2.4S.6 Probable Maximum Tsunami

The following site-specific supplement addresses the probable maximum tsunami. Probable maximum tsunami flooding events are discussed in Subsection 2.4S.2.

2.4S.6.1 Probable Maximum Tsunami

Previous estimates of “worst-case” tsunami flooding along the Texas Gulf Coast have been made for near-field and far-field (i.e., a tsunami that occurs from a source over a 1000 km away) sources. These previous estimates have been based on both historical tsunamis and simulated events. With respect to near-field sources, the National Oceanic and Atmospheric Administration’s (NOAA) West Coast and Alaska Tsunami Warning Center has estimated “worst-case” events by using a two-dimensional depth-integrated hydrodynamic model developed at the University of Alaska, Fairbanks (Reference 2.4S.6-1). The model was run on a Cray X1 supercomputer and included four “worst-case” scenarios based on geoseismic events originating in the Caribbean Sea and the Gulf of Mexico:

(1) A moment magnitude (M_w) 9.0 in the Puerto Rico trench (66W, 18N)

(2) A M_w 8.2 in the Caribbean Sea (85W, 21N)

(3) A M_w 9.0 in the North Panama Deformed Belt (66W, 12N)

(4) A hypothetical scenario off the coast of Veracruz, Mexico (95W, 20N)

For all near-field modeled scenarios, the peak shoreline wave height along the Gulf coast was less than 0.35 meters. The peak shoreline wave height for the first scenario in the vicinity of STP 3 & 4 was predicted as being between 0.04 meters and 0.06 meters (Figure 2.4S.6-1). The peak shoreline wave height for the second scenario in the vicinity of STP 3 & 4 was less than 0.1 meter (Figure 2.4S.6-2). The peak shoreline wave height for the third scenario in the vicinity of STP 3 & 4 was less than 0.06 meters (Figure 2.4S.6-2). The peak shoreline wave height for the fourth scenario in the vicinity of STP 3 & 4 was less than 0.35 meters (Figure 2.4S.6-3).

However, an extensive literature review of historical accounts, tsunami databases, and model postulations indicates the probable maximum tsunami wave height in the Gulf of Mexico is expected to occur from a far-field source. The magnitude of the tsunami is expected to be no more than 1 meter. The tsunamigenic source for such a tsunami wave would be a seismic event similar to the 1755 Lisbon earthquake (Reference 2.4S.6-2).

With respect to other tsunamigenic sources, the 1-m to 2-m seiche event along the Texas coast from the 1964 Alaska earthquake (References 2.4S.6-3 and 2.4S.6-4) is considered to approximate the maximum possible seismic seiche event.

With respect to submarine landslides and slumps, the 7.6 meter wave height estimated to have been generated by the East Breaks slump (Reference 2.4S.6-5) is not considered probable. It is noted that an extensive literature search did not reveal any information or data regarding any potential submarine areas in the Gulf of Mexico of the size of the East Breaks slump that are considered to have a probable risk for sliding. Additional slides or slumps producing tsunamis have also not been documented for the period after this event occurred. Therefore, a tsunami along the Texas Coast of the magnitude estimated to have been generated by the East Breaks slump is considered highly unlikely and is not a consideration for STP 3 & 4.

2.4S.6.2 Historical Tsunami Record

Sources of information and data on tsunami-generating earthquakes and runup events affecting the Gulf coast include primarily the National Geophysical Data Center (NGDC) tsunami database, Science of Tsunami Hazards journal archives, the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) Center for Tsunami Research and published literatures on historical Caribbean tsunamis. The NGDC database contains information on source events and runup elevations for worldwide tsunamis from about 2000 B.C.E. to the present (Reference 2.4S.6-6). Similarly, the archives of the Science of Tsunami Hazards journal include source events and runup elevations for the Caribbean Sea and Eastern United States from 1498 to 1997 (Reference 2.4S.6-7) and 1668 to 1998 (Reference 2.4S.6-8). The USGS has published a fact sheet on improving earthquake and tsunami warnings for the Caribbean Sea, the Gulf of Mexico, and the Atlantic coast (Reference 2.4S.6-9) that includes a map showing the locations of the tsunami-generating earthquakes in the Caribbean Sea and Gulf of Mexico from 1530 to 1991. The map is reproduced in Figure 2.4S.6-4, which shows the locations of these tsunami-generating earthquakes and the plate boundaries in this area. NOAA's Center for Tsunami Research, in conjunction with the Pacific Marine Environmental Laboratory, has developed a database that includes worldwide event monitoring and numerical model simulations. NOAA's database includes recent tsunami events (Reference 2.4S.6-10). Finally, the publication titled "Caribbean Tsunamis: A 500-Year History from 1498-1998," is a compendium of data and anecdotal material on tsunamis reported in the Caribbean from 1498 to 1997 (Reference 2.4S.6-11).

Three historical tsunamis have been documented for the Gulf coast in the available tsunami databases and literature referenced above. The first of these tsunami events occurred on October 24, 1918. This tsunami was presumed to be an aftershock of the M_W=7.3 October 11, 1918 earthquake near Puerto Rico (Reference 2.4S.6-7, p. 73). The epicenter of the earthquake was reported at 18.5ºN, 67.5ºW (Reference 2.4S.6-11, p. 201), which is approximately nine miles northwest of Puerto Rico in the Mona Rift. As described in Reference 2.4S.6-11 (p. 201), this earthquake was "considered a terrific aftershock of the October 11 event, both this and another earthquake on November 12 had epicentral intensities of R-F [Rossi-Forel scale] equal to approximately VIII to IX. In marked contrast to the vertical vibrations of the initial disturbance, these were characterized by horizontal oscillations. A small wave was recorded at the Galveston, Texas, tide gauge." This event has a validity rating in the NGDC database of four on a scale from zero to four, where zero and one are used for erroneous or very doubtful events, respectively, and four is used for definite events. The magnitude of the runup of this tsunami was not reported.

