

**EXECUTIVE SUMMARY**

**DESIGN STORM SURGE HYDROGRAPHS  
FOR THE FLORIDA COAST**

**SUBMITTED TO:**

**FLORIDA DEPARTMENT OF TRANSPORTATION  
605 Suwannee Street  
Tallahassee, Florida 32399-0450**

**FDOT Contract Number  
BC-354 RWPO 70**

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**SUBMITTED BY:**

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**Introduction:**

The objectives of this investigation were to 1) review the literature and determine what information was available regarding 50, 100 and 500 year return interval open coast storm surge peak elevations and time history hydrographs and 2) based on this information recommend which of these should be used by the FDOT for the ocean boundary condition for modeling inland storm surge propagation in Florida's coastal waters.

A number of Federal and State agencies have attempted to produce peak storm surge elevations for various frequency hurricanes along the Florida coast. There have been far fewer published hydrographs associated with these elevations. Most, if not all, of the computer models used in analyzing storm surge start with the same basic governing equations. The difference between the models lies in 1) the numerical schemes used to solve the equations, 2) the surge generation mechanisms included in the analysis, 3) the boundary conditions imposed, 4) the types of storms analyzed (real or synthetic), 5) the manner in which astronomical tides are treated (or not treated as the case may be) and 6) the methods and procedures used to estimate the different return interval events. With such a complex problem and so many different solution approaches taken it should not come as a surprise that the results from the various agencies differ from each other, in some cases significantly. Even though a number of papers and reports have been published on these models and the procedures used, many of the details are missing and attempts to obtain more information (through telephone calls and email) were, for the most part, not successful. Each of the approaches have certain advantages and disadvantages. Some of the more recently developed computer models are believed to do a better job in solving the governing equations as a result of more accurate and efficient numerical schemes and methods. However, to date the solutions using these models have not included one of the important storm surge generation mechanisms, namely wave setup.

**Design Storm Surge Elevations**

This survey of existing storm surge information did not produce a clear cut best set of design storm surge elevations. It then becomes somewhat subjective as to what values should be used by the FDOT. The approach taken by the U.S. Army Corps of Engineers using the ADCIRC model where actual storms were modeled using NOAA's HURDAT data set is perhaps the best

approach of those covered in this survey. The problems with these results are that wave setup was not included in the analysis and the grid along the Florida Coast is too coarse and does not extend to the shoreline. These shortcomings have resulted in unreasonably low (or high) predicted 50, 100 and 500 year return interval storm surge elevations as analyzed and reported in the final report of the Pooled Fund Study (which uses the USACE model results).

While the approach taken by the Florida Department of Environmental Protection (FDEP) is less appealing than that taken by the USACE it does include wave setup and produces more reasonable elevations (reasonable as compared to water marks inside buildings from past hurricanes). The problem here is that only the counties with sandy beaches (25 of the 34 coastal counties) in Florida have been analyzed by FDEP. FDEP has published storm surge elevations for 25 counties and 100 year storm surge hydrographs for 24 counties.

On the basis that FDEP has included all of the major generation mechanisms in their analyses and that they have compared their results with near coast water marks in buildings where possible, the FDEP storm surge heights for 50, 100 and 500 return interval hurricane storm surges are recommended for use by FDOT at this time. For the counties not covered by FDEP values have been interpolated from the surrounding counties using FEMA and NOAA results as guides. The locations for each of the stations are shown in Figure 1 and listed in Tables 1. Values of the 50, 100 and 500 year peak elevations are listed in Table 1. Plots of 50, 100 and 500 year peak elevations for the entire coastline of Florida are shown in Figures 2-4.

### **Design Storm Surge Hydrographs**

There is very little published information on open coast storm surge hydrographs. NOAA provided FDOT with hardcopy plots of category 5 storm surge hydrographs for locations along the coast of Florida in the late 1980s. There is no record of how these hydrographs were generated. The USACE has a synthetic hydrograph (mathematical expression of water height as a function of time), the coefficients of which are related to the specific hurricane parameters whose hydrograph is being represented. A Pooled Fund Study, with funding from Departments of Transportation in several U.S. coastal states, modified the USACE hydrograph to make it better fit the hydrographs produced by the USACE's ADCIRC generated data set in the areas investigated in this study. It should be noted that the storm surges produced by this analysis did not include wave setup and astronomical tide. This not only affected the heights of the surges

but the shapes of the hydrographs as well. The grid for the ADCIRC model used to generate the data set analyzed in the Pooled Fund Study is relatively coarse and the nearshore bathymetry in the model is not as accurate as perhaps it should be (according to the engineers at USACE that configured and ran the model and generated the data set used by the Pooled Fund Study). The combinations of coarse grid, less accurate nearshore bathymetry and the exclusion of wave setup most likely accounts for some of the unreasonably low (or high) values reported in the Pooled Fund Study Reports.

For the counties evaluated (and reevaluated) in recent years by FDEP, 100 year return interval hydrographs have been published as part of the report. These hydrographs are the ones (of the approximately 600 synthetic storms run at each location) that achieved a peak height at the coast near the 100 year return interval prediction. Note that the combination of parameters that produced the hurricane that achieved this elevation is not unique. That is, other combinations could achieve the same elevation and thus the hydrograph shape is not unique.

The hydrograph shape, as well as its peak height, is important in establishing accurate peak flow velocities and peak water elevations at bridge crossings within coastal waterways subject to storm surges.

Another important factor for which little information exists is the lateral extent of the surge on the open coast. This is particularly important in situations where tidal inlets are in close proximity or where the coastal land masses are sufficiently low that overtopping occurs during the storm event.

Again, since the FDEP included all of the important storm surge generation mechanisms in their analysis, their results are used as the basis for the hydrographs recommended for use by FDOT. For those counties not covered by FDEP an interpolation scheme was used to provide design hydrographs for these locations. The 100 year hydrograph published by FDEP along with extrapolated hydrographs with 50 and 500 year return interval peak elevations are presented for each of the FDEP sites along the Florida coast. Interpolated hydrographs are presented for the 10 counties not covered (or published) by FDEP.

The locations for each of the stations are shown in Figure 1 and listed in Table 1. Plots of the recommended hydrographs are shown in Figures 5-20. Electronic files with hydrographs with 50, 100 and 500 year return interval peak elevations are included on the attached CD in ASCII format.

The attached dataset contains two additional hydrographs with a 100 year return interval peak elevation for each location. The three hydrographs have different rates of rise and fall and durations. The additional hydrographs can be used to examine the impact of increased rates of rise and fall and different duration storms on the flow parameters at the point of interest provided time and resources allow such an analysis.

Table 1. Recommended Peak Storm Surge Heights.

Ref	Location	Latitude (deg N)	Longitude (deg W)	Peak Storm Surge Heights (ft, NGVD)		
				50-yr	100-yr	500-yr
101	Escambia W, Esc.	30.28	87.52	9.8	11.4	15.3
102	Pensacola Bay, Esc.	30.32	87.27	9.7	11.0	14.3
103	Pensacola Bch, Esc.	30.35	87.07	9.4	10.8	13.9
104	Eglin AFB, Esc.	30.38	86.87	9.2	10.7	13.8
301	Eglin AFB, Oka.	30.40	86.63	9.9	11.2	13.0
302	Destin W, Oka.	30.39	86.60	10.2	11.4	13.7
303	Destin E, Oka.	30.38	86.40	10.2	11.4	13.7
401	Miramar Bch, Wal.	30.37	86.35	9.8	11.4	14.2
402	Grayton Bch, Wal.	30.33	86.16	9.4	11.2	14.1
403	Inlet Bch, Wal.	30.29	86.05	8.9	10.5	13.6
501	Hollywood Bch, Bay	30.27	85.99	10.6	11.9	14.8
502	Panama City, Bay	30.10	85.69	11.0	12.2	15.1
503	Mexico Bch, Bay	29.93	85.39	10.7	12.0	15.0
600	Beacon Hill, Gulf	29.92	85.38	10.1	11.7	16.3
601	St Joseph Pt, Gulf	29.85	85.41	8.0	9.3	12.6
602	St Joseph Park, Gulf	29.76	85.40	7.7	8.8	11.9
603	Cape San Blas, Gulf	29.68	85.37	9.3	11.1	16.0
604	McNeils, Gulf	29.68	85.30	10.8	12.4	16.9
605	Indian Pass, Gulf	29.68	85.25	11.0	12.6	17.0
701	St Vincent Is, Fra.	29.59	85.05	10.1	12.0	14.7
702	West Pass, Fra.	29.63	84.93	10.2	12.1	15.1
703	Sikes Cut, Fra.	29.68	84.81	10.2	12.3	15.4
704	St George Is, Fra.	29.75	84.71	10.5	12.6	16.0
705	Dog Is, Fra.	29.80	84.59	11.5	13.0	16.4
706	Alligator Hbr, Fra.	29.90	84.35	12.2	14.7	18.7
801	Lighthouse Pt, Wak.	29.93	84.29	13.1	14.7	17.3
802	Shell Pt, Wak.	29.96	84.23	13.3	15.1	17.3
803	Goose Creek Bay, Wak.	30.00	84.17	13.5	15.3	17.8
804	Whale Is, Wak.	30.03	84.12	13.9	15.3	18.1
805	Palmetto Is, Wak.	30.07	84.06	14.2	15.5	18.3
806	Little Redfish Pt, Wak.	30.10	84.00	13.9	15.2	17.9
1001	Stake Pt, Tay.	30.00	83.80	13.6	14.9	17.7
1002	Deadman Bay, Tay.	29.60	83.50	13.4	14.6	17.5
1101	Horseshoe Bch, Dix.	29.40	83.25	13.1	14.3	17.2
1102	Suwannee River, Dix.	29.30	83.10	12.8	14.0	17.0
1201	Cedar Key, Levy	29.15	83.00	12.6	13.7	15.5
1202	Waccasassa River, Levy	29.15	82.83	12.3	13.3	16.0
1301	Crystal River, Cit.	28.88	82.64	12.0	13.0	15.9
1302	Homasassa Bay, Cit.	28.75	82.64	11.7	12.7	15.8
1303	Chassahowitzka Bay, Cit.	28.65	82.64	11.5	12.4	15.6
1401	Little Pine Is Bay, Her.	28.50	82.64	11.2	12.1	15.5
1501	Port Richey, Pas.	28.25	82.75	10.9	11.8	15.4
1601	Anclote River, Pin.	28.08	82.83	9.5	11.5	15.3

Table 1. Recommended Peak Storm Surge Heights (continued).

Ref	Location	Latitude (deg N)	Longitude (deg W)	Peak Storm Surge Heights (ft, NGVD)		
				50-yr	100-yr	500-yr
1602	Hurricane Pass, Pin.	27.89	82.85	8.5	10.1	13.4
1603	St Pete Bch, Pin.	27.73	82.74	9.9	11.5	14.7
1604	Bunces Pass, Pin.	27.62	82.72	8.5	9.9	13.1
1701	Tampa Bay, Man.	27.54	82.74	11.0	12.3	15.0
1702	Bradenton Bch, Man.	27.46	82.70	11.1	12.5	15.0
1703	Longboat Key, Man.	27.39	82.64	11.3	12.8	15.7
1801	Longboat Key, Sar.	27.38	82.64	11.4	12.9	16.0
1802	Venice Inlet, Sar.	27.17	82.49	11.3	12.6	15.6
1803	Manasota, Sar.	26.95	82.38	11.7	13.1	15.5
1901	Manasota, Cha	26.95	82.38	11.7	13.1	15.5
1902	Don Pedro Is, Char.	26.89	82.33	11.5	12.9	15.0
1903	Gasparilla Pass, Char.	26.81	82.28	11.4	12.7	15.0
2001	Gasparilla Is, Lee	26.79	82.27	10.7	12.5	15.4
2002	Captiva Pass, Lee	26.65	82.25	10.6	12.2	14.7
2003	Captiva, Lee	26.52	82.19	10.6	12.2	14.9
2004	Sanibel Is, Lee	26.42	82.09	11.6	13.4	16.2
2005	Ft Myers Bch, Lee	26.43	81.91	12.9	14.8	17.4
2006	Bonita Bch, Lee	26.34	81.85	12.9	14.7	17.9
2101	Wiggins Pass, Col.	26.32	81.84	13.1	15.2	18.9
2102	Doctors Pass, Col.	26.19	81.82	12.2	14.1	17.5
2103	Keewaydin Is, Col.	26.06	81.79	11.5	13.1	16.3
2104	Naples, Col.	25.92	81.73	11.5	12.9	15.1
2201	Highland Pt., Mon.	25.50	81.20	11.6	13.0	15.5
2202	Shark Pt, Mon.	25.30	81.20	11.7	13.2	15.8
2203	Key West, Mon.	24.70	81.40	11.7	13.3	16.2
2204	Big Pine Key, Mon.	24.80	80.80	11.8	13.5	16.5
2205	Long Key, Mon.	25.10	80.40	11.9	13.6	16.9
2206	Key Largo, Mon.	25.25	80.30	12.0	13.7	17.3
2207	N. Key Largo, Mon.	25.10	80.40	12.1	13.9	17.6
2301	Key Biscayne, Dade	25.68	80.16	12.1	14.0	18.0
2302	Miami Bch, Dade	25.83	80.12	10.8	13.6	17.7
2303	Bakers Haulover, Dade	25.95	80.12	11.4	13.5	17.6
2401	Hollywood, Bro.	26.03	80.11	11.4	13.6	16.9
2402	Ft Lauderdale, Bro.	26.06	80.11	11.2	13.1	17.2
2403	Pompano Bch, Bro.	26.22	80.09	10.9	12.5	17.1
2501	Boca Raton, Palm.	26.33	80.07	9.9	11.6	14.6
2502	Boynton Inlet, Palm.	26.53	80.05	9.9	11.5	15.0
2503	Lake Worth Inlet, Palm.	26.76	80.04	9.7	11.1	15.0
2504	Jupiter Inlet, Palm.	26.96	80.08	9.8	11.2	15.4
2601	Blowing Rocks, Mar.	27.01	80.09	10.3	11.2	12.6
2602	St. Lucie Inlet, Mar.	27.15	80.15	10.8	11.6	13.0
2603	Jensen Bch, Mar.	27.26	80.20	11.1	11.9	13.5
2701	Jensen Bch Park, StL.	27.27	80.20	10.4	11.4	13.3

Table 1. Recommended Peak Storm Surge Heights (continued).

