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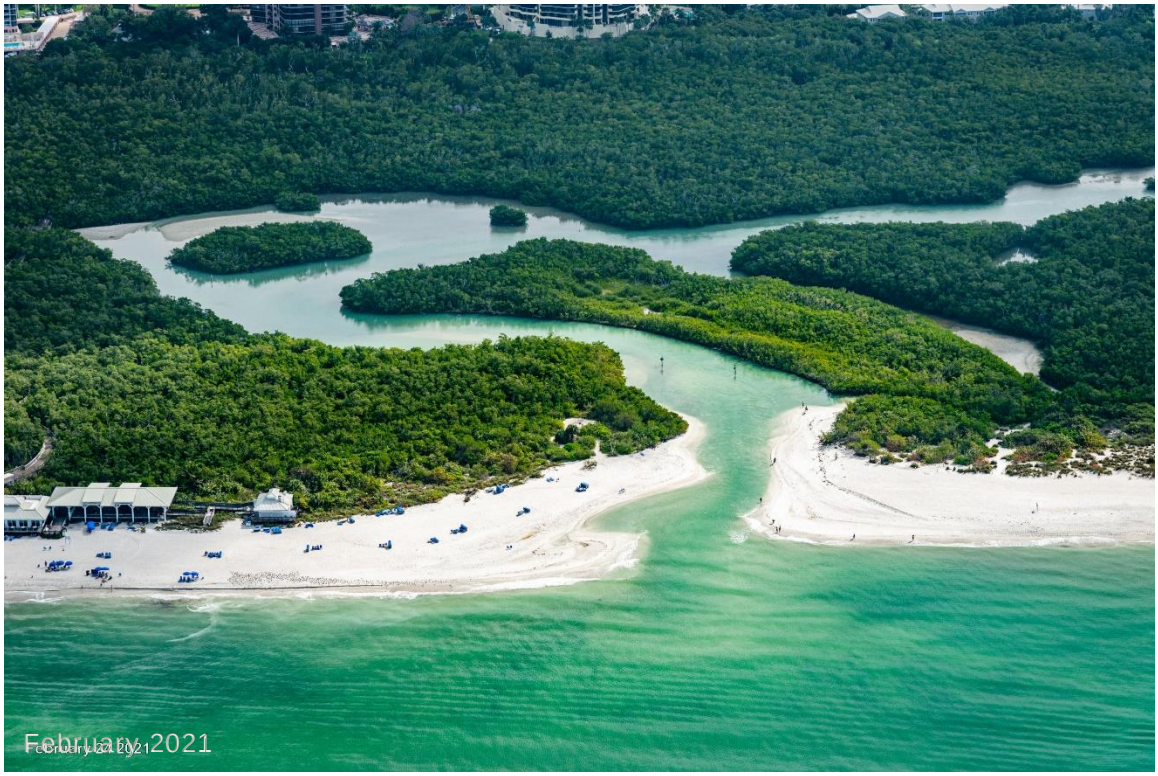
Clam Pass
Physical and Tidal Monitoring Report
2020



March, 2021

Prepared for
Pelican Bay Services Division

Prepared by

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1. BACKGROUND

This report provides the annual assessment of the bathymetric and hydrologic conditions of Clam Pass during 2019. Clam Pass is a small wave dominated inlet on the southwest coast of Florida that provides a tidal connection to 560 acres of nature preserve including 420 acres of mangroves. The relatively small tidal prism of Clam Bay provides a critical balance between tidal flow and littoral processes moving to the inlet. This affects the inlet hydraulic efficiency over time, especially when littoral transport rates are high due to periods of high wave energy. Clam Pass requires maintenance dredging to remain an open and viable inlet and bay system. The pass and wetland preserve have been managed according to a Natural Resource Protection Area (NRPA) Management Plan first adopted in 1999. An updated NRPA Management Plan was developed in 2014 and adopted by Collier County in 2015. Following the implementation of the Clam Bay NRPA Management Plan, prior to 2019, maintenance dredging occurred in 1999, 2002, 2007, 2013, 2016, and most recently in 2018. An emergency maintenance excavation was completed in August of 2017 to restore flow following the passage of Tropical Storm Cindy and other high energy events in early summer. After the 2017 maintenance excavation, the area was impacted by Hurricane Irma and Tropical Storm Nate in 2017, followed by a series of cold fronts during early 2018. A maintenance dredging event in April/May of 2018. The maintenance project completed during 2018 removed approximately 8,200 cubic yards of sand from sections A, B, and C. An additional ±2,000 cubic yards were graded to simulate natural shorelines along inlet banks. A bathymetric survey was completed in May 2019, approximately one year post dredging. In November 2019, an informal mapping of the inlet bathymetry was conducted by Humiston & Moore Engineers for a qualitative assessment of inlet conditions since the Review of Inlet Management report.

