

# **Field Survey Report of Tsunami Effects Caused by the August, 2012 Offshore El Salvador Earthquake**



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## Report Status

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**Cover Picture:** Aerial view of the inundation zone along the San Juan del Gozo peninsula.



## Participant Affiliations and Survey Sponsors

SURVEY SPONSORS	
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## CONTENTS

<b>1</b>	<b>INTRODUCTION .....</b>	<b>7</b>
1.1	ITST EL SALVADOR GUIDING PRINCIPLES.....	9
1.2	ITST EL SALVADOR SUMMARY OF ACTIVITIES .....	9
<b>2</b>	<b>EARTHQUAKE AND TSUNAMI.....</b>	<b>13</b>
2.1	EARTHQUAKE ANALYSIS.....	14
2.2	INSTRUMENTAL TSUNAMI OBSERVATIONS.....	16
2.3	PRELIMINARY HYDRODYNAMIC MODELLING .....	21
<b>3</b>	<b>TSUNAMI FIELD SURVEY .....</b>	<b>23</b>
3.1	DEFINITIONS .....	25
3.2	SITES IN EL SALVADOR .....	25
3.2.1	<i>Site 01: Isla De Mendez.....</i>	<i>25</i>
3.2.2	<i>Site 02: Corral de Mulas 2 .....</i>	<i>30</i>
3.2.3	<i>Site 03: Corral de Mulas 1 .....</i>	<i>32</i>
3.2.4	<i>Site 04: Ceiba Doblada .....</i>	<i>33</i>
3.2.5	<i>Site 05, 06, 07: Manglarón/Monte Alto/Los Manglares.....</i>	<i>35</i>
3.2.6	<i>Site 08, 09, 10, 11: Unnamed Sites west of Isla de Mendez. ....</i>	<i>40</i>
3.2.7	<i>Costa del Sol and La Puntilla.....</i>	<i>43</i>
3.2.8	<i>Additional tsunami reports .....</i>	<i>46</i>
3.3	SITES IN NICARAGUA .....	47
3.3.1	<i>Mechapa .....</i>	<i>47</i>
3.3.2	<i>Manzanillo 1 .....</i>	<i>49</i>
3.3.3	<i>Manzanillo 2.....</i>	<i>51</i>
<b>4</b>	<b>INTERVIEW SUMMARIES .....</b>	<b>53</b>
<b>5</b>	<b>DATA SUMMARY .....</b>	<b>55</b>
<b>6</b>	<b>SUMMARY FINDINGS AND NEXT STEPS .....</b>	<b>58</b>
<b>7</b>	<b>REFERENCES .....</b>	<b>60</b>
<b>8</b>	<b>APPENDIX 1: INVITATION LETTERS .....</b>	<b>62</b>
<b>9</b>	<b>APPENDIX 2: ITST GUIDING PRINCIPLES .....</b>	<b>64</b>
<b>10</b>	<b>APPENDIX 3: PACIFIC TSUNAMI WARNING CENTER (PTWC) EVENT SUMMARY .....</b>	<b>68</b>
<b>11</b>	<b>APPENDIX 4: PACIFIC TSUNAMI WARNING CENTER (PTWC) EVENT MESSAGES AND TIMELINE .....</b>	<b>71</b>
<b>12</b>	<b>APPENDIX 5: EARTHQUAKE FAULT SOLUTIONS .....</b>	<b>75</b>
<b>13</b>	<b>APPENDIX 6: EL SALVADOR MARN REPORT .....</b>	<b>79</b>
<b>14</b>	<b>APPENDIX 7: NICARAGUA INETER REPORT .....</b>	<b>83</b>

## TABLE OF FIGURES

Figure 1.1 A political map of El Salvador. The Capital of San Salvador is indicated with a red star while red dots show the locations of the two tide stations that recorded the tsunami. Acajutla, the country's principal port in the west and La Union in the Gulf of Fonseca in the east. The area affected by the tsunami (Peninsula San Juan del Gozo) is circled in red.....	7
Figure 1.2 A political map of Nicaragua. The Capital of Managua is indicated with a red star while the red dot show the locations of the La Union tide gauge in the Gulf of Fonseca. The area surveyed for the tsunami effects is circled in red.....	8
Figure 2.1 The Bathymetry offshore of El Salvador and Northern Nicaragua and the location of the USGS defined earthquake epicenter (red star). Black dots correspond to epicenters of aftershocks through 11 September, 2012. Contours labeled in meters. ....	13
Figure 2.2 The preliminary energy-time relationships produced by the Real-Time Earthquake Energy and Rupture Duration Estimate project of the Georgia Institute of Technology and emailed to a distribution list approximately 10 minutes after the earthquake.....	14
Figure 2.3 Energy release function for the 27 August 2012 El Salvador earthquake (Mw 7.3). Energy release occurs over 70 seconds. ....	15
Figure 2.4 Energy release functions for the 31 August 2012 Philippines earthquake (Mw 7.6, left) and the 5 September 2012 Costa Rica Earthquake (Mw 7.6, right). Note that although both of these are larger in terms of magnitude, the energy is released in less time than in the El Salvador event, particularly in the case of the Philippines event. ....	15
Figure 2.5 Locations of the two tide stations in El Salvador that recorded the August 26 <sup>th</sup> , 2012 tsunami. The earthquake source location is indicated with the red star. ....	16
Figure 2.6 Acajutla tide gauge data from the time of the earthquake.....	17
Figure 2.7 PTWC plot of the El Salvador tsunami on the Acajutla, El Salvador tide gauge.....	18
Figure 2.8 PTWC plot of the El Salvador tsunami on the La Union, El Salvador tide gauge.....	18
Figure 2.9 PTWC plot of the El Salvador tsunami on the Baltra, Galapagos Islands tide gauge. The gauge is located ~1400 km away along a 191° path.....	19
Figure 2.10 PTWC plot of the El Salvador tsunami on the Santa Cruz, Galapagos Islands tide gauge. The gauge is located ~1400 km away along a 191° path. ....	19
Figure 2.11 PTWC plot of the El Salvador tsunami on DART 43413. The station is located ~1200 km away along a 264° path. ....	20
Figure 2.12 PTWC plot of the El Salvador tsunami on the La Libertad, Ecuador tide gauge. The gauge is located ~1800 km away along a 153° path.....	20
Figure 2.13 Preliminary hydrodynamic modeling results using the MOST hydrodynamic model and the USGS finite fault solution as the tsunami source. ....	21
Figure 2.14 Plot of maximum tsunami wave heights in the far field using the MOST hydrodynamic model initialized with the USGS Finite Fault model slip distribution. ....	22



Figure 3.1 Survey sites along the San Juan del Gozo peninsula.....	23
Figure 3.2 Sites surveyed in northern Nicaragua by the INETER team. ....	24
Figure 3.3 Definition sketch for tsunami height measurements and terminology.....	25
Figure 3.4. Aerial views of Isla de Mendez. The browning of the vegetation due to salt water penetration from the tsunami is evident. The structures had been rebuilt since the tsunami. The inundation extent is to the edge of the photo frame. ....	27
Figure 3.5 Jose Barrera-Garcia at the newly rebuilt ramada. Mr. Barrera-Garcia was swept away by the tsunami and suffered minor injuries. The tsunami flow depth at this location was reported by Mr. Barrera-Garcia to be over 2 m. ....	28
Figure 3.6 Transect of tsunami data from Isla de Mendez. ....	28
Figure 3.7 The ramada at Isla de Mendez and the turtle egg hatchery in the background.....	29
Figure 3.8 Estimated tsunami flow depth at the tree where Mr. Barrera-Garcia was deposited by the tsunami surge. ....	29
Figure 3.9 Corral de Mulas 2. The tsunami reportedly flowed over the beach dune but did not reach the hut in the back ground. No damage to the hut. ....	30
Figure 3.10 Aerial view of Corral de Mulas 2. Extensive tsunami inundation is not evident.....	31
Figure 3.11 A view towards the east of the San Juan del Gozo peninsula. The extent of tsunami inundation is evident by the brown color of the vegetation towards the shoreline.....	31
Figure 3.12 Corral de Mulas 1. The surge overtopped the dune and washed through the ramada. ....	32
Figure 3.13 Possible tsunami overwash debris wrapped around a post at the Ceiba Doblada ramada.....	33
Figure 3.14 The palm fronds aligned perpendicular to the shore line are evidence of tsunami inundation and overwash.....	34
Figure 3.15 A wrack line of palm fronds deposited by the tsunami, 155 m from the shoreline.....	34
Figure 3.16 Aerial view towards the west. The dead/dying mangrove forest is clearly evident.....	35
Figure 3.17 Aerial view towards the east over the dead/dying mangrove forest.....	36
Figure 3.18 Resident at Manglarón indicates the flow depth at the site. The walls of the shed had been ripped off by the tsunami and replaced since the event. ....	36
Figure 3.19 Aerial view of El Manglarón.....	37
Figure 3.20 Turtle hatchery built since the tsunami.....	37
Figure 3.21 Debris caught in the fence behind the hut at El Manglarón.....	38
Figure 3.22 In the forest of dead mangroves.....	38
Figure 3.23 At the edge of the dead forest. Evidence of tsunami surge flowed under the intact piece of corrugated metal. ....	39
Figure 3.24 Transect of field data from El Manglarón. ....	39

Figure 3.25 Transect of field data from Site 7 (near Manglarón).....	39
Figure 3.26 Tsunami debris line. ....	40
Figure 3.27 Tsunami debris line. ....	41
Figure 3.28 Dead vegetation from salt water intrusion. ....	41
Figure 3.29 Aerial view of a tsunami debris line. ....	42
Figure 3.30 Aerial view of sand deposits from tsunami overwash.....	42
Figure 3.31 La Puntilla.....	43
Figure 3.32 La Puntilla.....	44
Figure 3.33 Costa del Sol. ....	44
Figure 3.34 Costa del Sol. ....	45
Figure 3.35 Aerial view towards La Puntilla and Costa del Sol to the west.....	45
Figure 3.36 A location map of Mechapa. The blue color shows the extent of inundation. ....	47
Figure 3.37 Mechapa, the blue color indicates the area flooded by the tsunami. ....	48
Figure 3.38 Mechapa, the blue color indicates the area flooded by the tsunami. ....	48
Figure 3.39 A resident of Mechapa indicates the flow depth from the tsunami.....	48
Figure 3.40 Overview map of Manzanillo 1 .....	49
Figure 3.41 The coast at Manzanillo 1 .....	50
Figure 3.42 Extent of tsunami inundation at Manzanillo 2.....	51
Figure 3.43 Flow depth indicated by a resident of Manzanillo 2.....	52
Figure 3.44 Inundation of the Manzanillo 2 area. ....	52
Figure 5.1 Summary of data collected during the field survey.....	55

**TABLE OF TABLES**

Table 2.1 Source parameters for the 27 August 2012 El Salvador earthquake as reported by different monitoring agencies. ....	16
Table 2.2 PTWC Summary of tide gauge recordings from the El Salvador tsunami. ....	17
Table 3.1 Survey site names corresponding to numbers in Figure 3.1. ....	24
Table 4.1 El Salvador interview summaries .....	53
Table 4.2 Nicaragua Interview Summaries.....	54
Table 5.1 Runup measurements from the 2012 El Salvador tsunami. ....	56
Table 5.2 Flow depth and tsunami height data from the 2012 El Salvador tsunami. ....	57
Table 5.3 Data from northern Nicaragua. ....	57

# 1 INTRODUCTION

This report describes the field survey of the western zone of El Salvador and Northern Nicaragua following the earthquake and tsunami of 27 August 2012 (04:37 UTC, 26 August 10:37 pm local time). The earthquake generated a tsunami with a maximum height of ~ 6 m causing inundation of up to 300 m inland along a 40 km section of coastline in eastern El Salvador. Less severe inundation was also reported in northern Nicaragua.

El Salvador is located on the Pacific Coast of Central America bordered by Guatemala to the north and Honduras to the East (Figure 1.1). The Gulf of Fonseca at the eastern end of the country is a water body also shared by Honduras and Nicaragua. At just over 21,000 km<sup>2</sup> and with 6 million inhabitants, El Salvador is the smallest and most densely populated country in Central America. In contrast, Nicaragua (Figure 1.2) is much larger at over 130,000 km<sup>2</sup> much less densely populated with a total population of 5.9 million in 2010 (Wikipedia, 2012).



**Figure 1.1 A political map of El Salvador. The Capital of San Salvador is indicated with a red star while red dots show the locations of the two tide stations that recorded the tsunami. Acajutla, the country's principal port in the west and La Unión in the Gulf of Fonseca in the east. The area affected by the tsunami (Peninsula San Juan del Gozo) is circled in red.**



**Figure 1.2** A political map of Nicaragua. The Capital of Managua is indicated with a red star while the red dot show the locations of the La Union tide gauge in the Gulf of Fonseca. The area surveyed for the tsunami effects is circled in red.

The National Geophysical Data Center / World Data Service for Geophysics (NGDC/WDS) maintains a global historical tsunami event and run-up database. According to the database, 20 tsunamis were observed in El Salvador from 1859 to 2012, 15 of these are confirmed (validity 3-4) and 5 are questionable (validity 1-2). Nine of the sources were local, two were regional (Costa Rica, Guatemala) and nine were far field (Chile, Ecuador, Indonesia, Japan, Mexico, Russia, Alaska USA). A local tsunami in 1859 caused damage to warehouses and houses in La Union, El Salvador; a far field tsunami in Alaska 1957 caused damage to pilings in Acajutla, El Salvador. A local event on 26 February 1902 resulted in 185 deaths, 100 injuries and houses were washed out to sea at Barra del Santiago and Barra del Pas, El Salvador. This event is questionable and may have been the result of a combination of a high tide and abnormal meteorological conditions. The tsunami of 2 September 1992 (M7.7) tsunami is particularly notable in that it was caused by a slow



earthquake (Kanamori and Kikuchi, 1993). That tsunami had a maximum runup height of ~10 m and caused 170 deaths and USD \$30 million in damage (Abe et al., 1993; Satake et al., 1993).

### **1.1 ITST El Salvador Guiding Principles**

UNESCO's Intergovernmental Oceanographic Commission (IOC) and International Tsunami Information Center (ITIC) coordinated an international post-tsunami field surveys of the tsunami and its effects. It is doing so at the request of the Governments of El Salvador and Nicaragua (GoES, GoN). The goals include:

- Promote sharing of data with affected countries
- Minimize logistical problems for visitors and hosts
- Link visitors to country collaborators
- Provide the governments with a summary of the ITST findings

The coordination for this effort will be handled by the International Tsunami Information Center, in close coordination with the IOC and the affected countries.

Tsunami disasters can attract a large number of local, national, international professionals to investigate scientific, economic, social impacts. Some of these data are perishable making it essential that they be collected quickly. Important data may also be desirable from locations that are logistically difficult to assess without local assistance and access. At the same time, Emergency Agencies are focusing on public safety, critical support lifelines and infrastructure, resource mobilization to meet its citizens immediate post-event emergency response needs. To carry out both efforts, coordination and cooperation is critical. If data from science teams are made available, it will immediately contribute to better-informed and ultimately, more practical and efficient response and recovery decision-making.

Building from concepts employed in post-earthquake technical clearinghouses, the ITST utilizes a simplified implementation of a science/technical clearinghouse to provide an efficient framework for central coordination, information sharing and integration of the data collected from the 2012 El Salvador tsunami.

### **1.2 ITST El Salvador Summary of Activities**

The Pacific Tsunami Warning Center (PTWC) issued its first information bulletin on the El Salvador event eight minutes after the earthquake at 0445 UTC on 27 August 2012 (10:45 pm local time on August 26), and upgraded its advice to a tsunami warning for Central America countries at 0458 UTC as a precaution based on strong indications that this event was a slow "tsunami" earthquake. Instrumental data recorded at sites in El Salvador showed a tsunami with a 10-cm amplitude at Acajutla to the north and no clear tsunami at La Union in the Gulf of Fonseca. There were, however, no gauges along coasts closest to the epicenter. The warning was cancelled at 0627 UTC when there was no expectation of new destructive impacts outside the area already potentially affected. About 3 hours after the earthquake, sea level recordings from the Galapagos Islands showed a tsunami signal with an amplitude of 40 cm. This indicated that a significant tsunami had been generated,

even if its main impact was only localized near the epicenter. No reports came out of El Salvador in those first few hours of any damaging or destructive tsunami activity.

Within El Salvador however, there were reports of tsunami waves on the night of 26 August (local time) that were brought to the attention of government scientists at MARN (Ministerio del Medio Ambiente y Recursos Naturales) in San Salvador. On the basis of these reports, a preliminary survey was conducted in the field on 27 August by scientists from MARN. The preliminary survey established that a tsunami did occur and primarily affected the Peninsula of San Juan del Gozo, a sparsely populated area located directly shoreward of the epicenter. This survey also determined that there were no deaths caused by the tsunami but that there were several injuries caused by the wave.

Based on this preliminary survey, a larger international response was organized. This effort began after Dr. Jose Borrero (USC, eCoast) and Professor Herman Fritz (Georgia Institute of Technology) received reports of significant tsunami waves through emails forwarded to them. The email from the MARN scientists suggested a field survey was necessary. This message was also sent to Dr. Patrick Lynett (USC).

On 28 August, ITIC inquired to El Salvador MARN and Nicaragua INETER on the impact of the tsunami on their shores and received an initial eyewitness report through MARN that tsunami waves had inundated up to 250 m inland, with some damage and people caught in the waves; a further survey was planned for the next day. On 29 August, Dr. Borrero contacted Dr. Laura Kong (ITIC) to state his readiness to participate in any surveys of the region, and separately, Dr. Hermann Fritz contacted Bernardo Aliaga (IOC PTWS Technical Secretary).

Between 28 and 30 August through a series of emails and phone calls involving the UNESCO IOC PTWS Technical Secretary (Bernardo Aliaga), ITIC (Dr. Laura Kong), MARN, Nicaragua INETER, and the ITST (International Tsunami Survey Team) lead scientists, it was decided that an international tsunami survey would be conducted to at least El Salvador. An official request for post-tsunami survey assistance was received by the IOC Executive Secretary (Dr. Wendy Watson-Wright) and ITIC Director on 30 August 2012 (Appendix 1) from the General Director, Observatorio Ambiental, MARN. An official request was received by IOC Executive Secretary requesting IOC and ITIC assistance on 3 September 2012 (Appendix 1) from the Executive Director, INETER. Upon receiving these requests, the IOC and ITIC commenced official planning for a team to visit El Salvador and assess the tsunami impacts. Nicaragua INETER was invited to join the El Salvador Survey to learn the survey techniques so that a similar survey could be conducted in Nicaragua where impacts were smaller.

In addition to Dr. Borrero and Dr. Fritz, additional team members included Mr. Nic Arcos – a tsunami information specialist from the International Tsunami Information Center (ITIC); Ms. Julie Leonard, Regional Advisor for the USAID Office of Foreign Disaster Assistance and Dr. Diego Arcas, tsunami researcher and project manager at the NOAA Center for Tsunami Research in Seattle Washington.

Dr. Borrero and Dr. Fritz arrived in San Salvador on 3 September and immediately went to the MARN offices to be briefed on the information collected to date and to

begin making plans for the arrival of the rest of the team and the overall logistics of the survey.

On 4 September, Dr. Borrero and Dr. Fritz gave a series of informal seminars to MARN scientists describing previous tsunami field surveys of regional and of historical significance. Dr. Fritz also conducted some informal training sessions on the usage of the surveying equipment in preparation for the work of the subsequent days. During this time, MARN scientist Ms. Jeniffer Larreynaga, worked to develop the logistics for the survey including vehicle transportation, fuel, field accommodations and routes. Mr. Arcos arrived to San Salvador on the afternoon of 4 September and Ms. Leonard arrived later that evening.

A final pre-survey meeting was held on the evening of 4 September over dinner. This meeting was attended by survey team members Jose Borrero, Hermann Fritz, Jeniffer Larreynaga, Nic Arcos and Julie Leonard. Also in attendance were Mary Rodriguez, Mission Environmental Officer/El Salvador United States Agency for International Development (USAID) Economic Growth Office, and her colleague, Ms. Ingrid Olivo, a specialist on public policy and natural disasters. By the time of this meeting, the plan had been set to depart the next morning at 7 am and drive in a caravan of three vehicles to the tsunami affected area and commence the survey.

The survey began as planned on 5 September, with the team making the 3 hour drive to the San Juan del Gozo peninsula. Along the way, the team received the news of the M 7.6 Costa Rica earthquake and tsunami alert. As a result, one of the vehicles returned to MARN to attend to the situation while the rest of the team continued to the coast to begin the survey. The survey began at approximately 11 am on 5 September and continued through the end of the day with a short break for lunch.

The survey resumed on the morning of 6 September and was completed by 1 pm for that region. The team returned to San Salvador to prepare for one last day of surveying on 7 September. Also arriving on the evening of the 7<sup>th</sup> was the final team member, Dr. Diego Arcas.

The final survey was to be conducted by helicopter with the support of the El Salvador Air Force. The purpose of the aerial survey was to identify any areas of tsunami effects that had been missed by the land based survey and to visually inspect areas that could not be accessed by land. Survey participants departed the airfield at approximately 9 am and were flown directly to sections of the tsunami affected area that were not accessible by land. The helicopter over flight also scanned the previously surveyed areas, and extended our observations to the east and west. These observations confirmed that 1) the land survey had covered all of the affected area and 2) that the inaccessible regions were not affected any differently by the tsunami than the areas surveyed by land. The aerial over flight also gave the all-important 'bird's eye view' of the tsunami effects, allowing the team to capture imagery that was not obtainable from ground level.

Upon returning to San Salvador, the team regrouped and prepared a preliminary summary of findings for a 3 pm meeting with the Minister, other Salvadoran officials, and US Government invitees. This meeting occurred as planned and consisted of a

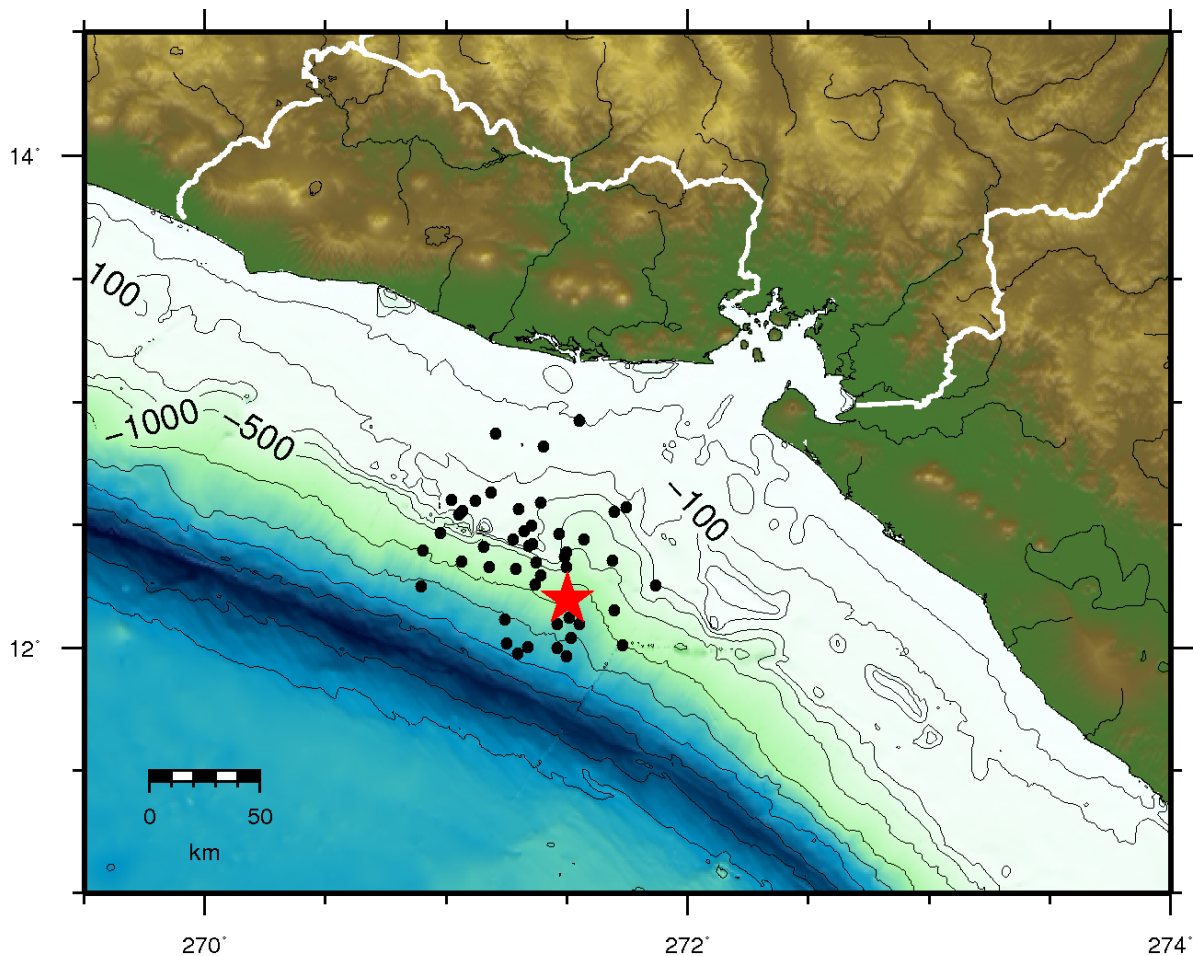
broad ranging discussion and presentations by team members on the survey findings.

A final team meeting was held on Saturday 8<sup>th</sup> September. At this meeting the group worked to share all information, photos, and data collected on the trip. The team also divided up tasks for the preparation of the final report. Since departing El Salvador team members have been in contact working towards the development of the final report. After the completion of the field survey, 2 ITST scientists (Dr. Diego Arcas, Nic Arcos) remained in San Salvador through 11 September 2012 to further discuss ways in which to strengthen tsunami warning and preparedness in El Salvador.