Ref	Location	Latitude (deg N)	Longitude (deg W)	Peak Storm Surge Heights (ft, NGVD)		
				50-yr	100-yr	500-yr
2702	Ft Pierce Inlet S, StL.	27.42	80.27	10.8	12.1	13.9
2703	Ft Pierce Inlet N, StL.	27.54	80.32	11.1	12.3	14.7
2801	Vero Bch, Ind.	27.58	80.33	10.2	11.5	13.9
2802	Indian R Shores, Ind.	27.74	80.38	10.0	11.3	13.4
2803	Sebastian Inlet, Ind.	27.84	80.44	9.9	11.2	13.4
2901	Sebastian Bch, Bre.	27.91	80.47	10.2	11.6	14.2
2902	Satellite Bch, Bre.	28.18	80.59	9.8	11.1	13.7
2903	Cocoa Bch, Bre.	27.58	80.33	9.4	10.7	13.3
2904	Cape Canaveral, Bre.	28.50	80.50	9.4	10.9	14.0
2905	N Cape Canaveral, Bre.	28.80	80.65	9.5	11.0	14.7
3001	New Smyrne Bch, Vol.	28.88	80.79	9.5	11.2	15.4
3002	Daytona Bch, Vol.	29.15	80.97	8.8	10.6	15.8
3003	N. Peninsula Rec., Vol.	29.43	81.10	9.2	11.3	15.7
3101	Flagler Bch, Flag.	29.44	81.10	8.7	10.7	15.2
3102	Painters Hill, Flag.	29.54	81.16	9.4	11.8	16.7
3103	Marineland, Flag.	29.67	81.21	9.8	12.6	18.3
3201	Matanzas Inlet, StJ.	29.70	81.22	9.2	12.3	16.3
3202	St. Augustine Inlet, StJ.	29.96	81.31	9.6	12.3	16.9
3203	Ponte Vedra Bch, StJ.	30.23	81.37	10.4	13.1	18.9
3301	Lake Duval, Duv.	30.26	81.38	10.5	13.2	17.8
3302	Manhattan Bch, Duv.	30.36	81.40	10.5	13.2	17.9
3303	Little Talbot Is, Duv.	30.48	81.41	10.6	13.1	17.8
3401	Nassau Sound, Nas.	30.54	81.44	11.1	13.2	18.8
3402	Fernandina Bch, Nas.	30.70	81.43	11.6	13.7	19.9
3403	St. Marys Ent., Nas.	30.71	81.43	11.9	13.9	20.2



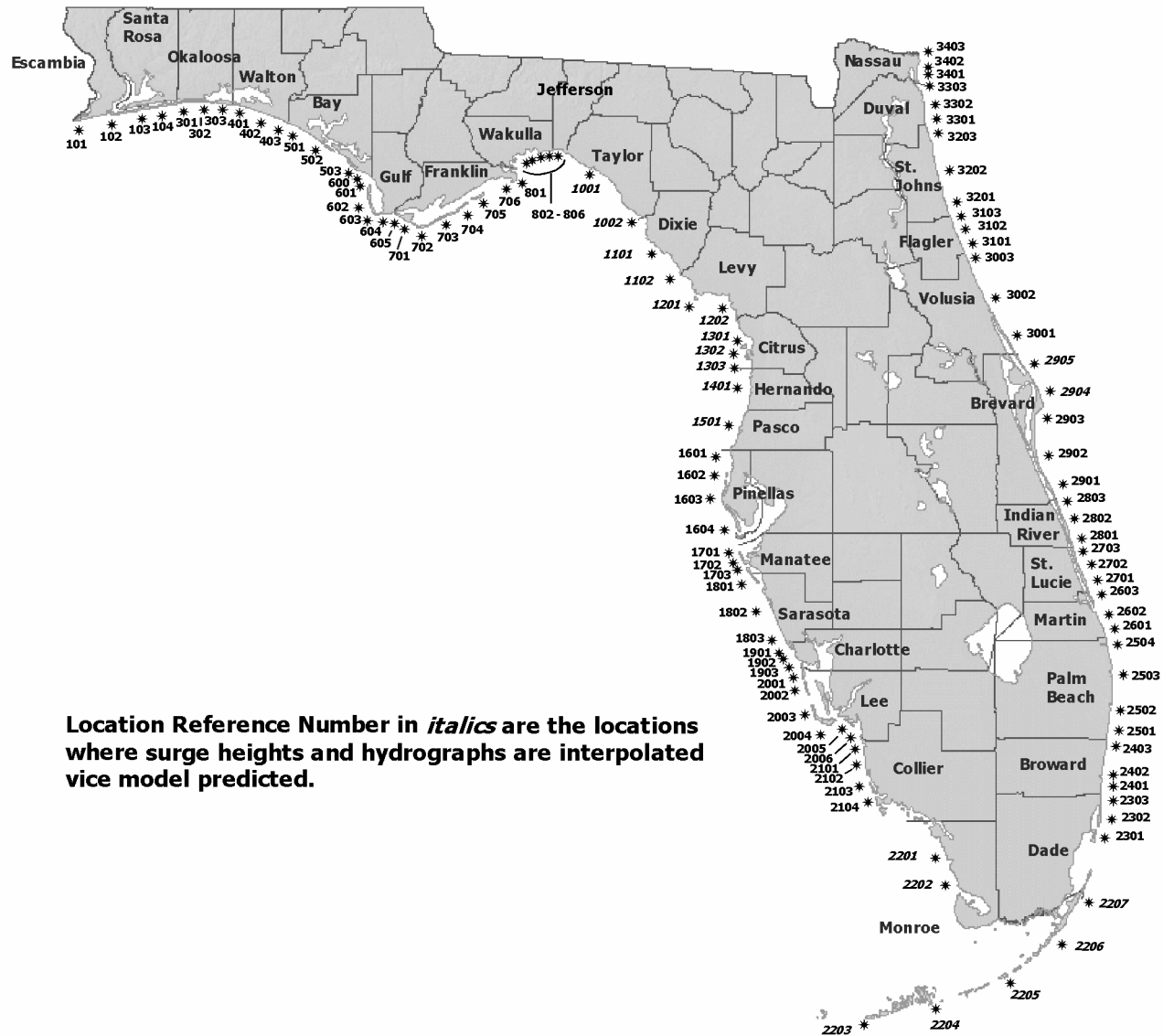


Figure 1. Storm Surge Peak and Hydrograph Locations.

### Recommend Peak Surge Heights, Escambia through Pinellas

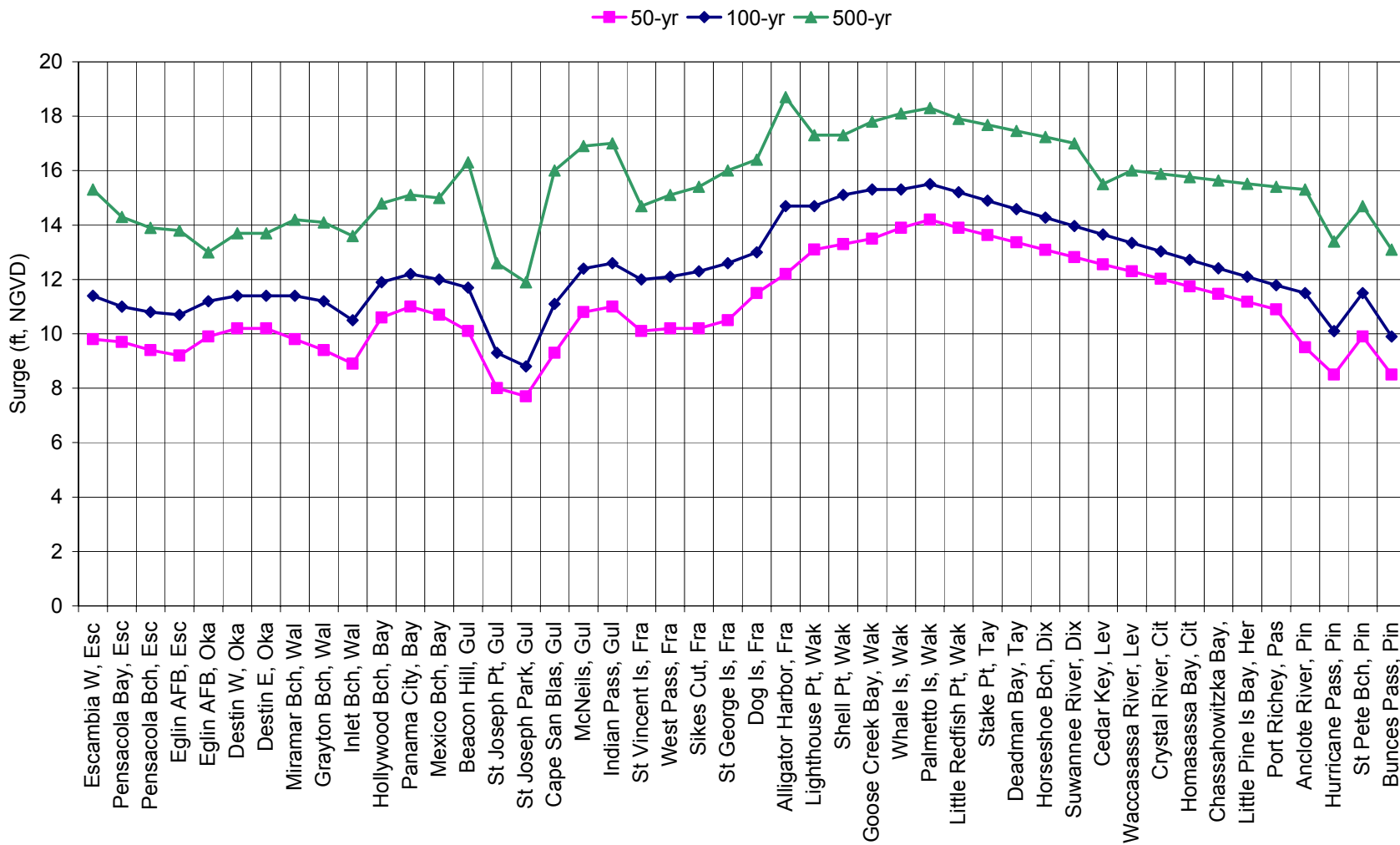


Figure 2. Plot of Recommended Peak Surge Heights, Escambia through Pinellas Counties.

