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2.4.5 PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

PTN COL 2.4-2 This subsection describes the probable maximum wind and associated meteorological parameters that could produce the probable maximum storm surge (PMSS) at Units 6 & 7. A summary of historical storm surge events and the effects of probable maximum surge and seiche flooding on the safety-related facilities at Units 6 & 7 are also presented in this subsection.

2.4.5.1 Probable Maximum Winds and Associated Meteorological Parameters

Subsection 2.4.5 of NUREG-0800 defines the PMSS as the surge that results from a combination of meteorological parameters of a probable maximum hurricane (PMH), a probable maximum wind storm (PMWS), or a moving squall line that has virtually no probability of being exceeded in the region involved.

The NOAA Technical Report NWS 23 defines the PMH as a hypothetical steady-state hurricane with a combination of meteorological parameters that will give the highest sustained wind speed that can probably occur at a specified coastal location (Reference 201). The meteorological parameters that define the PMH wind field include the hurricane peripheral pressure (p_n), central pressure (p_o), radius of maximum winds (R), forward speed (T), track direction (θ), and inflow angles of the hurricane winds (φ). NUREG-0800 (Subsection 2.4.5) indicates that the PMH, as defined by the NOAA Technical Report NWS 23 (Reference 201), should be estimated for coastal locations that may be exposed to these events.

The PMH parameters at the Atlantic coast near Units 6 & 7 are obtained from the NOAA Technical Report NWS 23 (Reference 201). The PMH parameter values were established based on data from historical hurricanes from 1851 to 1977 and were presented for multiple locations along the Gulf of Mexico and Atlantic Ocean coastlines corresponding to their milepost distances from the U.S.-Mexico border. The milepost distance to the shoreline location nearest to Units 6 & 7 is estimated to be 1450 nautical miles (1669 miles) (Reference 201).

The pressure difference between the hurricane peripheral and central pressures, Δp, is identified as the most important meteorological parameter in defining the hurricane wind field (Reference 201). NOAA Technical Report NWS 23 provides single values of PMH peripheral and central pressures along the mileposts, thereby giving single values for Δp. However, a range of values (i.e., lower and upper bounds) is provided for other PMH parameters. The PMH parameters, as estimated from the NOAA Technical Report NWS 23 for a location on the Atlantic Ocean shoreline at milepost 1450 nautical miles, are summarized in

Table 2.4.5-201. As can be seen in Table 2.4.5-201, the Δp at this location is 4.0 inches of mercury or 135.5 millibars.

The effect of long-term climate variability on hurricane intensity is an area of active research. Since 1977, several intense hurricanes had made landfall on the Gulf of Mexico and Atlantic coasts. Research on the effects of El Niño/Southern Oscillation indicated that while El Niño conditions tend to suppress hurricane formation in the Atlantic basin, La Niña conditions tend to favor hurricane development (Reference 202). Additionally, research has been performed into the relationship between the Atlantic Multi-decadal Oscillation (AMO), which is the variation of long-duration sea surface temperature in the northern Atlantic Ocean with cool and warm phases that may last for 20 to 40 years, and hurricane intensity (Reference 202). It shows that hurricane activities increase during the warm phases of the AMO compared to hurricane activities during the AMO cool phases. Recent hurricane data indicates that Atlantic hurricane seasons have been significantly more active since 1995. However, hurricane activities during the earlier years, such as from 1945 to 1970, were apparently as active as in the recent decade (References 202 and 203).

Blake et al. indicated that during the past 35 years, the conterminous U.S. was affected by the landfall of three Category 4 or stronger hurricanes: Hurricane Charley of 2004, Hurricane Andrew of 1992, and Hurricane Hugo of 1989 (Reference 203). Based on the analysis of hurricane data from 1851 to 2006, they summarized that, on the average, the U.S. is affected by a Category 4 or stronger hurricane approximately once every 7 years, thereby suggesting that there have been fewer exceptionally strong hurricane landfalls during the past 35 years than an expected 35-year average of approximately five (Reference 203).

Because NOAA Technical Report NWS 23 includes the last active hurricane period from 1945 to 1970 (and any such earlier periods from 1851) in the analysis, it is reasonable to assume that the PMH parameters derived are sufficiently conservative even in the considerations of future climate variability.

2.4.5.2 Surge and Seiche Water Level

Units 6 & 7 are located adjacent to the Biscayne Bay shoreline, approximately 8 miles west of the Elliott Key Barrier Island, as shown on Figure 2.4.5-201. The finished grade elevation at the plant area where safety-related facilities are located is at 25.5 feet NAVD 88. The elevation of floor entrances and openings of all safety-related structures (also referred to as the design plant grade elevation in the DCD, which is 100 feet or 30.48 meters in the DCD reference datum) is 26 feet NAVD 88. Following the guidance from NUREG-0800, the PMSS is postulated to be generated by the PMH approaching from the Atlantic Ocean. Because storm surges near Units 6 & 7 would inundate the barrier islands, seiche oscillations within the bay are not expected to coincide with large storm surge events like the PMSS, as addressed in Subsection 2.4.5.4.

2.4.5.2.1 Historical Hurricane Events and Storm Surges

A list of hurricanes that caused sustained hurricane wind damage to the Florida coast (including hurricanes that did not make landfall) between 1851 and 2006 is presented in Table 2.4.5-202 (Reference 203). Figure 2.4.5-202 shows the tracks of all hurricanes in the Atlantic basin during the same period with intensities equal to or greater than Hurricane Category 3 in the Saffir-Simpson Hurricane Scale. Unless specified otherwise, the Saffir-Simpson Hurricane Scale as shown in Table 2.4.5-203 (Reference 203), is used throughout this subsection to describe hurricane intensities. Blake et al. analyzed the frequencies of hurricanes of different categories that had landfall on the U.S. coast (Reference 203). They reported that approximately 40 percent of all hurricanes, Category 3 and above, that had landfall in the U.S. affected Florida, while 83 percent of hurricanes of Category 4 or higher struck the Florida and Texas coasts (Reference 203).

As indicated in Table 2.4.5-202, the Category 5 Labor Day hurricane of August/September 1935 was the most intense hurricane since 1851 that affected the Florida coast. The hurricane had made landfall on the islands of Islamorada in the upper Florida Keys, south of Units 6 & 7. The track for the 1935 Labor Day hurricane is shown on Figure 2.4.5-202. The 1935 Labor Day hurricane, with a central pressure of 892 millibars, also had the lowest central pressure at landfall for any hurricane on the U.S. coast since 1851 (Table 2.4.5-202).

The most severe recent hurricane that made landfall near Units 6 & 7 was Hurricane Andrew. Originating as a tropical depression in August 1992 near the Cape Verde Islands, Hurricane Andrew moved through the northwestern Bahamas, the southern Florida peninsula, and south-central Louisiana, bringing unprecedented devastation (Reference 204). With damage in the U.S. estimated to be near 26.5 billion U.S. dollars, Hurricane Andrew is ranked as the second most costly hurricane in U.S. history after Hurricane Katrina (Reference 203). This Category 5 hurricane had landfall at Fender Point, Florida in Miami-Dade County, approximately 8 nautical miles (9.2 miles) east-northeast of Homestead, Florida (Reference 204). The landfall location was approximately 8 miles north of the plant area. At landfall, the hurricane had a central pressure of 922 millibars and a maximum sustained wind speed (1-minute average, 33-foot-high) of 145 knots

(167 miles per hour). It is also the fourth most intense hurricane in history to make landfall in the United States (References 203 and 204).

Hurricane Andrew produced significant storm surges within the Biscayne Bay region. The combined storm surge and astronomical tide in the northern Biscayne Bay ranged from 4 to 6 feet NGVD 29 (Reference 204), which is approximately 2.4 to 4.4 feet in NAVD 88 based on the datum relationship given in Subsection 2.4.1. The maximum surge level of 16.9 feet NGVD 29 (15.3 feet NAVD 88) from Hurricane Andrew was observed on the western shoreline near the center of the Biscayne Bay (Reference 204). In the southern part of the Biscayne Bay, the surge elevation ranged from 4 to 5 feet NGVD 29 (2.4 to 3.4 feet NAVD 88) (References 203 and 204). Details of storm surge elevations within the bay due to Hurricane Andrew are shown on Figure 2.4.5-203.

2.4.5.2.2 Storm Surge Analysis

The PMSS elevation from the PMH at Units 6 & 7 is simulated using the NOAA computer model *Sea, Lake, and Overland Surges from Hurricanes* (SLOSH) (Reference 205). The antecedent water level, as defined in RG 1.59, is estimated separately and used to establish the initial water level condition in the SLOSH model simulation. The PMH parameters (Δp, radius of maximum wind, forward speed, track direction), as described in Subsection 2.4.5.1, are used to define the physical attributes of the PMH in the model. Model simulations are performed with numerous combinations of input PMH parameters to obtain the maximum storm surge elevation in the determination of the PMSS elevation. The effect of wind-wave run-up is superimposed on the PMSS elevation to obtain the maximum water level at Units 6 & 7.

The SLOSH computer model is developed by the NWS to forecast real-time hurricane storm surge levels on continental shelves, across inland water bodies and along coastlines, including inland routing of water levels. The SLOSH is a depth-averaged two-dimensional finite difference model on curvilinear polar, elliptical, or hyperbolic grid schemes. Modification of storm surges due to the overtopping of barriers (including levees, dunes, and spoil banks), the flow through channels and floodplains, and barrier cuts/breaches are included in the model. The effects of local bathymetry and hydrography are also included in the SLOSH simulation. Details of model formulation and application can be found in Reference 205.