This annual report provides a summary of the physical and tidal monitoring metrics incorporated in the 2015 Clam Bay NRPA Management Plan. Physical monitoring is based upon surveys and mapping of the inlet system. Hydraulic monitoring of the bay system includes continuous water level and tidal data collection at four locations within the bay system.

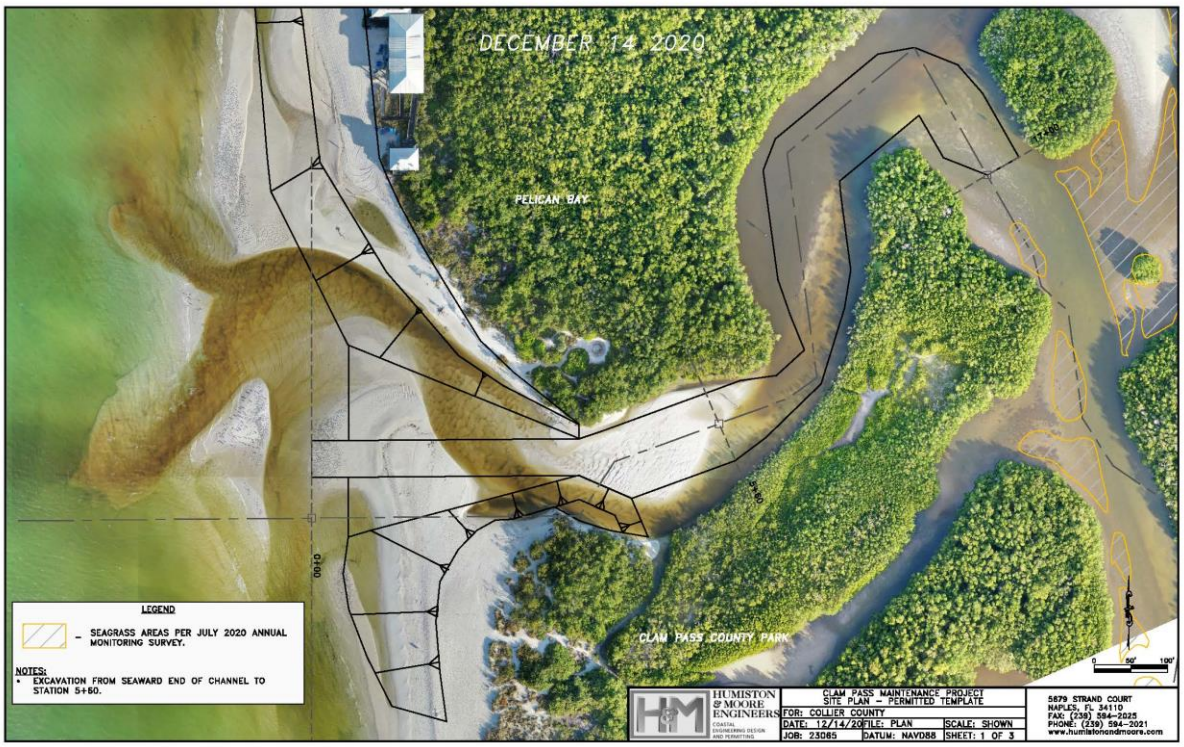
2020 Clam Pass Conditions.