### Recommend Peak Surge Heights, Pinellas through Dade

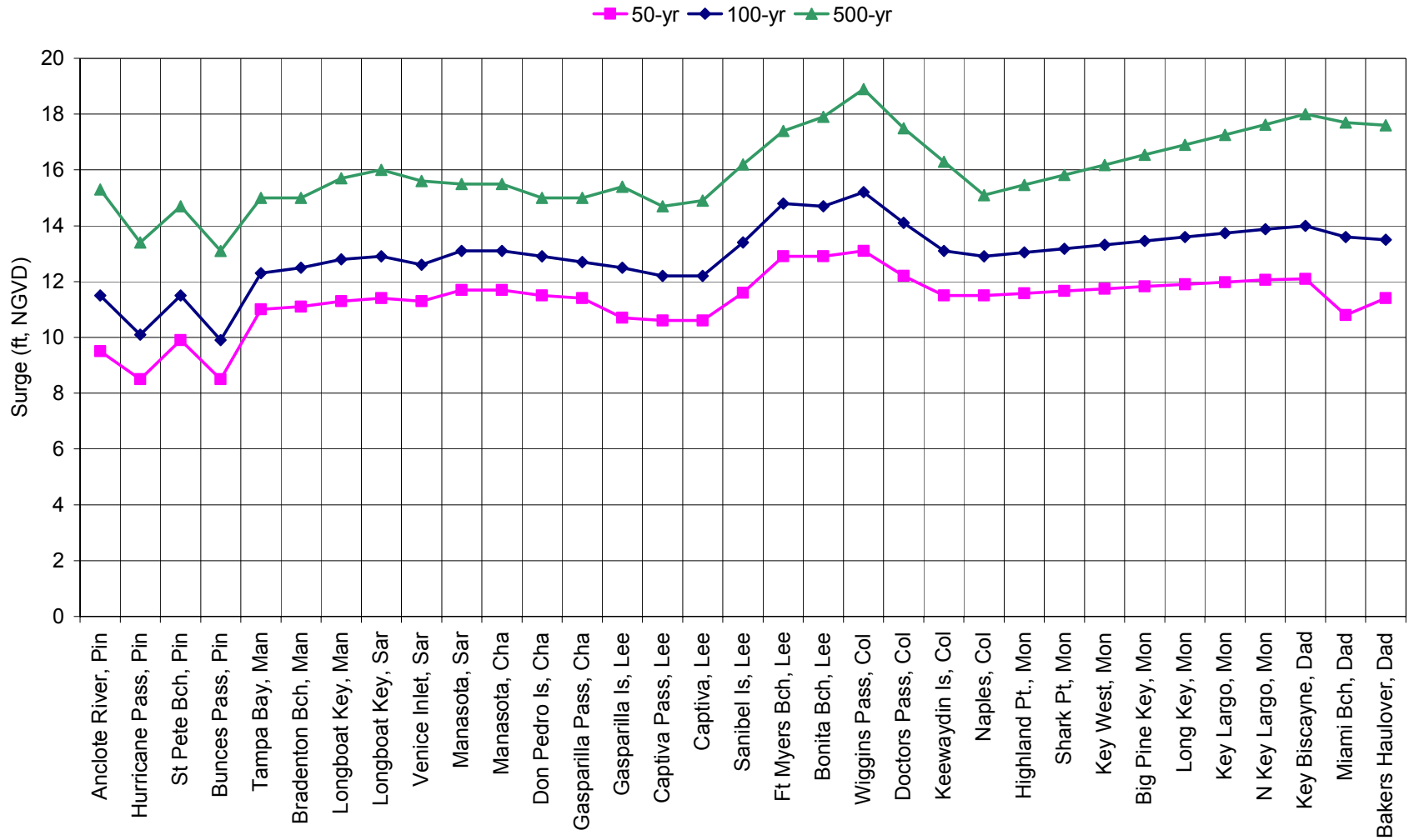


Figure 3. Plot of Recommended Peak Surge Heights, Pinellas through Dade Counties.

Recommend Peak Surge Heights, Dade through Nassau

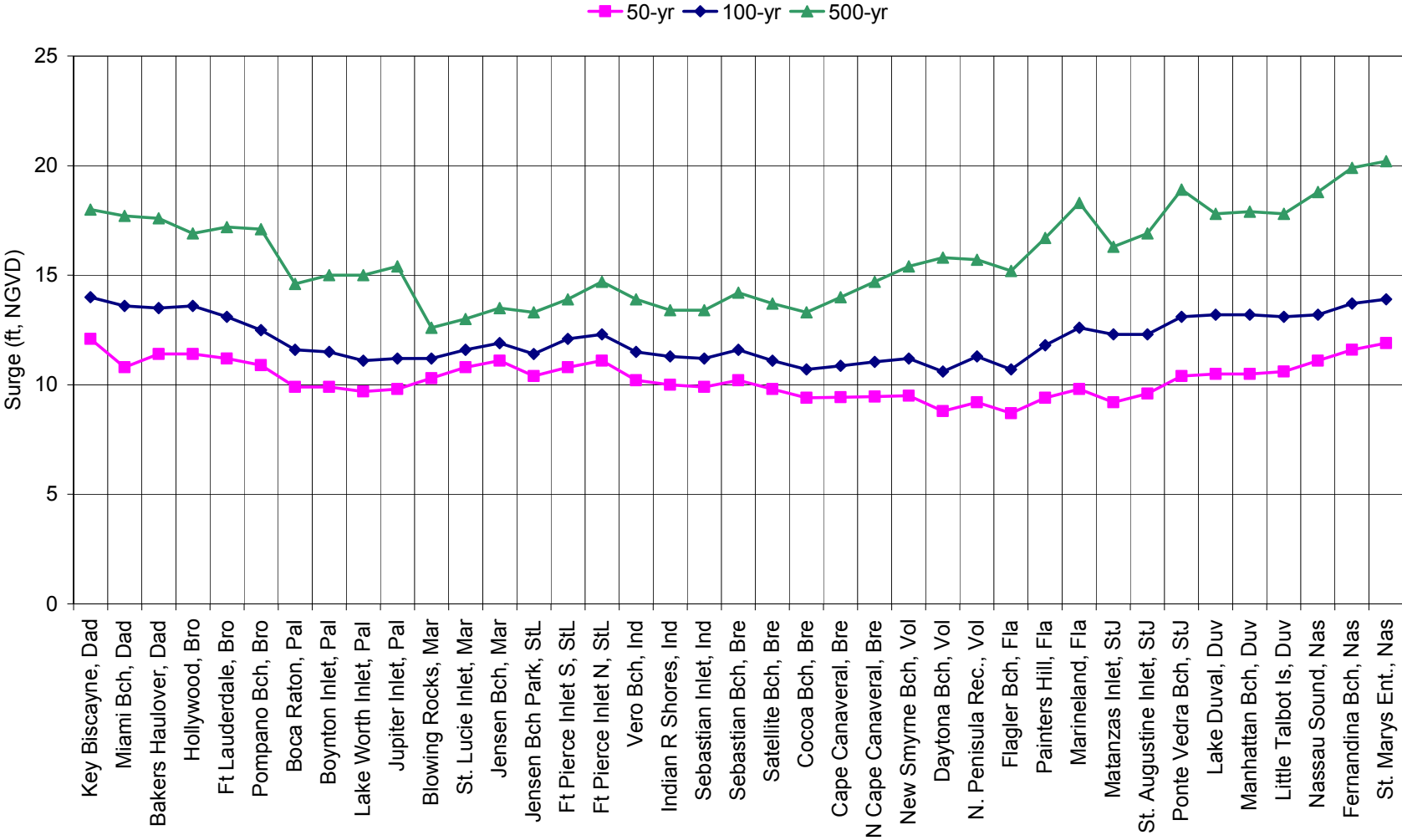


Figure 4. Plot of Recommended Peak Surge Heights, Dade through Nassau Counties.

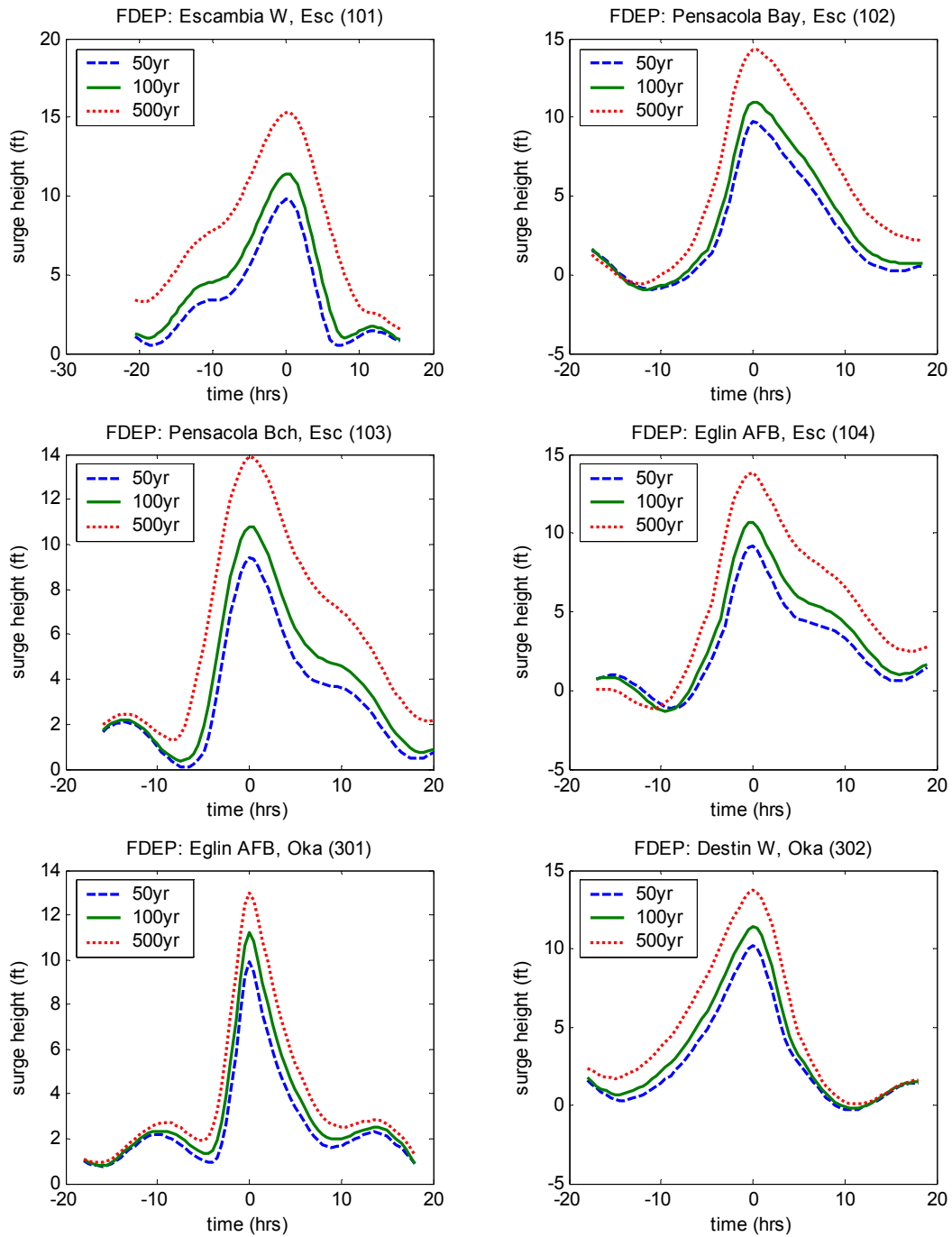


Figure 5. Storm Surge Hydrograph Plots for Escambia and Okaloosa Counties.

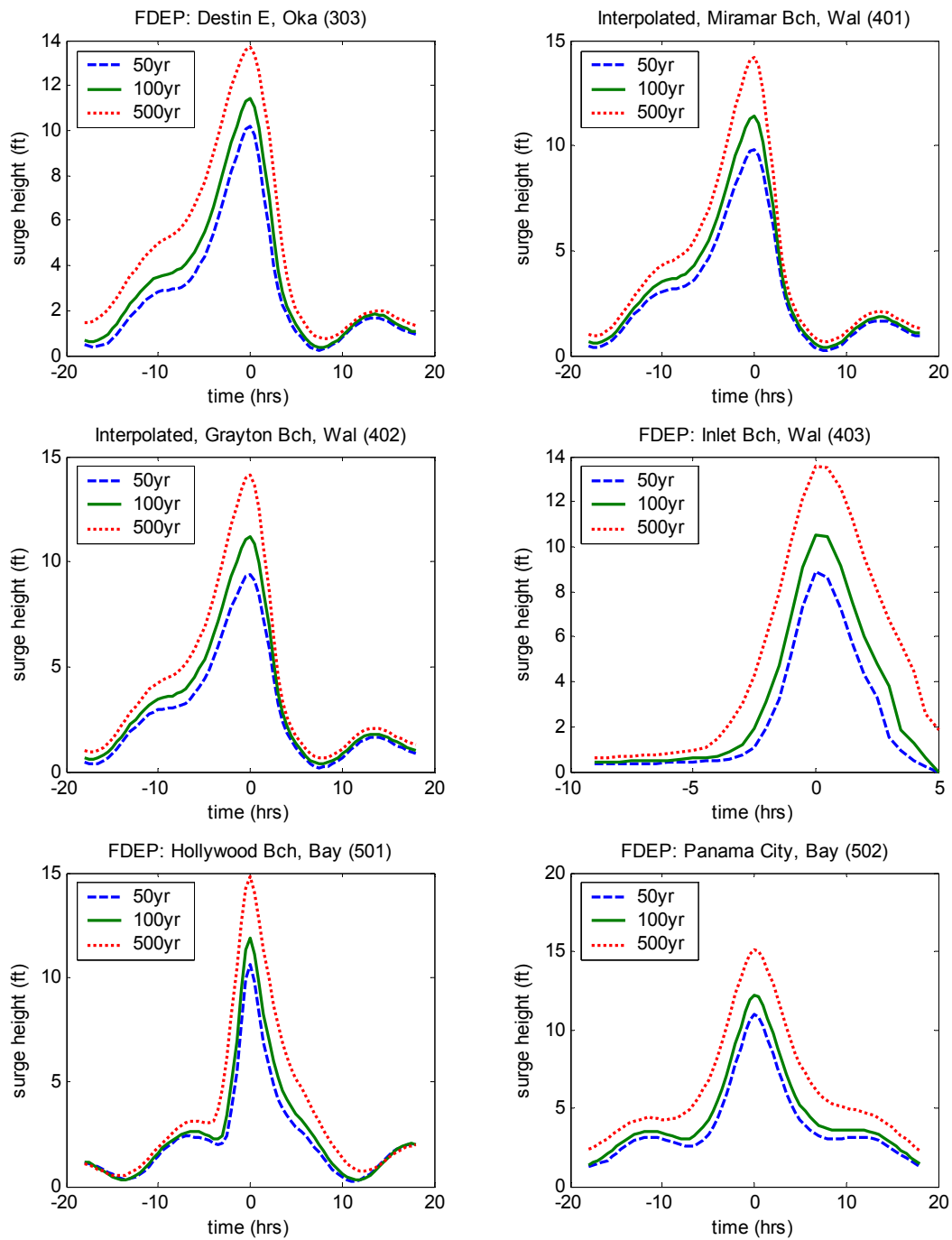


Figure 6. Storm Surge Hydrograph Plots for Okaloosa, Walton and Bay Counties.