The second documented tsunami event in the Gulf occurred on May 2, 1922. The epicenter of the earthquake associated with this event was reported at 18.4ºN, 64.9ºW (Reference 2.4S.6-11, p. 201). Reference 2.4S.6-11 (p. 201) states that "a wave with an amplitude of 64 cm was reported on a tide gauge at Galveston. A train of three waves with a 45-minute period was followed in 8 hours by a 28-cm wave in a similar train of smaller waves. Parker (Reference 2.4S.6-12) associated it with an earthquake felt 4 hours earlier at Vieques, Puerto Rico. According to Campbell (Reference 2.4S.6-13), the two-second shock was slight and unlikely to have been the tsunamigenic source." The validity rating of this event in the NGDC database is a two (i.e., doubtful). No runups were documented along the Gulf coast for the primary shock of the 1922 earthquake, and the surge was presumed to have been locally amplified by the inland position of the tidal gauge (Reference 2.4S.6-12, p. 30). The magnitude of the 1922 earthquake and the aftershock has not been estimated.

The third reported tsunami event in the Gulf occurred on March 27, 1964, and was recorded on a tide gauge in Freeport, Texas (Reference 2.4S.6-3). While the validity of this event was a four, estimates of the wave height vary considerably between eyewitness accounts and tide gauge data. Reference 2.4S.6-3 (p. 261) notes that "in several reports from eyewitnesses in the coastal regions of Louisiana and Texas, waves up to 6 feet (2 meters) in height were observed." However, Reference 2.4S.6-3 (p. 261) reports that the "maximum height of the recorded seiche at 0400 GMT is about seven inches (18 cm)," and that the "true wave height may have been several feet (about a meter)." This event coincided with the 1964 Alaska (M_W=9.2) earthquake located between the Aleutian Trench and the Aleutian Volcanic Arc (Reference 2.4S.6-14). Additional analyses of tide gauge records from the 1964 event report the maximum measured height of the low-frequency waves along the Texas coast coinciding with the Alaska earthquake ranged from 0.22 to 0.84 feet (Reference 2.4S.6-4, p. 26).

In addition to the recorded events in the Gulf of Mexico, numerical simulations of tsunamis generated by historic earthquakes provide additional insight into the potential tsunami hazards along the Texas coast. Wave generation and propagation modeling of the tsunami generated by the 1755 Lisbon (M_W=8.7) earthquake (Reference 2.4S.6-15) was conducted using the nonlinear long wave equations and a 10-minute Mercator grid for the Atlantic Ocean (Reference 2.4S.6-2). The modeling predicted a teletsunami (i.e., a tsunami from a source over 1000 km away) arriving in the Caribbean and entering the Gulf of Mexico. Reference 2.4S.6-2 (p. 95) states that "the east coast of the U.S.A. and the Caribbean [would] receive a tsunami wave offshore in deep water about two meters high with periods of 1.25 to 1.5 hours. Such a wave would give waves along the shore about 10 feet high with Saba being unique with about a 20 feet high wave after run-up. After the wave travels into the Gulf of Mexico the wave amplitudes are less than one meter." Saba is an island in the Netherlands Antilles located off the north coast of Venezuela. The estimate of the Saba runup elevation in Reference 2.4S.6-2 agrees well with the reported runup in Saba of 7.0 meters (Reference 2.4S.6-7, p. 78), and provides verification of the numerical model, even for unique situations such as Saba.

2.4S.6.3 Source Generator Characteristics

Several tsunamigenic sources have been documented for the Gulf of Mexico and the Texas-Louisiana coast. These sources include seismic events in the Azores-Gibraltar fracture zone near Lisbon, Portugal, seismic events in the North Caribbean, seiche mechanisms associated with earthquakes in other parts of the world (e.g., the large Alaskan earthquakes), volcanism in the Atlantic Ocean (e.g., in the Canary Islands). While submarine landslides and submarine slumps causing tsunamis have not been documented in historical times, at least one event has been conjectured to have occurred within the Gulf of Mexico within the last 5,000 to 10,000 years. These tsunamigenic sources are discussed in further details below.

2.4S.6.3.1 Seismic tsunamis

In comparison to islands in the Caribbean, the Gulf of Mexico and the Texas coast has had relatively few seismic tsunamis. Reference 2.4S.6-1 (p. 311) states that “the Atlantic and Gulf coasts are nearly independent since the hydrodynamic connection between basins is through the narrow Straits of Florida and through the Caribbean, where bottom friction losses appear to be large.” As discussed in Reference 2.4S.6-1 (p. 307), wave propagation takes two routes, “one through the Caribbean and the other through the Straits of Florida.” The Caribbean route is faster by about one hour, and energy transfer into the Gulf is computed with an energy flux vector that is a function of the wave momentum and kinetic energy. While wave propagation is faster through the Caribbean than the Straits of Florida, energy dissipation is larger in the Caribbean Sea than in the Straits of Florida (Figure 2.4S.6-5). Consequently, although the wave arrives later, more energy moves into the Gulf through the Straits of Florida. Reference 2.4S.6-1 (p. 311) therefore concluded that “sources outside the Gulf are not expected to create a tsunami threatening to the Gulf coast.”

2.4S.6.3.2 Seismic seiches

The only documented event that has produced a seismic seiche in the Texas coast is the 1964 Alaska earthquake. Reference 2.4S.6-4 indicated that the horizontal acceleration associated with the seismic surface waves from the Alaska shock appears to have varied markedly within North America according to data from seiches recorded by surface-water gages at the time of the Alaska shock. The amplitude of horizontal acceleration was especially large along the Gulf coast. Reference 2.4S.6-4 (p. 27) further stated that “the thick deposits of sediments of low rigidity along the Gulf coast, for example, are capable of amplifying the horizontal acceleration of surface waves to a considerable extent; this accounts for the concentration of seiches that occurred along the Gulf coast.”

While the M_W=9.5 magnitude 1960 earthquake in Chile might also have been expected to have caused seiches along the Texas coast, tide gauges along the Gulf coast did not record any such event. The M_W=7.8 New Madrid earthquake occurred on February 7, 1812 (Reference 2.4S.6-16), which is the largest earthquake recorded in the contiguous United States, produced significant seiches in the Mississippi River and in waterways along the Texas state boundary (Reference 2.4S.6-8, p. 124). However, no records exist to indicate that the 1812 New Madrid earthquake directly affected the Texas coast or the Lower Colorado River in the vicinity of STP 3 & 4.