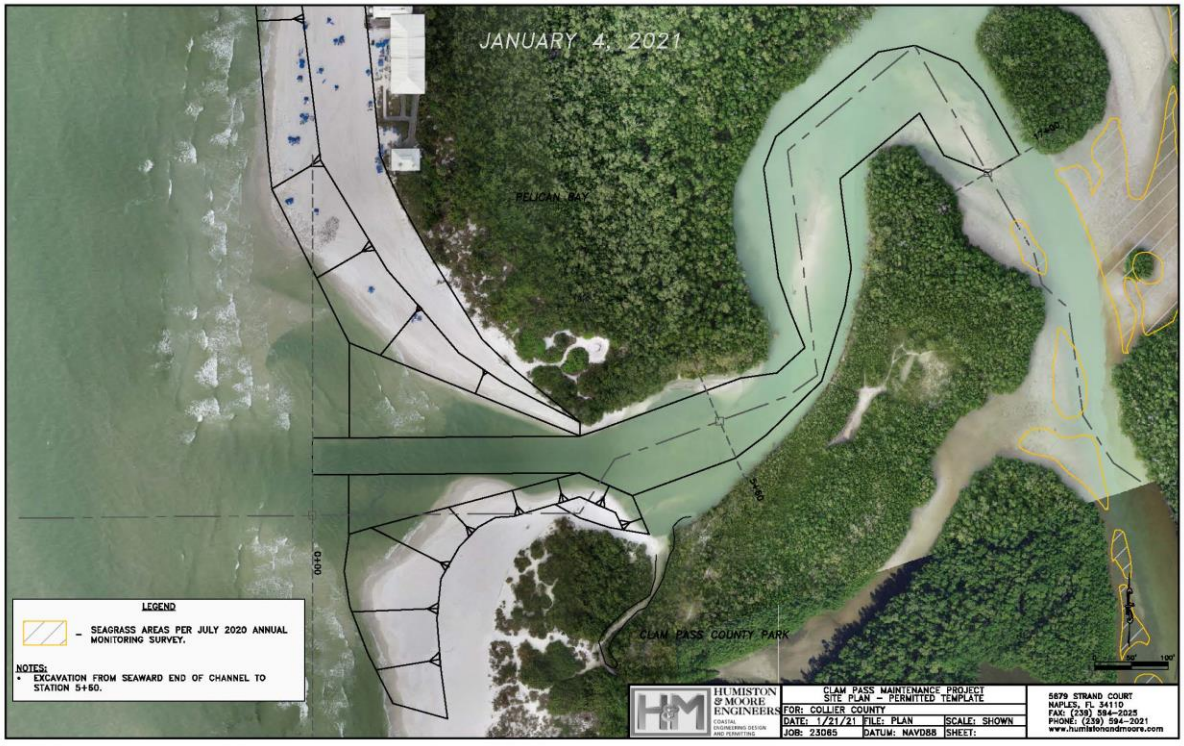
The monitoring of the inlet conditions over the early months of 2020 indicated high rates of sand accumulation at the south bank of the inlet and progressive channel migration northward. This was primarily due to persistent flow of sand from south side of the inlet since the sand placement at the Clam Pass park in the 2019/2020 winter.

A limited maintenance excavation and grading was completed in April 2020 to mechanically bypass the sand accumulation at the south side of the inlet and restore the inlet channel to its design template. This helped restore tidal flow in time prior to turtle nesting season and the summer tropical season. Over the 2020 summer months wave energy from the south continued the accelerated rate of sand inflow towards the inlet from the south and sand accumulation at the inlet mouth continued to push the inlet northward.

A second limited maintenance work included removal of the sand spit formed from the south bank across the inlet entrance and re-grading the inlet banks using mechanical equipment. The December 2020 also included excavation of sand accumulated in the flood shoal area in section B. The project removed approximately 10,300 cy from the permitted template and grading areas between Station 0+00 and Station 5+50. Approximately 3,900 cubic yards were removed mechanically from the inlet and 6,400 cubic yards were regraded; the excavated material was placed on the adjacent banks and in the vicinity of R-41.

This project was substantially completed on January 4, 2021 and surveys were completed on January 5, 2021. Aerial photos for condition pre and post the December 2020 dredging event are shown below.