In the week following the El Salvador survey, Mr. Norwin Acosta of INETER (Nicaragua) conducted a field survey of sites affected in Nicaragua. His report on the observations and effects there is also included in this document.

## 2 EARTHQUAKE AND TSUNAMI

On 26 August 2012 at 10:37 pm local time (27 August, 2012, 0437 UTC), an earthquake with magnitude 7.3 (USGS) occurred off the coast of El Salvador. The earthquake epicenter as reported by the USGS was located some 75 km due south of the coast, in-line with the entrance to Jiquilisco Bay (Figure 2.1). As shown in the regional bathymetry (GEBCO), the earthquake source region is in the vicinity of a canyon-like bathymetric feature where water depths range from 2000 to 5000m. Approximately 50 aftershocks with magnitudes between 5.5 and 4.2 occurred in the vicinity of the main event between 27 August 27 and 11 September 2012.



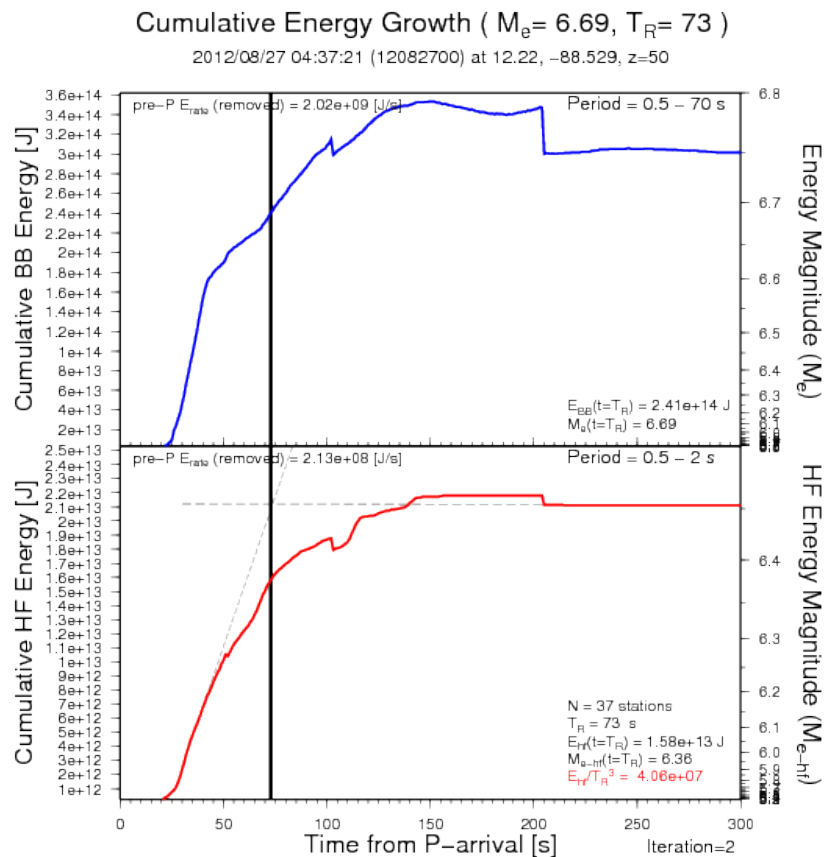
**Figure 2.1** The Bathymetry offshore of El Salvador and Northern Nicaragua and the location of the USGS defined earthquake epicenter (red star). Black dots correspond to epicenters of aftershocks through 11 September, 2012. Contours labeled in meters.



## 2.1 Earthquake Analysis

The initial assessment of the earthquake by staff of the Pacific Tsunami Warning Center (PTWC) determined that the earthquake was significant due to the magnitude of the strength of the seismic signals and the long period nature of the initial seismic waves (See Appendix 3 and 4). Within 10 minutes of the main shock, additional analysis by the PTWC suggested that the earthquake could be characterized as a 'slow' earthquake. This was indicated by  $\Theta$  values ( $\log_{10}(E/M_0)$ ; Newman and Okal, 1998) in the range of -6.5 to -6.0 as computed by the PTWC. Typical values of  $\Theta$  for 'normal' thrust earthquakes are generally larger, in the range of -4.7. Additionally,  $\Theta$  values derived by the West Coast Alaska Tsunami Warning Center (WCATWC) were even lower at -7.0, further suggesting a very slow event.

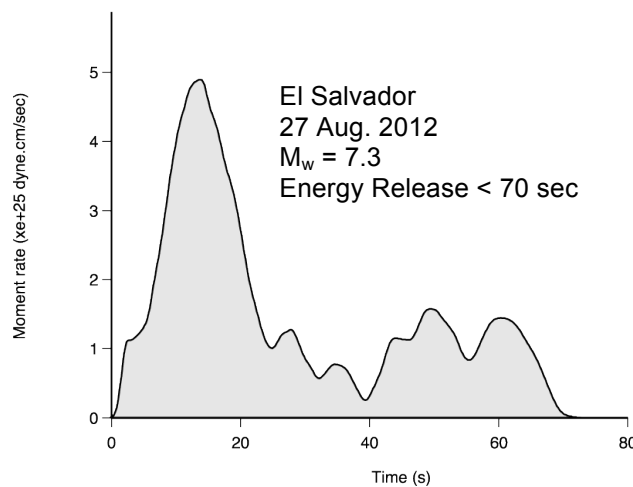
Analysis provided by the Real-Time Earthquake Energy and Rupture Duration Estimate project of the Georgia Institute of Technology (Mr. Jaime Convers, *pers. comm.*) and released within 10 minutes of the main shock, were also suggestive of a slow event (Figure 2.2). This analysis has been updated and the revised energy release plots are presented in Appendix 5.



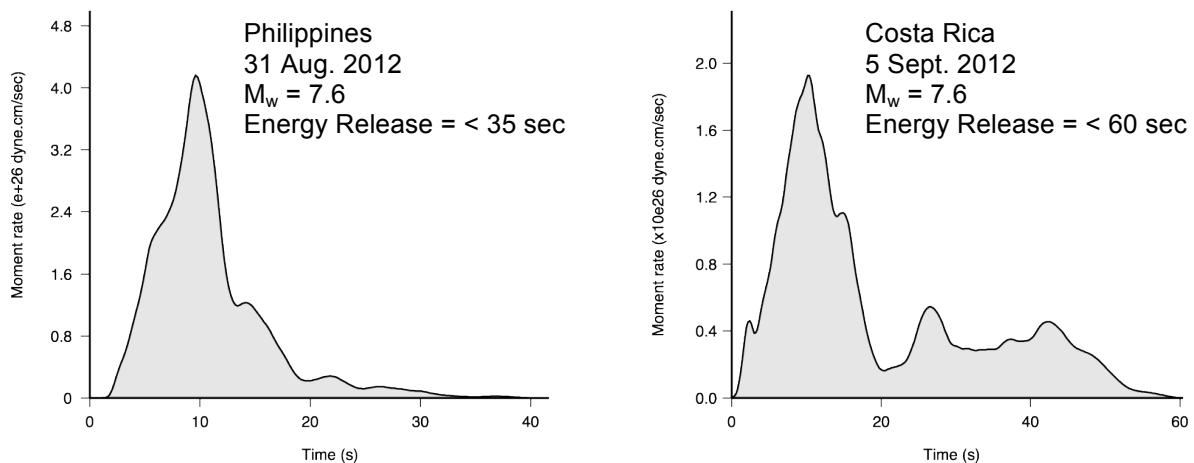
**Figure 2.2** The preliminary energy-time relationships produced by the Real-Time Earthquake Energy and Rupture Duration Estimate project of the Georgia Institute of Technology and emailed to a distribution list approximately 10 minutes after the earthquake.

Finally, analysis by the USGS finite fault method released in the days after the earthquake confirmed the slow nature and extended duration of the earthquake source, this is shown in the energy release function reproduced in Figure 2.3. This Figure shows that the energy released from this event occurred over a time period of approximately 70 seconds, which is quite long for an earthquake of that magnitude.

For comparison, we also show the energy release functions from two slightly larger earthquakes occurring around the same time as the El Salvador event (Figure 2.4). Comparison with the Philippines event is particularly illustrative of the slowness of the El Salvador event. The Philippines earthquake released nearly twice as much energy in approximately half the time as the El Salvador event. The difference relative to the Costa Rica earthquake is not as extreme as it was only 50% larger and occurred in roughly the same time frame.



**Figure 2.3 Energy release function for the 27 August 2012 El Salvador earthquake ( $M_w$  7.3). Energy release occurs over 70 seconds.**



**Figure 2.4 Energy release functions for the 31 August 2012 Philippines earthquake ( $M_w$  7.6, left) and the 5 September 2012 Costa Rica Earthquake ( $M_w$  7.6, right). Note that although both of these are larger in terms of magnitude, the energy is released in less time than in the El Salvador event, particularly in the case of the Philippines event.**

As with most earthquakes, several estimates of the earthquake epicenter, total energy release and faulting parameters are generally available following each event. Table 2.1 summarizes the available data on this event.

**Table 2.1 Source parameters for the 27 August 2012 El Salvador earthquake as reported by different monitoring agencies.**

Agency/Method	Epicenter		$M_w$	$M_o$ (Nm)	strike (deg)	dip (deg)	slip (deg)	Centroid		D (km)
	Lat (deg)	Long (deg)						Lat (deg)	Long (deg)	
PTWC	12.2	88.5								50.6
USGS: CMT	12.282	88.482	7.4	$1.8 \times 10^{20}$	289	11	81	11.984	88.8	19
Global CMT				$1.18 \times 10^{20}$	287	15	81	11.91	89.18	12
USGS: WPhase	12.279	88.530	7.3	$1.2 \times 10^{20}$	279	13	69	12.079	88.53	11
USGS: Finite Fault				$1.25 \times 10^{20}$						

## 2.2 Instrumental Tsunami Observations

The tsunami was observed instrumentally on both near and far field water level recorders. In the near field the tsunami was observed on the Acajutla and La Union tide gauges (Figure 2.5). In the far-field, the tsunami was observed on tide gauges in the Galapagos Islands, Ecuador (La Libertad), Easter Island and on DART station 43413 (see Figure 2.9 through Figure 2.11).

Due to the location of the earthquake and the fact that tsunamis radiate the majority of their wave energy perpendicular to the axis of the fault plane, neither of the El Salvador gauges were ideally located to receive the tsunami signal. Furthermore, Acajutla is located on the far side of a large headland while La Union is located several kilometers from the open ocean in the Gulf of Fonseca.



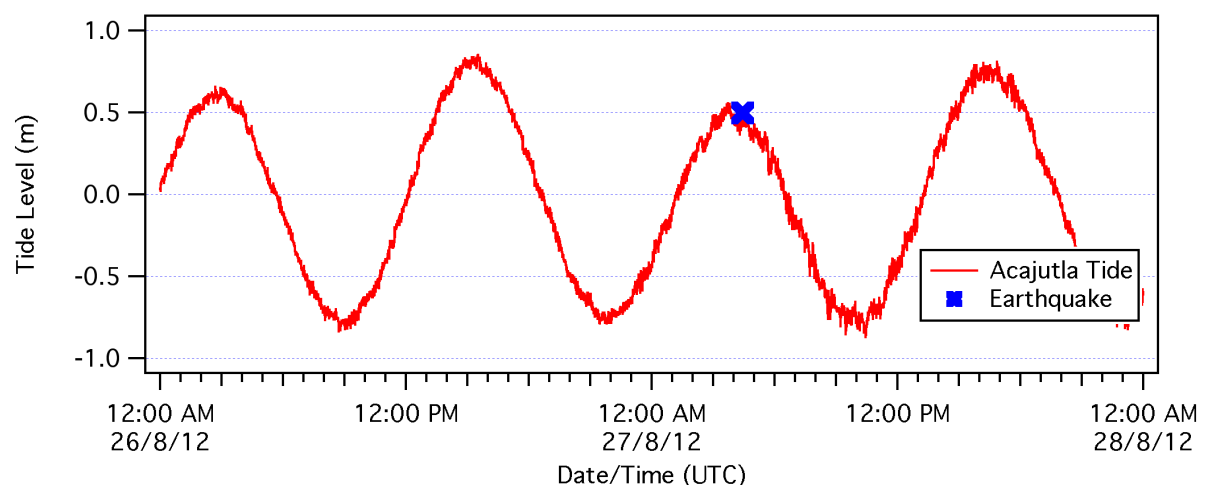
**Figure 2.5** Locations of the two tide stations in El Salvador that recorded the August 26<sup>th</sup>, 2012 tsunami. The earthquake source location is indicated with the red star.

In contrast, the Galapagos Islands are nearly ideally located to receive a strong signal from this event. Although they are approximately 1400 km away, they are located on a 190° deg (SSW) path from the source region, just 15° off of the trench perpendicular direction of 205°, and favorably situated for energy focusing by the Cocos Ridge. As a result the two stations in the Galapagos (Baltra and Santa Cruz) recorded a very strong, clear tsunami signal that arrived some 2.5 hours after the earthquake. Following the initial wave packet, both stations also responded with a secondary (and in the case of Santa Cruz tertiary) wave packet with amplitudes nearly as large as the initial wave. A similar extended duration and resurgence of wave height was also observed on these stations during the March 11, 2011 Tohoku tsunami (Lynett et al., 2012).

Further off axis were DART 43413 (1200 km at 264°) and the La Libertad, Ecuador station (1800 km at 153°). Evident in the DART record (Figure 2.11) is the high frequency signal from the earthquake followed ~1.5 hours later by a single tsunami wave pulse with a peak to trough (P2T) height of 0.024 m. The La Libertad signal is characterized by long period non-tsunami oscillations present before the tsunami arrival. The tsunami itself appears clearly some 3.5 hours after the earthquake, with the largest signal occurring some 5 hours after the tsunami arrival.

**Table 2.2 PTWC Summary of tide gauge recordings from the El Salvador tsunami.**

Station	Country	Lat (deg)	Long (deg)	arrival (hrs)	Z2P (m)	P2T (m)	Period mm:ss
Acajutla	El Salvador	13.57	-89.84	0:52	0.11	0.21	8:00
DART 43413	n/a	10.84	-100.08	1:36	0.01	0.02	8:00
La Union	El Salvador	13.31	-87.81	1:40	0.03	0.04	9:00
Baltra	Ecuador (Galapagos Is)	-0.44	-90.28	2:30	0.35	0.70	10:00
Santa_Cruz	Ecuador (Galapagos Is)	-0.72	-90.31	2:49	0.22	0.39	13:20
La_Libertad	Ecuador	-2.22	-80.91	3:36	0.21	0.37	11:30



**Figure 2.6 Acajutla tide gauge data from the time of the earthquake.**

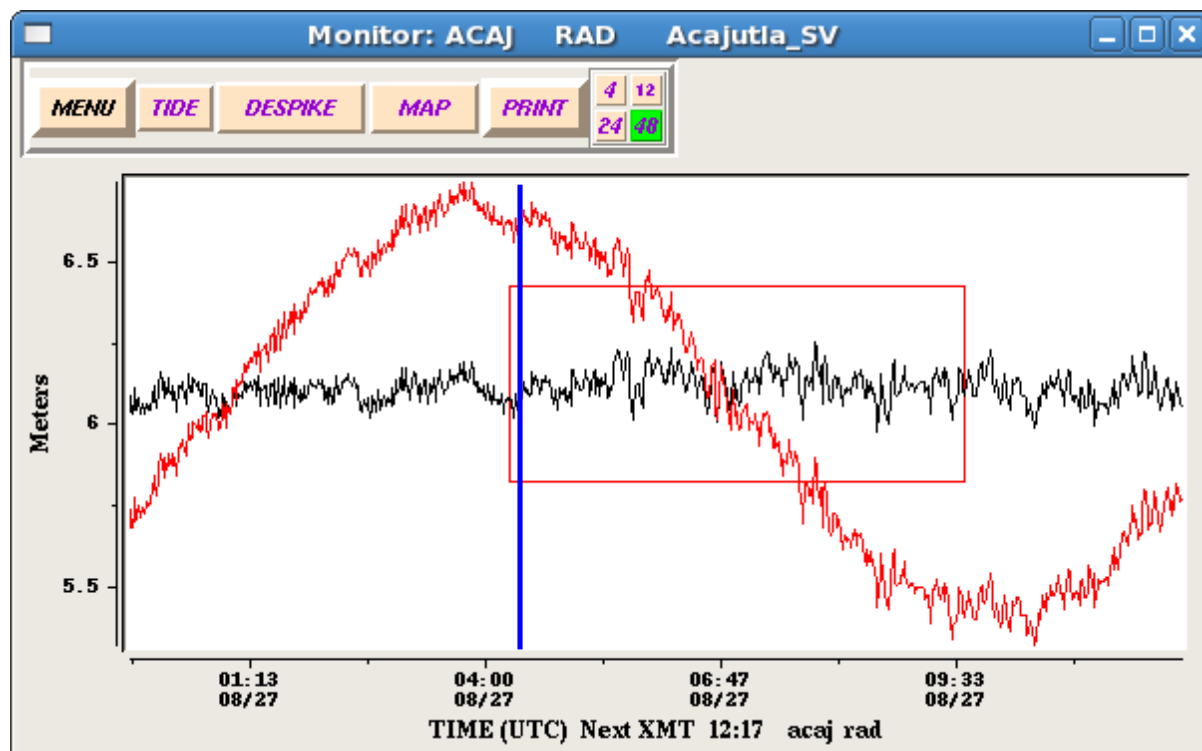


Figure 2.7 PTWC plot of the El Salvador tsunami on the Acajutla, El Salvador tide gauge.

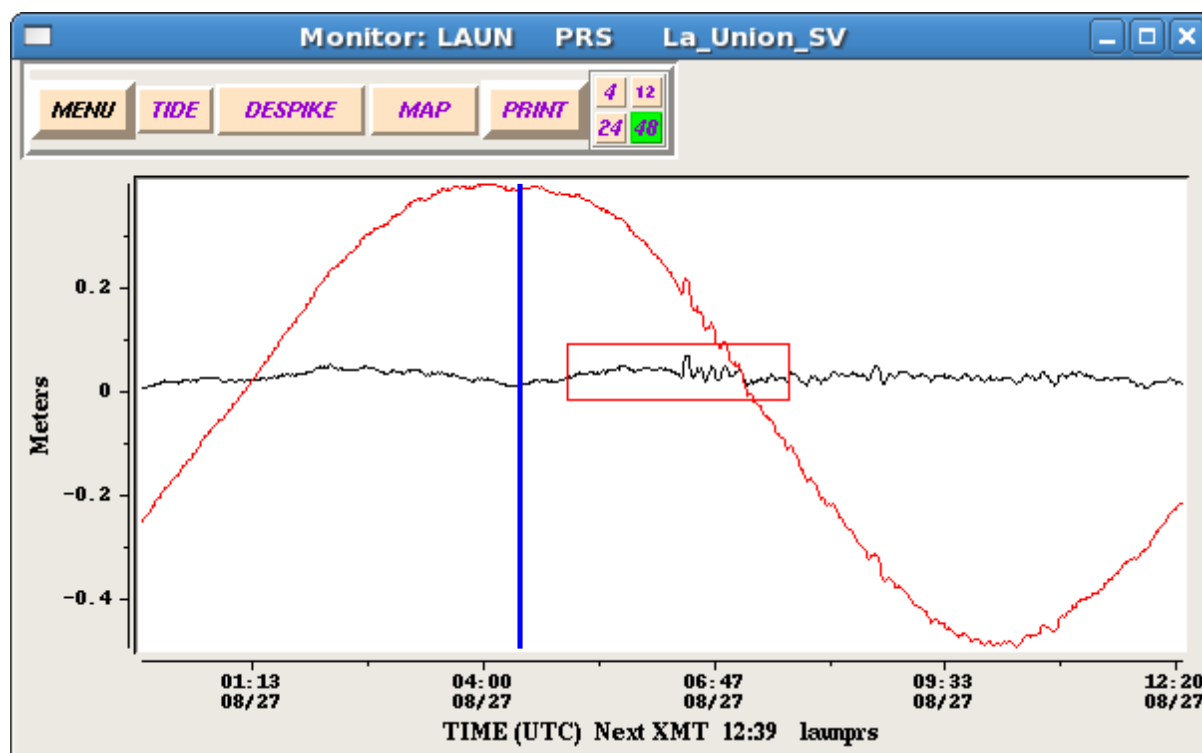


Figure 2.8 PTWC plot of the El Salvador tsunami on the La Union, El Salvador tide gauge.



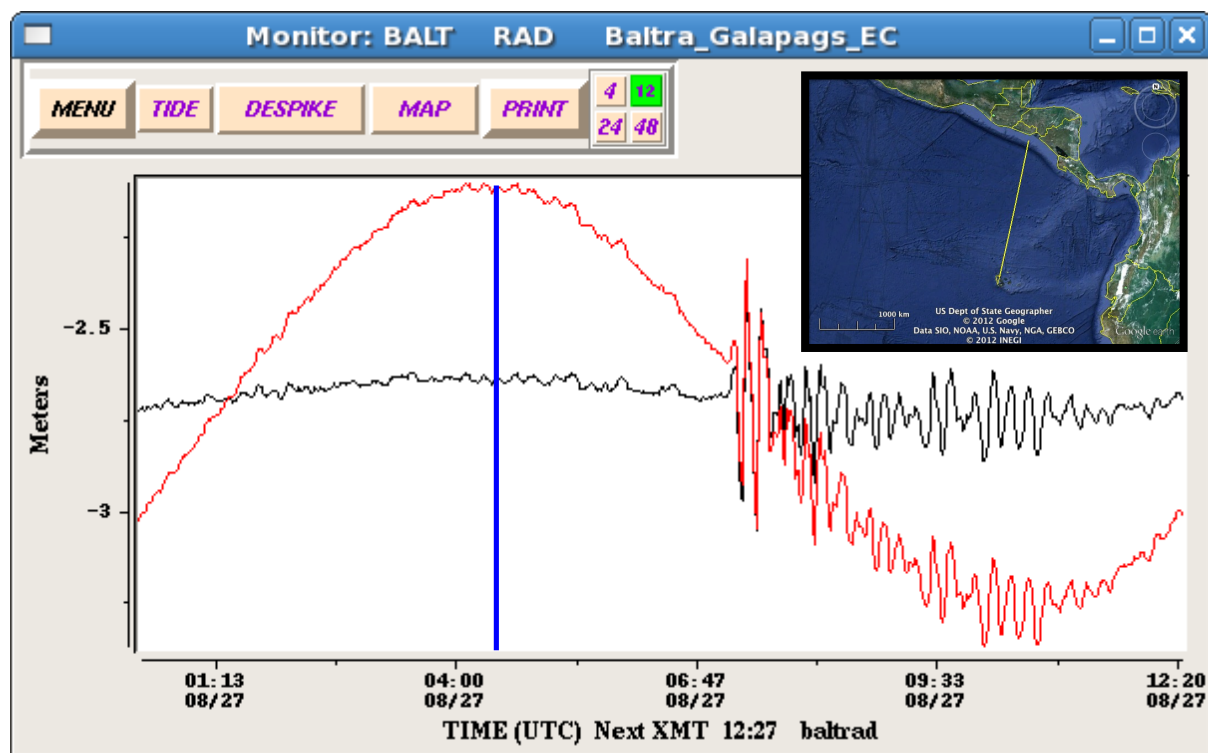


Figure 2.9 PTWC plot of the El Salvador tsunami on the Baltra, Galapagos Islands tide gauge. The gauge is located ~1400 km away along a  $191^\circ$  path.

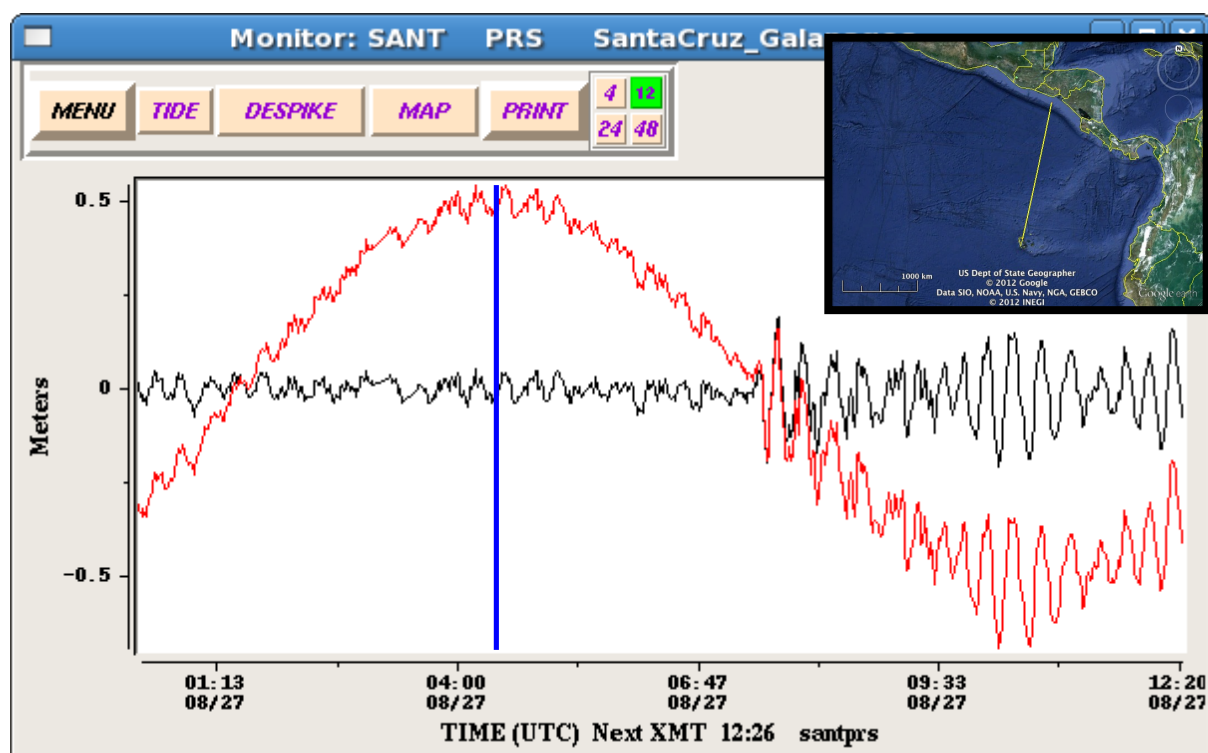


Figure 2.10 PTWC plot of the El Salvador tsunami on the Santa Cruz, Galapagos Islands tide gauge. The gauge is located ~1400 km away along a  $191^\circ$  path.