2.4S.6.3.3 Volcanism-based tsunamis

While volcanism and volcanism-based tsunamis have been significant in the Caribbean and Canary Islands (Reference 2.4S.6-17), no tsunamis have been documented in the Gulf of Mexico as a result of recent volcanic eruptions or associated mass wasting events (i.e., the gravity-driven mass movement of soil, regolith, or rock downslope). The largest postulated tsunami in the Atlantic Ocean that may have been caused by a volcanic eruption is that associated with the eruption and collapse of the Cumbre Vieja Volcano on the Island of La Palma in the Canary Islands about 550,000 years before the present time (Reference 2.4S.6-17). The collapse of 500 cubic kilometers of material from Cumbre Vieja has been estimated as capable of generating a transatlantic tsunami with a wave height on the order of 10-25 meters. Reference 2.4S.6-18 (p. 38) states that “during an eruption in 1949 a fault broke surface along the crest of the volcano and part of its western side slid five meters down and toward the ocean. The volcano again may be showing initial stages of instability. However, certainly collapse is not imminent and it may take many eruptive cycles over the next few thousand years to give it that final shove.” In addition, the distribution of slide blocks on the ocean bottom suggests the collapse of the Cumbre Vieja may not have been the result of a single catastrophic event, but of several smaller events. A recent report on potential tsunami threats to the UK concludes that “studies of the offshore turbidities [i.e., poorly sorted sediment that is deposited from a density flow of mixed water and sediment] created by landslides from the flanks of the Canary Islands suggest that these result from multiple landslides spread over periods of several days” and are therefore “likely to create tsunamis of only local concern” (Reference 2.4S.6-19, p. 23 and p. 30, respectively). Consequently, this mechanism is not considered further as a potential source of tsunamis along the Texas coast.

2.4S.6.3.4 Submarine slump tsunamis

Recent tsunami research has differentiated tsunamis from submarine sources into two types of events: tsunamis for translational landslides and tsunamis from rotational slumps (Reference 2.4S.6-20). While translational landslides are relatively frequent in the Gulf of Mexico (Reference 2.4S.6-21), no tsunamis generated by this type of landslide have been documented in the geologic record or the instrumental record for the Gulf coast. The only evidence of a submarine slump in the Gulf of Mexico with the potential to have caused a tsunami is from a topographic scar known as the East Breaks slump that occurred in the northwestern Gulf of Mexico. The slump originated within late Wisconsinian Colorado/Brazos River shelf edge deposits estimated as early Holocene in age (i.e., 10,000 to 5000 years before the present time) (Reference 2.4S.6-5). The location of the East Breaks slump is shown in Figure 2.4S.6-6. Figure 2.4S.6-7 shows the extent of the slump. The East Breaks slump has been conjectured to have initiated in unconsolidated prodeltaic sediments, with a 20-km wide head scarp, at about the 180-m isobath. The length of the erosional chute was estimated to have been about 55 km, and the maximum thickness of the slump equal to about 70 meters. The total estimated volume of the slide was about 50 to 60 cubic kilometers.

Reference 2.4S.6-5 provides a preliminary order-of-magnitude estimate of the offshore wave height associated with such a slump as 7.6 meters. However, no calculation or methodology was included in the conference paper where this estimate was presented. In addition, this wave height estimate from the East Breaks slump has not been supported by subsequent publications in any peer-reviewed technical or scientific journals. In part, the lack of a credible estimate is due to a poor understanding of slump-based tsunamis. For example, the first slump that has high quality runup data is the 1998 Papua New Guinea event (References 2.4S.6-8 and 2.4S.6-20). Slump tsunamis in areas with low bed slopes, such as that for the Gulf of Mexico, are very poorly understood. There is no geologic evidence that has been obtained validating a wave height of this magnitude impacting the Gulf coast. In the absence of credible evidence, it is concluded that the East Breaks slide is not a probable candidate to consider for the probable maximum tsunami (PMT) runup event for STP 3 & 4.

2.4S.6.4 Tsunami Analysis

Based on the discussion presented in Section 2.4S.6.3, and considering that no other specific information exists on potential seismic sources and submarine landslides that may cause a tsunami in the Gulf of Mexico, no further detailed modeling analysis of tsunami wave height and its propagation is warranted.

2.4S.6.5 Tsunami Water Levels

Because Caribbean-based tsunamis are unlikely to produce a shoreline wave height exceeding 0.35 meter at the Texas coast near STP 3 & 4, the most likely candidate for the probable maximum tsunami is from an event similar to the 1755 earthquake in the Azores-Gibraltar fracture zone near Lisbon, Portugal. As discussed in other tsunami investigations (Reference 2.4S.6-19), the 1755 Lisbon event is considered to be the ‘worst-case’ scenario with respect to a tsunami forming in the Azores-Gibraltar fracture zone.

The numerical model study described in Reference 2.4S.6-2 suggested that the 1755 Lisbon event could produce wave amplitudes of less than one meter in the Gulf of Mexico. With a runup amplification of two to three times the deep water wave amplitude (References 2.4S.6-2, p. 95 and 2.4S.6-22), a conservative estimate of the maximum tsunami runup at the Texas coast would be no more than three meters (10 feet). It should be noted that in many cases, runup elevation is often lower than the shoreline wave height (Reference 2.4S.6-23). To determine the maximum flood level for a PMT event, Regulatory Guide 1.59 (Reference 2.4S.6-24) requires the consideration of the coincidental occurrence of the 10% exceedance of the astronomical high tide and sea level anomaly in addition to the wave runup. Based on tide gauge data for Freeport, Texas, the 10% exceedance of the astronomical high tide is 2.2 feet above mean low water (MLW), and the initial rise is 2.4 feet (Reference 2.4S.6-24). To account for the long-term sea level rises due to global climate change, it is assumed that the historical mean sea level trend at Freeport, Texas of 5.87 mm/year or 1.93 feet/century, with a standard error of 0.74 mm/yr, from 1954 to 1999 (Reference 2.4S.6-25) will continue. The peak flood level due to a probable maximum tsunami event is therefore estimated to be of the order of 17 feet MLW within the next century. This is equivalent to 16.3 feet MSL (or NGVD 29) considering the datum shift of 0.68 feet from MLW to MSL at Freeport, Texas (Reference 2.4S.6-25).