2.4.5.2.2.1 Antecedent Water Level

According to RG 1.59, the 10 percent exceedance high spring tide including initial rise should be used to represent the PMSS antecedent water level. RG 1.59 defines the 10 percent exceedance high spring tide as the high tide level that is equaled or exceeded by 10 percent of the maximum monthly tides over a continuous 21-year period. For locations where the 10 percent exceedance high spring tide is estimated from observed tide data, RG 1.59 indicates that a separate estimate of initial rise (or sea level anomaly) is not necessary.

RG 1.59 also provides estimates of 10 percent exceedance high spring tide and initial rise at the Miami Harbor Entrance on the Atlantic Ocean, which is located close to the NOAA tide gage station at Virginia Key, Florida, north-northeast of Units 6 & 7. The 10 percent exceedance high spring tide and the initial rise at Miami Harbor Entrance are given as 3.6 feet above mean low water and 0.9 foot, respectively. The water level including the 10 percent exceedance high spring tide and initial rise, therefore, is ([3.6 + 0.9] feet =) 4.5 feet above mean low water. Using the datum conversion relation given in Subsection 2.4.1, the water level at the Miami Harbor Entrance is approximately 2.6 feet NAVD 88.

NOAA maintains tide gage stations along the Atlantic Ocean shoreline near Units 6 & 7. Long-term records of measured tidal levels are available at Virginia Key, Florida (station number 8723214); Vaca Key, Florida (8723970); and Key West, Florida (8724580). The tidal range at these currently active stations is provided in Table 2.4.1-211. However, only the station at Key West has data records longer than a 21-year period that can be used to estimate the 10 percent exceedance high spring tide consistent with the definition in RG 1.59. The combined 10 percent exceedance high spring tide and initial rise at the Miami Harbor Entrance from RG 1.59 of 2.6 feet NAVD 88 is higher than the estimated 10 percent exceedance high spring tides at the Virginia Key, Florida station at 1.43 feet NAVD 88 and Key West, Florida station at 0.97 foot NAVD 88 based on available data records (15 years of record for Virginia Key station and 38 years of record for Key West station). Consequently, the combined 10 percent exceedance high spring tide and initial rise at the Miami Harbor Entrance as obtained from RG 1.59 is conservatively used in the PMSS estimate.

In addition to the 10 percent exceedance high spring tide and initial rise, the long-term trend observed in tide gage measurements is also considered to account for the expected sea level rise for a period consistent with the DCD Tier 2 Section 1.2.1.1.2 plant design objective of 60 years without replacement of the reactor vessel. The NOAA station nearest to Units 6 & 7 where long-term trend in sea level rise is available is the Miami Beach, Florida (8723170), station. The station is located close to the Virginia Key, Florida, station and is no longer active. The long-term sea level rise trend at Miami Beach, Florida, as estimated based on data from 1931 to 1981, is 0.78 foot per century (Reference 206). Accordingly, a nominal long-term sea level adjustment of 1 foot is applied to the 10 percent high tide level resulting in an antecedent water level of 3.6 feet NAVD 88 (2.6 feet NAVD 88 + 1 foot), which represents the initial water level condition in the SLOSH model simulations.

2.4.5.2.2.2 SLOSH Biscayne Bay Basin Model

The NOAA SLOSH model requires the hurricane pressure difference (Δp), hurricane track description including landfall location, forward speed, and size, given as the radius of maximum wind, as input to define the physical attributes of a hurricane in performing a surge simulation (Reference 207). The SLOSH Biscayne Bay basin model includes Units 6 & 7. The model is setup using a curvilinear hyperbolic-type grid system (Reference 207). The corresponding bathymetry data are obtained from the NOAA NWS. The basin bathymetry and water levels in the model input and output are referenced to NGVD 29. The datum conversion relationship at the NOAA Virginia Key, Florida, station, as given in Subsection 2.4.1, is adopted for converting elevation data from NGVD 29 to NAVD 88 or vice-versa.

The time sequence of the movement of a hurricane or the hurricane track is a required input to the SLOSH model. It is represented in the model by a series of successive locations of the center of hurricane derived as a function of the hurricane direction (angle), forward speed, and landfall location (defined as the location where the hurricane crosses the shoreline). The hurricane direction defined in SLOSH is different from the hurricane direction given in NOAA Technical Report NWS 23 (Table 2.4.5-201). While NWS 23 provides the angle of incoming hurricane from the north as the hurricane direction, SLOSH defines the hurricane direction as the angle between north and the direction of hurricane propagation (References 201 and 207). As a result, SLOSH hurricane directions are 180 degrees ahead of hurricane directions in NWS 23.

Model simulations are performed for different combinations of the PMH parameters to obtain the maximum surge water level at Units 6 & 7. The model results are processed using the NOAA SLOSH Display Program (Reference 208). The centerline of Units 6 & 7 (25.425° N, 80.333° W) is located in the SLOSH model grid cell (63, 40) and the simulated time histories of water levels are extracted from this grid cell for the PMSS evaluation. The model grid for the

Biscayne Bay basin and the location of Units 6 & 7 are shown on Figure 2.4.5-204.

2.4.5.2.2.3 Sensitivity of PMH Parameters on Storm Surge Elevation

A total of 53 SLOSH model runs are performed to investigate the effects of the PMH forward speed, size, direction, and track distance from Units 6 & 7 on the storm surge elevation. The ranges of the parameters used in the simulations include two steady state PMH forward speeds (the lower and upper bounds), three PMH radiuses of maximum wind (the mean, the lower bound and upper bound), five PMH directions and seven track distances. The selected hurricane directions are 225, 247.5, 258.75, 270, and 315 degrees from the north. The range of the hurricane directions modeled corresponds to the sector between 45 and 135 degrees in the convention adopted in the NOAA Technical Report NWS 23. The selected track distances from Units 6 & 7 are 0, 5.75, 11.5, 17.25, 23, 34.5, and 46 miles. The simulations are performed with the PMH Δp (4.0 inches of mercury or 135.5 millibars) as given in Table 2.4.5-201. Two initial water level conditions, with and without adding the long-term sea level rise to the combined 10 percent exceedance high spring tide and initial rise as given in Subsection 2.4.5.2.2.1, are simulated in the model. The initial water level condition excluding the long-term sea level rise is selected to facilitate a comparison of surge elevation from RG 1.59 at Miami Harbor Entrance with SLOSH simulation results. The comparison is described in Subsection 2.4.5.2.2.5.

Figure 2.4.5-205 shows the variation of storm surge elevations at Units 6 & 7 for two PMH forward speeds, three radii of maximum wind, and three hurricane directions, 225, 270, and 315 degrees from the north. Based on the simulation results as presented in Figure 2.4.5-205, the following may be concluded:

- Higher PMH forward speed results in higher surge elevations.
- At the upper bound PMH forward speed, the surge elevation increases with increasing hurricane size for all directions simulated.
- At the lower forward speed, the largest (upper bound) hurricane size does not lead to the highest surge elevation.
- The variation of surge height for the selected PMH directions, between 225 and 315 degrees from the north, is the maximum at the upper bound PMH size, which is 1.3 feet for both forward speeds.

The effect of PMH size beyond the upper bound radius of maximum wind for the upper bound forward speed is described later in this subsection.

The variation of surge elevation for different PMH directions and distances of the PMH track from Units 6 & 7 is presented in Figure 2.4.5-206. The figure shows that the maximum surge elevation is predicted to occur when the PMH direction is 258.75 degrees from the north (78.75 degrees according to NWS 23). Additionally, the surge height is the maximum when the PMH track is located at a distance from Units 6 & 7 equal to approximately 0.75 times the PMH radius of maximum wind.

Based on the results of the SLOSH model sensitivity runs, it is concluded that the PMSS would be generated by a PMH that has the upper bound forward speed (20 knots or 23 miles per hour) and size (radius of maximum wind of 20 nautical miles or 23 miles), approaches Units 6 & 7 with a direction of 258.75 degrees from the north, and passes by with a track distance of approximately 15 nautical miles (17.25 miles) south of Units 6 & 7.

Figure 2.4.5-205 indicates that the surge elevation increases with increasing PMH size at the upper bound forward speed. This behavior is further investigated by varying the PMH size beyond the upper bound specified in NWS 23 for a PMH approaching at a direction of 270 degrees from the north. The hurricane track is assumed at a distance from Units 6 & 7 equal to the PMH radius of maximum wind. The Δp is artificially kept constant for the hurricane sizes beyond the upper bound of 20 nautical miles (23 miles). The resulting surge elevations are presented on Figure 2.4.5-207. For the selected set of parameters, Figure 2.4.5-207 shows that the surge elevation would be the maximum when the PMH size (radius of maximum wind) is 30 nautical miles (34.5 miles). The maximum surge elevation is approximately 2.6 percent higher than the surge elevation from the PMH upper bound radius of maximum wind. Beyond 30 nautical miles (34.5 miles) surge elevation decreases.