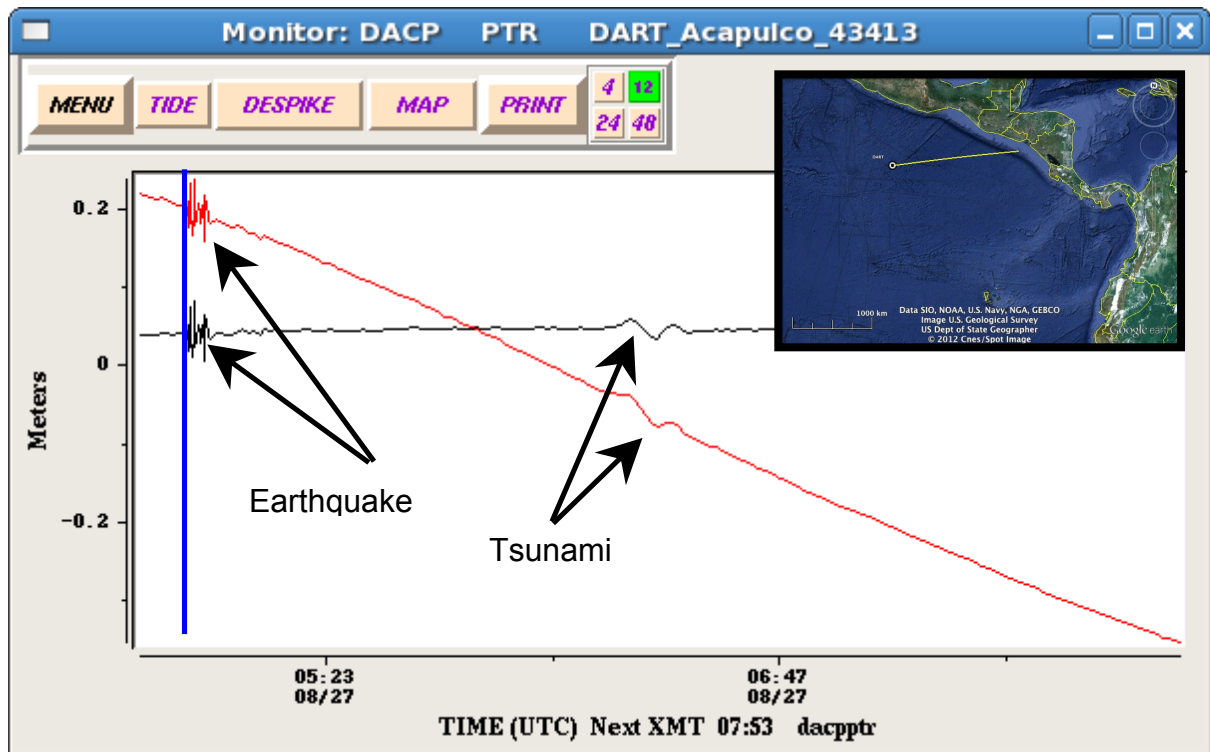


Figure 2.11 PTWC plot of the El Salvador tsunami on DART 43413. The station is located ~1200 km away along a  $264^\circ$  path.

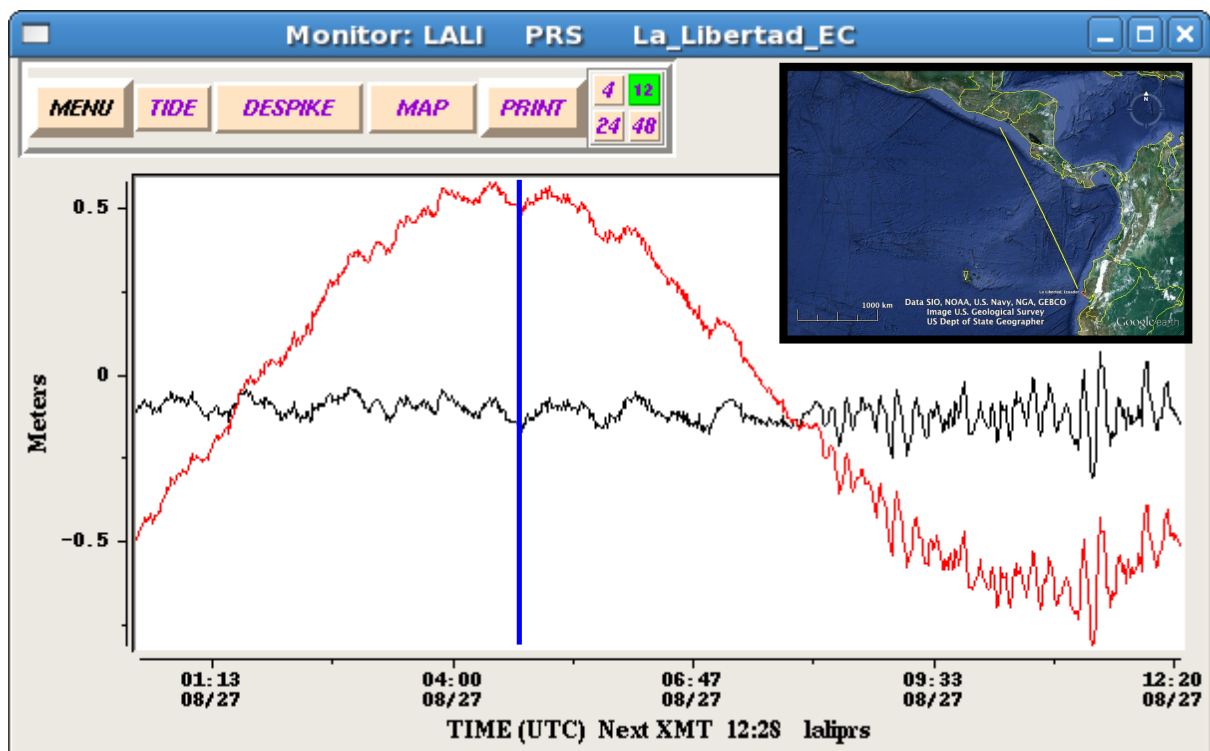
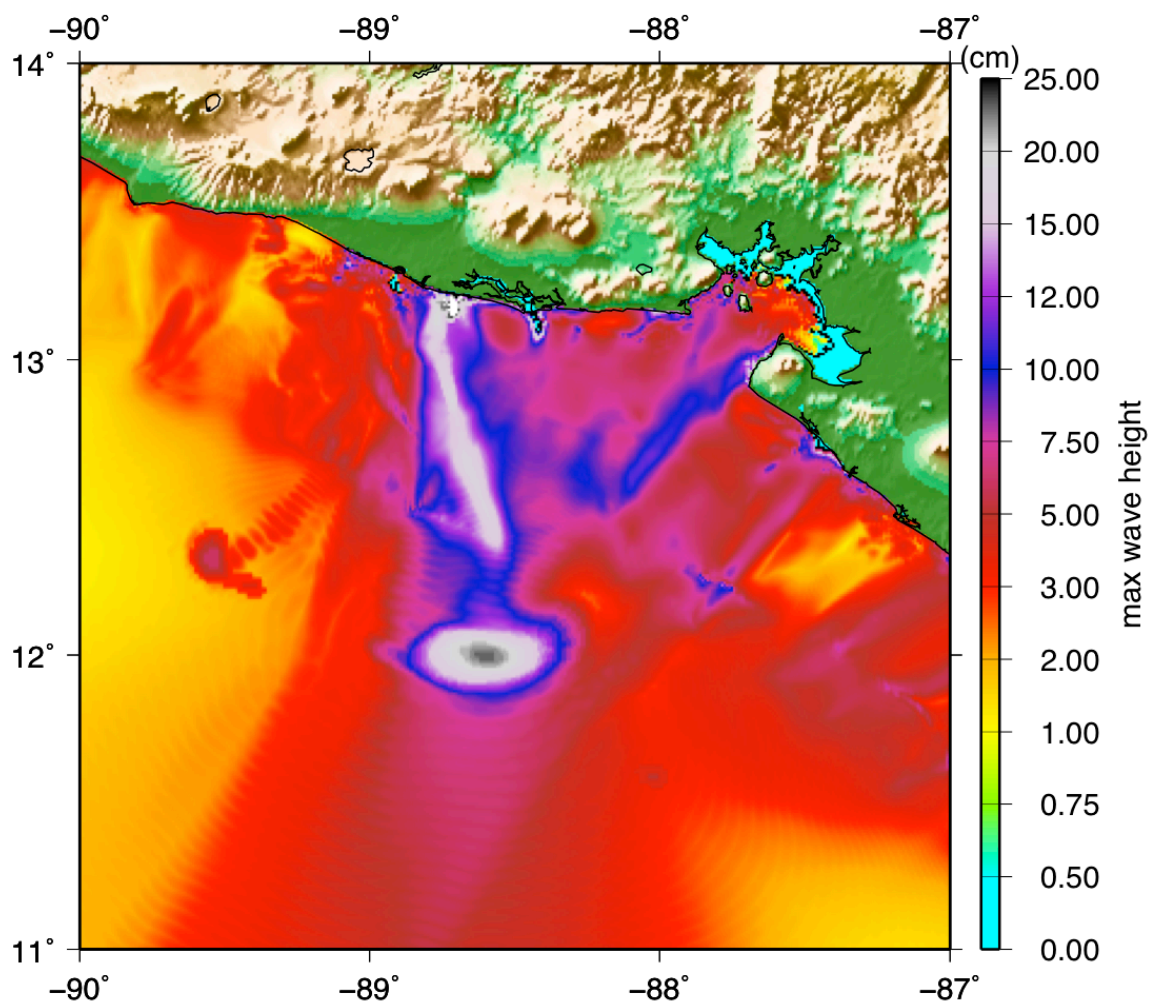


Figure 2.12 PTWC plot of the El Salvador tsunami on the La Libertad, Ecuador tide gauge. The gauge is located ~1800 km away along a  $153^\circ$  path.

### 2.3 Preliminary Hydrodynamic Modelling

Within days of the event preliminary hydrodynamic models of the tsunami had become available. Results from the MOST tsunami model (Titov and Gonzalez, 1997) are presented in Figure 2.13 (Nikos Kalligeris, *pers. comm.*). For this simulation, the model was initialized using the USGS finite fault solution for the slip distribution (See Appendix 5). The finite fault solution describes a distributed slip distribution across the source area with a maximum slip amount on the order of 1 m. While the model result shows strong focusing of wave energy towards the western end of the San Juan del Gozo peninsula, the absolute wave heights are somewhat deficient to have caused the reported 5 m tsunami heights in that area. The model also shows some focusing of wave energy towards the east in to northern Nicaragua and corresponding with areas that reported some tsunami effects.

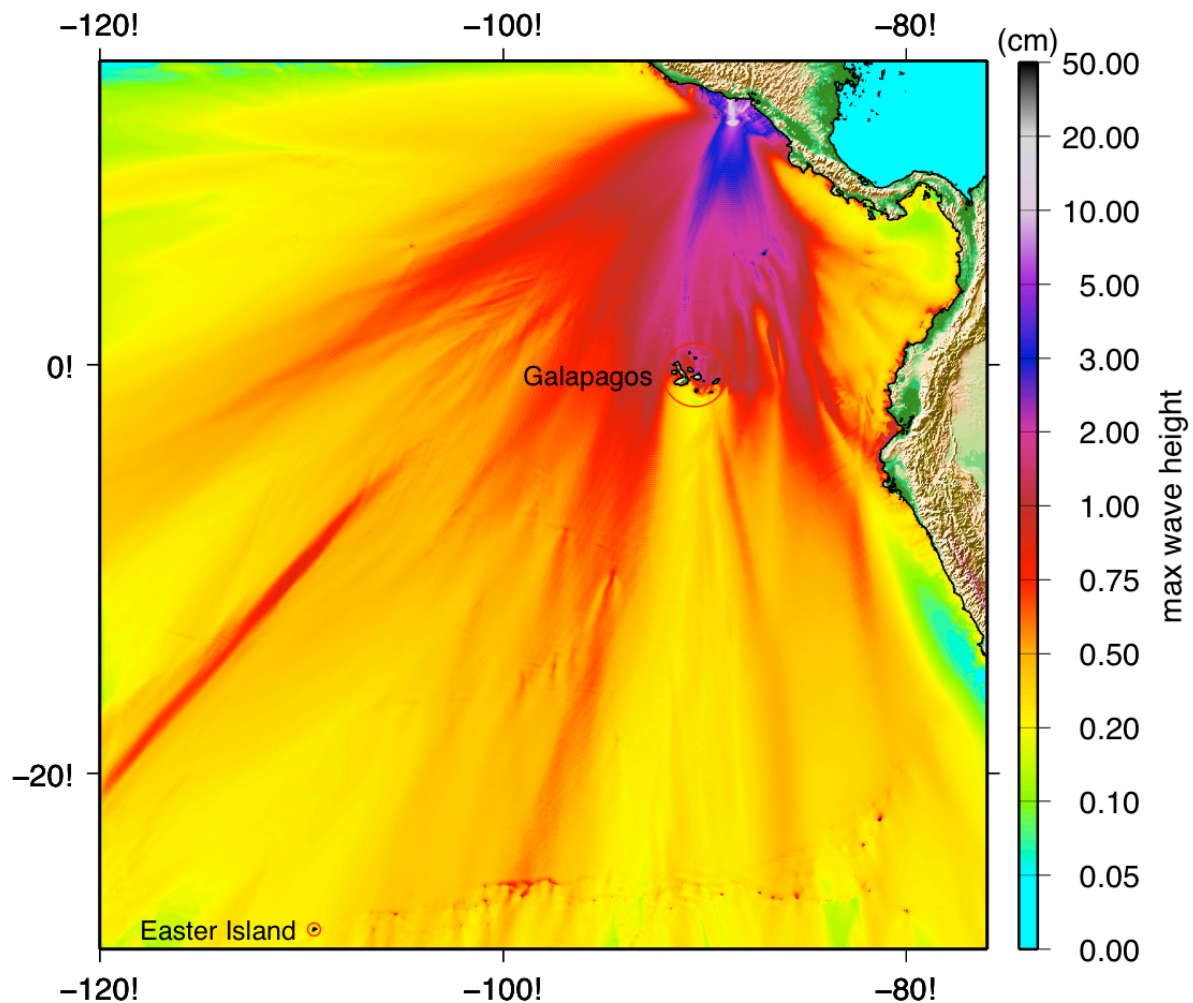


**Figure 2.13 Preliminary hydrodynamic modeling results using the MOST hydrodynamic model and the USGS finite fault solution as the tsunami source.**

The fact that the direct application of the USGS Finite Fault model as the initial condition for the tsunami hydrodynamic yields results deficient in wave heights necessary to explain the reported effects should not come as a surprise. Indeed, in the case of the October 2010 Mentawai earthquake and tsunami, hydrodynamic simulations initialized with a direct application of the finite-fault slip amounts also

severely under predicted the observed wave heights (Hill et al., 2012). In order to match the observed wave effects, it was necessary to scale the slip amounts by an average value of 5.6 (Newman et al., 2011). The necessity for this scaling factor was attributed to the slow, shallow nature of the earthquake rupture and the correspondingly lower shear wave velocities encountered in the shallower portions of the earth's crust (Newman et al., 2011).

Far-field simulation using the same initial condition described above (Figure 2.14) shows a concentrated beam of wave energy directed towards the Galapagos Islands, with strong secondary beams of energy heading towards Ecuador (and northern Peru) thereby explaining the strong tsunami signals recorded at these sites.



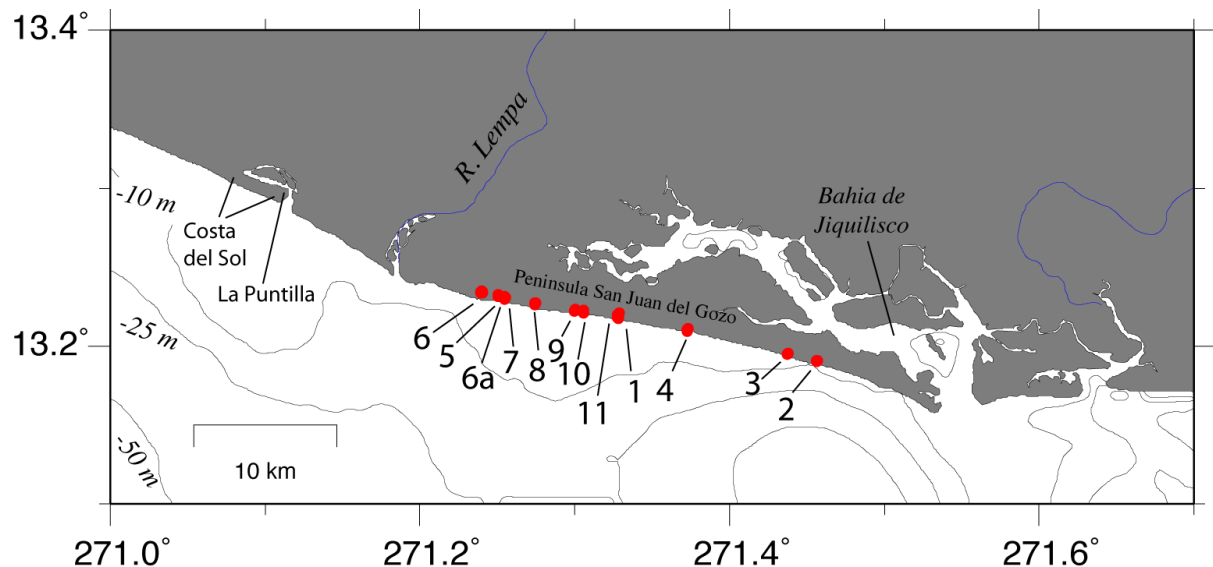
**Figure 2.14** Plot of maximum tsunami wave heights in the far field using the MOST hydrodynamic model initialized with the USGS Finite Fault model slip distribution.



### 3 TSUNAMI FIELD SURVEY

An initial survey was conducted by representatives of MARN, the El Salvadorean Ministry for the Environment and Natural Resources (Ministerio del Medio Ambiente y Recursos Naturales) in the days immediately following the event. This survey focused on attending to the immediate needs and disseminating factual information to the affected population. A number of interviews were recorded from eyewitnesses

Following the organization of the International Tsunami Survey Team (ITST), a second survey visited the affected areas on 5-7 September 2012. The survey team visited 11 separate sites throughout the affected area. These sites are depicted in Figure 3.1. The survey focused on the San Juan del Gozo Peninsula where the strongest tsunami effects were observed. At each of the 28 sites one or more measurements of tsunami height, runup, flow direction and inundation distance were recorded using established protocols (Synolakis and Okal, 2002, Dominey-Howes et al., 2012). Watermarks were surveyed with a Trimble GPS rover connected via Bluetooth to a laser range finder (Lasercraft XLRic) to record offset points and differentially corrected during post-processing with the base station network of UNAVCO. Measured data are presented relative to the tide level at the time of tsunami arrival.

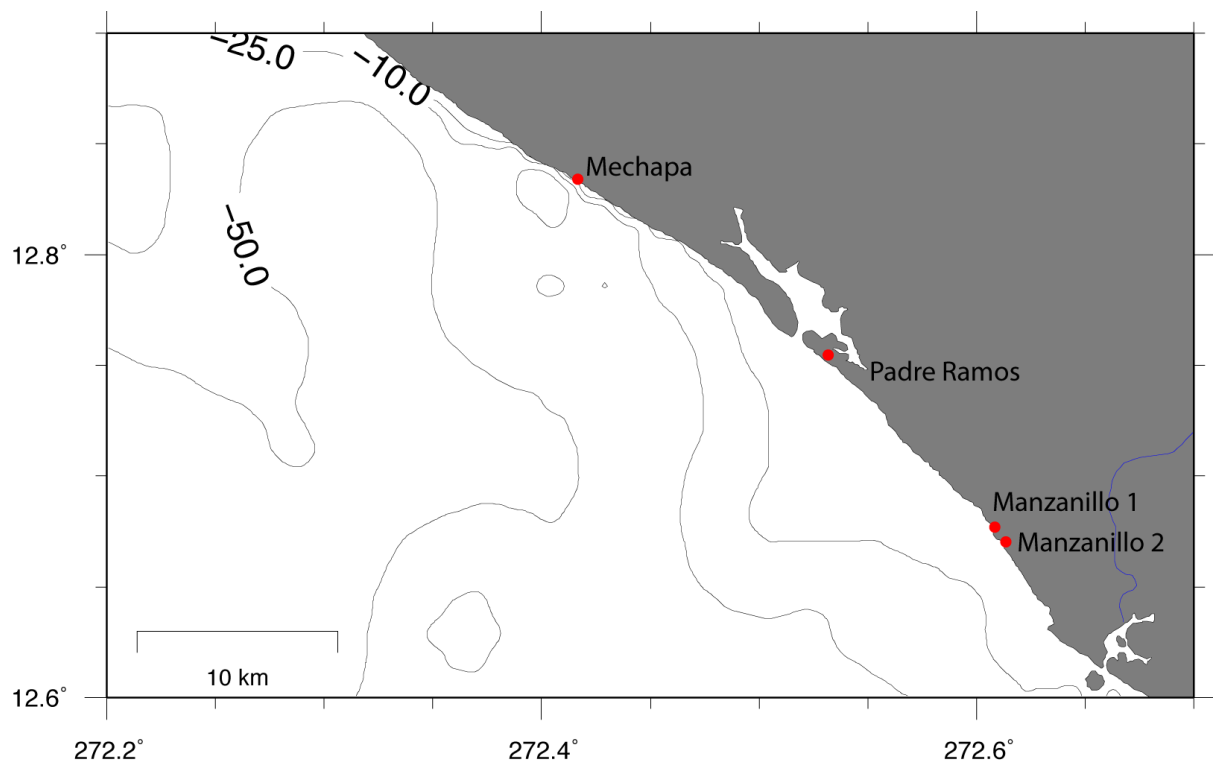


**Figure 3.1 Survey sites along the San Juan del Gozo peninsula.**

**Table 3.1 Survey site names corresponding to numbers in Figure 3.1.**

Number	Site Name (closest town or between towns)
1	Isla de Mendez
2	Corral de Mulas #2
3	Corral de Mulas #1
4	Ceiba Doblada
5	Manglarón/Monte Alta
6	Manglarón/Monte Alta
6a	Playa San Juan del Gozo
7	Playa San Juan del Gozo
8	Playa San Juan del Gozo-Isla de Méndez
9	Playa San Juan del Gozo-Isla de Méndez
10	Isla de Méndez
11	Isla de Méndez

An additional survey of affected sites was also carried out by INETER staff in northern Nicaragua in the week following the El Salvador survey. The northern Nicaragua survey was in response to reports of moderate inundation at several coastal villages in that area and focused on the sites of Mechapa, Peninsula de Padre Ramos, Manzanillo 1 and Manzanillo 2.

**Figure 3.2 Sites surveyed in northern Nicaragua by the INETER team.**

### 3.1 Definitions

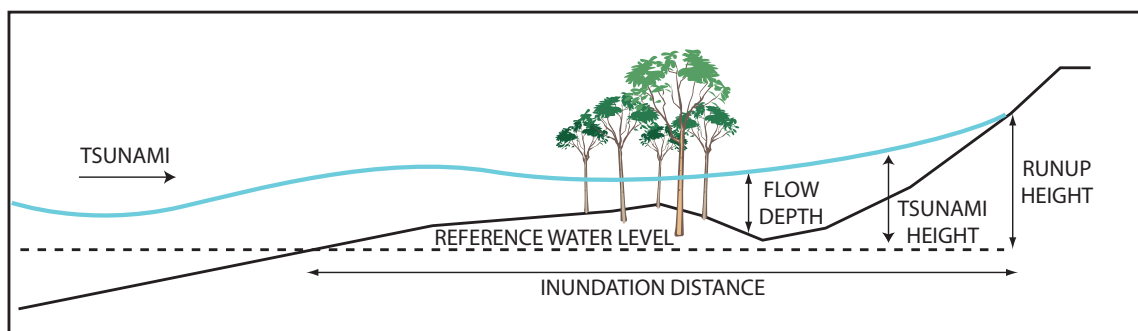
The terms runup, inundation, flow depth and tsunami height are defined as follows:

**Runup** is the height above sea level reached by the tsunami at the point of maximum inundation.

**Inundation** is the horizontal distance wetted by the tsunami flow.

**Flow depth** is the depth of the tsunami surge above the ground as indicated by flow markers such as piles of debris, impact scars on tree trunks, bark stripped from trees or mud marks on the walls of buildings.

**Tsunami height** is the sum of flow depth and the local topographic height.



**Figure 3.3** Definition sketch for tsunami height measurements and terminology.

### 3.2 Sites in El Salvador

All of the sites surveyed in El Salvador were located on the San Juan del Gozo peninsula which separates Jiquilisco Bay from the Pacific Ocean. In total 11 sites were surveyed as indicated in Figure 3.1. All of the sites were very similar in terms of the geography; characterized by a relatively steep, dark sand beach with a dune crest at the top of the beach berm. Landward of the beach berm the terrain was either level or sloping slightly downward. The vegetation was comprised of low beach plants, sea grape (icacos) plants, grasses and spiny cactus type plants. There were very few tall trees.

#### 3.2.1 Site 01: Isla De Mendez

Despite the name, Isla de Mendez is not an island. It is a nondescript section of the beach along the San Juan del Gozo Peninsula. It was in this area however where the most people were affected by the tsunami and the strongest effects were observed. This area is also the site of one of larger sea turtle hatcheries (vivero) in the area.

