THRUST

First Annual Report

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CONTENTS

EXECUTIVE SUMMARY

AID awarded PMEL the contract in June, 1983 to proceed on the Tsunami Hazard Reduction Utilizing System Technology (THRUST) Project. The project crystallized in September 1983, when the project team conducted a site visit of Chile. After discussing the THRUST concept with Captain Barison of the Navy Hydrographic Office, the Chileans endorsed the project. Since that time, utilizing the knowledge and skills of three NOAA components, two subcontractors, an AID advisor, a program director and project coordinator, 100% of the first year's proposal of work has been completed and capsulized into the following list:

- the collection of U.S. and Chilean data to form a data base
- a tsunamigenic earthquake map of the Pacific Basin
- numerical model simulations of the Valparaiso, Chile area
- examination and formulation of existing Chilean infrastructure
- configuration of event detection sensors
- configuration of dissemination instruments
- instruments to be utilized for a successful configuration
- permission to utilize the GOES satellite system
- established good working relationship with Chileans
- endorsement of Chileans by supportive letter and monetary commitment
- formulation of a typical event scenario
- publicity (conferences, meetings, publication)

These items are the important items accomplished during the first year. Specifics on each above item and other accomplishments are explained in detail in this report.

INTRODUCTION

The seismic sea wave, or tsunami, has been one of the most destructive natural hazards within the Pacific Basin. More than 70,000 lives have been lost in the Pacific since the early 1850's (1). Today more than two million people reside or sustain themselves in tsunami-prone areas.

Mitigation procedures are especially vital to these coastal populations in areas close to the source of the tsunami. Developing countries, with minimal or no regional warning system, cannot be alerted of tsunamis originating close to their shores until approximately one hour after generation due to the present operating limitations of the existing Pacific-wide tsunami warning network, located at the Pacific Tsunami Warning Center (PTWC) near Honolulu, Hawaii, USA (2). A "gap," therefore, exists in the present warning structure.

The Agency for International Development (AID), Office of U.S. Foreign Disaster Assistance (OFDA) has commissioned the National Oceanic and Atmospheric Administration (NOAA), Pacific Marine Environmental Laboratory (PMEL) to conduct a three year pilot project (named THRUST). AID is authorized by the U.S. Congress to help alleviate suffering from disasters in foreign countries by providing emergency relief and strengthening the ability of developing nations to cope with disasters by increased reliance on their own resources. Helping host countries achieve adequate levels of preparedness and early warning capabilities represents OFDA's principal focus in disaster prevention and mitigation.

The purpose of the THRUST project has been to examine existing technology and to ascertain if an early warning system can be designed that would fill the "gap" in nations with minimal or no regional warning system. Specifically, the objective is to design, assemble, test and evaluate a

system that can deliver early warnings to a developing country within the Pacific Basin (3).

Before a country could be selected, it had to meet certain criteria. Those criteria were: a) potential threat due to a tsunam , b) existing tsunami warning infrastructure, c) access to the GOES satellite system, d) national commitment to the program, and e) be categorized as a developing country.

Chile was selected as the first country in which the THRUST program would occur. Chile met all of the above criteria. We felt that Chile's existing infrastructure was compatible with our concepts of systems technology. The pilot system will be utilized in the port city of Valparaiso. As seen by the enclosed Chartlet (Diagram 1), the area is very vunerable to tsunami.

An early warning system would prove to be very beneficial to this large population center.

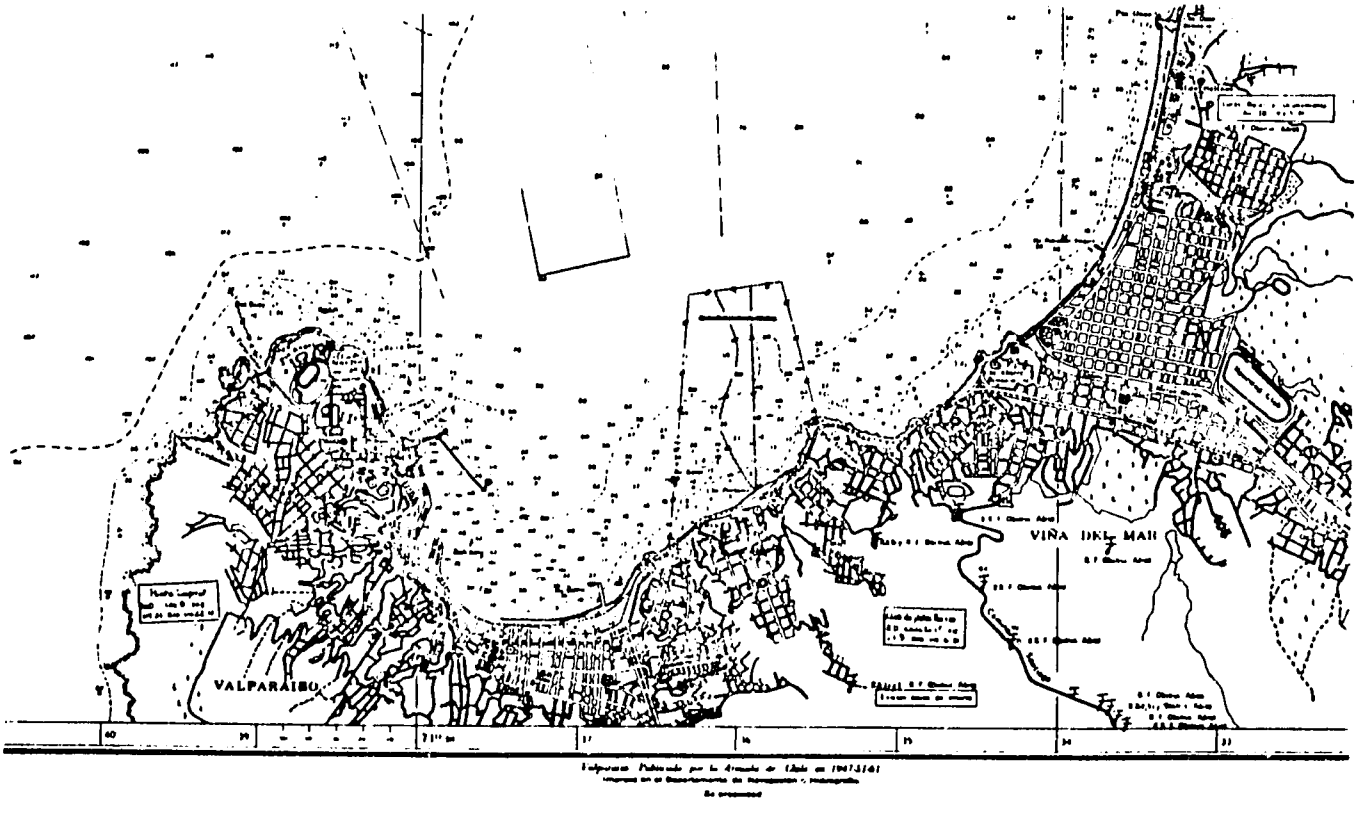

Diagram 1 (4)

PROGRAM MANAGEMENT

The management of the THRUST program has been centralized in Seattle, Washington at NOAA's Pacific Marine Environmental Laboratory (PMEL). Offices were established for Dr. Eddie Bernard, Director of PMEL and Project Director, and Richard Behn, Project Coordinator, at NOAA's PMEL Sand Point Facility in August 1983.

Dr. Bernard, serving as the representative for THRUST, has been assisted by Mr. Behn who is responsible for the day-to-day management of the program. The team has been coordinating efforts in each of the six functional areas (see diagram 2)

THRUST SCHEMATIC PILOT STUDY

FUNCTIONAL AREA / TIME FRAME	DATA COLLECTION	DATA ANALYSIS	DISSEMINATION
PRE-EVENT	DEVELOP TSUNAMI DATA BASE	EVALUATION OF HAZARD USING SIMULATIONS	DEVELOPMENT OF EMERGENCY OPERATIONS, PROCEDURES
REAL-TIME	SENSOR DEVELOPMENT INSTRUMENT + PROCESSING + TRANSMISSION	OPERATIONAL "PREDICTIVE" MODEL	INTEGRATION OF EARLY WARNING DEVICE INTO EMERGENCY SYSTEM

Diagram 2

The activities of the program managment area of the project can be categorized and described in the following manner:

Trips:

A total of 17 trips were made by THRUST participants during the first year. Trips were made to Chile, Germany, Alaska, California (2), Colorado, Hawaii (2), Washington (2), New Mexico, and Washington D.C. (4). All

trips were made for THRUST participants to attend scientific conferences or planning meetings which are described in detail in the following sections (Conferences and Meetings).

The September, 1983 site visit to Chile was the most important trip for the THRUST project. This visit enabled the THRUST personnel to meet the Chilean officials that would be working on the project for the next three years. The Chilean Navy Hydrographic Institute (NHI) (Instituto Hidrografico De La Armada) is the principal organization and operator of the existing Chilean tsunami warning system. Personnel from NHI were paired up with the corresponding (related fields of work) THRUST participants forming three working groups. These groups then exchanged ideas, information and data. These working groups then visited other Chilean agencies to inform them of the THRUST project. NHI (along with the other agencies) endorsed the THRUST concept and agreed to work closely with THRUST participants. The trip was concluded with a news conference at the American Embassy in Santiago (Oct. 5, 1983) (See folder titled "Monthly Newsletters, Quarterly Reports, and Trip Reports" for details).

Conferences:

The THRUST project was presented at 14 conferences during the past year. The following is a list of conferences (dates, cities and personnel presenting the program):

1) Chilean Navy Hydrographic Institute - Sept. 1983 - Valparaiso, Chile - THRUST team
2) ONEMI (Oficena Nacional de Emergencia) - Sept. 1983 - Santiago, Chile - THRUST team
3) University of Chile - Sept. 1983 - Satiago, Chile - THRUST team

4) American Embassy - Sept. 1983 - Santiago, Chile, THRUST team

5) IUGG (International Union of Geodesy and Geophysics) - Aug. 1983 - Hamburg, Germany - E. Bernard

6) National Conference on Resource Management - Aug. 1983 - San Franscisco, CA - G. Hebenstreit

7) NWS Tsunami Conference - Sept. 1983 - Anchorage, AK - E. Bernard

8) Greater Seattle Scientific Community - Sept. 1983 - Seattle, WA - E. Bernard

9) ITSU (International Coordinating Group for Tsunami Warnings in the Pacific) - March 1984 - Honolulu, HI - E. Bernard

10) NOAA Environmental Satellites Come of Age - March 1984 - Washington D.C. - G. Hebenstreit

11) IGDG (Interagency Geophysics Discussion Group) - April 1984 - Washington D.C. - J. Lander

12) California Division of Mines and Geology - April 1984 - Sacramento, CA - R. Behn

13) UJNR (US-Japan Panel on Wind and Seismic Effects) - May 1984 - Washington D.C. - E. Bernard, J. Lander, G. Hebenstreit

14) GOES Users Conference - May 1984 - Los Alamos, N.M. - H. Milburn

A slide presentation and/or paper was presented at each of the conferences. The project has obtained a large amount of exposure.

Meetings:

Besides the normal day to day contact with the THRUST personnel, other planning meetings were conducted. Two coordination meetings were held in which three or more of the six THRUST participants. The most recent, which included all components (except CyberLink) of the project,

was held in Hawaii and included Captain Barison and Sr. Lorca from Chile. This meeting was used as a progress report from all components to the Chileans. They, in turn, gave us a report on the Chilean progress. Meetings between PMEL and the following groups occurred during the last year; NESDIS, SAI, CYBERLINK, NGDC, NWS, and ITIC.

Newsletters:

On the first day of every month since August 1983, a newsletter has been distributed to twenty offices around the world. This list includes personnel from New Zealand to France. The newsletter is a summary of the month's activities in a brief capsulized format. A copy of each newsletter is attached to this report (see folder titled "Monthly Newsletter, Quarterly Reports and Trip Reports").

Publicity:

The THRUST project has received much publicity throughout the year. The list of periodicals in which articles were featured are:

News Release, Office of Public Affairs (AID), June 17, 1983

Science News - July 9, 1983, pg 29

Discover - August 1983, pg 18-24

Front Lines - August 1983, pg 1

Bulletin of American Meteorological Society - Sept. 1983, pg 1085

Tsunami Newsletter - December 1983, pg 11-12

Natural Hazard Observer - January 1984, pg 12

Sea Technology - January 1984, pg 78

Honolulu Star Bulletin - March 17, 1984, pg 1

Interview on local (Seattle) radio station (Aug., 1983)

Interview on local (San Francisco) radio station (Aug., 1983)

Articles in Chilean newspapers and periodicals

These articles are available and attached to the corresponding monthly newsletters (see folder titled "Monthly Newsletter, Quarterly Reports, and Trip Reports").

PRE-EVENT

As seen in the THRUST schematic (Diagram 3) the project can be broken down into six working areas. The next two sections are summaries of work in each area by its area coordinator.

THRUST PRE-EVENT
Objectives and Personnel

DATA COLLECTION	DATA ANALYSIS	DISSEMINATION
DEVELOP TSUNAMI DATA BASE	EVALUATION OF HAZARD USING SIMULATIONS	DEVELOPMENT OF EMERGENCY OPERATIONS, PROCEDURES
NATIONAL GEOPHYSICAL DATA CENTER James Lander	SCIENCE APPLICATIONS, INC. Gerald Hebenstreit	NATIONAL WEATHER SERVICE - ITIC George Pararas-Carayannis
PROGRAM MANAGEMENT: PMEL / E. Bernard, R. Behn		

Diagram 3

1) Data Collection

Mr. James Lander of NOAA's National Geophysical Data Center in Boulder, Colorado is coordinating all efforts of data collection. This task centered on two tasks: the collection of data about Chilean tsunami and the production of a public use tsunami occurrence and effects map of the Pacific. Mr. Lander has been able to collect extensive quantities of U.S. and Chilean

(obtained from NHI) records on seismic history, wave records, flood data, tsunami runup heights, and land and sea topographies. Mr. Lander has also obtained, from Chile, 21 digitized marigrams of tsunamis that have occurred in Chile since 1952. An additionaly 35 tsunami tide records were obtained from the U.S. Archives. The compilation of all these data has resulted in a complete and up-to-date data base. This data base has been used to assemble a tsunamigenic earthquake map of the Pacific Basin that conveys information on the tsunami hazard to the general public. In addition the map contains information on local and remote effects of tsunamis. The data base has also been utilized for validating numerical models and assisting in the development of a Standard Operating Plan (SOP).

The data file which was utilized to produce the map, aid in validating models and assist in the SOP, has proven to be more flexible than anticipated. This allows for a range of analyses and graphics not originally conceived (see folder titled "Pre-Event Data Collection" for further details).

2) Data Analysis:

Dr. Gerald Hebenstreit of Science Applications Inc. in McLean, Virginia, is coordinating the modeling efforts for this area of the project. SAI, under contract with PMEL, produced computer simulations which provided estimates of potential inundation levels, flood hazard areas, and worst case effects of observed and potential tsunami for the pilot study area - Valparaiso, Chile.

Data obtained, during the site analysis trip from NHI, on the May 22, 1960 tsunami in the coastal cities of Tacahuano and Corral, Chile were used to verify the numerical model. Four Chilean charts of the Valparaiso harbor area were used to digitize the local topography. This digitization

of the area was completed and placed in the model grid. The model, which provided limits of potential inundation levels for the worst case tsunami, will be used to formulate the evacuation plan for the Standard Operating Plans (SOP) for the Chilean tsunami warning network. The results will also be utilized in the development of the Real-Time Processor (RTP) which will be completed during the second year of the project.

3) Information Dissemination

Dr. George Pararas-Carayannis of the International Tsunami Information Center (ITIC) in Honolulu, Hawaii, has been responsible for all work completed in this area. Dr. Pararas-Carayannis examined the existing Chilean infrastructure and formulated a way to integrate the THRUST system into the existing structure. The following flow chart (Diagram 4) reflects the realities of the present System, with its inherent strengths and weaknesses as determined by the present study of the organizational infrastructure of the National Tsunami Warning System in Chile. Final versions will define better the THRUST input and alternate fail-safe communications between national components.

Mr. E. Lorca, Director of the Chilean Tsunami Warning Center, will be visiting Dr. Pararas-Carayannis for six weeks in which they will formulate the Standard Operating Plan and improved public education programs for Chile (see folder titled "Pre-Event Information Dissemination" for details).

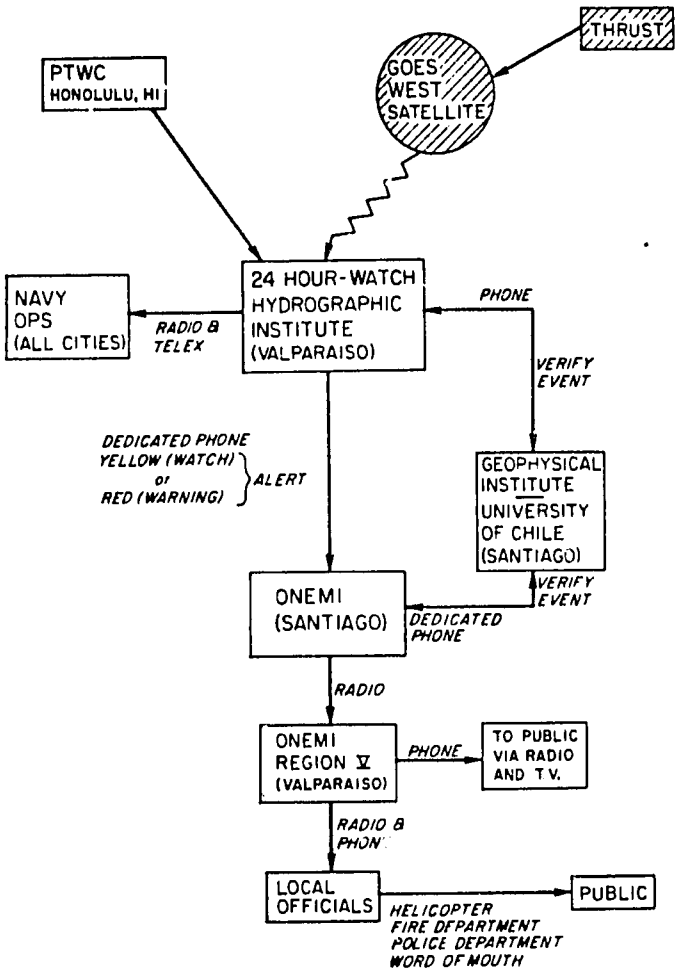

Diagram 4

The system works in the following manner: the Hydrographic Institute receives information that an earthquake and/or tsunami event has occurred from either PTWC in Honolulu or the Geophysical Institute in Chile. The Hydrographic Institute then informs NAVY OPS, ONEMI, and the Geophysical Institute of the event and the danger involved. ONEMI then informs its subdivisions, which, in turn, notifies the public. (5)

REAL TIME

THRUST REAL-TIME
Objectives and Personnel

DATA COLLECTION	DATA ANALYSIS	DISSEMINATION
SENSOR DEVELOPMENT INSTRUMENT + PROCESSING + TRANSMISSION PACIFIC MARINE ENVIRONMENTAL LABORATORY Hugh Milburn	OPERATIONAL "PREDICTIVE" MODEL	INTEGRATION OF EARLY WARNING DEVICE INTO EMERGENCY SYSTEM PACIFIC MARINE ENVIRONMENTAL LABORATORY Hugh Milburn CYBERLINK, INC. Peter McManamon
PROGRAM MANAGEMENT: PMEL/E. Bernard, R. Behn		

Diagram 5

1) Data Collection:

Mr. Hugh Milburn of PMEL's EDD Section in Seattle, WA is coordinating all efforts dealing with the collecting and reporting of seismic and water level data which will be used to rapidly identify the existence of a tsunami and to assess the potential threat. The use of a satellite-based communications system allows the lag time between the event and the receipt of initial data to be reduced to the order of minutes. Two Strong Motion Accelerographs, two water level sensors and the corresponding GOES radio transmitters or receivers will constitute the event detection sensors.

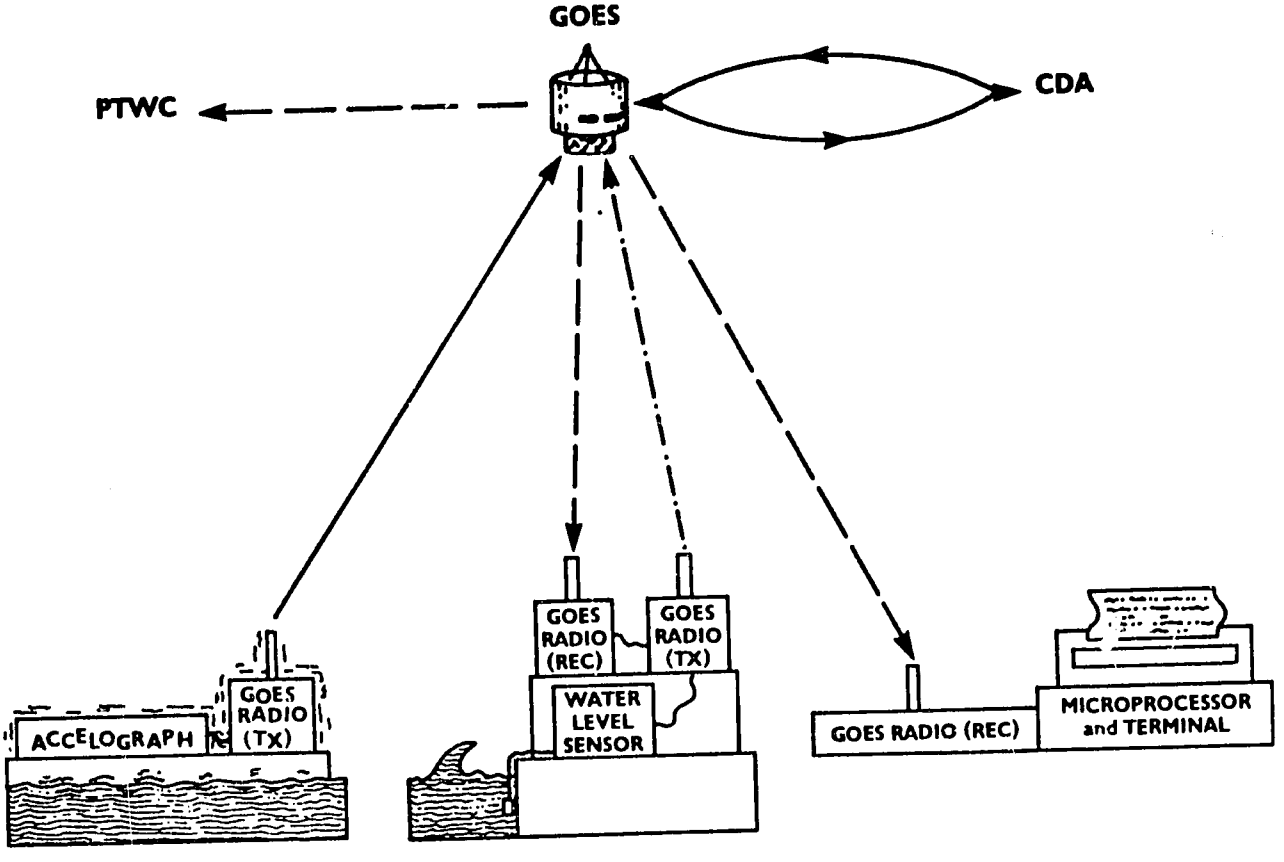

Diagram 6

Diagram 6 shows the configuration of instruments for the THRUST prototype early warning system. The instruments will be procured by PMEL. They will be assembled and tested at PMEL in Seattle. Upon completion of a six month test, the instruments will be shipped to Chile for their final installation (see folder titled "Real-Time Data Collection" for details).

2) Data Analysis

In this task, data that was produced from the modeling efforts in the pre-event phase, and the incoming real-time data are combined to develop an operational predictive model allowing the assessment of the potential

threat during the first hour of the tsunami. The Real-Time Processor (RTP) will be the result of this work (5).

No work in this area was done during the first year. Work will start during year two.

3) Information Dissemination

Mr. Hugh Milburn (PMEL) and Mr. Peter McManamon of CyberLink Inc., Boulder, Colorado, are coordinating all efforts of the transmission of warning information to threatened population areas. In this final step of the warning process the incoming data and the accompanying analysis are used to determine which areas to warn, in what order to warn them, and what instructions to issue (SOP).

Mr. McManamon has concentrated his efforts on negotiations with the National Environmental Satellite Data and Information Service (NESDIS). As a result of his meetings, it was decided that the random reporting mode of the GOES system was not suitable for the THRUST project due to its poor reliability rate (62%) of receipt of the first transmission from the SMA. Mr. McManamon was able to obtain permission to use an emergency frequency, which would be dedicated solely to THRUST. An application for use of a GOES frequency has been submitted to NESDIS. The THRUST project will utilize the GOES system under an existing Memorandum of Agreement (MOA) with PMEL.

The warning stations (microprocessor and terminal, as seen in diagram 6) will consist of a VHF receiver which will decode the GOES down-link signal, a small dedicated computer that will receive the information and format the message, and a printer to provide a hard copy of the warning message (see folder titled "Real-Time Information Dissemination: for details).

CHILE

The first year has proven to be very beneficial to THRUST and its relations with Chile. All U.S. THRUST components have met all Chilean THRUST counterpart components. Since our first meeting in Sept. 1983, we have established an excellent working relationship with the Chileans. A letter and list of monetary contributions (see folder titled "Chile" for details) from the Chileans show that they fully support the THRUST project.

During our meetings in March with Captain Barison (Director, NHI) and E. Lorca (Director, Chilean Tsunami Warning System), it was agreed upon that direct monthly correspondence was necessary to establish a good exchange of ideas and progress of THRUST. It was also agreed upon that the Chileans would submit input for each final report submitted to AID (see "Chile" folder).

An excellent working relationship must be maintained with the Chileans so the project can proceed through its 3 year life span without any problems.

THRUST SCENARIO

As envisioned now, once the THRUST study has been carried out, a typical event scenario should occur in the following manner (see Diagram 6).