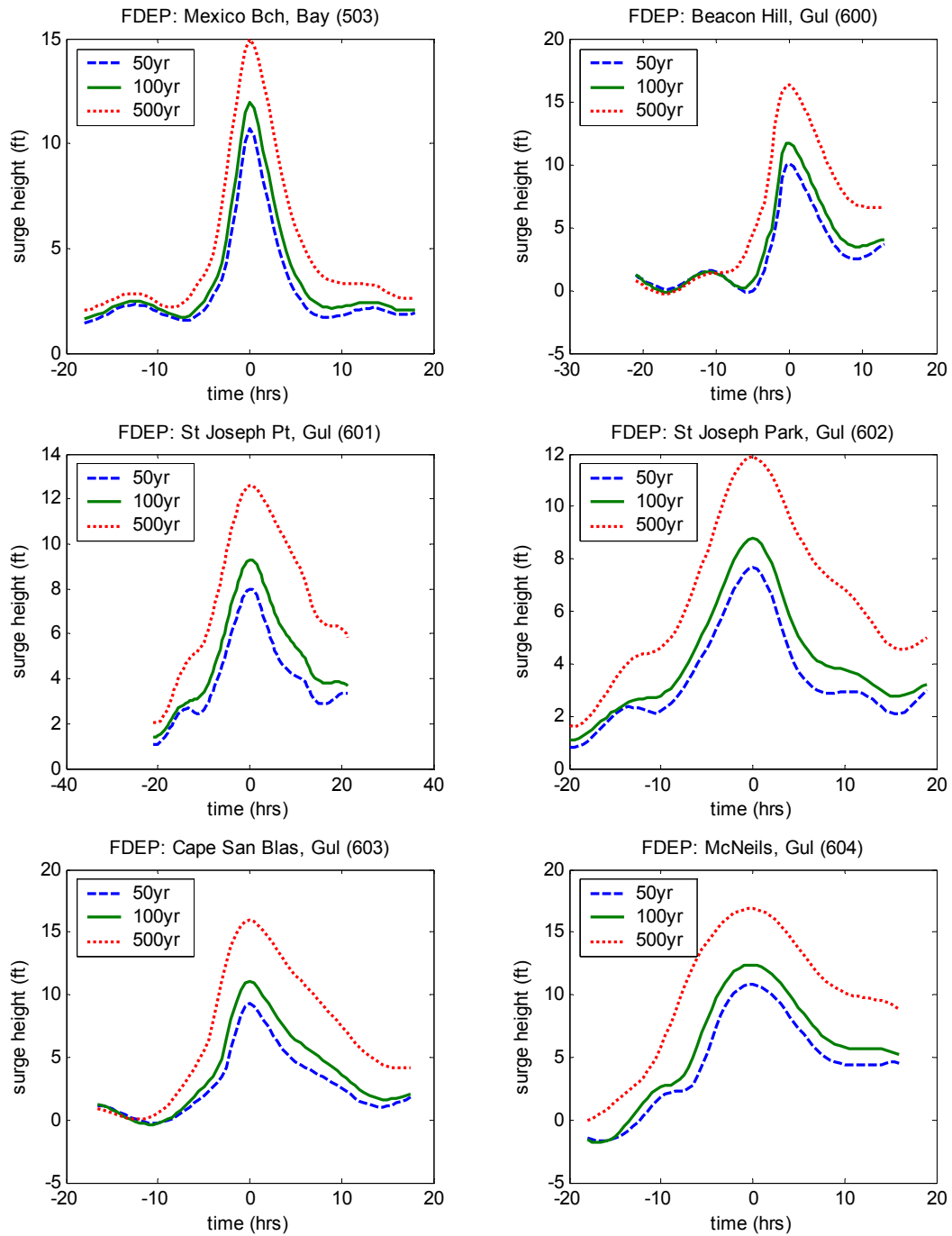


Figure 7. Storm Surge Hydrograph Plots for Bay and Gulf Counties.

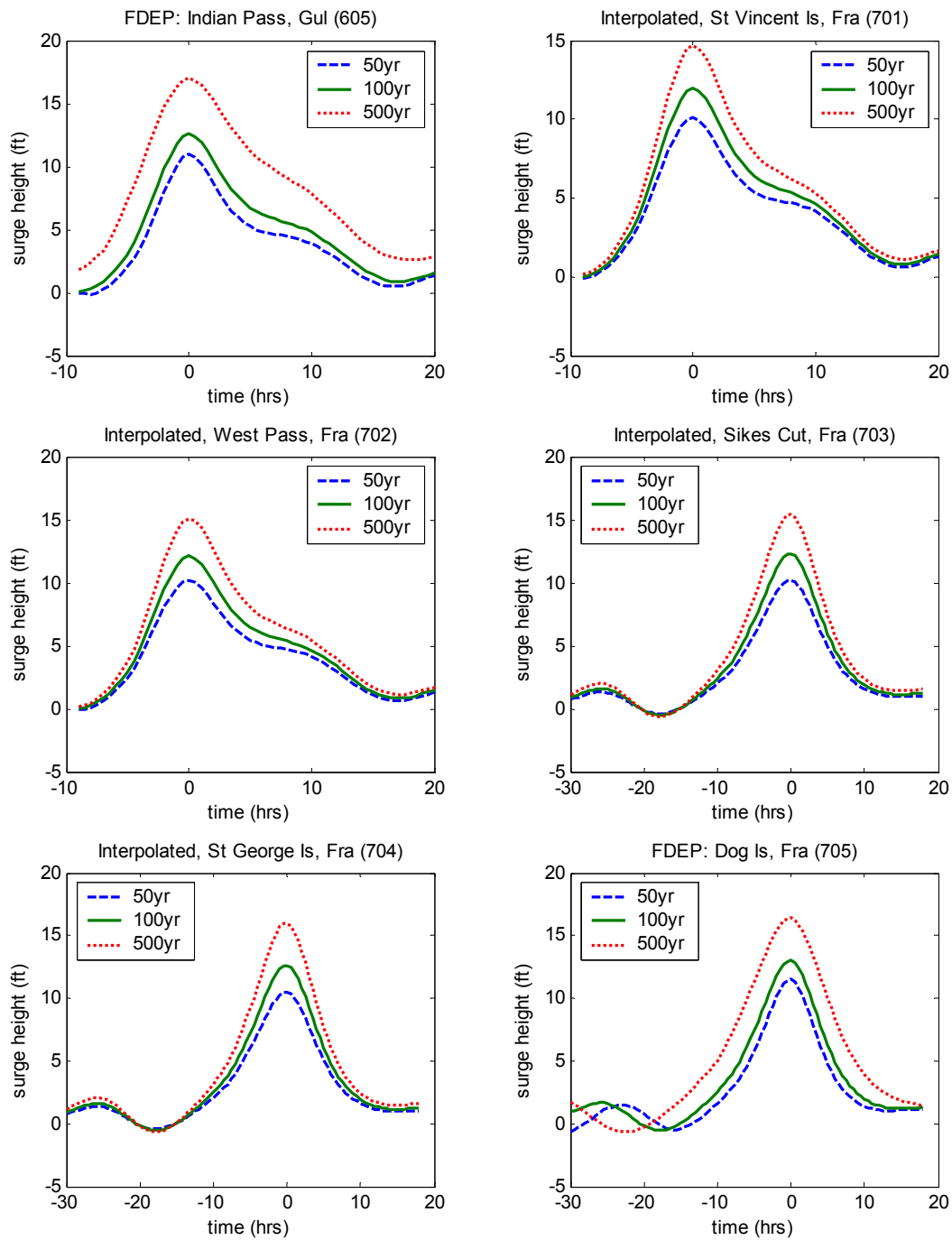


Figure 8. Storm Surge Hydrograph Plots for Gulf and Franklin Counties.



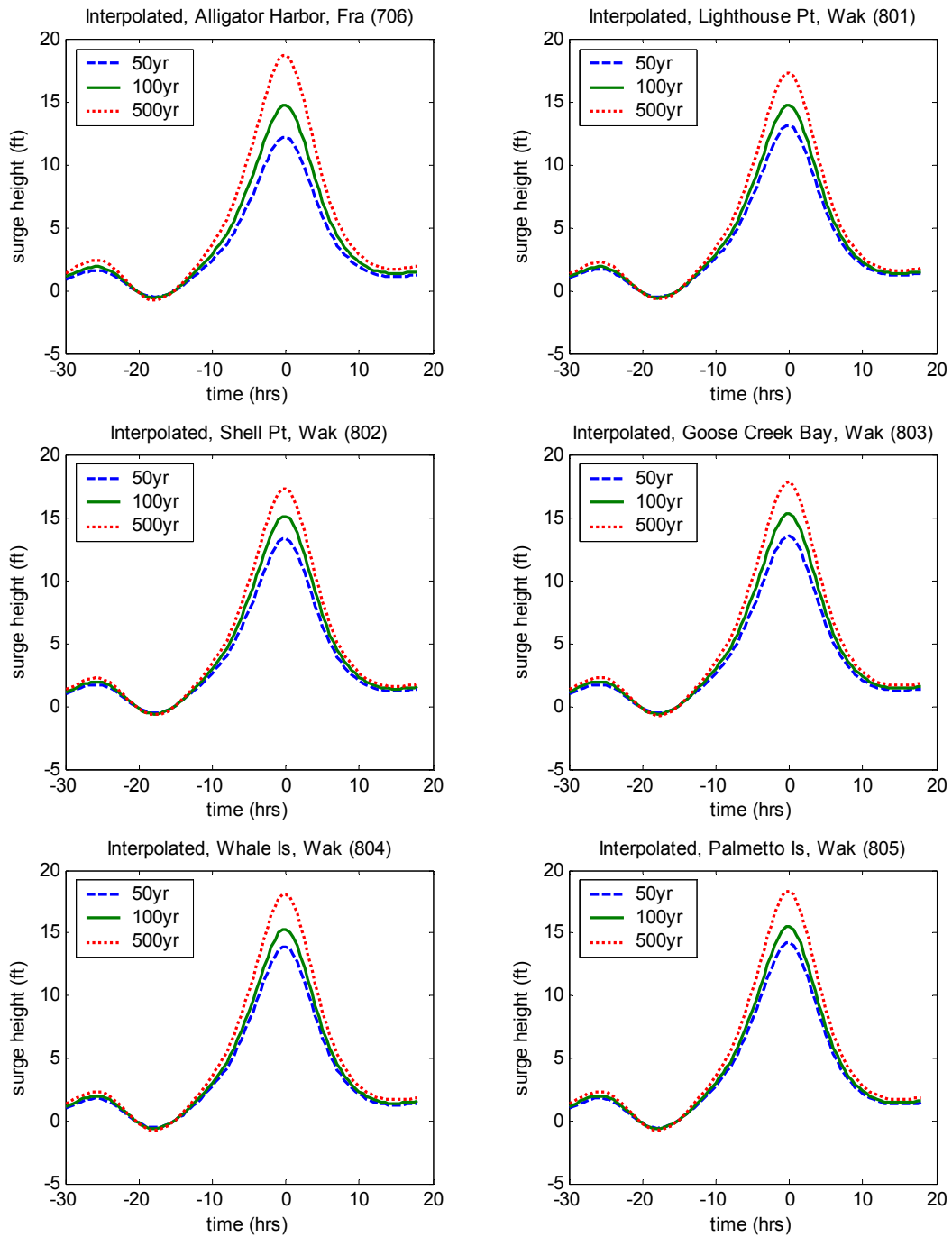


Figure 9. Storm Surge Hydrograph Plots for Franklin and Wakulla Counties.