Ofilio Herrera, MARN and Civil Proteccion, indicated that the peninsula lacked high ground to evacuate to, and few means of transportation for moving inland. Mr. Herrera said communities on peninsula did not receive any tsunami alert prior to the arrival of the tsunami.

We were met at site by the municipal Mayor (Alcalde), Mr. Rigoberto Herrera Cruz. He was accompanied by several representatives from the local Civil Protection group and turtle hatchery workers.

The site featured a small shed (ramada) with wood posts and the walls and roof made from aluminum siding (lamina) located next to the hatchery. The hatchery itself is a simple structure comprised of perimeter fence with concrete posts. Wooden posts supported a simple roof made of palm fronds for shade.

During the tsunami, the walls of the ramada were torn off of the posts that are deeply embedded in the sand. The posts themselves were not pulled out of the ground, but some were leaned over by the force of the water. By the time of the survey the ramada had been repaired and had new walls and roof.

A worker at the hatchery, Jose Barrera-Garcia, was in the ramada as the tsunami struck and came out when he heard people crying out. He was dragged some 90 m by the wave from the ramada to a tree, where he was suspended in tree branch. The height of the branch was measured at ~2.1 m above ground. Mr. Barrera-Garcia reported that he saw three waves, however we suspect there is some confusion in differentiating between wind and tsunamis waves. Mr. Barrera-Garcia said it took 20 minutes for water to recede and fully drain. He said flow depth reached just beneath the roof of the ramada as indicated in Figure 3.5. At maximum inundation extent observed (340 m) by Mr. Garcia, he said less than 1 m water depth.

Jose Fermin Piñeda, 25 years old, from Isla de Mendez, was on the beach when the tsunami arrived. He had just delivered a turtle to the hatchery. He was standing just outside the shed that Jose Barrera-Garcia was sitting in. He also described 3 waves, the first of which carried him beyond the tree that Jose Barrera was caught in, near the bushes.

Jose Gabriel Chavez, local coordinator for Civil Protection, said he was inland and felt the earthquake describing it like he was in a swaying boat. He felt the swaying for 30-40 seconds. He said when he arrived at the impacted area (turtle hatchery referenced above) he found ~40 people injured, 3 of which are still in hospital. He also described gurgling noises (water draining into sand) on the beach area.

Jose Maria Argueta, local Civil Protection worker and member of local NGO Asociación Mangle that is working with Save the Children a USAID/OFDA-funded disaster risk management project, said that at the organizational level the Civil Protection personnel had basic tsunami knowledge but needed more support and training. Training by the project has covered first aid and early warning for flooding events up to now. Mr. Arqueta indicated the local population had no knowledge about tsunamis and did not know it was a hazard in their area. Mr. Arqueta stated that no one in Isla de Mendez received a tsunami alert, but that the community passed the information about the wave(s) up the chain to the next level, which was the municipality of Jiquilisco.

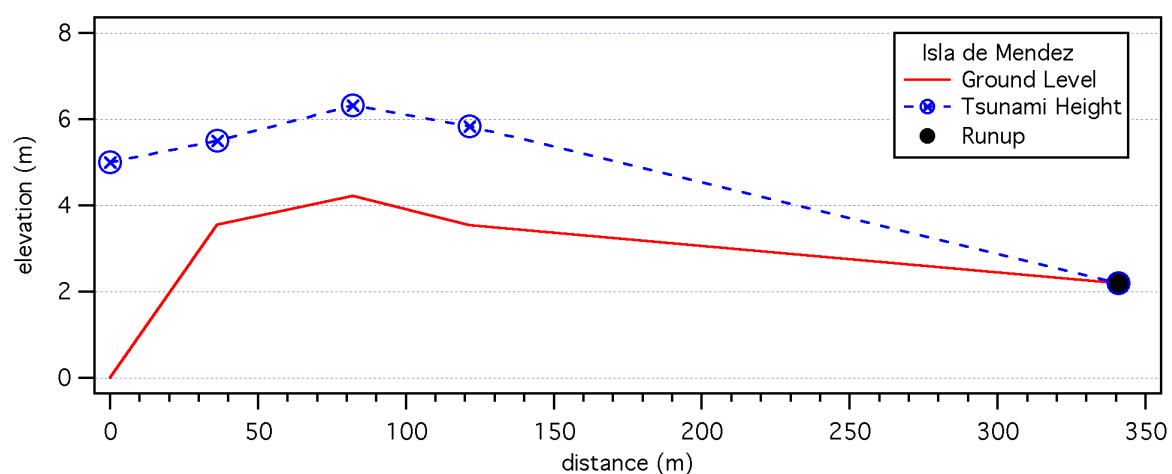




**Figure 3.4. Aerial views of Isla de Mendez. The browning of the vegetation due to salt water penetration from the tsunami is evident. The structures had been rebuilt since the tsunami. The inundation extent is to the edge of the photo frame.**



**Figure 3.5 Jose Barrera-Garcia at the newly rebuilt ramada. Mr. Barrera-Garcia was swept away by the tsunami and suffered minor injuries. The tsunami flow depth at this location was reported by Mr. Barrera-Garcia to be over 2 m.**



**Figure 3.6 Transect of tsunami data from Isla de Mendez.**





**Figure 3.7 The ramada at Isla de Mendez and the turtle egg hatchery in the background.**



**Figure 3.8 Estimated tsunami flow depth at the tree where Mr. Barrera-Garcia was deposited by the tsunami surge.**

### 3.2.2 Site 02: Corral de Mulas 2

After Isla de Mendez the team moved towards the eastern end of the Gozo Peninsula, stopping at three locations while driving along the beach dunes. At the first site we spoke with Jaime Enrique Mejia, a worker at turtle hatchery who was not at site at time of event. However, he showed us debris (tree trunk and palms) that were deposited just in front of a hut used by workers. The hut was not impacted. At the time of the earthquake, Mr. Mejia was inland and reported that he felt the earthquake, which he described as light ('leve' in Spanish). He reported that light fixtures hanging from the ceiling swayed during earthquake and that corrugated sheet metal ("lamina") used for walls and roofing vibrated strongly.



**Figure 3.9 Corral de Mulas 2. The tsunami reportedly flowed over the beach dune but did not reach the hut in the back ground. No damage to the hut.**





**Figure 3.10 Aerial view of Corral de Mulas 2. Extensive tsunami inundation is not evident.**



**Figure 3.11 A view towards the east of the San Juan del Gozo peninsula. The extent of tsunami inundation is evident by the brown color of the vegetation towards the shoreline.**

### 3.2.3 Site 03: Corral de Mulas 1

Francisco Esteban Elena Aguilar, turtle hatchery worker said that the shaking lasted 2-3 minutes. He describes two waves, second being the largest. Aguilar mentioned his goods and personal items stored in the hut were lost. He also mentioned that water reached the top of near by fence post, measured at ~1 m higher than the dune crest and a few meters inland.



**Figure 3.12 Corral de Mulas 1. The surge overtopped the dune and washed through the ramada.**



#### **3.2.4 Site 04: Ceiba Doblada**

No witnesses were encountered at Ceiba Doblada, however a resident of the area working with the survey team (Mr. Ofilio Herrera) reported that at this location a child as well as a man and a horse were dragged down the beach by the wave. At this site the team encountered evidence of tsunami overwash and inundation.



**Figure 3.13 Possible tsunami overwash debris wrapped around a post at the Ceiba Doblada ramada.**





**Figure 3.14** The palm fronds aligned perpendicular to the shore line are evidence of tsunami inundation and overwash.



**Figure 3.15** A wrack line of palm fronds deposited by the tsunami, 155 m from the shoreline.



### 3.2.5 Site 05, 06, 07: Manglarón/Monte Alto/Los Manglares

El Manglarón or Monte Alto is located to the west of Isla De Mendez (see Figure 3.1). This marks the beginning of a forest of tall mangroves that extends approximately 6 km to the west towards the mouth of the Rio Lempa. The mangroves at the shoreline are dying off as evidenced by the brown color and seen in overhead images. The exact cause of the mangroves dying off is not known, however it is a slow, ongoing process and is not related to the tsunami.

Witness Evan Antonio Coronel was sitting near the shed area at the time of wave arrival. He described three waves, the third of which carried him inland. Mr Coronel indicated the furthest inundation point, ~150 m from the shoreline. His testimony of the effects indicated a maximum of ~4.5m flow depth. He also indicated a loud noise preceding wave arrival which he described as like a loud bus.

Another local resident, Carlos Antonio mentioned that there were approximately 50 people working on that part of the beach on the night of the tsunami. He himself was in the community of San Juan del Gozo that evening, and didn't feel the tremor. They did not receive a warning. He said that 6 turtle nests were lost.

From this location, the survey team walked approximately 1 km further west to the edge of the dead mangrove forest. In this area there was evidence of tsunami inundation. A runup point and inundation distance were measured.



**Figure 3.16 Aerial view towards the west. The dead/dying mangrove forest is clearly evident.**



**Figure 3.17 Aerial view towards the east over the dead/dying mangrove forest.**



**Figure 3.18 Resident at Mangalrón indicates the flow depth at the site. The walls of the shed had been ripped off by the tsunami and replaced since the event.**





**Figure 3.19 Aerial view of El Manglarón.**



**Figure 3.20 Turtle hatchery built since the tsunami.**





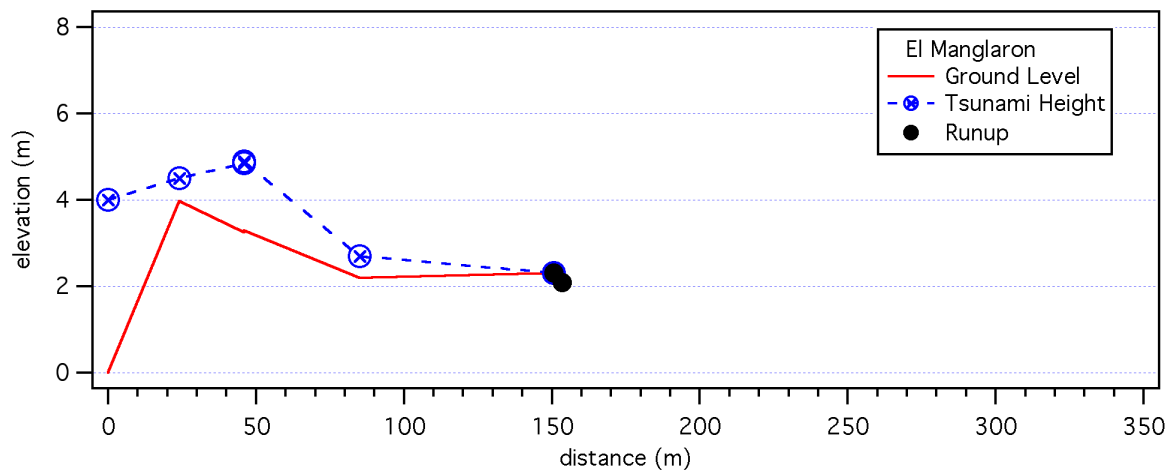
**Figure 3.21 Debris caught in the fence behind the hut at El Manglarón.**



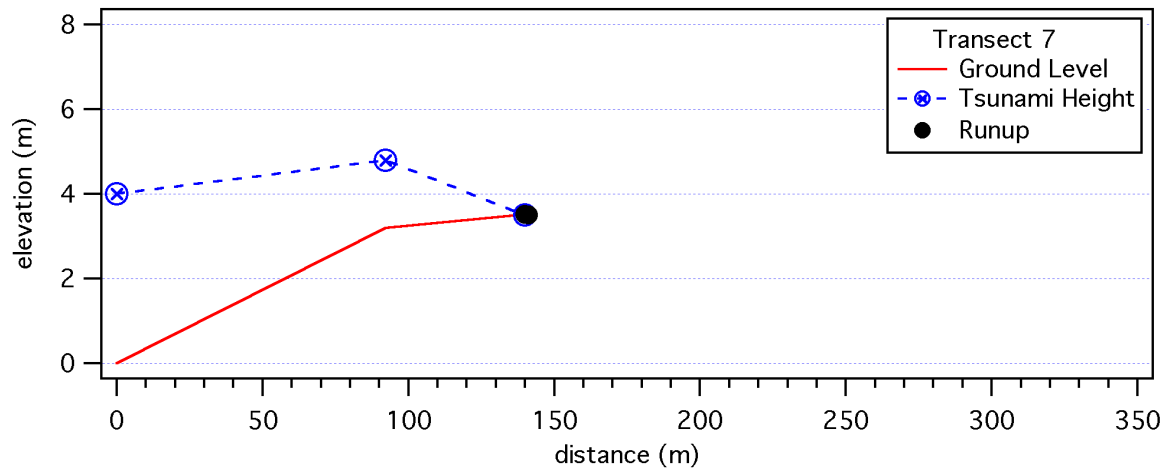
**Figure 3.22 In the forest of dead mangroves.**



**Figure 3.23** At the edge of the dead forest. Evidence of tsunami surge flowed under the intact piece of corrugated metal.



**Figure 3.24** Transect of field data from El Manglarón.



**Figure 3.25** Transect of field data from Site 7 (near Manglarón).



### **3.2.6 Site 08, 09, 10, 11: Unnamed Sites west of Isla de Mendez.**

Driving eastward towards Isla de Mendez, the team stopped at several sites where there was clear evidence of tsunami inundation. There were no residents or locals in the area available for interviews. At these sites the teams measured runup and inundation and documented the evidence of the tsunami (Figure 3.26 through Figure 3.28). During the helicopter over flight of the following day, several aerial images of this area were recorded (Figure 3.30 and Figure 3.30).



**Figure 3.26 Tsunami debris line.**





**Figure 3.27 Tsunami debris line.**



**Figure 3.28 Dead vegetation from salt water intrusion.**





**Figure 3.29 Aerial view of a tsunami debris line.**



**Figure 3.30 Aerial view of sand deposits from tsunami overwash.**



### 3.2.7 Costa del Sol and La Puntilla

To the west of the study area is a popular and highly developed beach resort area known as Costa del Sol (see Figure 3.1). At the eastern end of this area is a grouping of restaurants built directly on the water front. Indeed some of the restaurants have seating areas set directly over the water (Figure 3.31 and Figure 3.32). Given the extremely vulnerable location of these structures, it could be reasonable to expect that if a tsunami wave the same size as that which affected Isla de Mendez hit this area, there would have been reports of significant effects or damage. During the initial survey immediately after the earthquake and tsunami conducted by MARN, residents and proprietors here did not report any such effects, nor was any evidence observed supporting that notion.

Just to the west of La Puntilla is the popular resort area of Costa del Sol (Figure 3.34 and Figure 3.34). As seen in the aerial images, the area is very developed with numerous structures built close to shore and many potential witnesses in the area on the night of the tsunami. During the preliminary MARN survey, there were no reports from this area of inundation, damage or effects, again suggesting that the tsunami here was very small.



**Figure 3.31 La Puntilla.**



**Figure 3.32 La Puntilla.**



**Figure 3.33 Costa del Sol.**





**Figure 3.34 Costa del Sol.**



**Figure 3.35 Aerial view towards La Puntilla and Costa del Sol to the west.**

### **3.2.8 Additional tsunami reports**

The preliminary MARN survey received reports from several other areas around El Salvador regarding the tsunami (Appendix 6).

At the Port of Acajutla, there were no observations of sea level changes and ships moored in the port did not experience any unusual surges. We note that a surge of 0.2 m with an 8 minute period was recorded on the Acajutla tide gauge (Table 2.2). Workers at the port maintained their normal shifts, however they were alerted to the possibility of tsunami effects that night by MARN.

Playa El Espino is located to the east of the entrance to Jiquilisco Bay. Resident and president of the local Restaurants Association Mrs. Blanca Yorahimi Larreynaga was interviewed by telephone on the morning after the tsunami. She reported that there were no observable tsunami effects and that the local police had moved into the peninsula of St. Juan del Gozo to help assist people affected in that area.

Playa El Cuco is located well to the east of the Bay of Jiquilisco. A phone call was placed to the administrators of the Hotel Las Flores, a popular surfing resort for North Americans. They reported that on the night of the tsunami there were no unusual events. The local surf guide and boat captain said that the boats left parked on the beach were not moved or disturbed in any way and that activities of the next day resumed normally.

### 3.3 Sites in Nicaragua

Following the survey of El Salvador, Mr. Norwin Acosta of Nicaragua's INETER agency returned to Nicaragua and carried out a follow up survey at four sites in northern Nicaragua. This survey was conducted in response to reports from that area describing some tsunami related inundation. The complete INETER report is contained in Appendix 7.

#### 3.3.1 Mechapa

In the Mechapa region, locals generally did not feel the earthquake shaking. On the night of the tsunami the weather was calm. At the time of the tsunami the tide level was dropping and visibility was low due to the lack of a moon that night. Respondents were not sure of the exact time of the tsunami arrival, but they estimate that it was between 9 and 10 pm on 26 August (NOTE: The earthquake actually occurred at 10:27 pm local time). Because of the darkness, they could not determine if the sea withdrew before the tsunami arrival, however the general consensus was that it did not. The respondents reported that there was a large wave followed immediately by another larger wave. Based on the witnesses responses, the flow depth at the survey site was approximately 50 cm and the surge penetrated 106 m inland. There was no damage as a result of the tsunami, however some boats parked on the beach were moved by the surge. There was evidence of salt water intrusion indicated by salt-burned vegetation near shore.







**Figure 3.37 Mechapa, the blue color indicates the area flooded by the tsunami.**



**Figure 3.38 Mechapa, the blue color indicates the area flooded by the tsunami.**



**Figure 3.39 A resident of Mechapa indicates the flow depth from the tsunami.**

### 3.3.2 Manzanillo 1

At Manzanillo 1, the people interviewed did not feel the earthquake. Similar to Mechapa, the respondents reported normal, calm weather conditions, with a dropping tide and low light. People who were able to see the sea that night reported that the water withdrew, but then simply returned to the normal level, i.e. there was no inundation or flooding. There were no reports of damage to structures or affects on the local population.

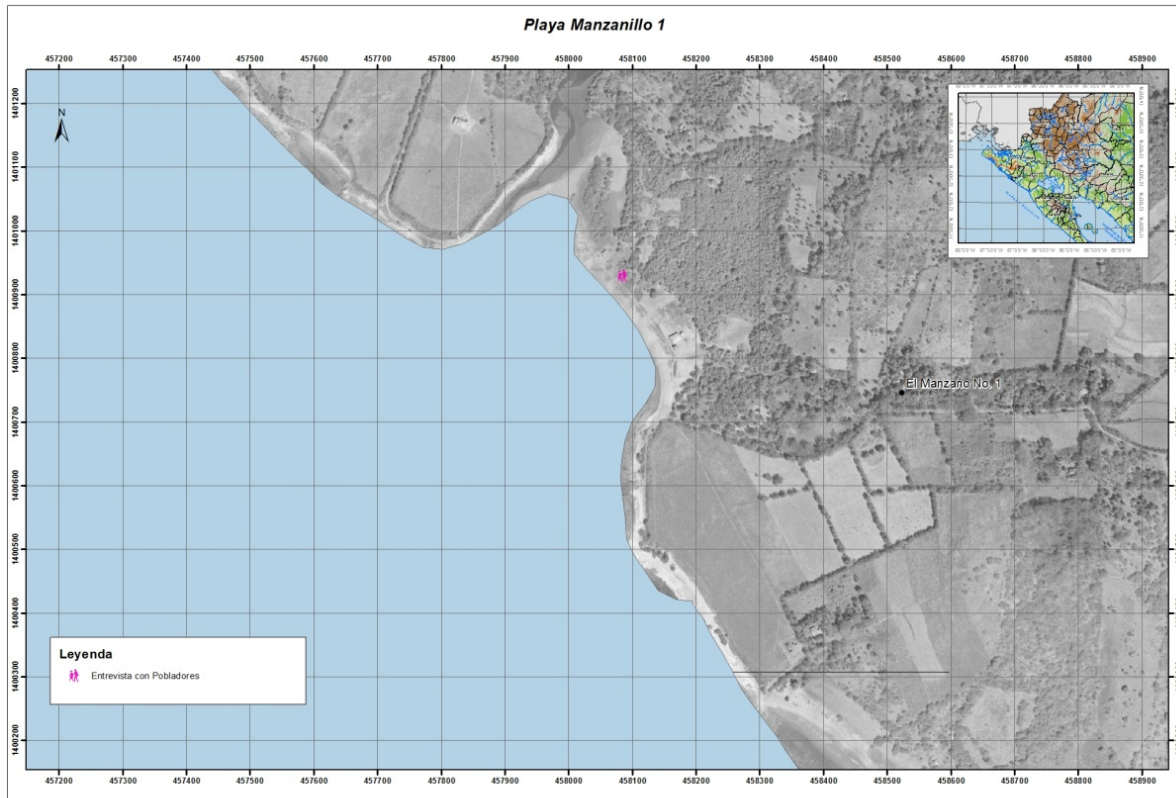


Figure 3.40 Overview map of Manzanillo 1





**Figure 3.41 The coast at Manzanillo 1**



### 3.3.3 Manzanillo 2

At Manzanillo 2, again the respondents reported that they did not feel the earthquake shaking. Those that were able to see the ocean, reported that they saw the water recede, despite the low light. Some respondents reported seeing a large wave. There was a flow depth estimate of 50 cm by one resident and indications of flooding up to 62 m inland along the coast and up to 120 m up a river channel. No damage to structure was evident; some fishing boats were displaced by the surge.

There were no indications of damage as a result of the tsunami. Some fishing boats were dragged several meters.



Figure 3.42 Extent of tsunami inundation at Manzanillo 2.






**Figure 3.43 Flow depth indicated by a resident of Manzanillo 2.**





**Figure 3.44 Inundation of the Manzanillo 2 area.**

## 4 INTERVIEW SUMMARIES

Table 4.1 El Salvador interview summaries

<p>Jose Barrera Garcia</p> 	<p><b>Interview 1, Isla de Mendez</b></p> <ul style="list-style-type: none"> <li>• Dragged by water from hatchery shed to tree (~70m).</li> <li>• Tsunami reached just beneath shed roof (~2.3m).</li> <li>• Suspended in tree branch by water (~2.1m).</li> <li>• Water drained after ~20 minutes.</li> <li>• Tsunami inundation reached ~300m inland, with less than ~1m flow depths at further extents.</li> <li>• Water drained after ~20 minutes.</li> <li>• No natural tsunami warnings signs were noticed.</li> </ul>
<p>Francisco Esteban Elena Aguilar</p> 	<p><b>Interview 2, Corral de Mulas #1</b></p> <ul style="list-style-type: none"> <li>• Shaking lasted 2-3 minutes.</li> <li>• Tsunami arrived ~23 minutes following earthquake.</li> <li>• Described 2 waves.</li> <li>• Tsunami reached top of nearby tree (~5m above sea level).</li> <li>• Goods and personal items in hut were lost.</li> </ul>
<p>Evan Antonio Coronel</p> 	<p><b>El Manglaron/Monte Alto</b></p> <ul style="list-style-type: none"> <li>• Four “abnormal” waves arrived within seconds.</li> <li>• Tsunami dragged him ~40m until he hit a tree.</li> <li>• Loud noise preceding wave arrival, described it like a droning sound of an approaching bus.</li> </ul>

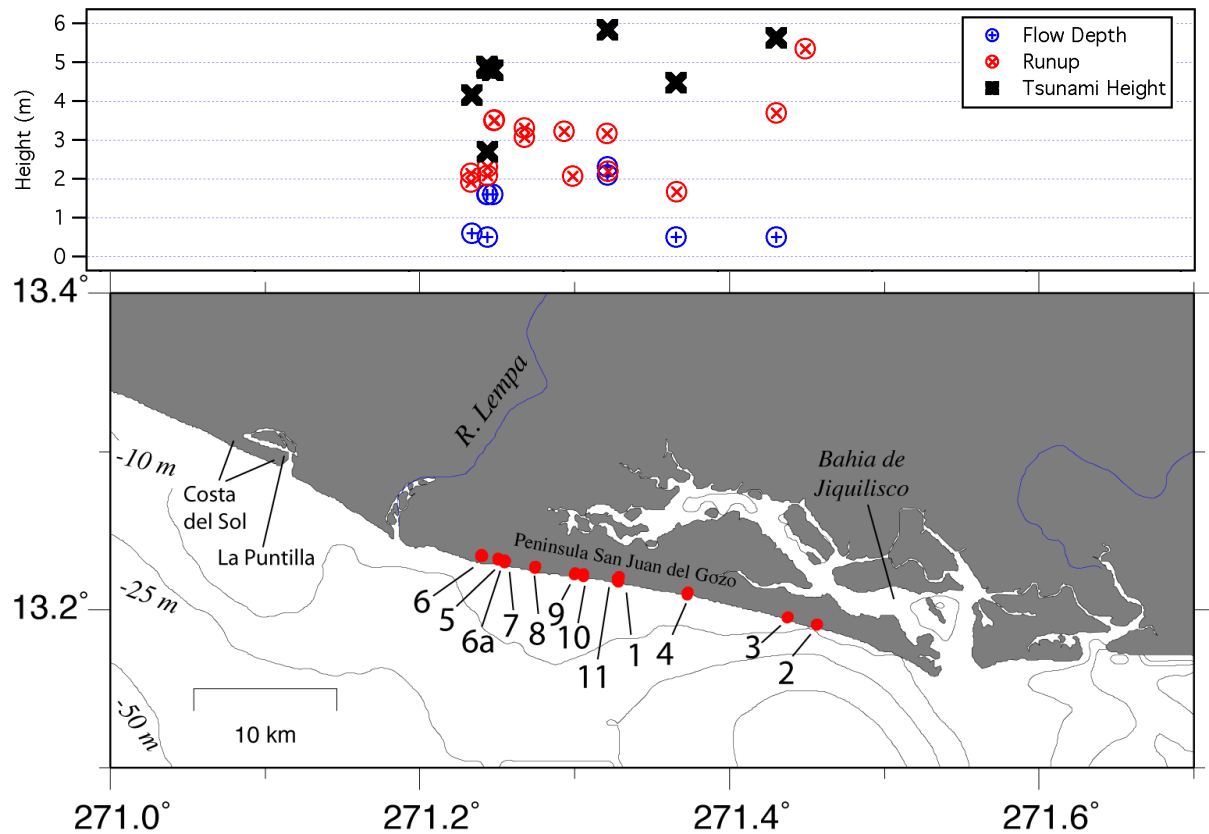
**Table 4.2 Nicaragua Interview Summaries**

	<p><b>Mechapa</b></p> <ul style="list-style-type: none"><li>• Earthquake not felt.</li><li>• Weather normal</li><li>• a large wave followed immediately by another larger wave</li></ul>
	<p><b>Manzanillo 1</b></p> <ul style="list-style-type: none"><li>• Earthquake not felt.</li><li>• Weather normal</li><li>• Saw the sea level recede, then returned to normal</li></ul>

## 5 DATA SUMMARY

The data collected by the El Salvador survey team is summarized in Figure 5.1, Table 5.1 and Table 5.2.