An earthquake activates a seismic instrument (accelograph). This instrument then transmits a signal through the GOES system (satellite and Command Data Acquisition (CDA) facility), which responds by automatically transmitting an alert code back through the GOES system to the alarm device located at the Hydrographic Institute in Valparaiso (microprocessor and terminal). The alarm device instantly responds by initiating a set of prerecorded messages based on the SOP, RTD and procedures established prior to the tsunami. The message format THRUST will use is similar to the following:

EARTHQUAKE ALERT

A strong earthquake occurred at 1216 hours on February 11, 1984 in the vicinity of the city of Valparaiso. Contact the following authorities:

- Captain Barison, Director — Telephone No. _____
  Instituto Hydrografico de la Armada
- Brigadier General Barrenechea — Telephone No. _____
  Oficina Nacional De Emergencia
- Dr. Edgar Vecchiola — Telephone No. _____
  National Geophysical Institute

and advise them of this earthquake alert and tsunami watch message.

TSUNAMI WATCH

Establish a tsunami watch. A tsunami may accompany the earthquake. If a tsunami occurred near Valparaiso, the wave would come ashore at the following locations about the time shown:

Coquimbo	1315 hours
Concepcion	1345 hours
Chanaral	1438 hours
Corral	1452 hours
Antofagasta	1628 hours
Chiloe Island	1647 hours
Tocopilla	1819 hours
Iquique	1938 hours
Arica	2106 hours

Remember, this is only a tsunami watch. No tsunami has been detected but one may occur.

Diagram 7

In addition, GOES alerts the water level sensors in the Valparaiso harbor to begin sending data via satellite to CDA. This information can then be accessed via telephone line.

Note that this process is entirely automatic and should take no more than 10 minutes to complete. But no real decisions have been made, except possibly a predetermined one to sound a general alert. Final authority to make decisions, to issue further alerts or sound the evacuation alarm, must rest with human officials. This task should be made simpler because of several factors. The decision makers will be familiar with the historical and potential hazard analyses performed during the pre-event phase and

thus will be aware of the general type of threat the coast of Chile faces. Also, because of the Standard Operating Plan implemented during the project the Hydrographic Institute will have a more complete set of procedures to follow which should improve their existing response. In addition, because of the public awareness program established during the project, the Chileans should be confident that the threatened population know how to respond to ensure their own safety. And lastly, the Chileans can be sure that the sensors and the real-time analysis package are providing them with the most timely information available (6).

CONCLUSIONS

At the completion of the THRUST project, title to all instruments will be transferred from the U.S. government to the government of Chile. It will be the responsibility of the government of Chile to utilize this new technology and to keep the system in proper working order.

The goals of THRUST are to show that such a system can be built, to work with the Chilean government to integrate the technical system into its disaster control structure, and to train the Chilean personnel in the operation and maintenance of the system. Each phase of THRUST, then, will be conducted in conjunction with personnel from Chile. In this way the technology behind THRUST can be demonstrated to other tsunami-prone (and, indeed, geophysical hazard-prone, in general) nations, while concurrently enhancing the technological capabilities of Chile. Successful completion of the THRUST project will not only enhance the tsunami protection of Chile but will, by adding additional input to PTWC, improve the protection of the entire Pacific community (6).

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1) Iida, K., D. Cox and G. Pararas-Carayannis, Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean. H.I.G. University of Hawaii, 1967.

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5) Bernard, E.N., G.T. Hebenstreit, J.F. Lander, P.F. Krumpe, Regional Tsunami Warnings Using Satellites, Proceedings of 1983 Tsunami Symposium, U.S. Dept. of Commerce, PMEL, Seattle, WA, 1983.

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Monthly Newsletters

Quarterly reports

Trip Reports

THRUST

PMEL

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ENVIRONMENTAL RESEARCH LABORATORIES
Pacific Marine Environmental Laboratory
NOAA Building Number
7600 Sand Point Way N.E.
Seattle, WA 98115

August 9, 1983

TO: All THRUST Participants

FROM: Richard Behn - Project Coordinator

SUBJECT: THRUST Project Newsletter

You have now acquired a THRUST project coordinator to take care of any problems or questions you might have during the next couple of years. I'm attempting to arrange individual meetings with all of you in the near future.

I will try to get a newsletter out to you every month to keep you informed of our progress. Some months might require a couple of newsletters if our progress is rapid, but never less than one a month. I welcome and encourage all comments and complaints about the project. The only way I know whether things are going O.K. is by your input. Also, it works the other way, too. If I feel there is something wrong I will let you know. So please keep in contact with me either by letter or phone call. Please forward all correspondence to the above address. My phone number is (206) 527-6238 and (FTS) 446-6238.

O.K. now that the basic "bull" of the letter is over, lets get to the main issue. On June 1, 1983, we were awarded the money for year one by A.I.D.

Since that time, a visit to the National Geophysical Data Center was undertaken. The Geophysical Center is developing a map of all epicenters and tsunami heights for the Pacific Region. This map and information will be utilized for tsunami warning procedures and for hazard mitigating planning.

The letters to the Chilean government were sent during the first week in August. At this time we are still awaiting a reply.

It is tentatively planned that the trip to Chile will be during the last week in September and first week in October. The purpose of this trip is for site analysis. All personnel involved in this trip will be receiving a letter about details in the near future.

The contract for the dissemination consultant has not been awarded at this time. This decision will be made in the very near future.

Attached to this letter are copies of some of the publicity the THRUST Project has received. Also, Dr. E. Bernard had a 60 second interview on a local all news radio station. If you see or hear of any news about THRUST, please send it to me for the file.

Again, I would appreciate any information, comments, or complaints (not too many of the latter) about THRUST you may have. Please, keep in touch!

News Release
From the Office of Public Affairs
Agency for International Development Washington, D.C. 20523

FOR IMMEDIATE RELEASE
FRIDAY, JUNE 17, 1983

0043
Contact: John Metelsky
(202) 632-4274

AID AND NOAA LAUNCH STUDY TO WARN DEVELOPING NATIONS OF TIDAL WAVES

The Agency for International Development (AID) announced today it is funding a pilot study to use modern technology to warn coastal residents in developing nations of tidal waves (tsunamis).

The study will be carried out by the National Oceanic and Atmospheric Administration (NOAA). It is funded by a $235,000 first-year grant from the AID Office of U.S. Foreign Disaster Assistance (OFDA).

The study will develop, test, and evaluate an early tsunami warning system for coastal South America, a tsunami-prone region.

"It takes at least an hour after a tsunami-generating earthquake occurs to warn the people in the Pacific Basin," said Dr. Eddie Bernard, a tsunami expert and Director of NOAA's Pacific Marine Environmental Laboratory.

"In the past 135 years," he said, "more than 70,000 people in the Pacific Basin lost their lives to tsunamis. Regional warning systems, using existing technology, could alert people in the threatened areas in minutes, giving them time to leave the coastal areas."

- more -

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A study panel commissioned by OFDA recommended the pilot study. Dr. Bernard identified Lima, Peru, and Valpariso, Chile, as high-risk areas that would benefit from a demonstration program.

The program is expected to take three years to complete. The tsunami experts in the program will collect and assimilate all available information about tsunami effects in the region. They will use the information to develop computer models of how tsunamis physically impact on vulnerable areas.

"At the same time," Dr. Bernard said, "we will gather seismic and water level data to identify a tsunami and assess its potential threat. We also will determine how to set this type of tsunami warning system in Peru or Chile."

He said the program would set up automatic sensors monitoring seismic activity and tide heights in appropriate locations. When an underwater earthquake occurs, the sensors automatically would transmit information through NOAA's Geostationary Operational Environmental Satellite (West) to the Pacific Tsunami Warning Center in Honolulu and to warning centers in South America.

"This entire process would take up to ten minutes," Dr. Bernard said. "When notified that a tsunami is in process, the local center will evaluate the threat using the computer models and alert the people in endangered areas".

In developing the pilot program, Dr. Bernard will use experts from NOAA's National Weather Service and the National Environmental Satellite Data and Information Service.

The National Weather Service will help establish a system to disseminate public education information as well as warnings. The Satellite Service will develop a data base and tsunami maps and help set up the warning system and the emergency broadcast by satellite.

# # #

Hazards in Love Canal monitoring

The Congressional Office of Technology Assessment (OTA) has added its voice to the chorus expressing doubts about the habitability of the Love Canal neighborhood in Niagara Falls, N.Y. (SN: 8/14/82, p. 102). Last summer, the Environmental Protection Agency (EPA), after surveying the area around the Love Canal hazardous waste landfill, concluded there was no clear evidence of canal-related contamination. On this basis, the Department of Health and Human Services (HHS) stated that houses near Love Canal were as habitable as those in control areas in Niagara Falls with which they were compared (SN: 7/24/82, p. 52). At the request of Sen. Alfonse M. D'Amato (R-N.Y.) and Sen. Daniel P. Moynihan (D-N.Y.), OTA analyzed EPA's monitoring data and examined the technical basis for the HHS decision.

OTA's principal finding is that "with available information, it is not possible to conclude either that unsafe levels of toxic contamination exist or that they do not exist" in the Love Canal area.

The OTA report argues that the design of the EPA monitoring study, especially its sampling strategy, was inadequate to detect the true level and pattern of toxic chemical contamination. Current cleanup and other remedial measures are insufficient to guarantee future safety, the report also states. "There remains a need to demonstrate more unequivocally that the [Love Canal area] is safe immediately and over the long term for human habitation," says the report. "If that cannot be done, it may be necessary to accept the original presumption that the area is not habitable."

Assessing risk assessments

At a time when many communities "are gripped by something approaching panic" about the hazards of toxic chemicals in the environment, William D. Ruckelshaus, Environmental Protection Agency administrator, has called for a uniform federal policy to assess and deal with risks to human health. "What I'm after is a government-wide process for assessing and managing health, safety and environmental risks," Ruckelshaus recently told a National Academy of Sciences audience of scientists and engineers in his first major policy address since becoming EPA administrator in May (SN: 5/28/83, p. 343).

Ruckelshaus' speech was, in part, a plea to scientists for their help in finding ways to estimate better the association between exposure to a particular substance and the incidence of some disease. For some pollutants, especially those associated with cancer and reproductive disorders like birth defects, a safe level is difficult to establish, he said. Advice from the scientific community outside government is needed, for example, on how best to focus accelerated research efforts on the health effects of substances regulated by EPA, he added.

Ruckelshaus also saw danger in the spectacle of federal agencies taking opposing views on the potential health risks of a given toxic substance and "then arguing about it on television." He pointed out that various laws apply different standards and techniques and often fail to distinguish between risk assessment and risk management. "Scientists assess a risk to find out what the problems are," Ruckelshaus said. "The process of deciding what to do about the problems is risk management." There is a need to coordinate procedures across all federal regulatory agencies, he said, and a need to amend the laws to make them more consistent. Other administrators have tried to do the same in the past but with little success.

Many of Ruckelshaus' comments drew on a National Academy of Sciences report, released earlier this year (SN: 3/5/83, p. 152), that recommended the development and use of uniform guidelines for risk assessments. That report noted, "The basic problem in risk assessment is the sparseness and uncertainty of the scientific knowledge of the health hazards addressed, and this problem has no ready solution."

Fool's gold leads to unique fossil

Sometimes "fool's gold" is better than the real thing. Recently a deposit of iron pyrite, the bane of generations of gold prospectors, led to the discovery of the first known fossil ctenophore. Ctenophores are swimming marine organisms whose soft bodies defy fossil preservation. The recently described animal is lauded in the June 9 NATURE as the "rarest of all fossils." It is the sole fossil representative of the phylum Ctenophora, which until now was the only one of 21 generally recognized living animal phyla unrepresented in the fossil record.

The fossil is embedded in a rock extracted from the fossil-rich Hunsrück Slate formation in West Germany. The slate entombs millions of animals, exquisitely preserved through the conversion of organic sulfur to iron sulfides and iron pyrite — fool's gold. For more than a decade retired physicist Wilhelm Stürmer of Erlangen, West Germany, has been taking high-resolution X-rays of rocks from the formation, and has accumulated a file of "UPO's" or Unidentified Paleontological Objects. When he invited George D. Stanley Jr. of the University of Montana in Missoula to look at an X-ray image of an unclassified trilobite, Stanley's attention was diverted by a speck in the background. When the image was blown up, it proved to be a fossil of a 400-million-year-old ctenophore, 13 millimeters high and 9 mm in diameter, and with tentacles intact. The animal is of the cydippid form, the most primitive ctenophore living today. "Our discovery demonstrates that the basic ctenophore body plan has changed very little over the past 400 million years," Stanley and Stürmer write, "and suggests that the origin of the phylum must extend even further back in time."

Amoco Cadiz oil is almost gone

On March 16, 1978, the supertanker *Amoco Cadiz* impaled itself on rocks off the Brittany shore of France, spilling a total of 223,000 metric tons of oil into French coastal waters. It was the worst oil spill in maritime history. For the most part, the environment has recovered, but what became of the oil? Its fate through 1981 is summarized in the July 8 SCIENCE. Erich R. Gundlach of Research Planning Institute, Inc., in Columbia, S.C., and colleagues report that the seawater claimed 30,000 tons of oil. Eighteen thousand tons found their way into submerged coastal sediments, while 62,000 tons were carried into zones shoreward of the low tide lines. Sixty-seven thousand tons evaporated, and an additional 10,000 tons of oil were consumed by microbes before ever reaching the coast. The energetic waves along the Brittany shore proved efficient at scouring the residue from open areas, but subtidal and intertidal stretches fared less well, because the tides and the seasonal advance and retreat of beach sand may have enhanced the dispersion of oil, which penetrated as deep as one meter beneath the surface. While waves and humans cleaned moderate- to high-wave action beaches, in sheltered environments, microbes took over the job. Ronald M. Atlas of the University of Louisville in Kentucky, one of the authors of the study, says that most of the oil is gone, and that what remains in sediments is inert, but may persist indefinitely.

While the *Amoco Cadiz* spill was massive, he says it was "the most rapid degradation and removal of an oil spill that has ever been documented."

Project to test tsunami warning system

The Agency for International Development and the National Oceanic and Atmospheric Administration have announced that they are beginning a project to develop ways to warn coastal residents in developing nations that a seismic sea wave, or tsunami, is approaching. The three-year program will focus initially on a pilot system for Lima, Peru and Valpariso, Chile, which are in an area considered prone to tsunami damage.

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NOAA Building Number 3
7600 Sand Point Way N.E.
Seattle, WA 98115

September 7, 1983

To: All THRUST Participants

From: Richard Behn

Subject: THRUST Project Newsletter

Number one on the agenda is that I have a new phone number. It is as follows: (206) 527-6813 or (FTS) 446-6813. The address remains the same.

No confirmation as of this day has been received from the Chilean government. Action will be taken very soon to find out if the country of Chile wants to be the pilot study area. The trip is still slated for September 27 thru October 11, 1983.

The contract for the dissemination contract ran into a stumbling block. It should be awarded sometime this week.

We have received permission from NESDIS to use the interrogatable GOES Satellite System. A new system within the GOES Satellite System called "Remote Ready" is being looked into to be utilized for the THRUST project.

It seems that our letter to the Chilean government ruffled a few feathers with the American Embassy in Santiago. A "FOR INFO" copy of the letter was sent to the Embassy in Chile. The Embassy thought that the project was already being undertaken in Chile. So the Embassy was not pleased that the project was already going without their knowing about it. Well, after five telegrams explaining what exactly was going on, the matter is well in hand.

Information about seismographs is being gathered at this time. Any literature about products or people you might know that could be helpful to us, please let me know. Thanks.

Dr. E. Bernard spoke about the project at the IUGG conference in Germany. Dr. P. Krumpe and Dr. G. Hebenstreit did the same at a conference in San Francisco. They also had a TV spot with a local station in the Bay Area.

Attached is an article that appeared in the AID publication called Front Lines (8/83).

Hope this newsletter has found you in the best of health and spirit. I appreciate everyone's input and please keep it up. Look forward to meeting some of you in the near future.

Tsunami Warning Project Launched

by Pamela Stallsmith

The Office of U.S. Foreign Disaster Assistance (OFDA) is providing the National Oceanic and Atmospheric Administration (NOAA) with a $235,000 first-year grant for a pilot study which, within three years, will lead to developing a tsunami early warning system for coastal South America.

The Japanese word for "harbor wave," a tsunami is a tidal wave which packs a devastatingly destructive force. Tsunamis are particularly prevalent along the shores of the Pacific Ocean—one of the earth's most seismically active areas. The project will develop, test and evaluate the warning system in either Peru or Chile, two particularly tsunami-prone areas.

Tsunamis are caused when a large earthquake occurs under or near the ocean floor, triggering a series of ocean waves of extremely long length and duration. They travel with amazing speed across the ocean, exceeding up to 600 miles per hour. (The speed of sound is 750 miles per hour at sea level.) Although a tsunami's length from crest to crest may be 100 miles or more, its height from trough to crest may be only a few feet.

But it's when the tsunami waves reach the shoals of a coastline that they pose a threat. For in these shallow waters, although they lose their speed, tsunamis reach heights of more than 100 feet, striking with killer force.

The real danger, however, is that without using advanced technology, tsunamis caused by near-shore

(continued on page 11)

FRONT LINES

AUGUST 1983

Tsunamis

From page 1, column 2

earthquakes cannot be detected before they crash into the coastline. They cannot be felt aboard ships under which they pass, nor can they be seen from the air.

This is what the AID/NOAA project intends to counter. The early warning system will monitor closely the occurrence of underwater earthquakes and confirm generation of a tsunami offshore, warning countries whose coastal zones are in the path of its advance.

Peru and Chile were selected as possible project sites because, according to Paul Krumpe, OFDA's disaster early warning program coordinator, they are subject to large earthquakes. "The Peru-Chile Trench is an area where the oceanic Nazca Plate moves beneath the continental South American Plate," he explains. "Evidence of the continent's shifting in this seismically active area can be seen, particularly along this trench. Many earthquake faults and active volcanoes exist in the Andean Mountain region. It is therefore not unlikely that a major underwater earthquake, followed by a tsunami, could occur at any time."

Eddie Bernard, director of NOAA's Pacific Marine Environmental Lab in Seattle, WA, points out that more than 70,000 people in the Pacific Basin lost their lives to tsunamis in the last 135 years. Today, however, "regional warning systems, using existing technology, can alert people in the threatened areas within minutes, giving them time to leave the coastal areas," he says.

The area affected by tsunamis touched off by a single ocean-bottom earthquake is astonishing. In May 1960, a major earthquake off the coast of Chile brought death and destruction to Hawaii, the Philippines, Okinawa and Japan. Waves of 15 to 35 feet razed the Hawaiian city of Hilo, leaving 61 dead and causing property losses of $22 million. In northern Japan and Okinawa, 180 people were missing or dead after the waves' impact. Twenty died in the Philippines, and over $500,000 in damage was reported along the coastal United States. Meanwhile, all Chilean coastal towns between the 36th and 44th parallels were either destroyed or severely damaged.

The only early warning systems are in the United States (Alaska and Hawaii), Japan and Russia. Other nations bordering the Pacific—most of them developing—rely on the Pacific Tsunami Warning System (PTWS) in Hawaii where seismic instruments throughout the ocean basin are monitored around the clock.

When an earthquake of enough magnitude occurs to generate a tsunami, the PTWS issues a watch to alert people in its path. It is relatively easy to predict when a tsunami will arrive because its speed is proportionate to the square root of the water's depth.

However, the Honolulu system has its limitations. It cannot warn areas within one hour's travel time from the earthquake's epicenter before it's too late.

If a tsunami is generated off the coast of Peru, for instance, it can take only two to four hours to reach Chile, but approximately 15 hours to hit Hawaii. The time for issuing an alert in Chile and preparing for impact is short.

"The time between when the earthquake occurs and wave formation is confirmed by automated analysis through satellite telemetry is minutes," Krumpe says. "The system we plan to use—the Geostationary Operational Environmental Satellite (GOES) telemetry link, combined with tsunami modeling and run-up analysis —will enable early warning of vulnerable population centers within minutes of tsunami generation offshore."

The AID/NOAA pilot study is called THRUST (Tsunami Hazard Reduction Utilizing Systems Technology). In THRUST, when an earthquake occurs it will activate coastal seismic instruments, which in turn transmit signals to the GOES West system, which, explains Krumpe, "is a meteorological satellite controlled by NOAA. It's a geosynchronous satellite, meaning it's over the same point on earth at all times and can be used for rapid telemetry of data and warnings."

The signal travels from the satellite to NOAA's Command Data Acquisition (CDA) station at Wallops Island, VA. There, the analysis of an earthquake at sea and generation of seismic sea waves is confirmed. A signal from CDA trips an alarm device at the THRUST site in the host country. PTWS in Hawaii will receive the warning at the same time. Because PTWS will have received the information sooner than it would have using its own system, it will be able to alert the entire Pacific region more quickly.

"It now takes at least an hour after an earthquake to warn the people in the Pacific Basin," says Bernard. But with the regional tsunami warning system, he explains, it will take no more than 10 minutes. When notified that a tsunami is in process, the local center will evaluate the threat using the computer models and alert the people in the endangered areas.

The THRUST project will develop one experimental site in either Chile or Peru. "Site selection will be based on recommendations of a scientific team that will visit both countries this fall. The team will take into account the area's warning systems, scientific expertise and institutional framework," Krumpe said.

NOAA's Bernard will lead the team, which includes Krumpe, James Lander of the U.S. World Data Center-A complex in Boulder, CO, and other contractors, such as tsunami modeling experts.

"Tsunami researchers are very interested in the outcome of THRUST," Krumpe says. "The money AID has contributed has stimulated the tsunami research community to the point where the Japanese recently expressed interest in building a similar capability. The project is getting tremendous visibility."

Stallsmith is a summer employee in the Office of Public Affairs.

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NOAA Building Number
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Seattle, WA 98115

October 20, 1983 R/E/PM:RB

TO: All THRUST Participants

FROM: R/E/PM - Richard Behn

SUBJECT: THRUST Project Newsletter

Since our trip to Chile, the project has really started to take shape. A lot has happened since my last newsletter, so lets get right down to business.

On September 14, 1983, a presentation of the THRUST project was given by Dr. Bernard at the National Weather Service Tsunami Conference in Anchorage, Alaska.

The dissemination contract was awarded on September 16, 1983 to CYBERLINK CORP. in Boulder, Colorado.

The site analysis team made it back from Chile with no problems. The entire trip went so well that the team was able to return to the States a couple of days early.

A trip report (attached) outlines the trip and gives results.

A 7.1 (Richter scale) earthquake occurred one hour before the press conference that was scheduled during our last day in Chile. The earthquake helped to show the significance of the project.

If anyone desires more details, please feel free to contact me. I will try to answer all questions. My phone number is (206) 527-6149 or (FTS) 446-6149.

Attachment:

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ENVIRONMENTAL RESEARCH LABORATORIES
Pacific Marine Environmental Laboratory
NOAA Building Number
7600 Sand Point Way N.E.
Seattle, WA 98115

November 3, 1983 R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Project Newsletter

With your permission I would like to start out each newsletter with a quote to "break the monotony" of the usually ho-hum boring letter.

Today's quote: Man can master any tongue, except his wife's!

On October 18, 1983, Dr. Bernard lectured to the local scientific community on the subject of Tsunami research. The THRUST project stimulated some interest in the group.

Many foreign countries have expressed interest in the results of our project. So remember many eyes are upon us.

The budget for the next year's money was submitted this week to AID.

Mr. Earl Bolton from CYBERLINK visited the PMEL lab in Seattle. Details of the prototype system were discussed.

A complete slide show presentation is being assembled at this time.

I would like to extend my best wishes to you and your family during the Thanksgiving holidays.

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Seattle, WA 98115

December 5, 1983 R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Project Newsletter

Here's this month's quote"

Nothing is opened more by mistake than the mouth!

The slide presentation is now completed. Dr. Bernard, who is in Washington, D. C. this week, is presenting the slides along with the semi-annual report and review to AID.

Peter McManamon (CyberLink) went to NOAA/NESDIS (Satellite Service) in Washington, D. C. to review all aspects of the satellite communication component at THRUST. His trip was very successful.

The California Division of Mines & Geology has contacted us and informed us that they are working on a somewhat similar system for earthquake warning. The communications between California and PMEL will be kept open for the exchange of ideas and results.

E. Bernard, J. Hebenstreit (SAI), G. Pararas-Carayannis (ITIC) and I met in Hawaii this month. The meeting was conducted to obtain the parameters SAI needed for the modeling of the Valparaiso area. Mr. Hebenstreit also gathered data from ITIC needed to support the verification of the model. While there we briefed Richard Hagemeyer, Director, NWS, Pacific Region Headquarters and Gordon Burton, Director, Pacific Tsunami Warning Center on the progress of THRUST.

Jim Lander, NGDC, has sent a compilation of data (seismic and tsunami) that was available at his center, to Chile to supplement the existing Chilean data. We received the Chilean data during our site analysis trip.

Attached you will find an article that appeared in American Meteorological Society Bulletin. A letter was sent to correct them about Lima, Peru not being selected as the study area.

I would like to extend to you and your family a most healthy and happy holiday season.

Attachment:

Bulletin of the American Meteorological Society

Volume 64 Number 9 September 1983

NOAA tsunami study funded by AID

The Agency for International Development (AID) has funded a National Oceanic and Atmospheric Administration (NOAA) pilot study that uses modern technology to alert coastal residents of developing nations that a tsunami is endangering them. The pilot program will develop, test, and evaluate an early tsunami warning system for Lima, Peru, a tsunami-prone area.

Eddie Bernard, a tsunami expert with NOAA's Pacific Marine Environmental Laboratory, said that it takes at least an hour after an earthquake has occured before the public in the Pacific Basin can be warned that a life-threatening tidal wave is sweeping toward them from the open ocean. Using existing technology, regional warning systems could alert threatened areas in a matter of minutes, giving much of the population time to flee endangered coastal areas. In an area where more than 70 000 lives have been lost to tsunamis in the past 135 years, the results of the study will be very important.

The program, which will take three years to complete, will start with the collection and assimiliation of all available information relative to tsunami effects in the Lima area. This information will be used for developing computer models of the physical impact tsunami's have in that area. Seismic and water level data that could be used to identify the existence of a tsunami and to assess its potential threat will be gathered, and a study will also be made to determine how a tsunami warning system could be set up in Peru.

Automatic sensors monitoring seismic activity, tide heights, and other tsunami-generated signatures would be put in appropriate locations, Bernard said. When an underwater earthquake occurred, the sensors automatically would transmit information through NOAA's GOES West satellite to the existing Pacific Tsunami Warning Center in Honolulu, and to a local warning center for the Lima area. This entire process, he said, would take no more than three minutes. Upon notification of a tsunami event in process, the local center would then evaluate the threat using the computer models, and would alert endangered areas.