With respect to the assumption of the MSL datum (or NGVD 29) shift relative to actual mean sea level from tidal measurements, it should be noted that the Freeport, Texas, tide gauge does not have a published or official NGVD29 orthometric height mark. Since the one mark that does exist suggests the difference between MSL (or NGVD 29) to actual mean sea level is small (i.e., within ±0.2 ft of the Mean Lower-Low Water datum), the shift to MSL (or NGVD 29) should be considered as an approximation of the actual value.

Based on the discussion above, it is concluded that the flood elevation at STP 3 & 4 due to the postulated probable maximum tsunami event will not be the controlling design basis flood elevation for STP 3 & 4 because it is lower than the maximum flood elevation of 47.6 feet MSL predicted for a hypothetical breach event of the MCR embankment as described in Section 2.4S.4. Coincident wind waves are not considered in the analysis since the PMT event will have no flooding impacts on safety-related facilities of STP 3 & 4.

2.4S.6.6 Hydrography and Harbor or Breakwater Influences on Tsunami

Because STP 3 & 4 is over 15 miles inland from the Gulf coast and the grade elevations for the plant are much higher than 16.3 feet MSL, there will be no local onsite effects associated with different tsunami types, including breaking waves, bores, or any resonance effects that would result in higher tsunami runup on the safety-related facilities. Therefore, no analysis of the translation of tsunami waves from offshore generator locations to the site is warranted.

2.4S.6.7 Effects on Safety-Related Facilities

The postulated maximum flood level of no more than 16.3 ft MSL due to the PMT event is lower than the nominal plant grade of 34 ft MSL and the entrance level grade elevation of 35 ft MSL for all safety-related facilities of STP 3 & 4. Therefore, the PMT event will have no flooding impacts on safety-related facilities or the design basis functions of STP 3 & 4, and there will be no impact of debris and water-borne projectiles and impacts of sediment erosion and deposition on the safety-related facilities of STP 3 & 4.

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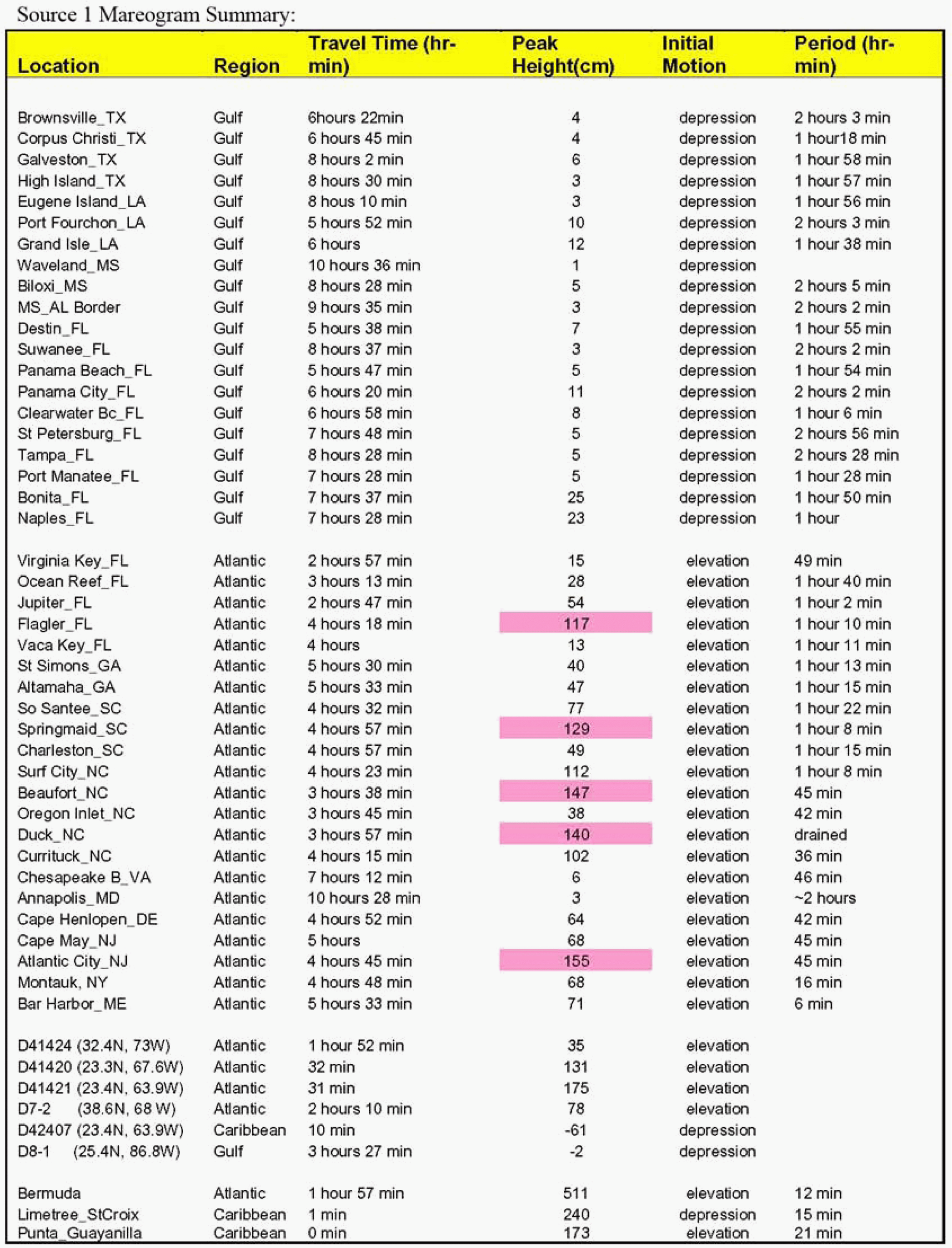