The data are divided into flow depths, tsunami heights and runup heights as defined in Figure 3.3. Because the topography landward of the dune ridge sloped downward, runup heights are generally lower than the maximum tsunami heights.



**Figure 5.1 Summary of data collected during the field survey.**

**Table 5.1 Runup measurements from the 2012 El Salvador tsunami.**

Date	Time	Lat	Long	Runup	Watermark	Description
UTC-6	UTC-6	N°	E°	R[m]		
5-Sep-2012	12:05:34	13.221	-88.671	2.20	Wrack Line	eyewitness confirmed
5-Sep-2012	15:15:09	13.191	-88.543	5.35	Wrack Line	eyewitness confirmed on top of dune tree log
5-Sep-2012	15:46:52	13.195	-88.562	3.69	Wrack Line	eyewitness confirmed brown grass
5-Sep-2012	16:38:15	13.211	-88.627	1.66	Wrack Line	wrack line
6-Sep-2012	8:32:22	13.232	-88.749	2.08	Wrack Line	brown vegetation eyewitness confirmed
6-Sep-2012	8:56:52	13.232	-88.749	2.30	Wrack Line	brown vegetation eyewitness confirmed
6-Sep-2012	10:01:02	13.235	-88.760	2.14	Wrack Line	embankment next to mangroves
6-Sep-2012	10:06:42	13.235	-88.760	1.91	Wrack Line	wrack line next to mangroves
6-Sep-2012	10:54:07	13.231	-88.745	3.51	Wrack Line	field next to fence
6-Sep-2012	10:58:39	13.231	-88.745	3.50	Wrack Line	field next to fence
6-Sep-2012	11:18:21	13.227	-88.725	3.30	Wrack Line	
6-Sep-2012	11:24:57	13.227	-88.725	3.07	Wrack Line	
6-Sep-2012	12:27:27	13.223	-88.700	3.22	Wrack Line	brown vegetation eyewitness confirmed
6-Sep-2012	12:47:18	13.223	-88.694	2.07	Wrack Line	brown vegetation eyewitness confirmed
6-Sep-2012	13:03:53	13.220	-88.672	3.17	Wrack Line	brown vegetation eyewitness confirmed

**Table 5.2 Flow depth and tsunami height data from the 2012 El Salvador tsunami.**

Date	Time	Lat	Long	Terrain	Flow Depth	Tsunami Height	Watermark	Description
UTC+9	UTC+9	N°	E°	z[m]	h[m]	z+h[m]		
5-Sep-2012	11:42:07	13.218	-88.672	4.22	2.1	6.32	Mud Line Inside	eyewitness confirmed house pole
5-Sep-2012	11:53:35	13.219	-88.672	3.54	2.3	5.84	Broken Branch	eyewitness confirmed wrapped in sheet metal
5-Sep-2012	15:51:40	13.195	-88.562	5.13	0.5	5.63	Other, see comment	dune overtopped eyewitness confirmed
5-Sep-2012	16:34:33	13.210	-88.627	3.97	0.5	4.47	Damaged Trim Line	wooden palm leaf hut
6-Sep-2012	8:26:22	13.232	-88.749	3.25	1.6	4.85	Damaged Trim Line	hut with sheetmetal eyewitness confirmed Manglaron Monte Alto
6-Sep-2012	8:48:35	13.232	-88.749	3.29	1.6	4.89	Damaged Trim Line	house siding eyewitness confirmed
6-Sep-2012	9:14:26	13.232	-88.749	2.19	0.5	2.69	Raft Debris	debris in fence
6-Sep-2012	9:46:06	13.234	-88.759	3.55	0.6	4.15	Damaged Trim Line	hut with sheetmetal eyewitness
6-Sep-2012	10:59:56	13.231	-88.746	3.19	1.6	4.79	Broken Branch	tree on top of dune

**Table 5.3 Data from northern Nicaragua.**

Site	Lat	Long	Inundation Distance	Flow depth
	N°	W°	(m)	(m)
Mechapa	12.833	87.583	106	0.5
Manzanillo 1	12.672	87.387	0	n/a
Manzanillo 2	12.657	87.376	120	0.5



## 6 SUMMARY FINDINGS AND NEXT STEPS

A tsunami was generated by the 26 August 2012, magnitude ( $M_w$ ) 7.4 earthquake centered offshore of south eastern El Salvador. The causative earthquake was a 'slow earthquake', a type of earthquake known to cause tsunamis disproportionately higher than the earthquake magnitude alone would suggest. The tsunami generated by the earthquake primarily affected approximately 30 km of the El Salvador coastline directly landward of the earthquake epicentre. Less severe tsunami effects were also reported and observed in northern Nicaragua.

The strongest tsunami effects were observed along the beaches of the San Juan del Gozo peninsula which runs eastward from the mouth of the Lempa River and separates Jiquilisco Bay from the Pacific Ocean. Peak tsunami heights were measured up to 6 m at Isla de Mendez with tsunami heights of 3 to 6 m measured approximately 15 km east and east of this location. The tsunami caused inundation of up to 350 m inland at Isla de Mendez. Tsunami heights were relatively uniform across the survey area. Coastal areas 25 km to the west (i.e. Costa del Sol) were not affected by damaging tsunami waves, nor were areas just to the east, suggesting relatively localised effects. The effects in northern Nicaragua, while less severe than in El Salvador, were nevertheless significant with flooding up to 120 m inland and flood depths of 0.5 m.

In addition to the Field Survey, ITST team members were also requested to provide advice to MARN on how to strengthen its national tsunami warning and mitigation system. The observations and findings from the ITST team were supplemented with advice from Directors of the Pacific Tsunami Warning Center and International Tsunami Information Center, and the Technical Secretary of the ICG/PTWS. The findings should be considered preliminary. Further detailed discussions with subject matter experts will be necessary to develop action plans that can lead to robust and reliable improvement to El Salvador's tsunami warning and mitigation system. The overall findings were as follows:

1. The 26 August 2012 earthquake highlighted the insufficiency of current El Salvador seismic resources to rapidly and accurately determine the magnitude of a great earthquake in time to identify the risk of an impending tsunami and allow authorities to act on that information. Denser national and regional seismic networks and quick magnitude estimation techniques will be required for timely local earthquake source characterization. In the interim, MARN may want to utilize the PTWC Earthquake Observatory Message as a first indicator of earthquake size.
2. MARN should review of their existing tsunami alert and warning protocols, particularly for near-field events. For local tsunamis and immediate alert dissemination in minutes, warnings should be based solely on earthquake information since seismic signals are currently the fastest early tsunami warning signals.
3. To determine the severity and longevity of dangerous tsunami waves, real or near-real time monitoring of sea levels is required. Currently, El Salvador has 2 working

coastal sea level stations and Nicaragua 1 coastal sea level station. More are required, especially facing the open ocean, and should be given highest priority as the most economical means of confirming tsunamis. Actual observations, whether by coastal or deep-ocean sensors, along with eyewitness reports by local authorities, are essential for determining when to cancel tsunami warnings, and when it is safe for the public to return to the evacuated area.

4. At present, local tsunami wave forecasting must utilize database-driven pre-calculated tsunami scenarios. In general, near real-time data, whether by DART systems or coastal gauges, are too late to be used as input to local tsunami wave forecasting. Deployment of a deep-ocean sensor off El Salvador will be of most use to countries around the Pacific monitoring a Central America source as a distant tsunami that might impact them.
5. To enable communities to better respond to local tsunamis, they must know their tsunami hazard and what to do. Development of tsunami inundation maps and evacuation zones for at-risk areas of El Salvador will assist greatly. Additionally, outreach and education are essential activities. Place emphasis on the recognition of a tsunami's natural warnings signs as a key local tsunami preparedness message. Development and mainstreaming tsunami preparedness into school curricula will ensure sustainability over generations.
6. Civil Protection should develop tsunami response plan at the national level, as well as the local level. Response plans should document agencies, protocols, and standard operating procedures to enable rapid and seamless warning communication and evacuation of vulnerable communities, followed by immediate disaster response to save lives.
7. To focus on the tsunami hazard, a national-level tsunami coordination committee comprised of key stakeholder agencies should be formed to regularly meet to discuss, agree, and oversee the development on sustainable, effective end-to-end warning system. Topics should include (1) hazard risk assessment, (2) warning, (3) emergency response, and (4) preparedness and mitigation.
8. Identify a sustainable source for tsunami information and technical assistance. Technical assistance on (1) hazard risk assessment, (2) warning, (3) emergency response, and (4) preparedness and mitigation is available from several sources including but not limited to technical cooperation agencies like JICA, GIZ, USAID, or others, intergovernmental mechanisms like the ICG/PTWS and its International Tsunami Information Center ITIC and from UN agencies like UNDP, UNESCO and ISDR. These should be considered as subsidiary to internal capacities El Salvador is trying to develop to address and mitigate tsunami risk.

## 7 REFERENCES

- Abe, K., Tsuji, Y., Imamura, F., Katao, H., Iio, Y., Satake, K., Bourgeois, J., Noguera, E., and Estrada, F. (1993) Field Survey of the Nicaragua Earthquake and Tsunami of September 2, 1992, Bulletin of the Earthquake Research Institute of the University of Tokyo (in Japanese), 68, 23-70.
- Dominey-Howes, D., Dengler, L., Dunbar, P., Kong, L., Fritz, H., Imamura, F., McAdoo, B., Satake, K., Yalciner, A., Yamamoto, M., Yulianto, E., Koshimura, S., and Borrero, J. (2012). International Tsunami Survey Team (ITST) Post-Tsunami Survey Field Guide. 2nd Edition. UNESCO-IOC, Paris.
- Gica E.M., Spillane, M., Titov, V.V., Chamberlin, C., and Newman, J.C. (2008) Development of the forecast propagation of the forecast propagation database for NOAA's Short-term Inundation Forecast for Tsunamis (SIFT), NOAA Tech. Memo OAR PMEL-139, 89 pp.
- Hill, E, Borrero, J., Huang, Z., Qiu, Q., Banerjee, P., Natawidjaja, D., Elosegui, P., Fritz, H., Pranantyo, I., Li, L., Macpherson, K., Skanavis, V., Synolakis, C., and Sieh, K. (2012) The 2010 Mw 7.8 Mentawai earthquake: Very shallow source of a rare tsunami earthquake determined from tsunami field survey and near-field GPS. Journal of Geophysical Research, Vol 117, B06402, doi:10.1029/2012JB009159.
- Kanamori, H. (1972) Mechanism of tsunami earthquakes, *Phys. Earth Planet. Int.*, 6, 346-359.
- Polet, J. and Kanamori, H. (2000) Shallow subduction zone earthquakes and their tsunamigenic potential, *Geophys. J. Int.*, 142, 684-702.
- Kanamori, H. and Kikuchi, M. (1993) The 1992 Nicaragua earthquake: a slow tsunami earthquake associated with subducted sediments. *Nature*, 361, 714-716.
- Newman, A.V., and Okal, E.A. (1998) Teleseismic estimates of radiated seismic energy: The E/M0 discriminant for tsunami earthquakes, *J. Geophys. Res.*, 103, 26885-26898.
- Newman, A. V., G. Hayes, Y. Wei, and J. Convers (2011), The 25 October 2010 Mentawai tsunami earthquake, from real-time discriminants, finite- fault rupture, and tsunami excitation, *Geophys. Res. Lett.*, 38, L05302, doi:10.1029/2010GL046498.
- Satake, K., Bourgeois, J., Abe, K., Abe, K., Tsuji, Y., Imamura, F., Iio, Y., Katao, H., Noguera, E., and Estrada, F. Tsunami Field Survey of the 1992 Nicaragua Earthquake, *Eos: Trans. Am. Geophys. Un.* 74,13, pp145, 156-157.
- Synolakis, C.E. & Okal, E.A., 2005. 1992–2002: Perspective on a decade of post-tsunami surveys, in: *Tsunamis: Case studies and recent developments*, ed. K. Satake, Adv. Nat. Technol. Hazards, 23:1–30.



Titov, V., and F. I. González (1997), Implementation and testing of the Method of Splitting Tsunami (MOST) model, NOAA Tech. Memo. ERL PMEL-112 (PB98-122773), 11 pp., Pac. Mar. Environ. Lab., NOAA, Seattle, Wash.

Wikipedia contributors, "El Salvador," Wikipedia, The Free Encyclopedia, [http://en.wikipedia.org/w/index.php?title=El\\_Salvador&oldid=523734824](http://en.wikipedia.org/w/index.php?title=El_Salvador&oldid=523734824) (accessed November 21, 2012).

Wikipedia contributors, "Nicaragua," Wikipedia, The Free Encyclopedia, <http://en.wikipedia.org/w/index.php?title=Nicaragua&oldid=523656605> (accessed November 21, 2012).

## 8 APPENDIX 1: INVITATION LETTERS

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From: **Deisy Lopez** <dlopez@marn.gob.sv>  
Date: Thu, Aug 30, 2012 at 7:40 AM  
Subject: Request for cooperation  
To: w.watson-wright@unesco.org, laura.kong@noaa.gov  
Cc: Ministro Herman Rosa <hrosa@marn.gob.sv>, Viceministra Lina Pohl <lpohl@marn.gob.sv>, Francisco Gavidia <fgavidia@marn.gob.sv>, Manuel Diaz <mdiaz@marn.gob.sv>

Wendy Watson-Wright, PhD  
Executive Secretary, Intergovernmental Oceanographic Commission  
Assistant Director General, UNESCO  
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Laura S. L. Kong, Ph.D.  
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Tel: [1-808-532-6423](tel:1-808-532-6423), Cell: [1-808-392-4415](tel:1-808-392-4415)  
Fax: [1-808-532-5576](tel:1-808-532-5576)  
Email: [laura.kong@noaa.gov](mailto:laura.kong@noaa.gov)

Dear Sirs:

Preliminary (eyewitness) reports from coastal communities in El Salvador, are reporting that tsunami waves inundated their coasts, causing damage in some parts.  
We would welcome the immediate involvement of IOC and ITIC in supporting and coordinating an international post-tsunami survey team to help us document the tsunami impacts. And also to try to understand the earthquake mechanism and the local propagation of the wave that result in a local event in order to improve our knowledge, research program and protocols to warning about tsunami treats on time.

My best regards and thanks for your attention to this request

Att

Ana Deisy Lopez  
General Director  
Observatorio Ambiental  
MARN  
El Salvador

Enviado desde mi dispositivo de bolsillo inalámbrico BlackBerry® de Telecom.



Gobierno de Reconciliación  
y Unidad Nacional  
*El Pueblo, Presidente!*



DS-JMB-0940-08-12  
Managua, 30 de Agosto del 2012

Señora  
**WENDY WATSON – WRIGHT, PHD.**  
Secretario Ejecutivo,  
Comisión Oceanográfica Intergubernamental, COI  
Asistente Director General, UNESCO  
París, Francia.  
Su Despacho.-

Estimada Señora Watson:

Por medio de la presente muy respetuosamente me dirijo a Usted, en su calidad de Secretario Ejecutivo de la Comisión Oceanográfica Intergubernamental, COI/UNESCO, para solicitar su apoyo a Nicaragua en la evaluación insitu sobre el impacto del reciente tsunami tras el terremoto ocurrido el pasado 26 de agosto de 2012, en el Océano Pacífico, frente a las costas de El Salvador y Nicaragua.

Informes preliminares (de testigos) de comunidades costeras en El Salvador, afirman que las ondas (olas) de tsunami inundaron sus costas, causando daños en algunas partes. En Nicaragua se especula que hubo penetración de una pequeña marejada en el sector de Los Farallones de Cosiguina, Potosí y Jiquilillo.

Damos la bienvenida a la participación inmediata de los expertos de IOC Y ITIC, para apoyarnos y coordinar el estudio Post Tsunami con la finalidad de documentar los impactos de este fenómeno en la Región de América Central.

Agradeciendo de antemano su atención, aprovecho la ocasión para saludarle con las muestras de mi consideración y estima.

Atentamente,

  
**JAVIER MEJÍA BALDODANO**  
Director Ejecutivo



cc.: -Dra. Laura Kong /Centro de Información Internacional de Tsunami, ITIC, Hawái  
-Dr. Bernardo Aliaga /COI, UNESCO, Francia.  
Dr. Guillermo González /Secretario Ejecutivo, SINAPRED  
-Cnel. Néstor Solís /Jefe de la D.C del Ejército de Nicaragua  
-Dra. Angélica Muñoz /Directora de Geología y Geofísica, INETER.  
-Archivo

**NICARAGUA  
DE VICTORIA  
EN VICTORIA!**

**CRISTIANA, SOCIALISTA, SOLIDARIA!**  
INSTITUTO NICARAGÜENSE DE ESTUDIOS TERRITORIALES



## 9 APPENDIX 2: ITST GUIDING PRINCIPLES

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### **International Post-Tsunami Survey for the 27 August 2012 Offshore El Salvador Tsunami International Tsunami Survey Team – Offshore El Salvador (ITST-Off El Salvador)**

#### **GUIDANCE**

#### **BACKGROUND** (as of 1 September 2012)

The 27 August 2012 magnitude 7.3 offshore El Salvador earthquake and tsunami caused inundation of up to 250 m along coasts in southern El Salvador. The Pacific Tsunami Warning Center issued its first information bulletin at 0444 UTC, and upgraded its advice to a tsunami warning for Central America countries at 0456 UTC as a precaution based on indications that this event might be slow earthquake; national authorities are then responsible for issuing warnings to their populations on the tsunami threat to their coasts. Subsequent monitoring showed no destructive tsunami (maximum 0.10 m amplitude at Acajutla, El Salvador; no tsunami at La Union, El Salvador), and the warning was cancelled at 0623 UTC. Eyewitness reports indicated the waves around 30 min after the earthquake, with strong waves along San Juan del Gozo peninsula, from the mouth of the Rio Lempa to the beach El Lindero. Other reports of wave heights were 1.75 m in El Salvador and 0.45 m in Nicaragua. It is not known if the tsunami affected Honduras or the Gulf of Fonseca.

According to the National Geophysical Data Center (NGDC, <http://www.ngdc.noaa.gov/hazard/>) Global Historical Event databases, there have been three confirmed local tsunamis that have hit El Salvador (1859, 2001, 2012), and three confirmed tsunamis that have hit Nicaragua (1901, 1951, 1992). The 2 September 1992 M7.7 tsunami was a slow earthquake that caused 170 deaths and USD \$30 million in damage; maximum runup was 9.9 m. NGDC compiles data on significant earthquakes, volcanic eruptions, and tsunamis including socio-economic information such as deaths and damage.

#### **ITST – OFF EL SALVADOR SUMMARY**

UNESCO's Intergovernmental Oceanographic Commission (IOC) and International Tsunami Information Center (ITIC) are coordinating international post-tsunami field surveys of the tsunami and its effects. It is doing so at the request of the Governments of El Salvador and Nicaragua (GoES, GoN). The goals include:

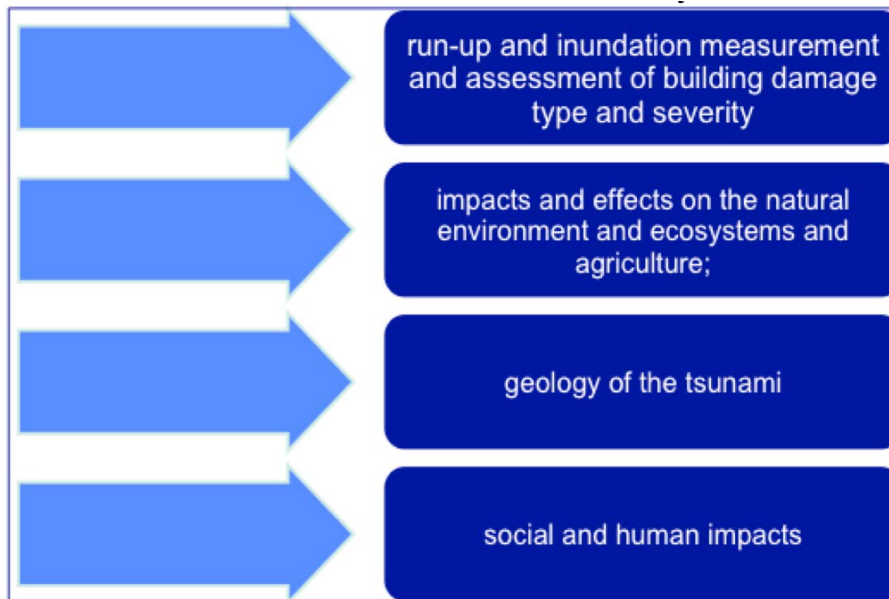
- Promote sharing of data with affected countries
- Minimize logistical problems for visitors and hosts
- Link visitors to country collaborators
- Provide the governments with a summary of the ITST findings

The coordination for this effort will be handled by the International Tsunami Information Center, in close coordination with the IOC and the affected countries.

Tsunami disasters can attract a large number of local, national, international professionals to investigate scientific, economic, social impacts. Some of these data are perishable making it essential to collect quickly. Important data may also be desirable from locations that are logistically difficult to assess without local assistance and access. At the same time, Emergency Agencies are focusing on public safety, critical support lifelines and infrastructure, resource mobilization to meet its citizens immediate post-event emergency response needs. To carry out both efforts, coordination and cooperation is critical. If data from science teams are made available, it will immediately contribute to better-informed and ultimately, more practical and efficient response and recovery decision-making. Building from concepts employed in post-earthquake technical clearinghouses, the ITST will utilize a simplified implementation of a science/technical clearinghouse to provide an efficient framework for

central coordination, information sharing and integration of the data collected from the 2012 off-El Salvador tsunami.

### ITST – OFF EL SALVADOR GUIDING PRINCIPLES



1. The Mission of the ITST-Off El Salvador is

- To understand the character of the tsunami and its impact in both the near-source and distant regions
- Provide information on the impacts to the GoC/GoN to enable it to enhance their tsunami disaster risk management practice

2. Logistics and Planning

- There will be an ITST-Off El Salvador Coordination Team to consist of UNESCO IOC (Bernardo Aliaga, PTWS Technical Secretary), UNESCO/IOC-NOAA ITIC (Dr. Laura Kong), El Salvador Ministerio de Medio Ambiente y Recursos Naturales (MARN, Jeniffer Larreynaga), and Nicaragua Instituto Nicaragüense *de* Estudios Territoriales (INETER, Angélica Muñoz)
- The ITST Coordination team will work with local and international scientists and government officials to enable a coordinated survey and to keep information flowing amongst Survey Teams with a goal of seeking to minimize overlap and duplication.
- Transportation, Lodging: Survey Teams are responsible for their own
- Funding: UNESCO and IOC are unable to provide funding support to Survey Teams.

3. Tasks: The ITST should carry out the following tasks. Teams may focus on the collection of just one data type:

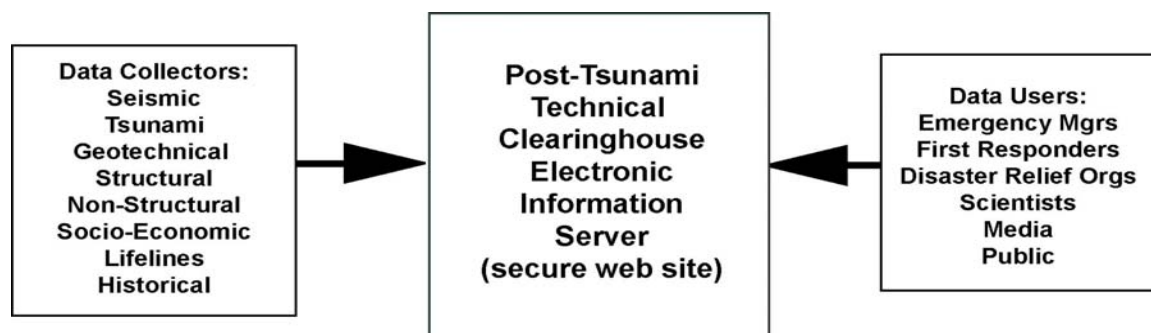
- Measure maximum tsunami inundation, flow depths, and maximum run-up; to the extent possible ‘walk the inundation’ line in order to collect an exact summary of the inundation of impacted communities.
- Collect geological samples of sediments left by the tsunami;
- Measure the type and severity of damage to different types of buildings and record what factors appeared to control damage levels;
- Collect and measure information about the environmental and biophysical system impacts of the tsunami;

- Collect information about survivor experiences and stories through interviews;
- Explore the human and community vulnerability and resilience factors at work in different places;
- Provide a map the above information in their summary

#### 4. Survey Team Guidance and Logistics

- Each team shall make known its dates of travel and survey plan to ITST Coordination Team. The ITST Coordination Team will make every effort to:
  - Compile the main objectives of each Survey;
  - Inform each Survey Team of activities done by other previous Surveys;
  - Inform each Survey Team on the general situation and present conditions.
  - For specific needs, assist to facilitate contacts, information, and other requests.
  - Receive the general outcomes of each Survey in order to facilitate the next Surveys.
- Survey Schedule
  - Prior to field start, the Team should pre-brief official country representatives on their plan and receive the most up-to-date status of the situation.
  - During the survey, the Team should provide regular updates through the Basecamp tool, email, or other means.
  - After the end before departing, the Team should out-brief official country representatives by providing a summary of their preliminary findings
- It is requested that local scientists or other local organizations or volunteers be included with your international team wherever possible. This is to bridge any language or cultural sensitivities, as well as to build local science experience and capacity.
- Please review the IOC Post-Tsunami Survey Field Guide (IOC Manual and Guides 37, Second Edition. 2012, English, Final Draft) and conduct your surveys consistent with these objectives. ITIC will provide you with its Tsunami Questionnaire (English and Spanish) and Eyewitness Survey to guide your data collection work. You are encouraged to use them. As needed, these can be translated into languages other than English.