The National Weather Service will assist in the program by establishing a system for dissemination of public educational information as well as warnings, while the National Environmental Satellite, Data and Information Service (NESDIS) will develop a data base and a tsunami map. Once the program nears operational stage, NESDIS will also assist in setting up the warning system.

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NOAA Building Number
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Seattle, WA 98115

January 16, 1984 R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Project Newsletter

How about this quote? "There ain't nothin' as much fun as having a good time!"

The ITSU IV meeting will be held in March, 1984 in Hawaii. We are trying to schedule a THRUST coordination meeting immediately following the ITSU conference. The possibility does exist of the Chilean representatives being present at our THRUST meeting.

The budget for THRUST's next fiscal year was submitted to AID. We are awaiting the review and approval.

Attached is a copy of the article that appeared in the December 1983 Tsunami Newsletter.

December was a very quiet month for THRUST. A very cold and joyous holiday season was celebrated by all.

Attachment:

TSUNAMI NEWSLETTER

December 1983
Volume XVI, No. 2

INTERNATIONAL
TSUNAMI
INFORMATION
CENTER

INTERGOVERNMENTAL
OCEANOGRAPHIC
COMMISSION - UNESCO

Tsunami warnings were issued for the west coasts of Honshu and Hokkaido. Waves measuring 9 cm and 14 cm were observed at Fukaura, north of Honshu and 28 cm at Esashi, south west of Hokkaido. No casualties were reported.

U.S. - Japan Tsunami Workshop Held

A workshop on tsunami was held in Tsukuba, Japan May 12-13, 1983. The purpose of the workshop was to promote interchange of ideas and research in progress between U.S. and Japanese scientists and engineers working in the field of tsunami. Participation was by invitation. There were a total of 26 participants and 5 observers from both countries. The topics discussed included the following:

A. Tsunami Behavior in Coastal Water and on Land

B. Nonlinear Problems of Tsunami

C. Mesh Consideration in Numerical Work

D. Finite Difference vs. Finite Element Methods

E. Tsunami Protective Measures in Japan and U.S.

After the conference, the participants toured Kamaishi and Sendai. In Kamaishi, they visited the tsunami breakwater construction on the Sanriku Coast, an estimated 500 million dollar project. In Sendai, they went to Tohoku University to visit the laboratories of Professors Iwasaki and Shuto where on-going experiments were demonstrated to them.

THRUST Team Visits Chile

A team of scientists consisting of Dr. Eddie Bernard, Mr. Paul Krumpe, Mr. Richard Behn, Mr. James Lander, Mr. Peter McManonan and Dr. George Pararas-Carayannis, completed in early October a visit to Chile for the THRUST tsunami project in that country. THRUST is the acronym for a pilot program on Tsunami Hazard Reduction Utilizing System Technology.

The primary objective of the project is to develop, test, and evaluate an early tsunami warning system for a tsunami prone urban area. Valparaiso, Chile was chosen as the site for the THRUST project because it represents an urban area with high probability of tsunami occurrence.

The project is sponsored by the Office of U.S. Foreign Disaster Assistance of the Agency for International Development (OFDA) and it is envisioned as a three year project. The scope of work of the THRUST project entails the development of tsunami and earthquake data base, verification of a tsunami numerical model, preparation of hazard assessment maps for the coastline combining historical and modeling results, the establishment of seismic and tidal sensors using satellite telemetry to provide early warning information, and finally, the integration of the new early warning technology to existing local systems.

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February 2, 1984 R/E/PM:RRB

To: All THRUST Participants

From: R/E/PM - Richard R. Behn

Subject: THRUST Project Newsletter

This month's quote: "Even a family tree has to have some sap."

The American Embassy in Chile has endorsed attendance by Captain Eduardo Barison (Director, Instituto de Hydrografico), Chilean Tsunami Delegate, at the ITSU IX conference in March. AID has expresed interest in funding his trip.

As most of you know by now, there will be an ITSU IX conference this March in Honolulu, Hawaii. A THRUST coordination meeting will immediately follow, on March 19, which the Chilean representatives are scheduled to attend. Any other interested personnel should contact me.

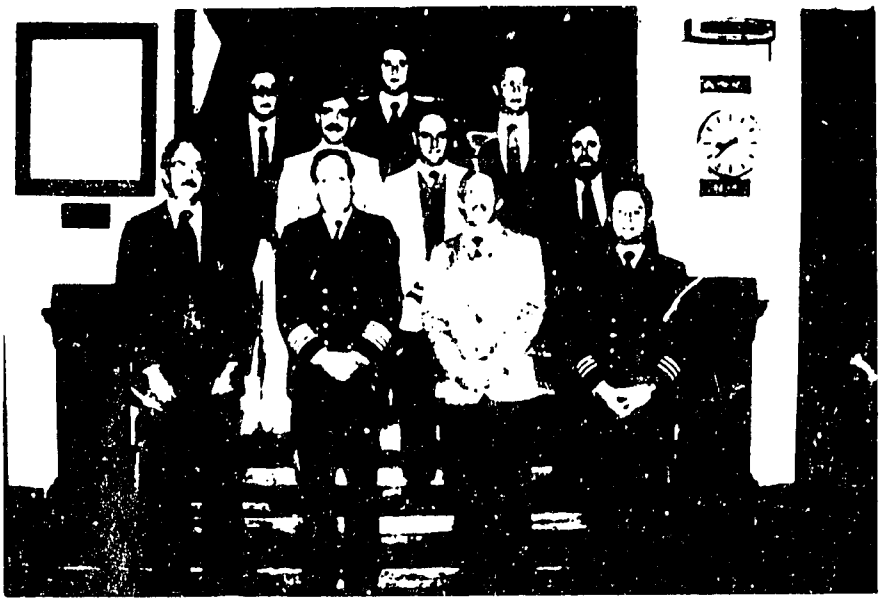
Our budget for the next year has not received final approval by AID. Efforts are being made by PMEL, AID, and the American Embassy (Chile) to obtain the necessary approval.

A quarterly progress report was received from Dr. G. Hebenstreit, Science Applications, Inc. SAI is doing all the modeling for the THRUST project. Some production runs should be made by the end of this month. A draft of the report will be ready for the THRUST coordination meeting.

One article on THRUST appeared last month in Natural Hazards Observer (see attached). A couple of other articles on disaster and disaster preparedness are attached.

Attachments

THRUST NEWSLETTER



1st row (L-R) Mr. James Lander, Capt. Eduardo Barison Roberts, Mr. Paul Krumpe, Cmdr. Patricio Figueroa. 2nd row: Mr. Richard Behn, Mr. Emilio Lorca, Dr. George Pararas-Carayannis. 3rd row: Mr. Ariel Vera, Mr. Ricardo Rojas, Mr. Ricardo Montaner.

While in Chile, the team of scientists met with their Chilean counterparts on the project and planning and coordination meetings were held at the U.S. Embassy, at the University of Chile and at the National Emergency Office in Santiago. In Valparaiso, coordination meetings were held at the headquarters of the Chilean Tsunami Warning Center at the Navy Hydrographic Institute. The Hydrographic Institute is the lead agency in Chile responsible for data collection and tsunami warning dissemination. Captain de Fragata, Eduardo Barison Roberts, the Institute's Director hosted the conference and members of his staff Mr. Ricardo Montaner, Mr. Alfonso Campusano, Mr. Emilio Lorca, Mr. Ricardo Rojas and Mr. Ariel Vera coordinated with the team the decisions of site selection data collection, telemetry and integration with the existing tsunami warning system in Chile.

In Santiago, the project was coordinated with the Director of the National Emergency Office, General Victor Lopez and his staff, and with the Director of the Department of Geophysics of the University of Chile, Dr. Edgar Kausel and his staff.

On the last day of the U.S. team's visit in Chile a press conference was given by the U.S. scientists and their Chilean counterparts on the proposed project and on the progress which was achieved during the visit. Ironically an earthquake of 7.4 on the Richter scale shook northern Chile and was distinctly noticeable in Santiago. Dr. Pararas-Carayannis who was talking to reporters at the time interrupted his presentation and smiling explained that the team had not programmed this particular earthquake and disclaimed any responsibility for it.

Natural Hazards
OBSERVER

VOLUME VIII NUMBER 3 January, 1984

TSUNAMI WARNING SYSTEM

With funding from the Agency for International Development, the National Oceanic and Atmospheric Administration is working on a pilot project to provide early warning of destructive tsunamis that threaten coastal areas of Chile. In the 135 years for which records have been kept, more than 70,000 persons in countries ringing the Pacific Ocean have been killed by tsunamis. Chile is one of several South American nations considered to be high-risk areas.

A team of NOAA experts has met with Chilean authorities to discuss connecting tidal and seismic sensors by satellite with local Chilean offices and the Pacific Tsunami Warning Center in Honolulu. With such satellite communications, Chilean emergency units could be alerted to a tsunami threat within ten minutes of an undersea earthquake.

For more information, contact *Eddie N. Bernard, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way, N.E., Seattle, WA 98105, (206) 527-6800.*

The Honolulu Advertiser

Established July 2, 1856

Thurston Twigg-Smith — *President & Publisher*
George Chaplin — *Editor-in-Chief*
Buck Buchwach — *Executive Editor*
John Griffin — *Editorial Page Editor*
Mike Middlesworth — *Managing Editor*

Thursday, November 17, 1983

Another disaster

Hawaii has suffered more than its share of natural disasters and unfortunate events over the past year. A week before the first anniversary of Hurricane Iwa, a major earthquake yesterday caused millions of dollars of damage and some personal injuries on the Big Island.

In between, parts of Oahu and the Big Island experienced droughts, Oahu sweated through a major power outage in July, and Madame Pele vented her fiery volcanic wrath on the Big Island. Only Maui has escaped most of the confusion and concern accompanying some of these disasters.

What, one wonders, could possibly be next?

LINKING THESE events is the important but often neglected subject of emergency preparedness.

The Big Island, which has suffered more natural disasters than other islands, has an enviable record of preparation for, and response to, such unfortunate events.

Oahu, as a recent citizens' committee report points out, has a less satisfactory record. This, the report suggests, is not the fault of the Oahu Civil Defense Agency but is more the result of benign neglect in the community. Fortunately, that situation appears to be improving.

There can be no excuse for citizen ignorance of, and lack of concern about, some of the potential dangers posed by both our unique Island environment and other phenomena.

For residents, being prepared means knowing what to do in particular situations, whether it's a high-rise fire, a tsunami or other occurrence.

At the state and county levels, emergency preparedness means planning for a variety of contingencies. Such plans should stress firm decision-making, coordination between government agencies and effective communication with the public by way of the Emergency Broadcast System.

IF THERE is anything positive in recent disasters, it perhaps lies in the improved preparedness of government, business, educators and individuals toward potential perils.

Yesterday's earthquake, the largest since 1975, will not be our last natural disturbance. But at least the experiences of the past year suggest we are now better able to handle such emergencies.

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NOAA Building Number
7600 Sand Point Way N.E.
Seattle, WA 98115

February 29, 1984 R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Project Newsletter

This month's quote: Nothing is ever a total failure ... it can always serve as a bad example.

The THRUST coordination meeting slated for March 19 is still on. I have been informed that Captain Eduardo Barison (Director, Navy Hydrographic Institute) will be at the meetings. The meeting will be utilized as a thorough annual review and a discussion of the future coordination of the project.

Dr. Pete McManamon, CyberLink, visited PMEL on February 22nd. A meeting was held to discuss which communication link will be utilized between the seismic instruments, tide gauges, printers and GOES satellite system. Dr. McManamon was going to NESDIS to obtain final approval on this link.

Abstracts have been submitted, by the principal investigators, for topics of discussions (in reference to THRUST) at the following conferences: 1) ITSU IX, 2) UNJR, 3) OCEANS 84.

A quarterly report was submitted to AID on March 1.

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NOAA Building Number
7600 Sand Point Way N.E.
Seattle, WA 98115

April 3, 1984 R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Newsletter

This month's quote: "A sharp tongue may improve its edge with constant use ..... but you usually end up cutting your own throat with it."

The month of March was a very eventful month for the THRUST project. The biggest event being the meetings (ITSU and THRUST) that were held in Hawaii. The International Coordination Group for the Tsunami Warning System in the Pacific (ITSU) held it's ninth session. Twenty-one official delegates from countries around the Pacific Basin were present. An overview of the THRUST Project was presented to the group. Most of the delegates expressed interest in the project and want to be kept abreast of the project's progress. An attached newspaper article gives details.

A THRUST coordination meeting was held and not only was Captain Barison, Director, Chilean Navy Hydrographic Institute, present, but also Sr. Lorca, who is Chief of the Chilean Tsunami Warning System. During the meeting we received the formal endorsement of the project from the government of Chile. We also received a counterpart funds list, magazine articles on THRUST from Chilean periodicals and information on tasks the Chilean Hydrographic Institute is doing for THRUST. All U.S. THRUST components gave a review of their work with the following results. Mr. Lander (NOAA, NGDC) reviewed his tsunami hazard map which is nearing it's production run. Dr. Hebenstreit (SAI) reviewed his results in the modeling effort for the Valparaiso harbor. Dr. Pararas-Carayannis reviewed his process in developing a merged Chilean/THRUST standard operating plan (S.O.P.). Needless to say both meetings were a huge success.

Pete McManamon (CyberLink) met with NOAA/NESDIS personnel in March. The THRUST system concept was presented at that time. The overall results of the meeting were very favorble. NESDIS feels that the approach is compatible with the GOES System.

Presentations on THRUST were given at the following conferences:

1) ITSU IX - Hawaii - Dr. Bernard
2) THRUST Coordination Meeting - Hawaii - Mr. Behn
3) NOAA Environmental Satellites Come of AGE - Washington, D.C. - Dr. Hebenstreit

THRUST NEWSLETTER

At this time, AID has still not funded the second year of the project. Certain documents needed reviewing and agreement by all agencies involved before funding could be approved.

And last but not least, not only my phone, but all phones in the NOAA Western Regional Center will have a new prefix as of April 9, 1984. All 527 prefixes will change to 526 and FTS prefixes will change from 446 to 392. So my new numbers will be:

(206) 526-6205
(FTS) 392-6205

Thank you for your time.

Attachment

HONOLULU STAR BULLETIN
SATURDAY MARCH,17,1984
PAGE ONE

Tsunami Warning Problems Exist

By Helen Altonn
Star-Bulletin Writer

A big Pacific-wide tsunami is "long overdue" and despite great improvements in the warning system many areas remain vulnerable because of information or communication problems.

Technology is available to provide tsunami warnings within minutes in some of those areas where it now takes an hour or more, but financial and logistical problems hamper use of the technology.

This is the dilemma facing the International Coordination Group for the Tsunami Warning System in the Pacific (ITSU), which sought to close some of the gaps in warning coverage during meetings this week at the East-West Center.

The conference was attended by 21 official delegates from the United States, Canada, Chile, China, Japan, New Zealand, Russia and the United Kingdom (Hong Kong). There were also about 25 observers from other countries and state, county and federal agencies in Hawaii.

Hawaii is at the hub of the tsunami warning network. The Pacific Tsunami Warning Center — the heart of the warning system — is at Ewa Beach on Oahu. The International Tsunami Information Center (ITIC) is in the Prince Kuhio federal building.

The warning system has 22 member-nations and includes about 31 seismic stations and 71 tidal stations throughout the Pacific.

AMONG LATEST developments to try to speed up regional warnings is a three-year pilot project planned in Chile to develop and test an automatic alarm system using the Geostationary Operational Environmental Satellite (GOES).

Eddie Bernard, leader of that project and former director of the tsunami warning center, said the goal of the tsunami system is to provide warning services "within the shortest possible time. I think, with satellite concepts, that we're talking about 10 to 20 minutes, but it will take the concerted effort of everyone to pull it off."

George Pararas-Carayannis, director of the tsunami information center, said a regional system should be able to respond within five or 10 minutes so a warning can be issued. It can be done with present technology, but the problem is "establishing stations, maintaining them and training people to use the equipment," he said.

He said the ITSU is looking for

Turn to Page A-3, Col. 3

Problems in Tsunami Alert System

Continued from Page One

international sources of funding and "trying to piggyback ride" on nationally funded, sea-level monitoring programs and other activities that would benefit the tsunami system.

THE LAST MAJOR tsunami in Hawaii was in 1975 when an earthquake occurred in Puna and generated a local tsunami that killed two campers on the south coast of the Big Island. The last major Pacific-wide tsunami was in 1964.

"So we're long overdue for one," Carayannis said. "It's just a question of time."

Among those welcoming the delegates when the conference opened Tuesday was Mayor Eileen Anderson, who recalled the 1946 tsunami disaster that killed 159 persons in Hawaii.

Her family lived about a block from the beach at Hilo at that time. For a long time afterward, she said that whenever they heard a siren they would "get the kids out of bed and go to higher ground."

She commended the tsunami group for improvements that have eliminated unnecessary evacuations and given residents adequate time to respond to a tsunami.

The conference closed today with resolutions proposed for development of a master plan for the tsunami warning system and preparation of tsunami travel time charts for new stations.

It was also recommended that the member countries provide additional funding to support expanded responsibilities of the tsunami information center.

Carayannis said there has been "tremendous progress" since the international tsunami group was formed in 1968 with seven member countries, but there is still a long way to go in using and developing new techniques for quick response.

IT'S HOPED in the future to be able to determine the type of motion of an earthquake — horizontal or vertical displacement — so tsunamis can be predicted more accurately, he said. "The day will be coming."

Bernard, director of the National Oceanic & Atmospheric Administration's Pacific Marine Environmental Laboratory in Seattle, said Hawaii and Chile will receive alert signals simultaneously from the GOES satellite project.

It is called THRUST — "Tsunami Hazard Reduction Utilizing Systems Technology," and it is funded by the U.S. Agency for International Development (AID).

Bernard said Chile was chosen for the test because it has a long coastline and is one of the most vulnerable countries in the warning network.

Any delays in understanding what is happening there on earthquakes and tsunamis not only endangers Chile's coastline, but affects warnings for Hawaii and other tsunami-risk areas, he said.

BERNARD NOTED that one of the original purposes of the GOES satellite was for tsunami warnings, but it never happened.

He said the concept is fairly simple: A seismometer activated by an earthquake will send a message to the satellite, which will have an "emergency broadcast" channel.

The satellite will send a alert signal to a warning center automatically and set off pre-recorded instructions, such as turning on sirens, telephoning officials or transmitting messages to a disaster control headquarters.

"It doesn't mean we've issued a warning, just that we speeded up communications," Bernard said, pointing out that the final decision on warnings will be left to humans.

But he said teletype messages and telephone calls — traditional methods used by observers — can be bypassed with the satellite.

"Once we get the bugs ironed out we can hit a whole area with one burst. It's mind-boggling," he said.

He said it can also be used internationally. Japan already is interested in using the system with one of its satellites.

It's not the answer to all tsunami warning problems, Bernard said, but "a major small step, if you will."

He said educating the public on tsunamis so they will respond to warnings is one of the biggest problems: "On the West Coast of the Mainland they don't even know what the word 'tsunami' means."

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ENVIRONMENTAL RESEARCH LABORATORIES
Pacific Marine Environmental Laboratory
NOAA Building Number
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Seattle, WA 98115

May 4, 1984 R/E/PM

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Newsletter

This month's quote: "How come people drive on parkways and park in driveways?"

Captain Barison, Director of the Navy Hydrographic Institute in Chile has sent a letter to the American Embassy in Chile stating Chile's full endorsement and participation in the THRUST project. The Chilean counterpart contribution to the THRUST project is U.S. $1,633,068.00. (This is salaries, facilities, equipment, etc.).

A visit was made to the California Division of Mines and Geology in Sacramento, California. Rich Behn gave a talk and slide presentation to the group. Mr. Brian Tucker advised us on the type of instruments to utilize for the project.

The Inter-governmental Agreement for THRUST has been finalized and passed to the AID office and on to the State Department.

Mr. James Lander gave a talk and slide presentation on THRUST at the IGDG meeting on April 11, in Washington, D.C.

A new slide presentation is being developed. It will be ready and available for the WNR meeting in May.

Who said Tsunami is not becoming a household word? (See attached article).

Attachment

Tsunami Slew probably out of Derby after upset

Compiled from news services

Distant Ryder defeated favorite Tsunami Slew in the $219,000 California Derby at Golden Gate Fields yesterday to join some other 3-year-old upset winners in races leading up to the Kentucky Derby.

Leroy S. was an upset winner in the Wood Memorial at Aqueduct and Althea, a filly, was a somewhat surprising winner in the Arkansas Derby.

Distant Ryder, not eligible for the Kentucky Derby in two weeks, claimed his first stakes victory yesterday. Distant Ryder tracked the pace-setting Fifty Six In A Row to the far turn and then opened up a sizeable lead to finish three-quarters of a length in front of runner-up Majestic Shore.

Tsunami Slew, son of Triple Crown winner Seattle Slew, appeared to duck in at the quarter pole and barely held off King Tobin for third place, finishing nearly four lengths behind the winner. Laffite Pincay Jr., said of Tsunami, "He just had no response at all in the stretch. He was just fooling around. It's frustrating to ride a horse like this that has a lot of talent but doesn't get the job done."

Because of yesterday's finish, Tsunami Slew is not expected to qualify for the Kentucky Derby field. Pincay Jr. is scheduled to ride Swale another offspring of the great Seattle Slew, at Churchill Downs.

Will Leroy S., scoring his first stakes victory in the Wood, be shipped to the Derby? "Might," was the cautious response of Jan Nerud, who trains the colt owned by his father, John.

"Might. I ran him pretty hard to get him ready to win this race. I want to see how much it took out of him," the younger Nerud said. "Kentucky is a long way to ship for nothing. If we go, you'll know he's ready to run. Personally, I'd love to win that race."

The next step for Althea will be decided in a board meeting. Board members are trainer D. Wayne Lukas and owners Helen Groves, David Aykroyd and Helen Alexander.

"Most people standing in this spot at this minute would say on to Kentucky," Lukas said after a seven length victory that equaled a track record. "We're not necessarily going to do anything that's not in the best interest in her total career."

"If the Kentucky Derby is what we think is absolutely best for her and everybody concerned we'll take that approach."

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June 4, 1984

R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn R. Behn

SUBJECT: THRUST Newsletter

This month's quote: "If you are not fired with enthusiasm - you will be fired with enthusiasm!"

A 3 month no cost extension to the existing PASA between AID and PMEL has been granted. This will enable PMEL to continue coordinating all contractors and other NOAA personnel working on the THRUST project. The new PASA, which has not been approved yet, should be O.K.'d and signed by the end of this 3 month period (August 31).

An application for a frequency allocation has been filed with NESDIS, Washington, D. C. This will enable the THRUST program to utilize the GOES satellite communication system.

Presentations were made by Dr. Bernard, Mr. Lander and Dr. Hebenstreit at the UJNR meeting. (United States - Japan Panel on Wind and Seismic Effects) about THRUST. The concept was readily accepted by the Japanese panel.

THRUST personnel attended the GOES user conference. Information on the user's responsibility to the GOES system was obtained.

The new slide presentation is complete. Copies of slides will be sent to all THRUST major components.

The final report will be completed by June 30. Anyone interested in receiving a copy, please let me know.

And one last note, Dr. Jerry Hebenstreit's wife gave birth to a healthy baby boy on May 12th. Congratulations!

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September 8, 1983 R/E/PM:RRB

TO: AID/OFDA - Paul Krumpe

FROM: R/E/PM - Richard R. Behn Richard R Behn

SUBJECT: THRUST Quarterly Progress Report

It has been three months since AID/OFDA has awarded NOAA - Pacific Marine Environmental Laboratory (PMEL) the money for the THRUST project. That means that a quarterly report is due.

As of August 1, 1983, I have assumed responsibility as the Project Coordinator. Since that time I have been gathering all the "building blocks" to assemble a sound project. An office with all the necessary equipment was set up at the new NOAA Sand Point facility in Seattle. Dr. Eddie Bernard, PMEL Director and Project Director, and myself, are located in Building 3 which houses PMEL.

Since our "start up" of the project, we have tackled the most important issue which was obtaining permission from the host country. Valparaiso, Chile was selected as our locale for the pilot study. Letters have been sent through the proper channels to the Chilean government. As of this day, no letters of permission have been received. I have been informed that a cable of positive response is on its way. A team of six people will conduct the "site analysis" trip to Chile. It is tentatively scheduled for September 27 through October 8, 1983.

We have obtained permission from the NOAA - National Environmental Satellite, Data, and Information Service (NESDIS) for the use of the GOES Data Collection System (DCS). I have conversed with NESDIS about the parameters we require. I have been assured that our requirements will be met. The NOAA - National Geophysical Data Center is developing a map of all epicenters and tsunami heights for the Pacific Region. This map and information will be utilized for tsunami warning procedures and hazard mitigating planning.

Science Application, Inc. (SAI) is currently working on pre-event modeling for the project. Precise modeling cannot be completed until after certain information is gathered from Chile.

The contract for the dissemination consultant has been awarded to CyberLink in Boulder, Colorado. The Source Evaluation Board (SEB) made it's decision this week. It favored this company due to it's complete and thorough proposal.

The project has obtained a fair amount of publicity. Attached are copies of the monthly newsletters. The publicity is covered in the newsletters.

As soon as permission is obtained from Chile - or - a change in location occurs, I will inform you.

Thank you very much for your time and interest.

Attachments:

U.S. DEPARTMENT OF COMMERCE
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Seattle, WA 98115

December 5, 1983 R/E/PM:RRB

TO: AID - Paul Krumpe

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Quarterly Report

For this quarterly report I will break the THRUST program into six functional areas for you, as it is done in the budget and other publications about THRUST. After these areas will be some general notes about the program.

The major event in the life of the THRUST program in the last 3 months was the visit of the site analysis team to Chile. The trip was a huge success. Every task that was planned was completed. Details of the trip are outlined in the attached Chile Trip Report.

Here are the functional areas:

PRE-EVENT DATA COLLECTION:

The major effort in this area has been improving the digital tsunami data base. To do this we collected large amounts of data from Chile which included 21 digitized Chilean marigrams, tsunami arrival times, tsunami wave heights, and strong motion seismometer locations.