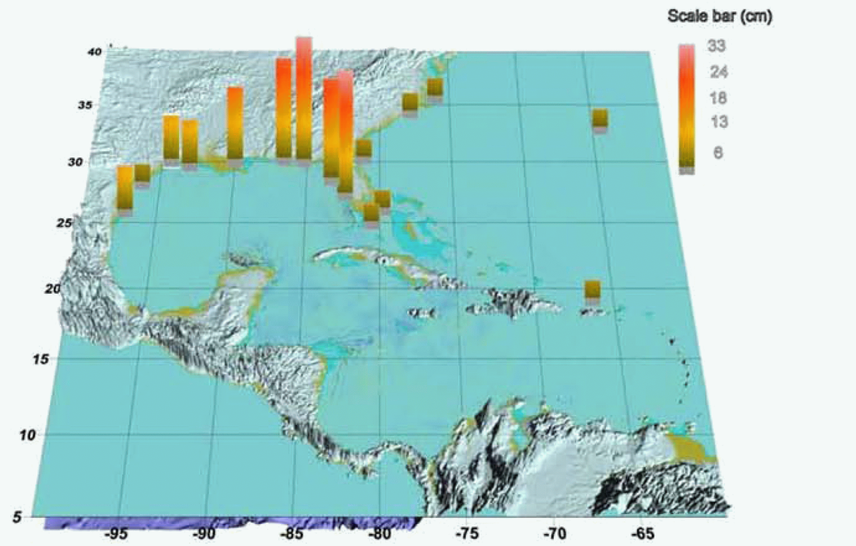
Source 1 Mareogram Summary:

Location	Region	Travel Time (hr-min)	Peak Height(cm)	Initial Motion	Period (hr-min)
Brownsville_TX	Gulf	6hours 22min	4	depression	2 hours 3 min
Corpus Christi_TX	Gulf	6 hours 45 min	4	depression	1 hour18 min
Galveston_TX	Gulf	8 hours 2 min	6	depression	1 hour 58 min
High Island_TX	Gulf	8 hours 30 min	3	depression	1 hour 57 min
Eugene Island_LA	Gulf	8 hous 10 min	3	depression	1 hour 56 min
Port Fourchon_LA	Gulf	5 hours 52 min	10	depression	2 hours 3 min
Grand Isle_LA	Gulf	6 hours	12	depression	1 hour 38 min
Waveland_MS	Gulf	10 hours 36 min	1	depression	
Biloxi_MS	Gulf	8 hours 28 min	5	depression	2 hours 5 min
MS_AL Border	Gulf	9 hours 35 min	3	depression	2 hours 2 min
Destin_FL	Gulf	5 hours 38 min	7	depression	1 hour 55 min
Suwanee_FL	Gulf	8 hours 37 min	3	depression	2 hours 2 min
Panama Beach_FL	Gulf	5 hours 47 min	5	depression	1 hour 54 min
Panama City_FL	Gulf	6 hours 20 min	11	depression	2 hours 2 min
Clearwater Bc_FL	Gulf	6 hours 58 min	8	depression	1 hour 6 min
St Petersburg_FL	Gulf	7 hours 48 min	5	depression	2 hours 56 min
Tampa_FL	Gulf	8 hours 28 min	5	depression	2 hours 28 min
Port Manatee_FL	Gulf	7 hours 28 min	5	depression	1 hour 28 min
Bonita_FL	Gulf	7 hours 37 min	25	depression	1 hour 50 min
Naples_FL	Gulf	7 hours 28 min	23	depression	1 hour
Virginia Key_FL	Atlantic	2 hours 57 min	15	elevation	49 min
Ocean Reef_FL	Atlantic	3 hours 13 min	28	elevation	1 hour 40 min
Jupiter_FL	Atlantic	2 hours 47 min	54	elevation	1 hour 2 min
Flagler_FL	Atlantic	4 hours 18 min	117	elevation	1 hour 10 min
Vaca Key_FL	Atlantic	4 hours	13	elevation	1 hour 11 min
St Simons_GA	Atlantic	5 hours 30 min	40	elevation	1 hour 13 min
Altamaha_GA	Atlantic	5 hours 33 min	47	elevation	1 hour 15 min
So Santee_SC	Atlantic	4 hours 32 min	77	elevation	1 hour 22 min
Springmaid_SC	Atlantic	4 hours 57 min	129	elevation	1 hour 8 min
Charleston_SC	Atlantic	4 hours 57 min	49	elevation	1 hour 15 min
Surf City_NC	Atlantic	4 hours 23 min	112	elevation	1 hour 8 min
Beaufort_NC	Atlantic	3 hours 38 min	147	elevation	45 min
Oregon Inlet_NC	Atlantic	3 hours 45 min	38	elevation	42 min
Duck_NC	Atlantic	3 hours 57 min	140	elevation	drained
Currituck_NC	Atlantic	4 hours 15 min	102	elevation	36 min
Chesapeake B_VA	Atlantic	7 hours 12 min	6	elevation	46 min
Annapolis_MD	Atlantic	10 hours 28 min	3	elevation	~2 hours
Cape Henlopen_DE	Atlantic	4 hours 52 min	64	elevation	42 min
Cape May_NJ	Atlantic	5 hours	68	elevation	45 min
Atlantic City_NJ	Atlantic	4 hours 45 min	155	elevation	45 min
Montauk, NY	Atlantic	4 hours 48 min	68	elevation	16 min
Bar Harbor_ME	Atlantic	5 hours 33 min	71	elevation	6 min
D41424 (32.4N, 73W)	Atlantic	1 hour 52 min	35	elevation	
D41420 (23.3N, 67.6W)	Atlantic	32 min	131	elevation	
D41421 (23.4N, 63.9W)	Atlantic	31 min	175	elevation	
D7-2 (38.6N, 68 W)	Atlantic	2 hours 10 min	78	elevation	
D42407 (23.4N, 63.9W)	Caribbean	10 min	-61	depression	
D8-1 (25.4N, 86.8W)	Gulf	3 hours 27 min	-2	depression	
Bermuda	Atlantic	1 hour 57 min	511	elevation	12 min
Limetree_StCroix	Caribbean	1 min	240	depression	15 min
Punta_Guayanilla	Caribbean	0 min	173	elevation	21 min