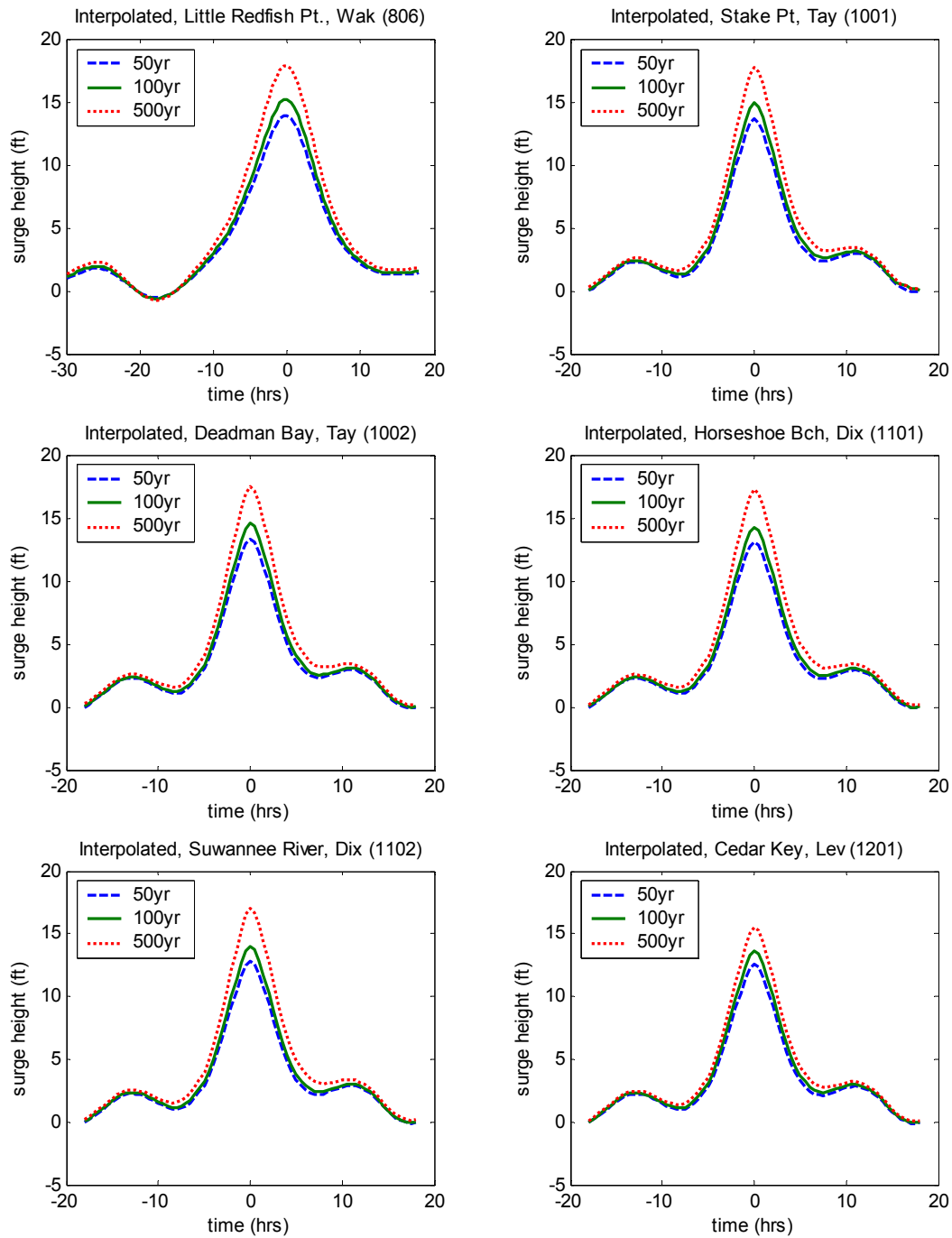


Figure 10. Storm Surge Hydrograph Plots Wakulla, Taylor, Dixie and Levy Counties.

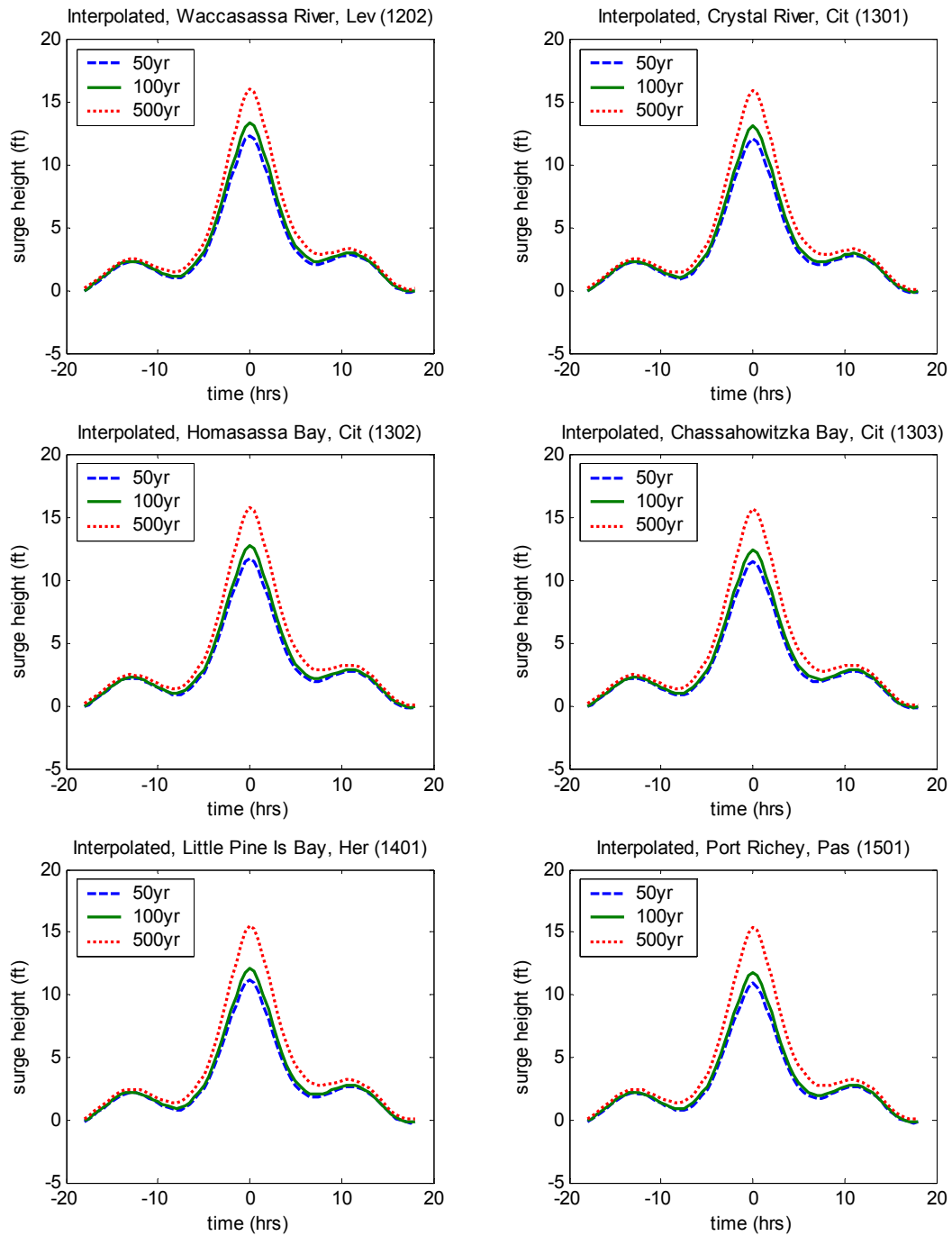


Figure 11. Storm Surge Hydrograph Plots for Levy, Citrus, Hernando and Pasco Counties.

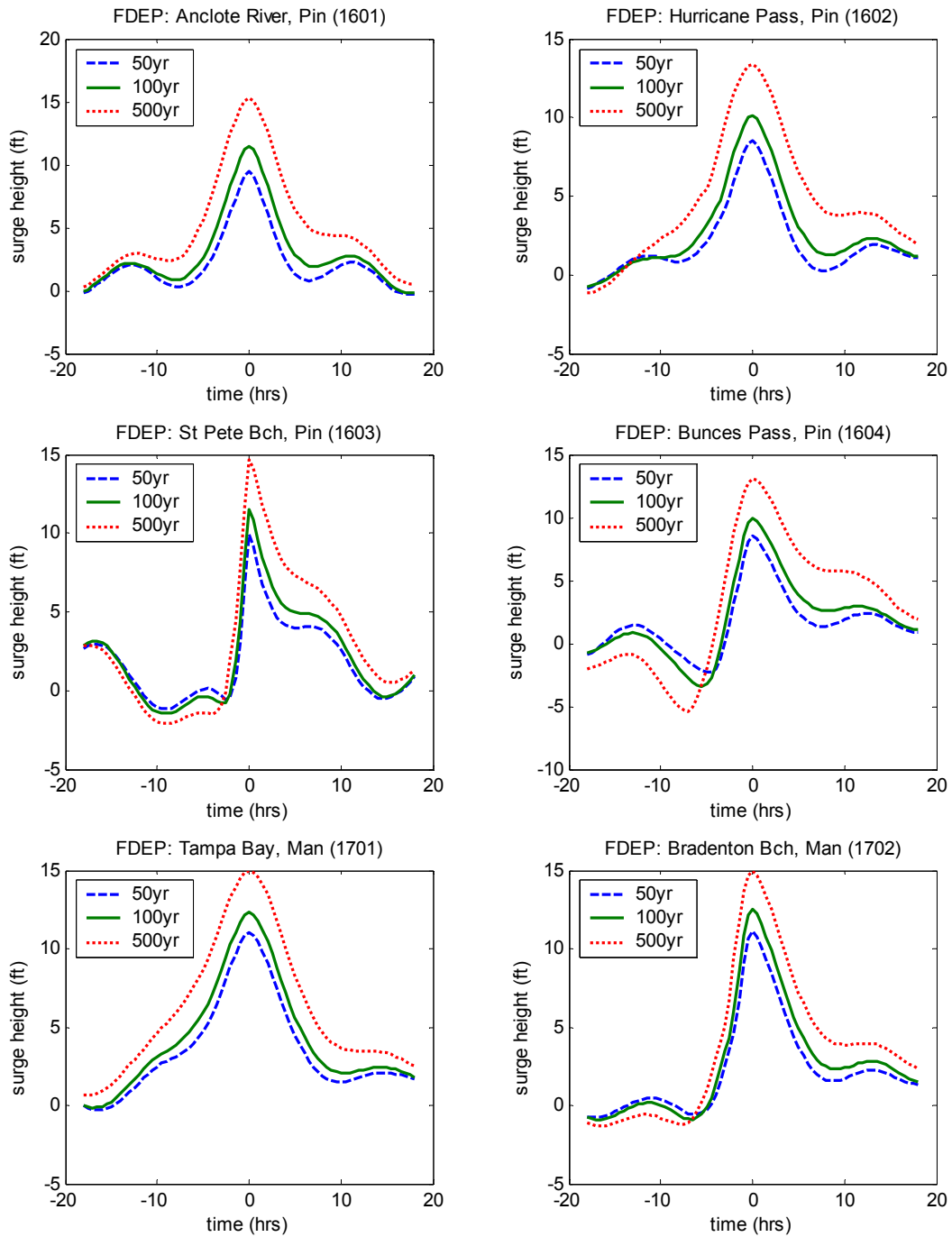


Figure 12. Storm Surge Hydrograph Plots for Pinellas and Manatee Counties.

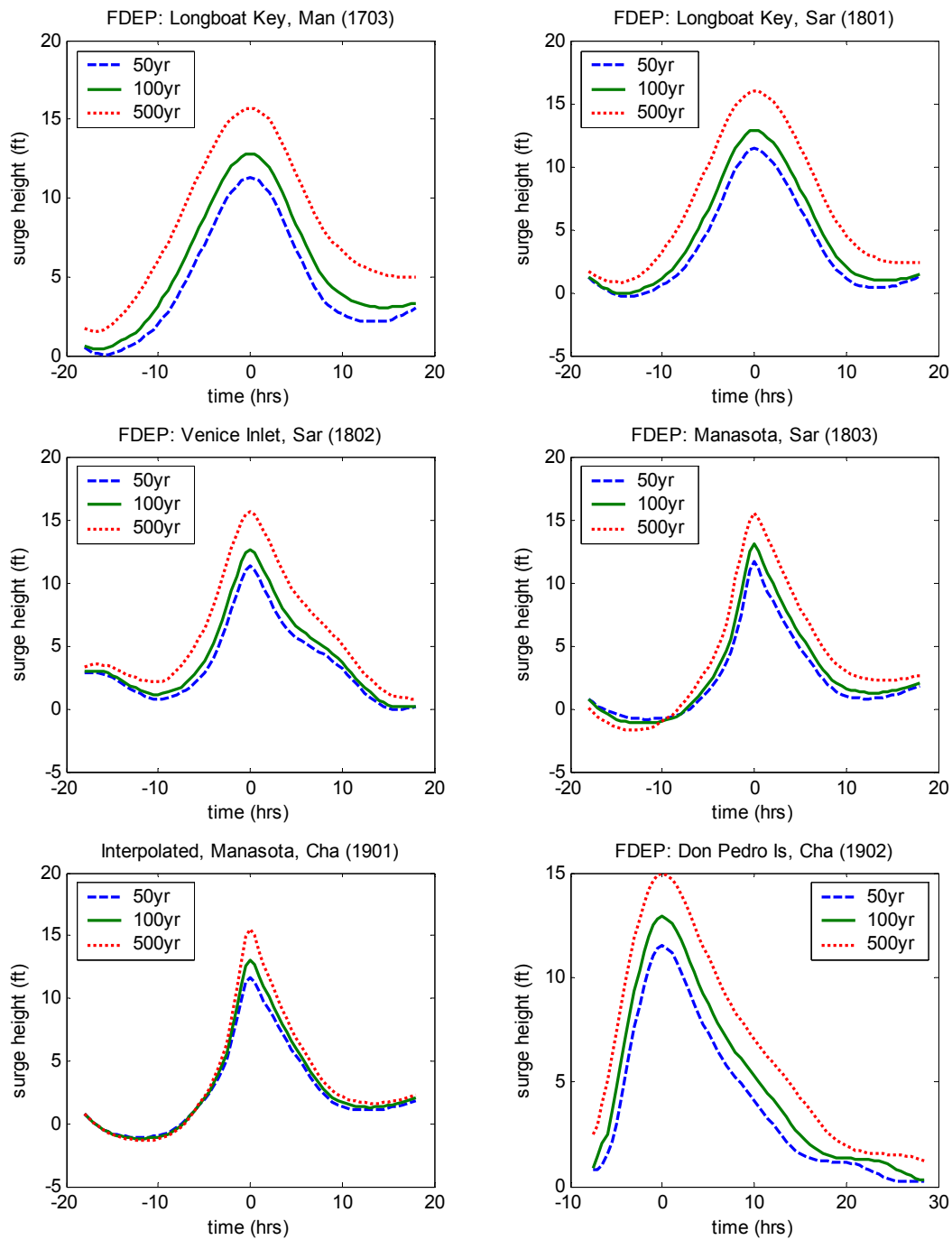


Figure 13. Storm Surge Hydrograph Plots for Manatee, Sarasota and Charlotte Counties.