A package of data and information was just forwarded to the Chilean Hydrographic Institute which included: 1) a magnetic tape of all earthquakes of a magnitude 6 or greater in the Pacific (some 6,000 quakes), 2) enlargements of microfilm copies of Chilean marigrams which they did not have, 3) information on bottom sediments, bathymetry and other holdings.

PRE-EVENT DATA ANALYSIS:

This area is concentrating on the digitization of data to produce a tsunami model run for the Valparaiso area. The digitizing of data in the Peru-Chile trench for propagation simulation has begun. The digitization of the topography around the Valparaiso harbor (information gathered from charts obtained from Hydrographic Institute). The model verification test of the May 1960 Chilean tsunami has begun.

A trip to Hawaii to the International Tsunami Information Center (ITIC) yielded very helpful data which will be utilized for the verification of the model. While in Hawaii the exact parameters to be used for the modeling were finalized.

PRE-EVENT DISSEMINATION:

All information that was needed to evaluate the existing tsunami warning system was collected while in Chile. A thorough investigation into this information will help formulate the procedures that will help merge the THRUST program with the existing Chilean tsunami warning system. An example of this structure is seen as Attachment I in the Chile Trip Report.

REAL-TIME DATA COLLECTION:

Manufacturers of strong motion seismographs, strong motion triggers, and water level gauges have been contacted. Information on these gauges has been collected and is being evaluated.

REAL TIME DATA ANALYSIS:

No work in this area during the first of the year.

REAL-TIME DISSEMINATION:

All time and effort in this area has been devoted to the investigation of the GOES satellite communication system.

A visit to NOAA/NESDIS in Washington, D. C. yielded that the random reporting mode of the GOES satellite system was not as dependable as we had anticipated. We have been advised of two other alternatives which are being investigated at this time. Visits to manufacturers who produce GOES related products have been initiated.

CyberLink (the subcontractor) visited PMEL in October. A thorough discussion of the THRUST program occurred.

Other related information:

NOAA, National Weather Service (NWS) held a tsunami conference in Anchorage, Alaska on September 14th. Dr. Bernard spoke to this committee about the THRUST program.

Many other countries (Japan, Mexico), world-wide organizations, as well as local agencies have expressed interest in the THRUST program. Many of these people are being informed of our progress through monthly newsletters.

On October 18th, Dr. Bernard spoke to the local Seattle scientific community about the THRUST program. Much interest was stimulated after the presentation.

On November 15th, Dr. Bernard made a presentation to the Director, (NWS) Pacific Region Headquarters and the Director, Pacific Tsunami Warning Center about the THRUST program.

Attached is an article that appeared in the American Meteorological Societies publication. A letter has been sent to correct the pilot study area from Lima to Valparaiso.

Speaking for all THRUST components, I would personally like to extend my wishes for a healthy and happy holiday season.

Thank you very much for your time.

Attachment:

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Pacific Marine Environmental Laboratory
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7600 Sand Point Way N.E.
Seattle, WA 98115

February 29, 1984 R/E/PM:RRB

TO: AID - Paul Krumpe

FROM: R/E/PM - Richard R. Behn Richard R Behn

SUBJECT: THRUST Quarterly Report

As in the last quarterly report, I have divided the project up for you into it's six functional areas, so as to coincide with the budget and other THRUST publications.

The major event that has had the most impact on THRUST in the last three months was the endorsement and funding of Captain Eduardo Barison (Director, Navy Hydrographic Institute of Chile) attendance at the ITSU IX conference and THRUST coordination meeting. His presence will be very instrumental to THRUST's success and world-wide acceptance.

Here are the functional areas:

PRE-EVENT DATA COLLECTION

Dr. J. Lander of the National Geophysical Data Center (NOAA/NGDC) has been coordinating all work in this area. The major effort of his work has been on two items; 1) Tsunami Data Base, and 2) Tsunami Hazard Map.

The collecting, interpreting, cataloging, and writing of the tsunami data base is an ongoing project at NGDC. A draft of this report is due in the near future with the final copy due in May.

The Tsunami Hazard Map data has been collected and test plots are underway. The map will show earthquake epicenters, tsunami intensities, and overall effects. This map will be used for education and planning programs.

PRE-EVENT DATA ANALYSIS

This area, which is being coordinated by Dr. G. Hebenstreit of Science Applications Inc., is concentrating on modeling efforts for the Valparaiso area. A simulation of the May 22, 1960 tsunami that occurred in Talchuano, Chile is being utilized to verify all model runs. This tsunami was used because it was the worst case event in Chile to date. The verification run for Talchuano and the digital topography for Valparaiso has been completed. By March 1, initial production runs for the model of the Valpariso area should be done. First drafts of the reports on the verification and model runs will be completed by mid-March.

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PRE-EVENT DISSEMINATION

The evaluation of the existing tsunami warning system has been a continuing project for Dr. G. Pararas-Carayannis. The formulation of a new merged (existing Chilean and new THRUST) tsunami warning system is being drafted.

Information from the model runs (Pre-Event Data Analysis) will be included in the new warning system. The model run information will be utilized to plan evacuation routes, areas of severe tsunami impact, inundation levels, etc.

REAL TIME DATA COLLECTION

This area will concentrate on the assembling of the instrument package with PMEL being the coordinator.

All printed information relating to the instruments (seismographs, tide gauges, radios, printers, etc.) has been received and reviewed. CyberLink will meet with NESDIS to agree on the design requirements and specifications (see Real Time Dissemination). CyberLink will then supply PMEL with these specs which will dictate which instruments need to be purchased. Procurement will begin immediately following receipt of these specs.

REAL TIME DATA ANALYSIS

No work in this area during the first year.

REAL TIME DISSEMINATION

Dr. P. McManamon of the CyberLink Corp has concentrated his efforts on the GOES satellite communication system. A final visit to NOAA/NESDIS this week will yield the communication link and final specification in our communication system. These specs will dictate which instruments will lead to a successful system design.

Other related information:

The budget for THRUST's next 18 months was submitted to AID for approval.

Abstracts for topics to be presented at the following conferences have been submitted:

1) ITSU IX
2) UNJR
3) OCEANS 84

A THRUST coordination meeting has been scheduled to follow the ITSU IX meeting. The meeting will be utilized as a thorough annual review and also to discuss the future coordination of the project. Captain Barison's attendance at this meeting will be very beneficial to all parties involved.

Attached are copies of the THRUST newsletters.

Attachments:

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October 20, 1983 R/E/PM:RB

TO: R - Ned D. Ostenso

THRU: R/Ex1 - Vernon E. Derr

FROM: R/E/PM - Eddie N. Bernard

SUBJECT: Chile Trip Report, 28 September to 5 October 1983

On September 28, 1983 a six person team of U.S. scientists arrived in Santiago, Chile to conduct a site analysis of the Valparaiso area for the THRUST project. Upon completion of the analysis, it was decided that Valparaiso would be the pilot study area.

The American Embassy approved of our project and work completed (see attachment III). We have received verbal approval from the local Chilean officials. Further conferences and meetings are needed before a final decision can be made. Our Chilean colleagues assured us that the project would receive their full endorsement.

Site Analysis Team:

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Bin C15700
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Personnel and Places Visited

Ambassador James D. Theberge
American Embassy
Augustinias 1343
Santiago, Chile
or
APO Miami, FL. 34033

September 29, October 5

Contact: John Moran

Captain de Fragata Eduardo Barison Roberts
Director
Instituto Hidrografico de la Armada
Casilla 324
Valparaiso, Chile

September 30, October 3,4,5

Contact: Sr. Ricardo Montaner Sepulveda

Dr. Edgar Kausel
Director
Departamento de Geofiscia
Universidad de Chile
Blanco Encalada 2085
Santiago, Chile

October 1

Contact: Dr. Edgar Kausel

Brigadier General Victor Lopez Barrenechea
Director General
Oficena Nacional de Emergencia - ONEMI
Beaucheff 1637
Santiago, Chile

October 1

Contact: General Victor Lopez

Juan B. Gonzalez Cabello
Interdencia Va Region
Edificio Esmeralda - 5° Piso
Melganjo 669
Valparaiso, Chile

October 3

Contact: Juan B. Gonzalez

Tasks Accomplished

The team met with officials at the Hydrographic Institute - the principal organization. Managing the existing Chilean Tsunami Warning System is the Hydrographic Institute.

While at the institute, three working groups were established. Chilean scientists were paired up with the corresponding American scientist to exchange information and gather data which was needed. The following working groups were established:

Scientists	Responsibilities
Group 1	
Alfonso Campusano Emilio Lorca Richard Behn Peter McManamon	Site selection, instrumentation, and satellite communication
Group 2	
Ricardo Rojas Ricardo Montaner James Lander	Historical data collection
Group 3	
Emilio Lorca Ariel Vera George Pararas-Carayannis	Existing tsunami warning system

All necessary tasks were completed ahead of schedule because of the thorough preparedness and competent staff at the institute. The major tasks that were completed are as follows:

a) Twelve bathymetric charts were obtained to provide the information needed for the numerical modeling.
b) All marigraphic data (digital form) from tsunamis which have occurred along the Chilean coast since 1952.
c) A thorough examination of the existing tsunami warning system was conducted.
A "flow diagram" for the warning system was established. (see attachment I)

The Chileans announced that funding was secured to establish a 24 hour warning center at the Hydrographic Institute to issue regional tsunami warning/watch. To assist in this endeavor, a Telex System will be installed (funds + labor provided by the Chilean government) in the Hydrographic Institute. This will enable the institute to communicate with other agencies within Chile as well as world wide communications. (This communication plan was established before our arrival. This is the Chilean solution to the removal of the NASA Communication System). The Telex will help the Tsunami Warning System with rapid transmission of data to other agencies.

A visit to the Chilean National Emergency Center (ONEMI) proved to be beneficial. An investigation into the ONEMI warning procedures was completed (results on attachment I). The center keeps a record (deaths, property damage, flood heights, etc.) of every natural or man-made disaster that occurs in Chile. Records of any tsunamis or earthquakes were gathered. These records will be supplemented with the records received from the Hydrographic Institute to form a more complete Data Base. The U.S. team was given a full tour of the facility.

A visit to the local ONEMI Office (Region V) in Valparaiso proved very beneficial as well. We received information on how this office warns the local people (results on attachment I).

The Geophysical Institute, University of Chile was also visited. Dr. Kausel gave us a briefing on the existing seismic network in Chile. Dr. Kausel informed us that the Hydrographic Institute would be funding the University to establish a 24 hour watch at it's seismic information data center. This center would be essential in upgrading the Tsunami Warning System (see attachment I).

The American Embassy was the first and last stop on our trip. The embassy was helpful in making travel plans and appointments for the team. The embassy arranged a press conference to be held immediately following the teams debriefing. Reporters from the countries science magazines and local newspapers were present. The occurrence of an earthquake one hour before the press conference underlined the importance of the project.

Site Selection

The city of Valparaiso was selected as the project site. The instrumentation that will be installed in Chile is: two strong motion triggers; two pressure tide gauges; and one printer, all with appropriate up-links and down-links for GOES Communication.

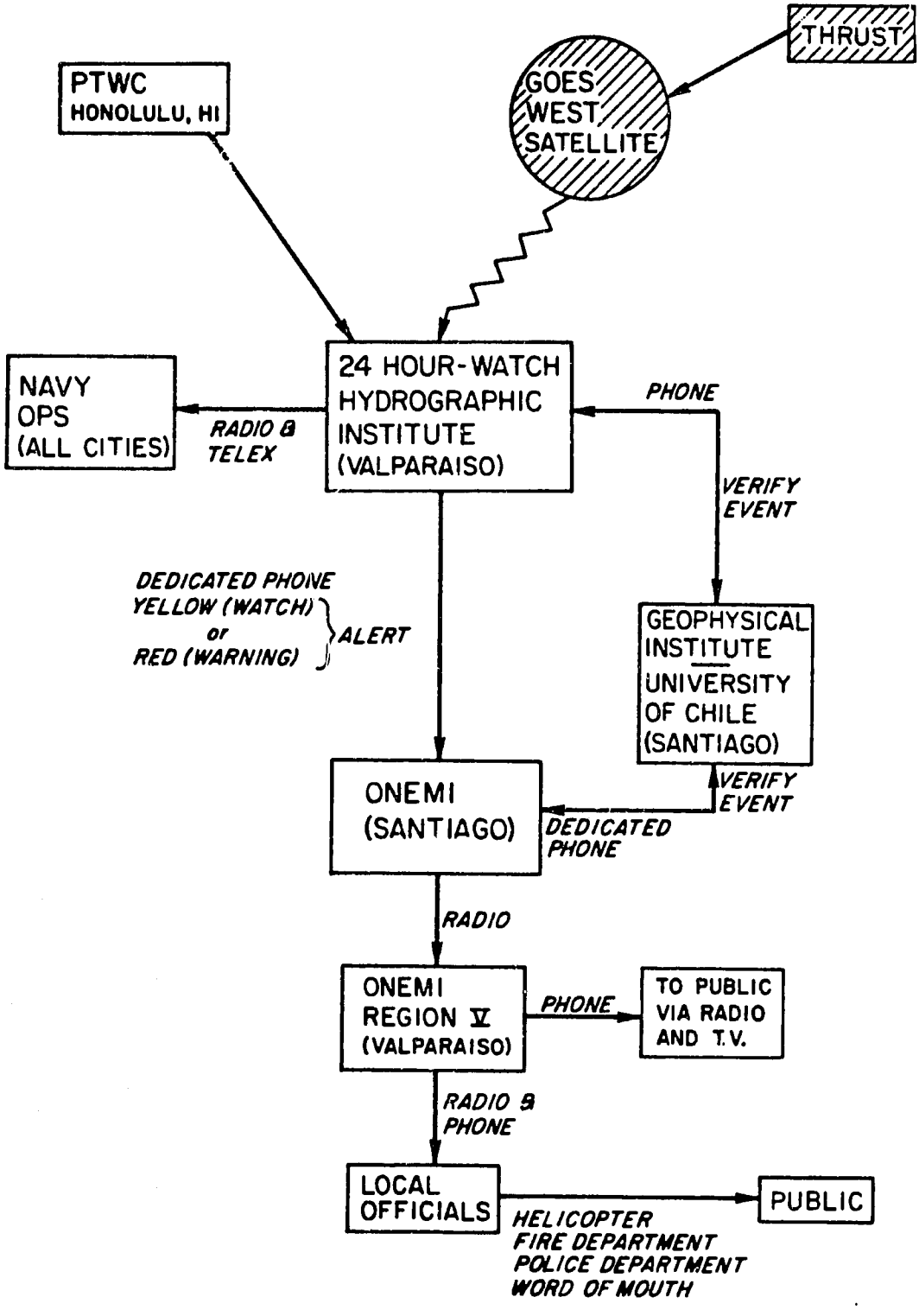
One seismic trigger will go at the Geophysical Institute, University of Chile, Santiago. The other trigger will go at the Hydrographic Institute, Valparaiso. Both instruments will have the GOES up-link capability.

The two tide gauges will be located in the Valparaiso harbor. A large "L" shaped concrete pier/breakwater will host both gauges (see attachment II). Each tide gauge will have the GOES up-link and down-link capability.

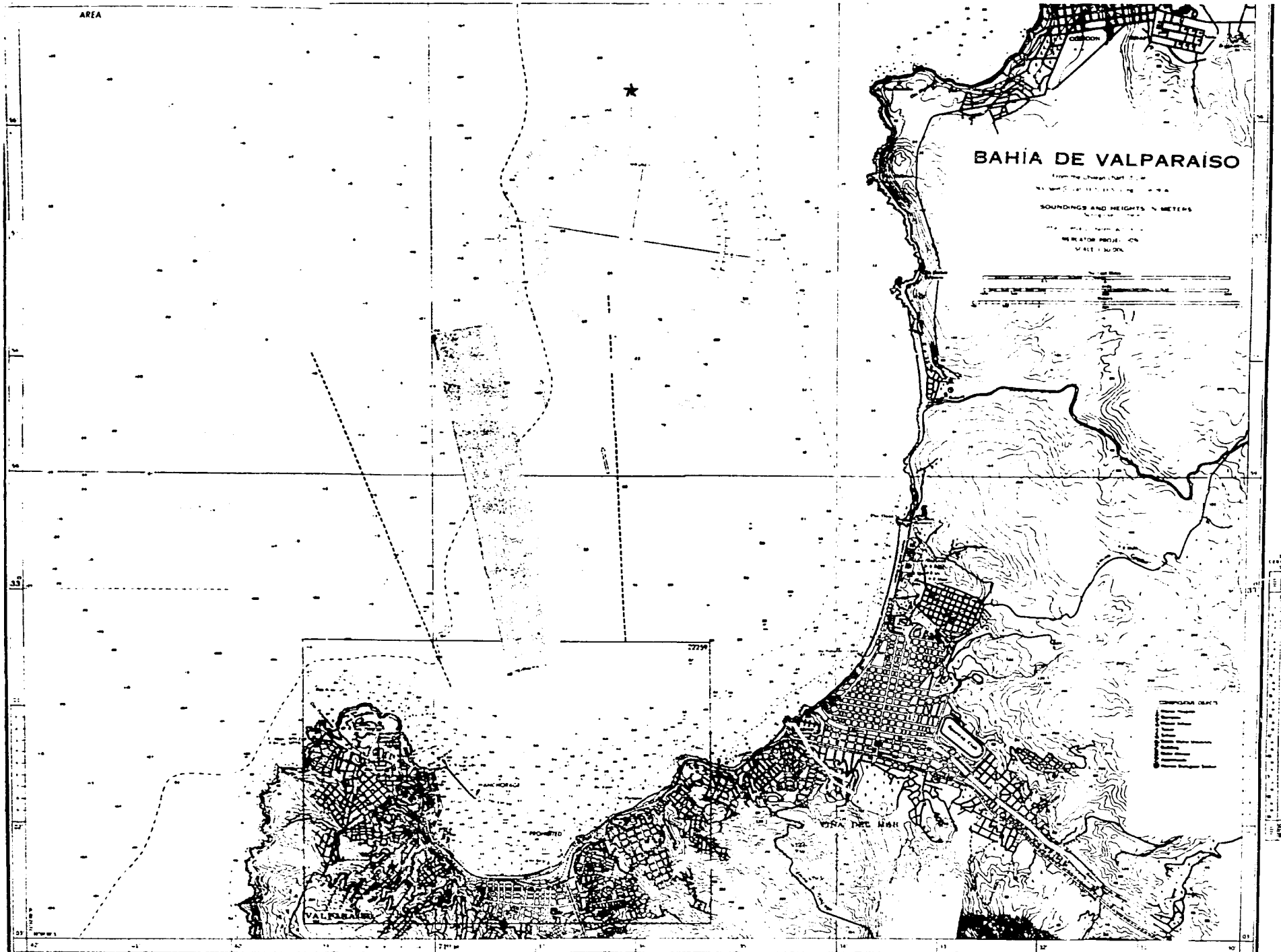
The printer that will display the tsunami warning message, with its appropriate GOES down-link, will be located at the Hydrographic Institute in Valparaiso.

Attachments:

ATTACHMENT 1



ATTACHMENT II



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TELEGRAM

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SUBJ: VISIT OF U.S. EARTH SCIENCE TEAMS TO SANTIAGO

1. TWO GROUPS OF VISITORS CONCERNED WITH GEOPHYSICAL AND GEOLOGICAL TOPICS CONDUCTED SEPARATE VISITS TO SANTIAGO THIS WEEK. BOTH TEAMS SUCCESSFULLY CONDUCTED THEIR INTENDED BUSINESS AND COOPERATED WITH EMBASSY IN PURSUIT OF OUR OVERALL GOALS. PRESS INTEREST FOCUSSED ON U.S. EXPERTISE AND ASSISTANCE, WHILE SUBTANTIVE RESULTS MAY LEAD TO BETTER RECOGNITION AND WARNING OF NATURAL DISASTERS AND MORE EFFICIENT RESPONSE, WITH ULTIMATE REDUCTION OF BURDEN ON EXTERNAL SOURCES OF RELIEF.

2. THE FIRST GROUP IS EXECUTING AN AID-FINANCED AND NOAA-MANAGED PROJECT TO EMPLACE A SATELLITE-LINK SYSTEM TO DETECT AND COMMUNICATE THE EXISTENCE OF TSUNAMI WAVES GENERATED BY OFFSHORE EARTHQUAKES. THE TEAM WAS WELL-RECEIVED BY CHILEAN GEOPHYSICAL, HYDROGRAPHIC, AND EMERGENCY PLANNING AUTHORITIES. EMBASSY BELIEVES THAT THE PROPOSED EQUIPMENT, WHEN EMPLACED AND INTEGRATED WITH THE EXISTING CHILEAN NETWORK OF SEISMIC AND TIDAL SENSORS, WILL PROVIDE A CRUCIAL LINK IN BOTH CHILE'S AND OUR OWN ABILITY TO PREPARE FOR AND RESPOND TO POTENTIAL DISASTERS. THE OCCURRENCE OF AN EARTHQUAKE DURING THE TEAM'S OCTOBER 4 USIS-SPONSORED PRESS CONFERENCE UNDERLINED THE IMPORTANCE OF THE TOPIC IN CHILE.

3. THE SECOND TEAM, FROM THE U.S. GEOLOGICAL SURVEY, BRIEFED 30 GEOLOGISTS AND ADMINISTRATORS ON GEOLOGIC AND HYDROLOGIC HAZARDS (QUAKES, FLOODS, VOLCANOES, EARTH SLIDES) AND ON TWO EARLY-1984 COURSES WHICH USGS WILL OFFER TO HELP INVENTORY SUCH HAZARDS, AND PLAN AND EXECUTE RESPONSES TO EVENTS. IMMEDIATE AUDIENCE INTERESTS IN THE PLANNED COURSES WAS HIGH, AND EMBASSY EXPECTS TO SEE MORE SERIOUS APPLICATIONS FROM HIGHLY-QUALIFIED CHILEAN CANDIDATES THAT CAN BE ACCOMMODATED. MATTHEWS

ATTACHMENT III

Pre - Event

Data Collection

THRUST

NGDC

1st Annual Report THRUST Project

Pre-Event Data Collection

A. Introduction

The pre-event data collection effort centered on two tasks: the collection of data about Chilean tsunamis and the production of a public use tsunami occurrence and effects map of the Pacific.

B. Task Completed

Data Compilation. James Lander collected extensive quantities of data while in Chile as part of the site selection team and we have received additional data in subsequent exchanges. We received from Chile 21 digital tsunami mareograms produced from Chilean tide records. We were able to find 36 additional tsunami tide records in the U.S. Archives from the earlier years when the tide stations were being established with U.S. help. The Chileans will digitize these and send us copies together with arrival times and wave heights for all events. Tsunamis were observed instrumentally by Chile only since the late 1940's. We have information on the location, instrumentation and installation of Chilean tide gauges, and seismic stations and descriptive material of earlier tsunamis. We have supplied Chile with digital epicenter files, graphics plotting software, and an inventory of marine geological data holdings.

Tsunami Map. We have made the major decisions on the map layout and have produced a draft color proof of the map. A wall-sized multi-color map depicting Pacific Basin Tsunamis (1900-1983) will be available in July 1984. This map will show the location of the earthquake epicenters of tsunamigenic earthquakes in the Pacific Basin, the location of earthquakes of magnitude 7.5 and greater which did not generate tsunamis, the magnitude of the tsunamigenic earthquakes, and the magnitude of the resulting tsunamis. More information about an event will be available in a table describing the location, depth and magnitude of the earthquake, the tsunami magnitude, source region name, cause of tsunami and a reference. A table of destructive events of the twentieth century will also be included on the map. A booklet containing pre-twentieth century tsunami data will be published later. The map will also show representative areas which have experienced tsunami run-up heights of 1.5 or more. The run-up heights, earthquake locations and information in the tables may be cross referenced by the event number.

As part of the mapping project, we have generated a digital file of tsunamis around the Pacific. This allows easy searches and plots of frequency of occurrence of each region, of any wave height, of any fatality level, or of areas affected by any tsunami.

C. Tasks to be completed

- Publication of map in July 1984

- Compilation of data relevant to tsunamis in Chile. This will be shared with the Chileans to revise their "Chilean Tsunamis" publication. The material in English could be used as a model for other national efforts.

° A companion pamphlet to the map will be produced describing causes of tsunamis, operation of warning systems, and descriptions of major tsunamis.

° The digital file will be completed and graphics prepared of its contents as examples of its uses.

D. Summary

The tasks are on schedule. As a result of the advance work done by the Chileans, the work may achieve more than originally planned. The digital file used to produce the map is proving to be more flexible than anticipated. This allows a range of analyses and graphics not originally conceived.

J. F. Lander
May 8, 1984

Pre - Event

Data Analysis

THRUST

SAI

Section 1
INTRODUCTION

Tsunamis are long ocean surface waves generated by sudden displacements of large volumes of water. Most tsunamis are caused by shallow-focus submarine earthquakes. Major tsunamis do not occur very often, but when they do occur, they can quite easily become large-scale catastrophes.

A tsunami always poses a threat to coastal areas close to the epicenter of the earthquake which generates it. Major tsunamis can also threaten coastal areas thousands of kilometers away from their source, but in this report we are concerned only with the close-by or near-field threat.

A single tsunami can cause death, injury, and destruction in a number of ways. The most obvious threat is from the inundation of low-lying coastal areas as the tsunami propagates slowly, implacably inland. A second threat stems from the force of waves breaking against obstacles in the path of the tsunami. A third, and in some cases the most serious, threat is posed by the flotation of objects varying from small pieces of debris to large ships and the impact such objects can have when they are driven against coastal structures.

Many steps can be taken to reduce the threat of damage and destruction due to tsunamis. Local and national governments can plan ahead to reduce or eliminate residential and commercial development in areas subject to tsunami inundation. They can devote resources to the placement of a wide

variety of barriers designed to dissipate or divert wave energy before it can reach threatened areas. They can also develop systems and infrastructures designed to detect local tsunamis and issue appropriate warnings rapidly enough to allow threatened populations to take precautions necessary to save themselves. This latter tool is the purpose of the THRUST program, but all of these steps for reducing tsunami threat must be based on a thorough analysis of the threat prior to its occurrence. This report discusses one technique for conducting such analyses and its application in the pre-event phase of the THRUST program.

