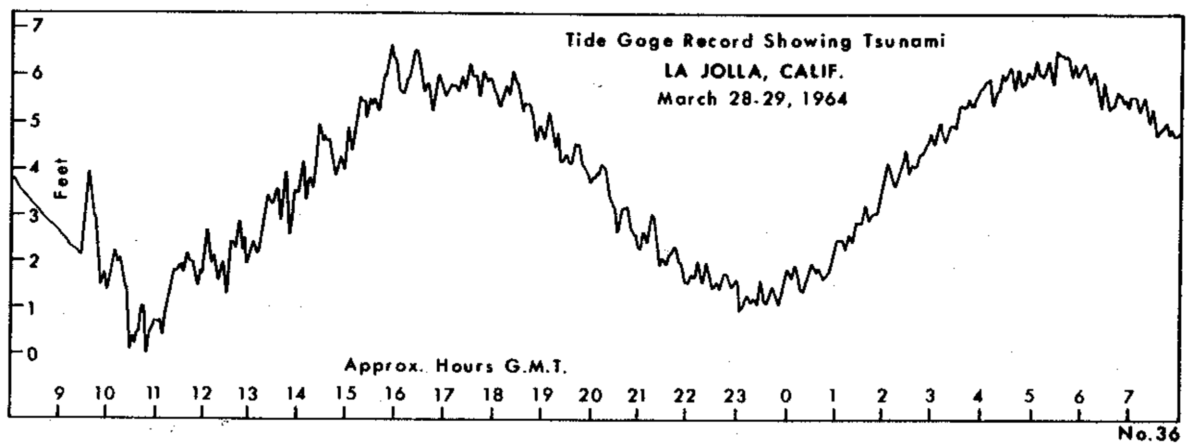
No.31

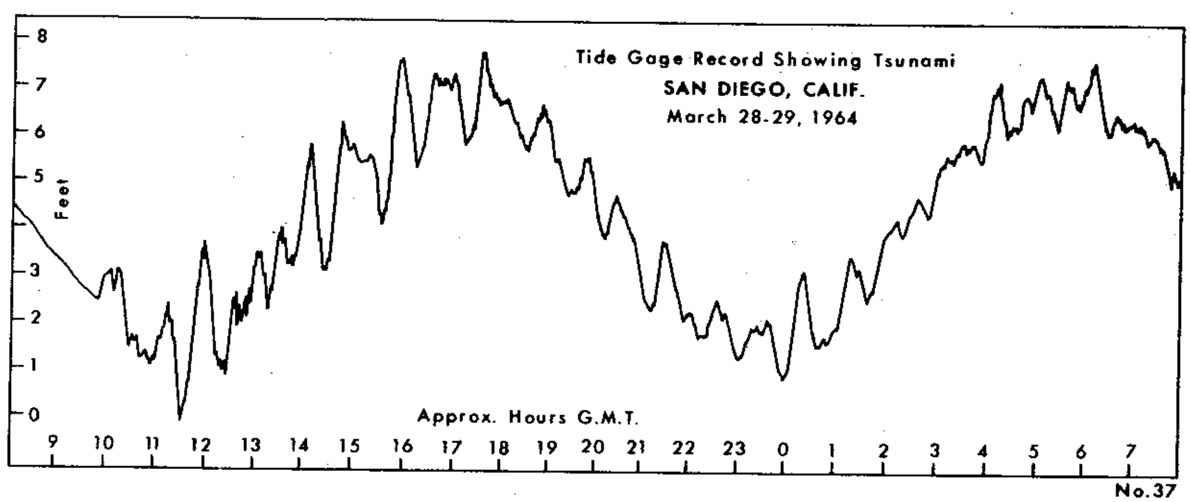

Tide Gage Record Showing Tsunami
SANTA MONICA, CALIF.
March 28-29, 1964
Feet
9
8
7
6
4
3
2
1
0
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7
No.32

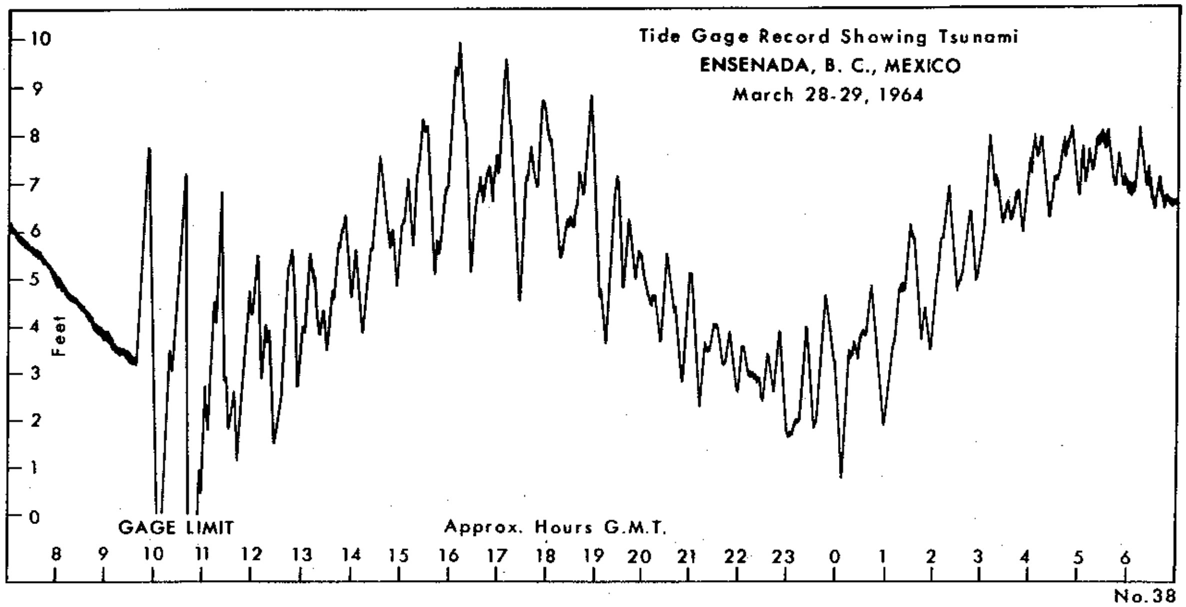

Tide Gage Record Showing Tsunami
LOS ANGELES (BERTH 60), CALIF.
March 28-29, 1964
Feet
8
7
6
5
3
2
1
0
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7
No.33

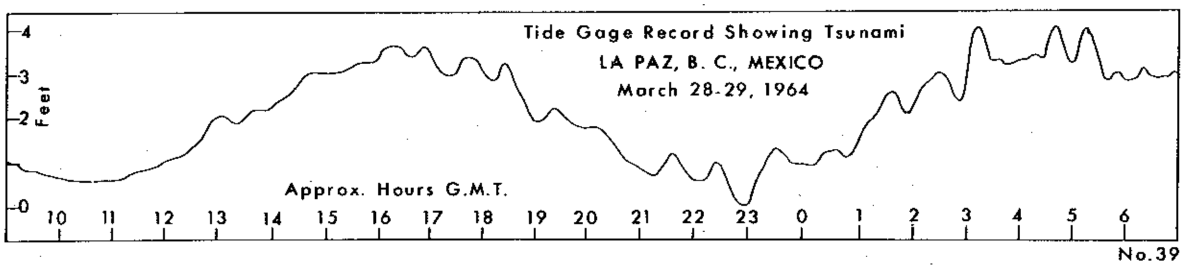

Tide Gage Record Showing Tsunami
ALAMITOS BAY, CALIF.
March 28-29, 1964
Feet
8
7
6
5
3
2
1
0
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7
No.34

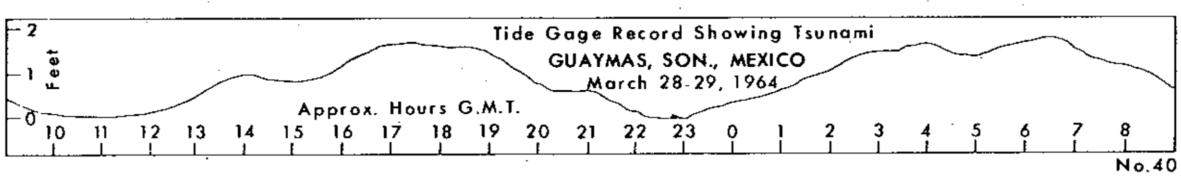

Tide Gage Record Showing Tsunami
NEWPORT BAY, CALIF.
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.35

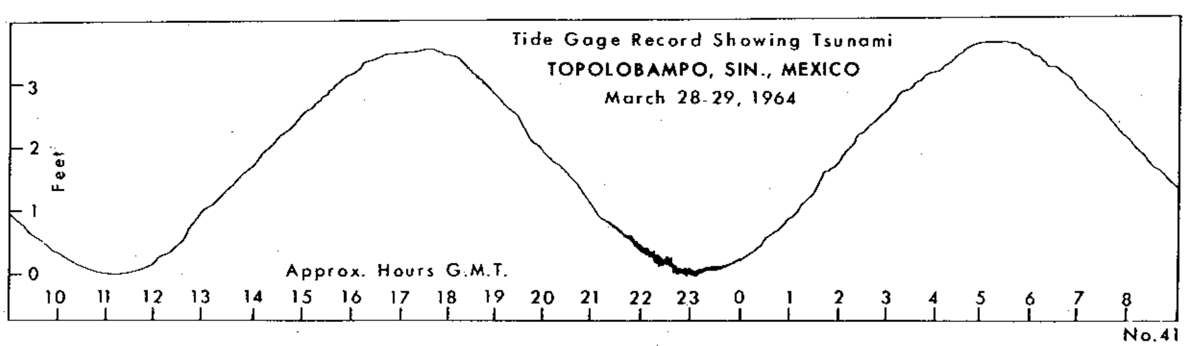

Tide Gage Record Showing Tsunami
LA JOLLA, CALIF.
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.36

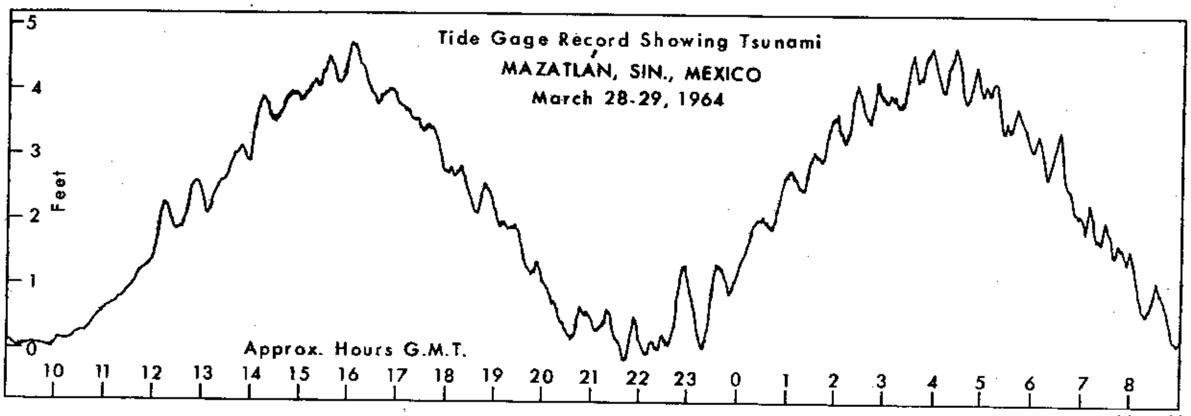

Tide Gage Record Showing Tsunami
SAN DIEGO, CALIF.
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.37


Tide Gage Record Showing Tsunami
ENSENADA, B. C., MEXICO
March 28-29, 1964
Feet
GAGE LIMIT
Approx. Hours G.M.T.
No.38

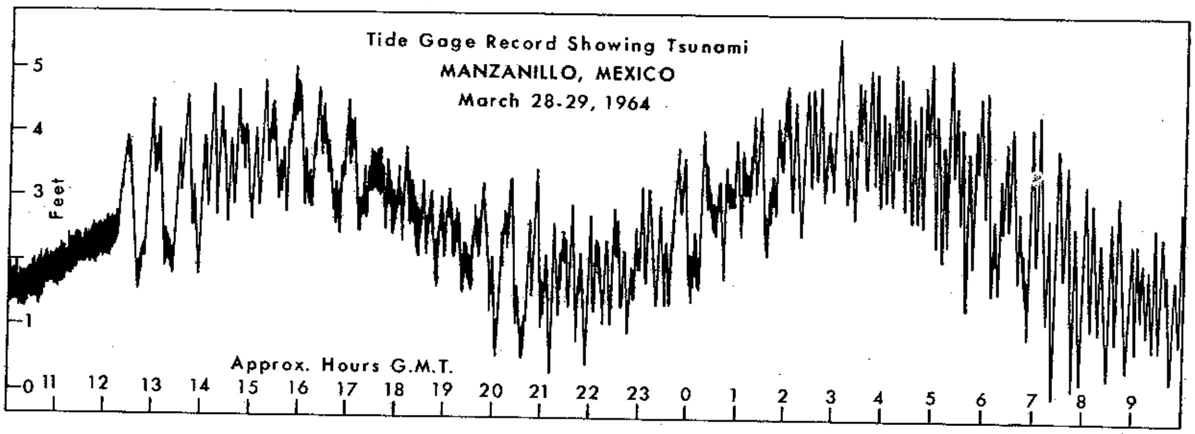

Tide Gage Record Showing Tsunami
LA PAZ, B. C., MEXICO
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.39


Tide Gage Record Showing Tsunami
GUAYMAS, SON., MEXICO
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.40

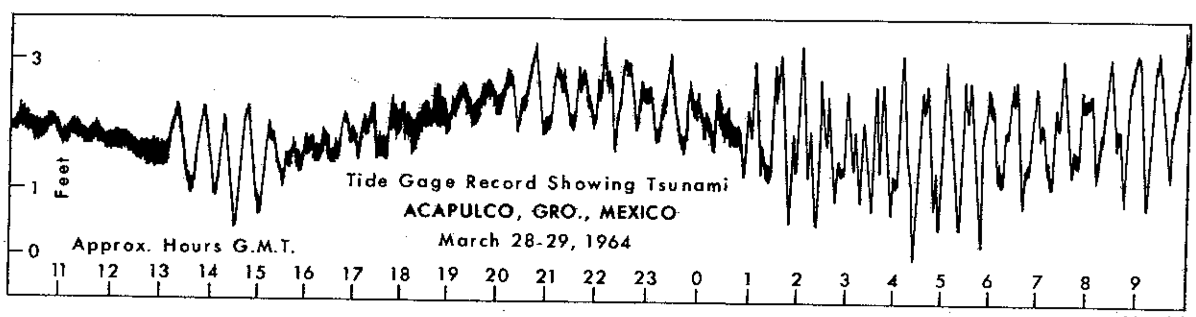

Tide Gage Record Showing Tsunami
TOPOLOBAMPO, SIN., MEXICO
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.41