Figure 2.4S.6-1 Map of Predicted Runup Elevations for a Simulated "Worst Case" M_W 9.0 Earthquake in the Puerto Rico Trench

Source: Reference 2.4S.6-1, p. 309

Source 2 –mareogram summary (source in Caribbean Sea near Cancun)



Source 3 mareogram summary (source near Venezuela)

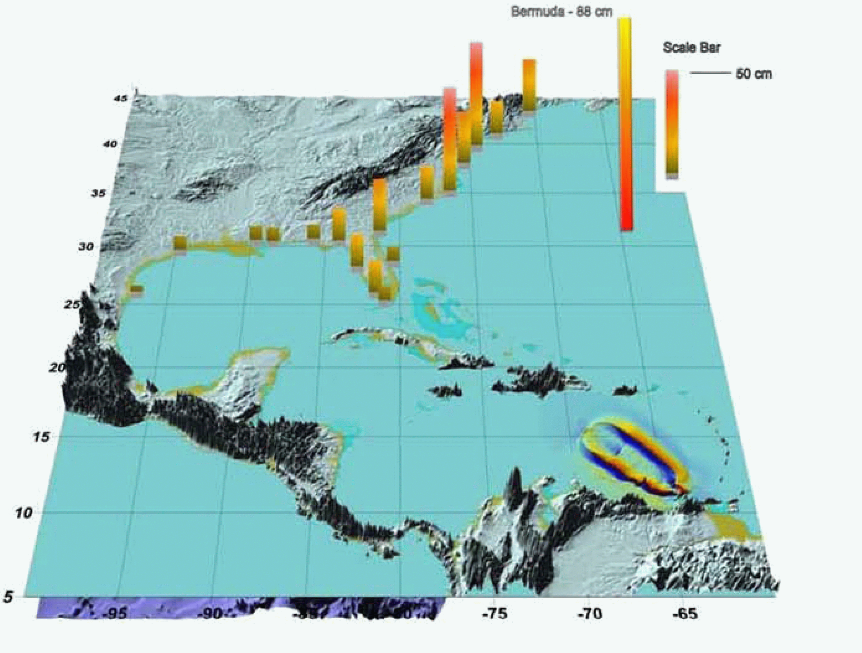
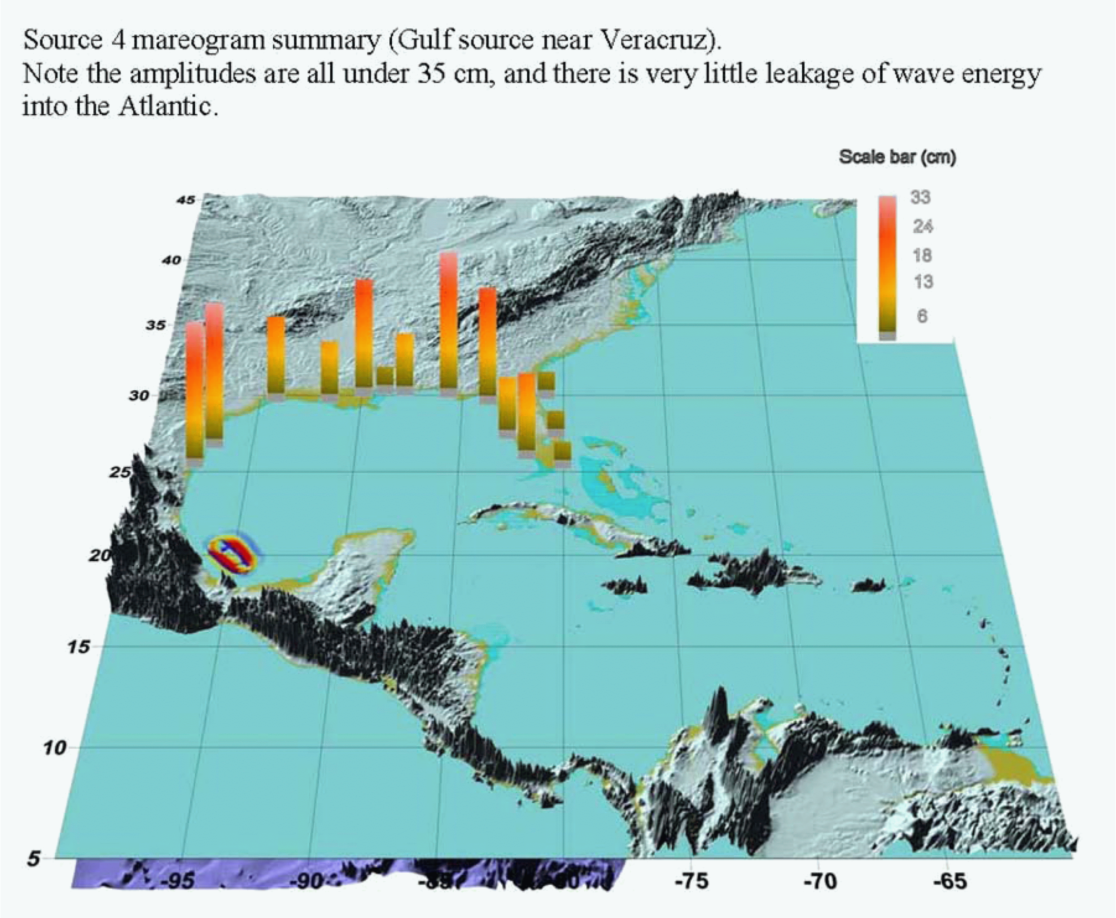


Figure 2.4S.6-2 Map of Predicted Runup Elevations for a Simulated “Worst Case” M_W 8.2 earthquake (Source 2) along the North Caribbean Plate Boundary and a M_W 9.0 in the North Panama Deformed Belt (Source 3)

Source: Reference 2.4S.6-1, p. 309 Reference 2.4S.6-1, p. 310



Source 4 mareogram summary (Gulf source near Veracruz).
Note the amplitudes are all under 35 cm, and there is very little leakage of wave energy into the Atlantic.