Section 2
VALPARAISO, CHILE

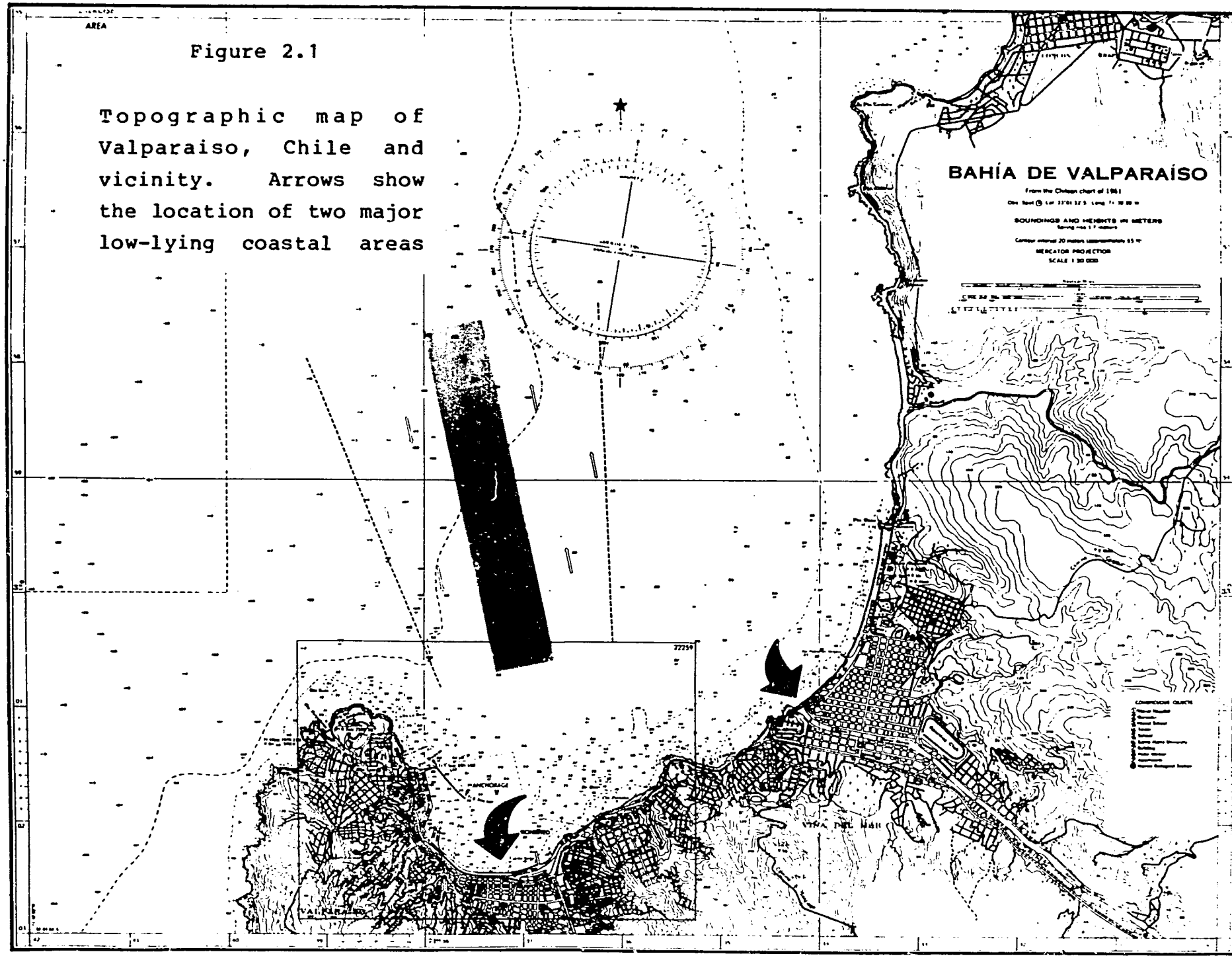
Valparaiso is a major port city on the Chilean coast, located northwest of the capital of Santiago. Several hundred thousand people live in Valparaiso and adjacent Viña del Mar. The city is a major seaport and fishing center, as well as a region of textile, chemical, and cement manufacturing. The Chilean Navy also has several major installations in Valparaiso. Several kilometers north of Valparaiso, at the mouth of the Aconcagua River, lies the resort area of Concón.

A topographic map of Valparaiso/Viña del Mar (Figure 2.1) reveals that the area is made up of a series of canyons opening to the Pacific. The port facilities of Valparaiso lie at the mouth of one canyon (indicated by an arrow in the lower center of the figure), while much of the developed area of Viña del Mar straddles the Marga Marga Estuary. Development does extend up the sides of the hills around Valparaiso, but much economically important infrastructure lies in low-lying coastal areas.

The submarine topography off shore of Valparaiso (see Figure 2.2) is fairly smooth. Bahia del Valparaiso is the southern end of a shallow, gently sloping shelf which extends to the north of Concón. The 100-meter contour runs roughly parallel to the coast. This gentle slope carries seaward to about the limit of 200-meter depth water; beyond that point the bottom begins to drop off sharply to form the eastern wall of the Peru-Chile Trench.

Figure 2.1

Topographic map of Valparaiso, Chile and vicinity. Arrows show the location of two major low-lying coastal areas



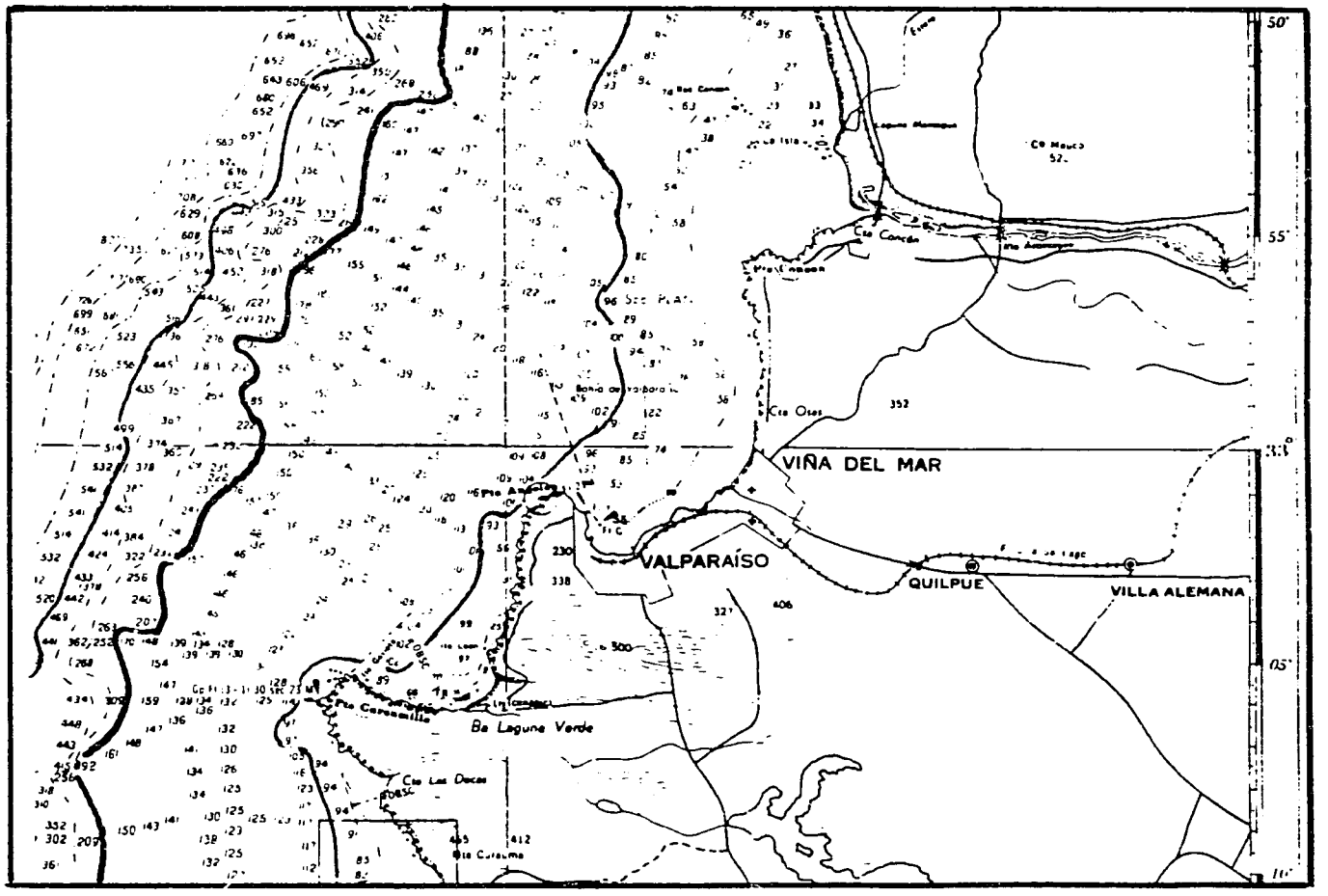


Figure 2.2. Submarine topography offshore of Valparaiso

This portion of Chile is seismically active, lying, as it does, in a subduction zone formed by the thrusting of the oceanic Nazca tectonic plate under the continent. Great earthquakes (magnitude 7 or greater) are fairly common, with rupture zones as long as 30 kilometres. McCann et al. (1978) place Valparaiso in the middle of a seismic gap with an estimated recurrence interval of 85 years. An earthquake in 1906 (magnitude 8.2) was the last event occurring throughout the gap. A magnitude 7.9 earthquake in 1971 ruptured the portion of the gap north of Valparaiso. McCann et al. speculate that the next major earthquake in the area will occur in a region that includes Valparaiso. Since ruptures in this portion of Chile generally run from north to south, the initial disturbance of such an event would probably center around the Valparaiso area.

The coast of Chile is highly tsunami-prone. The Chilean Navy Hydrographic Office has ennumerated 104 tsunamis which have affected the Chilean coast between 1570 and 1975 (IHA Pub. 3016). Of these, only 19 originated in areas other than the Chilean coast. The rest were of local origin. Twelve of these local tsunamis were observed at Valparaiso. One, in 1730, was reported to have severely damaged the city.

Although Valparaiso, in contrast to some other Chilean cities, does not seem to have a history of repeated tsunami-produced destruction, it is clear that the threat exists. If tsunamis generated from distant earthquakes, such as the 1946, 1952, and 1957 earthquakes in the Aleutian Islands region, can produce 2-meter high waves and some coastal flooding in the city (Berninghausen, 1962), then the potential for tsunami destruction arising from a local tsunami, especially one generated to the west or northwest, must be high.

The potential threat may, indeed, be great, but the historical record is sketchy and detailed depictions of damage are rare. Even highly meticulous records might be of little use if a threatened city has undergone intense development in the years since the last destructive event. One technique available for laying the groundwork for detailed assessments is to numerically simulate the levels and locations of wave inundation due to a possible tsunami. The use of this technique is described in the next section.

Section 3
MODEL TECHNIQUE

The propagation of a tsunami from its source to a coastal area and the resulting flooding (if any) can be mathematically depicted with reasonable accuracy by sets of coupled partial differential equations. Analytical solutions of these equations are usually unattainable, except in certain very simplified cases. However, solutions can be closely approximated, even in very difficult cases, by means of a number of different techniques well-suited to use by digital computers. These solutions, referred to as simulation models, can provide great insight into the nature of the process under study. One such simulation model, called SURGE II, has been applied to the problem of examining the impact that a catastrophic, locally generated tsunami could have on Valparaiso. The workings of the model have been described in detail elsewhere (Reid et al., 1977) and need not be repeated here. The two major items of information needed to implement the model do bear looking into, however.

In the first place, if a model is to realistically describe the evolution of a tsunami from its source to its termination, it must be provided with an accurate rendition of the shape of both the sea floor over which the wave travels and the shape of the ground it potentially floods. This is accomplished by compiling the bottom depths and land elevations of the area of interest. For mathematical reasons the model cannot use a continuously varying depiction of topography, but must deal with discrete depths/elevations which have been averaged over a certain finite area. In the case of the Valparaiso simulations, the topography is

provided on a model grid made up of grid squares measuring 0.5 km on a side. Contours of elevation derived from the model grid shown in Figure 3.1. Although detailed comparison with the topographic chart in Figure 2.1 is not possible because of the averaging process, it is apparent that the major relief features of the area are adequately depicted.

Knowledge of the nature of the numerical grid used in the model is the key to understanding of the results. Any topographic data point in the model represents the average depth/elevation over the appropriate 0.5-km box. Quantities calculated by the model likewise represent average quantities over the same areas. A calculated wave elevation of, say, 3.1 meters above sea level (MSL) does not mean that the water everywhere in the appropriate grid would be uniformally 3.1 m above MSL. Rather it means that the water depth on that particular grid block averages roughly 3.1 m. In the same sense, if flooding is indicated by the model in a grid block which contains both high and low points, this does not necessarily imply flooding at the highest elevations. The point is that simulation results must not be taken too literally, but should be interpreted with a measure of common sense.

The second type of information needed to conduct tsunami simulations concerns the nature of the waves approaching the threatened area under study. If the tsunami is generated a great distance from the target, then this information consists of a description of the wave elevation as it changes in time along the outer (seaward) side of the model grid (which, of necessity, has finite extent and cannot extend all the way to the source area). If, on the other hand, the tsunami is generated close to the target (i.e., within the extent of the model grid), then information on the

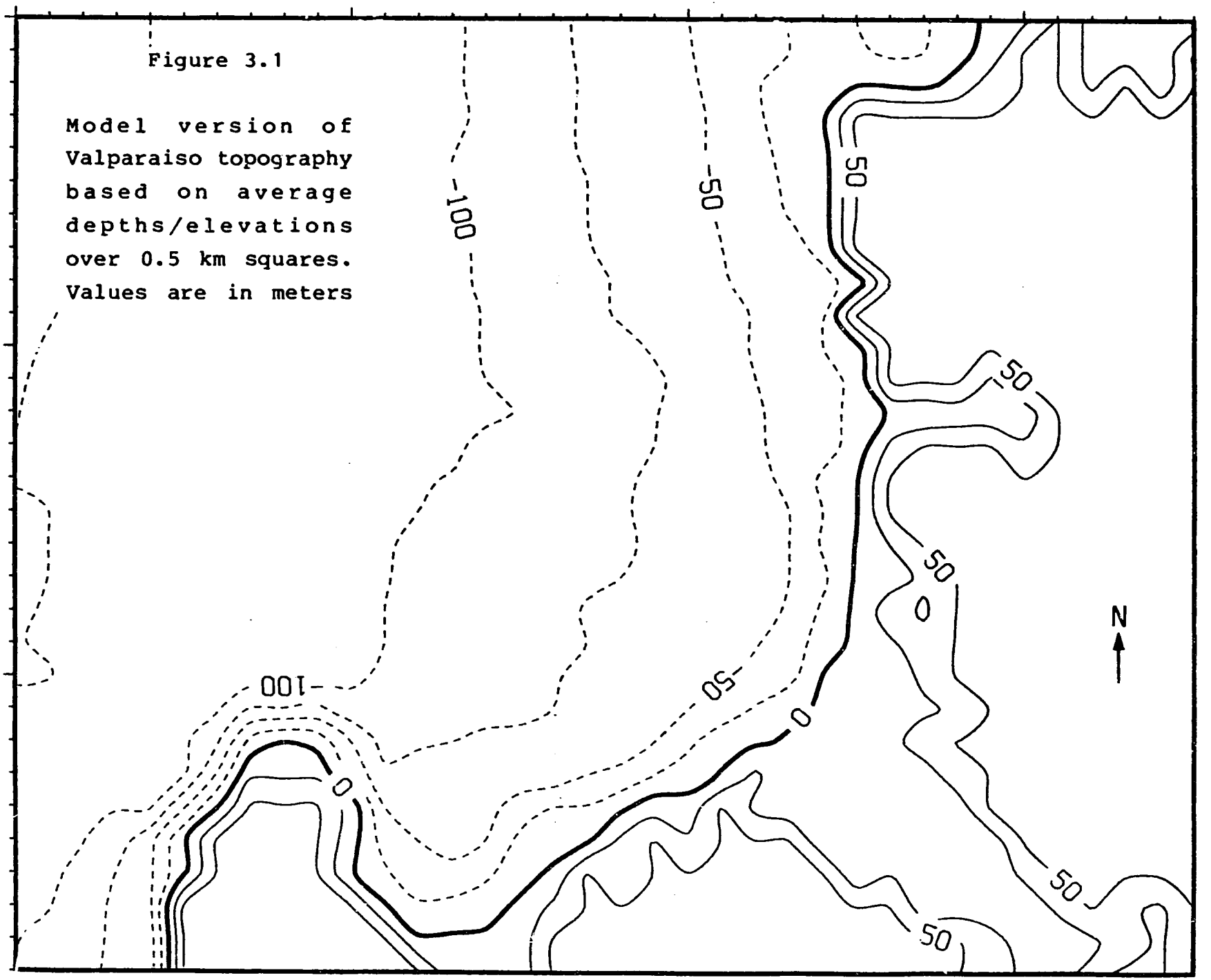


Figure 3.1

Model version of Valparaiso topography based on average depths/elevations over 0.5 km squares. Values are in meters

surface waves is derived from estimates of the way in which the subsurface earthquake dislocates the sea floor (and thus moves a volume of water sufficiently large to cause a tsunami).

The depiction of the seafloor uplift due to a major thrust earthquake is not a trivial matter. Several different models exist which can calculate uplift patterns based on assumptions about such parameters as the depth, fault length, fault width, and dip angle of the earthquake. The problem becomes one of making intelligent choices for specifying the problem. Fortunately, in the case of the Valparaiso simulations, the choices are fairly easy to make once the purpose of the simulations is clearly stated.

The goal of these simulations is to provide evidence which will assist local officials in planning for a catastrophic tsunami. Initially, then, we want to provide estimates based on a worst-case scenario. This is especially true when we consider that our ability to distinguish between levels of intensity of tsunamis in real-time is minimal. Every potential tsunami must be treated as a worst case when allowable reaction time is short.

The worst tsunami recorded in this century in South America arose from the great earthquake in southern Chile on 22 May 1960. This rupture extended over 900-1000 km along the Peru-Chile Trench, generated waves as high as 12 m in Chile, and caused great amounts of death and destruction throughout the Pacific, especially in Hawaii and Japan. The mechanics of the earthquake itself have been heavily studied (see, for example, Plafker, 1972) and it is possible to recreate the approximate sea floor uplift pattern. If we

assume, as is reasonable, that uplift of the sea floor results in an essentially identical uplift of the sea surface, then specifying the sea floor pattern will provide the initial surface perturbation from which the resulting waves propagate.

One piece of information which is not clear from seismic studies is how close to shore the uplift extended. This is vital, because of the finite length of time it takes the wave to reach shore. One way of estimating this distance from shore to source is to compare observations with model reconstructions of the event. Since the worst effects from this tsunami occurred within the generating region (which did not include Valparaiso), the logical course was to simulate the tsunami attack on an area south of Valparaiso, within the source zone. After consulting with officials of the Chilean Navy Hydrographic Institute, who were able to provide valuable charts and data, we chose the area of Puerto Corral, a port city west of Valdivia, Chile. Figure 3.2 shows the topography of the area. Two key points are noted by arrows: Corral (left arrow) and Pta. Niebla (right arrow). Figure 3.3 shows the model topography of the same area based on 1-km grid spacing.

The available tsunami data for simulation of this event is quite sparse. By reviewing several relevant documents (primarily Saint-Amand, 1961, and Japan Meteorological Agency Technical Report No. 26, 1963), we isolated two key facts: the wave arrived at Pta. Niebla approximately 15-20 minutes after the earthquake, and the maximum wave elevation at Corral was approximately 10 m. A number of simulations were run in which the earthquake-induced displacement was

Figure 3.2

Topographic map of the area around Bahia Corral, Chile. Arrows locate Puerto Corral (left arrow) and Pta. Niebla

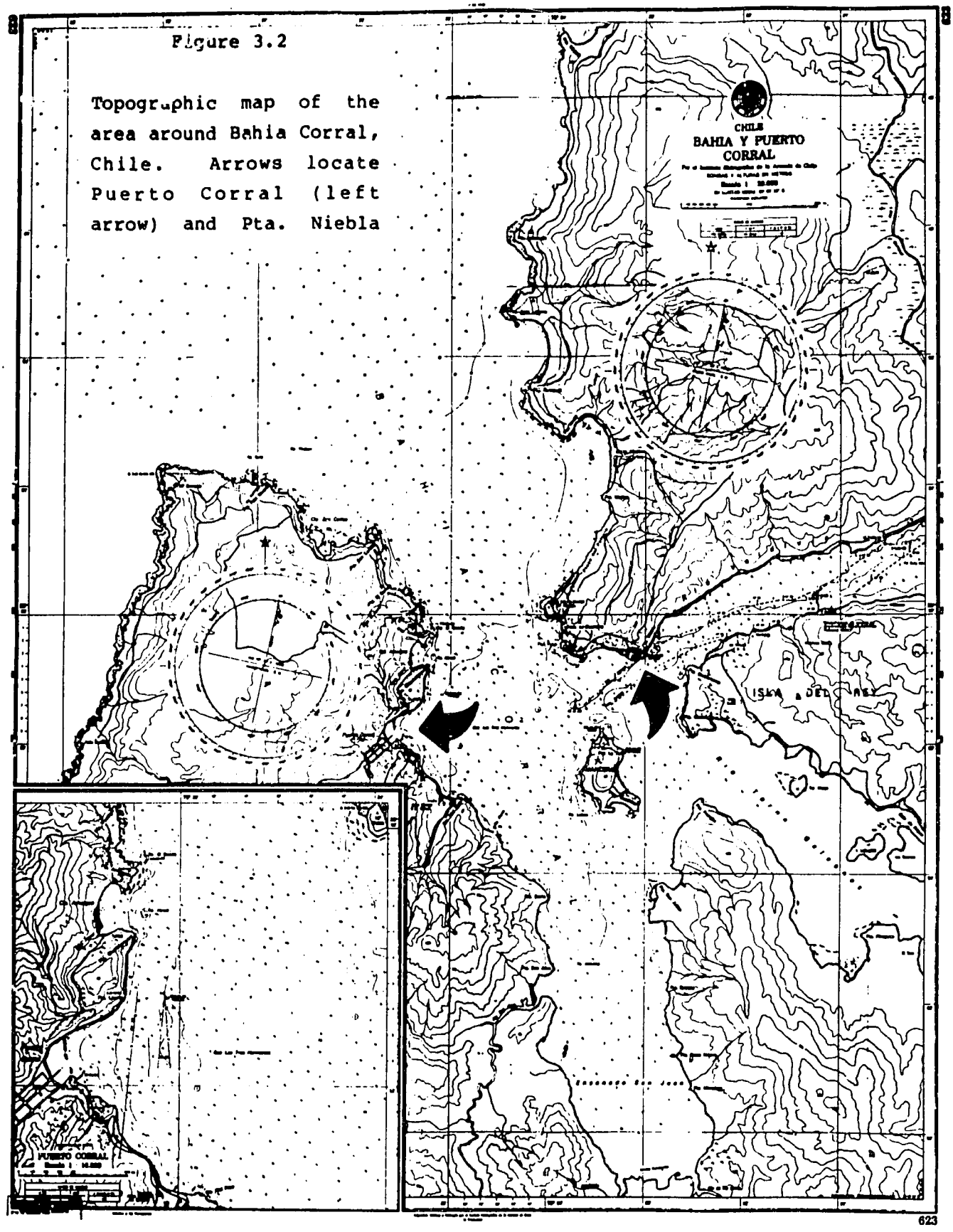
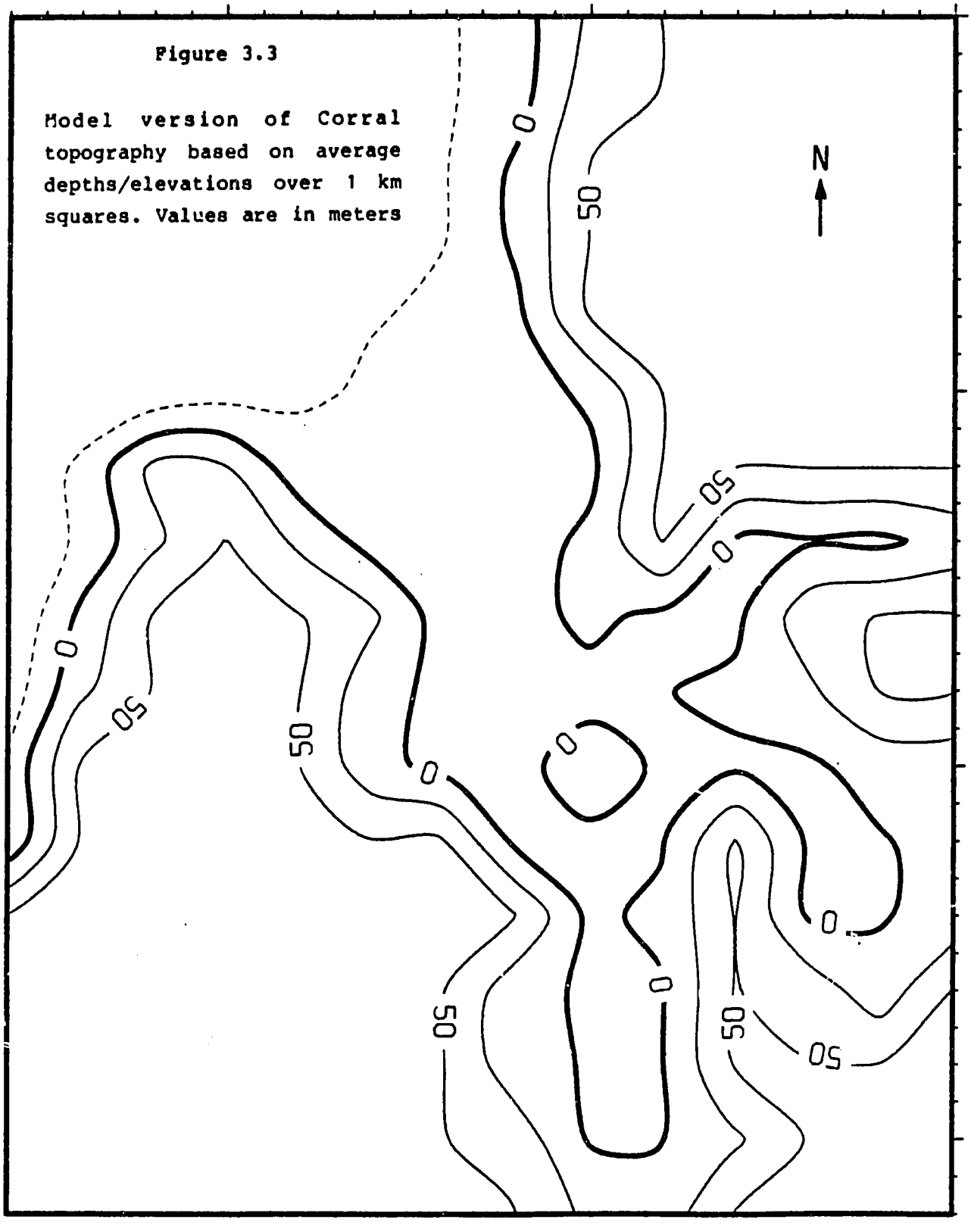


Figure 3.3

Model version of Corral topography based on average depths/elevations over 1 km squares. Values are in meters



patterned after Plafker's (1972) study and the location of the source was varied to improve the comparison between the model results and historical observations.