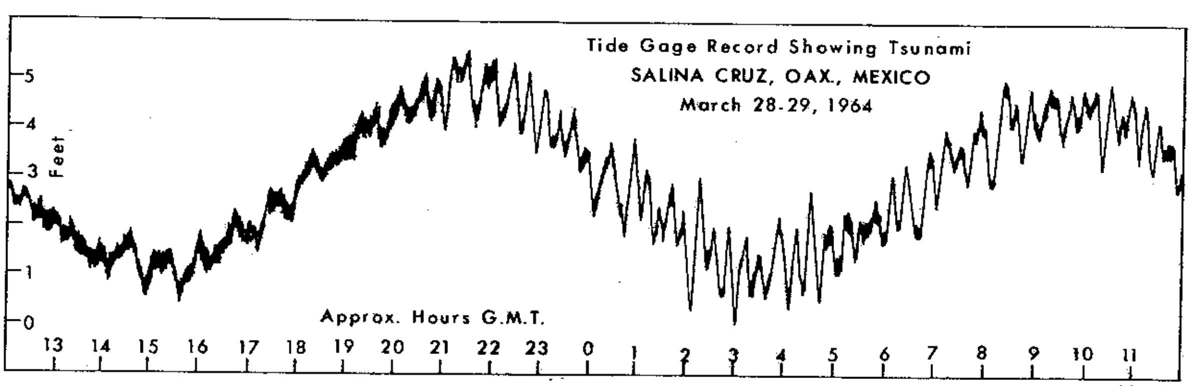
No.42



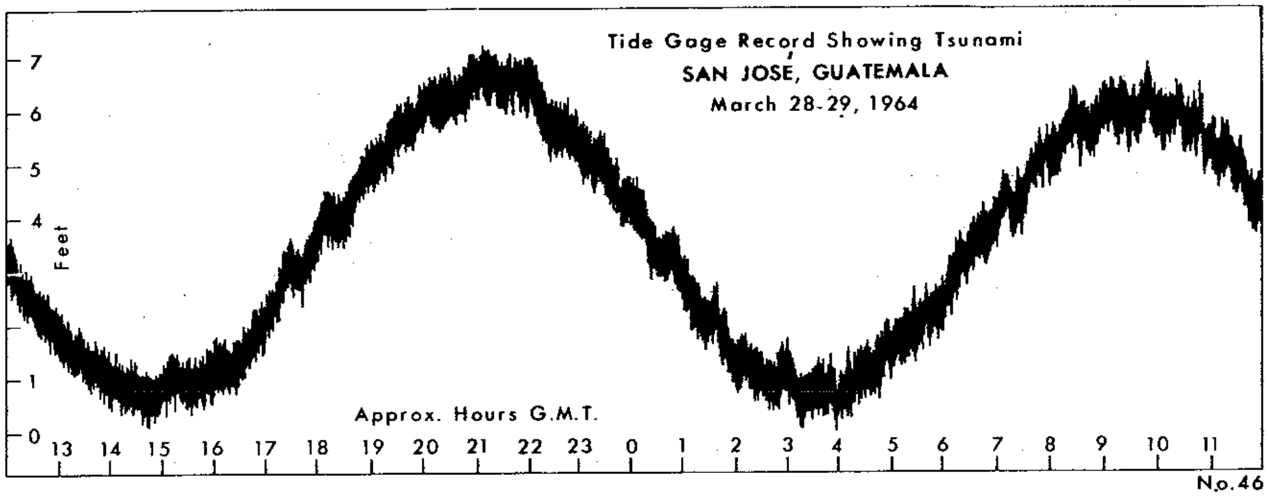
No.43

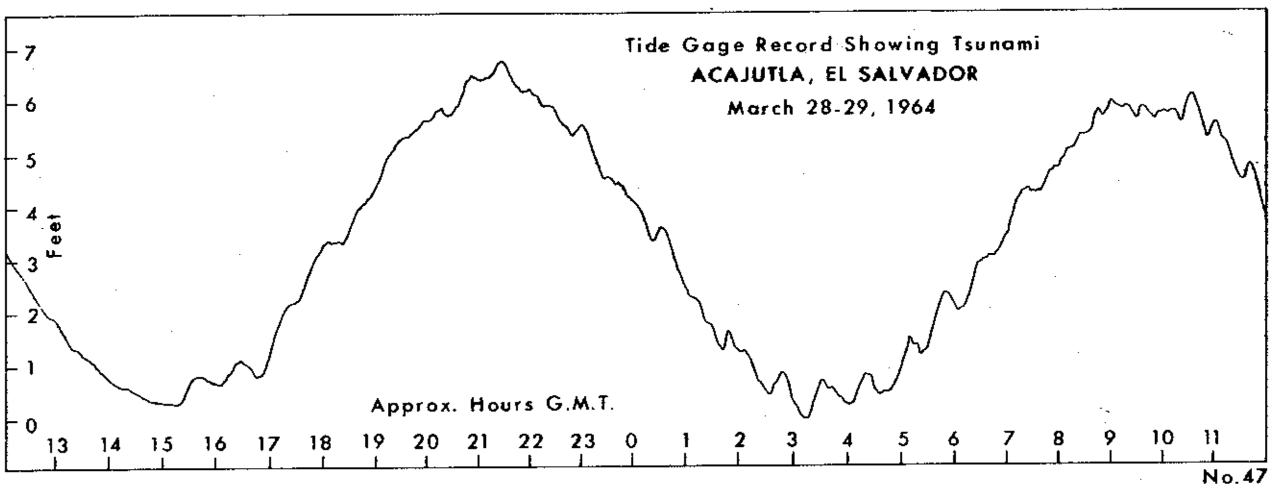


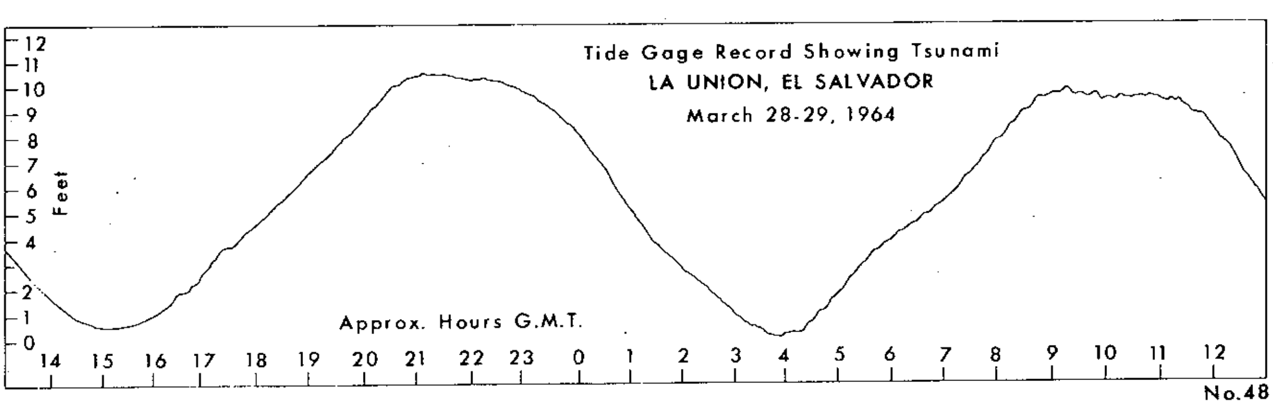
No.44

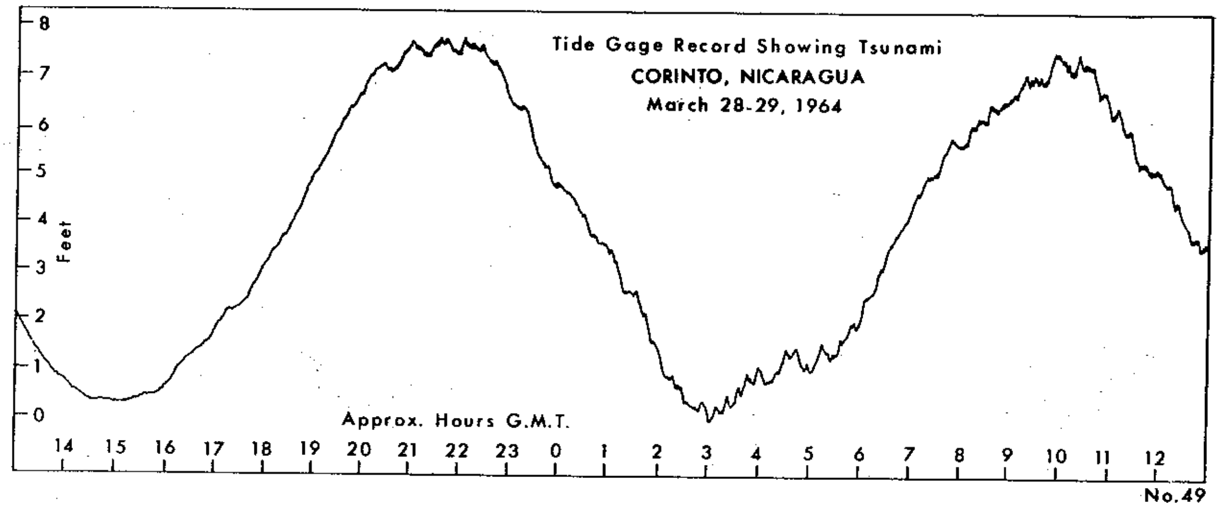


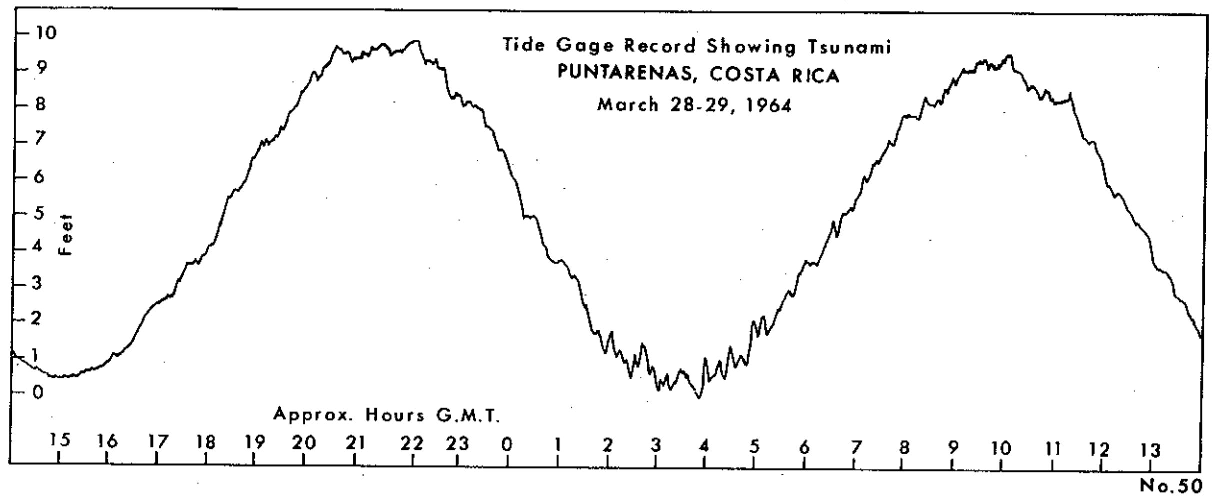
No.45

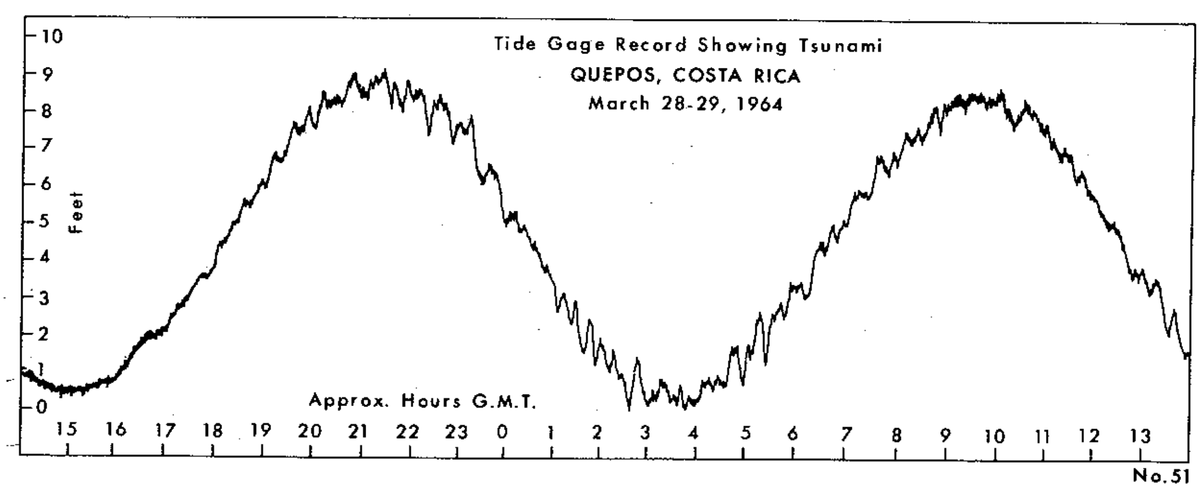

Tide Gage Record Showing Tsunami
SAN JOSE, GUATEMALA
March 28-29, 1964
Feet
7
6
5
4
1
0
Approx. Hours G.M.T.
13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11
No.46

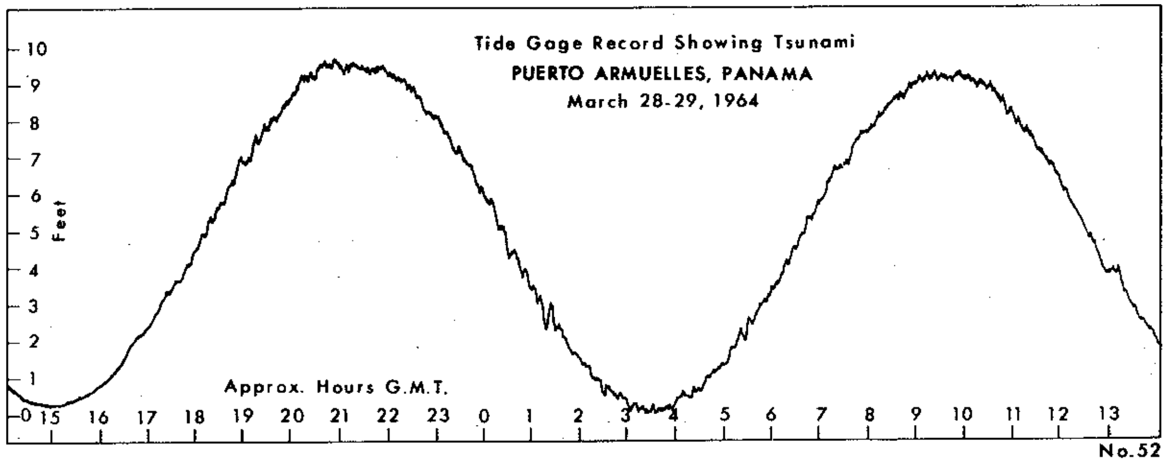

Tide Gage Record Showing Tsunami
ACAJUTLA, EL SALVADOR
March 28-29, 1964
Feet
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11
No.47


Tide Gage Record Showing Tsunami
LA UNION, EL SALVADOR
March 28-29, 1964
Feet
12
11
10
9
8
7
6
5
4
2
1
0
Approx. Hours G.M.T.
14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
No.48

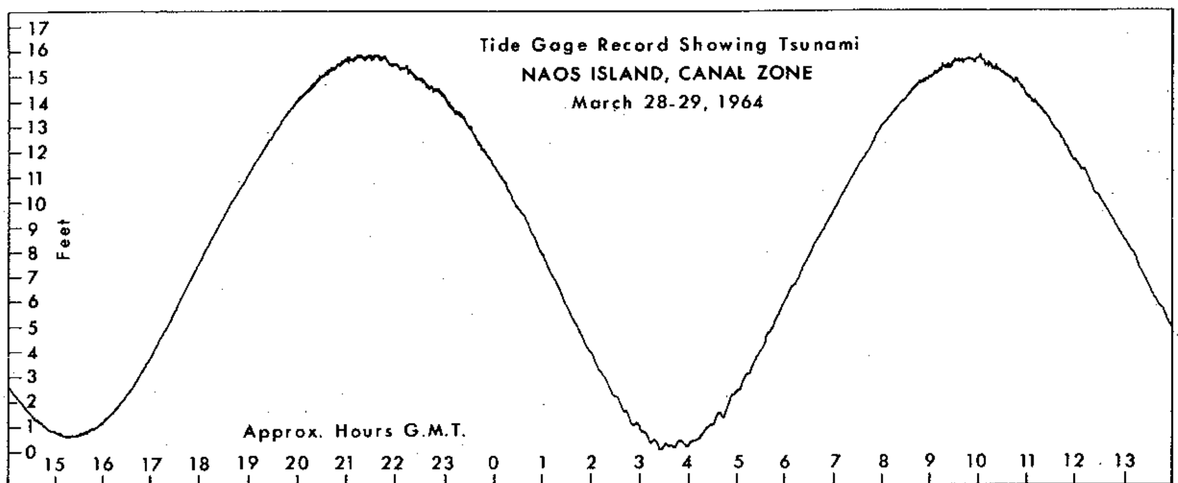

Tide Gage Record Showing Tsunami
CORINTO, NICARAGUA
March 28-29, 1964
Feet
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
No.49


Tide Gage Record Showing Tsunami
PUNTARENAS, COSTA RICA
March 28-29, 1964
Feet
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13
No.50

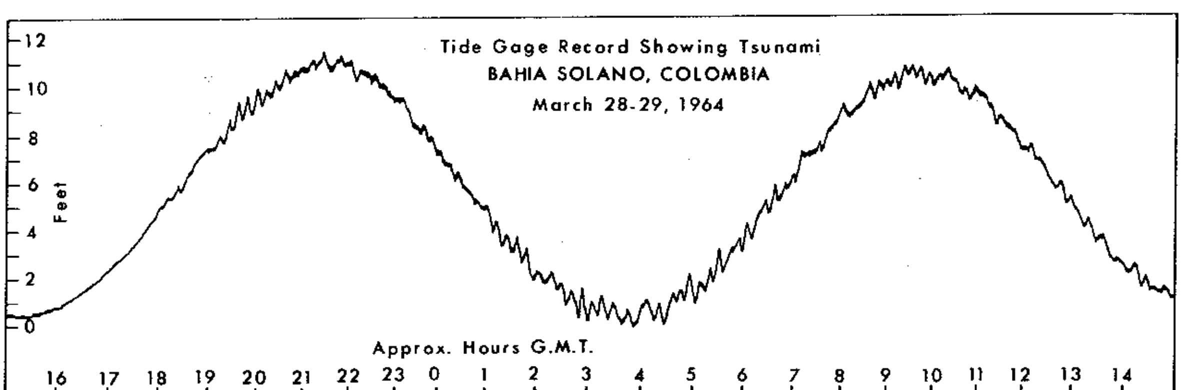

Tide Gage Record Showing Tsunami
QUEPOS, COSTA RICA
March 28-29, 1964
Feet
10
9
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13
No.51