Figure 2.4S.6-3 Map of Predicted Runup Elevations for a Hypothetical "Worst-Case" Earthquake near Veracruz, Mexico

Source: Reference 2.4S.6-1, p. 311

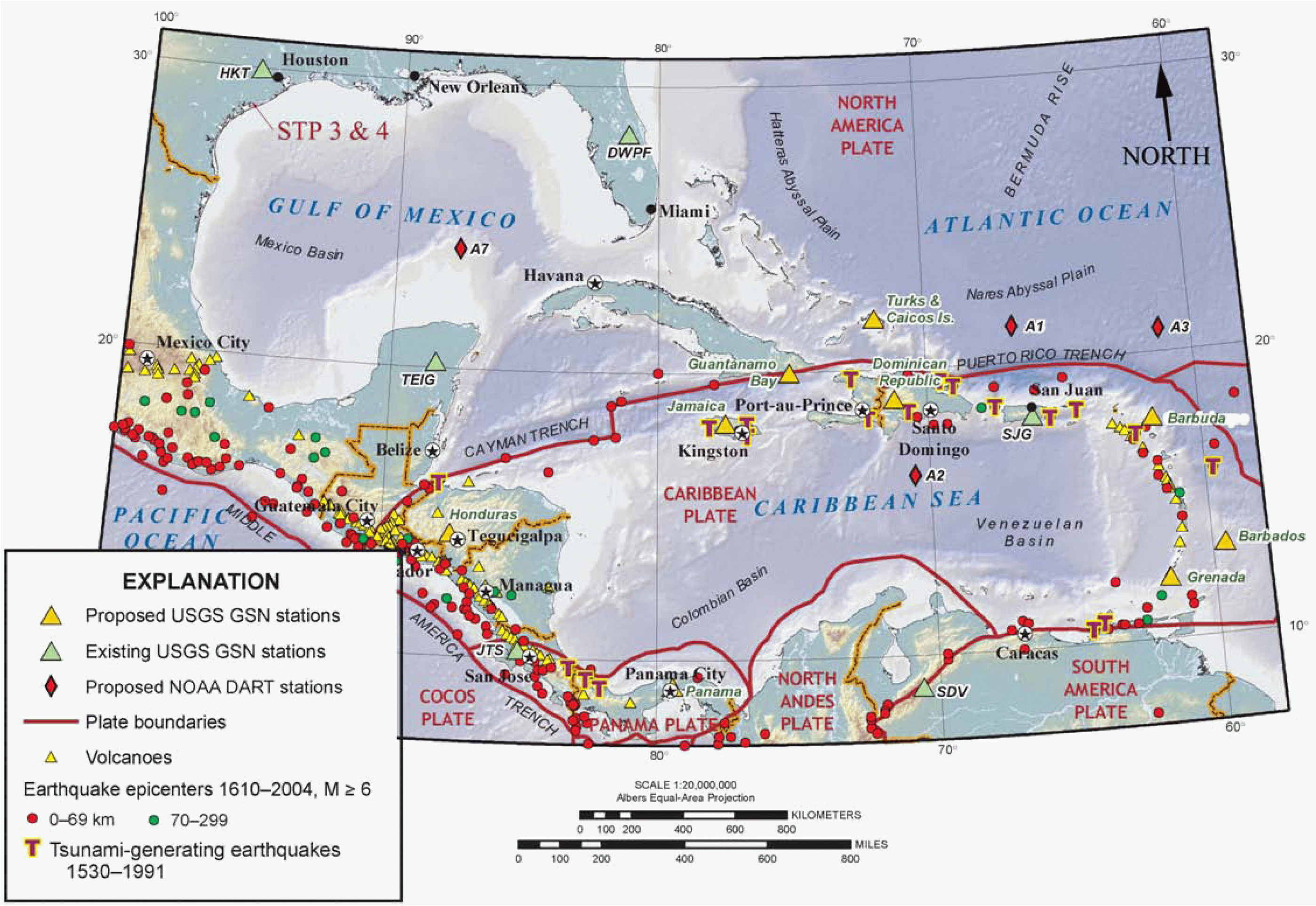


Figure 2.4S.6-4 Regional Map of Plate Boundaries and Tsunami-Generating Earthquakes from 1530-1991 in the Caribbean Sea (modified from Reference 2.4S.6-9)