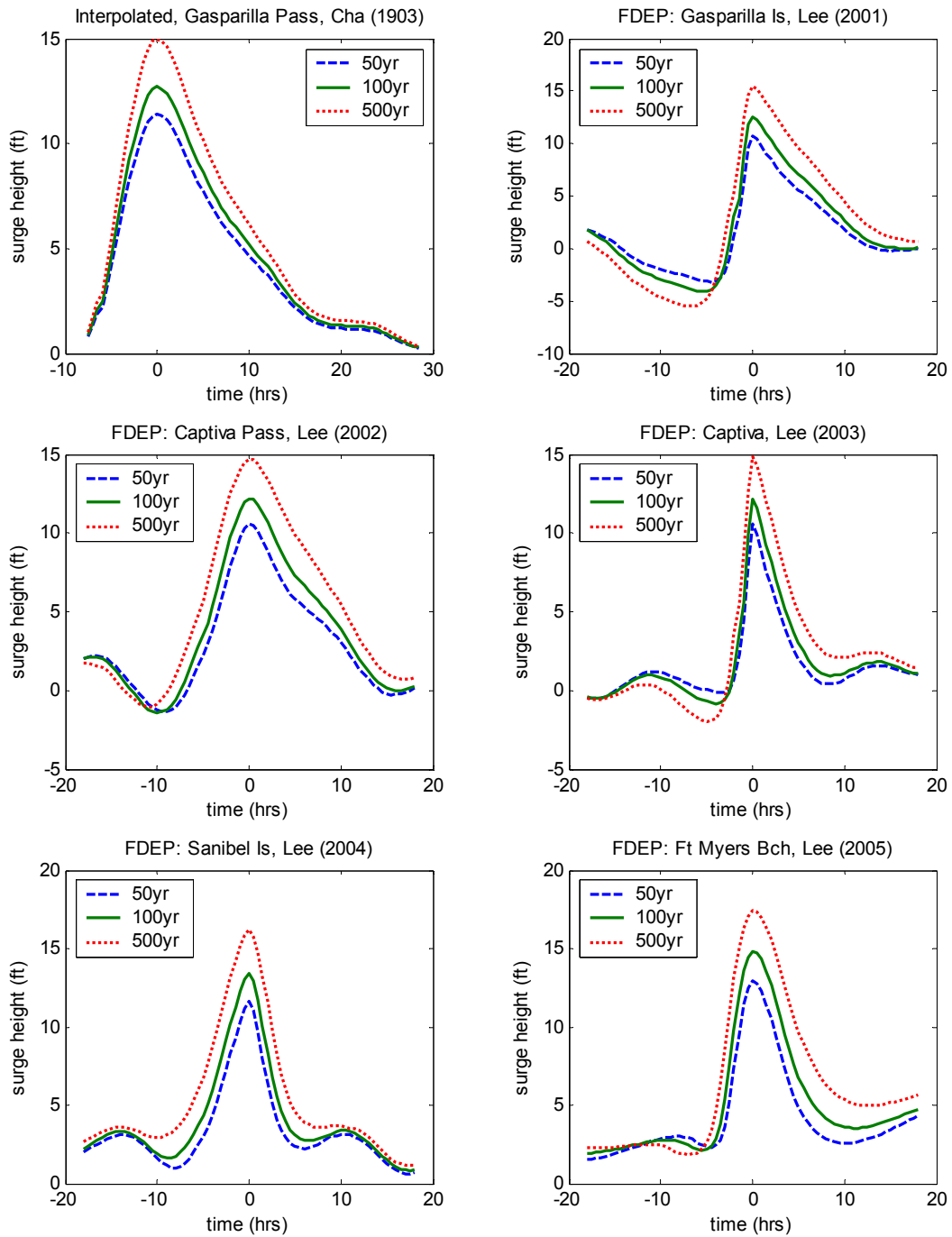


Figure 14. Storm Surge Hydrograph Plots for Charlotte and Lee Counties.

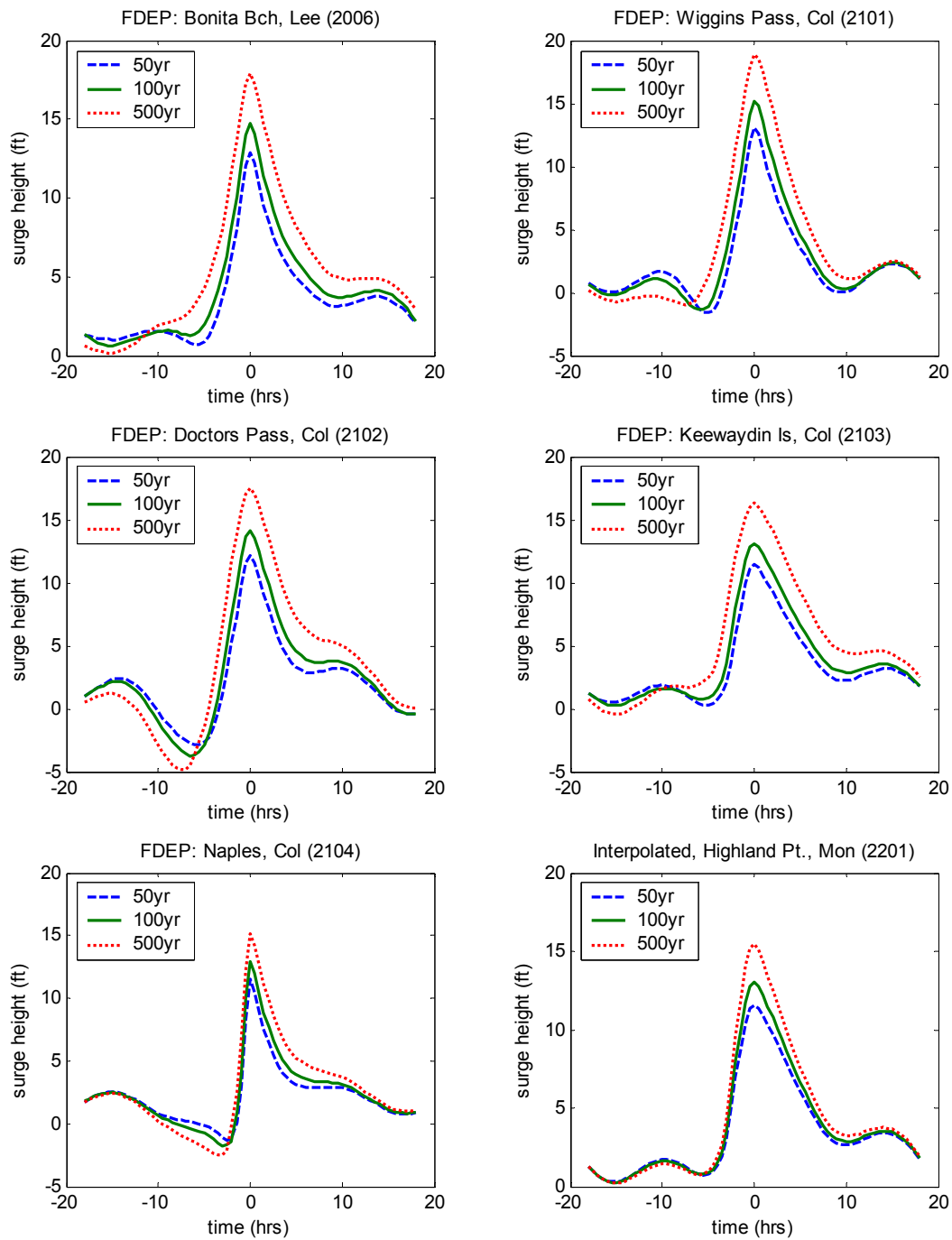


Figure 15. Storm Surge Hydrograph Plots for Lee, Collier and Monroe Counties.

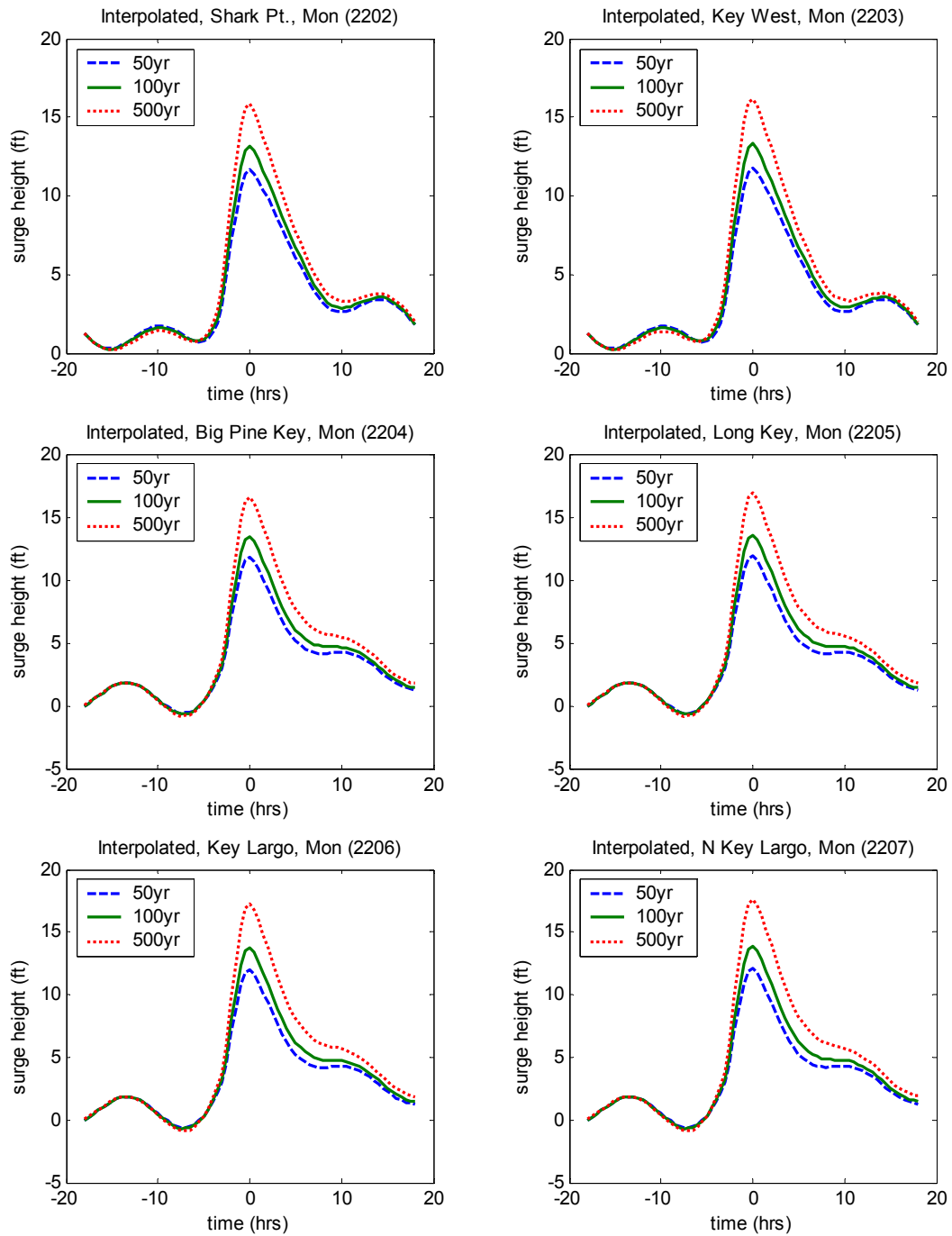


Figure 16. Storm Surge Hydrograph Plots for Monroe County.