#### 5. Information Sharing and Reporting



*Each Survey Team coordinated through ITST-Off El Salvador is requested submit to the ITST Coordination Team within 4 weeks of concluding the Field Survey a Summary Report, plus representative photos or maps, to be provided to the GoES/GoN.*

UNESCO is committed to preserve the data and intellectual property rights of the scientists who collect and interpret these important data. UNESCO also recognizes the high value of the data to governments for response and recovery planning, as well as for information sharing to enable better tsunami science understanding and so improve tsunami mitigation. To enable activities, UNESCO commits to the following:

- As ITST members are volunteers from organizations and research centers with related interests, participants should not lose the rights to publish data they collect. No data or outcomes from the



Summary Report to the governments, or data provided to other governments, will be released publicly for one year;

- At the conclusion and after quality-control by each Survey Team, the ITST Coordination Team will prepare a compilation Summary Report based on summaries received. The estimated delivery date of the report will be 4 months after the completion of ITST surveys. The Report will be shared with the governments only.
- The ITIC will provide a secure ITST electronic method (Basecamp tool) for data collectors to upload Survey metadata and data. The site will also contain Survey Team information, briefing reports, and other related information. Simple upload forms or spreadsheets can be provided to facilitate this process. Before and during fieldwork, Teams can upload daily Survey metadata so that everyone can keep track of progress and coverage, and in order to reduce duplication. If requested, ITIC can host a separate ITST Web site for general public viewing, and general document distribution.

### **ITST-Off El Salvador Coordination Team - Contact Information:**

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## 10 APPENDIX 3: PACIFIC TSUNAMI WARNING CENTER (PTWC) EVENT SUMMARY

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27 August 2012 PTWC Tsunami Warning for Central America

Summary of Decision Events

### UTC

04:37:26 Large earthquake occurs off the west coast of Central America

04:38:31 PTWC duty staff (Charles McCreery and David Walsh) alerted – large seismic signals at BOAB and SNET stations

The earthquake was recognized immediately from its first seismic signals as being a very large one due to the size of the signals, the emergent character of their first arrivals, and their very low-frequency content. Some of the automatic first-arrival picks were not good and were re-picked. Even with reviewed picks, the earthquake was difficult to locate and some picks had to be discarded before reaching a solution. The initial hypocenter solution was based on only 6 arrivals but it had decent azimuthal coverage and a low RMS. Its depth compared favorably with historical events at that location. (It turned out to be within 0.1 degrees of the later USGS epicenter and within 30km of the later USGS depth – very good for a quick solution.) Using this location the automatic Mwp earthquake magnitude process was initiated. Some of the automatic Mwp values were reviewed and re-picked. There was clearly a second larger peak in the moment rate curve and in some cases the automatic solution only picked the first peak. Based on the first 8 reviewed Mwp values, the magnitude was 7.4.

04:42:43 Observatory Message sent with preliminary earthquake parameters

A call was received from WCATWC asking about the PTWC magnitude and location. WCATWC indicated they were also getting a magnitude around 7.4. We advised we were going to issue a PTWS Information Bulletin.

04:44:57 Pacific Bulletin #1 sent – Tsunami Information Bulletin

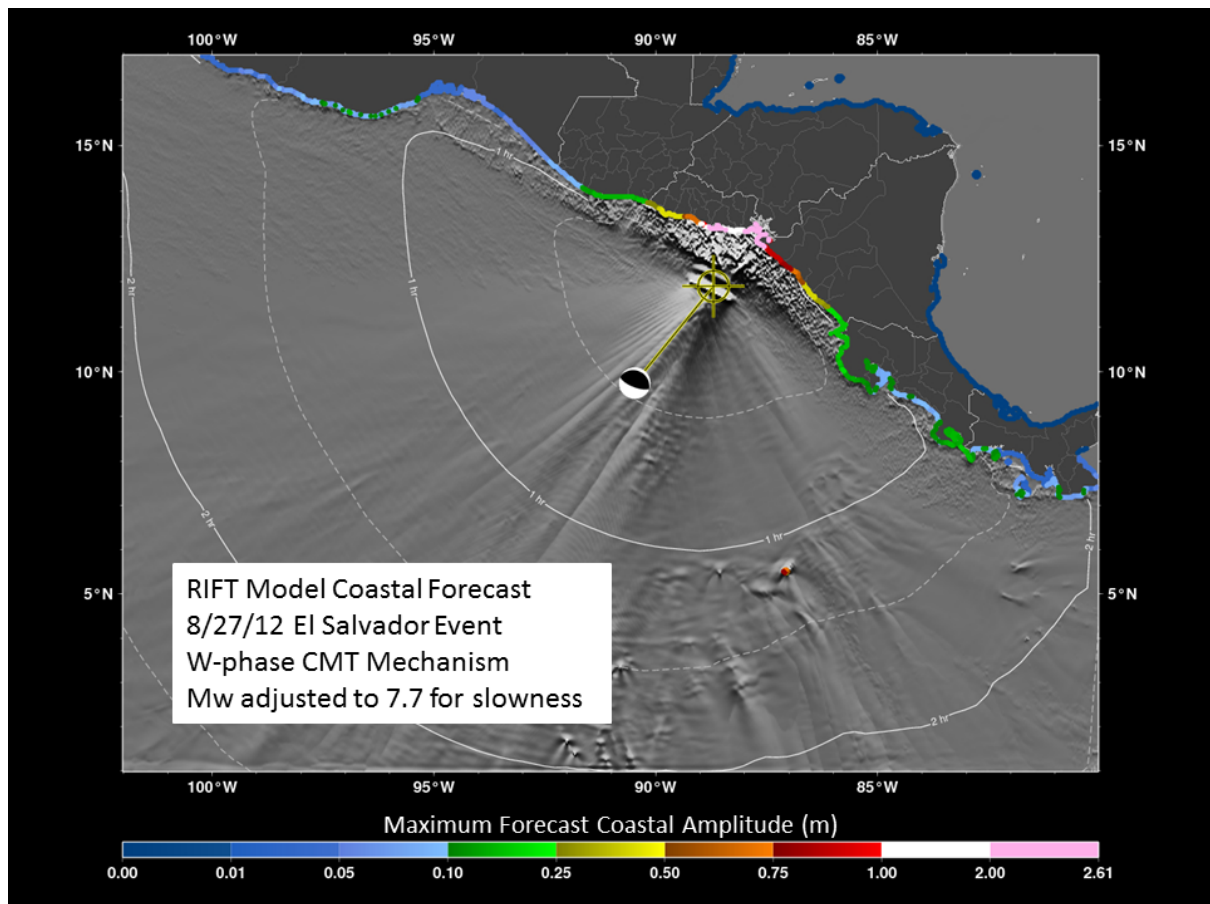
04:46:08 Hawaii Bulletin #1 sent – Tsunami Information Statement

Following issuance of the initial bulletins, the mantle magnitude (Mm), surface-wave magnitude (Ms), and Theta discriminant processes were initiated and monitored. Using an Mw of 7.4, Theta was -6.5 which indicates a very slow earthquake. Even adjusting the Mw downward by a few tenths didn't bring Theta above -6.0, the nominal value for a slow earthquake. Further, Theta as a function of time varied little over the first 100 seconds – a further indicator of slowness. The first few measurements of Mm gave an Mw of around 7.3 and by this time the Mwp had dropped a tenth to 7.3. I had expected Mw from Mm might be higher for a slow event but it wasn't. We called WCATWC to see if they were also getting a small Theta and they reported their value to be -7.0. These are extremely low Theta values. At this point we decided to upgrade to a Fixed Regional Warning that put all of Central America and Mexico into a warning. We issued a second Information Statement to Hawaii to reassure there remained no threat to this State.

04:56:02 Pacific Bulletin #2 sent – Fixed Regional Tsunami Warning

04:59:05 Hawaii Bulletin #2 sent – Tsunami Information Statement

We ran the RIFT model with the preliminary seismic parameters to get an initial estimate of potential impacts, taking into consideration that they could be much larger than the model predicted because of the earthquake slowness. By 05:03 UTC we had the result from our W-phase Centroid Moment Tensor (CMT) calculation. It showed a shallow thrust mechanism for the earthquake which was then used as input for a better constrained RIFT forecast. That result predicted the amplitudes of up to a meter for the southernmost coast of El Salvador and the northernmost coast of Nicaragua, with no significant threat elsewhere. But again, this forecast was for a normal earthquake, not a slow earthquake. To compensate for the earthquake slowness, the model was re-run with the CMT mechanism but the  $M_w$  magnitude artificially boosted to 7.7. The result, shown below, indicated potential tsunami coastal amplitudes of even more than 2 meters along some parts of the southern coast of El Salvador and northern coast of Nicaragua.



*This figure shows the output of a RIFT tsunami forecast model run made 38 minutes after the earthquake occurred. The earthquake magnitude was artificially increased from 7.3 to 7.7 to compensate for the fact that this was a “slow” earthquake with additional tsunamigenic potential. Colors along the coast indicate expected maximum tsunami amplitudes at those locations according to the color scale under the map. The RIFT coastal forecast is valid only for coasts directly exposed to the open ocean, not those within the Gulf of Fonseca and other bays and estuaries.*

We were waiting for sea level measurements to confirm the forecast or indicate a more significant threat. The closest coastal station at Corinto, Nicaragua, was unfortunately out of order. The next closest station at Acajutla, El Salvador was working and had an expected tsunami arrival time of 05:42 UTC. The closest DART, 32411, was also out of order, but the next closest DART, 43413, was

working with an expected arrival time of 06:31 UTC. It had triggered from the seismic waves. A third Pacific bulletin was issued at 05:40 UTC indicating PTWC was still waiting for initial sea level readings. The same areas remained in a warning.

05:40:07          Pacific Bulletin #3 sent – Fixed Regional Tsunami Warning

Shortly thereafter, a small tsunami signal began to arrive at Acajutla. At first it was unclear if the signal was the tsunami or a normal perturbation, but over the next 20 minutes or so the signal continued and grew to an amplitude of about 10 cm. This compared favorably with the RIFT amplitude prediction of 8 cm. A fourth Pacific bulletin was issued to report this observation. The same areas remained in a warning.

06:14:21          Pacific Bulletin #4 sent – Fixed Regional Tsunami Warning

Over the following few minutes it became clear that the signal at Acajutla was not going to increase, and no tsunami signal was seen at La Union, El Salvador, which had an expected arrival time of 05:50 UTC but is not on the open coast. Based on these readings, especially the one from Acajutla that is a station close to the epicenter and exposed to the open ocean, we decided to cancel the warning.

06:23:37          Pacific Bulletin #5 sent – Tsunami Warning Cancellation

Over the next 40 minutes, a small tsunami signal was observed at La Union as well as on DART 43413. A cancellation supplement was issued to report these observations that were in agreement with our evaluation that there was no wider threat.

07:02:00          Pacific Bulletin #6 sent – Cancellation Supplement



## 11 APPENDIX 4: PACIFIC TSUNAMI WARNING CENTER (PTWC) EVENT MESSAGES AND TIMELINE

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----- Forwarded message -----

From: <ptwc@ptwc.noaa.gov>  
 Date: Sun, Aug 26, 2012 at 8:47 PM  
 Subject: preliminary timeline for event: OFF COAST OF CENTRAL AMERICA, 2012-08-27 04:37:26  
 To: michael.angove@noaa.gov, jane.hollingsworth@noaa.gov, laura.kong@noaa.gov,  
 bill.ward@noaa.gov, edward.young@noaa.gov, jeff.ladouce@noaa.gov, staff@ptwc.noaa.gov,  
 ptwc@ptwc.noaa.gov

PTWC PRELIMINARY TIMELINE  
 Event Location: OFF COAST OF CENTRAL AMERICA  
 Pacific Tsunami Warning Center  
 August 27, 2012

UTC	LocalTime	Event
yymmdd hhmmss	hhmmss	

120827 043726 UTC	183726 HST	Earthquake occurs near OFF COAST OF CENTRAL AMERICA (12.667N, 88.526W)
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120827 043831 UTC	183831 HST	PTWC Operations alerted by : EQ: CARIBBEAN: BOAB SNET
-------------------	------------	--

120827 044243 UTC	184243 HST	PTWC sends observatory message: H 04:37:21Z AUG 27 2012Z LAT 12.2N LONG 88.5W DEPTH 50.6km MWP 7.4 ( 8 STATIONS)
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120827 044457 UTC	184457 HST	PTWC prepares and issues TSUNAMI BULLETIN NUMBER 001
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THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC  
 OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...  
 WASHINGTON...OREGON AND CALIFORNIA.

... TSUNAMI INFORMATION BULLETIN ...

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY  
 NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE  
 DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND  
 ANY ACTIONS TO BE TAKEN IN RESPONSE.

ORIGIN TIME	-	0437Z 27 AUG 2012
COORDINATES	-	12.2 NORTH 88.5 WEST
DEPTH	-	51 KM
LOCATION	-	OFF COAST OF CENTRAL AMERICA
MAGNITUDE	-	7.4

120827 044608 UTC	184608 HST	PTWC prepares and issues TSUNAMI INFORMATION STATEMENT NUMBER 1
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TO - CIVIL DEFENSE IN THE STATE OF HAWAII

SUBJECT - TSUNAMI INFORMATION STATEMENT

THIS STATEMENT IS FOR INFORMATION ONLY. NO ACTION REQUIRED.

ORIGIN TIME	-	0637 PM HST 26 AUG 2012
COORDINATES	-	12.2 NORTH 88.5 WEST
LOCATION	-	OFF COAST OF CENTRAL AMERICA
MAGNITUDE	-	7.4 MOMENT

120827 045642 UTC	185642 HST	PTWC prepares and issues TSUNAMI BULLETIN NUMBER 002
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THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC  
 OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...  
 WASHINGTON...OREGON AND CALIFORNIA.

THIS EARTHQUAKE APPEARS TO BE A SLOW EARTHQUAKE WITH ADDITIONAL  
 TSUNAMI POTENTIAL. THEREFORE A WARNING IS BEING ISSUED.

A TSUNAMI WARNING IS IN EFFECT FOR

## 2012 El Salvador Tsunami Field Survey

COSTA RICA / NICARAGUA / EL SALVADOR / HONDURAS / GUATEMALA /  
PANAMA / MEXICO

FOR ALL OTHER AREAS COVERED BY THIS BULLETIN... IT IS FOR  
INFORMATION ONLY AT THIS TIME.

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY  
NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE  
DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND  
ANY ACTIONS TO BE TAKEN IN RESPONSE.

ORIGIN TIME - 0437Z 27 AUG 2012  
COORDINATES - 12.7 NORTH 88.5 WEST  
DEPTH - 54 KM  
LOCATION - OFF COAST OF CENTRAL AMERICA  
MAGNITUDE - 7.3

120827 045905 UTC 185905 HST PTWC prepares and issues TSUNAMI INFORMATION STATEMENT NUMBER  
2  
659 PM HST SUN AUG 26 2012

TO - CIVIL DEFENSE IN THE STATE OF HAWAII

SUBJECT - TSUNAMI INFORMATION STATEMENT

THIS STATEMENT IS FOR INFORMATION ONLY. NO ACTION REQUIRED.

ORIGIN TIME - 0637 PM HST 26 AUG 2012  
COORDINATES - 12.7 NORTH 88.5 WEST  
LOCATION - OFF COAST OF CENTRAL AMERICA  
MAGNITUDE - 7.3 MOMENT

120827 054007 UTC 194007 HST PTWC prepares and issues TSUNAMI BULLETIN NUMBER 003

THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC  
OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...  
WASHINGTON...OREGON AND CALIFORNIA.

NO CHANGE IN STATUS. WE ARE STILL WAITING FOR INITIAL READINGS  
FROM THE NEAREST SEA LEVEL STATIONS.

A TSUNAMI WARNING IS IN EFFECT FOR

COSTA RICA / NICARAGUA / EL SALVADOR / HONDURAS / GUATEMALA /  
PANAMA / MEXICO

FOR ALL OTHER AREAS COVERED BY THIS BULLETIN... IT IS FOR  
INFORMATION ONLY AT THIS TIME.

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY  
NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE  
DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND  
ANY ACTIONS TO BE TAKEN IN RESPONSE.

ORIGIN TIME - 0437Z 27 AUG 2012  
COORDINATES - 12.7 NORTH 88.5 WEST  
DEPTH - 54 KM  
LOCATION - OFF COAST OF CENTRAL AMERICA  
MAGNITUDE - 7.3

120827 061421 UTC 201421 HST PTWC prepares and issues TSUNAMI BULLETIN NUMBER 004  
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS  
ISSUED AT 0616Z 27 AUG 2012

THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC  
OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...  
WASHINGTON...OREGON AND CALIFORNIA.

A SMALL TSUNAMI HAS BEEN OBSERVED AT ACAJUTLA.

... A TSUNAMI WARNING IS IN EFFECT ...

## 2012 El Salvador Tsunami Field Survey

A TSUNAMI WARNING IS IN EFFECT FOR

COSTA RICA / NICARAGUA / EL SALVADOR / HONDURAS / GUATEMALA /  
PANAMA / MEXICO

FOR ALL OTHER AREAS COVERED BY THIS BULLETIN... IT IS FOR  
INFORMATION ONLY AT THIS TIME.

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY  
NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE  
DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND  
ANY ACTIONS TO BE TAKEN IN RESPONSE.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 0437Z 27 AUG 2012  
COORDINATES - 12.7 NORTH 88.5 WEST  
DEPTH - 54 KM  
LOCATION - OFF COAST OF CENTRAL AMERICA  
MAGNITUDE - 7.3

MEASUREMENTS OR REPORTS OF TSUNAMI WAVE ACTIVITY

GAUGE LOCATION	LAT	LON	TIME	AMPL	PER
ACAJUTLA SV	13.6N	89.8W	0540Z	0.10M / 0.3FT	08MIN

LAT - LATITUDE (N-NORTH, S-SOUTH)  
LON - LONGITUDE (E-EAST, W-WEST)  
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)  
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.  
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.  
VALUES ARE GIVEN IN BOTH METERS(M) AND FEET(FT).  
PER - PERIOD OF TIME IN MINUTES(MIN) FROM ONE WAVE TO THE NEXT.

EVALUATION

SEA LEVEL READINGS CONFIRM THAT A TSUNAMI WAS GENERATED. THIS  
TSUNAMI MAY HAVE BEEN DESTRUCTIVE ALONG COASTLINES OF THE REGION  
NEAR THE EARTHQUAKE EPICENTER. AUTHORITIES IN THE REGION SHOULD  
TAKE APPROPRIATE ACTION IN RESPONSE TO THIS POSSIBILITY. THIS  
CENTER WILL CONTINUE TO MONITOR SEA LEVEL GAUGES NEAREST THE  
REGION AND REPORT IF ANY ADDITIONAL TSUNAMI WAVE ACTIVITY. THE  
WARNING WILL NOT EXPAND TO OTHER AREAS OF THE PACIFIC UNLESS  
ADDITIONAL DATA ARE RECEIVED TO WARRANT SUCH AN EXPANSION.

FOR AFFECTED AREAS - WHEN NO MAJOR WAVES ARE OBSERVED FOR TWO  
HOURS AFTER THE ESTIMATED TIME OF ARRIVAL OR DAMAGING WAVES HAVE  
NOT OCCURRED FOR AT LEAST TWO HOURS THEN LOCAL AUTHORITIES CAN  
ASSUME THE THREAT IS PASSED. DANGER TO BOATS AND COASTAL  
STRUCTURES CAN CONTINUE FOR SEVERAL HOURS DUE TO RAPID CURRENTS.  
AS LOCAL CONDITIONS CAN CAUSE A WIDE VARIATION IN TSUNAMI WAVE  
ACTION THE ALL CLEAR DETERMINATION MUST BE MADE BY LOCAL  
AUTHORITIES.

ESTIMATED INITIAL TSUNAMI WAVE ARRIVAL TIMES AT FORECAST POINTS  
WITHIN THE WARNING AND WATCH AREAS ARE GIVEN BELOW. ACTUAL  
ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE  
LARGEST. A TSUNAMI IS A SERIES OF WAVES AND THE TIME BETWEEN  
SUCCESSIVE WAVES CAN BE FIVE MINUTES TO ONE HOUR.

LOCATION	FORECAST POINT	COORDINATES	ARRIVAL TIME
COSTA RICA	CABO_SAN_ELENA	10.9N 274.0E	0526Z 27 AUG
	PUERTO_QUEPOS	9.4N 275.8E	0553Z 27 AUG
	CABO_MATAPALO	8.4N 276.7E	0555Z 27 AUG
NICARAGUA	CORINTO	12.5N 272.8E	0532Z 27 AUG
	PUERTO_SANDINO	12.2N 273.2E	0539Z 27 AUG
	SAN_JUAN_DL_SUR	11.2N 274.1E	0551Z 27 AUG
EL SALVADOR	ACAJUTLA	13.6N 270.2E	0543Z 27 AUG
HONDURAS	AMAPALA	13.2N 272.4E	0556Z 27 AUG
GUATEMALA	SIPICATE	13.9N 268.8E	0559Z 27 AUG
PANAMA	PUNTA_BURICA	8.0N 277.1E	0605Z 27 AUG
	PUNTA_MALA	7.5N 280.0E	0652Z 27 AUG
	BALBOA HTS.	9.0N 280.4E	0912Z 27 AUG
MEXICO	PUERTO_MADERO	14.8N 267.5E	0606Z 27 AUG

BULLETINS WILL BE ISSUED HOURLY OR SOONER IF CONDITIONS WARRANT.  
THE TSUNAMI WARNING WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE.

## 2012 El Salvador Tsunami Field Survey

THE WEST COAST/ALASKA TSUNAMI WARNING CENTER WILL ISSUE PRODUCTS  
FOR ALASKA...BRITISH COLUMBIA...WASHINGTON...OREGON...CALIFORNIA.

120827 062337 UTC 202337 HST PTWC prepares and issues TSUNAMI BULLETIN NUMBER 005  
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS  
ISSUED AT 0627Z 27 AUG 2012

THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC  
OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...  
WASHINGTON...OREGON AND CALIFORNIA.

... TSUNAMI WARNING CANCELLATION ...

THE TSUNAMI WARNING AND/OR WATCH ISSUED BY THE PACIFIC TSUNAMI  
WARNING CENTER IS NOW CANCELLED FOR

COSTA RICA / NICARAGUA / EL SALVADOR / HONDURAS / GUATEMALA /  
PANAMA / MEXICO

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY  
NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE  
DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND  
ANY ACTIONS TO BE TAKEN IN RESPONSE.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 0437Z 27 AUG 2012  
COORDINATES - 12.7 NORTH 88.5 WEST  
DEPTH - 54 KM  
LOCATION - OFF COAST OF CENTRAL AMERICA  
MAGNITUDE - 7.3

MEASUREMENTS OR REPORTS OF TSUNAMI WAVE ACTIVITY

GAUGE LOCATION	LAT	LON	TIME	AMPL	PER
-----	-----	-----	-----	-----	-----
ACAJUTLA SV	13.6N	89.8W	0540Z	0.10M / 0.3FT	08MIN
LA UNION SV	13.3N	87.8W	NO TSUNAMI OBSERVED		

LAT - LATITUDE (N-NORTH, S-SOUTH)  
LON - LONGITUDE (E-EAST, W-WEST)  
TIME - TIME OF THE MEASUREMENT (Z IS UTC IS GREENWICH TIME)  
AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO NORMAL SEA LEVEL.  
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.  
VALUES ARE GIVEN IN BOTH METERS(M) AND FEET(FT).  
PER - PERIOD OF TIME IN MINUTES(MIN) FROM ONE WAVE TO THE NEXT.

EVALUATION

SEA LEVEL READINGS INDICATE A TSUNAMI WAS GENERATED. IT MAY HAVE  
BEEN DESTRUCTIVE ALONG COASTS NEAR THE EARTHQUAKE EPICENTER. FOR  
THOSE AREAS - WHEN NO MAJOR WAVES ARE OBSERVED FOR TWO HOURS  
AFTER THE ESTIMATED TIME OF ARRIVAL OR DAMAGING WAVES HAVE NOT  
OCCURRED FOR AT LEAST TWO HOURS THEN LOCAL AUTHORITIES CAN ASSUME  
THE THREAT IS PASSED. DANGER TO BOATS AND COASTAL STRUCTURES CAN  
CONTINUE FOR SEVERAL HOURS DUE TO RAPID CURRENTS. AS LOCAL  
CONDITIONS CAN CAUSE A WIDE VARIATION IN TSUNAMI WAVE ACTION THE  
ALL CLEAR DETERMINATION MUST BE MADE BY LOCAL AUTHORITIES.

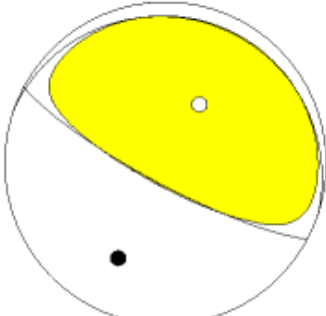
NO TSUNAMI THREAT EXISTS FOR OTHER COASTAL AREAS IN THE PACIFIC  
ALTHOUGH SOME OTHER AREAS MAY EXPERIENCE SMALL SEA LEVEL CHANGES.  
THE TSUNAMI WARNING IS NOW CANCELLED FOR ALL AREAS COVERED BY  
THIS CENTER.