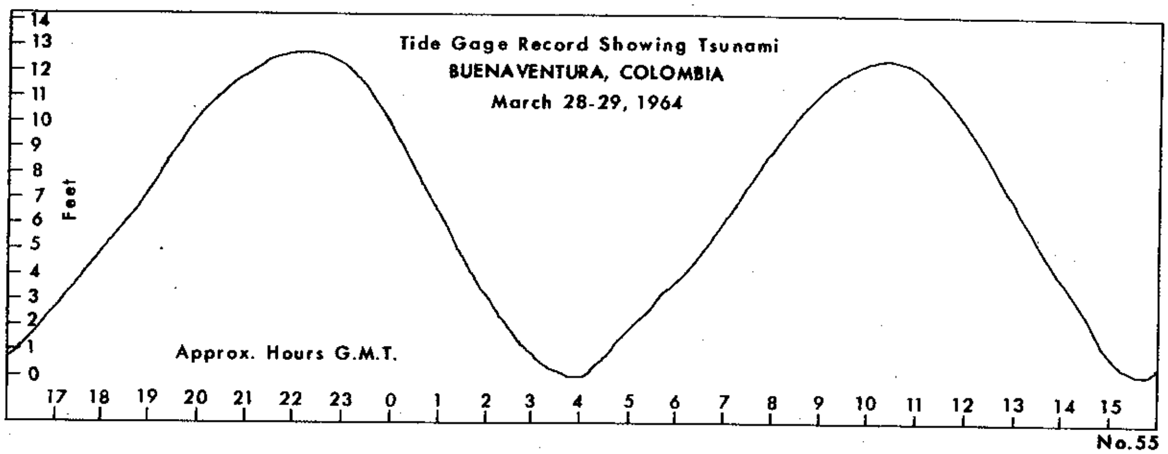
No.52

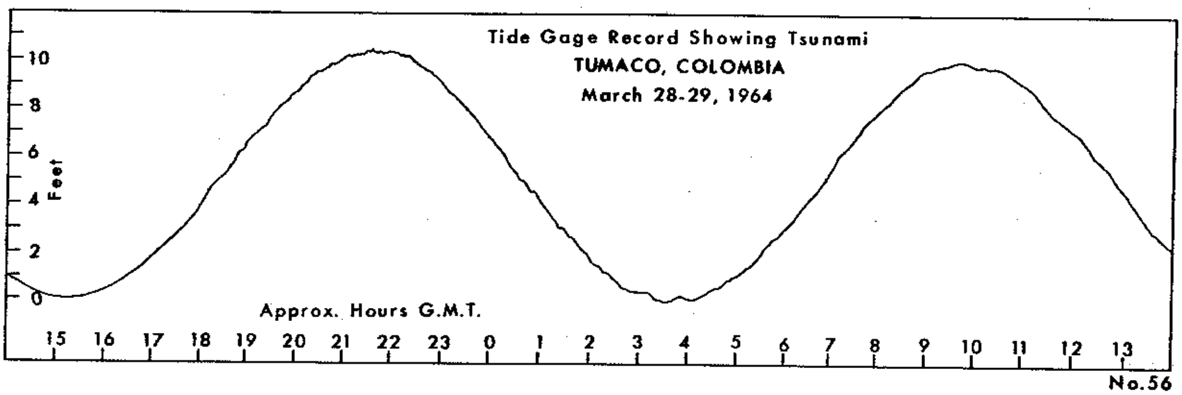


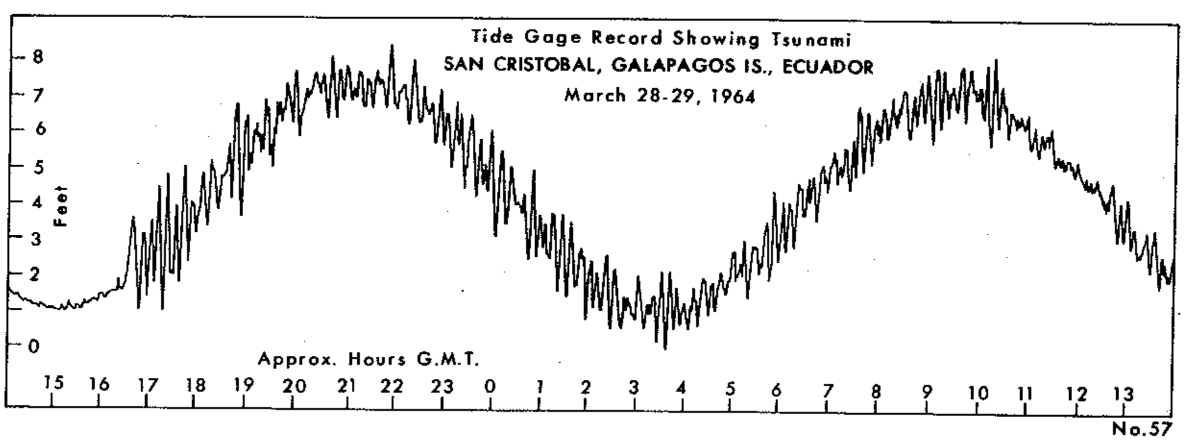
No.53

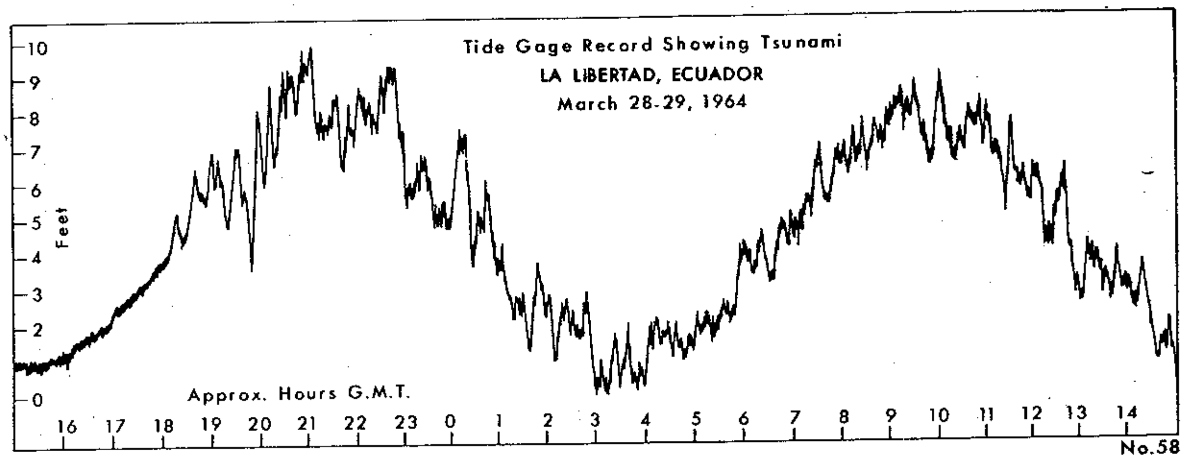


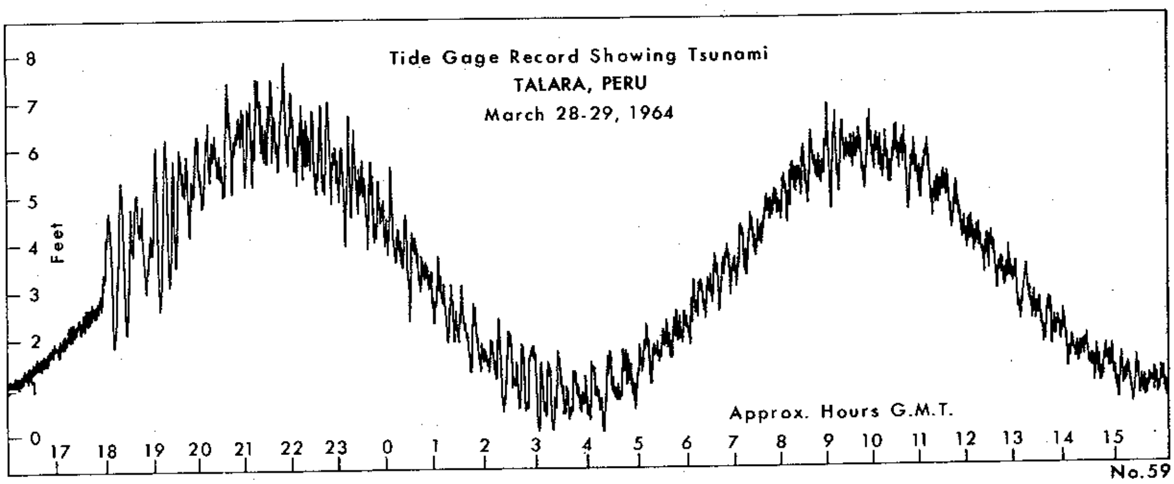
No.54

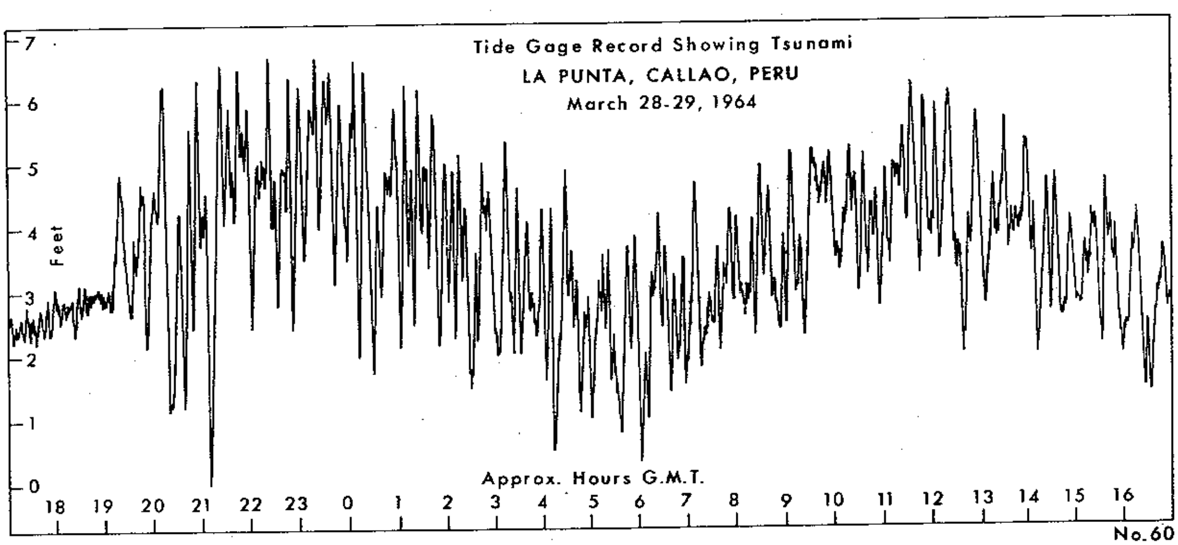

Tide Gage Record Showing Tsunami
BUENAVENTURA, COLOMBIA
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.55

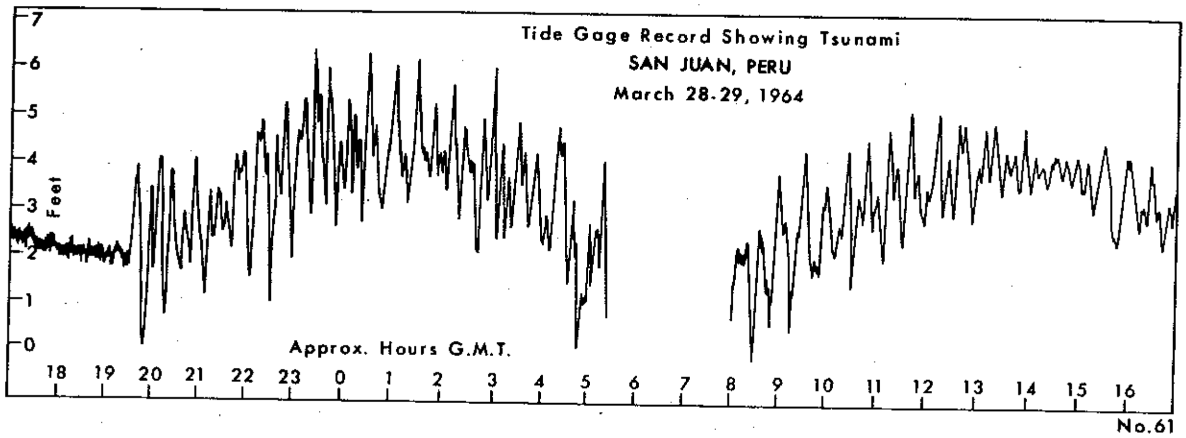

Tide Gage Record Showing Tsunami
TUMACO, COLOMBIA
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.56

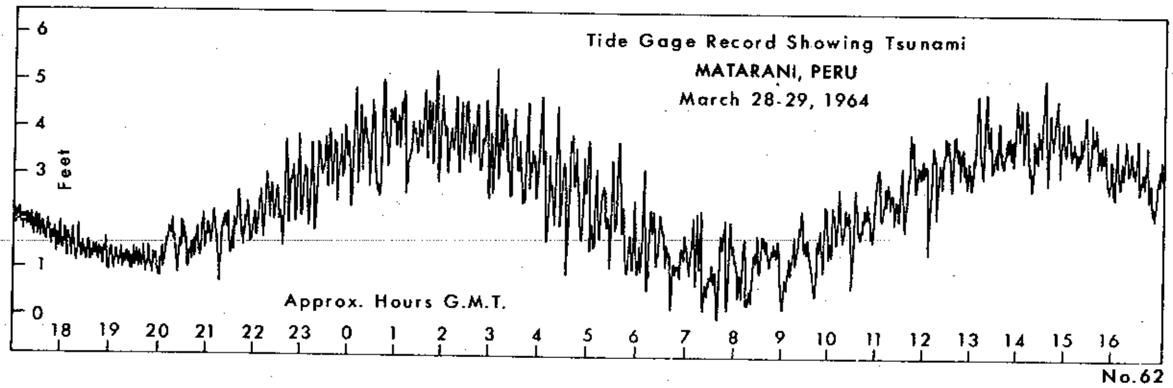

Tide Gage Record Showing Tsunami
SAN CRISTOBAL, GALAPAGOS IS., ECUADOR
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.57

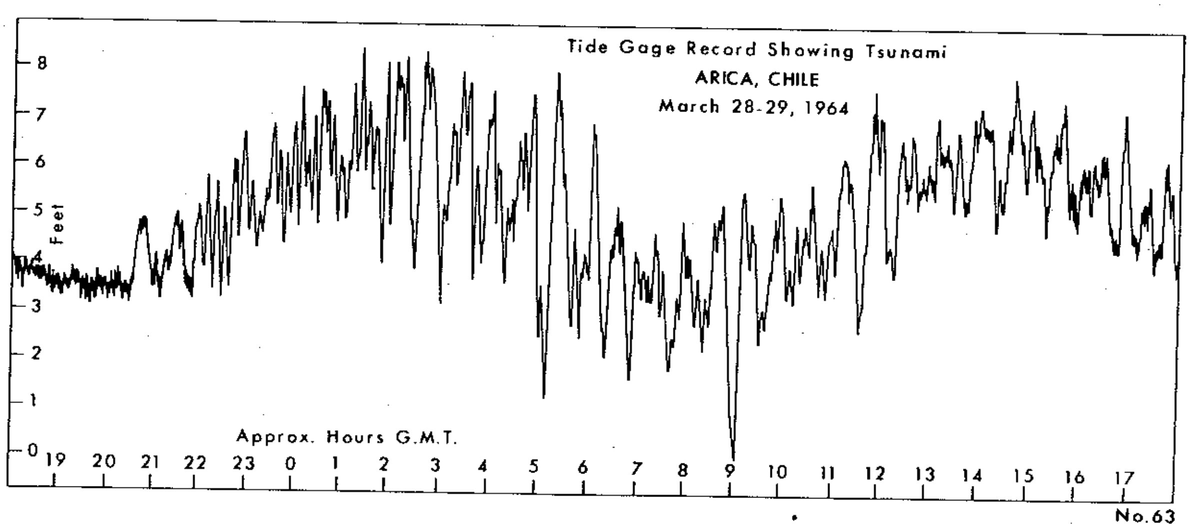

Tide Gage Record Showing Tsunami
LA LIBERTAD, ECUADOR
March 28-29, 1964
Feet
10
9
8
7
6
5
4
3
2
0
Approx. Hours G.M.T.
16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
No.58

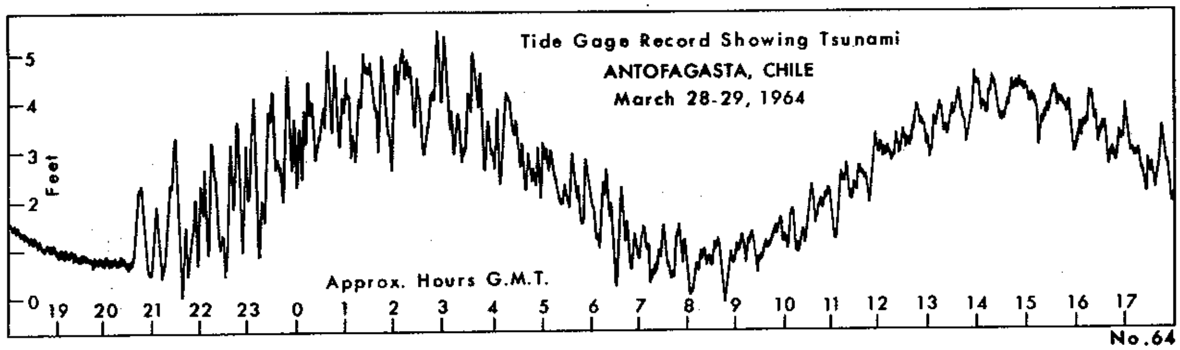

Tide Gage Record Showing Tsunami
TALARA, PERU
March 28-29, 1964
Feet
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
No.59

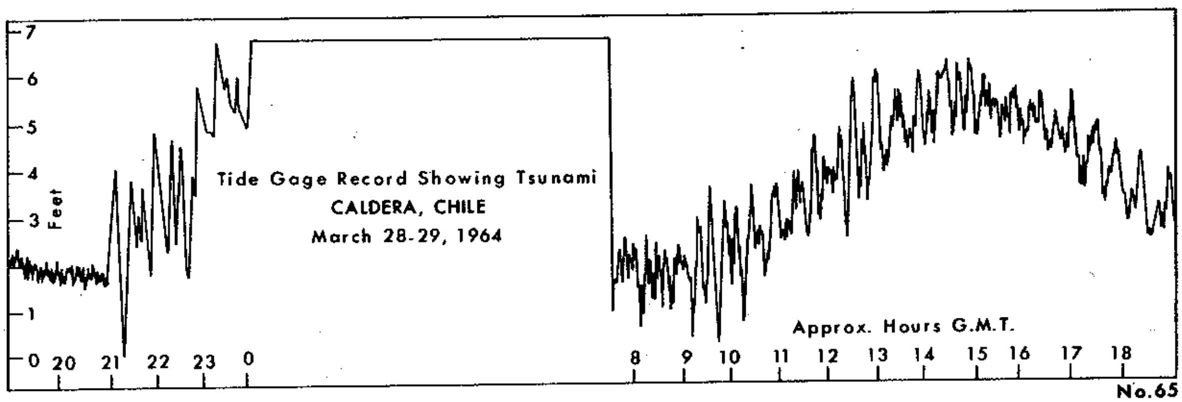

Tide Gage Record Showing Tsunami
LA PUNTA, CALLAO, PERU
March 28-29, 1964
Feet
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
No.60

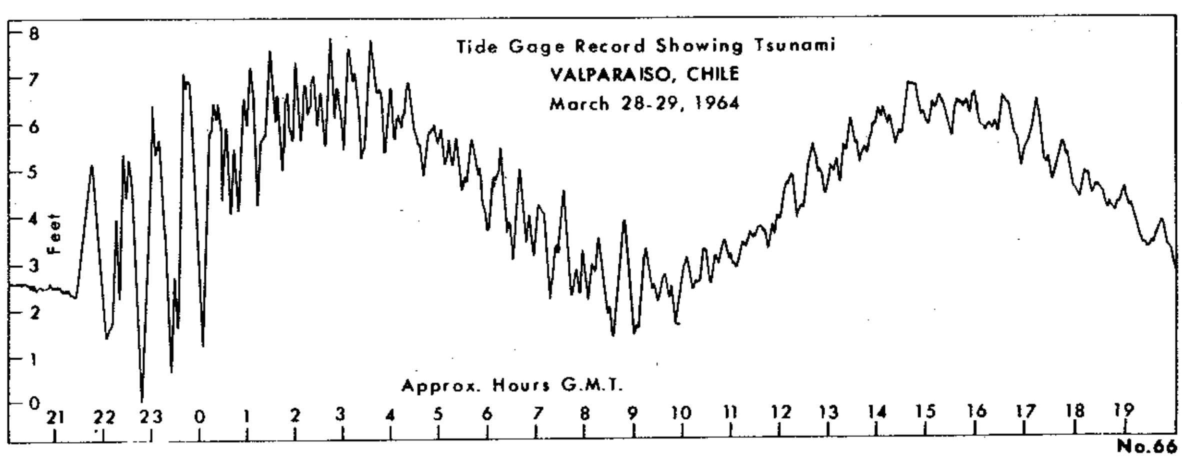

Tide Gage Record Showing Tsunami
SAN JUAN, PERU
March 28-29, 1964
Feet
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
No.61