As discussed below, for larger hurricanes, the Δp should not be kept constant and it would be smaller and would generate lower surge elevations. Figure 2.5 of NWS 23 shows that PMH radius of maximum wind increases with latitude. The highest PMH radius of maximum wind is 38 nautical miles (44 miles) at Eastport, Maine. However, as shown in NWS 23, Figure 2.3, the PMH Δp decreases with latitude and Eastport, Maine, has the lowest PMH Δp of 2.7 inch mercury lower than the PMH Δp of 4.0 inch mercury near the site. NWS 23 defines the PMH as a fully developed, tightly wound hurricane whose RMW for any particular coastal point is less than the RMW of the standard project hurricane (SPH) which is a less intense hurricane than the PMH. Near the site, SPH has an upper bound RMW of about 29 nautical miles (33 miles), higher than the PMH upper bound of 20 nautical miles (23 miles). However, the Δp for the SPH is 2.6 inch mercury which is lower than PMH Δp of 4.0 inch mercury. This suggests that, for larger hurricane sizes than the PMH upper bound value given in NWS 23, the Δp would be smaller. The purpose of Figure 2.4.5-207 is to better understand the impact of hurricane sizes on storm surge elevation by artificially keeping the Δp constant. Therefore, surge elevations shown in Figure 2.4.5-207, for the hurricane sizes larger than the NWS 23 upper bound of 20 nautical miles (23 miles), are not taken as bounding.

2.4.5.2.2.4 Maximum Surge Elevation with Selected PMH Parameters

The maximum surge elevation at Units 6 & 7 is obtained from the SLOSH model simulation with the selected set of PMH parameters described in Subsection 2.4.5.2.2.3. The time history of the simulated surge elevation at Units 6 & 7 is presented on Figure 2.4.5-208, which shows a maximum surge elevation of 19.8 feet NGVD 29 (18.2 feet NAVD 88). The envelope of maximum surge elevation over the model domain for the selected set of PMH parameters is shown on Figure 2.4.5-209. Figure 2.4.5-209 shows that the maximum surge elevation would occur at a location northwest of Units 6 & 7.

The time history of the 1-minute average, 33-foot-high wind speed at Units 6 & 7 during the PMH, as obtained from the SLOSH model results, is presented on Figure 2.4.5-210. The maximum wind speed corresponding to the PMH conditions that provide the maximum surge elevation is estimated to be 188.3 miles per hour.

2.4.5.2.2.5 Uncertainties in SLOSH Model Results

Comparison of SLOSH Results with Observations

The SLOSH model predictions have been validated against observed hurricane surge levels at several locations (References 205 and 209). The errors of the SLOSH model predictions, defined by subtracting the observed surge water levels from model predictions, were evaluated for ten storms in eight SLOSH model basins, 90 percent of which were in the Gulf of Mexico (Reference 209). Based on a comparison of the SLOSH simulated surge heights against 523 observations, a mean error of –0.09 meter (–0.3 foot) was reported. The range of errors was from –2.16 meters (–7.1 feet) to 2.68 meters (8.8 feet) with a standard deviation of 0.61 meter (2 feet) (Reference 209).

NOAA Technical Report NWS 48 also provides a comparison of SLOSH model results with observations for well-documented hurricanes. A total of 570 observations from 13 significant hurricanes in nine SLOSH basins were evaluated as shown on Figure 2.4.5-211. NOAA concludes that the model results generally stayed within ± 20 percent for significant surges (Reference 205). The +20 percent margin on the perfect fit line is also shown on Figure 2.4.5-211.

Uncertainties in Computed Surge Height during the PMH

The SLOSH predictions shown in Figure 2.4.5-211 are converted to surge heights without including the effects of antecedent water level. To establish the same basis in addressing the model uncertainty on the predicted surge height at Units 6 & 7, the antecedent water level of 5.2 feet NGVD 29 (3.6 feet NAVD 88) is subtracted from the simulated maximum surge level of 19.8 feet NGVD 29 (18.2 NAVD 88) giving a surge height of 14.6 feet. Applying conservatively the 20 percent margin suggested by NOAA on the simulated maximum surge height to account for the SLOSH model uncertainties, the adjusted maximum surge height would be approximately 17.5 feet.

Comparison with RG 1.59

RG 1.59 provides estimates of the PMSS elevation along the U.S. Gulf and Atlantic Coasts. The only location close to Units 6 & 7 where PMSS water level is available from RG 1.59 is Miami, Florida (25.787° N, 80.13° W). The four components contributing to the PMSS at this location, as given in RG 1.59, include a wind set-up of 2.51 feet, a pressure set-up of 3.9 feet, an initial rise of 0.9 foot, and a 10 percent exceedance high spring tide of 3.6 feet above mean low water. These four components combine to give a total storm surge elevation of 10.91 feet above mean low water (approximately 9 feet NAVD 88 or 10.6 feet NGVD 29) at Miami, Florida. By comparison, the surge elevation predicted by the SLOSH Biscayne Bay basin model at Miami, Florida (25.787° N, 80.13° W), represented by model grid cell (40, 88), is higher at 11.2 feet NGVD 29 (9.6 feet NAVD 88). The predicted surge elevation at Miami, Florida, corresponds to a PMSS elevation at Units 6 & 7, does not include the 20 percent margin, and is based on a SLOSH model simulation without the long-term sea level rise adjustment. Consequently, it is concluded that the PMSS elevation obtained from the SLOSH model is more conservative than that presented in RG 1.59.

2.4.5.2.2.6 The Probable Maximum Storm Surge Elevation

The PMSS elevation (still water level) at Units 6 & 7 is obtained by adjusting the maximum surge elevation for model uncertainties. The adjustment is applied to the surge height after subtracting the antecedent water level from the surge elevation. Subsequently, the PMSS elevation is obtained by adding the antecedent water level to the adjusted surge height. The final PMSS elevation thus obtained is approximately 22.7 feet NGVD 29 or 21.1 feet NAVD 88.

2.4.5.3 Wave Actions

The effect of PMH wind field on the PMSS still water level near Units 6 & 7 is investigated to estimate the PMH-induced waves, set-up, and run-up.

2.4.5.3.1 Hurricane Maximum Wind Speed

The maximum 1-minute average, 33-foot-high wind speed at Units 6 & 7 is obtained from the SLOSH model results. For the combination of PMH parameters that produces the PMSS, the maximum 1-minute average, 33-foot-high wind speed is 188.3 miles per hour. The 1-minute average, 33-foot-high wind speed is converted to the sustained 10-minute average, 33-foot-high wind speed following the procedure given in the Coastal Engineering Manual of the U.S. Army Corps of Engineers (Reference 210). The converted 10-minute average wind speed is approximately 159 miles per hour, which is then used to calculate the coincidental wind wave activities.

2.4.5.3.2 Wave Height, Period and Run-up

The wind setup due to the PMH wind field is included in the surge elevation obtained in the SLOSH model results. However, the hurricane wind field produces wind-induced waves that result in wave run-up at Units 6 & 7. The plant area is built up and surrounded by a retaining wall structure with a top of wall elevation of 21.5 feet NAVD 88 on the eastern side. The PMSS still water level would be located below the top of the retaining wall. Coincident wind-waves would overtop the retaining wall and run up the slopes in the plant area. The grade elevation from the top of the wall to the safety-related buildings acts as a berm and, therefore, reduces the effect of wave run-up at the plant safety-related facilities.

The SLOSH model results indicate that a PMH surge elevation inundates the Elliott Key Barrier Island east of the Biscayne Bay. Because the PMH maximum wind approaches from the Atlantic Ocean side, the fetch length to produce wind-waves is very large. The wave heights at the retaining wall, therefore, are likely limited by the water depth, with the breaking wave height representing the limiting wave condition. Wave breaking is the process of wave energy dissipation and wave height reduction due to shallow water depths (Reference 210), and the breaking wave height represents the limiting wave condition beyond which waveforms cannot sustain. Consequently, the significant and 1 percent wave heights are bounded by the breaking wave condition and are not presented separately. Following the procedures given in the Coastal Engineering Manual (Reference 210), breaking wave height and corresponding wave period in front of the retaining wall are calculated as approximately 15.4 feet and 5.1 seconds, respectively. The wave run-up at the safety-related facilities of Units 6 & 7 is calculated based on an equivalent slope considering that the grade elevations from the retaining wall to the safety-related facilities would act as a berm. The surf similarity parameter, a parameter that defines wave breaking and run-up and depends on approach bottom slope and wave steepness, hence, is calculated using equivalent deepwater wave parameters corresponding to the breaking waves at the retaining wall and the equivalent slope including the berm. Thus, the maximum wave run-up at the site is estimated to be approximately 3.7 feet.

2.4.5.3.3 Maximum Water Surface Elevation due to the PMH

Combining the PMSS still water level (21.1 feet NAVD 88) and wave run-up (3.7 feet), the maximum water level due to a PMH at Units 6 & 7 is estimated at 24.8 feet NAVD 88.

2.4.5.4 Resonance

Units 6 & 7 are located adjacent to the west shore of the Biscayne Bay approximately 8 miles west of the Elliott Key Barrier Island. There are no records of seismic seiches within the bay. However, because the bay is a semi-enclosed body of water, seiche oscillation may occur due to atmospheric forcing. It is likely that such oscillations would occur along the principal axis of the bay in the north-south direction. Assuming that the bay is approximately 25 miles long, the natural period of oscillation for the bay, during a PMH event, is estimated to be approximately 36.8 minutes (based on PMH still water depth of approximately 27.7 feet). This period is calculated conservatively using the half length of the bay and second mode of oscillation which gives a smaller period closer to the period of wind-waves. During a PMH event, storm surge elevation inundates the Elliott Key Barrier Island. Under such conditions, it is unlikely that seiches occur. In addition, the natural period of oscillation is much greater than the period of wind-waves and shorter than the period of storm surge waves. Therefore, natural oscillations within the bay do not result in a resonance and flooding of the plant area due to a seiche event in the Biscayne Bay is precluded.