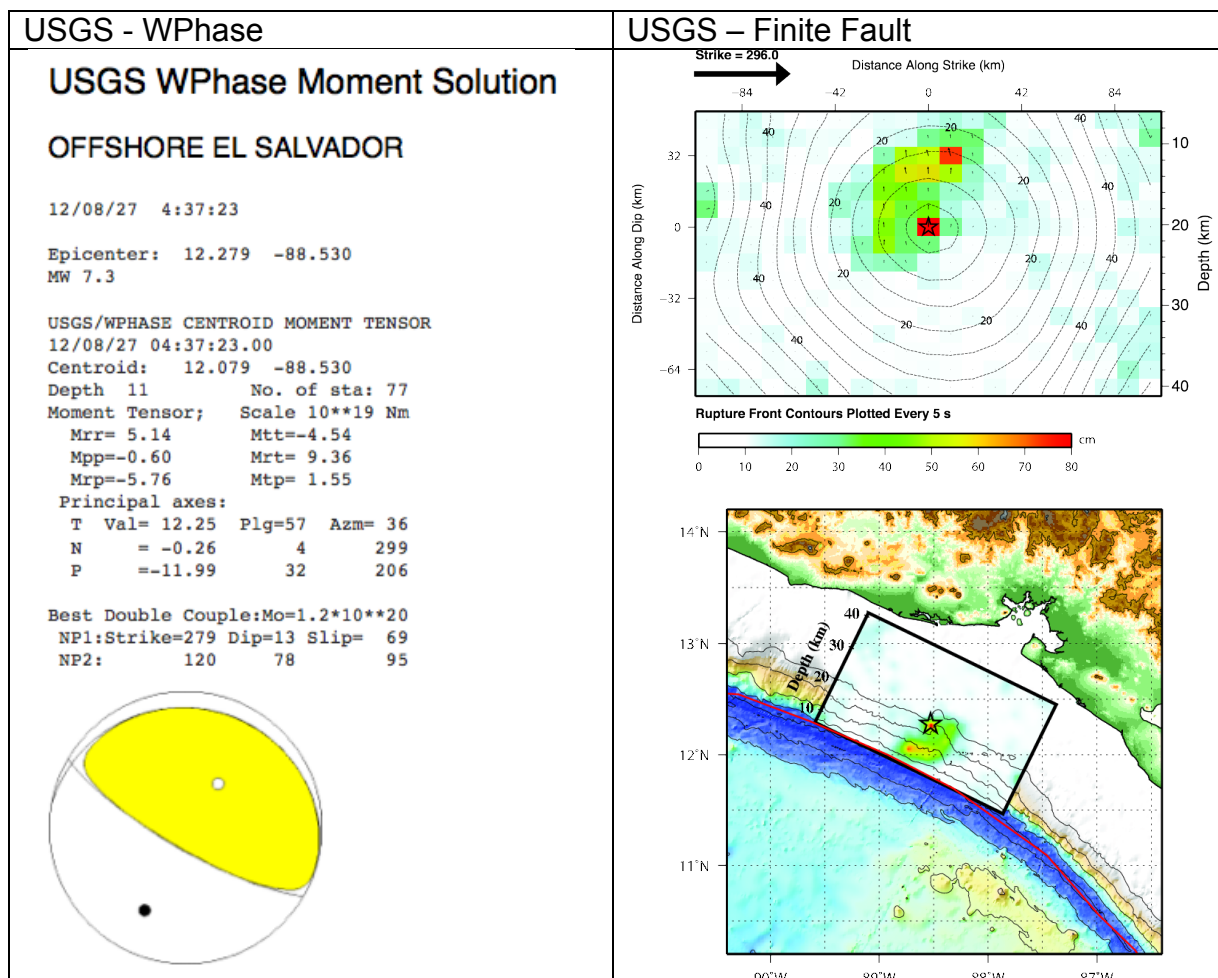
THIS WILL BE THE FINAL BULLETIN ISSUED FOR THIS EVENT UNLESS  
ADDITIONAL INFORMATION BECOMES AVAILABLE.

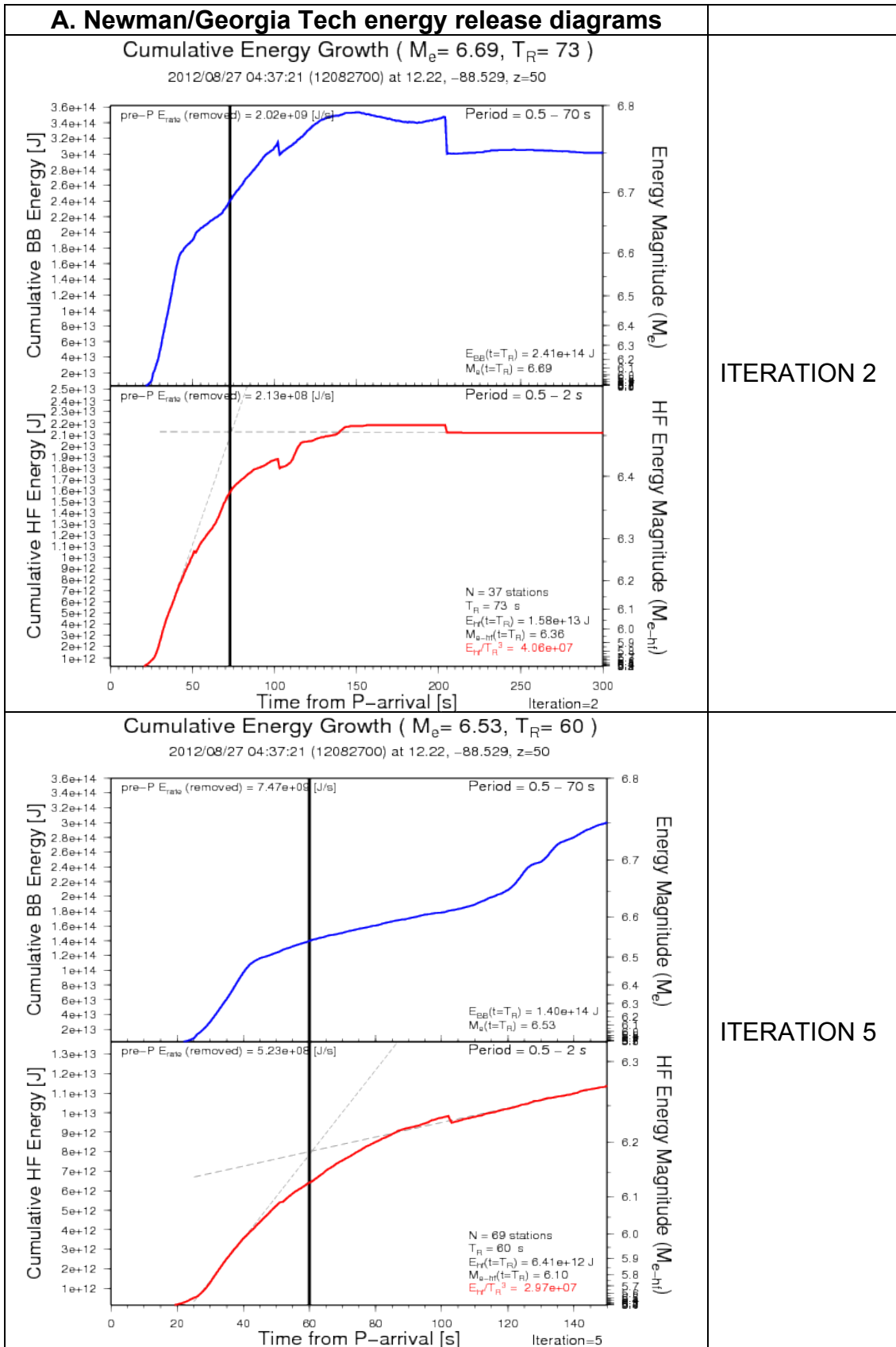
THE WEST COAST/ALASKA TSUNAMI WARNING CENTER WILL ISSUE PRODUCTS  
FOR ALASKA...BRITISH COLUMBIA...WASHINGTON...OREGON...CALIFORNIA.

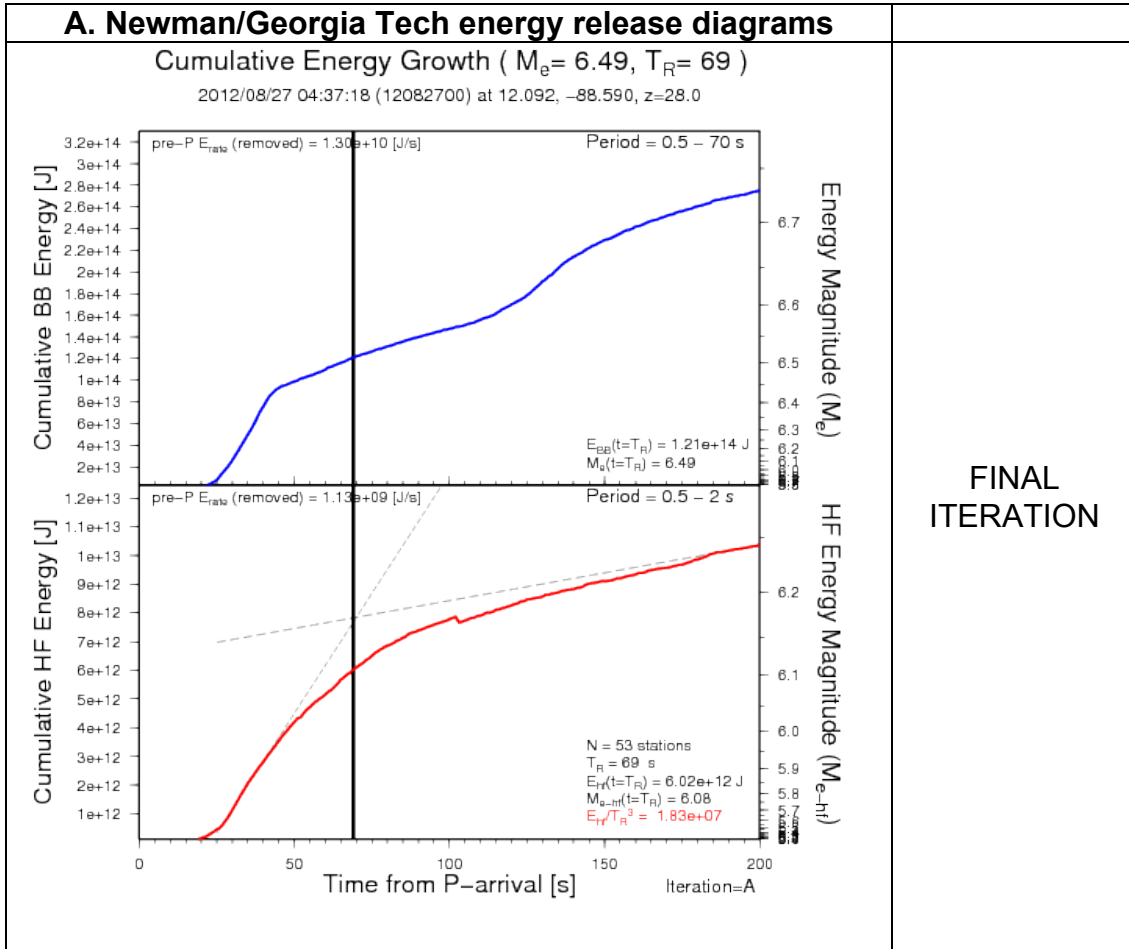


## 12 APPENDIX 5: EARTHQUAKE FAULT SOLUTIONS

USGS	Global CMT
<p><b>OFFSHORE EL SALVADOR</b></p> <p>12/08/27 04:37:23.40</p> <p>Epicenter: 12.282 -88.482 MW 7.4</p> <p>USGS CENTROID MOMENT TENSOR 12/08/27 04:37:50.29 Centroid: 11.984 -88.800 Depth 19 No. of sta: 90 Moment Tensor; Scale 10**20 Nm Mrr= 0.69 Mtt=-0.52 Mpp=-0.17 Mrt= 1.47 Mrp=-0.80 Mtp= 0.17 Principal axes: T Val= 1.84 Plg=55 Azm= 30 N -0.10 2 298 P -1.74 35 207</p> <p>Best Double Couple:Mo=1.8*10**20 NP1:Strike=118 Dip=80 Slip= 92 NP2: 289 11 81</p> 	<p>August 27, 2012, OFF COAST OF CENTRAL AMERICA, MW=7.3</p> <p>Howard Koss Meredith Nettles</p> <p>CENTROID-MOMENT-TENSOR SOLUTION GCMT EVENT: C201208270437A DATA: II LD IU DK CU MN G IC GE L.P.BODY WAVES:140S, 352C, T= 50 MANTLE WAVES: 144S, 345C, T=150 SURFACE WAVES: 150S, 366C, T= 50 TIMESTAMP: Q-20120827085123 CENTROID LOCATION: ORIGIN TIME: 04:37:38.2 0.1 LAT:11.91N 0.00;LON: 89.18W 0.01 DEP: 12.0 FIX;TRIANG HDUR: 11.0 MOMENT TENSOR: SCALE 10**27 D-CM RR= 0.589 0.002; TT=-0.485 0.002 PP=-0.104 0.002; RT= 0.915 0.016 RP=-0.472 0.018; TP= 0.172 0.001 PRINCIPAL AXES: 1.(T) VAL= 1.198;PLG=59;AZM= 30 2.(N) -0.043; 2; 296 3.(P) -1.155; 31; 204 BEST DBLE.COUPLE:M0= 1.18*10**27 NP1: STRIKE=287;DIP=15;SLIP= 81 NP2: STRIKE=116;DIP=76;SLIP= 92</p> <pre> ----- -----#####----- -----#####----- -----#####----- ##### ##### -----##### T ##### -----##### -----##### -----##### -----##### -----##### -----##### ----- ----- P ----- ----- ----- </pre>









## 13 APPENDIX 6: EL SALVADOR MARN REPORT

### INFORME DE AFECTACIONES POR EL TSUNAMI GENERADO POR SISMO MAGNITUD 6.7 FRENTE A LAS COSTAS DE USULUTÁN

#### 1. Información inicial

A las 10:37 de la noche del 26 de agosto, un sismo de 6.7 grados y 20 km de profundidad a 250 kilómetros al sur de Usulután que generó variaciones en el nivel del mar a lo largo de la costa e incrementos en la velocidad de las corrientes marinas.



Figura 1. Localización del sismo y de sensores de monitoreo del nivel del mar

A las 11:05 de la noche (28 minutos después del sismo) el Centro de Alerta por Tsunami para el Pacífico (PTWC por sus siglas en inglés) emitió alerta de tsunami para todos los países de Centro América y México presentando diferencias en los parámetros del sismo con respecto a la Red Sísmica de El Salvador; y estimó que la primera ola del tsunami podría arribar a las costas de Acajutla a las 11:43 de la noche.

#### 2. Evaluación del sismo y el tsunami

Basados en los parámetros sísmicos emitidos por la red sísmica nacional indicando un sismo de 6.7 Mw y profundidad 50 kilómetros, el Servicio Oceanográfico Nacional activó su protocolo de actuación emitiendo Informe Especial relativo al evento.

Se recomendó a la población alejarse de la zona costera y evitar el zarpe de pequeñas y medianas embarcaciones debido al incremento en la velocidad de las corrientes inducidas por el tsunami que elevan el potencial de arrastre del mar, enfatizando esta recomendación para la zona oriental del país.

Las señales de las estaciones que registraron el sismo infieren que este podría haber sido de ruptura lenta debido a la energía deficiente de las ondas P u ondas primarias emitidas. Estos

sismos son conocidos como “sismos lentos” y son llamados “tsunamis earthquakes”, y están caracterizados por tener el potencial de generar tsunamis muy inusuales de gran tamaño con relación a la magnitud del sismo.

A pesar de que los mareógrafos localizados en Acajutla y la Unión no registraron variaciones significativas en el nivel del mar se tiene evidencia de afectaciones por incrementos en el nivel del mar en la zona de Península San Juan del Gozo, Usulután inundando la playa en algunos casos hasta 250 metros tierra adentro.

Este fenómeno evidencia de manera concreta que a pesar de que los parámetros sísmicos indicaban la poca probabilidad de ocurrencia, se generó un **tsunami local** que afectó únicamente a las zonas costeras frente al epicentro del sismo (Península San Juan del Gozo, Usulután) sin producirse ningún efecto en el resto de la zona costera.

### 3. Afectaciones

Debido a los reportes recibidos de afectaciones en la zona de la Bahía de Jiquilisco los días 27 y 30 de agosto de 2012 se realizó un recorrido por la Península San Juan del Gozo evidenciándose lo siguiente:

#### **Zona costera cercana a la comunidad San Juan del Gozo donde se encuentra el vivero de tortugas:**

- El sismo solo fue sentido por algunas personas.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente media hora después del sismo.
- Debido a las condiciones de luminosidad no se puede determinar si el mar se retiró pero se estima que no.
- Las personas mencionas que vieron una ola grande al principio seguida inmediatamente por otras. Se puede inferir que las que le siguieron son oleaje sobre la ola del tsunami.
- Se realizaron mediciones en la caseta de recibo de huevos de tortuga y estimó por las marcas de agua que la profundidad de flujo en ese sitio fue de aproximadamente 1.70 metros.
- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 100 metros.
- La infraestructura del vivero hecha de lámina y palma fue parcialmente destruida.
- El total de la población afectada fueron hombres.
- La población que se encontraba cerca del vivero indicó que no tenían conocimiento de que un tsunami podía llegar ni sabían de eventos previos.
- Pobladores indicaron que en una comunidad cercana llamada las mesitas recibieron el mensaje de alerta por parte de Protección Civil y activaron su protocolo de comunicación. Lo mismo pasó en Babilonia y La Canoa.

**Zona costera cercana a la comunidad Isla de Méndez donde se encuentra el vivero de tortugas:**

- El sismo no fue sentido.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente media hora a una hora después del sismo.
- Debido a las condiciones de luminosidad no se puede determinar si el mar se retiró pero se estima que no.
- Las personas mencionas que vieron una ola grande al principio seguida inmediatamente por otras.
- Se realizaron mediciones en la caseta de recibo de huevos de tortuga y estimó por las marcas de agua que la profundidad de flujo en ese sitio fue de aproximadamente 2.40 metros.
- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 250 metros.
- La infraestructura de la caseta del vivero hecha de lámina fue parcialmente destruida.
- La ramada del vivero hecha de palma y su cerca de malla metálica fueron totalmente destruidas.
- De la población afectada, el total fueron hombres a excepción de dos mujeres que sufrieron fracturas en sus piernas.
- La mayoría de población resultó lastimada por la vegetación de la zona.
- La población que se encontraba cerca del vivero indicó que no tenían conocimiento de que un tsunami podía llegar ni sabían de eventos previos.
- El director de la ADESCO de la zona indico que a su comunidad no llegó el mensaje de alerta de Protección Civil porque no tienen radio de comunicación.

**Zona costera cercana a la comunidad Ceiba Doblada:**

- El sismo solo fue sentido por algunas personas.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- Debido a que en esta zona no hay vivero de tortugas, no hubo población afectada debido al tsunami.
- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 75 metros.
- No se encontró infraestructura o vegetación en la cual medir la profundidad de flujo estimada.



Adicionalmente se estableció contacto con observadores locales que apoyan las actividades de monitoreo de la zona costera en diferentes puntos, los cuales reportaron lo siguiente:

**Puerto de Acajutla:**

No se observaron variaciones en las condiciones del mar, los barcos atracados en puerto no experimentaron inestabilidad por posibles incrementos en la velocidad de las corrientes asociadas al tsunami. Los turnos de trabajo se mantuvieron de manera normal solo estando atentos a cualquier eventualidad reportada por el MARN.

**Playa El Espino:**

La señora Blanca Yarahimi Larreynaga, enlace local y presidenta de la Asociación de restaurantes de la zona indicó vía teléfono durante la madrugada que en esa zona no se ha presentado ningún evento que mencionar, y que la policía de la zona se había desplazado hacia la península de San Juan del Gozo para ayudar a asistir a las personas afectadas en esa área.

**Playa El Cuco:**

La administradora del Hotel de surfistas Las Flores reportó que durante la noche del tsunami y la mañana siguiente no hubo ningún evento fuera de lo normal. El guía de surfistas comentó que las lanchas estacionadas en la playa no reflejaban daño por el mar y que las actividades por la mañana se desarrollaron de manera normal.



## **14 APPENDIX 7: NICARAGUA INETER REPORT**

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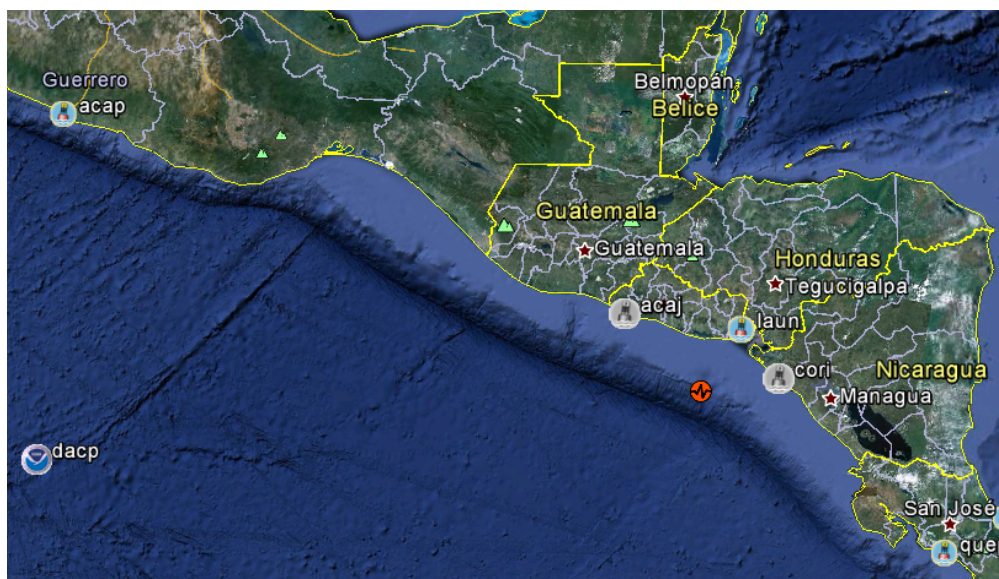
### **INFORME DE VISITA PARA EVALUACION DE AFECTACION DEL TSUNAMI EN ISLA DE MENDEZ EL SALVADOR DEL 4 AL 9 DE SEPTIEMBRE**

Norwin Acosta  
Ineter Dirección de Geología y Geofísica



## Introducción y Objetivo

A las 10:37 de la noche del 26 de agosto, un sismo de 6.7 grados y 20 km de profundidad a 250 kilómetros al sur de Usulután que generó variaciones en el nivel del mar a lo largo de la costa e incrementos en la velocidad de las corrientes marinas.



**Figura 1. Localización del sismo y de sensores de monitoreo del nivel del mar**

A las 11:05 de la noche (28 minutos después del sismo) el Centro de Alerta por Tsunami para el Pacífico (PTWC por sus siglas en inglés) emitió alerta de tsunami para todos los países de Centro América y México presentando diferencias en los parámetros del sismo con respecto a la Red Sísmica de El Salvador; y estimó que la primera ola del tsunami podría arribar a las costas de Acajutla a las 11:43 de la noche.

Con el objetivo de poder aprender técnicas en evaluaciones de afectación ante Tsunami se realiza una visita hacia el país de El Salvador del 4 al 5 de septiembre del 2012.

La realización de campo se realiza en compañía de diferentes especialistas del MARN (Jeniffer Lareynaga, Georgia Institute of Technology Savannah (Hermann M.. Fritz), ECoast (Jose C. Borrero) y International Tsunami Information Center (Nicolas P. Arcos) y Ineter (Norwin Acosta).

Durante la inspección se reconocen las características y condiciones generales del entorno del sitio de afectación y se toman datos de registros de alturas de Olas de Tsunami que posteriormente permitirán evaluar el grado de afectación en la península de San Juan del Gozo.

## Área de La Península de San Juan del Gozo

La bahía de Jiquilisco forma parte del sistema de paisaje "Llanura costera central" de El Salvador. El 31 de octubre del 2005 se declaró como «sitio Ramsar», en el

marco del convenio internacional sobre humedales, debido a su singularidad y fragilidad, por cuanto es el hábitat de la mayoría de aves marino-costeras del país. Es el único lugar de anidación para algunas de ellas, así como el lugar de destino o paso (alimentación, cambio de plumaje y descanso) de ochenta y siete aves migratorias de relevancia internacional.

Este sitio es el hábitat de una gran diversidad de especies terrestres vinculadas a los cuerpos acuáticos y áreas costeras. Es de hacer notar que se ha corroborado que cuatro de las siete especies de tortugas marinas conocidas mundialmente, visitan la bahía de Jiquilisco para su anidación.

### **Geomorfología**

La bahía de Jiquilisco

Está formada por numerosos esteros y canales: la bahía de Jiquilisco, la península San Juan del Gozo, y un conjunto de islas. La altitud varía de 0 a 10 msnm. La morfología es plana, y pequeños grupos de ríos drenan sus aguas en el canal principal de la bahía.

Los suelos cercanos a los esteros son halomórficos, con una elevada concentración de sal, siendo esto un obstáculo para el desarrollo normal de las plantas. Dichos suelos desarrollan vegetación halomórfica, de la cual constituyen un buen ejemplo los bosques de mangles. El río Grande de San Miguel, que es uno de los más contaminados del país, es el principal sistema fluvial que drena en la bahía.

### **Clima**

Tiene un clima de sabana caliente-tropical (según la clasificación de las regiones climáticas de Copen). El clima local sigue el patrón nacional y su distribución está influenciada por la vegetación de los esteros y manglares. La precipitación anual promedio oscila entre el rango de 1660-2019mm, y la temperatura anual promedio es de 26.7°C, con un nivel máximo de 34.6°C y un nivel mínimo de 20.3°C.