2. PHYSICAL MONITORING

2.1. INTRODUCTION TO INLET GEOMORPHOLOGY

An inlet channel is one part of a larger tidal inlet system where the inlet connects the bay system to the Gulf of Mexico. The tidal flow through flood and ebb tides interacts with active beach wave and sediment transport processes that influence the stability of a tidal inlet. The morphologic features of a tidal inlet include the ebb shoal, flood shoal and inlet channel. **Figure 1** illustrates these three features. The flood shoal includes the sand shoals on the bay side of the inlet channel. The flood shoal is less dynamic than the gulf side of the inlet as it is influenced mainly by tidal flow and sheltered from the varying wave conditions on the open coast side. The ebb shoal features can be explained as sand bar features forming a delta on the open coast side of the inlet. The ebb shoal delta shields the inlet channel from waves and provides pathways for sand transport along the coast to bypass the channel without shoaling the inlet closed. A stable inlet system requires an ebb shoal feature that prevents rapid shoaling at the inlet mouth. The inlet channel maintains its flow cross section through tidal flow that scours the channel to required flow area while the waves are moving large amounts of sand along the coast. The stability and dynamics of a tidal inlet is based on the balance of these two forces. The magnitude and direction of wave energy plays a significant role in the shape and dynamics of the inlet features.

2.2. AERIAL PHOTOS

Perspective aerial views are taken on monthly basis and provided to document the channel alignment and the overall condition of the inlet. Aerial photos are included in **Appendix A**. These illustrate the condition of the pass during 2020. The continuous process of sediment movement from the south toward the north beach can be observed throughout the year. As the inlet shoals are repeatedly reworked by the tides and waves, a gradual shift from south to north occurred over the past year across the inlet. During 2020 the inlet required two maintenance grading events to reshape the entrance due to spit formation.

2.3. HYDROGRAPHIC AND BEACH SURVEY

The physical monitoring data is used to characterize the flow areas and shoaling within the channel and flood shoal areas. Physical monitoring data includes bathymetric surveys of the inlet channel, flood shoal and ebb shoal features. The data analysis includes evaluation of the flow cross-section areas in three main sections of the dredging template, Sections A, B and C. **Figure 2** shows the three monitoring segments. Section A represents the inlet channel, Section B represents the seaward part of the flood shoal and Section C represents the bay side part of the flood shoal. The analysis included an evaluation of the cross section of flow below mean high water and volume of sand within each segment. The cross section of flow was computed at each survey station spaced approximately 50 feet apart. The average and minimum cross section areas were used as indicators of the physical condition of the flow area through each of the three segments. The scope of the survey and comparative profile plots with previous survey data are included in **Appendix B**. Each of these segments, along with the channel length and ebb shoal parameters were discussed in detail in the Review of Inlet Management. Changes since that report have been minor. A summary table including the data referenced above is provided in Section 4 of this report.