Florida Current is a major influence on the coastal circulation and current dynamics in the southeast Florida shelf. The Florida Current generates internal wave field and coastal ocean current oscillations with a dominant periodicity of about 10 hours (References 212, 213 and 214). Soloviev et al. 2003 (Reference 212) also illustrate that the presence of the Florida Current has no apparent effect on the sea level and its oscillations near the shore, which still follows the tidal constituents with dominant periods near 12 and 24 hours. Therefore, there is no evidence to support a hypothesis that the Florida Current has any impact on the sea level oscillations near the site, despite its influence on the velocity and density fields.

The natural oscillation periods of Biscayne Bay during a normal sea condition are estimated to be approximately 3.4 to 5.3 hours calculated using the methodology from Section II-5-6 of the USACE Coastal Engineering Manual (Reference 210), which are much smaller than the observed oscillation period of 10 hours in the current and density fields. Therefore, the potential for resonance in Biscayne Bay as affected by the Florida Current can further be precluded.

The potential of resonance within the Biscayne Bay from the forcing from sea breeze, which is caused by the diurnal (24-hour period) heating and cooling of the land and sea was also evaluated. This 24-hour period is much greater than the natural oscillation periods of the Biscayne Bay which are estimated to be approximately 3.4 to 5.3 hours. According to Militello and Kraus 2001 (Reference 215), sea breeze can introduce diurnal oscillations and generate higher harmonic motions into water bodies. Through the analytical solution and numerical modeling developed for a simplified one-dimensional idealized basin, their study illustrates that (i) the amplitudes of wind-forced motions at the higher harmonics are orders of magnitude smaller than that at the fundamental period, and (ii) the wind-forced motions near the resonant modes can be almost completely damped by relatively small bottom friction in the water body. Consequently, flooding from resonance within the Biscayne Bay due to sea breeze is not expected.

The potential for resonance within the Makeup Water Reservoir (MWR) during the maximum PMH wind condition is also evaluated. The natural periods of the MWR, which can be approximated as a rectangular basin, are estimated using an approach provided in the USACE Coastal Engineering Manual (Reference 210) for a closed water body. The dimensions along the two principal axes of the MWR are approximately 2200 feet and 766 feet (a north side dimension of 2260 feet is used for this evaluation). With the top of wall and bottom elevations at 24.0 feet and -2.0 feet NAVD 88, respectively (Subsection 2.4.8), the natural periods of the MWR are approximately 156 and 53 seconds, based on the two principal dimensions and a full reservoir with 26 feet of water to account for precipitation. The corresponding wave periods estimated for a maximum PMH wind condition at the site are 2.4 and 1.7 seconds, respectively, following the procedures in Reference 210. Because the natural periods of the MWR are significantly longer than the periods of waves generated from the PMH, the potential for resonance in the MWR due to any storm-driven wind waves is not expected.

2.4.5.5 Protective Structures

The PMSS still water level at Units 6 & 7, along with coincidental wind-wave run-up, is conservatively estimated to be approximately 24.8 feet NAVD 88. This estimated maximum PMH-induced water level is lower than the design plant grade elevation of 26 feet NAVD 88 for safety-related facilities. Therefore, the postulated PMH event does not affect the safety functions of the plant. Because the maximum PMH-induced water level is lower than the plant grade elevation, debris, waterborne projectiles, and sediment erosion and deposition are not of concern to the safety-related facilities of Units 6 & 7.

2.4.5.6 References

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PTN COL 2.4-2

Table 2.4.5-201
Probable Maximum Hurricane Characteristics

Hurricane Parameter	Magnitude
Peripheral Pressure (p_n)	30.12 inch mercury
Central Pressure (p_o)	26.12 inch mercury
Radius of Maximum Winds (R)	4 to 20 nautical miles
Forward Speed (T)	6 to 20 knots
Track Direction (θ)	72 to 185 degrees (clockwise from north)
Inflow angle (φ)	2 to 9 degrees (at a distance R from the hurricane center)

Source: Reference 201

PTN COL 2.4-2

Table 2.4.5-202 (Sheet 1 of 4) Summary of Historical Hurricane Events in the Florida Atlantic and Gulf Coasts

Date[(a)] (month & year)	Hurricane Name[(b)]	Saffir-Simpson Hurricane Category at Landfall[(c)]	Central Pressure at Landfall[(d)] (millibars)	Maximum Winds[(e)] (knots)
August 1851	Great Middle Florida	3	960	100
August 1852	Great Mobile	3	960	100
September 1852		1	985	70
October 1852	Middle Florida	2	969	90
September 1854	Great Carolina	3	950	100
August 1856	Southeastern States	2	969	90
September 1859		1	985	70
August 1861	Key West	1	970	70
October 1865		2	969	90
October 1867	Galveston	2	969	90
October 1870	Twin Key West (I)	1	970	70
October 1870	Twin Key West (II)	1	977	80
August 1871		3	955	100
August 1871		2	965	90
September 1871		1	985	70
September 1873		1	985	70
October 1873		3	959	100
September 1874		1	985	70
October 1876		2	973	90
September 1877		1	985	70
October 1877		3	960	100
September 1878		2	970	90
August 1880		2	972	90
October 1880		1	985	70
September 1882		3	949	100
October 1882		1	985	70
August 1885		3	953	100
June 1886		2	973	85
June 1886		2	973	85
July 1886		1	985	70

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Table 2.4.5-202 (Sheet 2 of 4)
Summary of Historical Hurricane Events in the Florida Atlantic and Gulf Coasts

Date[a] (month & year)	Hurricane Name[b]	Saffir-Simpson Hurricane Category at Landfall[c]	Central Pressure at Landfall[d] (millibars)	Maximum Winds[e] (knots)
July 1887		1	981	75
August 1888		3	945	110
October 1888		2	970	95
August 1891		1	985	70
August 1893	Sea Islands	3	954	100
September 1894		2	975	90
October 1894		3	955	105
July 1896		2	973	85
September 1896		3	960	110
August 1898		1	985	70
October 1898		4	938	115
August 1899		2	979	85
September 1903		1	976	80
October 1904		1	985	70
June 1906		1	979	75
September 1906		2	958	95
October 1906		3	953	105
October 1909		3	957	100
October 1910		2	955	95
August 1911		1	985	70
September 1912		1	985	95
September 1915		1	988	—
October 1916		2	972	—
November 1916		1	—	—
September 1917		3	958	—
September 1919		4	927	—
October 1921	Tampa Bay	3	952	—
September 1924		1	985	—
October 1924		1	980	—
Nov.-Dec. 1925		1	—	—
July 1926		2	967	—

PTN COL 2.4-2

Table 2.4.5-202 (Sheet 3 of 4)
Summary of Historical Hurricane Events in the Florida Atlantic and Gulf Coasts

Date[(a)] (month & year)	Hurricane Name[(b)]	Saffir-Simpson Hurricane Category at Landfall[(c)]	Central Pressure at Landfall[(d)] (millibars)	Maximum Winds[(e)] (knots)
September 1926	Great Miami	4	935	—
August 1928		2	—	—
September 1928	Lake Okeechobee	4	929	—
September 1929		3	948	—
August 1933		2	975	—
September 1933		3	948	—
September 1935	Labor Day	5	892	—
November 1935		2	973	—
July 1936		3	964	—
August 1939		1	985	—
October 1941		2	975	—
October 1944		3	962	—
June 1945		1	985	—
September 1945		3	951	—
October 1946		1	980	—
September 1947		4	940	—
October 1947		2	974	—
September 1948		3	963	—
October 1948		2	975	—
August 1949		3	954	—
September 1950	Easy	3	958	—
October 1950	King	3	955	—
September 1953	Florence	1	985	—
September 1956	Flossy	2	975	—
September 1960	Donna	4	930	—
August 1964	Cleo	2	968	—
September 1964	Dora	2	966	—
October 1964	Isbell	2	974	—
September 1965	Betsy	3	948	—
June 1966	Alma	2	982	—
October 1966	Inez	1	983	—
October 1968	Gladys	2	977	—

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Table 2.4.5-202 (Sheet 4 of 4)
Summary of Historical Hurricane Events in the Florida Atlantic and Gulf Coasts

Date[a] (month & year)	Hurricane Name[b]	Saffir-Simpson Hurricane Category at Landfall[c]	Central Pressure at Landfall[d] (millibars)	Maximum Winds[e] (knots)
June 1972	Agnes	1	980	—
September 1975	Eloise	3	955	—
September 1979	David	2	970	—
September 1985	Elena	3	959	100
November 1985	Kate	2	967	85
October 1987	Floyd	1	993	65
August 1992	Andrew	5	922	145
August 1995	Erin	2	973	85
October 1995	Opal	3	942	100
September 1998	Earl	1	987	70
September 1998	Georges	2	964	90
October 1999	Irene	1	987	70
August 2004	Charley	4	941	130
September 2004	Frances	2	960	90
September 2004	Ivan	3	946	105
September 2004	Jeanne	3	950	105
July 2005	Dennis	3	946	105
August 2005	Katrina	3	920	110
September 2005	Rita	3	937	100
October 2005	Wilma	3	950	105

(a) Only month and year of hurricane landfall are provided.
(b) Hurricane names are formally maintained from 1950.
(c) The highest Saffir-Simpson Hurricane Scale impact in the United States is based on estimated maximum sustained surface winds produced at the coast.
(d) The observed (or analyzed by NOAA from peripheral pressure measurements) central pressure of the hurricane at landfall or at the time closest to the shoreline.
(e) Estimated maximum sustained (1-minute) surface (at 10 meters or 33 feet) winds to occur along the U.S. coast. Winds are estimated to the nearest 10 knots for the period of 1851 to 1885 and to the nearest 5 knots for the period of 1886 to date.