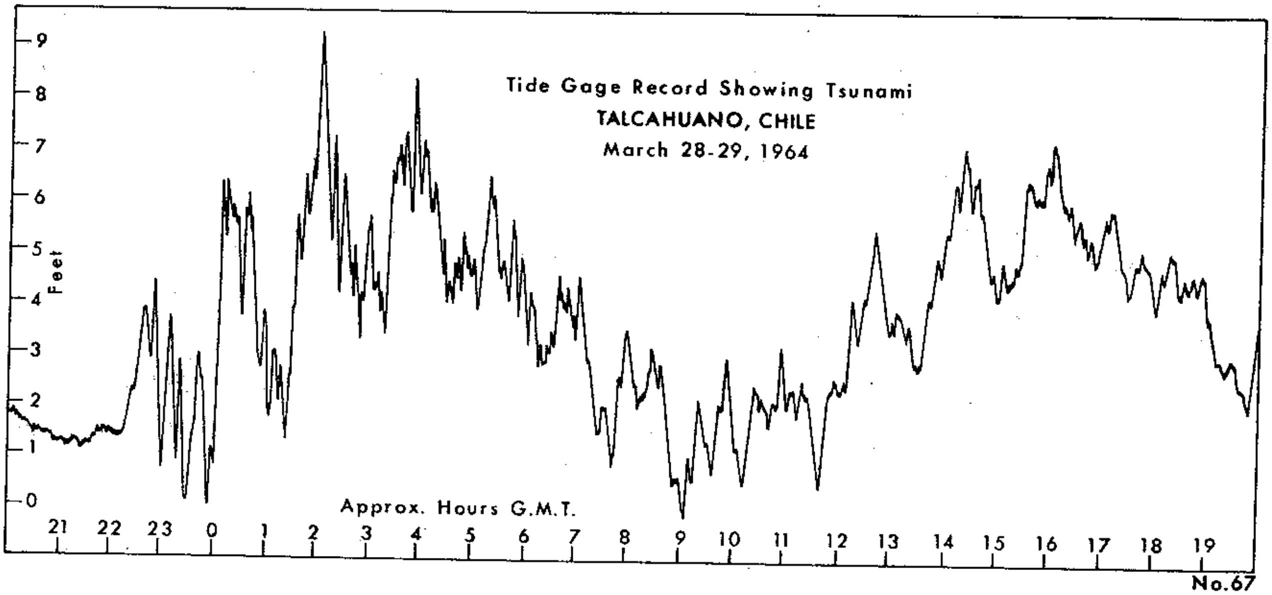

Tide Gage Record Showing Tsunami
MATARANI, PERU
March 28-29, 1964
Feet
6
5
4
3
1
0
Approx. Hours G.M.T.
18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
No.62

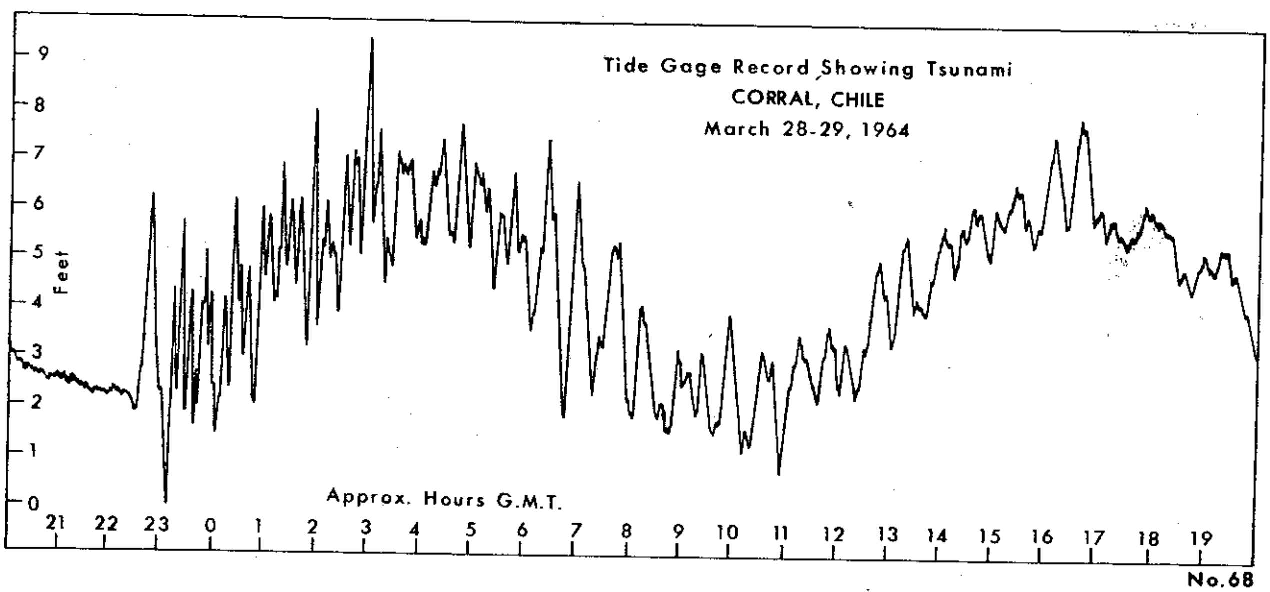

Tide Gage Record Showing Tsunami
ARICA, CHILE
March 28-29, 1964
Feet
8
7
6
5
4
3
2
1
0
Approx. Hours G.M.T.
19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
No.63

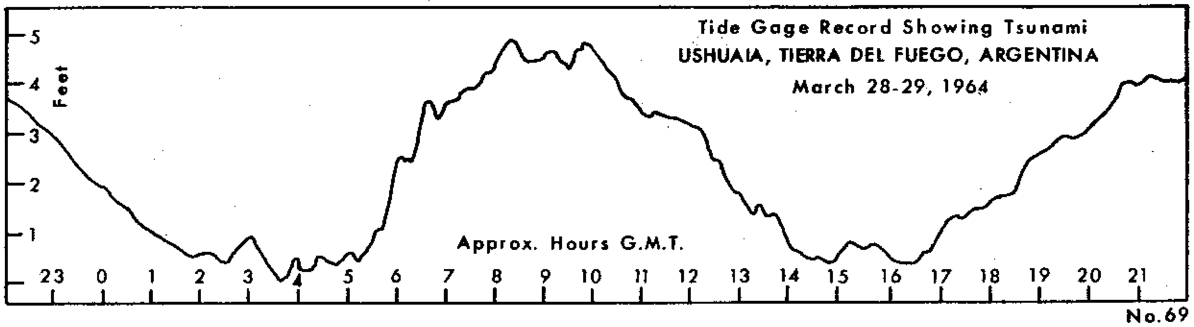

Tide Gage Record Showing Tsunami
ANTOFAGASTA, CHILE
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.64

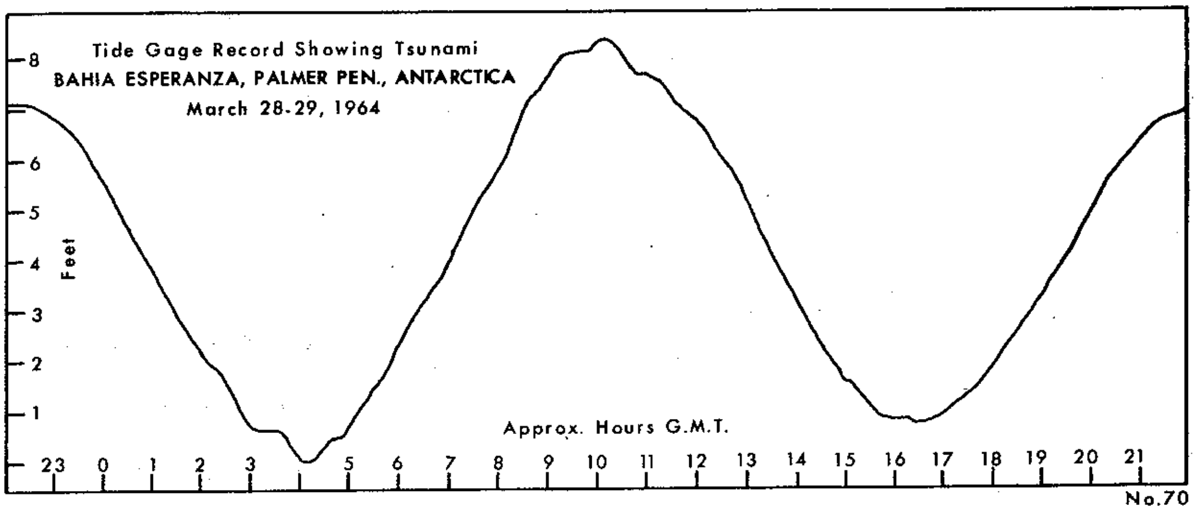

Tide Gage Record Showing Tsunami
CALDERA, CHILE
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.65

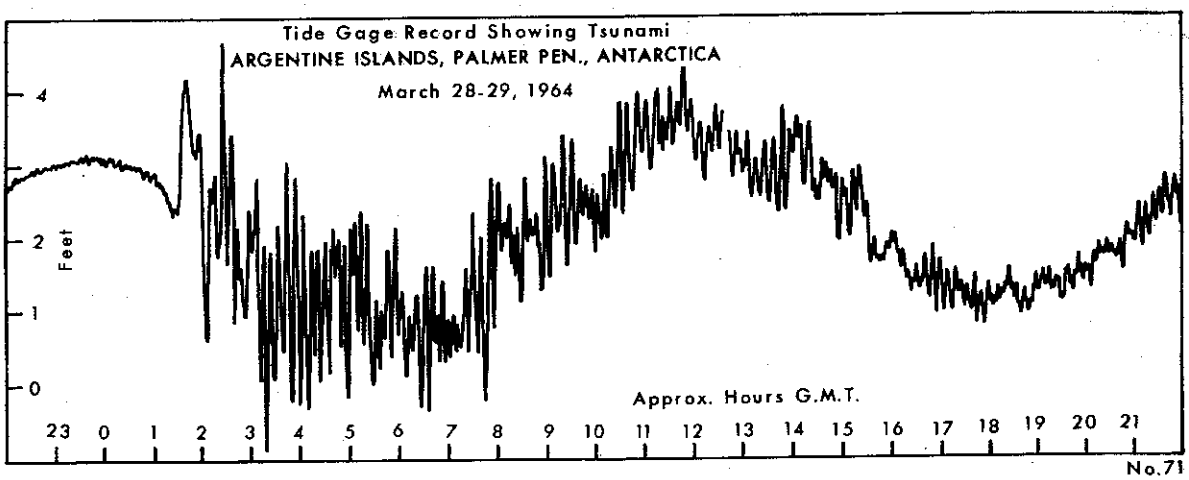

Tide Gage Record Showing Tsunami
VALPARAISO, CHILE
March 28-29, 1964
Feet
Approx. Hours G.M.T.
No.66

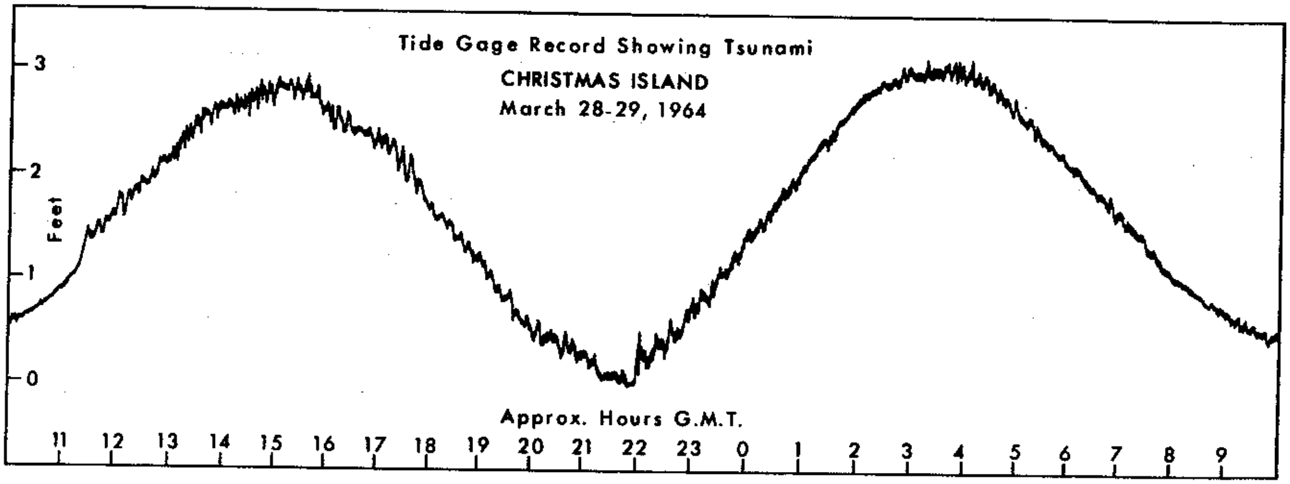

Tide Gage Record Showing Tsunami
TALCAHUANO, CHILE
March 28-29, 1964
Feet
0
1
2
3
4
5
6
7
8
9
Approx. Hours G.M.T.
21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
No.67


Tide Gage Record Showing Tsunami
CORRAL, CHILE
March 28-29, 1964
Feet
0
1
2
3
4
5
6
7
8
9
Approx. Hours G.M.T.
21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
No.68


Tide Gage Record Showing Tsunami
USHUAIA, TIERRA DEL FUEGO, ARGENTINA
March 28-29, 1964
Feet
5
4
3
2
1
Approx. Hours G.M.T.
23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
No.69

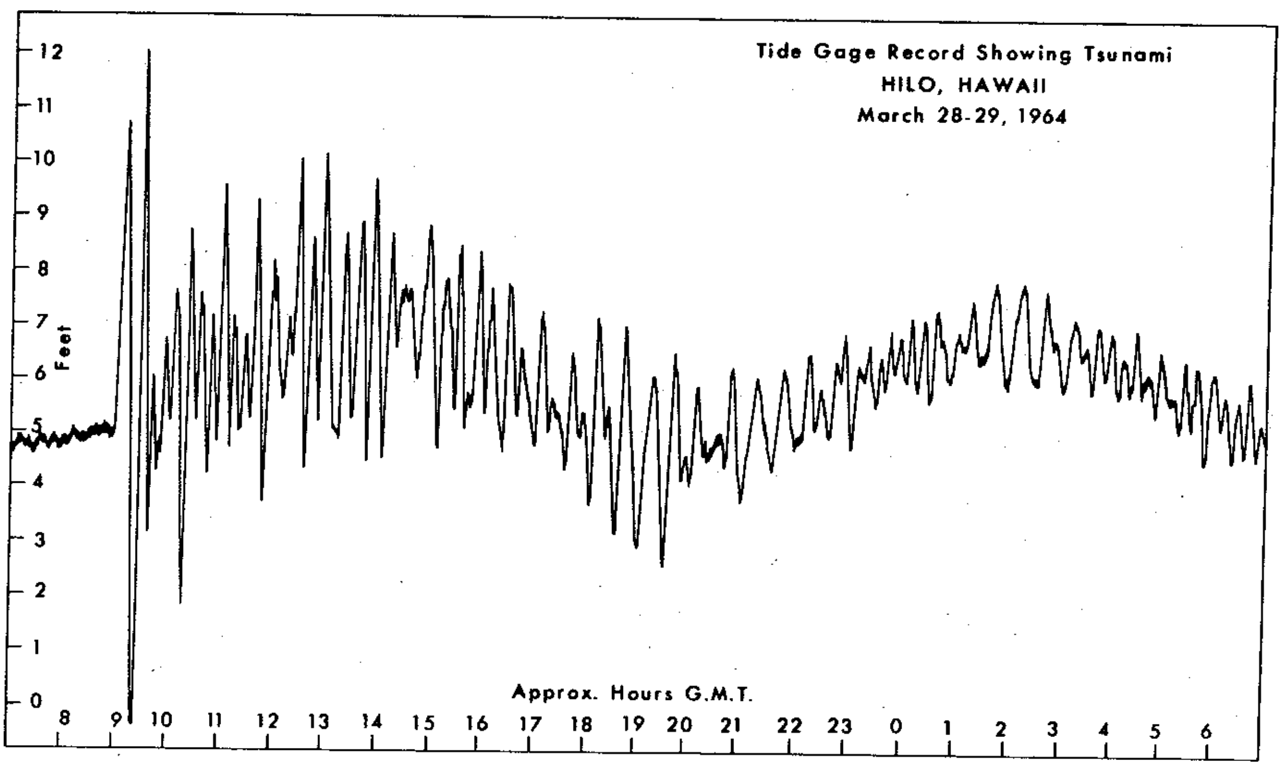

Tide Gage Record Showing Tsunami
BAHIA ESPERANZA, PALMER PEN., ANTARCTICA
March 28-29, 1964
Feet
8
6
5
4
3
2
1
Approx. Hours G.M.T.
23 0 1 2 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
No.70


Tide Gage Record Showing Tsunami
ARGENTINE ISLANDS, PALMER PEN., ANTARCTICA
March 28-29, 1964
Feet
4
2
1
0
Approx. Hours G.M.T.
23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
No.71



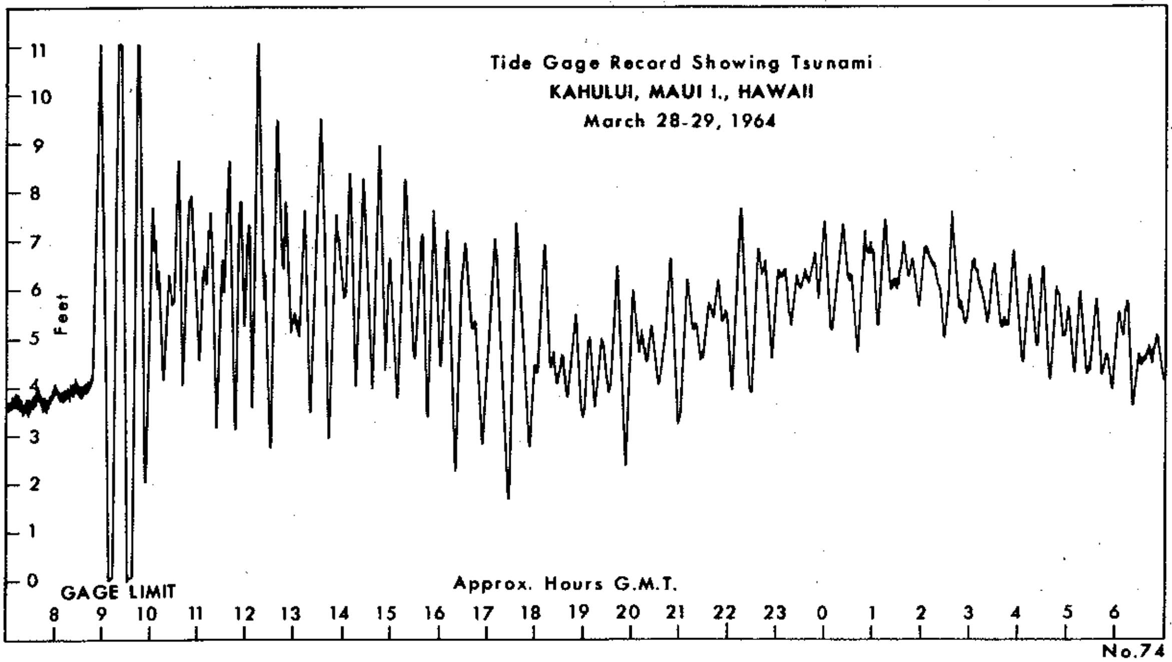
Tide Gage Record Showing Tsunami
CHRISTMAS ISLAND
March 28-29, 1964
3
2
1
0
Feet
Approx. Hours G.M.T.
11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9