In Figure 3.4 we see the results of the best of the simulations. The red areas show the extent of flooding predicted by the model. Since little data on flooding exists in the historical record, we can do little by way of comparison. The flooding around Corral seems to dovetail well with observations. The box in the upper left shows that the calculated results compare well with observations.

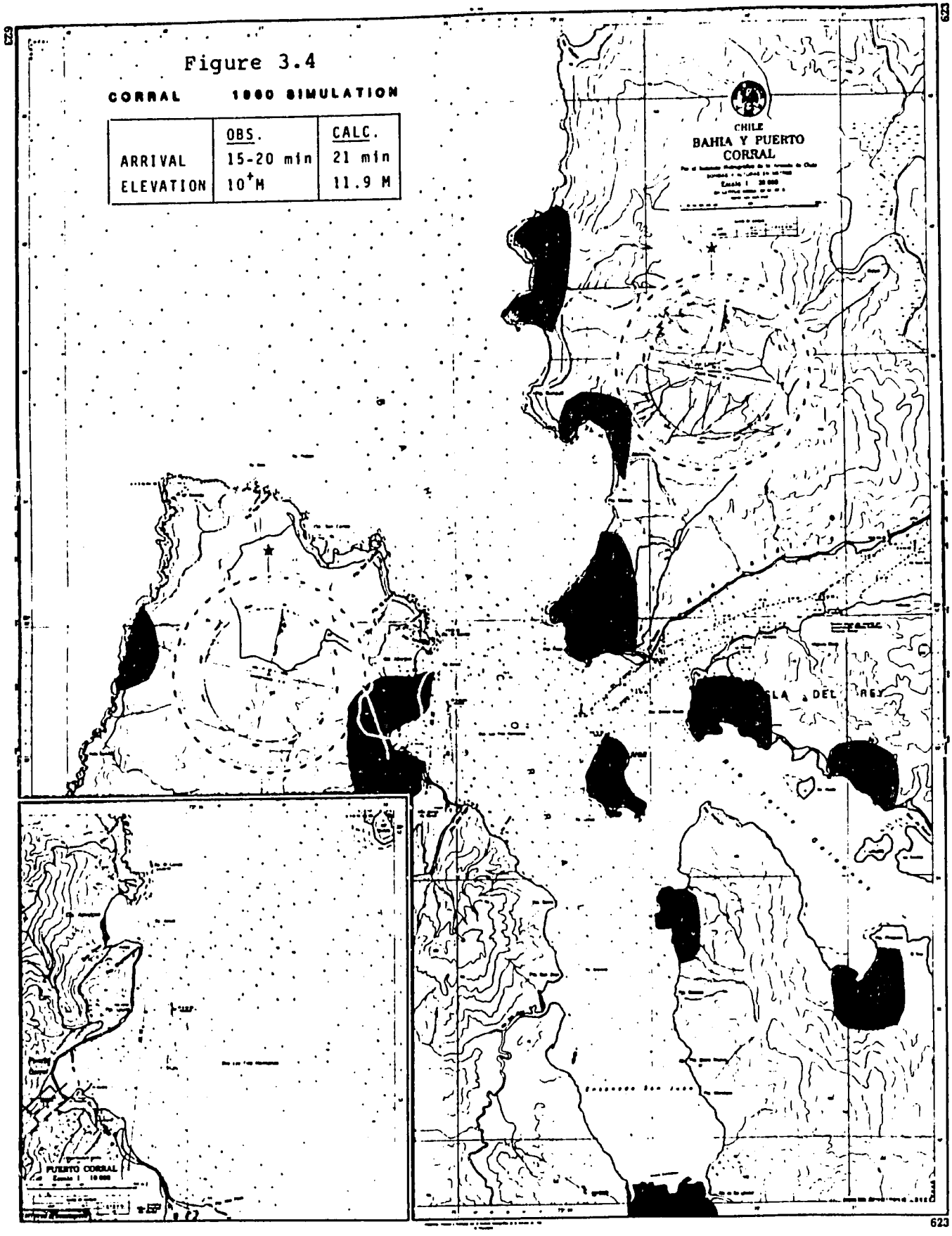
The particular source pattern which produced this simulation is depicted in Figure 3.5. The region of maximum uplift ($\simeq$ 15.7 m) lies 20-25 km offshore and the line of maximum uplift runs parallel to the coast.

This process of comparing observed and calculated tsunamis for Corral allowed us to specify the forcing function for the Valparaiso simulation by assuming that the worst case for Valparaiso would be an event comparable to the 1960 earthquake, but occurring 20-25 km offshore, rather than several hundred kilometers south, as actually happened in 1960. We will detail these resulting worst case simulations and their implications in the next section.

Figure 3.4

CORRAL 1960 SIMULATION

	OBS.	CALC.
ARRIVAL	15-20 min	21 min
ELEVATION	10+M	11.9 M



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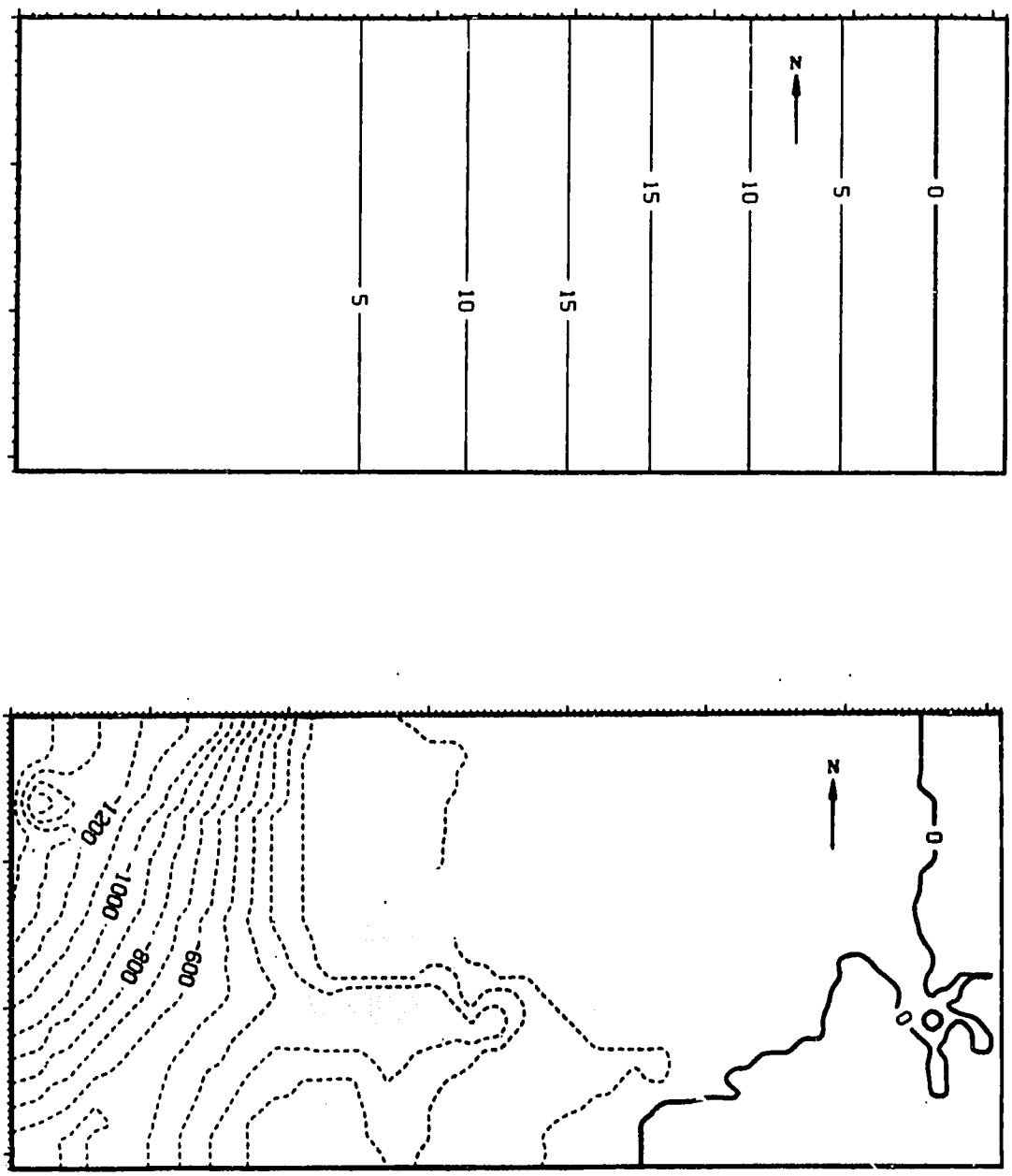


Figure 3.5

The uplift pattern which produced the results in Fig. 3.4. The upper figure is the uplift pattern. The lower figure is the topography drawn to the same scale for comparison

Section 4
VALPARAISO SIMULATIONS

As indicated in the previous section, the worst-case simulations of tsunamis at Valparaiso were patterned after the tsunami generated by the 1960 Chilean earthquake. Test simulations of the effects of this tsunami in Corral lead us to conclude that the maximum sea floor displacement was approximately 15 m and that it occurred quite close to the shore (within 25 km.) These factors lead to the specification of an initial case with subsurface displacement pattern as shown in Figure 4.1. The major axis of the uplift runs essentially north-south, parallel to the coastline. The resulting initial waves approach Valparaiso from due west. If this event were to actually occur, Valparaiso would be buffeted by secondary and later waves arriving from displacement areas farther north and south of the model zone. The model as it is presently configured is not able to reproduce these waves; this is not considered a deficiency in the simulations, since the initial waves from such a catastrophic tsunami would in all likelihood be the most destructive.

Note that the uplift pattern extends onto the shore. St. Amand (1961) postulated that this occurred during the 1960 earthquake also. This displacement pattern is translated by the model into a shift in both the bottom topography prior to uplift and a shift in the (initially flat) sea surface. If the bottom uplift is sufficient to lift the sea floor in a grid above sea level, then the model treats that grid block as land.

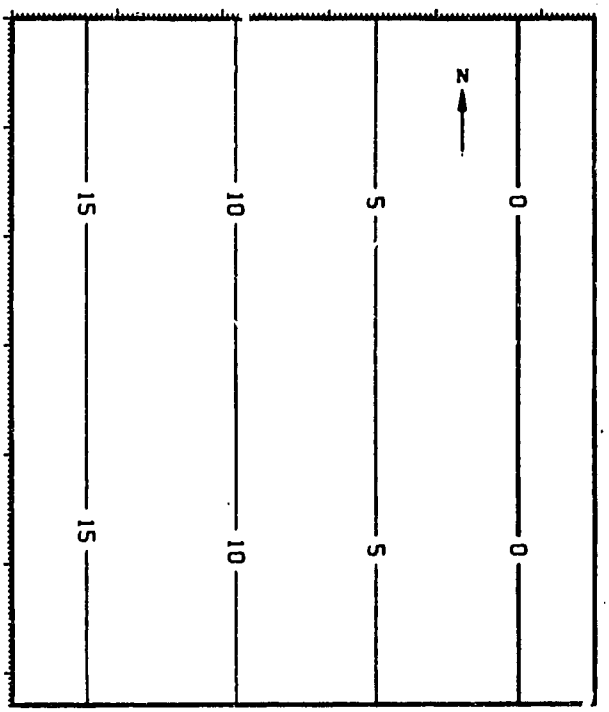
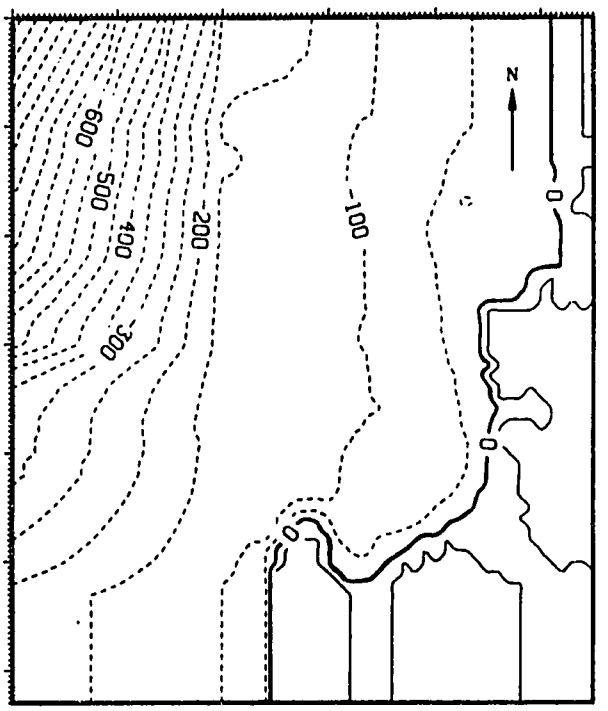


Figure 4.1

The uplift pattern for a catastrophic tsunami approaching Valparaiso from due west. The lower figure is the Valparaiso topography drawn to the same scale for comparison



The flooding pattern that results from this tsunami is depicted in red in Figure 4.2. Note that the main valleys are flooded for a good distance inland. Inundation for distances of several kilometers from the shore is not uncommon in major tsunamis. During the relatively small 1983 Japanese tsunami, for example, flooding was noted nearly a kilometer inland.

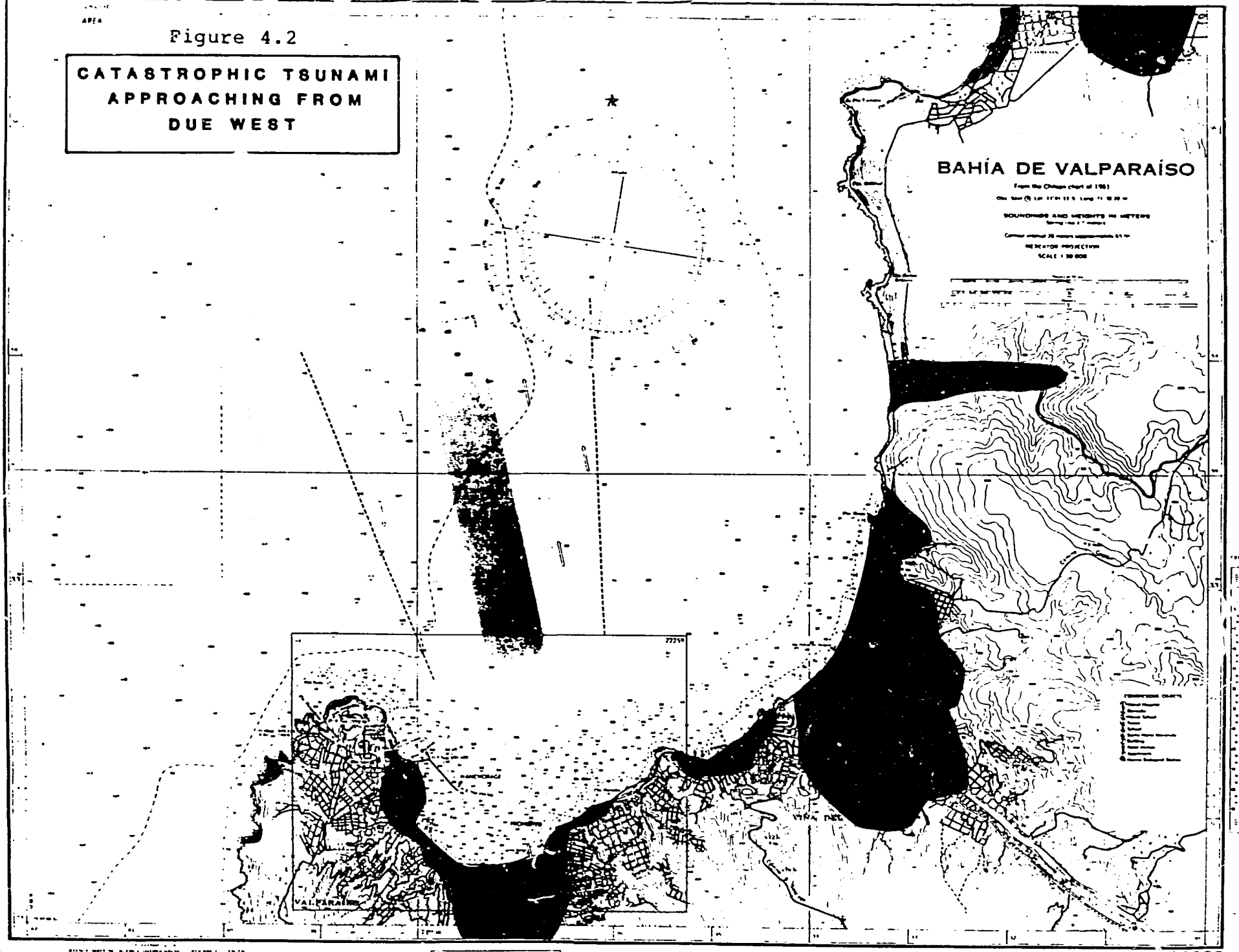
The break wall at the southern end of the harbor has been incorporated into the simulation as a "sub-grid scale barrier." At its highest point, it is approximately 10 m above sea level. This height is not sufficient to prevent inundation from surges greater than 10 m high. The same is true of the sea wall which rims the southern edge of the harbor.

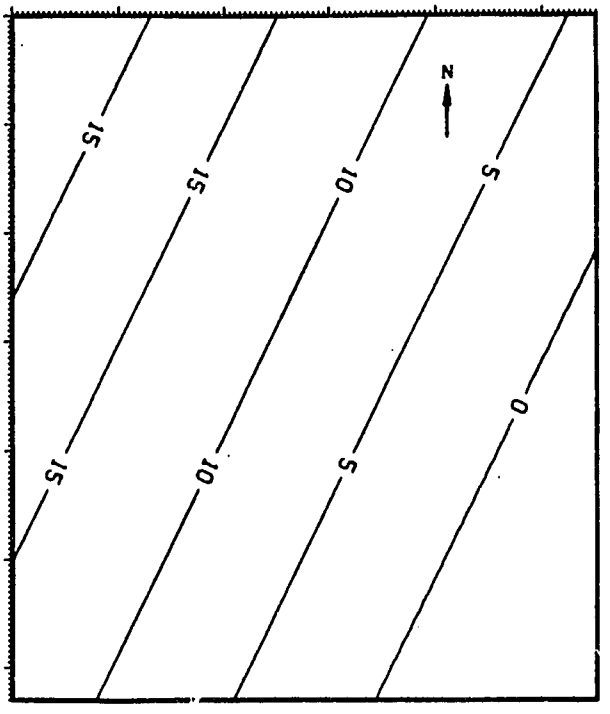
The landward extent of the flooding in this tsunami should be viewed as a probable overestimate of the actual flooding from such an event. The model is not able to adequately depict the presence of densely packed commercial buildings likely to be found in a developed seaport such as Valparaiso. These concentrated structures would slow the initial inland rush of the tsunami and allow some dissipation of the wave energy. It is not clear how much of an overestimate these calculations produce, since the data base for such considerations in urban areas is regrettably small. It is probably best, in discussing worst cases, to assume that the overestimate is small.

One other case was considered for this interim report -- that of a local tsunami approaching Valparaiso from the northwest (as depicted in Figure 4.3.) The 1730 tsunami, cited earlier as devastating the city, apparently approached from this direction.

Figure 4.2

CATASTROPHIC TSUNAMI APPROACHING FROM DUE WEST





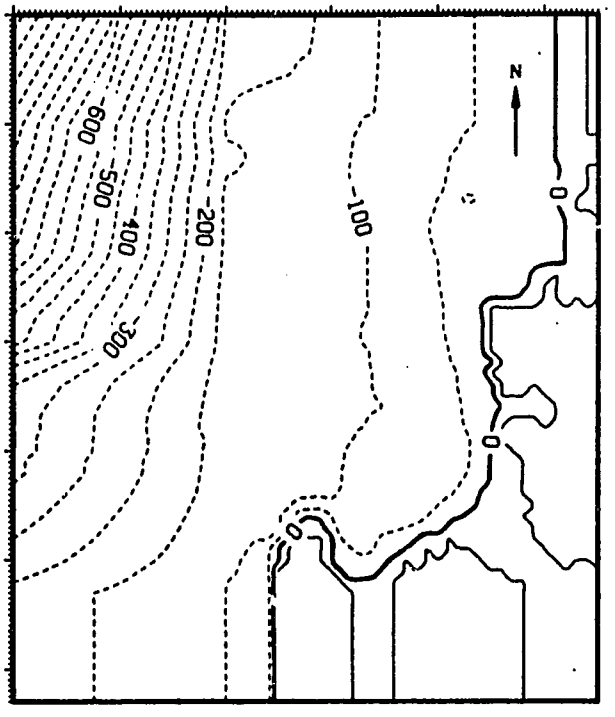


Figure 4.3
The uplift pattern for a catastrophic tsunami approaching Valparaiso from the northwest. The lower figure is the Valparaiso topography drawn to the same scale for comparison

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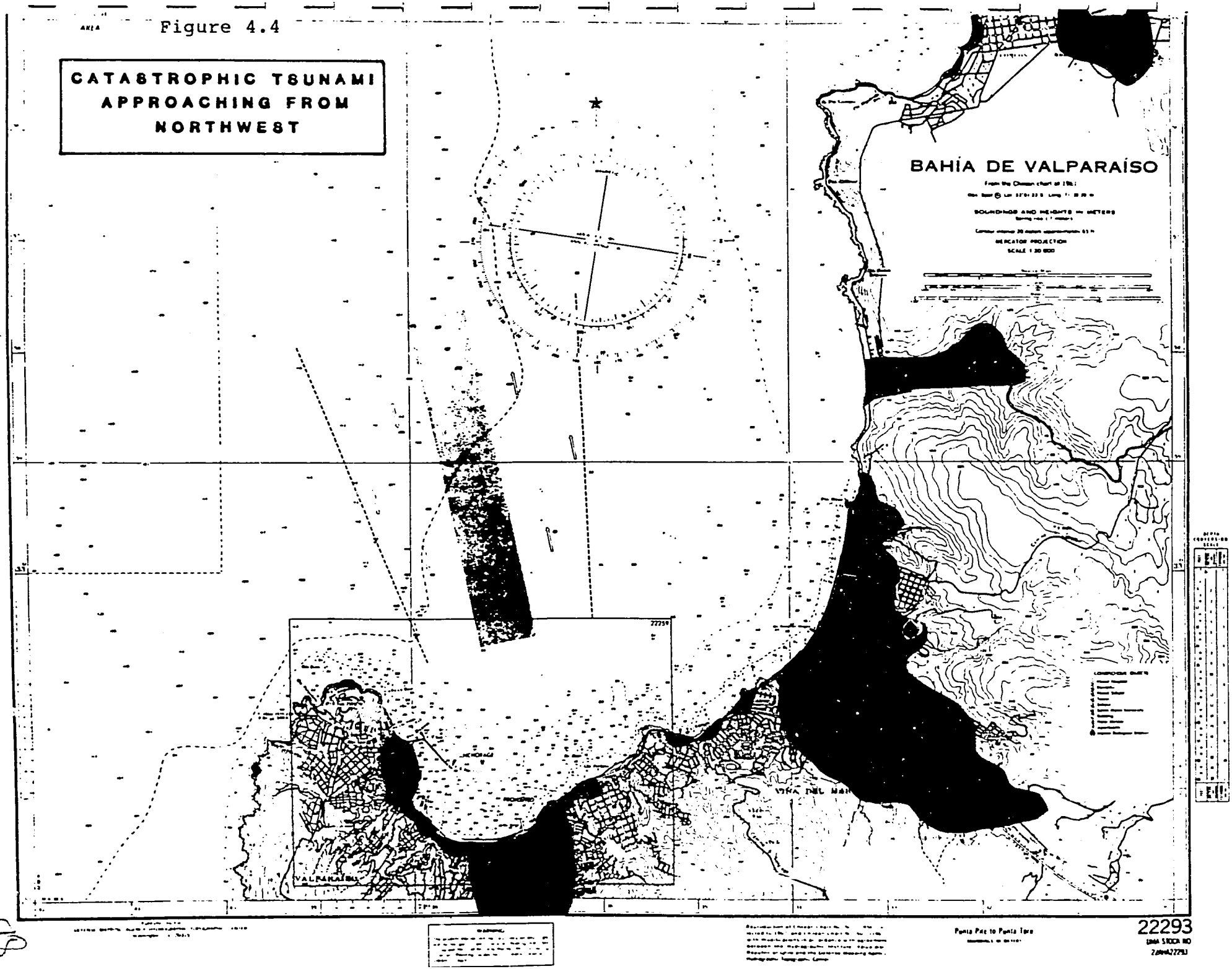
The calculated flooding from this tsunami is shown in Figure 4.4. The pattern is the same as that of the previous simulation. The flooding extends somewhat further inland in Viña del Mar because the direction of approach is closely aligned with the valley axis.

No tsunami approach from the southwest was modeled for this report. It does not appear from the historical record that tsunamis from that quarter have posed much of a threat. The 1960 tsunami produced waves of less than 2 m at Valparaiso.

It is clear from these two simulations that the threat to Valparaiso from local tsunamis approaching from the west and northwest is quite great. The major lowland areas along the coast are subject to extensive flooding if the waves are high enough to breach existing protective structures. The major rail link to Santiago runs along the shoreline and could be quite easily broken in a major tsunami. It appears that only a few major roads, capable of carrying evacuees out of the city and relief supplies in, run inland away from the coast, and these are in heavily threatened areas. Factors such as these should be taken into account in laying out tsunami warning, mitigation, and relief plans.