Source: Reference 203

PTN COL 2.4-2

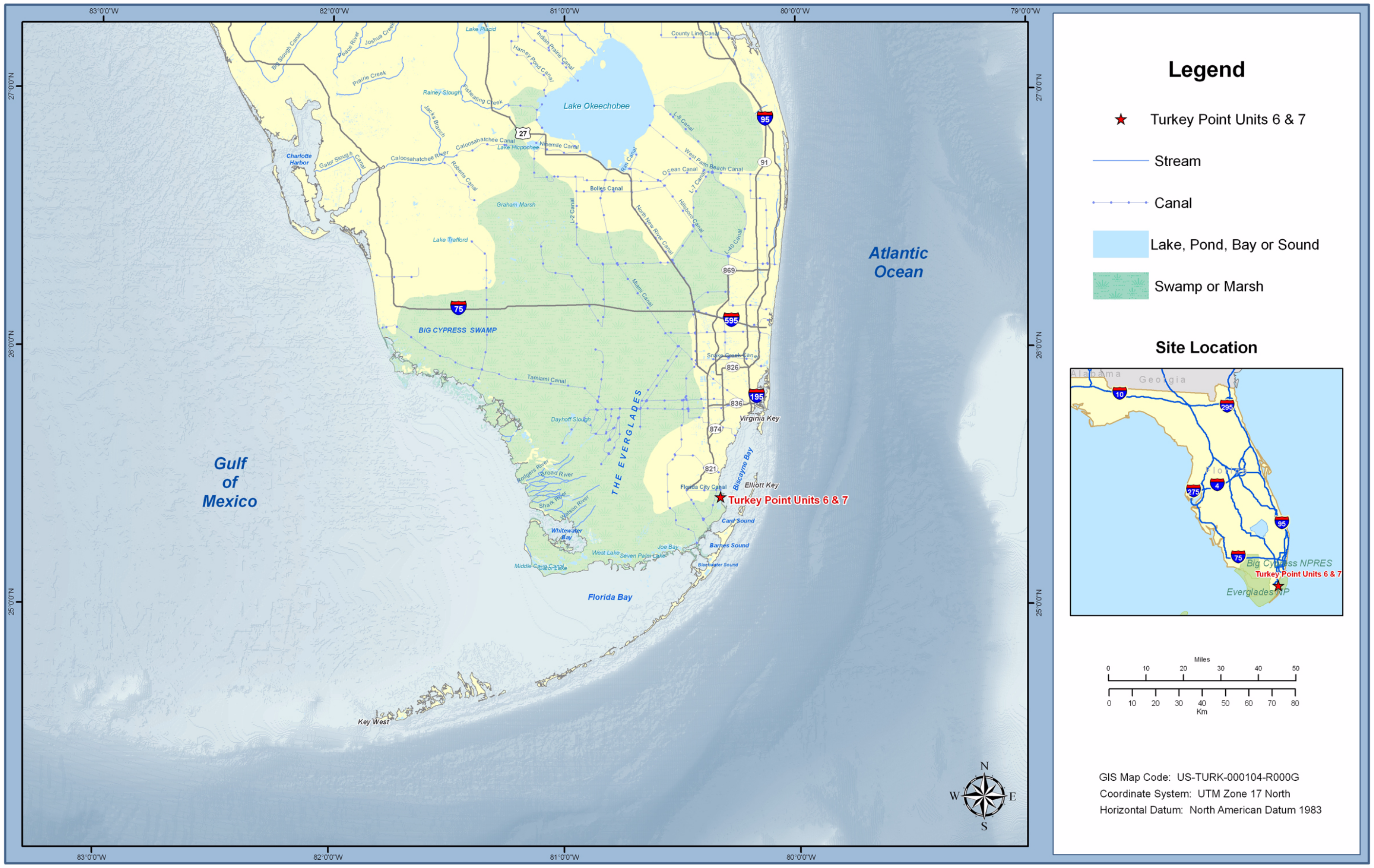
Table 2.4.5-203
The Saffir-Simpson Hurricane Scale

Hurricane	Wind	Hurricane Properties		
Category	Speed (miles per hour)	Central Pressure (millibars)	Surge Height (feet)	Damage
1	74–95	>979	4–5	Minimal
2	96–110	965–979	6–8	Moderate
3	111–130	945–964	9–12	Extensive
4	131–155	920–944	13–18	Extreme
5	>155	<920	>18	Catastrophic

Source: Reference 203

PTN COL 2.4-2

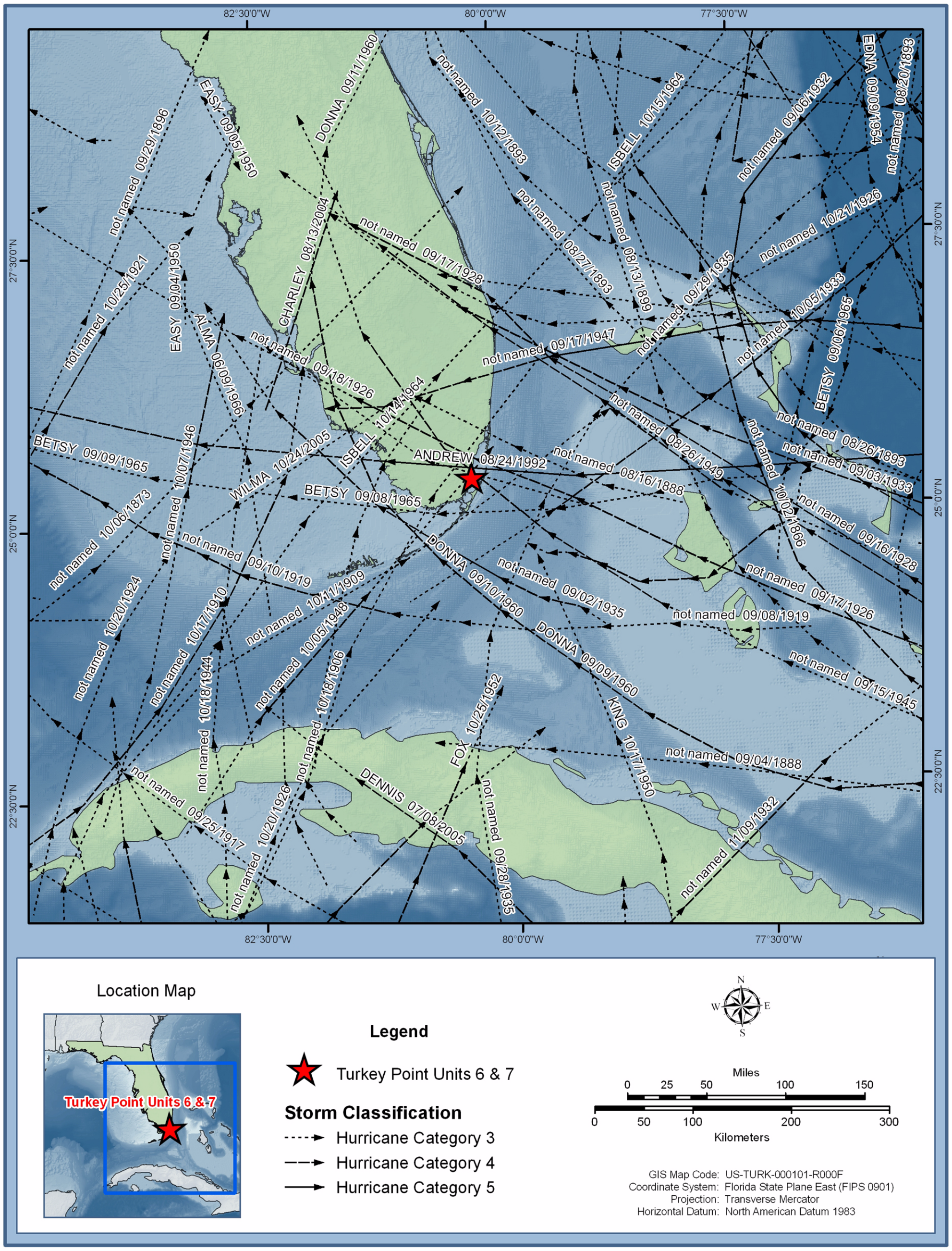
Figure 2.4.5-201 Location Map of Units 6 & 7 and Surrounding Water Bodies



GIS Map Code: US-TURK-000104-R000G
Coordinate System: UTM Zone 17 North
Horizontal Datum: North American Datum 1983