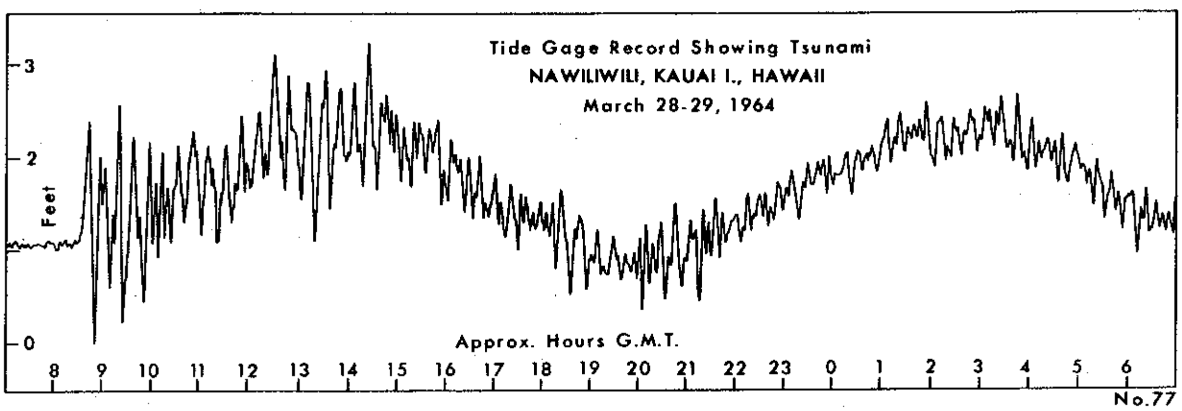
No.72

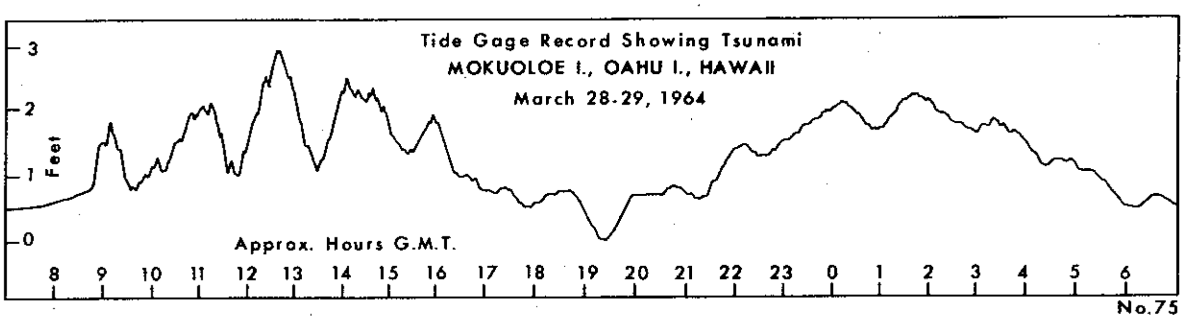


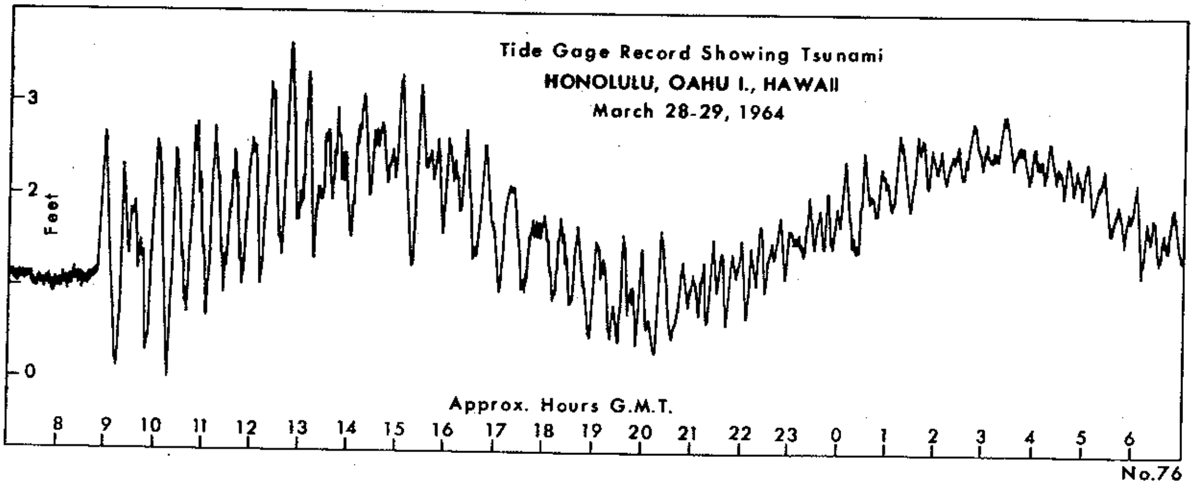
Tide Gage Record Showing Tsunami
HILO, HAWAII
March 28-29, 1964
12
11
10
9
8
7
6
5
4
3
2
1
0
Feet
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6

No.73

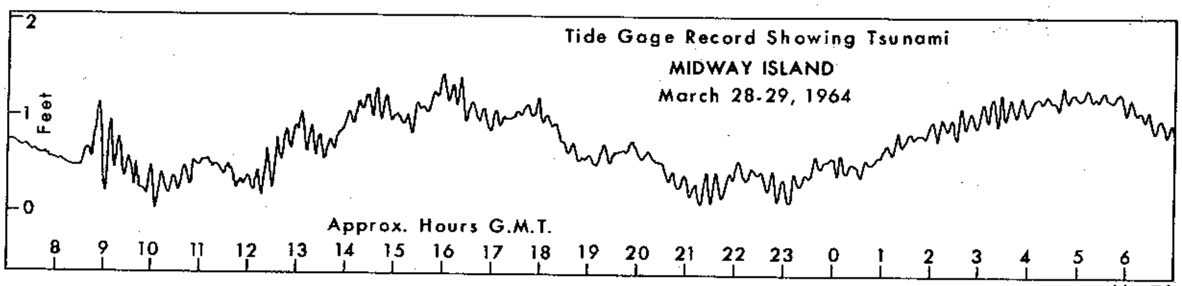

Tide Gage Record Showing Tsunami
KAHULUI, MAUI I., HAWAII
March 28-29, 1964
Feet
11
10
9
8
7
6
5
4
3
2
1
0
GAGE LIMIT
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.74


Tide Gage Record Showing Tsunami
NAWILIWILI, KAUAI I., HAWAII
March 28-29, 1964
Feet
3
2
0
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.77

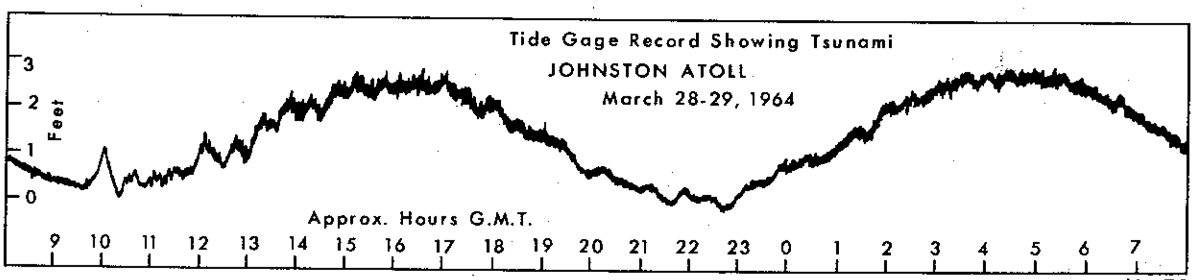

Tide Gage Record Showing Tsunami
MOKUOLOE I., OAHU I., HAWAII
March 28-29, 1964
Feet
3
2
1
0
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.75



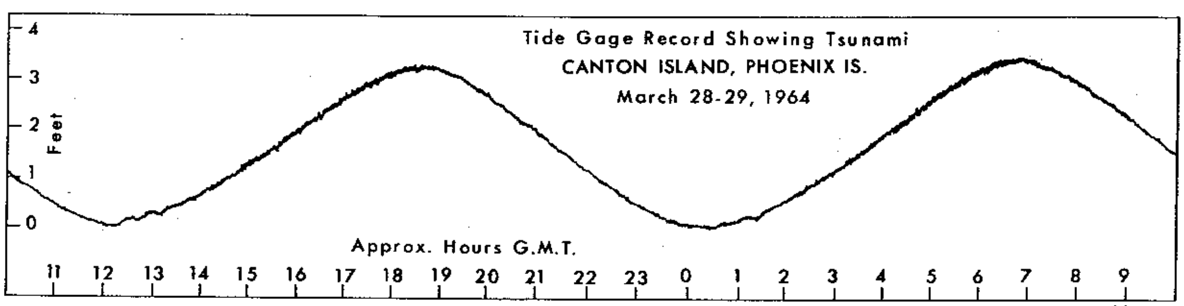
No.76



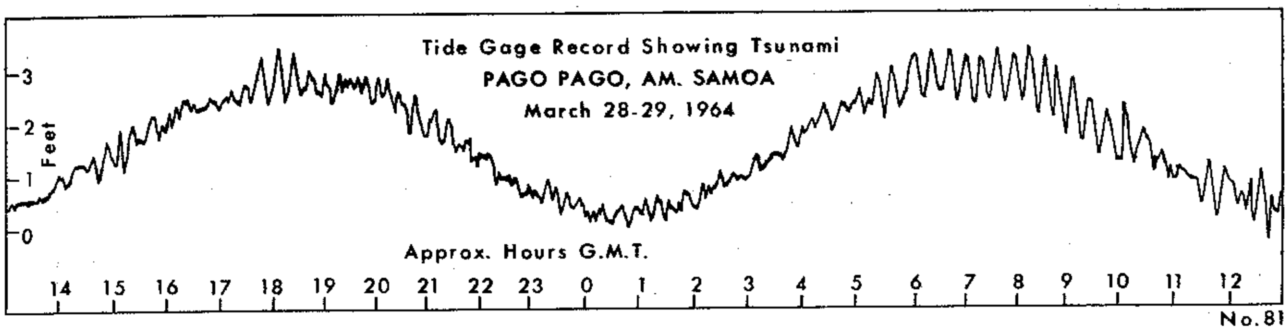
No.78

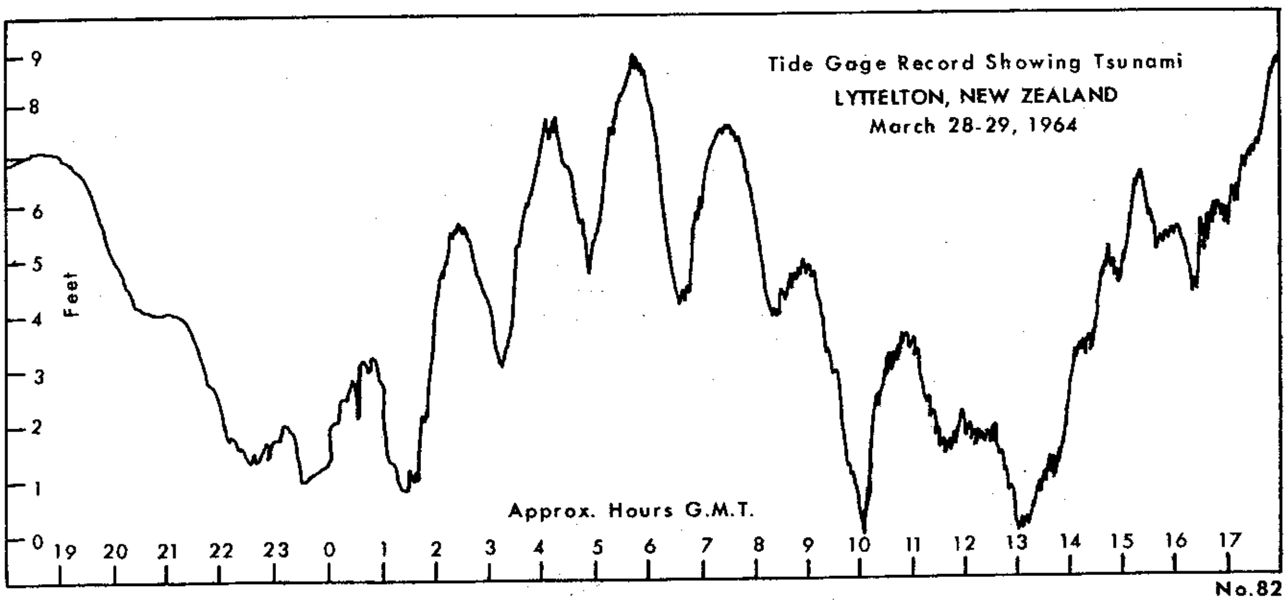


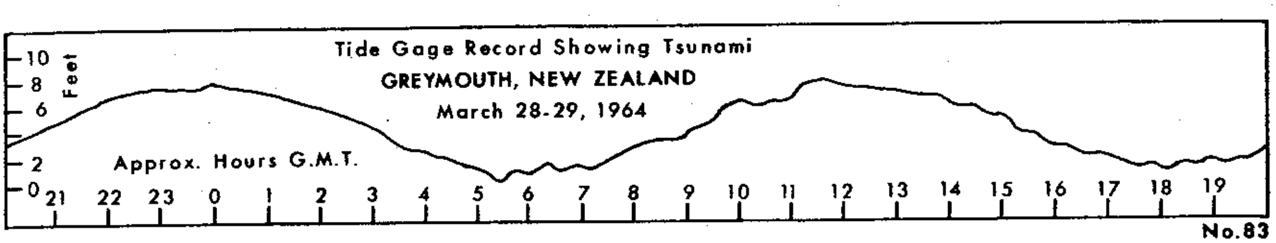
No.79

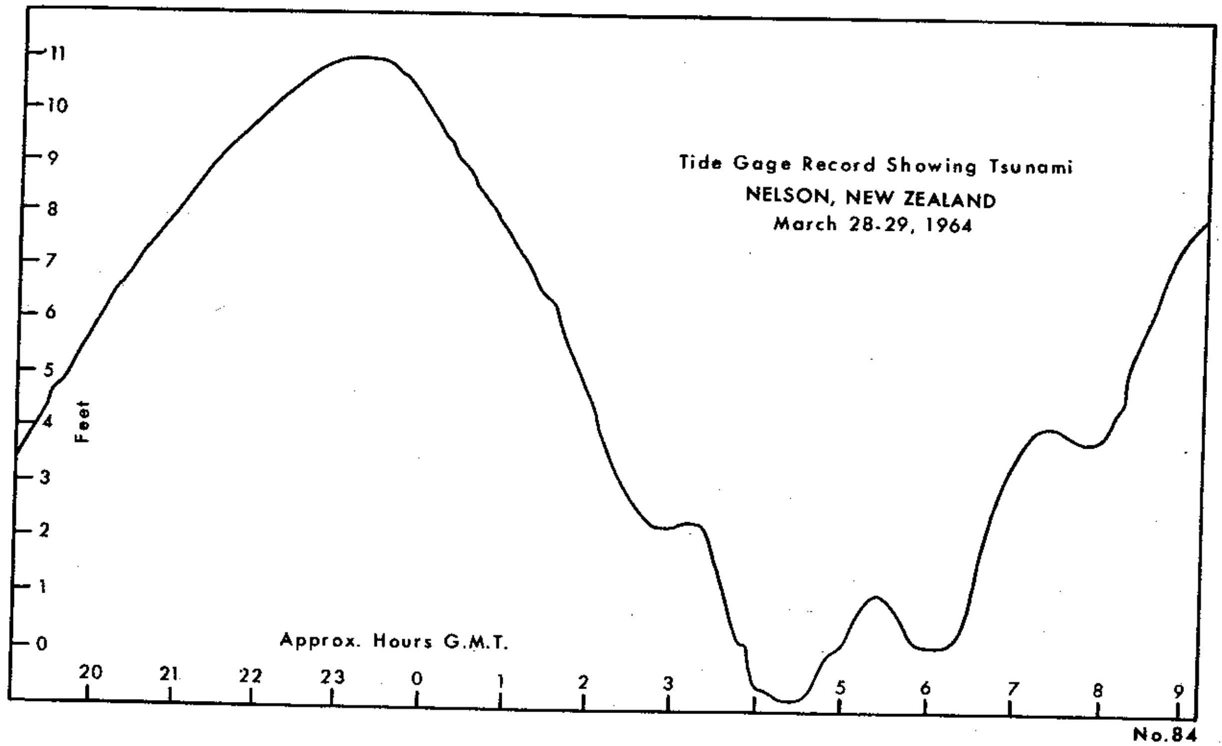


No.80

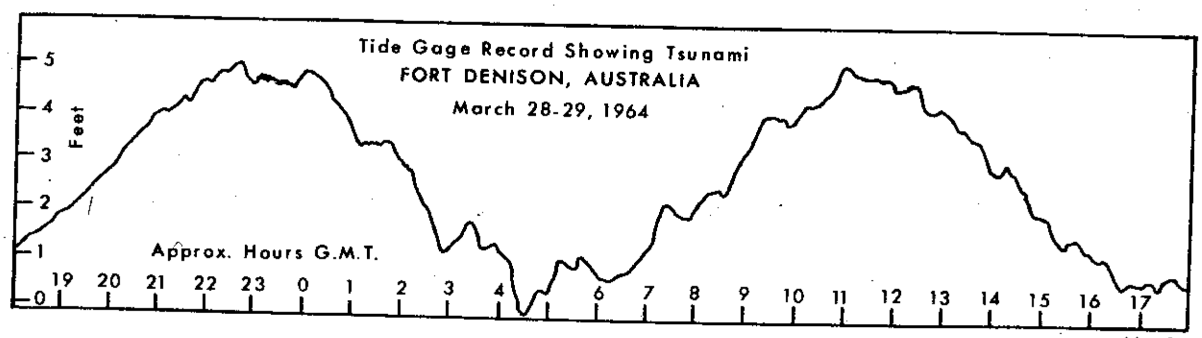

Tide Gage Record Showing Tsunami
PAGO PAGO, AM. SAMOA
March 28-29, 1964
Feet
3
2
1
0
Approx. Hours G.M.T.
14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
No.81


Tide Gage Record Showing Tsunami
LYTTELTON, NEW ZEALAND
March 28-29, 1964
Feet
9
8
6
5
4
3
2
1
0
Approx. Hours G.M.T.
19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
No.82