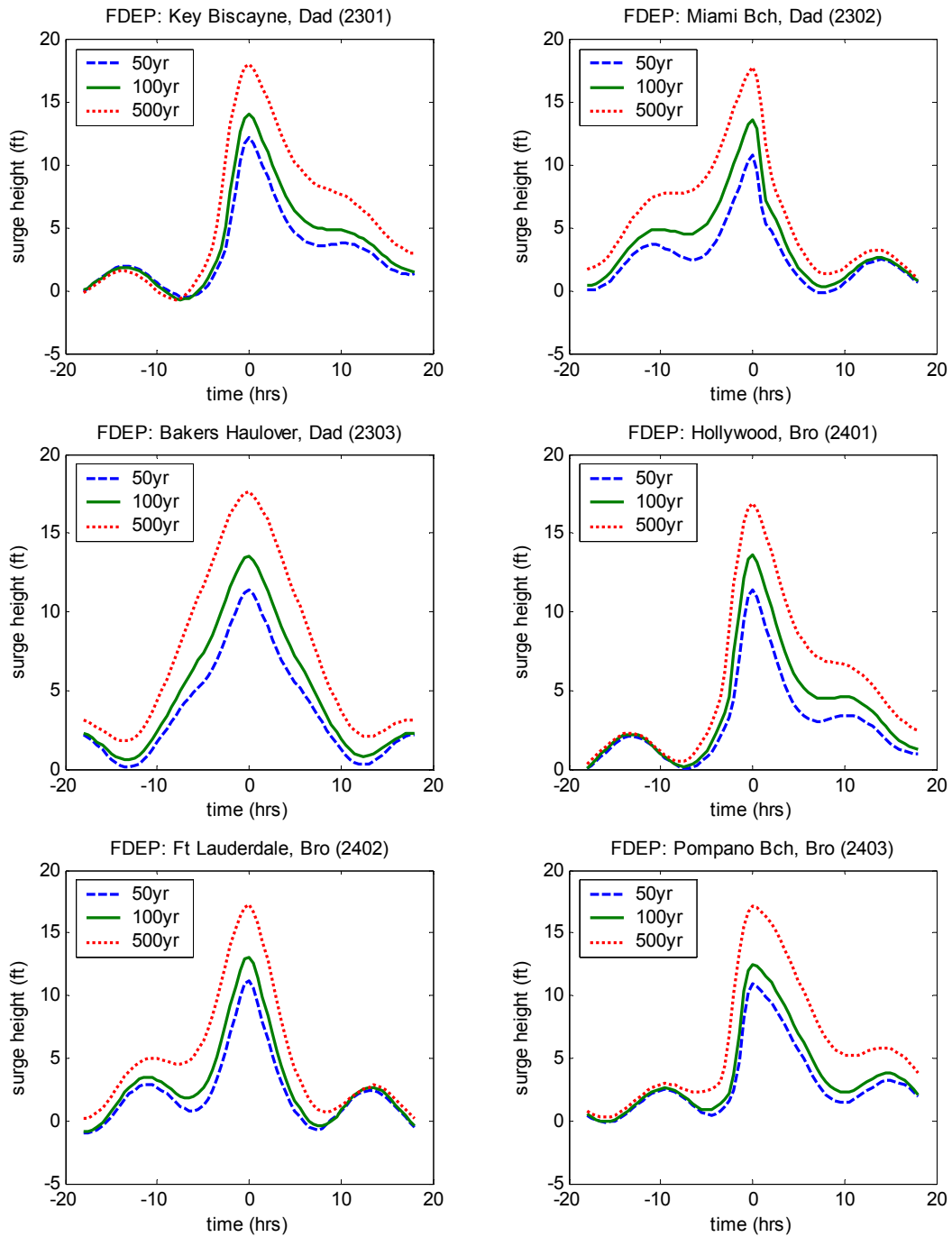


Figure 17. Storm Surge Hydrograph Plots for Dade and Broward Counties.

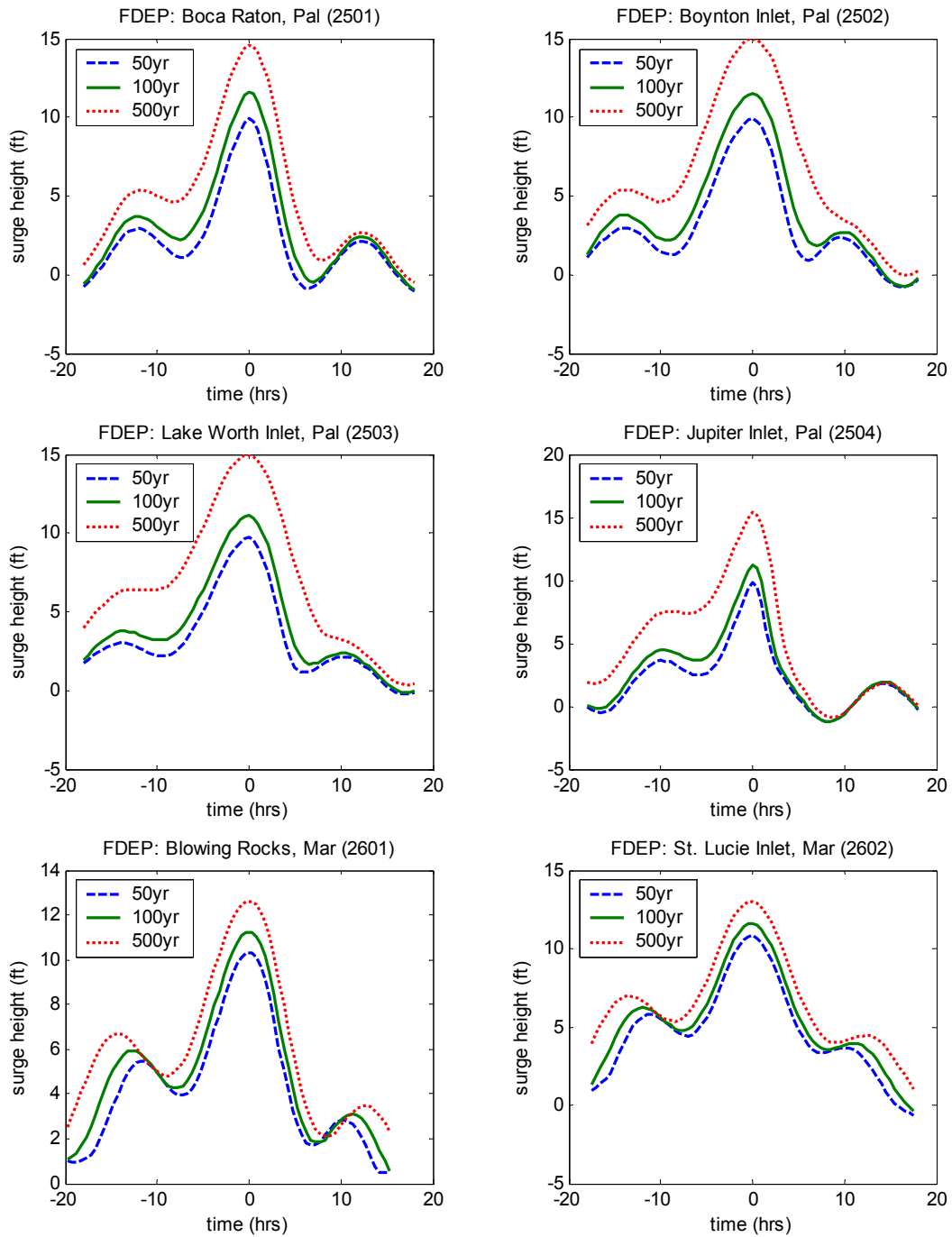


Figure 18. Storm Surge Hydrograph Plots for Palm Beach and Martin Counties.

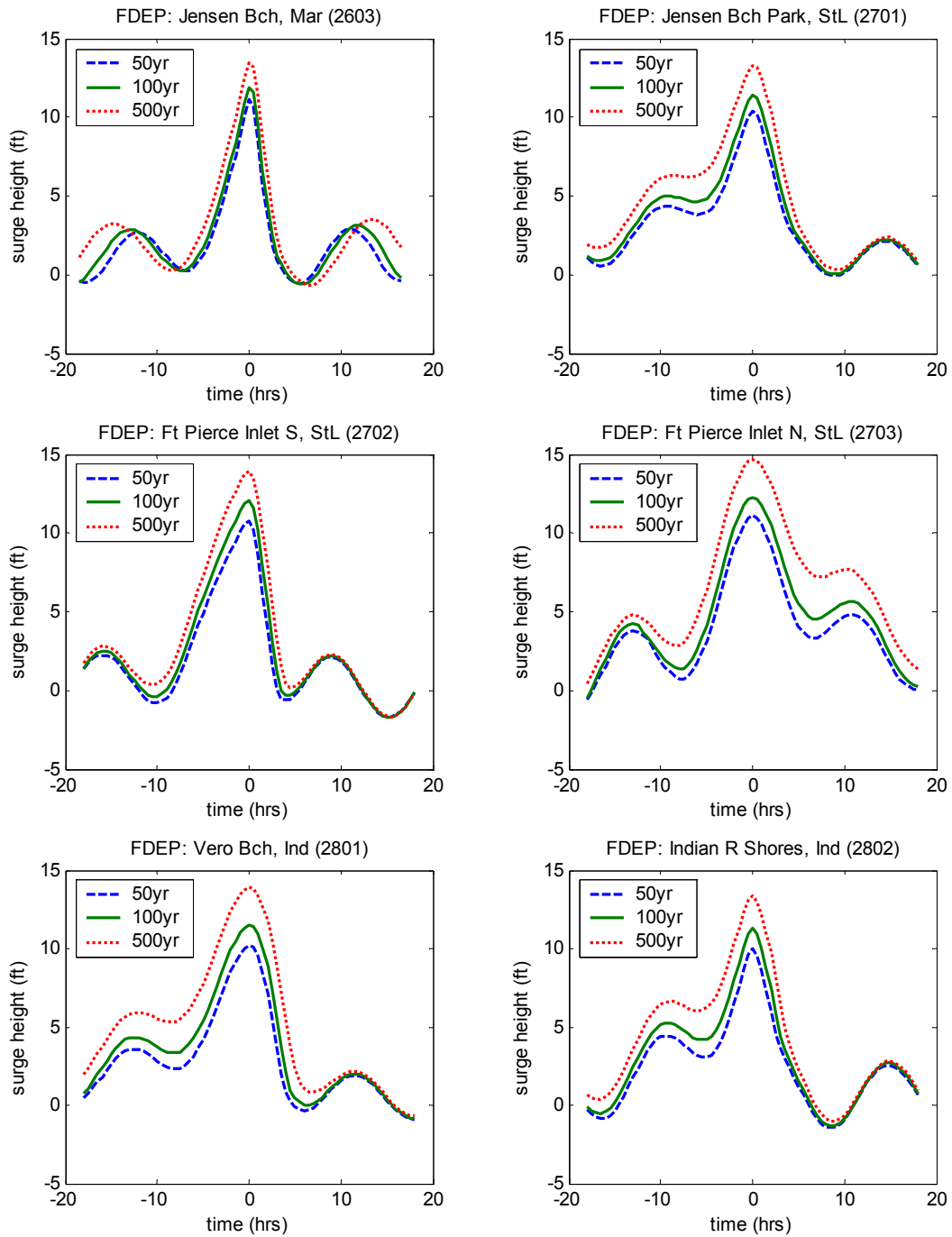


Figure 19. Storm Surge Hydrograph Plots for Martin, St. Lucie and Indian River Counties.