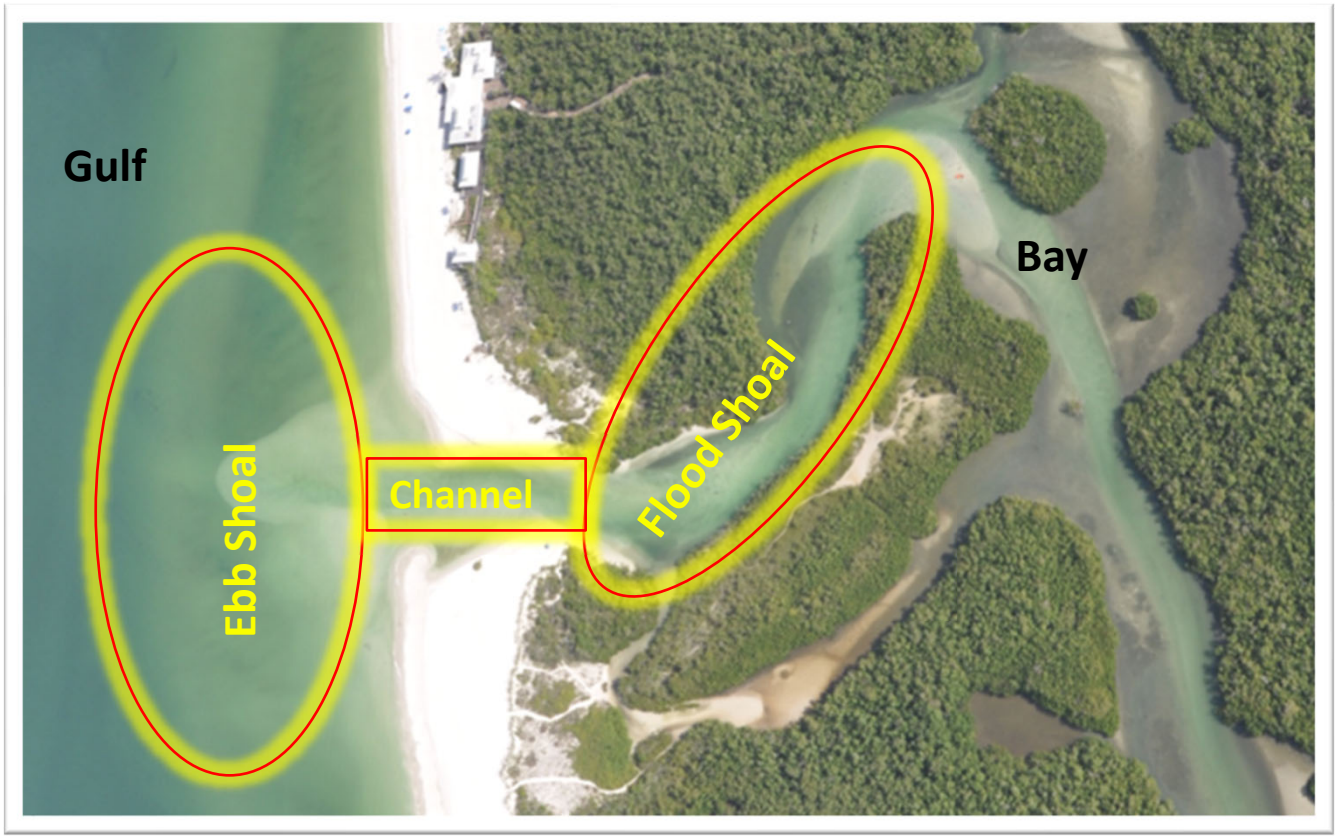


Figure 1. Clam Pass Morphologic Feature Definitions

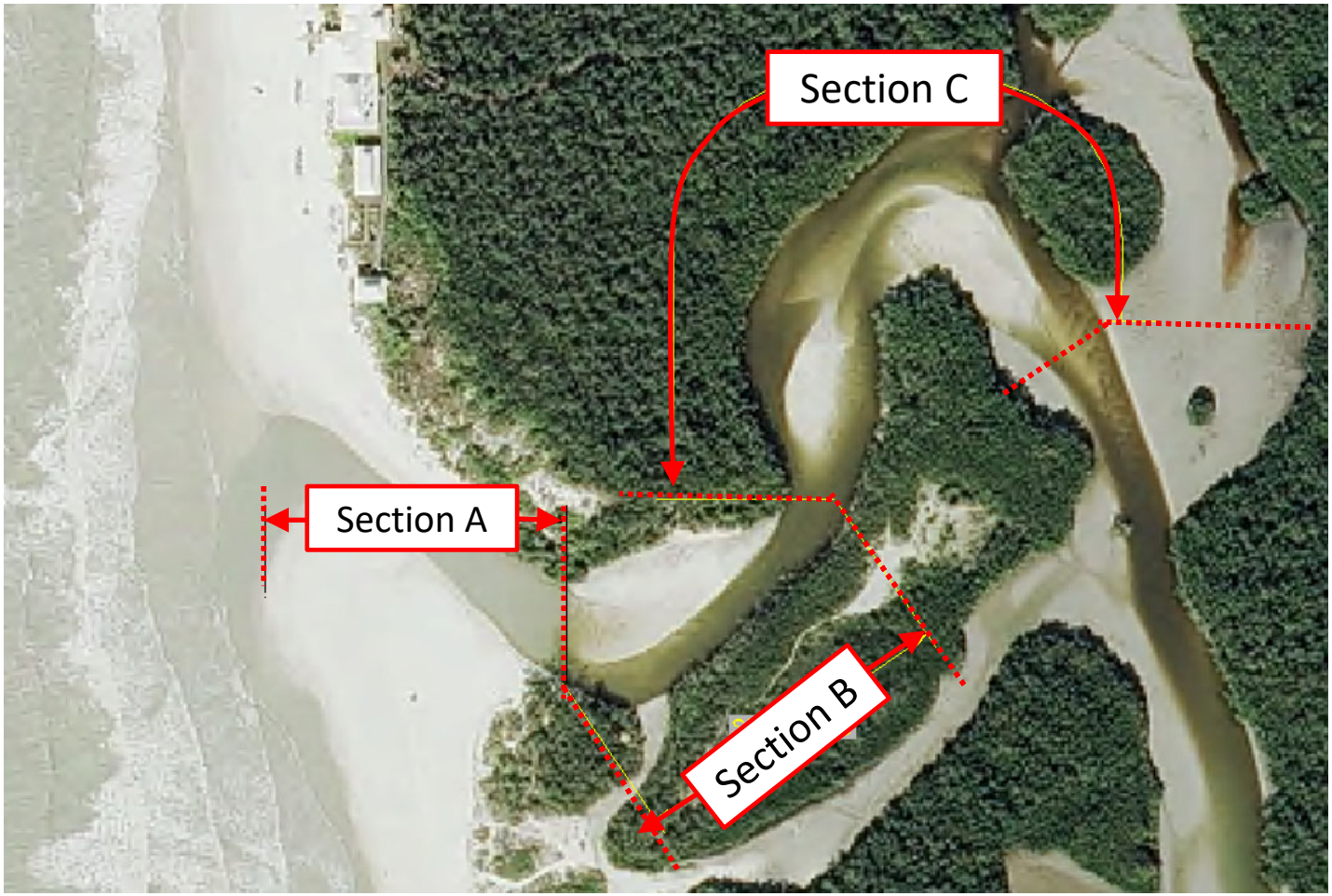


Figure 2. Clam Pass Monitoring Segments

3. TIDAL MONITORING

3.1. INTRODUCTION AND BACKGROUND

Prior to the commencement of the March 1999 dredging, water level recording gauges were installed at selected locations within the Clam Bay estuarine system and Gulf of Mexico to measure tidal ranges. Tides along the southwest Florida coast are mixed, meaning that they exhibit either diurnal (one tide per day) or semidiurnal (two tides per day) characteristics at different times during each month, primarily dependent on the phase of the lunar cycle. There are seasonal variations as well. The locations of the gauges are illustrated in **Figure 3**. This tidal monitoring program has been implemented through a cooperative effort with tidal data collection by PBSD, and data analysis and report preparation provided by H&M.

Understanding the mixed tide characteristics of this area is important for the tidal data analysis. Part of the month, during neap tide, when tidal currents are not particularly strong, the inlet may take on wave dominant characteristics and appear to be shoaling near the entrance. This is particularly true when neap tide coincides with high wave energy events. During the ensuing spring tide roughly two weeks later, however, tidal currents become considerably stronger and may efficiently scour out shoals that formed during the neap tide interval.