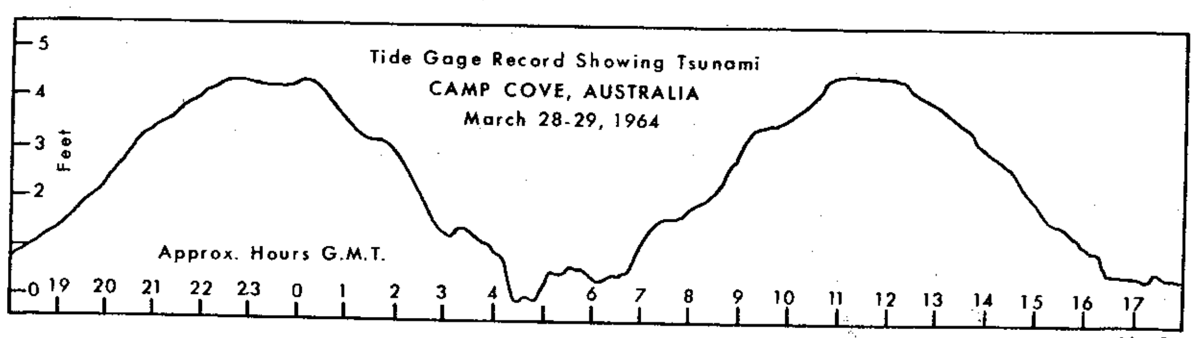

Tide Gage Record Showing Tsunami
GREYMOUTH, NEW ZEALAND
March 28-29, 1964
Feet
10
8
6
2
0
Approx. Hours G.M.T.
21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
No.83



No. 84



No. 85



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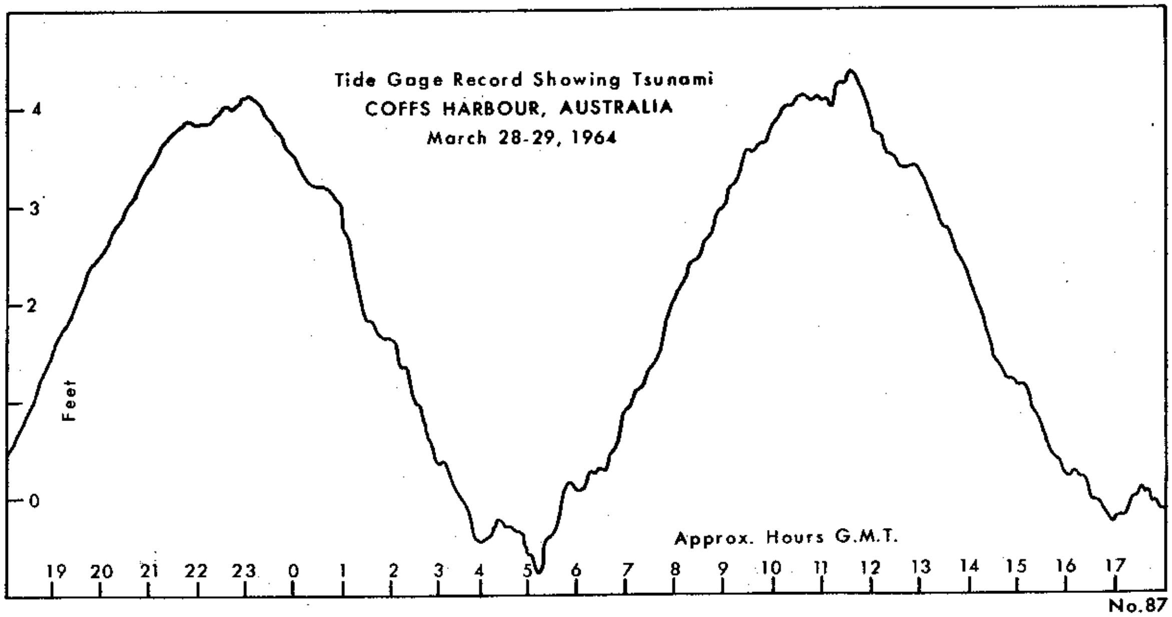
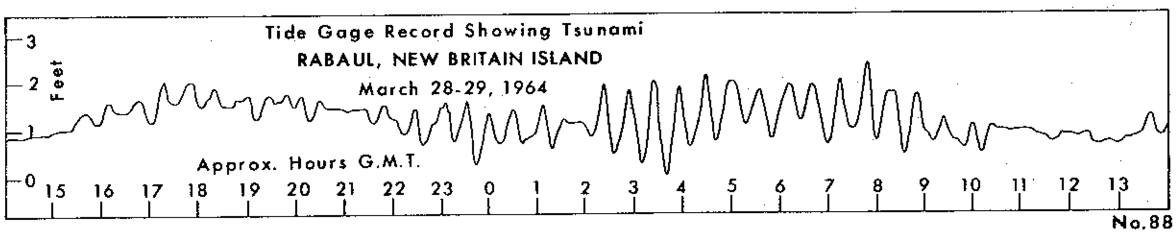
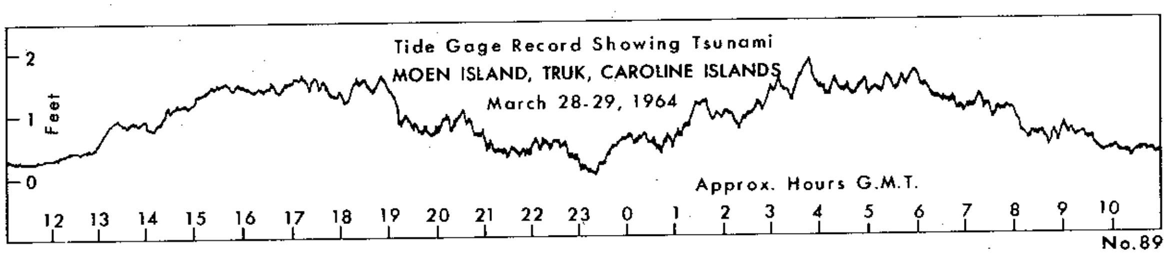
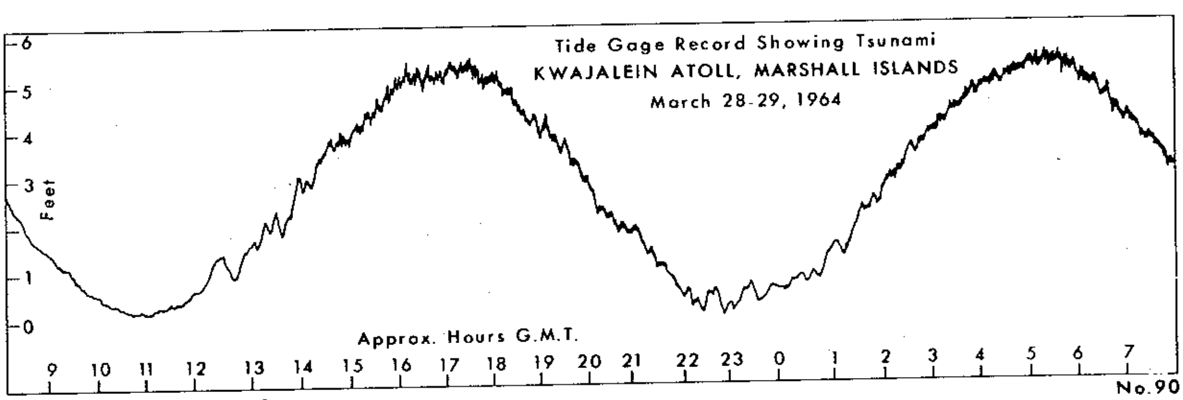
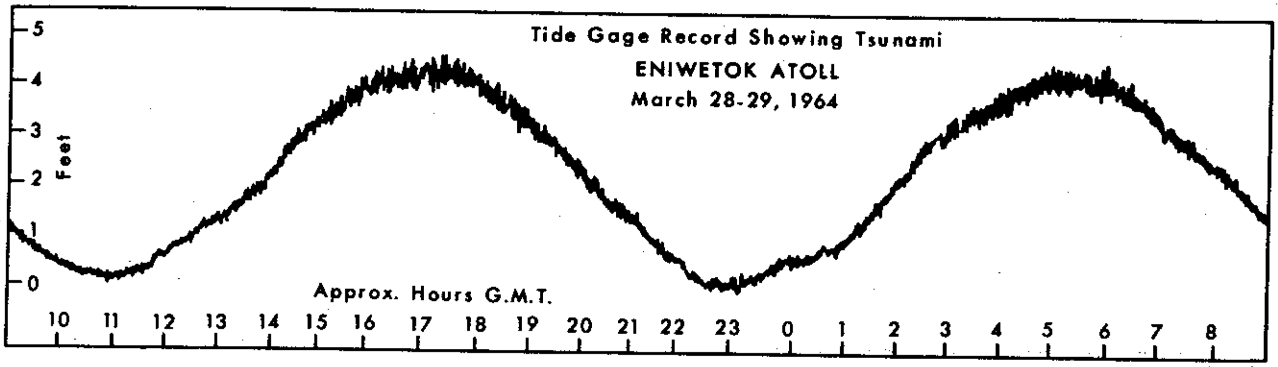

Tide Gage Record Showing Tsunami
COFFS HARBOUR, AUSTRALIA
March 28-29, 1964
Feet
4
3
2
0
Approx. Hours G.M.T.
19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
No.87


Tide Gage Record Showing Tsunami
RABAUL, NEW BRITAIN ISLAND
March 28-29, 1964
Feet
3
2
1
0
Approx. Hours G.M.T.
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13
No.88


Tide Gage Record Showing Tsunami
MOEN ISLAND, TRUK, CAROLINE ISLANDS
March 28-29, 1964
Feet
2
1
0
Approx. Hours G.M.T.
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10
No.89


Tide Gage Record Showing Tsunami
KWAJALEIN ATOLL, MARSHALL ISLANDS
March 28-29, 1964
Feet
6
5
4
3
1
0
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7
No.90



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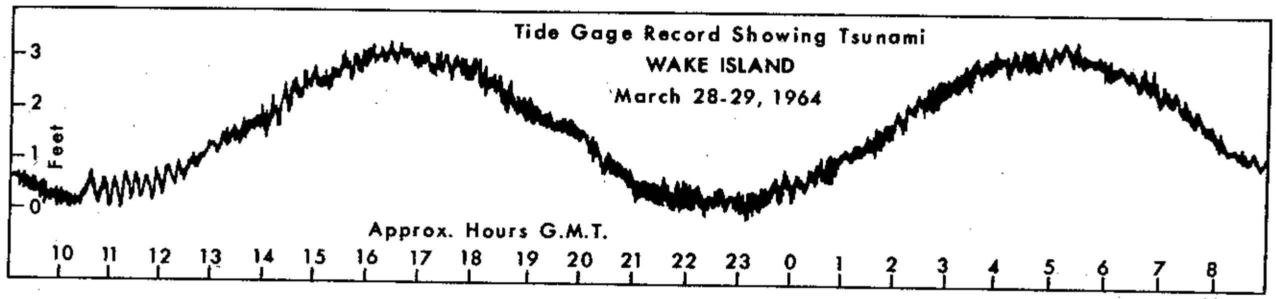

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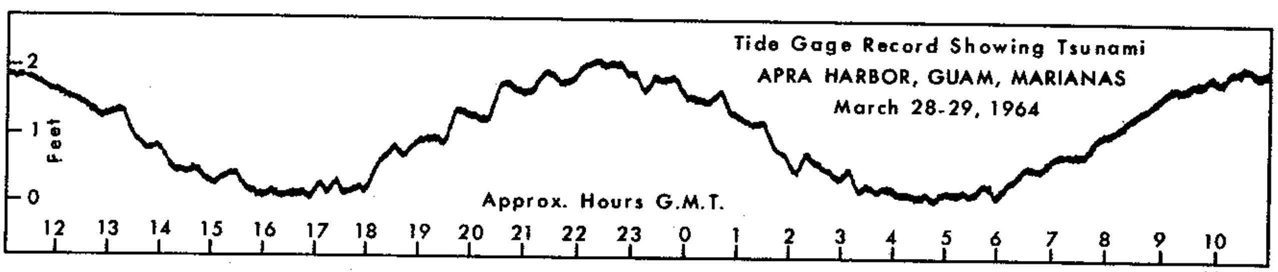

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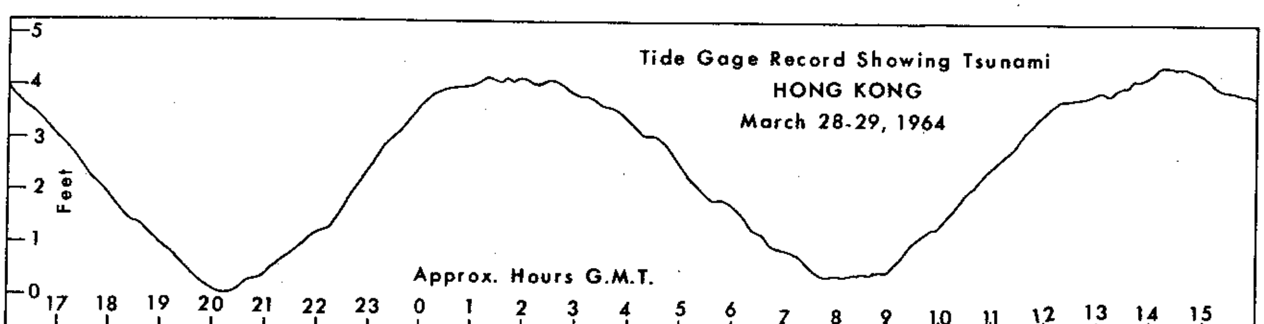

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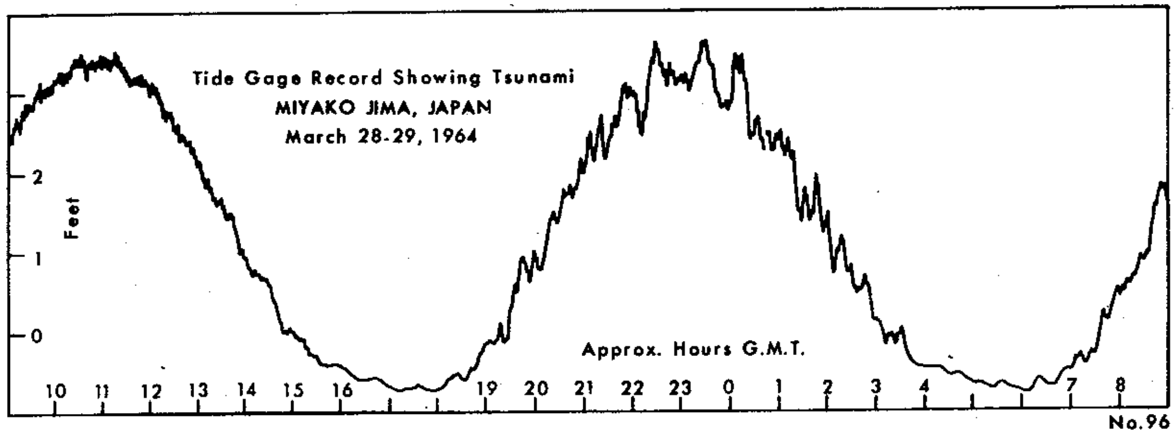
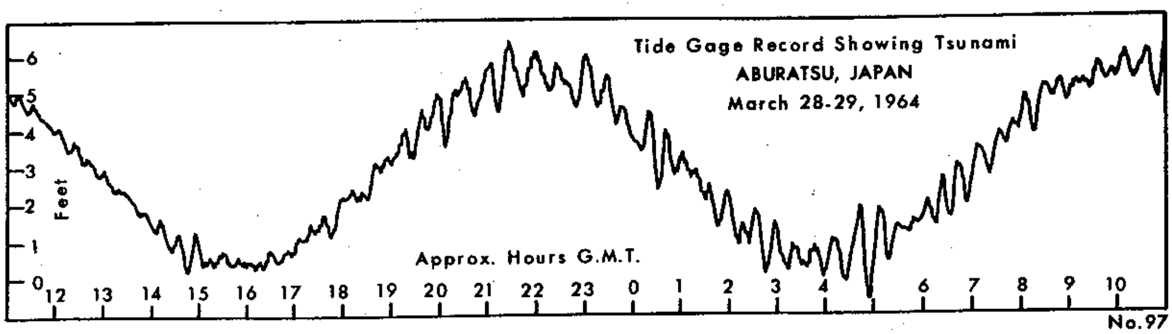
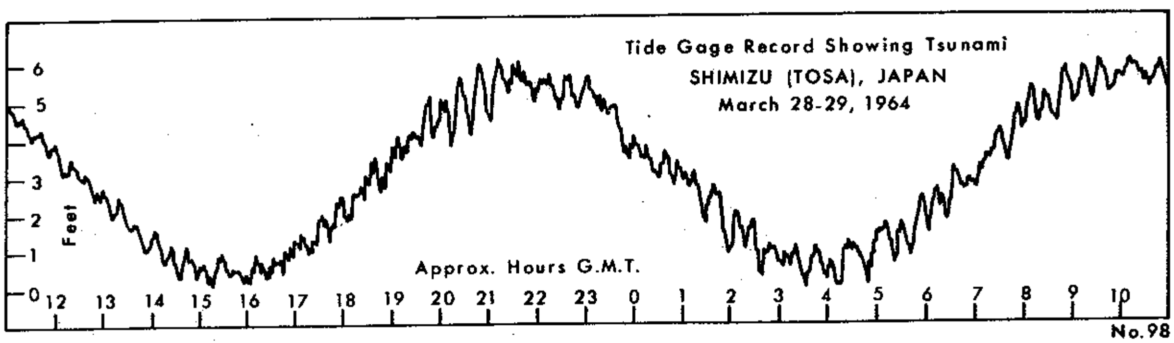
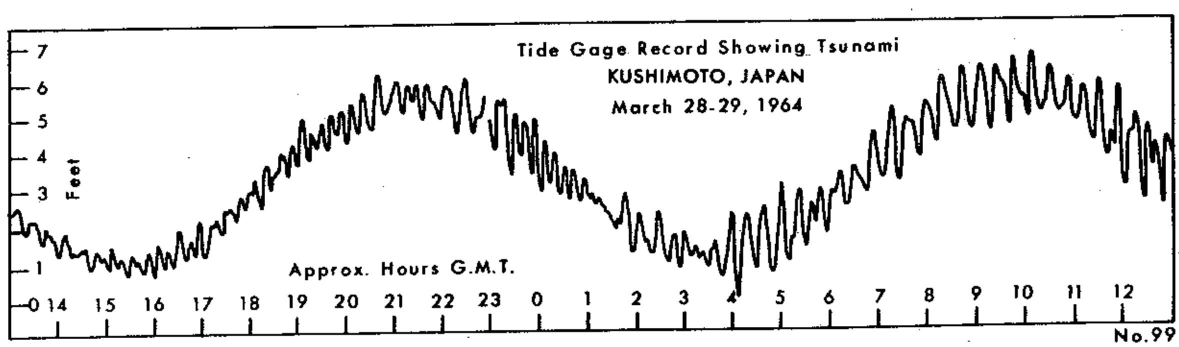
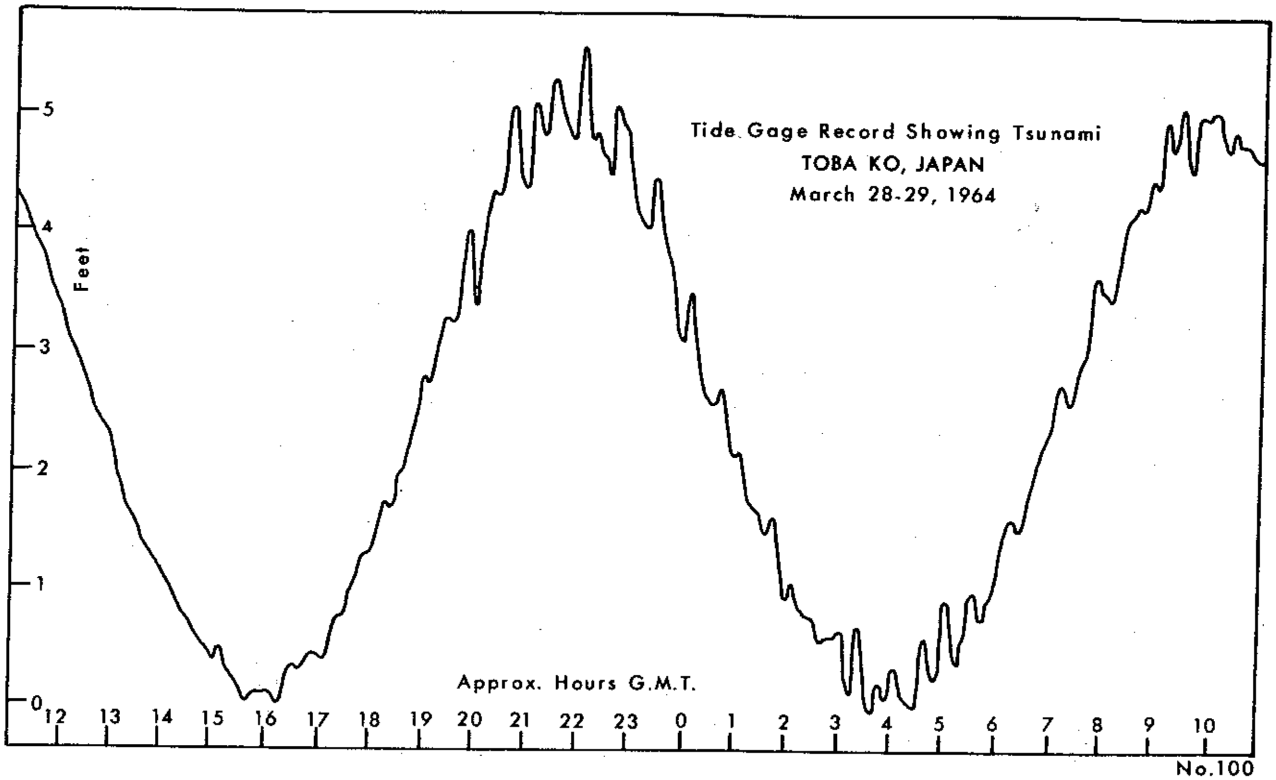
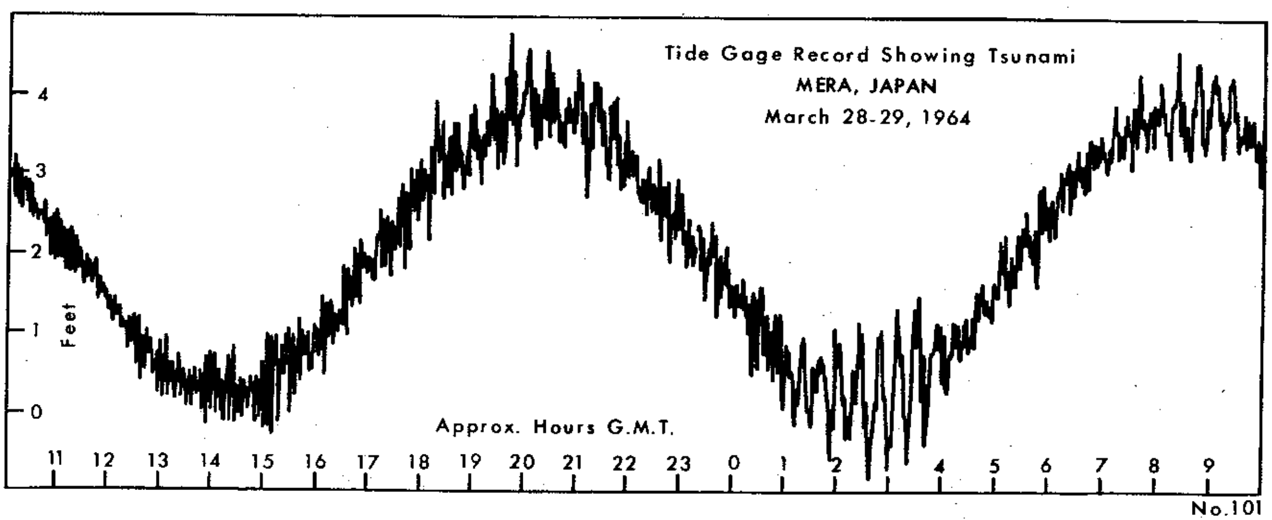