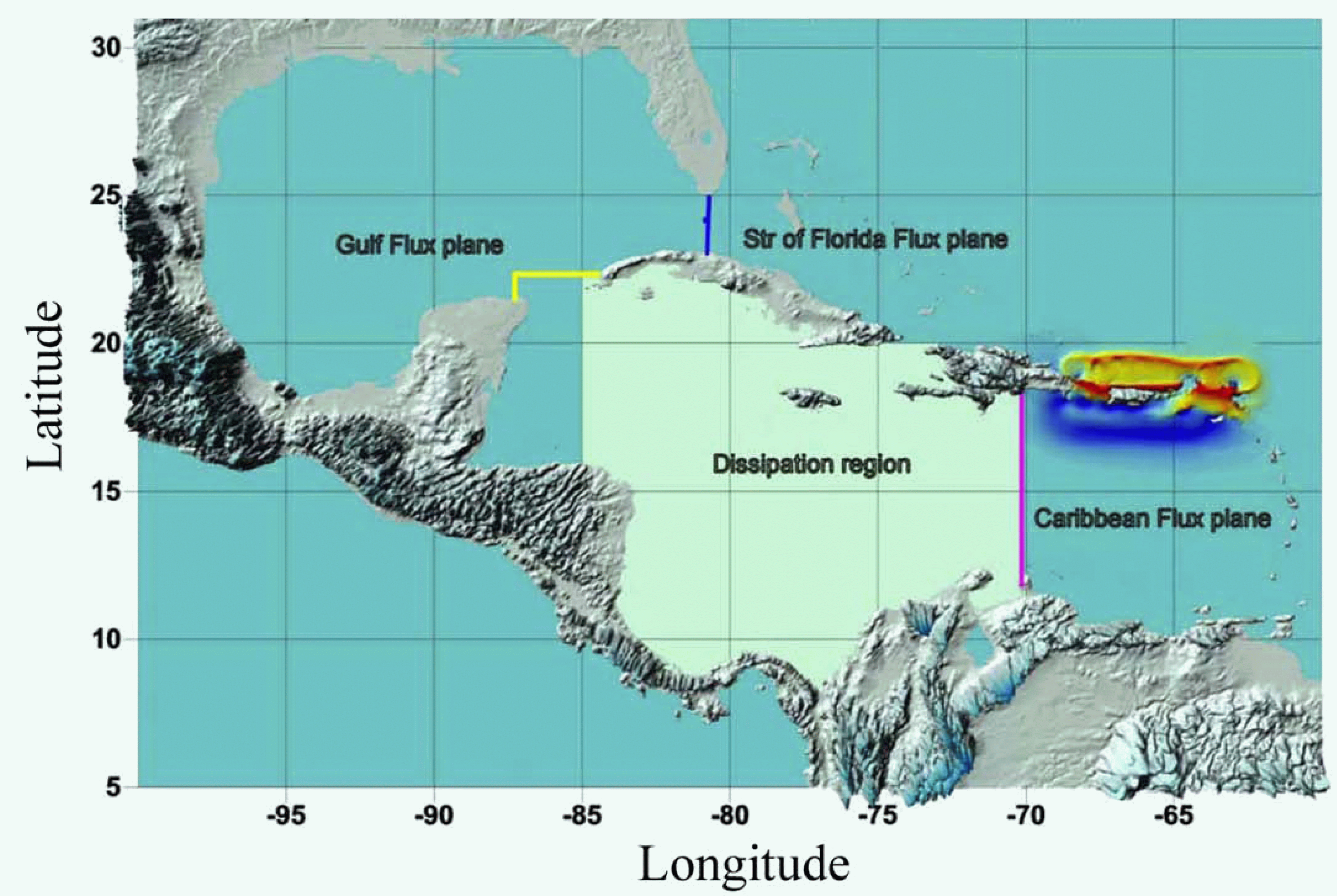


Figure 2.4S.6-5 Regional Map of the Straits of Florida, Gulf Flux, and Caribbean Flux Planes with Respect to Energy Dissipation in the Caribbean Sea

Source: Reference 2.4S.6-1, p. 308

Figure 2.4S.6-6 Gulf of Mexico Bathymetry and Location of the East Breaks Slump Area. The Contour Labels Represent Depths (feet) in the Gulf of Mexico

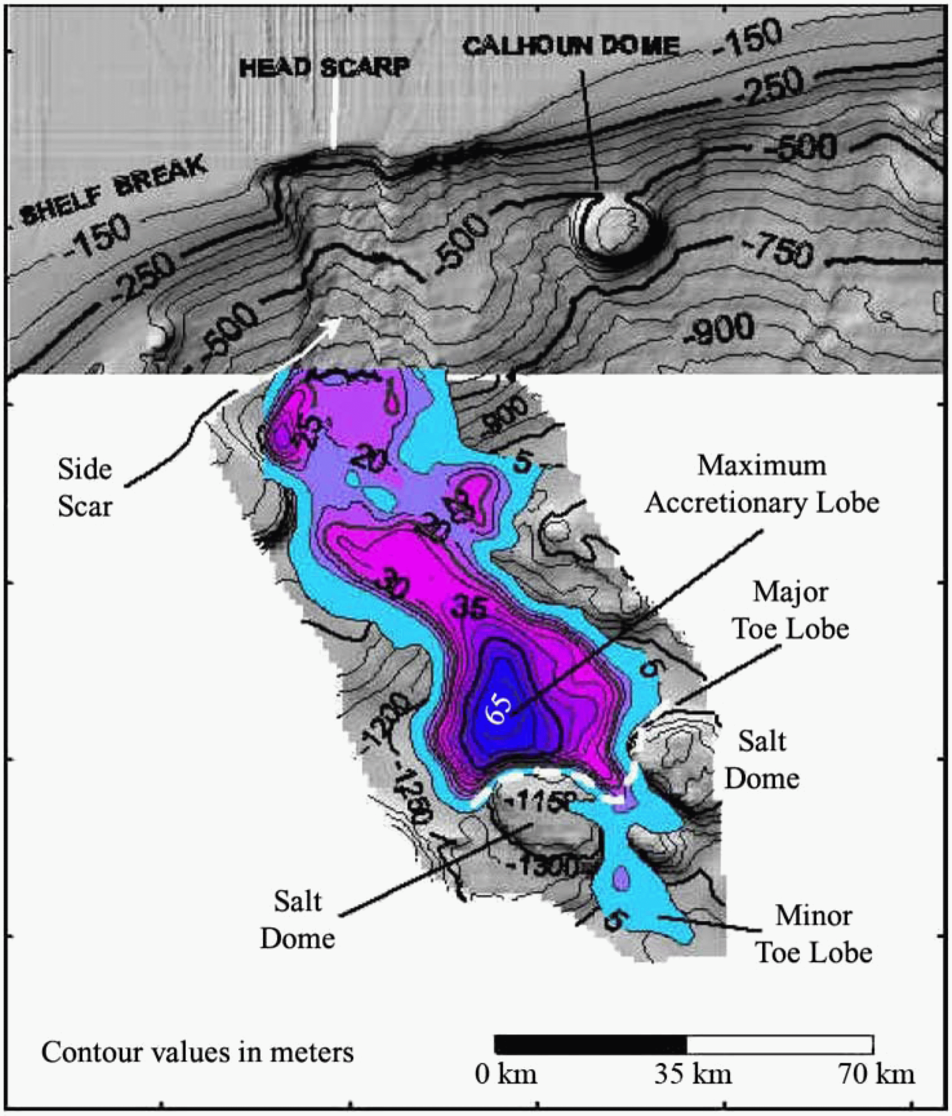


Figure 2.4S.6-7 Map and Dimensions of the East Breaks Slump Location from the Northwestern Gulf of Mexico

Source: Reference 2.4S.6-5, p. 5