The development of a tsunami warning system and its integration into the total disaster response infrastructure requires consideration of a large number of diverse factors. The simulations described in this report, and subsequent simulations which arise from it, should provide a framework within which to examine these factors and develop the techniques needed to address them.

Figure 4.4


CATASTROPHIC TSUNAMI
APPROACHING FROM
NORTHWEST
BAHIA DE VALPARAISO
22293

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Pre - Event

Information Dissemination

THRUST

ITIC

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ITIC's Progress Report on the THRUST Project
by
George Pararas-Carayannis

1. BACKGROUND

A prototype system has been proposed for tsunami warning purposes in Chile. The proposed system, Tsunami Hazard Reduction Utilizing System Technology (THRUST), will be used to demonstrate the adaptation of advanced technology in satellite communications in the dissemination, reception, and display of tsunami warnings in that country. The proposed prototype early Tsunami Warning System makes use of advanced water level and seismic sensors instrumentation transmitting data in real time via the Geostationary Operational Environmental Satellite (GOES), West system. This prototype Early Tsunami Warning System is presently being developed but before its installation in Chile, it will have to be tested and evaluated, not only in terms of technological efficiency, but also in relation to the realities of the existing tsunami warning network.

In designing a complete regional system, warning dissemination has to be based on complete and thorough examination of the host country tsunami response infrastructure to determine lines of responsibility, how the system works, where it can be improved, what its basic requirements are, and how best to integrate the early warning technology into it.

ITIC was asked to assist in the development of this information and in the development of a comprehensive emergency standard operations plan for Chile with special emphasis on Valparaiso. The purpose of this plan is to achieve effective preparedness and understanding of the tsunami hazard in Chile and to organize in a systematic fashion a prompt, fully coordinated program of tsunami warning dissemination which will insure prompt and flexible response by the populace, thus minimizing loss of life and property when the disaster strikes.

A site visit was completed in early October 1983 by a THRUST team to collect the necessary information and data. While in Chile, the team met with the Chilean counterparts on the project, and planning and coordination meetings were held at the U.S. Embassy, at the University of Chile, and at the National Emergency Office in Santiago. In Valparaiso, coordination meetings were held at the Headquarters of the Chilean Tsunami Warning Center at the Navy Hydrographic Institute. The Hydrographic Institute is the lead agency in Chile responsible for data collection and tsunami warning dissemination.

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In Santiago, the project was coordinated with the Directors and staff of the National Emergency Office, and of the Department of Geophysics of the University of Chile. A wealth of information, data, and publications were collected during this visit. These documents were later organized and translated. The site visit also permitted a close observation of the infrastructure of the existing Tsunami Warning System.

2. SCOPE OF WORK

Completion of the THRUST pilot project will require approximately three years. During the first year, ITIC was asked to concentrate on evaluating the Tsunami Warning System and to make recommendations for integrating the THRUST program with the local system. This general objective was broken down into the following specific elements:

A. Examination of the infrastructure of disaster response organizations in the host country.

B. Communications among disaster response organization.

C. Tsunami Assessment capability - Strengths and weaknesses.

D. Effectiveness of present tsunami warning procedures, and levels of public hazard awareness.

3. PROGRESS

A. Infrastructure of Disaster Response Organizations in Chile

The National Tsunami Warning System in Chile was officially inaugurated on 30 July 1964 under the jurisdiction of the Hydrographic Institute of the Chilean Navy. Also in January 1965 the Hydrographic Institute was designated as the official representative of Chile to the International Tsunami Warning System in the Pacific.

Although the Hydrographic Office has overall jurisdiction over the National Tsunami Warning System in Chile, there are several other organizations involved in data collection, warning dissemination, and population evacuation, under different government ministries (Table 1). A comprehensive national emergency plan exists for Chile, dealing with all emergencies and disasters. Figure 1 is a government organization plan of data and information flow in case of earthquakes or tsunamis. Each ministry, and each organization within each ministry, has its own emergency plan which can be implemented in the case of a natural disaster.

Figure 2 and Table 2 describe the different emergency plans in existence at the executive and regional levels. Although a number of organizations within the different ministries play an important role in the event of a natural disaster, there are only three organizational entities which play a very important role in geophysical data collection following a large earthquake, in the analysis and interpretation of the data, in the issuance of watches and warnings, and in the implementation of the warning information to safeguard life and property.

In addition to the Hydrographic Office of the Chilean Navy which has overall responsibility for the National Tsunami Warning System, the Office of National Emergency of the Department of Interior (ONEMI), and the Geophysical Institute of the University of Chile in Santiago are the other two organizations. Other government agencies play important roles primarily in the post disaster phase of relief and reconstruction. Describing the activities of these organizations is outside the scope of this report. Regional offices of ONEMI, Naval Operational Offices, local organizations such as the Fire and Police Departments, volunteer groups, and the Media, assist in public information, additional dissemination of tsunami information to the public, and in the evacuation.

Chilean Hydrographic Institute

The Instituto Hidrografico of the Chilean Navy was established in May 1874 for the purpose of preparing maps that would assure the safety of maritime navigation in the coastal zone and in improving the knowledge and study of the seas for the economic development of the country. The National Tsunami Warning System in Chile was officially established on 30 July 1964 and the responsibility for its operations was given to the Hydrographic Institute of the Chilean Navy. Also in January 1965 the Hydrographic Institute was designated as the official representative of Chile to the International Tsunami Warning System in the Pacific. Presently, the Hydrographic Institute utilizes mareographic stations at Arica, Antofagasta, Caldera, Easter Island, Coquimbo, Valparaiso, Talcahuano, Puerto Montt, Punta Areas, Puerto Williams and Base Arturo Prat (in the Antarctic Chilean Territory). Figure 3 shows locations of tidal stations that is presently operating in the Chilean Tsunami Warning System. The Institute does not operate seismic stations and relies on the Geophysical Institute of the University of Chile for geophysical data.

As early as 1965 the Hydrographic Institute established general instructions for the National Tsunami Warning System in Chile -- a plan which has been implemented but has had limited success because of the vast expanse of the coastal zone of the country and inadequate tsunami detection instrumentation and communications.

GH

This plan was considerably improved in 1975 and a new updated plan was published. This plan reflects improvements that were made in the country for a 10-year period and outlines the procedures to be followed in the event of the large earthquake and tsunami. The procedures outlined in this plan are based on data and information which may be collected locally or which may originate from the Pacific Tsunami Warning Center in Honolulu. The present Tsunami Warning System is adequate in providing sufficient protection for tsunamis which may originate from distant sources. It relies heavily on the Pacific Tsunami Warning System.

For tsunamis generated in the region, the National Tsunami Warning System, in its present status, is unable to respond and provide warning information in less than one hour for a locally generated tsunami.

Office of National Emergency of the Ministry of Interior (ONEMI)

The Office of National Emergency of the Ministry of Interior (ONEMI) was created by Public Law 369 in 1974. Its major objective is to plan, coordinate, and execute the necessary activities for the prevention or solution of problems resulting from national catastrophes. The national plan of emergency, published in 1977, outlines the active participation of all the ministries, organizations and institutions in the public and private sectors as well as the voluntary organizations for activities which will prevent or help solve problems caused by emergencies such as natural hazards or those created by men (Figures 1,2,3). In relation to these objectives ONEMI is presently developing, among other things, a project intiated in 1979 entitled "Program of National Mapping of Risks and Prevention of Catastrophes" which has as its end goal the identification and control of the different disasters that affect the country. In order to cover the entire country, ONEMI has organized regional, provincial and local emergency Committees under the jurisdiction of regional directors, governors and mayors. These Committees coordinate the use of local resources and for technical support are functionally an extension of ONEMI.

ONEMI deals with all disasters such as earthquakes and tsunamis, fires, droughts and flooding, accident involving a large number of victims, important interruption of vital public services, hurricanes, volcanic eruptions and problems of atomic radiation.

The Geophysical Institute of the University of Chile

The Geophysical Institute of the University of Chile operates a number of seismic stations and seismic accelerometers throughout the country primarily for research purposes and for understanding the seismicity of the region. Organizationally the Geophysical

Institute is under the University of Chile which is a governmental institution and it is the only seismological organization in Chile. The Geophysical Institute has been responsible for providing seismological information on earthquake epicenter and magnitude to the Navy Hydrographic Office. However, it wasn't until recently that a full, around-the-clock, coverage at the Geophysical Institute enabled the continuous data flow to the Hydrographic Institute.

B. Communications Among Disaster Response Organizations

The Hydrographic Institute communicates with all the Naval Operations Offices in the country via dedicated telephones, radio and telex. It also communicates with radio and telex with ONEMI in Santiago. Different naval port authorities are responsible for reporting data to the Hydrographic Institute in Valparaiso from the tide gauges in the event of a large earthquake.

ONEMI maintains a comprehensive communication system within the country which includes telex and telephones with all its subsidiary offices through the country, as well as radio communications and telephone communications with all the public, private and voluntary services. It has direct telephone contact with the Department of Seismology of the University of Chile and it has direct telephone lines with the Police and Fire Departments. Tsunami watches and warnings, as well as earthquake information, are disseminated to the public through the Naval Commands by radio and through ONEMI by radio and the phone to local officials (Fire and Police Departments), and the Media.

C. Tsunami Assessment Capability -- Strengths and Weaknesses

Administratively the National Warning System in Chile is well organized. For distantly generated tsunamis, where time delays in communications of data and information are not very critical, the System can be expected to function well, and to provide adequate warning information to the public so as to minimize the effects of a destructive tsunami. For such distantly generated events, the National Tsunami Warning System relies heavily on input provided by the Pacific Tsunami Warning Center (PTWC). Communications between PTWC and the Hydrographic Institute of the Chilean Navy have been considerably improved with direct telex communication and direct telephone dialing. Communications via the NASA link in Santiago will soon be discontinued but this is not expected to weaken communications with PTWC.

For locally generated tsunamis, the National Tsunami Warning System cannot provide at the present time warnings in less than an hour after tsunami occurrence. During that hour, extensive damage and loss of life can occur in the coastal region of generation.

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Furthermore, a large earthquake in the region can be expected to disrupt destructively electrical power and telephone, and telex communications. Only battery-powered radio communications in certain areas near the source of generation can be expected to function. If the earthquake is in the Valparaiso or Santiago areas where critical instrumentation and communications are located, the System may not function effectively in providing promptly the rest of the country with warning information.

These are the major considerations underlying the need for a regional, quick-responding, Tsunami Warning System addressed by the THRUST pilot study.

D. Effectiveness of Present Tsunami Warning Procedures and Levels of Public Hazard Awareness

Organizationally and administratively the National Tsunami Warning Sytem in Chile is one of the best in the Pacific. Both the Hydrographic Institute of the Navy and ONEMI have well organized plans of action in the event of a local or distant potentially destructive tsunami. Emergency procedures are well outlined in reports and operational manuals. Awareness of responsible officials is extremely high and a program of public education and awareness has been implemented by both the Hydrographic Institute and ONEMI. Numerous educational publications have been prepared and distributed by the responsible agencies throughout the country. Public hazard awareness in Chile is extremely high.

In spite of this public awareness and government preparedness to deal with disasters, in the event of a large tsunami serious loss of life and property can be expected. It is an accident of geography, in its proximity to one of the world's most seismic zones (the Peru-Chile trench), and because of its extremely long coastline, that Chile is so vulnerable to the tsunami hazard. The awareness of this hazard is reflected by the degree of preparation responsible agencies have devoted in their planning. Planning alone, however, will not avert the potential threat to Chile's coastal population. Modern technology, instrumentation, and communications must be integrated to this planning to minimize response delays, and damage to conventional communications, and to optimize tsunami warning dissemination. Thus, the need for the THRUST pilot study.

4. SUMMARY AND RECOMMENDATIONS

The need of applying current technological advances to this problem of early warning has been demonstrated. The equipment required to assemble an early warning system is currently available. Other participants in the THRUST study are looking into this. Integrating the THRUST proposed technology into the infrastructure of the existing Tsunami Warning Syester in Chile will

be necessary for effective tsunami hazard management during an actual event. This organizational infrastructure is now well defined, described, and understood. Decisions have been made regarding data collection, data analysis, and information dissemination. Instrument design and placement already have been taken into consideration.

On the basis of information and data gathered during the first year and reported presently, an Emergency System Design must be determined. This System must be practical and its effectiveness must be demonstrated. A great deal of work remains to be done in assembling the plethora of data that has been collected into such emergency preparedness plans, training exercises, etc., as part of a complete working package.

It is not in the scope of the 1st year's report to provide definitive recommendations in the adaptation of the THRUST technology. Such recommendations will evolve after the instrumentation has been installed, another site visit has been completed, and necessary coordination with other THRUST participants has been carried out. In the meantime, a report has been started outlining disaster protective measures that can play a role in mitigating the effects of a tsunami in Chile (or elsewhere for that matter). Finally an operational manual will be prepared describing tsunami response operations and responsibilities to be followed in disseminating rapidly to the population in Chile (Valparaiso, initially) tsunami warning information making use of THRUST technology and instrumentation.

Figure 4 is an idealized schematic of tsunami data flow between external sources, satellite telemetering instruments, the agency responsible for the Tsunami Warning System in Chile, and the other national components involved in data collection, data analysis and watch and warning dissemination. The flow chart, in its present form, reflects the realities of the present System, with its inherent strengths and weaknesses as determined by the present study of the organizational infrastructure of the National Tsunami Warning System in Chile. Final versions will define better the THRUST input and alternate fail-safe communications between national components. Operational manuals which will be prepared will include specific data and information flow diagrams and decision making charts based on satellite telemetry and automation.

Table 1

MINISTRIES AND ORGANIZATIONS
WITH PLANS FOR DISASTERS

1. Office of the President
2. Ministry of the Interior
3. Ministry of Foreign Affairs
4. Ministry of National Defense
5. Ministry of Economy and Reconstruction
6. Ministry of Housing
7. Ministry of Public Education
8. Ministry of Justice
9. Ministry of Public Works
10. Ministry of Agriculture
11. Ministry of Land and Colonization
12. Ministry of Labor and Social Security
13. Ministry of Public Health
14. Ministry of Mines
15. Ministry of Housing and Urban Development
16. Ministry of Transportation
17. Secretary General of the Governor
18. Office of National Planning

Table 2

DISASTER EMERGENCY PLANS
IN CHILE

MINISTRY OF THE INTERIOR

1. General Executive Emergency Plan
2. Regional Emergency Plans
3. Provincial Emergency Plans
4. Community Emergency Plans

ANEXO "C" AL PLAN NACIONAL DE EMERGENCIA

EJEMPLAR N° _____

HOJA N° _____

ORGANIZACION DEL PAIS PARA AFRONTAR SITUACIONES DE SISMOS O CATASTROFES

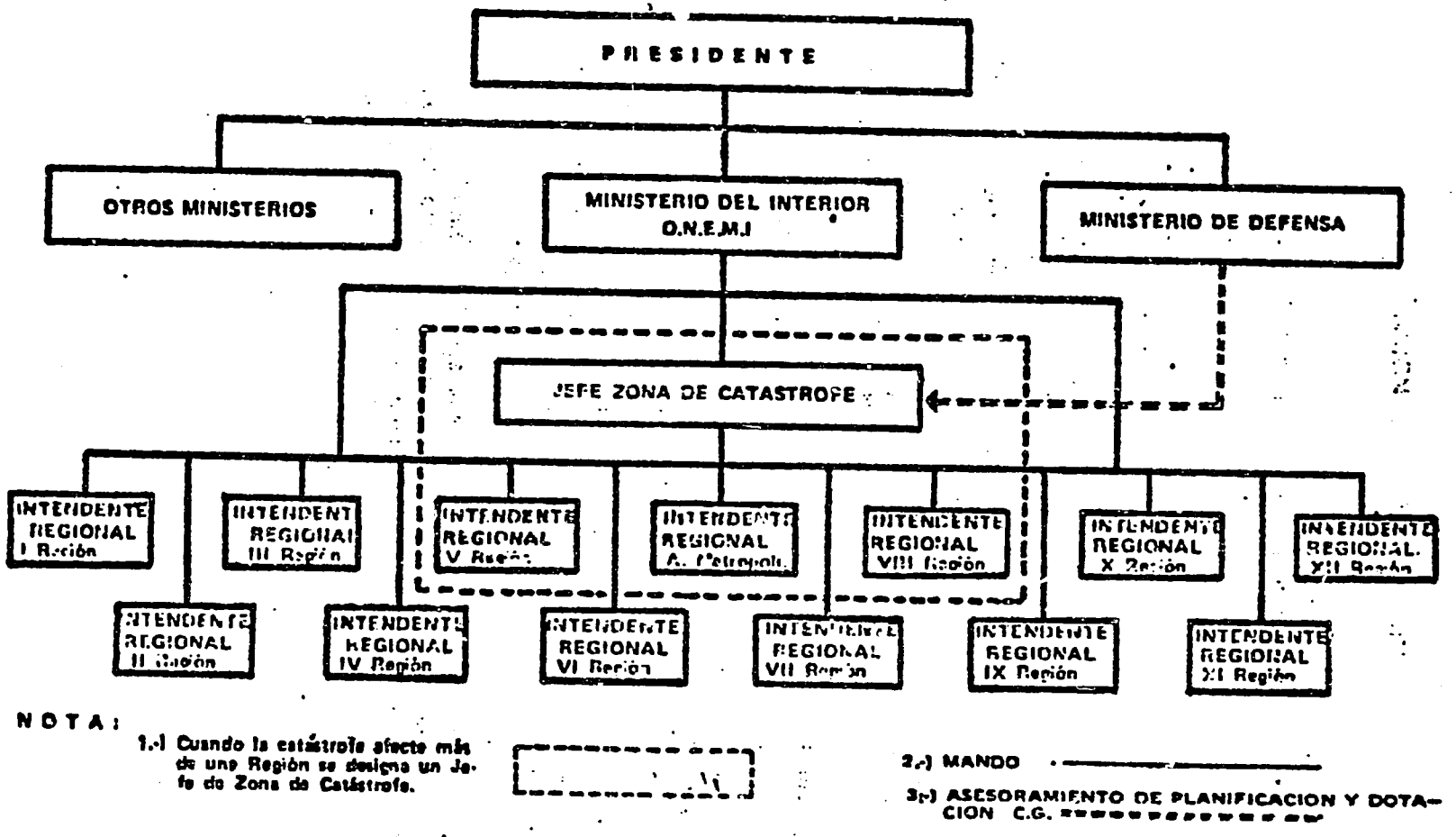

Figure 1

ORGANIZATIONAL PLAN OF THE COUNTRY TO DEAL WITH EARTHQUAKES OR OTHER CATASTROPHS

Figure 2.

EMERGENCY PLANS AND DIRECTIVES AT THE NATIONAL AND REGIONAL LEVELS DEALING WITH NATURAL DISASTERS SUCH AS EARTHQUAKES AND TSUNAMIS

EJEMPLAR N° _____

HOJA N° _____

ANEXO "D"

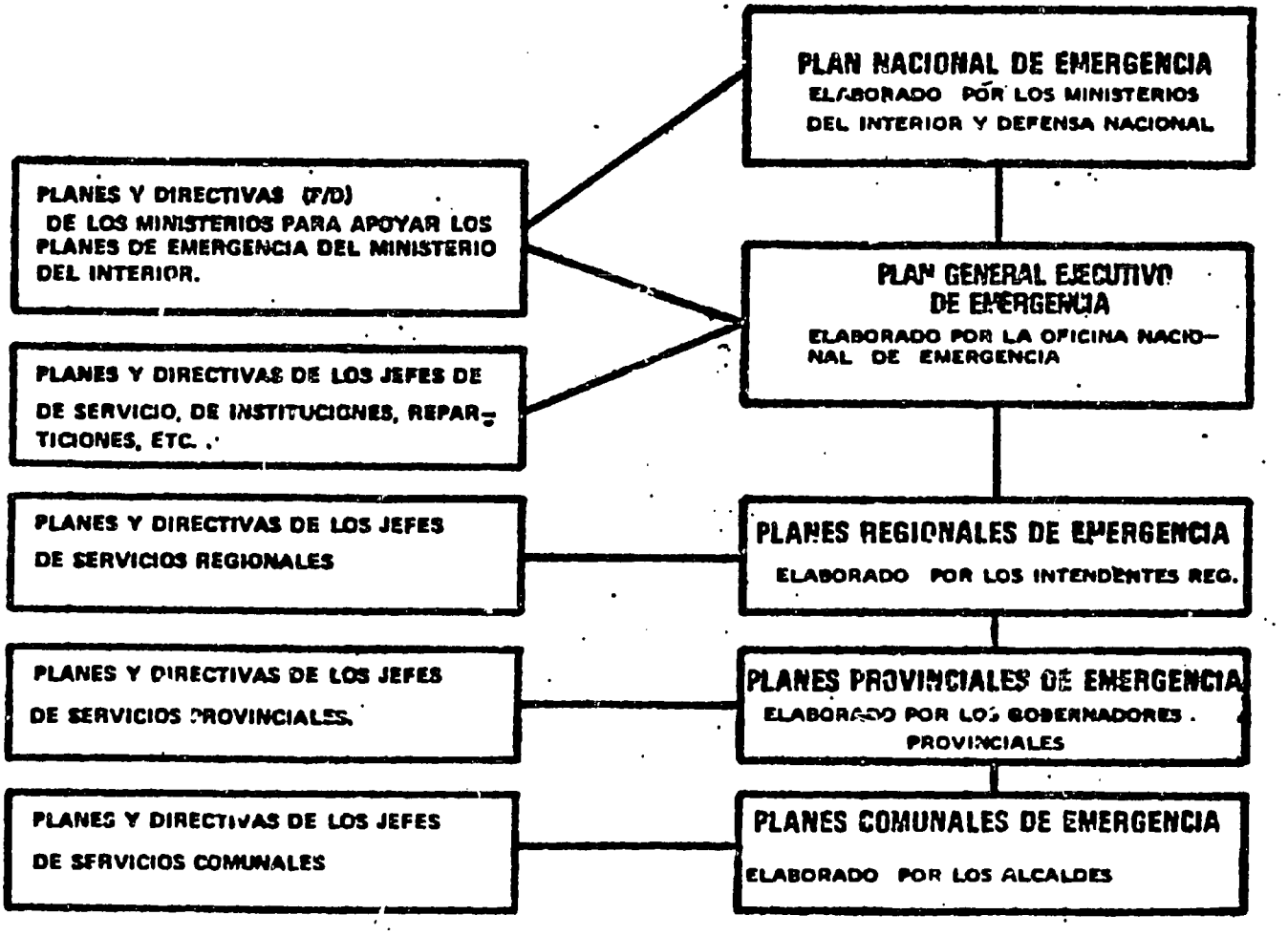

Figure 3

TIDE STATIONS IN THE
CHILEAN TSUNAMI WARNING SYSTEM

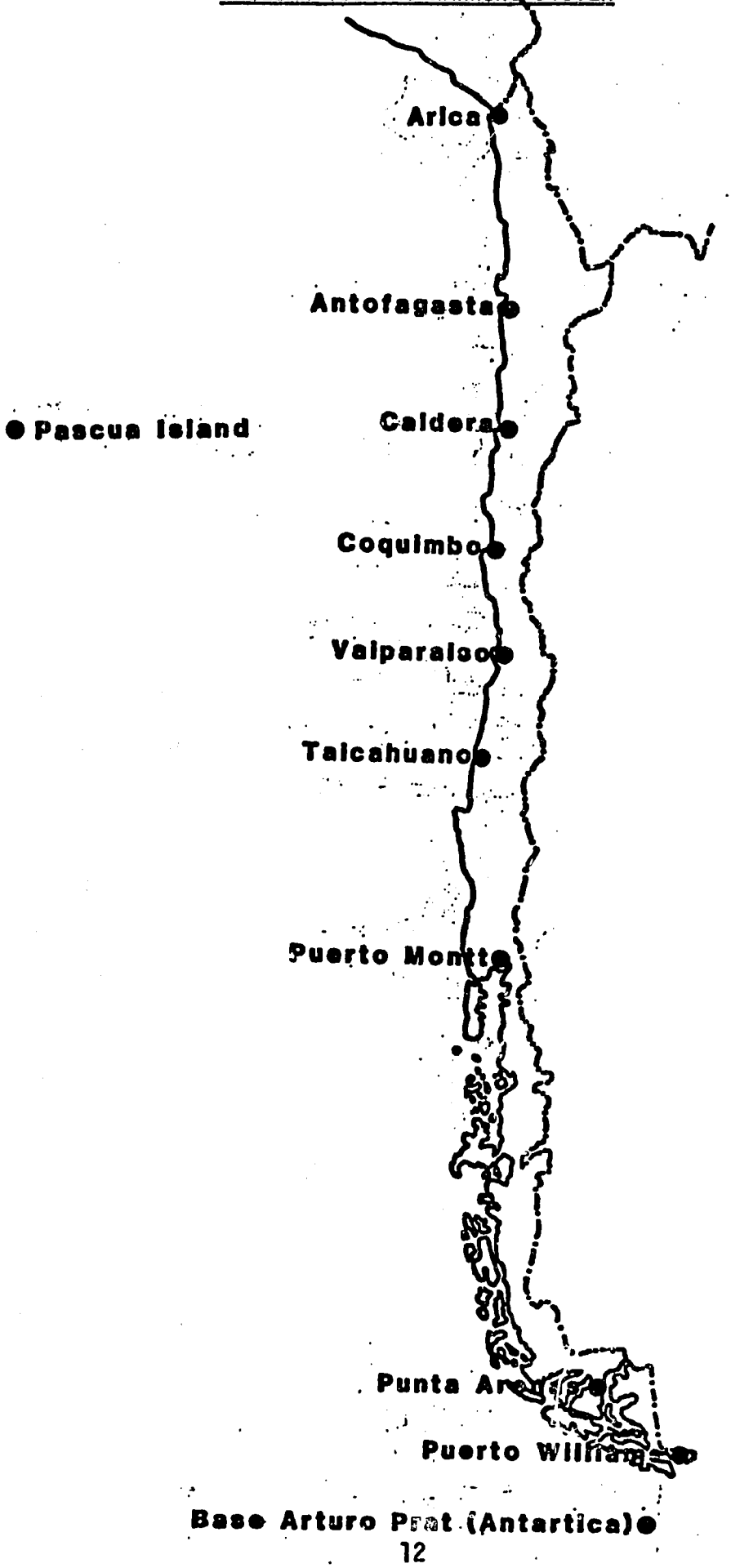

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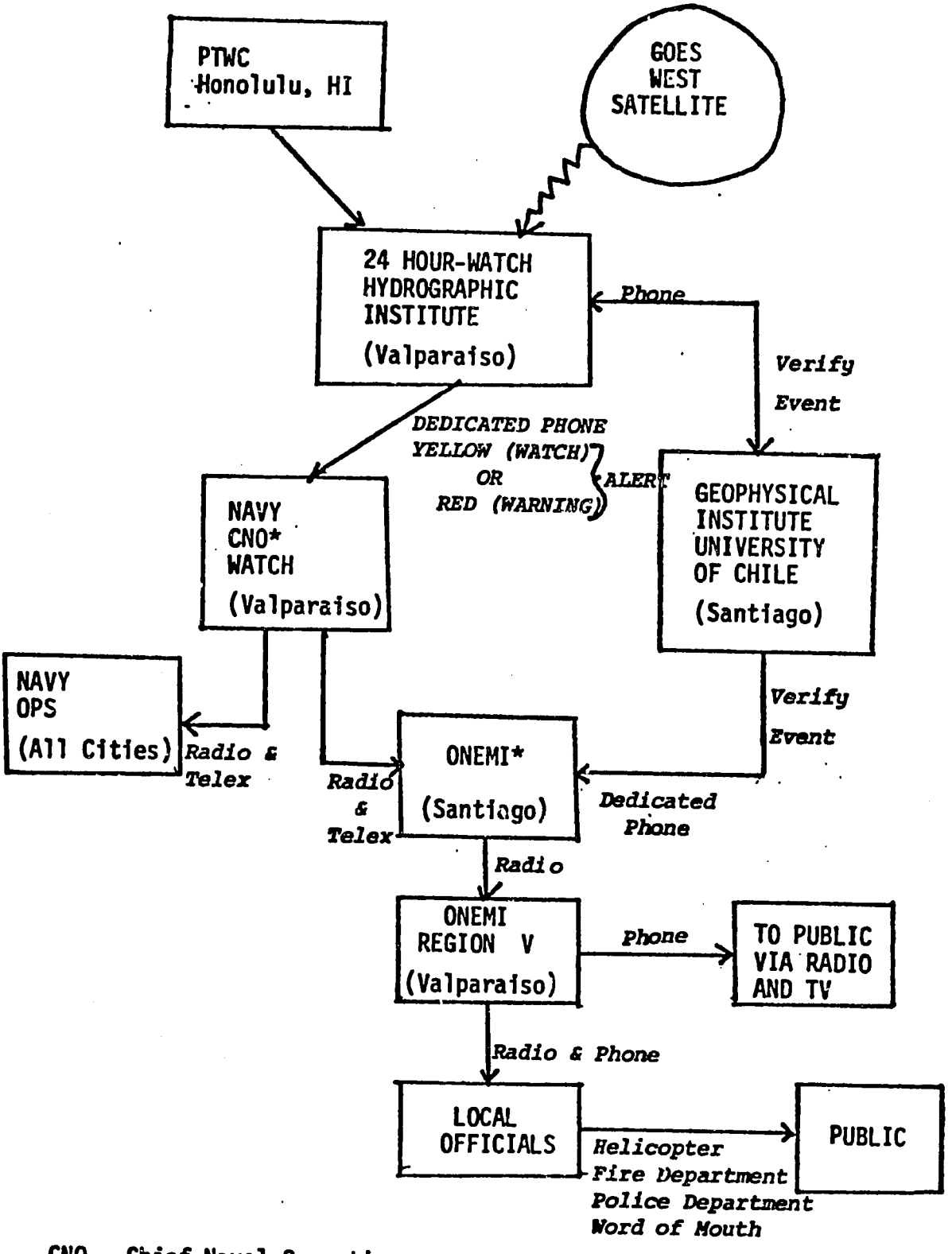
Figure 4