PTN COL 2.4-2

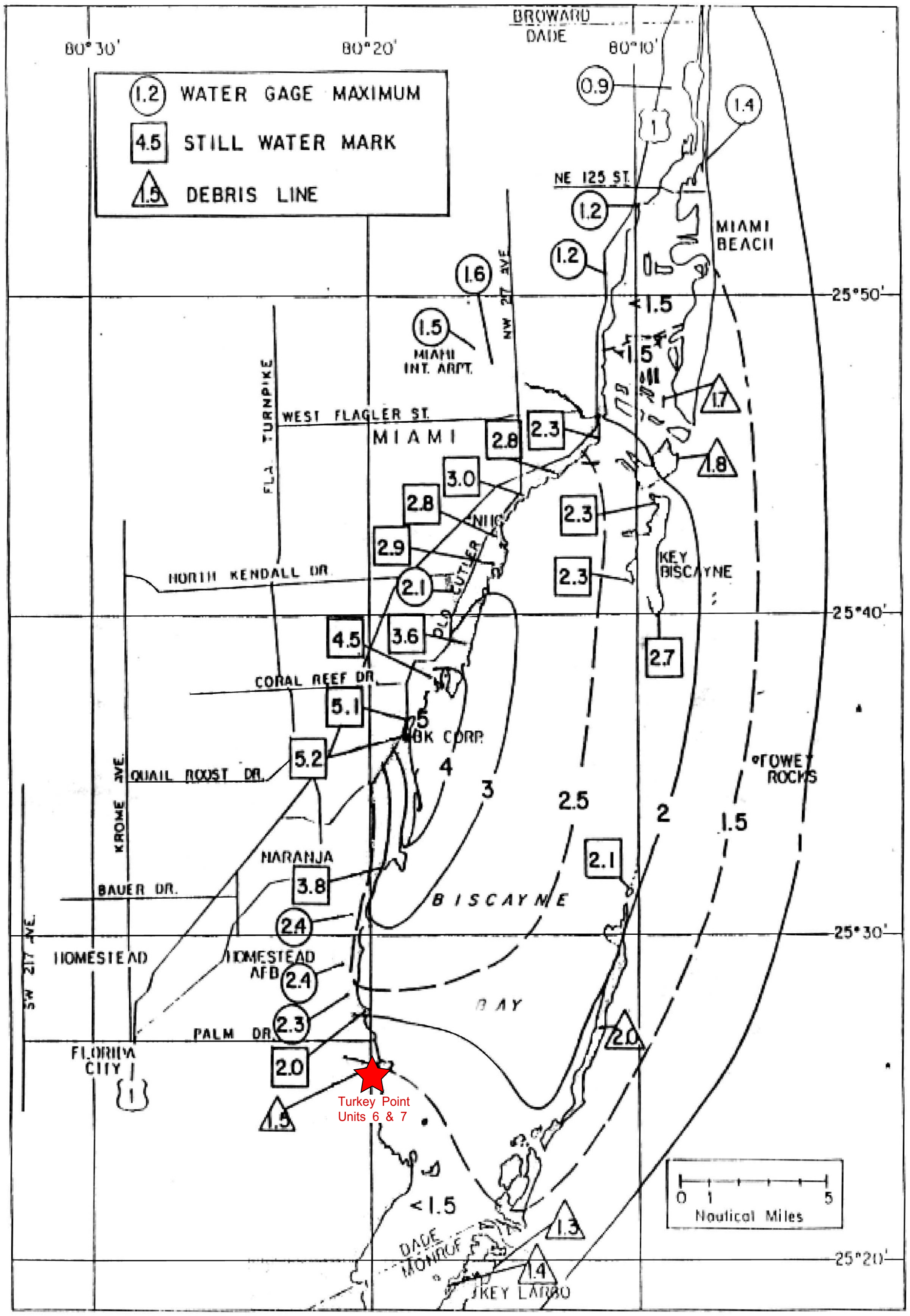
Figure 2.4.5-202 Tracks of Historical Hurricanes with Intensities of Category 3 and Above in Saffir-Simpson Hurricane Scale in the Region of Units 6 & 7



Source: Reference 211

PTN COL 2.4-2

Figure 2.4.5-203 Observed Storm Surge Elevations in and Around the Biscayne Bay During Hurricane Andrew

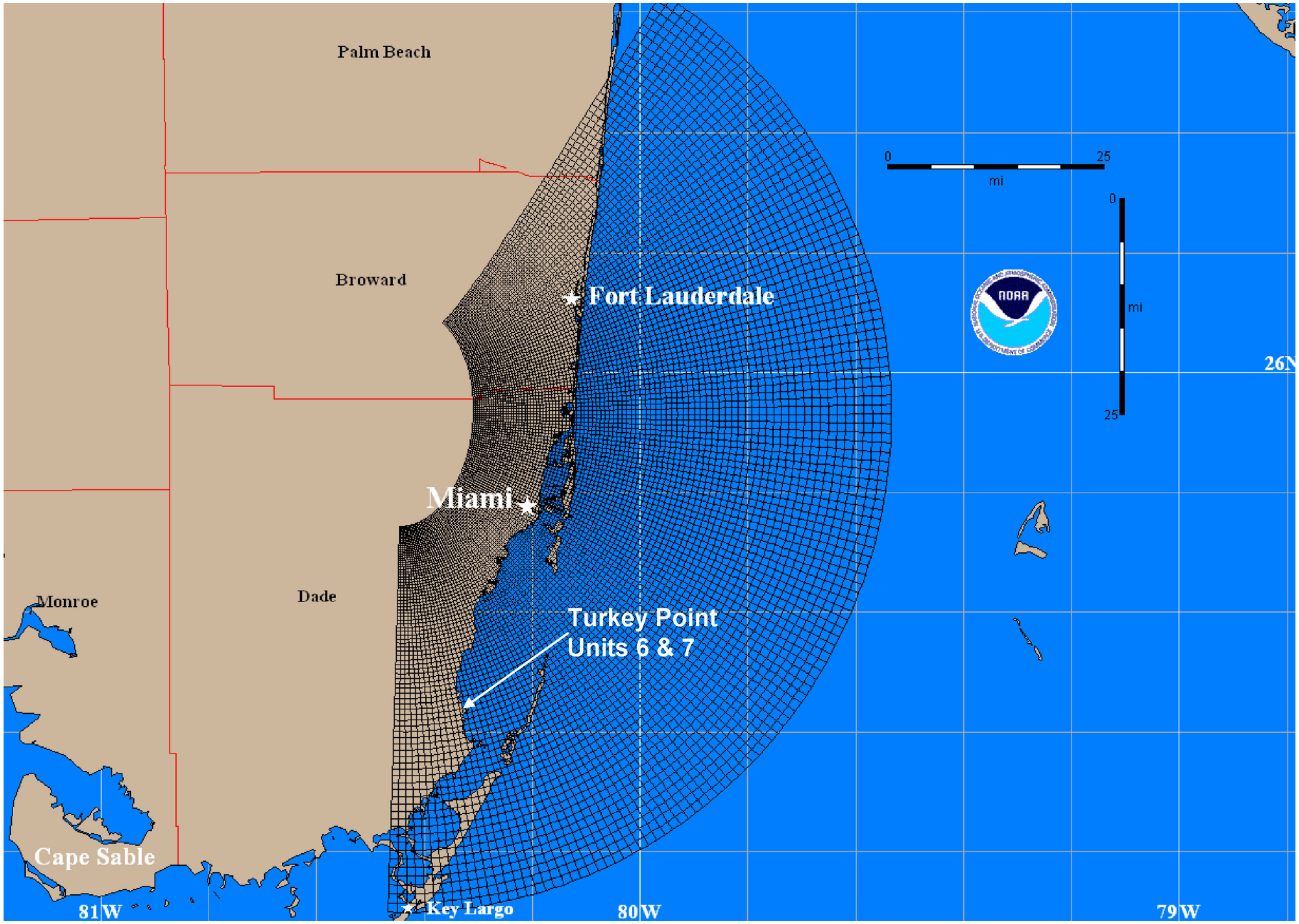


Note: location of Turkey Point site is aproximate.

Note: Surge elevations are in meters and referenced to the NGVD 29.
Source: Reference 204.

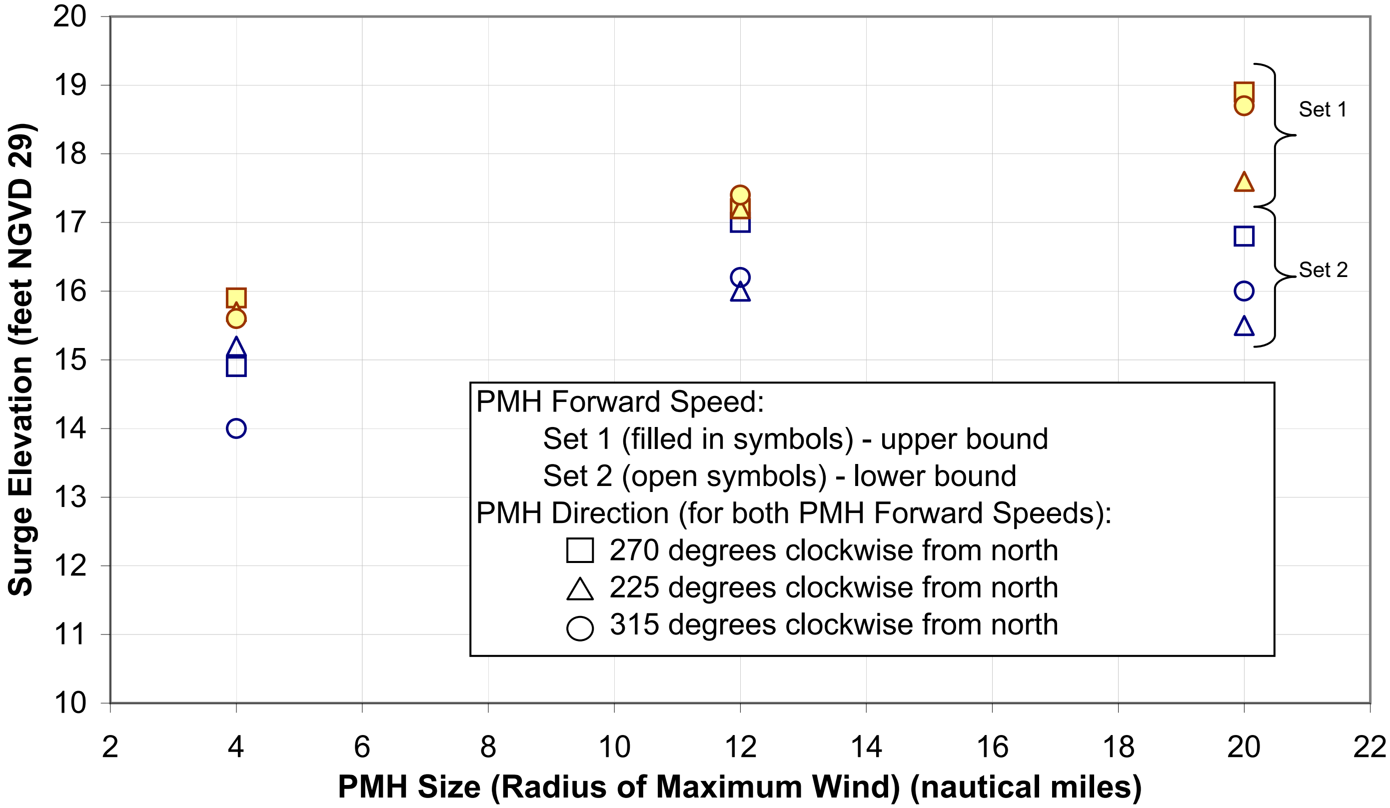
PTN COL 2.4-2

Figure 2.4.5-204 SLOSH Biscayne Bay, Florida Basin Model Grids and Location of Units 6 & 7