Short term channel shoaling and scouring that occurs in this manner causes short term variations in phase lag and tidal range data. This process therefore explains much of what appears as scatter in the phase lag and tide range data. When shoals are scoured out of the inlet channel, some of that sand is deposited on the ebb shoal, seaward of the beaches, restoring it to the littoral system. This is part of the sand supply for adjacent beaches; however, some of that sand scoured from the inlet channel becomes redistributed as net accumulation onto the broader interior flood shoals. It is this net accumulation on the flood shoals, usually over a period of several years, which eventually leads to the need for maintenance dredging.

The purpose of the monitoring program is to evaluate inlet characteristics on a comprehensive long term basis, with less emphasis on day to day, week to week changes, or even month to month and seasonal changes. Because of the dynamics of this system, the findings of this report provide a comprehensive evaluation of project performance which, at times, may not seem consistent with visual observation of inlet conditions over relatively short time intervals, particularly conditions that may be observed during or immediately after a storm.

CLAM PASS TIDE GAUGE LOCATIONS

Legend:

- Old Gauge Locations (1998 – 2015)
- New Gauge Location s (2016)

Figure 3 - Clam Pass Tide Gauge Locations

3.2. GAUGES

During 2015, PBSD initiated the purchase and installation new tidal gauges with solar recharging, onsite data logging and remote access capabilities. Installation and initiation of the new gauges was completed in January 2016. The new gauges were installed at marker locations near the previous gauges. Gauges are now installed at the following marker locations, their respective old gauge location is also shown (**Figure 3**):

- Marker 4: Registry (Hotel/County) Boardwalk
- Marker 14: South beach Facility Boardwalk
- Marker 26: North Beach Facility Boardwalk
- Marker 32: Upper Clam Bay