PROPOSED TSUNAMI DATA
INFORMATION AND WARNING FLOW



CNO - Chief Naval Operations
ONEMI - National Emergency Office

Real Time

Data Collection

THRUST

PMEL

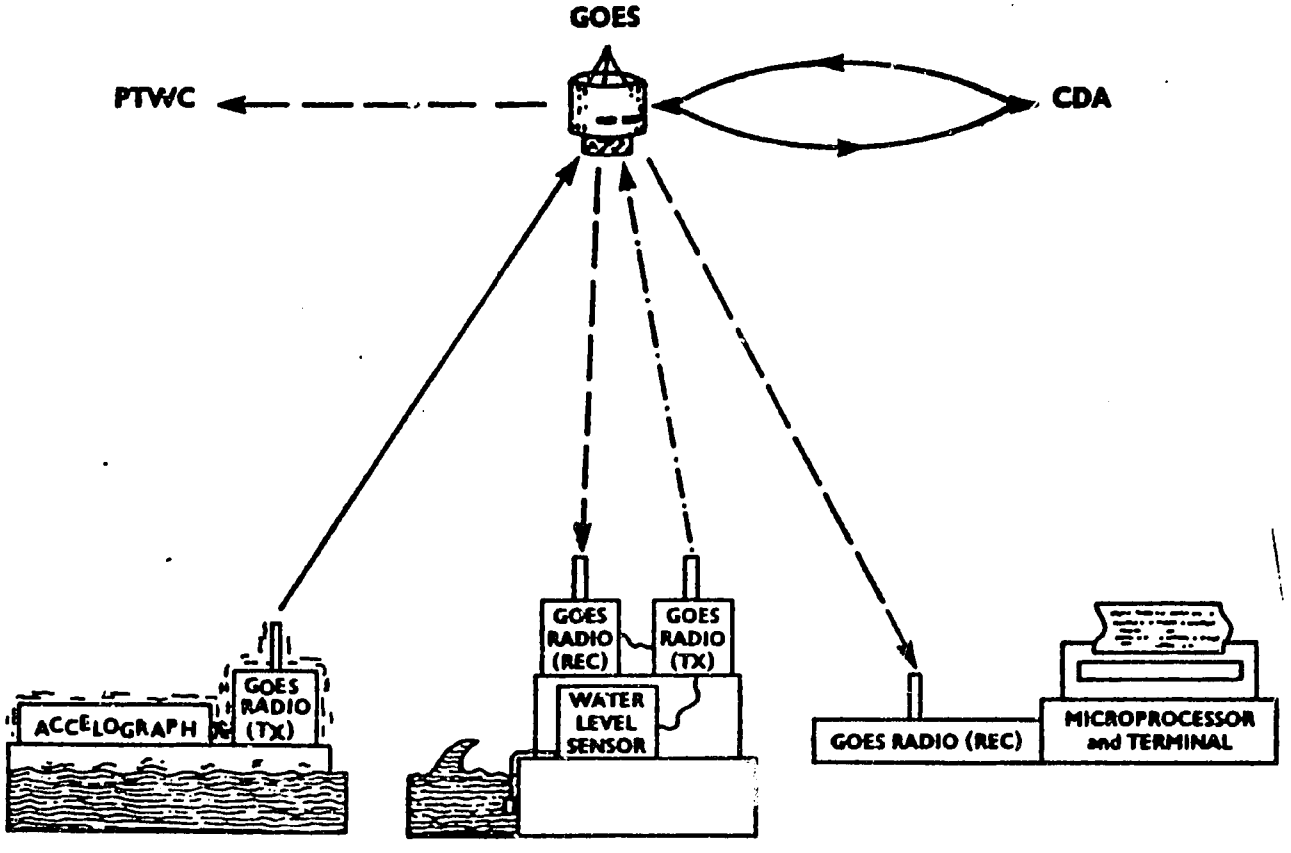
THRUST

First Annual Report

Real Time Data Collection

The use of a satellite-based communication system, in the form of the Geostationary Operational Environmental Satellite (GOES) system, allows the lag time between the event and the receipt of initial data to be reduced to the order of minutes--enough time to provide early warnings. This is the goal of the THRUST Project.

To provide these early warnings to a population, certain instruments are required. The diagram below shows the instruments that will be needed for the THRUST project.



PMEL's Engineering, Design and Development section has been concentrating its efforts on the design, development, test and installation of the above system. The first year's effort has concentrated on the design of the system. The most critical factor in designing a system is the compatibility of all the instruments. After thorough research we have been able to formulate the following criteria, compatible instruments and manufacturers.

Two Kinemetrics SMA's (Strong Motion Accelerographs) will be used in the project. Upon sensing a strong seismic signal in the vertical plane, corresponding to a 6.5 on the Richter scale centered near the site, SMA's will trigger a GOES transmitter to initiate the warning sequence. One trigger, which will be installed in Valparaiso, will have the capability of recording events on a film tape. The other unit, which will not have the recording capability, will be located in Santiago.

Two water level sensors will be placed on a large concrete pier in the Valparaiso harbor. Both water level sensors will consist of a robust pressure transducer, armored cable, interface electronics, and a GOES up-link platform. Although specifications have not been finalized, survivability through a large seismic and tsunami event will dictate the detail design parameters. The transducers will be installed by divers low on the pier face, and the electronics will be approximately 5 meters above MLLW. Data anomalous to the tidal signal will be sampled at a rate adequate to define the profile of a tsunami and will be transmitted into the GOES computer for post-event analysis.

The four U.S. manufacturers that are presently certified to manufacture GOES radio transmitters are Handar, Magnavox, Synergetics, and Sutron. Each of these units are somewhat unique, and a selection will soon be made

based on reliability and compatibility with the system requirements. With over 2500 GOES units active in the field, a semblance of reliability data is available which will aid the selection process. Overall system design will determine the feasibility of utilizing the GOES units for data aquisition versus incorporating an external quasi-intelligent device in the sensor/radio interface. This phase of the design should be complete by September 1984. Procurement will proceed accordingly, and the goal is to have all equipment assembled and operating for a minimum of six months. Thermal stress cycling during the test phase is planned to improve the final system reliability.

Upon completion of testing, the instruments would be shipped and deployed in Chile for their permanent installation.

Real Time

Information Dissemination

THRUST

PMEL and CyberLink

THRUST PILOT STUDY PROTOTYPE
SYSTEM WORKPLAN

Contract No. 83-ABC-00240

Progress Summary - May 9, 1984

A. Introduction

This progress summary covers the first seven months of the contract study, which is Phase I of a three-phase program.

The effort has been subdivided into four subtasks which are listed below. The estimated percentage completion status for each is also shown.

User Requirement Subtask	70%
GOES Satellite/DCS Subtask	80%
MOA and Assignments Subtask	65%
Design and Specification Subtask	25%

The activities planned for each subtask are listed in Table 1. These activities were presented in the program plan for the contract first phase.

The contract start date was September 12, 1983.

Phase I - System Definition	9/12/83 - 9/11/84
Phase II - System Implementation	9/12/84 - 9/11/85
Phase III - System Test and Evaluation	9/12/85 - 9/11/86

B. Tasks Completed

The User Requirements Subtask was originally divided into three parts in the original program schedule. The first two parts have been completed as scheduled. The last part is scheduled in the ninth month of the program after the system design, address assignments, and frequency assignment data

Table 1. THRUST PILOT STUDY PROTOTYPE SYSTEM WORKPLAN - TASK SUMMARY AND STATUS - May 9, 1984

User Requirement Subtask	Completion Status
1. Visit site in Chile	100%
2. Define warning message text in English and Spanish	90%
3. Visit AID/OFDA site	0%
4. Visit PMEL site	100%
5. Develop message format requirements	100%
6. Develop display and display interface requirements	80%
7. Develop operational requirements including message confirmation needs	90%
8. Determine equipment location and installation conditions	90%
9. Develop communication terminal functional and interface requirements	20%
10. Establish printer requirements	20%
11. Establish user test participation role and activities possible	100%
12. Establish warning message performance requirements for reliability of delivery, response time, etc.	60%
13. Coordinate THRUST system design details with users	50%
GOES Satellite/DCS Subtask	
1. Develop system design options	100%
2. Develop warning event data to be availabe at the CDA for warning message generation	100%
3. Evaluate and select the best option for THRUST system design	100%
4. Develop warning initiation requirements and coordinate	90%
5. Develop DCP message format and coordinate	80%
6. Develop GOES DCS computer software requirements and coordinate	90%
7. Develop dissemination system requirements and coordinate	90%
8. Develop THRUST system cost objectives and coordinate	10%

Table 1. THRUST PILOT STUDY PROTOTYPE SYSTEM WORKPLAN - TASK SUMMARY AND STATUS - May 9, 1984 (continued)

	Completion Status
MOA and Assignments Subtask	
1. Develop revised draft MOA for PMEL as necessary and assist coordination	100%
2. Develop request for address and channel assignments for PMEL submission to NESDIS and assist coordination	90%
3. Develop frequency assignment applications for PMEL submission and submission by Chile and assist coordination	10%
Design and Specification Subtask	
Upon receipt of the MOA and frequency-address assignments from NESDIS:	
1. Complete system design	80%
2. Prepare specifications for GOES DCS computer message format and software	60%
3. Prepare specifications for modified IDCPRS UHF receiver terminal	40%
4. Prepare specifications for the message storage device	10%
5. Prepare specifications for the printer	10%
6. Prepare specifications for the communications terminal and interface requirements	20%
7. Prepare specifications for the THRUST system terminal microprocessor	10%
8. Prepare specifications for required hardware and software for the Task III tests	0%
9. Prepare specifications for required data collection communications for the Task III tests	0%

have been reviewed by NESDIS. The study schedule is shown in the attached figure taken from the program plan (numbered as Figure 2 as in the program plan).

The GOES Satellite/DCS Subtask was scheduled to be completed at the end of the fifth month. This task is 80 percent complete. The system design has been completed except for the optional time data in the alert message and the warning message.

The MOA and Assignments Subtask is scheduled to be completed at the end of the tenth month and is now about 65 percent complete. The draft application for PMEL to submit to NESDIS has been completed and sent to PMEL. The application is expected to be submitted by PMEL to NESDIS during the week of May 14, 1984.

The Design and Specification Subtask was scheduled to begin in the eighth month. Some progress has been made (25 percent completion) in order to provide requested information to PMEL in a timely fashion.

C. Tasks to be Completed

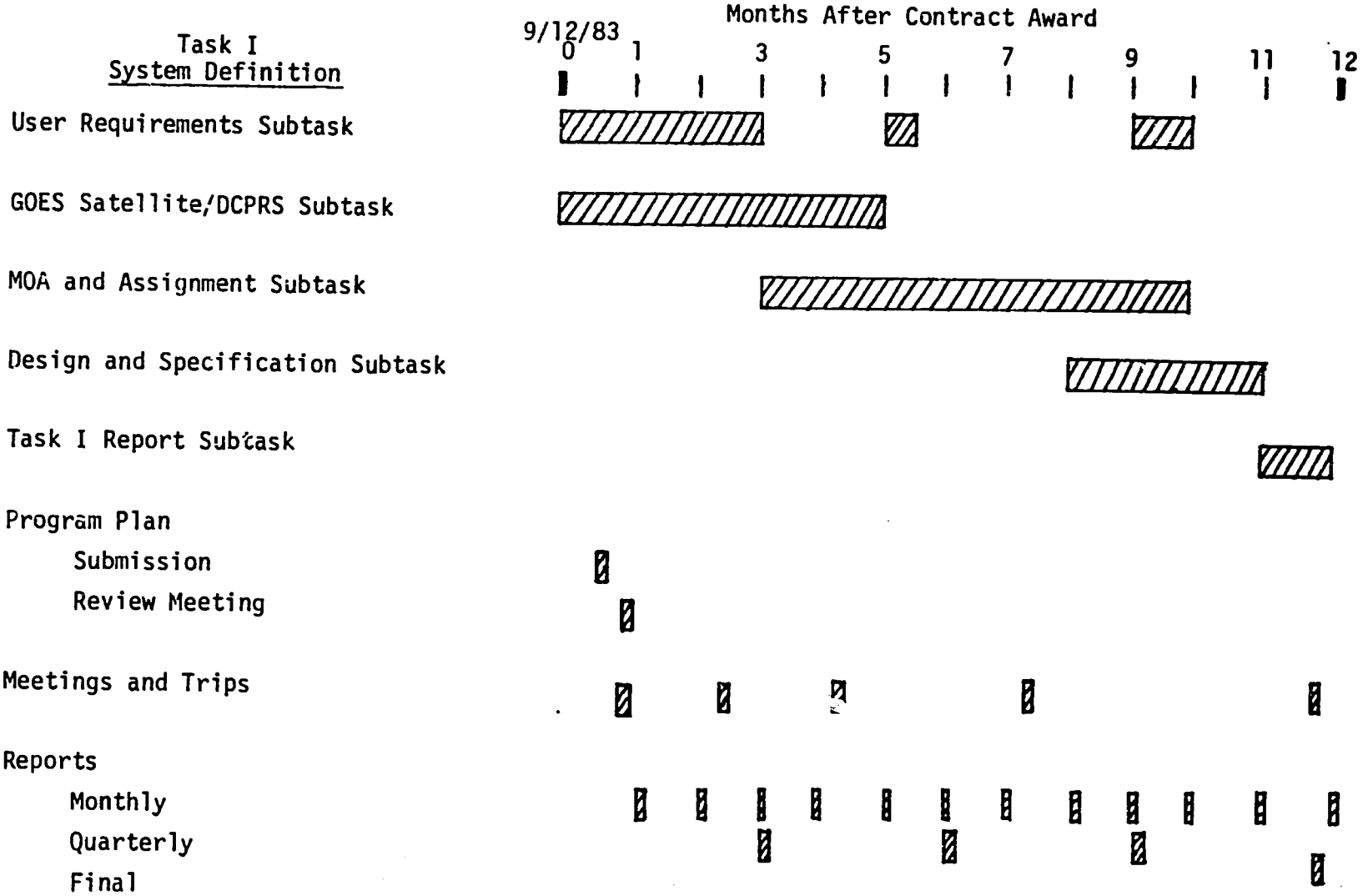
The four subtasks listed above for Phase I need to be completed during the last five months of the program. The next major milestone is to meet with NESDIS and finalize the system design and GOES/DCS software requirements. When this is completed, all the remaining activities can be completed. Some of the work can continue while NESDIS reviews the THRUST pilot program application. Frequency assignments are provided by NESDIS only after they have reviewed and approved the application.

The tasks for next year are given in the program plan.

D. Summary

A system design for the use of the GOES Satellite and DCS system in the THRUST pilot program demonstration in Chile has been completed. User requirements have been mostly established. The Application for use of the GOES/DCS system has been prepared and submitted. The system design was developed to be compatible with the existing GOES/DCS system with only minor software changes.

Figure 2. Task I Proposed Schedule



Chile

THRUST

NHI

INSTITUTO HIDROGRAFICO DE LA ARMADA
ERRAZURIZ 232 · CABLE HIDROVALPARAISO · FONO 51056 · CASILLA 324 · VALPARAISO · CHILE

12 de Marzo de 1984

Embajada de los Estados Unidos en Santiago, Chile

Estimado Sr. Embajador:

Deseo informar a Vuestra Excelencia que esta Dirección ha revisado cuidadosamente la proposición del Proyecto THRUST, elevada a la Oficina de Asistencia para Desastres en el Extranjero (OFDA) de los Estados Unidos, por el Laboratorio del Medioambiente Marino del Pacífico de la NOAA (PMEL). Nuestra conclusión, es que el programa detallado en el presente documento es beneficioso para Chile, por lo cual, concordamos con las tareas programadas en la mencionada proposición.

En la reciente reunión de Tsunamis, efectuada en Honolulu, Hawaii, en la tercera semana del mes de Marzo del presente año, el Sr. Emilio Lorca, asesor de este Instituto, y el Director que suscribe, se reunieron con el Sr. Bernard (PMEL), el Sr. Krumpe (OFDA) y representantes del programa THRUST. Se acordó en esa oportunidad, que ciertas tareas comprendidas en la proposición, deberán ser hecha en forma conjunta y que los informes técnicos finales sean suscritos por ambas partes.

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INSTITUTO HIDROGRAFICO DE LA ARMADA
ERRAZURIZ 232 · CABLE HIDROVALPARAISO · FONO 51056 · CASILLA 324 · VALPARAISO · CHILE

Esta Dirección, apoya el Proyecto THRUST para mantener la operación del Sistema Nacional de Alarma de Tsunami en el Instituto Hidrográfico de la Armada (I.H.A.), durante las 24 horas del día. Se han adjuntado las respectivas contribuciones de Chile; del Instituto Hidrográfico de la Armada, del Departamento de Geología y Geofísica de la Universidad de Chile y de la Oficina Nacional de Emergencia (ONEMI), que en total suman US.$ 1,633,068,00. Se estima que la contribución de la ONEMI será de US.$ 36,316 para sueldos US.$ 33,727 para sistemas de comunicaciones telefónicas y US.$ 336,725 para equipamiento de radiotransmisores. Estos significativos aportes de las tres principales instituciones nacionales y partes del sistema, indican nuestro decidido apoyo a este programa, el cual se estima debe ser llevado a cabo lo antes posible.

Atentamente,

EDUARDO BARISON ROBERTS
CAPITAN DE NAVIO
DIRECTOR

cc./

General Julius H. Becton, Director AID/OFDA
Eddie N. Bernard, Director PMEL, ERL/NOAA ✓

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DEPARTMENT OF STATE
DIVISION OF LANGUAGE SERVICES

(TRANSLATION)

LS NO. 113031
RHC/MM
Spanish

INSTITUTO HIDROGRAFICO DE LA ARMADA
(Naval Hydrographic Institute)

March 19, 1984

United States Embassy
Santiago, Chile

Mr. Ambassador:

I wish to inform Your Excellency that the Institute has carefully considered the Project THRUST proposal submitted to the Office of United States Foreign Disaster Assistance (OFDA) by the NOAA Pacific Marine Environment Laboratory (PMEL). We have concluded that the program outlined in this document is beneficial to Chile, and so we are approving the work outlined in this proposal.

At the recent Tsunamis meeting in Honolulu, Hawaii, during the third week of March 1984, Mr. Emilio Lorca, an advisor at the Institute, and I, the undersigned director, met with Mr. Bernard (PMEL), Mr. Krumpe (OFDA), and representatives of the THRUST program. On that occasion it was agreed that certain work outlined in the proposal would be performed jointly and that the final technical reports would be signed by both parties.

This Institute is in favor of the THRUST project to keep the Chilean Tsunami Alarm System at the Instituto Hidrografico de la Armada (I.H.A.) [Naval Hydrographic Institute] operating 24 hours a day. I am enclosing the respective contributions of Chile, the Instituto Hidrografico de la Armada, the University of Chile Department of Geology and Geophysics, and the Oficina Nacional de Emergencia (ONEMI) [Chilean Emergency Office], totalling US$1,633,068.00. ONEMI's contribution is estimated as US$36,316 for salaries, US$33,727 for telephone communications systems, and US$336,725 for radio transmittor equipment. These significant contributions by the three principal Chilean institutions that are part of the system are an indication of our firm support for this program, which we believe should be implemented as soon as possible.

Very truly yours,

[Signature]

Captain Eduardo Barison Roberts

Director

cc. General Julius H. Becton, Director AID/OFDA
Eddie N. Bernard, Director, PMEL, ERL/NOAA

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INSTITUTO HIDROGRAFICO DE LA ARMADA
ERRAZURIZ 232 · CABLE HIDROVALPARAISO · FONO 51056 · CASILLA 324 · VALPARAISO · CHILE

CHILE'S COUNTERPART CONTRIBUTION TO THRUST PILOT PROJECT

1.- HYDROGRAPHIC INSTITUTE CONTRIBUTION

a)	MAREOGRAPHS (EQUIPMENT)	US$ 50,500	
b)	MAREOGRAPHS (BUILDINGS)	7,200	
c)	SALARIES (OPERATORS)	62,700	(YEARLY)
d)	READINGS OF MARIGRAMS	32,100	ID.
e)	COMPUTER TIME	28,800	ID.
f)	COMMUNICATIONS	2,300	ID.
g)	MAINTENANCE	7,800-	ID.
h)	REPAIRMENTS	5,400	ID.
i)	9 SEISMIC SENSORS	32,500	
	SUB-TOTAL :	US$229,300.-	

2.- DEPARTMENT OF GEOLOGY AND GEOPHYSIC CONTRIBUTION

a)	SEISMIC NON TELEMETRIC EQUIPMENT	US$ 300,000
b)	SEISMIC TELEMETRIC EQUIPMENT	120,000
c)	SEISMIC STATIONS (BUILDINGS)	220,000
d)	SEISMOLOGIC SERVICE COMPUTER AND OTUER EQUIPMENT (PHOTOGRAPHICS, ELECTRONICS, ETC.)	120,000
e)	SEISMOLOGIC SERVICE FACILITIES	100,000
f)	SALARIES	80,000
g)	MATERIALS	20,000
h)	STATIONS MAINTENANCE	30,000
i)	CENTRAL COMPUTER	7,000
	SUB-TOTAL :	US$ 997,000

3.- NATIONAL EMERGENCY OFFICE CONTRIBUTION

a)	SALARIES	US$	36,316
b)	TELEPHONE SYSTEM		33,727
c)	RADIO SYSTEM		336,725
	SUB-TOTAL	US$	406,768

TOTAL CONTRIBUTION: US$ 1,633,068.00

INSTITUTO HIDROGRAFICO DE LA ARMADA

232 - CABLE HIDROVALPARAISO - FONO 51056 - CASILLA 324 - VALPARAISO - CHILE

THRUST PROJECT

FIRST YEAR FINAL REPORT (CHILE)

Chile's participation on the project
:d with the meeting of officials from the Hy-
ıphic Institute with the U.S. scientist THRUST
in late September at Valparaíso, Chile (see
ls in December Quaterly Report).

completed is as follows:

The endorsement of the Hydrographic Institute to THRUST project, was sent to U.S. Embassy at the begining of April.

2.- Pre-event data collection: Revision of existing marigrams (1943-1983), collecting 39 tsunami records.

- Pre-event dissemination:
  - Message formats for internal operations.
  - Navy procedures for Operations Plan.

Information meeting about THRUST project with national agencies involved in the Tsunami Warning System. Coordination meeting is scheduled for May.

EDUARDO BARISON
CAPTAIN
DIRECTOR

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DIAGRAMA DE COMUNICACIONES

SISTEMA NACIONAL DE ALARMA DE MAREMOTOS