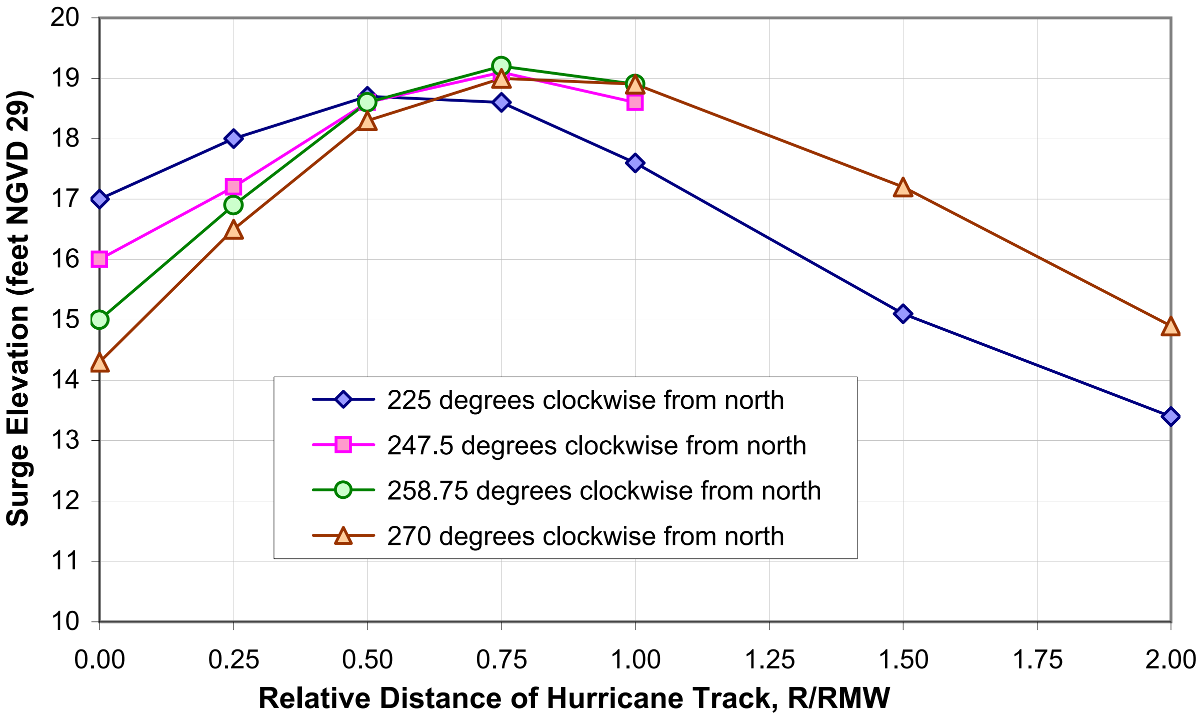
PTN COL 2.4-2

Figure 2.4.5-205 Simulated Surge Elevations For Different Combinations of the PMH Forward Speed, Size, and Direction



PTN COL 2.4-2

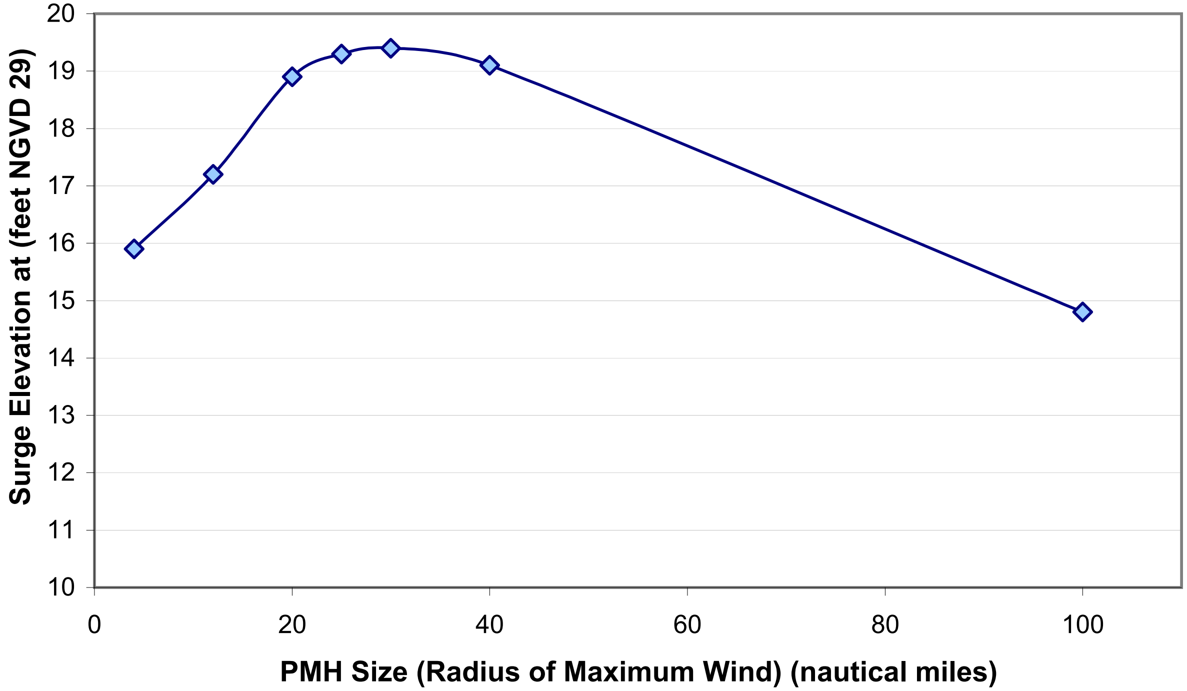
Figure 2.4.5-206 Simulated Surge Elevations for Different PMH Directions and Distances of PMH Track from Units 6 & 7



Note: R is the distance of the PMH track from Units 6 & 7.
RMW is the radius of maximum wind, which is 20 nautical miles or 23 miles.

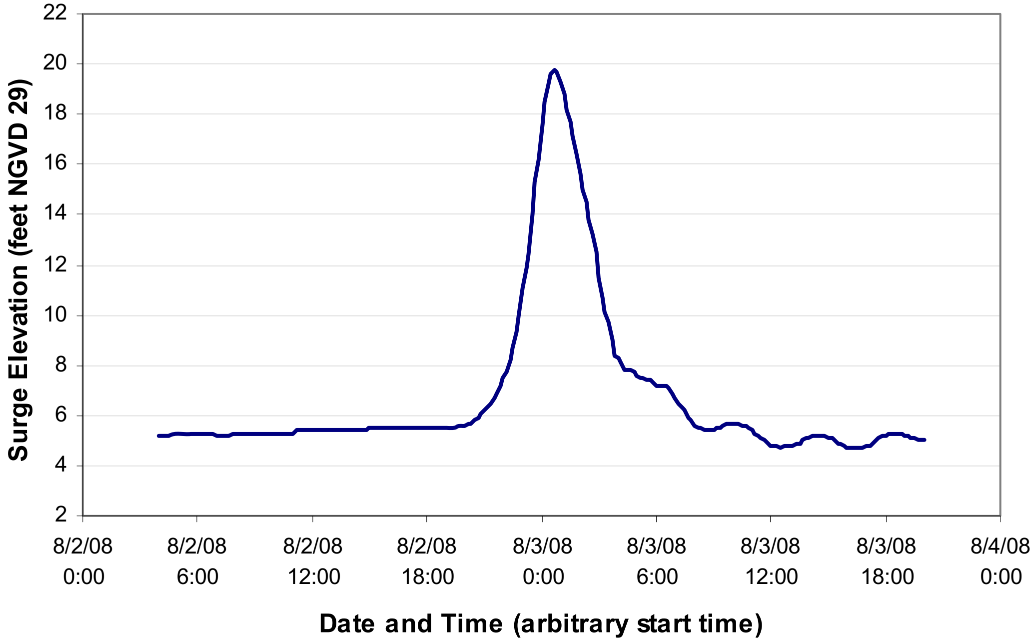
PTN COL 2.4-2

Figure 2.4.5-207 Simulated PMH Surge Elevations at Units 6 & 7 Versus Different PMH Sizes