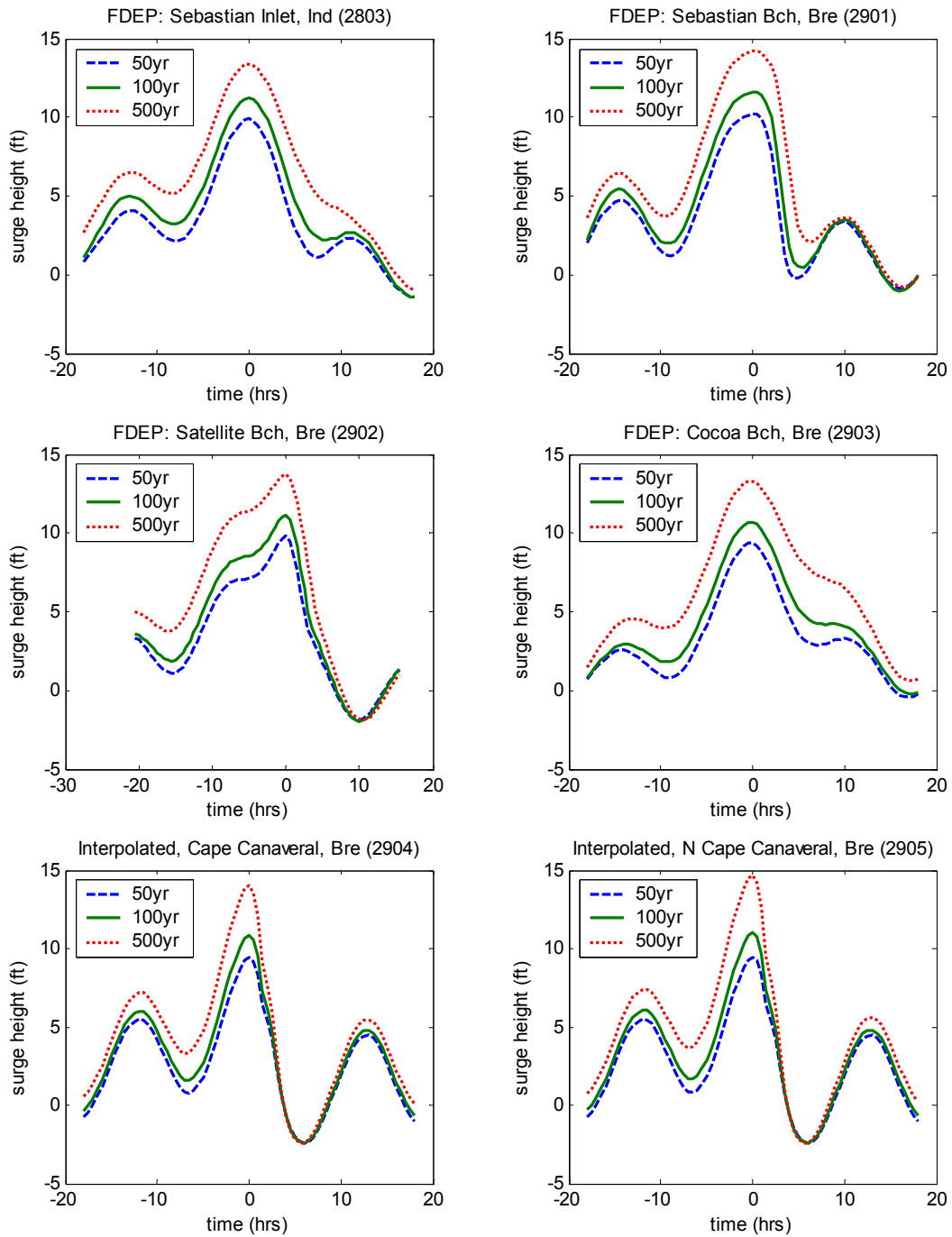


Figure 20. Storm Surge Hydrograph Plots for Indian River and Brevard Counties.

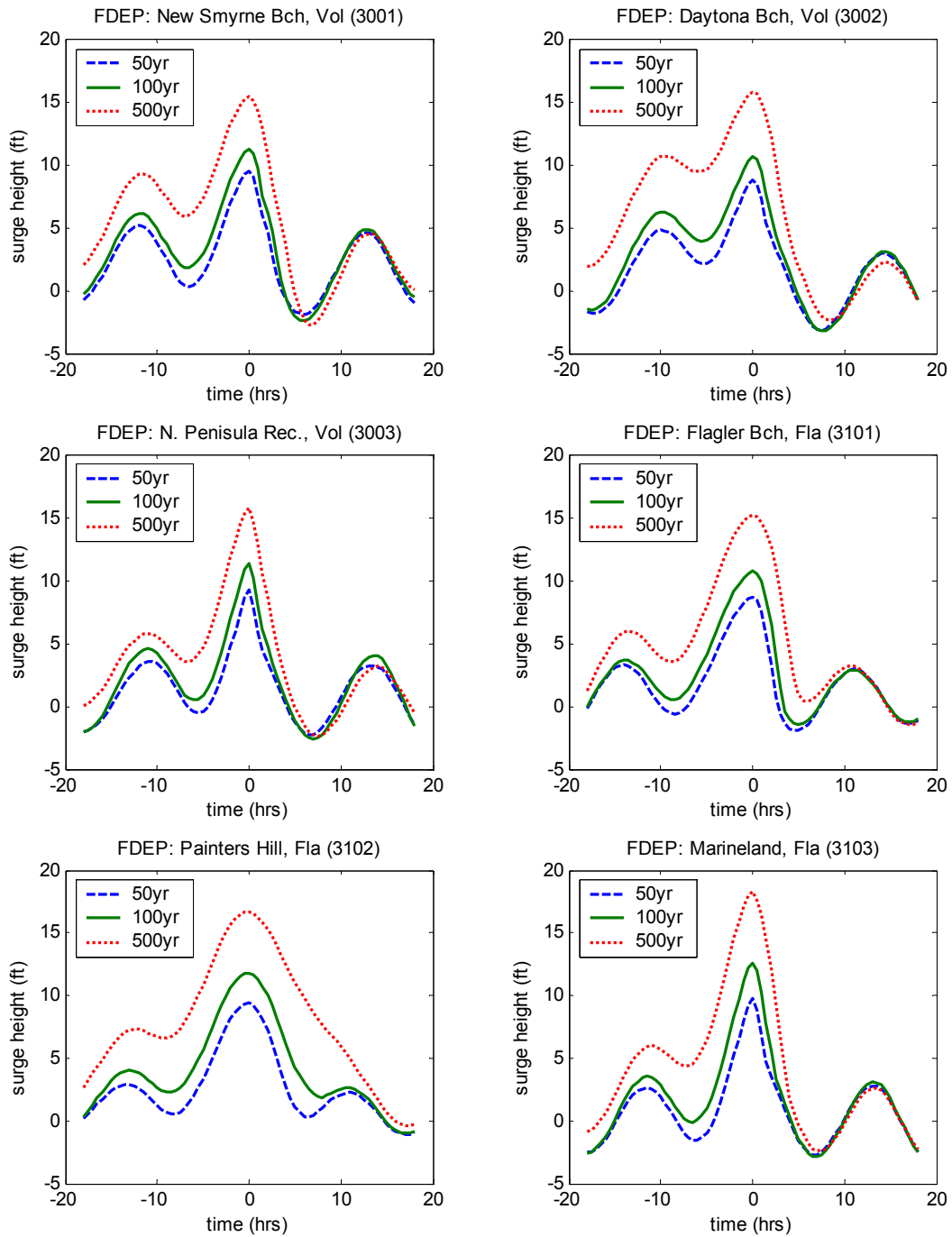


Figure 21. Storm Surge Hydrograph Plots for Volusia and Flagler Counties.

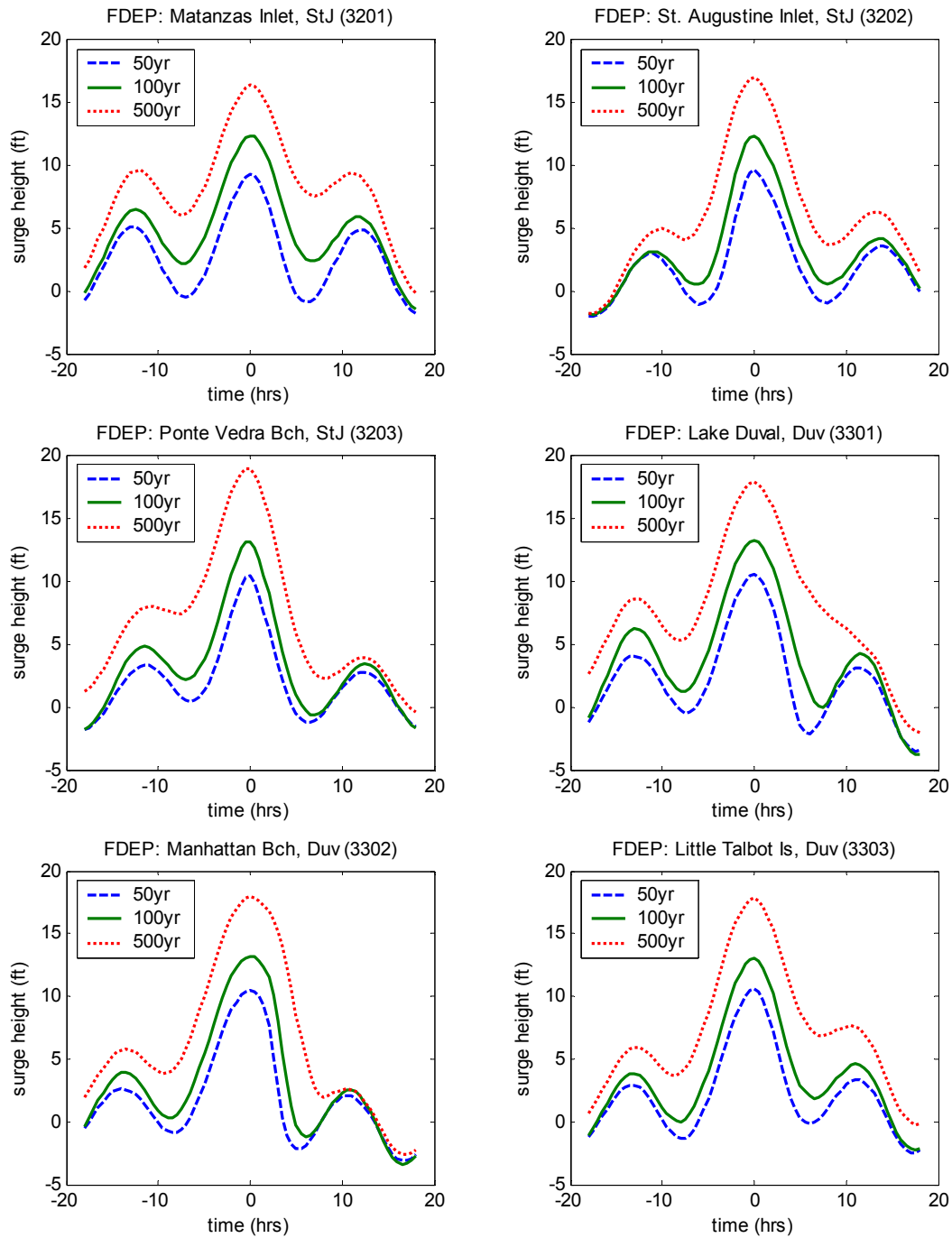


Figure 22. Storm Surge Hydrograph Plots for St. Johns and Duval Counties.

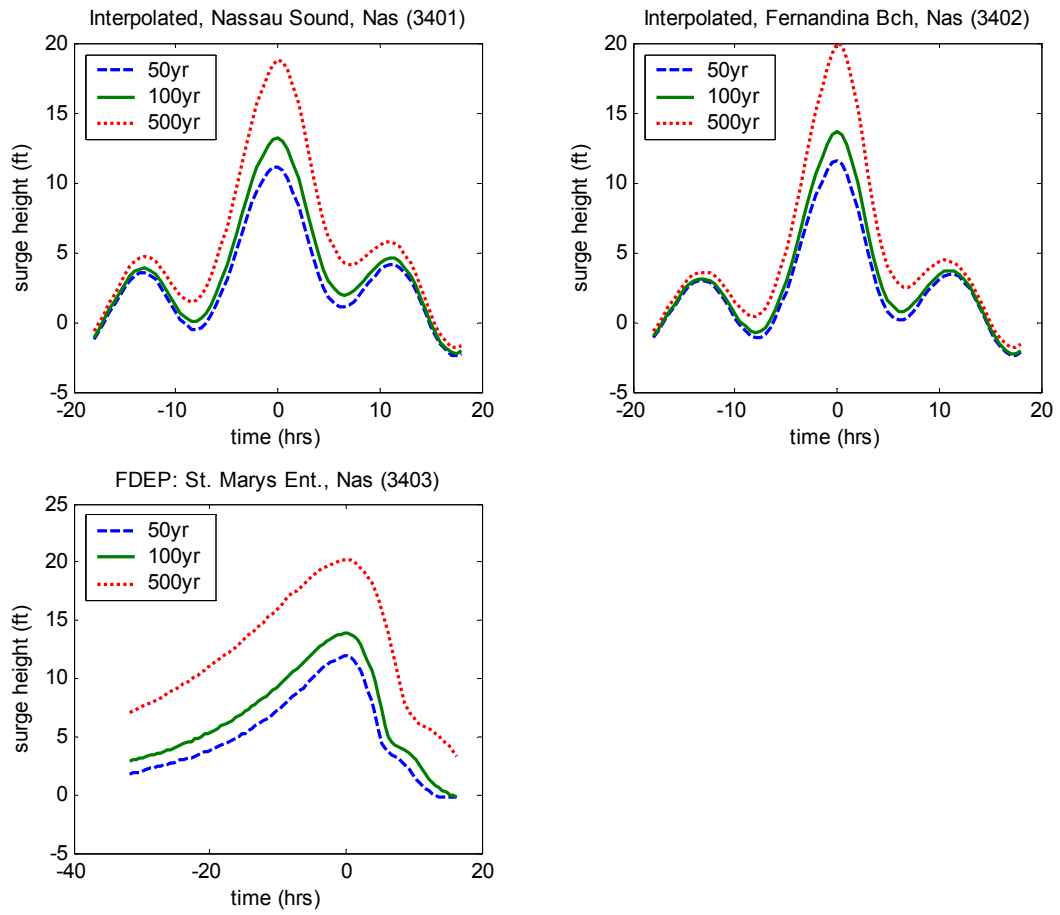


Figure 23. Storm Surge Hydrograph Plots for Nassau County.