Tide Gage Record Showing Tsunami
MIYAKO JIMA, JAPAN
March 28-29, 1964
Feet
2
1
0
Approx. Hours G.M.T.
10 11 12 13 14 15 16 19 20 21 22 23 0 1 2 3 4 7 8
No.96

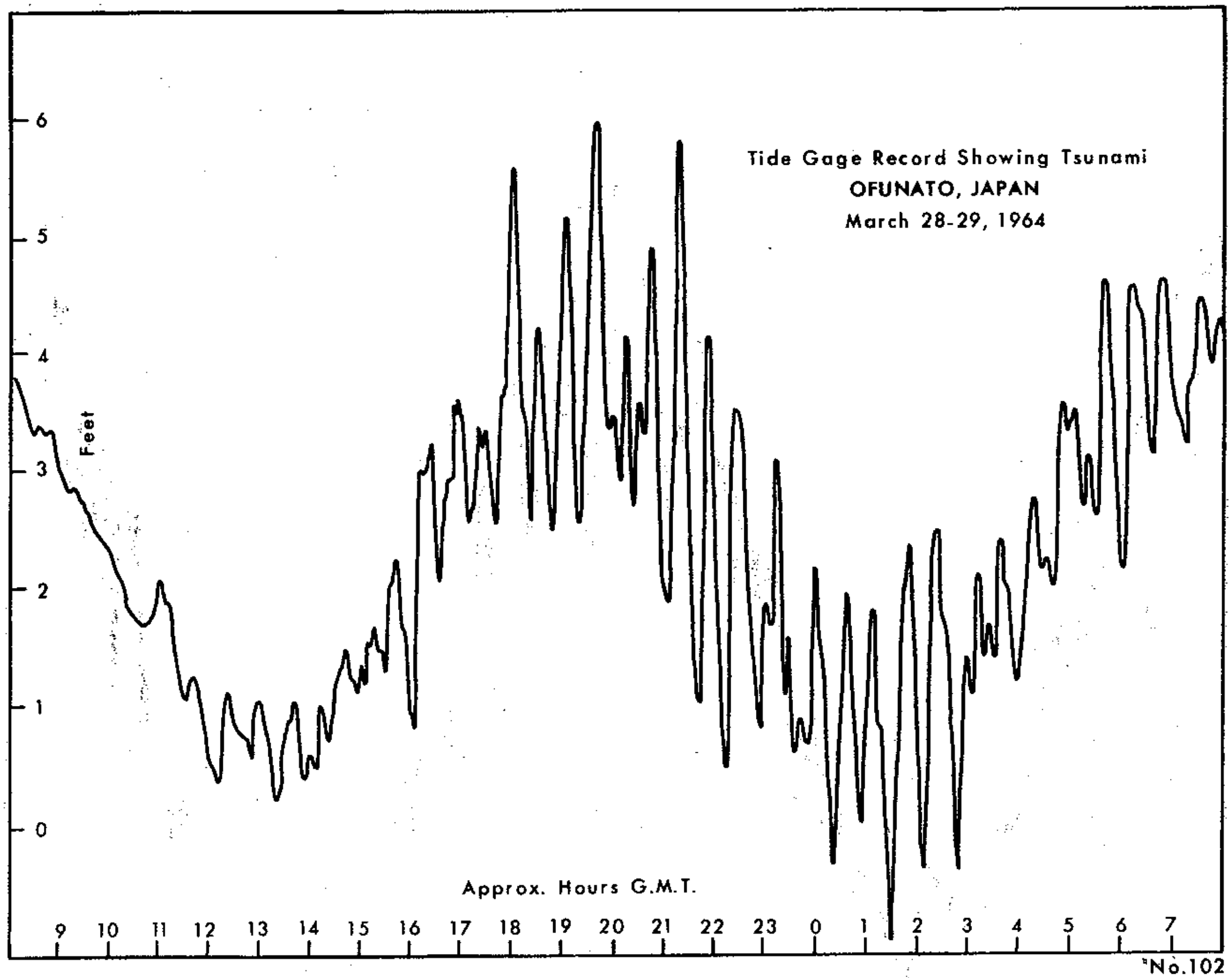

Tide Gage Record Showing Tsunami
ABURATSU, JAPAN
March 28-29, 1964
Feet
6
5
4
3
2
1
0
Approx. Hours G.M.T.
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 6 7 8 9 10
No.97

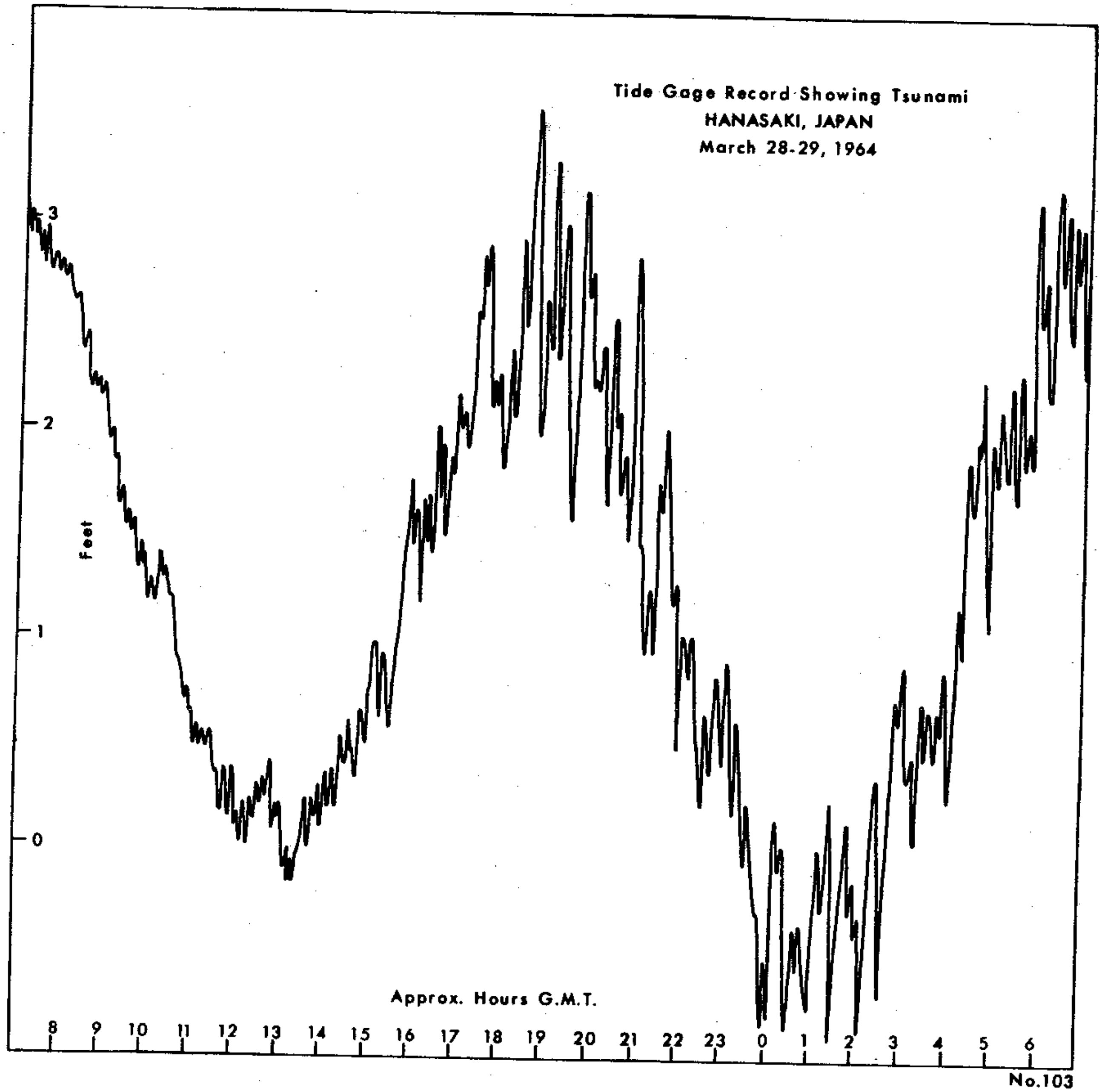

Tide Gage Record Showing Tsunami
SHIMIZU (TOSA), JAPAN
March 28-29, 1964
Feet
6
5
3
2
1
0
Approx. Hours G.M.T.
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10
No.98

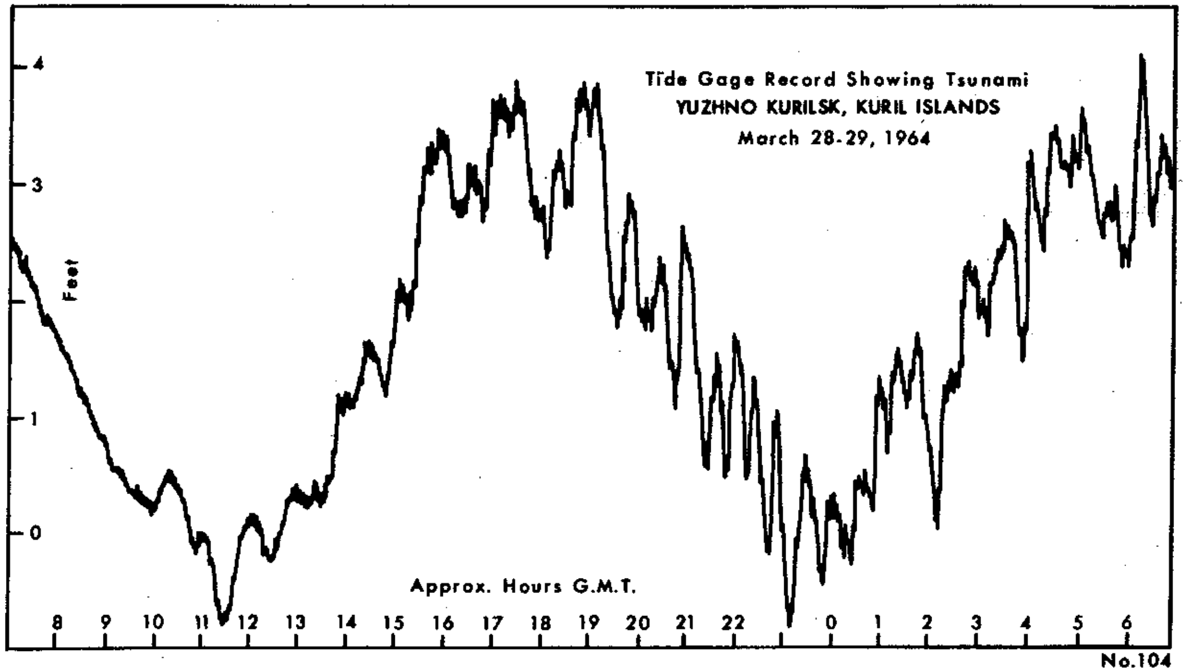

Tide Gage Record Showing Tsunami
KUSHIMOTO, JAPAN
March 28-29, 1964
Feet
7
6
5
4
3
1
0
Approx. Hours G.M.T.
14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
No.99

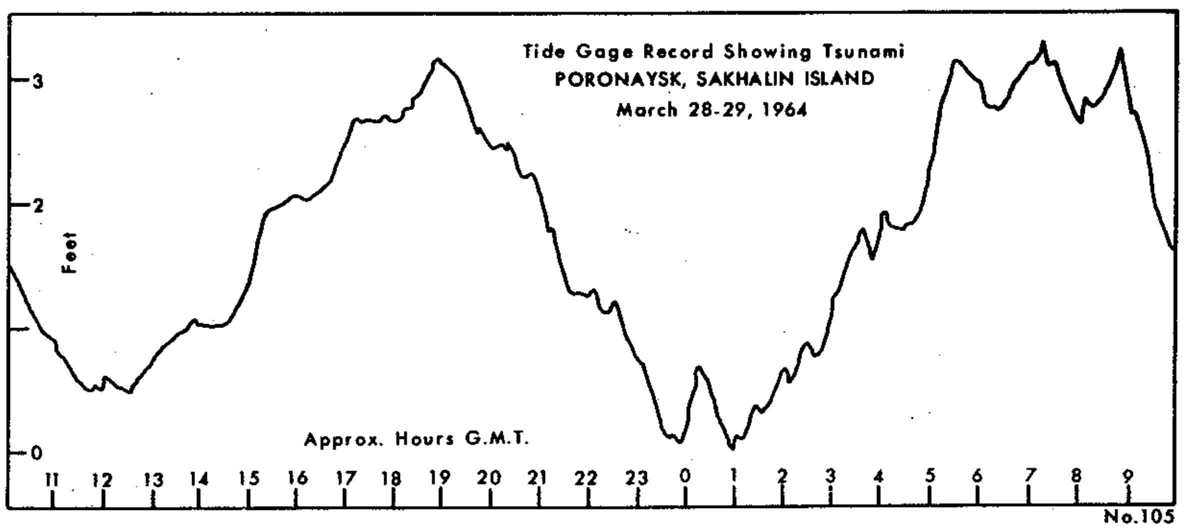

Tide Gage Record Showing Tsunami
TOBA KO, JAPAN
March 28-29, 1964
Feet
5
4
3
2
1
0
Approx. Hours G.M.T.
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10
No.100


Tide Gage Record Showing Tsunami
MERA, JAPAN
March 28-29, 1964
Feet
4
3
2
1
0
Approx. Hours G.M.T.
11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9
No.101


Tide Gage Record Showing Tsunami
OFUNATO, JAPAN
March 28-29, 1964
Feet
6
5
4
3
2
1
0
Approx. Hours G.M.T.
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7
No.102


Tide Gage Record Showing Tsunami
HANASAKI, JAPAN
March 28-29, 1964
Feet
3
2
1
0
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6
No.103