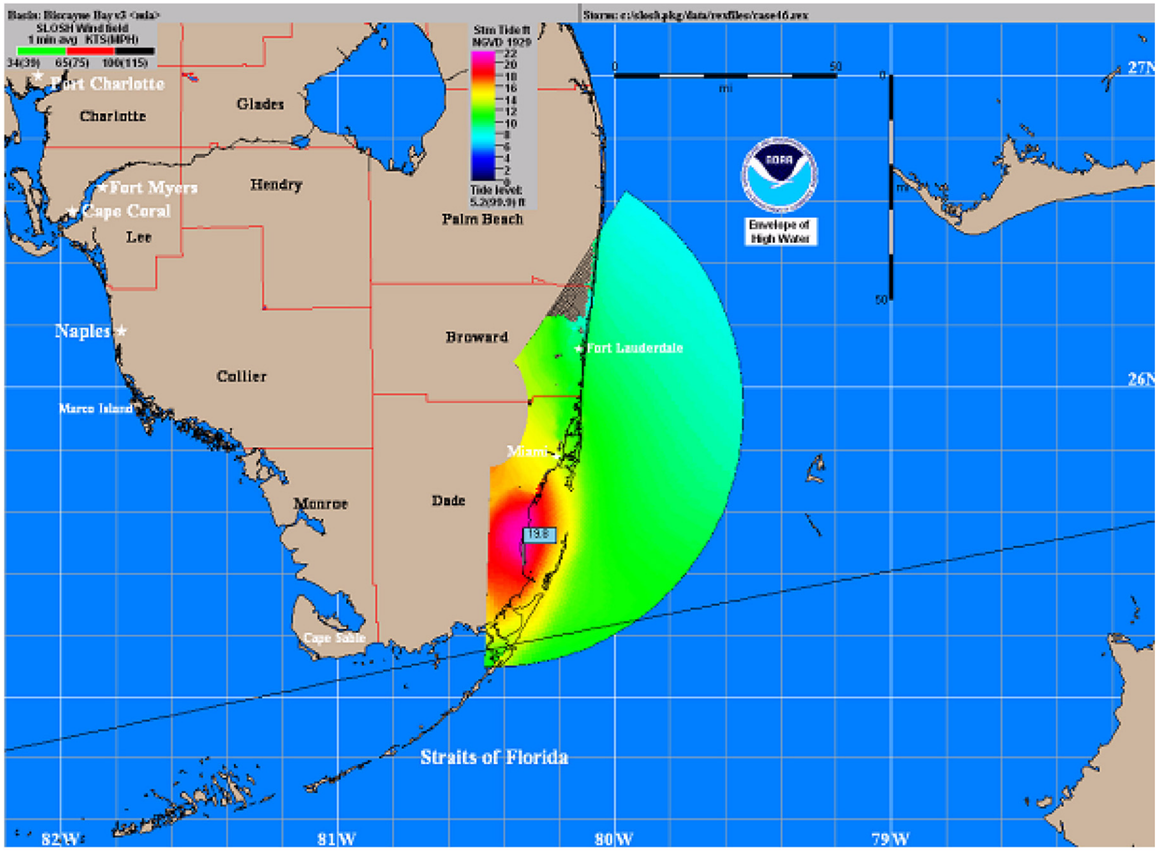


PTN COL 2.4-2

Figure 2.4.5-208 Time History of Simulated Maximum PMH Surge Elevation at Units 6 & 7



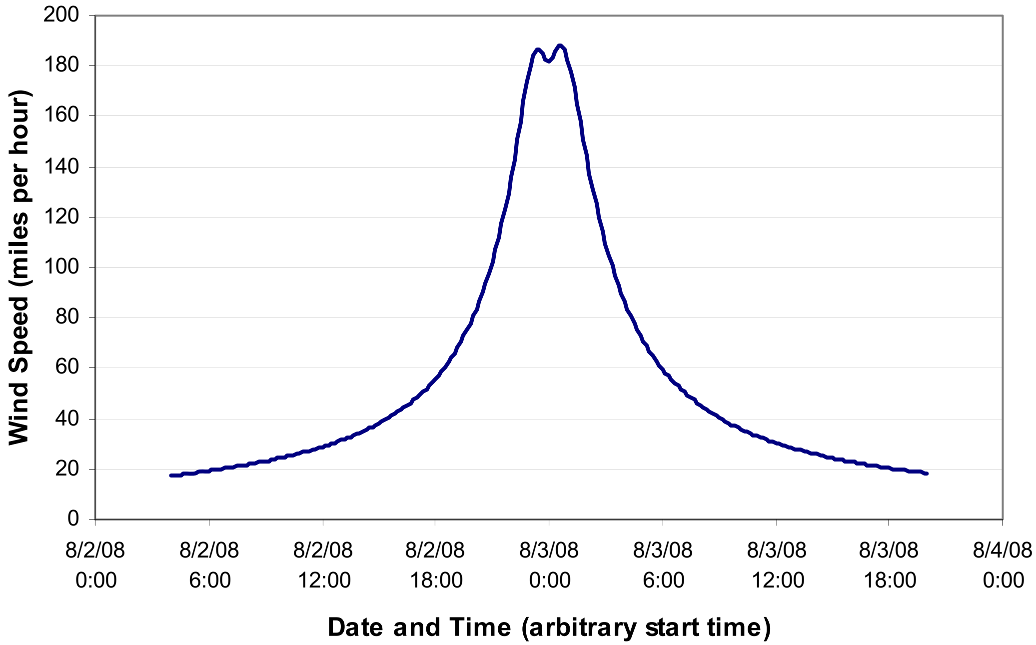
PTN COL 2.4-2 **Figure 2.4.5-209 The Envelope of Maximum Surge Elevation in the SLOSH Biscayne Bay, Florida Basin Model for PMSS at Units 6 & 7**



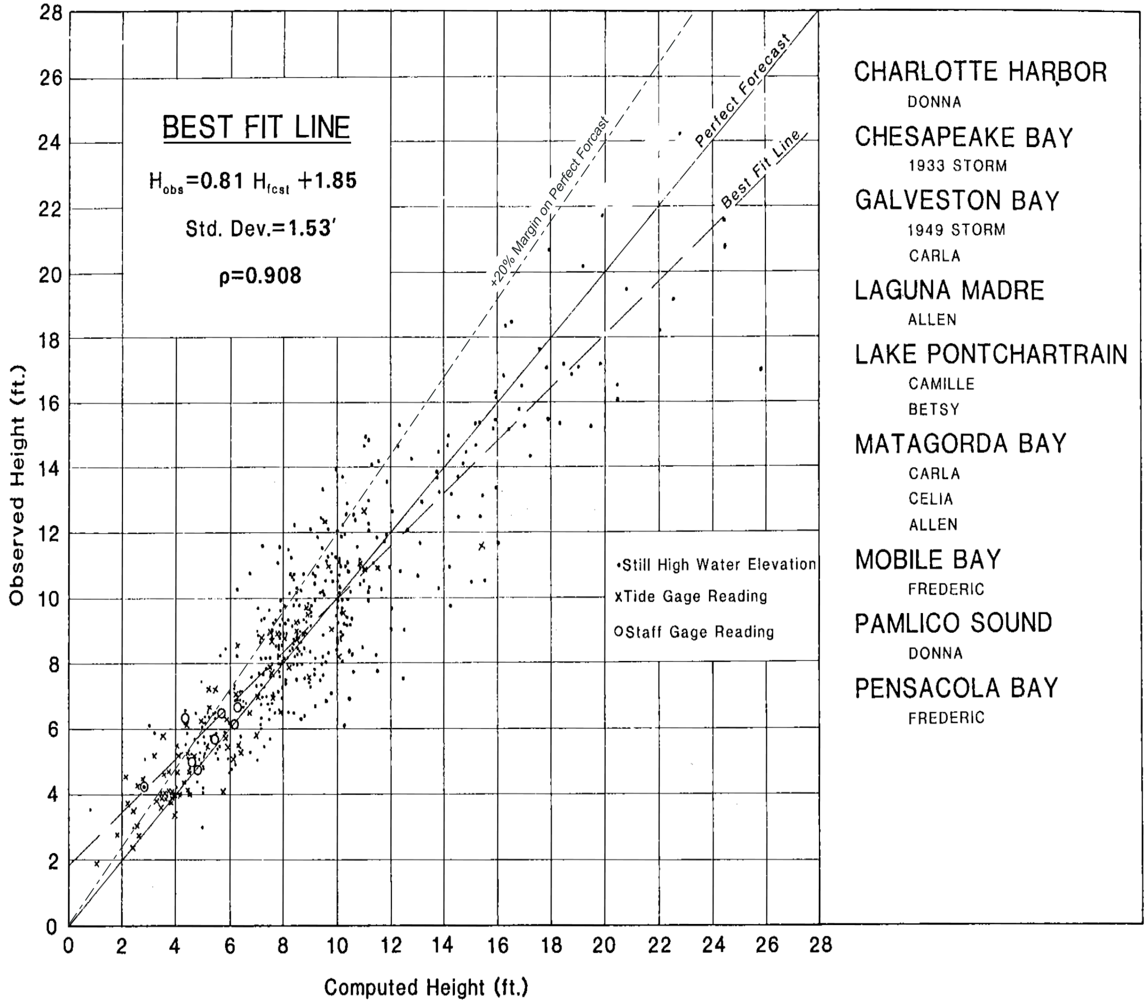
Note: Number in the flag indicates the maximum surge elevation (in NGVD 29) at Units 6 & 7.

PTN COL 2.4-2

Figure 2.4.5-210 Time History of PMH Wind Speed at Units 6 & 7



PTN COL 2.4-2 **Figure 2.4.5-211 Comparison of SLOSH Simulated Surge Heights Against Observed Data in different Basins**



Note: Modified from Reference 205 by adding a line showing the +20 percent margin on the perfect forecast.