Los vientos locales son muy débiles, con una velocidad promedio de 7km/h. La humedad relativa del aire es de 65.15% durante la época seca y de 78.15% durante la época lluviosa.

### **Marco histórico y cultural: situación actual y tendencias**

La Bahía de Jiquilisco, se enmarca en lo que históricamente fue la gran región habitada por el grupo Poton (Lenca-salvadoreño), uno de los principales grupos etnolingüísticos que habitaban el territorio salvadoreño al momento de la conquista, la cual abarcaba el territorio al oriente del país. Antiguamente la bahía era conocida como Xiriualtique, que en idioma poton, significa “lugar en la bahía de las estrellas”; proviene de xiri, estrella; ual, agua, río, bahía; y tique, cerro, sufijo de lugar (Lardé y Larín: 2000).

Aunque no existen evidencias claras de la cultura material indígena (artesanía, restos arqueológicos monumentales), la bahía de Jiquilisco, si ha sido una zona fundamental tanto para la economía regional como nacional, basada principalmente en la producción de sal y la pesca. A lo largo de los años, la tradición económica y cultural únicamente ha variado en el cambio de las tecnologías y los aperos que usa la población para realizar sus actividades.

En la región el puerto conocido como “Puerto El Triunfo” es reconocido desde 1522 y en aquel entonces era llamado con el nombre del Espíritu Santo y en distintos momentos los gobiernos realizaron diferentes acciones para reconstruir y remodelar dicho puerto. El 8 de julio de 1829, por Decreto Legislativo se le denominó Puerto del Triunfo de los Libres, en honor al triunfo alcanzado por el Ejército Aliado Protector de la Ley, que el general Francisco Morazán, logró derribar al gobierno dictatorial del Vicepresidente de la República Federal. En ese año se declaró libre de todo impuesto para efectos de importación y exportación, de lo cual pagaban únicamente el uno por ciento para la construcción de lanchas y edificios, seguridad y limpieza del mismo puerto.

Aunque el nombre original del Municipio de Jiquilisco era en poton Xiquilisco, “hombres del xiquilit”; de las raíces xiquilit, indigo, jiquilite (planta de la cual se extrae la tinta de añil), durante el auge del cultivo y comercialización del añil en este lugar y en la región no se extendió dicha planta. El Jiquilite fue cultivado en zona norte de la cordillera Tecapa-Chimaneca.

En realidad el área fue muy poca poblada y no fue sino con la expansión del cultivo del algodón que la población se incrementó. Por ejemplo, 1770 en Jiquilisco solamente habían 80 familias con 451 personas y en 1890 tenía aproximadamente 1,640 habitantes. Quizás el lugar más poblado en toda la región de la bahía fue el cantón de Ahuacayo, que en 1550 tenía unos 1000 habitantes y que en años posteriores se despobló debido a la expansión de epidemias como la malaria. Los vestigios de este asentamiento han sido reportados como Sitio arqueológico, sin embargo, hasta la fecha no se ha realizado ningún tipo de investigación.

No obstante en el marco de la región oriental, uno de los sitios arqueológicos más representativos de la sociedad prehispánica con presencia ininterrumpida por siglos en la zona, es el sitio conocido como “Quelepa”, este se ubica a pocos kilómetros antes de ocupación humana más antigua que existe en el país. Al parecer en la época prehispánica la región oriental era en sí misma una polo desarrollo más conectado con la actividad copaneca.

En el periodo colonial y durante la primera parte de la vida independiente de El Salvador, el territorio oriental constituía un solo departamento, San Miguel de la Frontera.

Posteriormente, en coincidencia con la muerte de Gerardo Barrios, es departamento se subdividió en cuatro. Durante este período la región tuvo una importancia marginal debido a la situación geográfica y a que el desarrollo económico del país provenía principalmente de la región occidental. La región inició un relativo despegue con la construcción de los ferrocarriles afinales del siglo XIX y con la construcción de la carretera El Litoral.

Actualmente, la población indígena descendiente de los lenca se ubican principalmente en la zona norte de Morazan y en menor escala al norte de Usulután, y en Chirilagua existe el consejo lenca de Chirilagua, el cual es miembro de la Organización de Indígenas de El Salvador, CCNIS. De acuerdo a Mac Chapin, la población indígena de la región oriental fue fuertemente afectada por el conflicto

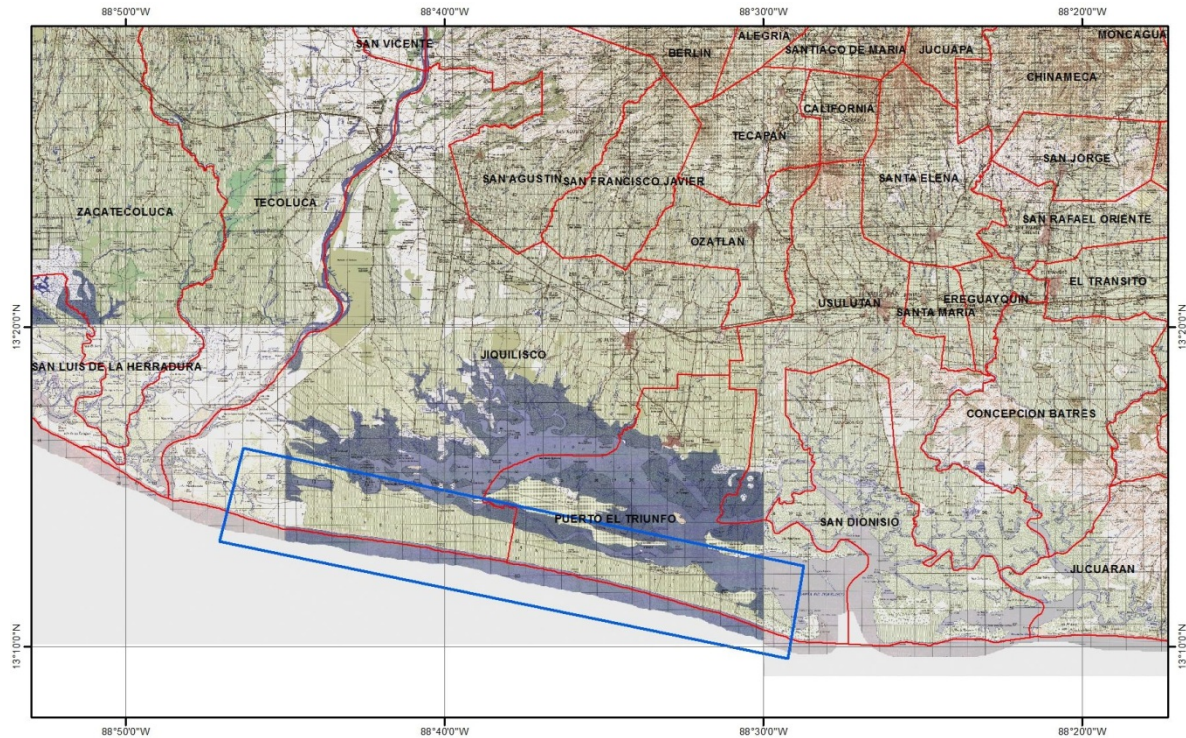


armado y las condiciones de pobreza obligo a buena parte de esta población a migrar hacia honduras.

Una de las tradiciones culturales de gran relevancia en la región de la bahía de Jiquilisco y de la zona oriental y reconocida en el ámbito nacional y centroamericano es la Romería dedicada a la Virgen de Candelaria.

En la historia de la región oriental la guerra civil desatada desde 1980 ha sido determinante principalmente por el impacto que causo en los diferentes ámbitos de la vida de la Población. Causó un impacto psicológico, modificó relaciones entre grupos por motivos políticos, fue una de las causas principales de movilización de la población tanto interna como hacia el extranjero, afectó la economía de la región tanto ganadera como agrícola, profundizo las condiciones de pobreza en la zona. Este impacto fue generalizado, pero con mayor incidencia en aquellas poblaciones que se ubicaban cerca de lugares estratégicos para los cuerpos militares y la guerrilla. Por ejemplo, las zonas del volcán Chaparrastique, montañas de Jucuaran y zona del bajo lempa. De hecho en las montañas de Jucuaran se encuentran los “tatus” que sirvieron de refugio a la guerrilla, y el cantón Los Limones, en Jiquilico, se encuentra totalmente deshabitado debido al conflicto armado.

En términos socioculturales, la región se ve afectada por procesos de aculturación que se manifiestan en diferentes patrones de la vida cotidiana; estas corrientes son canalizadas por las mismas redes familiares que conectan la región con la capital salvadoreña y sobre todo con el extranjero. No obstante, como uno de los cambios culturales más sobresalientes se puede mencionar la tendencia de procesos participativos que se han venido configurando desde el conflicto armado, como una estrategia de sobrevivencia y en los últimos años han sido fomentados por las OG's y ONG's. En este cambio sociocultural, también sobre sale una tendencia de procesos de sensibilización de una buena parte de la población ante el marcado deterioro de los recursos naturales.

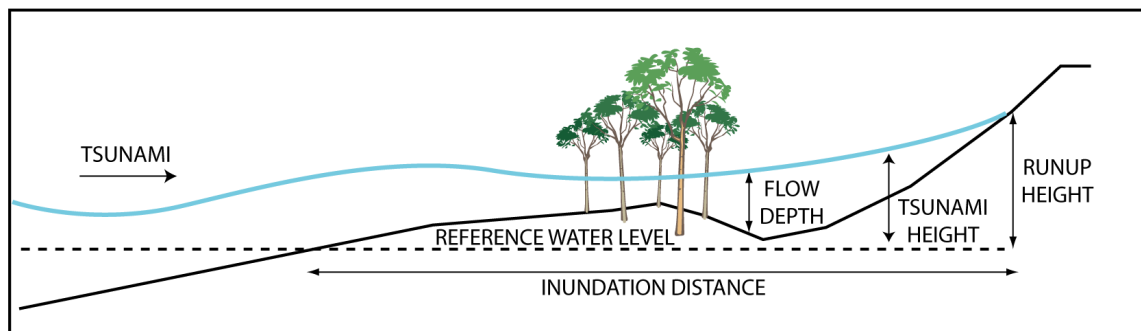


**Fig1. Los Municipios Costeros afectados fueron Puerto Triunfo y Jiquilisco.**

### Metodología para el levantamiento de Afectación.

la metodología utilizada para el levantamiento consistió en realizar encuestas a la población si el sismo fue sentido, la altura de ola con afecto el Tsunami, Cantidad de Olas que afectaron, Tiempo aproximado de la llegada de la Ola, Personas afectadas y Levantamiento Topográfico sobre la costa para determinar las características de la Dinámica del Tsunami.

### Características de la Dinámica de un Tsunami.



Tsunami = Ola marina de gran tamaño originada por un movimiento sísmico cuyo epicentro está localizado en el mar y esta puede entrar varios metros en tierra.

Profundidad de Flujo (Flow Depth)= Altura de la ola de Tsunami medida desde el nivel de terreno natural.

Tsunami Height (Altura de Tsunami) = Altura de ola de Tsunami medida desde nivel medio del mar.

Reference wáter level (Nivel Marea) = Nivel de marea presente en el momento del evento.

Runup Height (Altura del Runup) = Altura de ola de Tsunami en la distancia máxima de la inundación de Tsunami.

### **Afectaciones.**

Debido a los reportes recibidos de afectaciones en la zona de la Bahía de Jiquilisco los días 27 y 30 de agosto de 2012 se realizó un recorrido por la Península San Juan del Gozo evidenciándose lo siguiente:

#### **Zona costera cercana a la comunidad San Juan del Gozo donde se encuentra el vivero de tortugas:**

- El sismo solo fue sentido por algunas personas.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente media hora después del sismo.
- Debido a las condiciones de luminosidad no se puede determinar si el mar se retiró pero se estima que no.
- 
- Las personas mencionas que vieron una ola grande al principio seguida inmediatamente por otras. Se puede inferir que las que le siguieron son oleaje sobre la ola del tsunami.
- Se realizaron mediciones en la caseta de recibo de huevos de tortuga y estimó por las marcas de agua que la profundidad de flujo en ese sitio fue de aproximadamente 1.70 metros.
- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 167 metros.
- La infraestructura del vivero hecha de lámina y palma fue parcialmente destruida.
- La Mayoría de la población afectada fueron hombres.
- La población que se encontraba cerca del vivero indicó que no tenían conocimiento de que un tsunami podía llegar ni sabían de eventos previos.



- Pobladores indicaron que en una comunidad cercana llamada las mesitas recibieron el mensaje de alerta por parte de Protección Civil y activaron su protocolo de comunicación. Lo mismo pasó en Babilonia y La Canoa.



**Foto 1 . Altura de Ola alcanzada en San Juan del Gozo.**



**Foto 2 Cobertura Vegetal afecta por Agua salada de la Ola del Tsunami.**





**Fig 1. Llanura de Inundación en San Juan del Gozo.**

**Zona costera cercana a la comunidad Isla de Méndez donde se encuentra el vivero de tortugas:**

- El sismo no fue sentido.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente media hora a una hora después del sismo.
- Debido a las condiciones de luminosidad no se puede determinar si el mar se retiró pero se estima que no.
- Las personas mencionas que vieron una ola grande al principio seguida inmediatamente por otras.
- Se realizaron mediciones en la caseta de recibo de huevos de tortuga y estimó por las marcas de agua que la profundidad de flujo en ese sitio fue de aproximadamente 2.40 metros.
- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 304.63 metros.

- La infraestructura de la caseta del vivero hecha de lámina fue parcialmente destruida.
- La ramada del vivero hecha de palma y su cerca de malla metálica fueron totalmente destruidas.
- De la población afectada, el total fueron hombres a excepción de dos mujeres que sufrieron fracturas en sus piernas.
- La mayoría de población resultó lastimada por la vegetación de la zona.
- La población que se encontraba cerca del vivero indicó que no tenían conocimiento de que un tsunami podía llegar ni sabían de eventos previos.
- El director de la ADESCO de la zona indico que a su comunidad no llegó el mensaje de alerta de Protección Civil porque no tienen radio de comunicación.



**Foto 3 . Altura de Ola alcanzada en Isla de Méndez.**



Foto 4 Cobertura Vegetal afecta por Agua salada de la Ola del Tsunami.

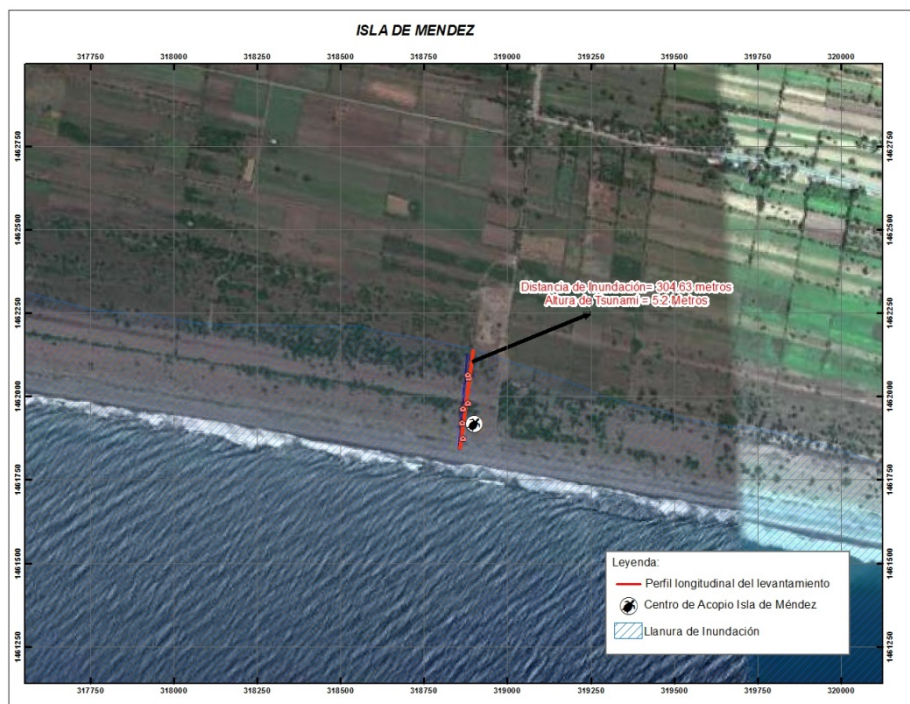


Fig 2. Llanura de Inundación para Isla de Méndez.

**Zona costera cercana a la comunidad Ceiba Doblada:**

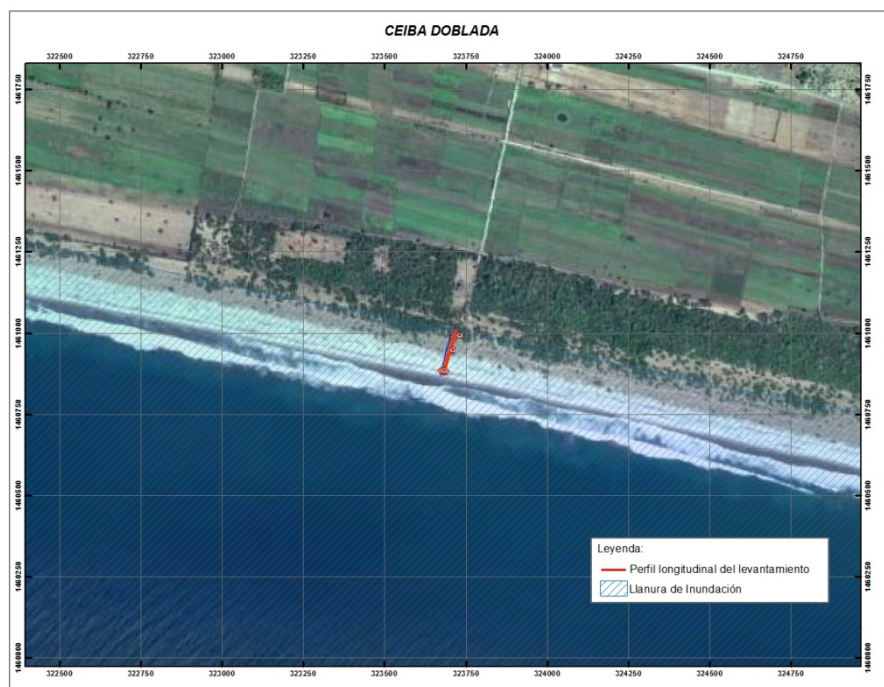
- El sismo solo fue sentido por algunas personas.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- Debido a que en esta zona no hay vivero de tortugas, no hubo población afectada debido al tsunami.



- Por las evidencias de vegetación destruida y quemada se estima que el mar ingresó tierra adentro hasta 142 metros.
- No se encontró infraestructura o vegetación en la cual medir la profundidad de flujo estimada.



**Foto 4 Cobertura Vegetal afectada por Agua salada de la Ola del Tsunami.**



**Fig 3. Llanura de Inundación para Ceiba Doblada.**



**Recorrido en la zona Nicaragüense para evaluar afectación del 26 de agosto del 2012.**

Dada una comunicación del estado Mayor de Defensa Civil de Nicaragua en cual comunica por medio el sistema de Radio Comunicaciones de Emergencias se logra conocer que el departamento de Chinandega en la franja costera de Mechapa hasta Venecia aproximadamente 25 km de costa las agua de penetraron 30 metros por lo cual el INETER responde a la solicitud procediendo a realizar una verificación a los Sitios Afectados por el Tsunami del 26 de Agosto en las Costa del El Salvador de Nicaragua.

El recorrido (ver Fig 4) se realizó desde de la costa de Mechapa, la Península de Padre Ramos, Manzanillo N.1 y Manzanillo N2.



**Fig 4. Recorrido realizado para verificar la afectación por el sismo del 26 de agosto en comunidades costeras de Nicaragua.**

**Zona costera de Mechapa :**

- El sismo no fue sentido.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente entre las 9 y 10 pm del día 26 agosto.
- Debido a las condiciones de luminosidad no se puede determinar si el mar se retiró pero se estima que no.
- Las personas menciona que vieron una ola grande al principio seguida inmediatamente por otra ola de mayor Tamaño.
- Según los pobladores del lugar se estima que la profundidad de flujo fue de 50 cms ( Foto 5) y la distancia máxima de inundación 106.15 metros (Fig 5).
- No se encontró ningún daño en la infraestructura del lugar. Algunas lanchas de pescadores fueron arrastradas varios metros.
- Se encontró alguna vegetación quemada debido al agua salada



**FIG5. Llanura de Inundación en la comunidad costera de Mechapa**





Foto 5. Profundidad de flujo en la comunidad costera de Mechapa



Foto 6. Posible Llanura de inundación en la comunidad costera de Mechapa.



Foto 7 .Posible inundación en la comunidad costera de Mechapa.



**Foto 8 .Pobladora de Mechapa relata haber visto que el mar se retiro.**



**Zona costera de Manzanillo 2:**

- El sismo no fue sentido.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente entre las 9 y 9:30 pm del día 26 agosto.
- Según relato de los pobladores lograron ver el mar se retiro a pesar de la poca luminosidad.
- Las personas mencionas que vieron una ola grande.
- Según los pobladores del lugar se estima que la profundidad de flujo fue de 50 cms ( Foto 9) y la distancia máxima de inundación 62 metros sobre la costa y 120 metros sobre un estero (Fig 6).
- No se encontró ningún daño en la infraestructura del lugar. Algunas lanchas de pescadores fueron arrastradas varios metros.
- No hubo afectación a la población del lugar



**FIG5. Posible llanura de Inundación en la comunidad costera de Manzanillo 2**



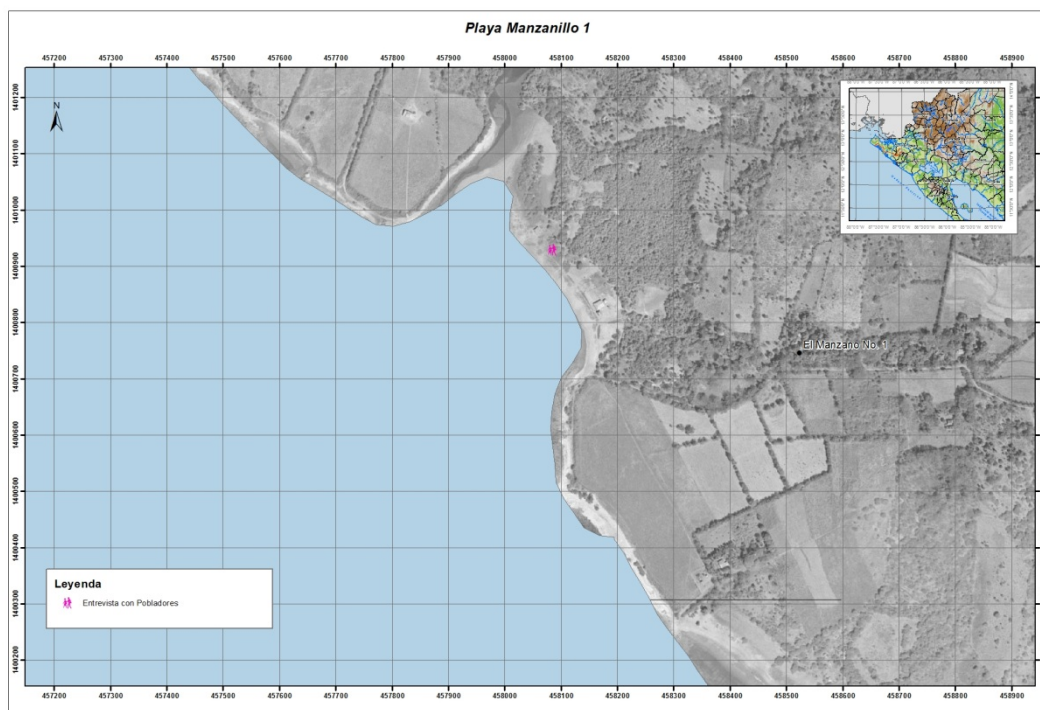
**Foto 9 .Profundidad de flujo en la comunidad costera de Manzanillo 2**



**Foto 10 .Posible Llanura de inundación en la comunidad costera de Manzanillo 2 .**

**Zona costera de Manzanillo 1:**

- El sismo no fue sentido.
- Las condiciones meteorológicas antes del tsunami eran normales, el nivel del mar se encontraba bajando y había poca luminosidad.
- No se ha determinado una hora específica de llegada de las ondas pero se estima que fue aproximadamente entre las 9 y 9:30 pm del día 26 agosto.
- Según relato de los pobladores lograron ver el mar se retiro a pesar de la poca luminosidad.
- Las personas entrevistadas vieron que el mar se retiro pero luego volvió a su normalidad lentamente.
- No se encontró ningún daño en la infraestructura del lugar.
- No hubo afectación a la población del lugar



**FIG6. Comunidad costera de Manzanillo 1**





**Foto 11 Comunidad costera de Manzanillo 1**



**Foto 12 Poblador encuestado en la comunidad costera de Manzanillo 1**



**Como conclusión**

- Las Razones del porque este Tsunami no causo daños mayores es debido que la Bahía de Jiquilisco es área protegida (Sitio RAMSAR) por lo cual tiene restricciones para la contrucciones de viviendas
- La guerra civil de los años 80 provoco que la personas emigraran a otras zonas del País
- Altura máxima de la ola de Tsunami fue de 5 metros sobre el nivel del mar
- La inundación máxima fue de 300 metros y esto ocurrió en Isla de Mendez.
- Que los Niveles Máximos de Inundación se encontraron en la parte Oeste y disminuyen el parte Este de la Bahía de Juiquilisco.
- En la parte Nicaragüense no se encontró afectación en la infraestructura o población de las costa afectadas teniendo una longitud de inundación máxima de 106.15 para Mechapa y 120 metros en Manzanillo 2.
- En el recorrido se visito las comunidades del Estero de Padre Ramos, pero los pobladores no registraron ninguna anomalía presenta en el estero.