Tide Gage Record Showing Tsunami
YUZHNO KURILSK, KURIL ISLANDS
March 28-29, 1964
Feet
4
3
1
0
Approx. Hours G.M.T.
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 0 1 2 3 4 5 6
No.104


Tide Gage Record Showing Tsunami
PORONAYSK, SAKHALIN ISLAND
March 28-29, 1964
Feet
3
2
0
Approx. Hours G.M.T.
11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9
No.105

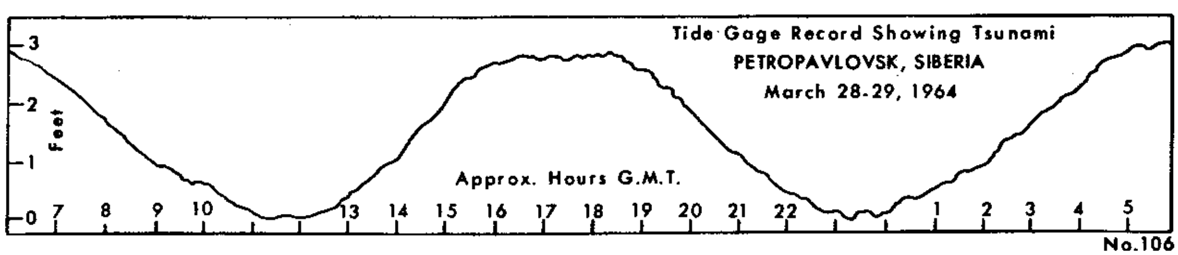
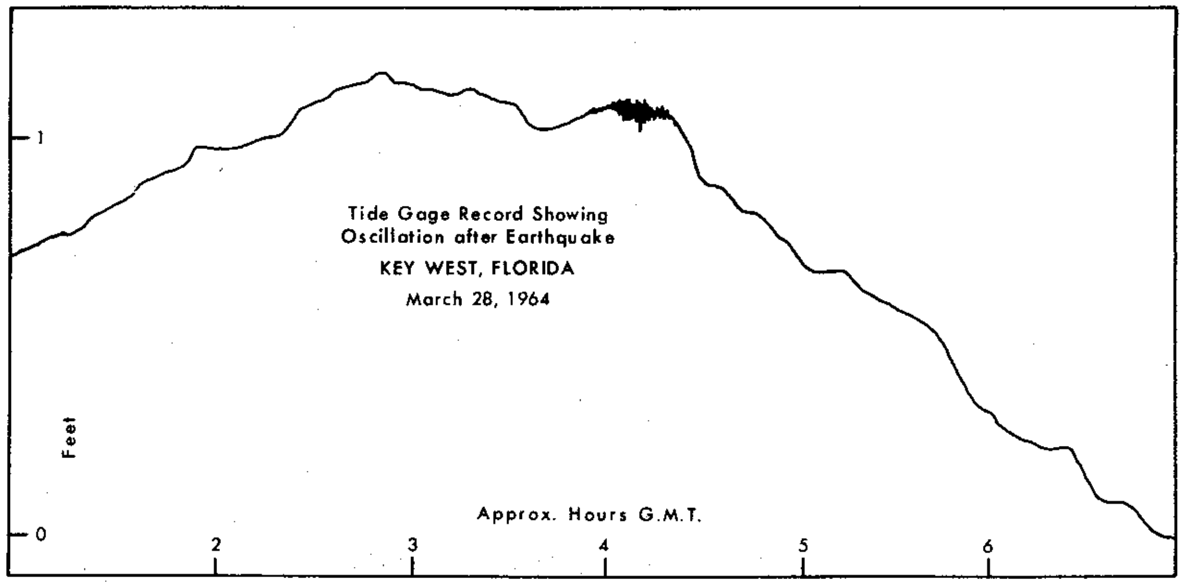

Tide Gage Record Showing Tsunami
PETROPAVLOVSK, SIBERIA
March 28-29, 1964
Feet
3
2
1
0
Approx. Hours G.M.T.
7 8 9 10 13 14 15 16 17 18 19 20 21 22 1 2 3 4 5
No.106

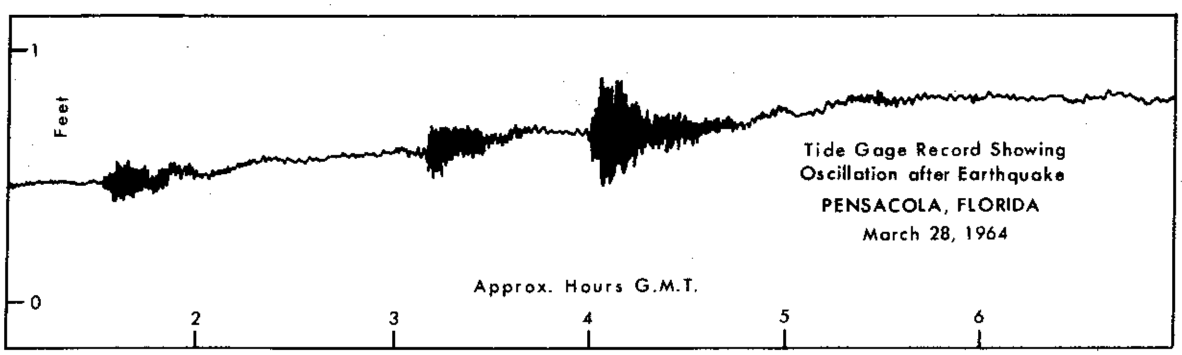
Table 5.—Seiche action caused by the Prince William Sound Earthquake of March 28, 1964, as recorded by tide gages

[See figure 11 for location of stations.]

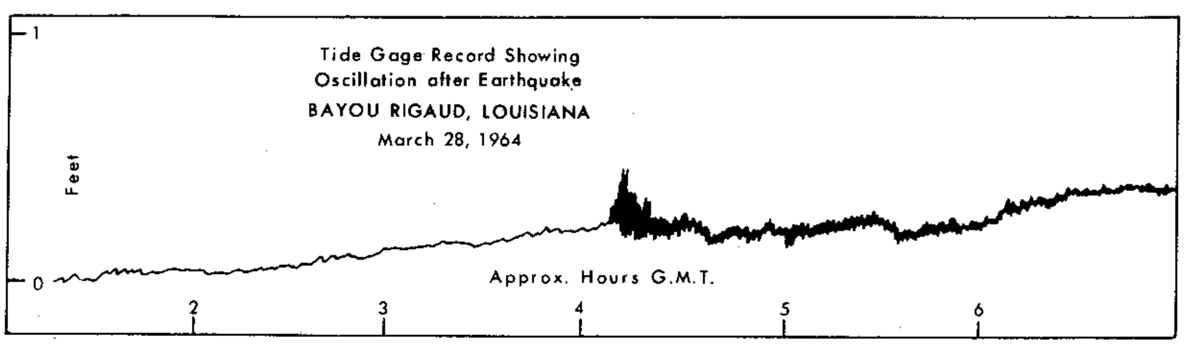
Tide station	Latitude N.		Longitude W.		Time of arrival			Maximum amplitude
	°	'	°	'	*Day*	*Hour*	*Minute*	*Feet*
a. Key West, Fla.	24	33	81	48	28	04	00	0.1
b. Pensacola, Fla.	30	24	87	13	28	04	02	0.5
c. Bayou Rigaud (Grand Isle), La.	29	16	89	58	28	04	00	0.3
d. Blakely Dam, Ark.	34	30	93	15	28	03	40	1.5
e. Narrows Dam, Ark.	34	10	93	45	28	03	40	0.5
f. Freeport, Tex.	28	57	95	19	28	04	00	0.6
g. Rockport, Tex.	28	01	97	03	28	04	02	0.8
h. Port Mansfield, Tex.	26	33	97	26	28	03	57	0.2



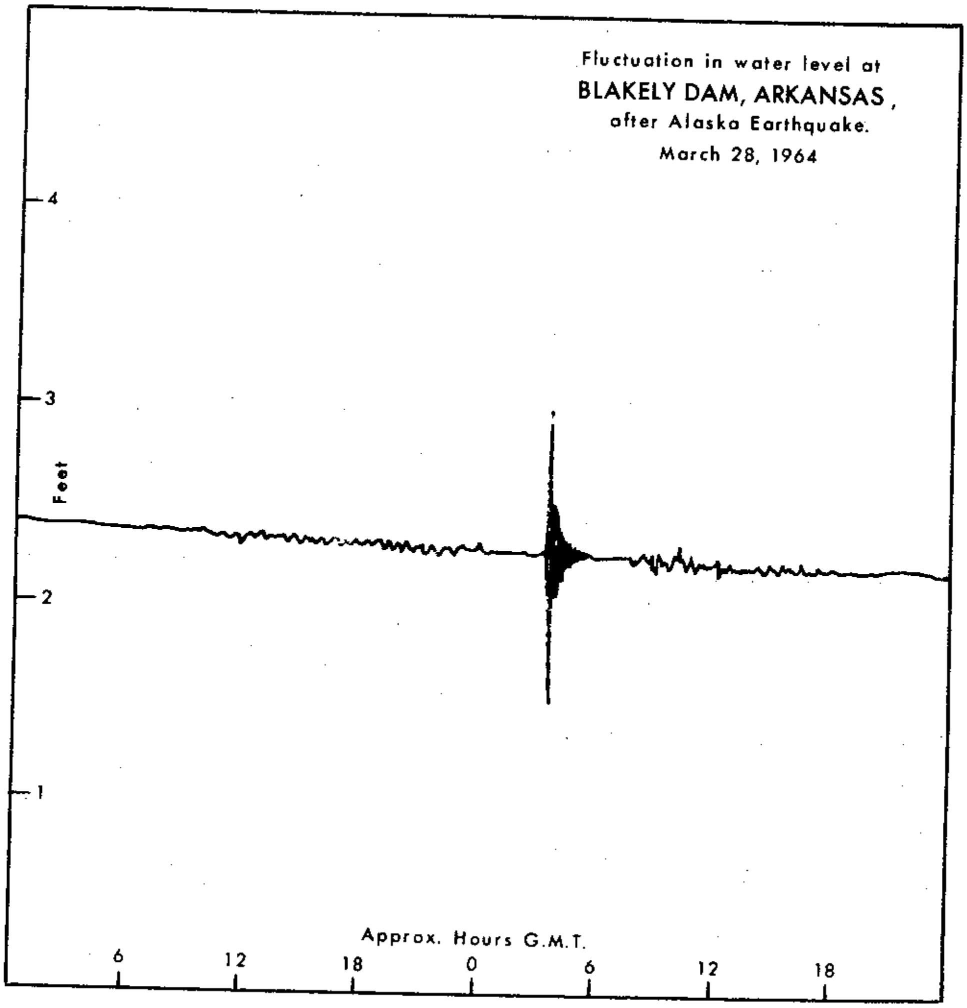
Station a

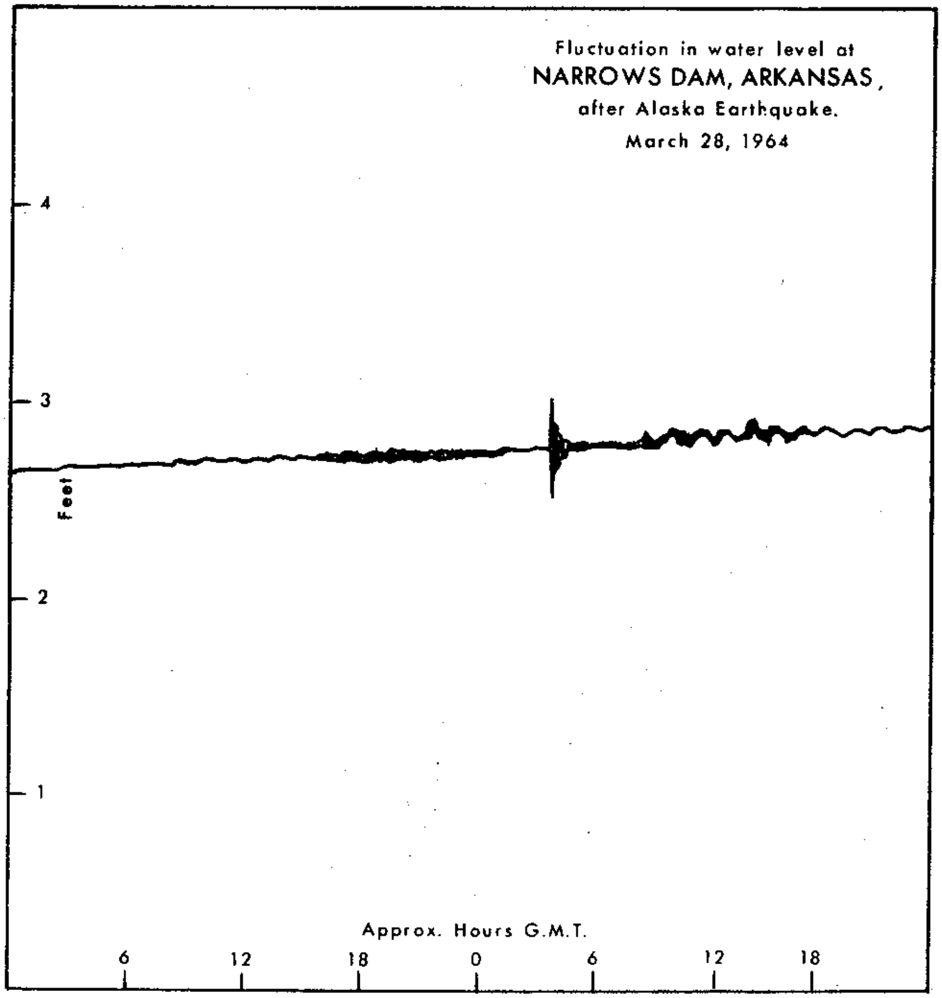


Station b



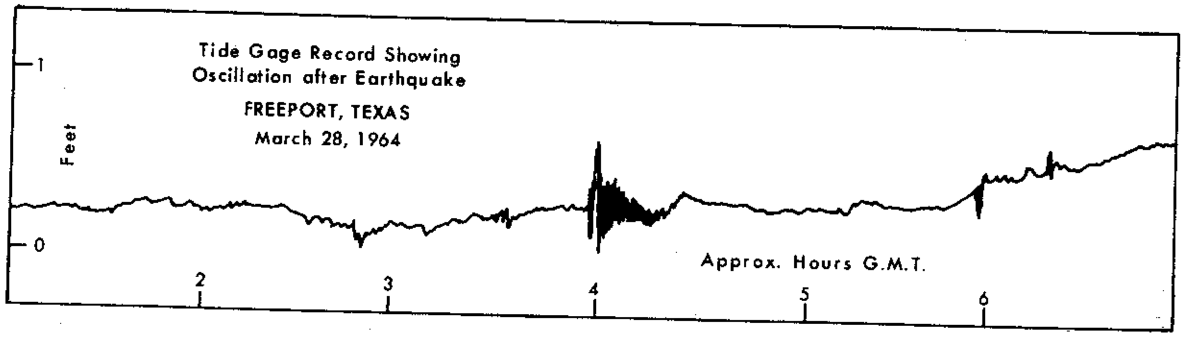
Station c


Fluctuation in water level at
BLAKELY DAM, ARKANSAS,
after Alaska Earthquake.
March 28, 1964
4
3
Feet
2
1
Approx. Hours G.M.T.
6
12
18
0
6
12
18
Station d

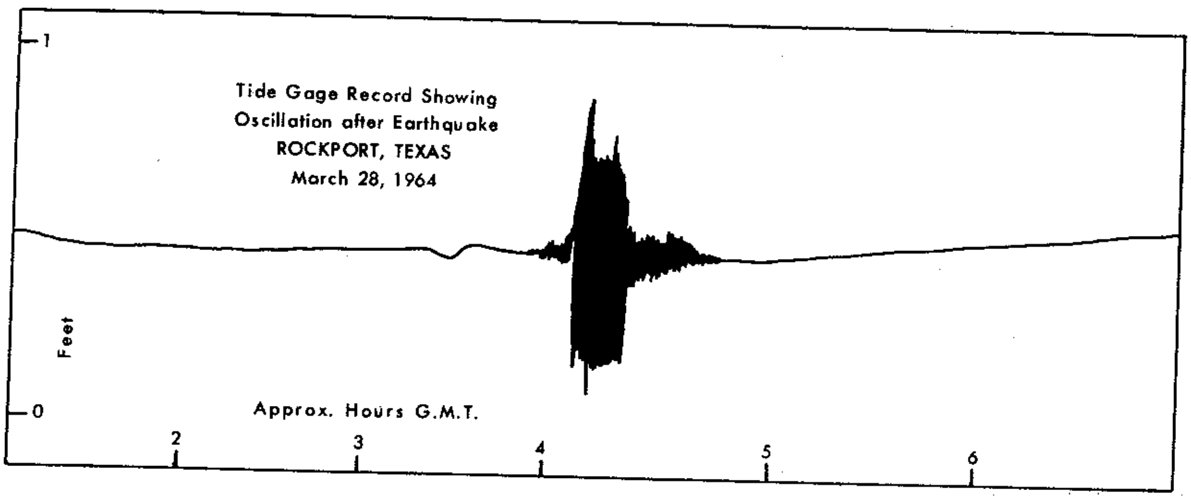


Fluctuation in water level at
NARROWS DAM, ARKANSAS,
after Alaska Earthquake.
March 28, 1964
4
3
2
1
Feet
Approx. Hours G.M.T.
6
12
18
0
6
12
18

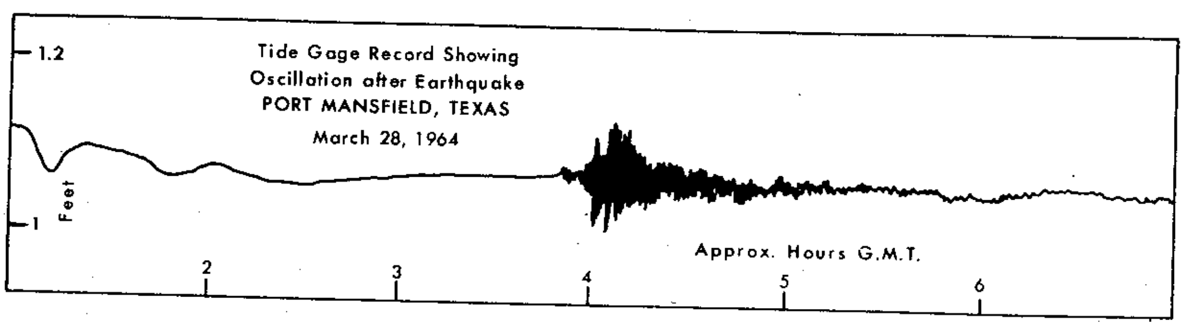
Station e



Station f



Station g



Station h

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