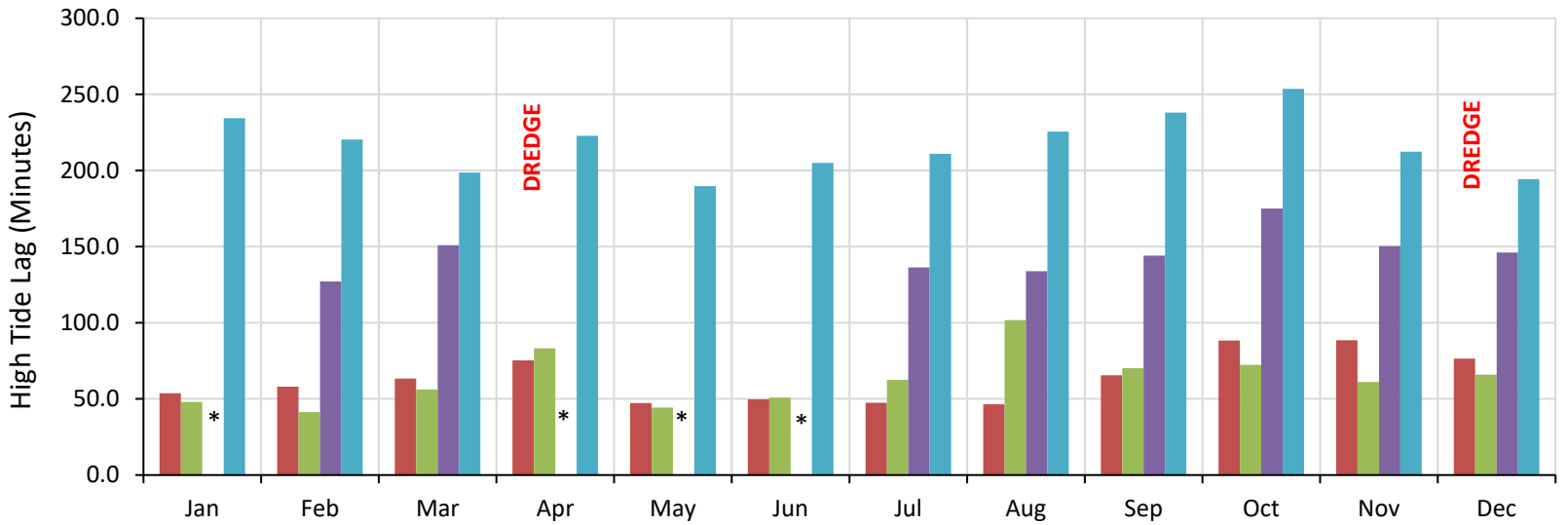
Remote access provides the ability to access the data at any time without interrupting data collection. Problems with data recording can be identified as they occur. Monthly data records can be accessed as soon as the month is completed, allowing for monthly updates to be posted on the web. The water elevation time series for each gauge are presented in **Appendix C** for each month of the 2020 monitoring period. During this time period, the gauge at Marker 26 location malfunctioned in the first half of 2020. The sensor was replaced.

3.3. TIDE PHASE LAG

One of the parameters monitored is tidal phase lag. This is the time difference between the high or low tide in the Gulf of Mexico and the corresponding high or low tide in the bay. The magnitude of this phase lag is an important indicator of inlet dynamics, because shoaling in an inlet that obstructs tidal flow will cause the phase lag to increase. Short time lags indicate good flushing and scouring ability, long time lags indicate potentially limited flushing and shoaling.

Figure 4 presents a monthly average of the low tide and high phase lags over the monitoring period of 2020. Monthly high and low tide lags decreased at Marker 4 and 14 directly after the April 2020 maintenance dredging of the Pass showing improved efficiency and then gradually increased until December 2020. A second maintenance dredging was subsequently implemented during the month of December 2020 and January 2021. Monthly time lags at Marker 32 remained the same suggesting no shoaling of the connector channels.

Figure 5 shows the annual averages of low tide and high tide phase lags from 2008 to 2020. The data indicates that the annual time lags for 2020 were slightly higher at Marker 4 and 14 than during 2019, this was the result of sand accumulation in the Pass entrance which resulted in two maintenance dredging events. The time lag at Marker 32 was on average slightly lower than for 2019 suggesting that the lower bay performed more efficiently than previous years.



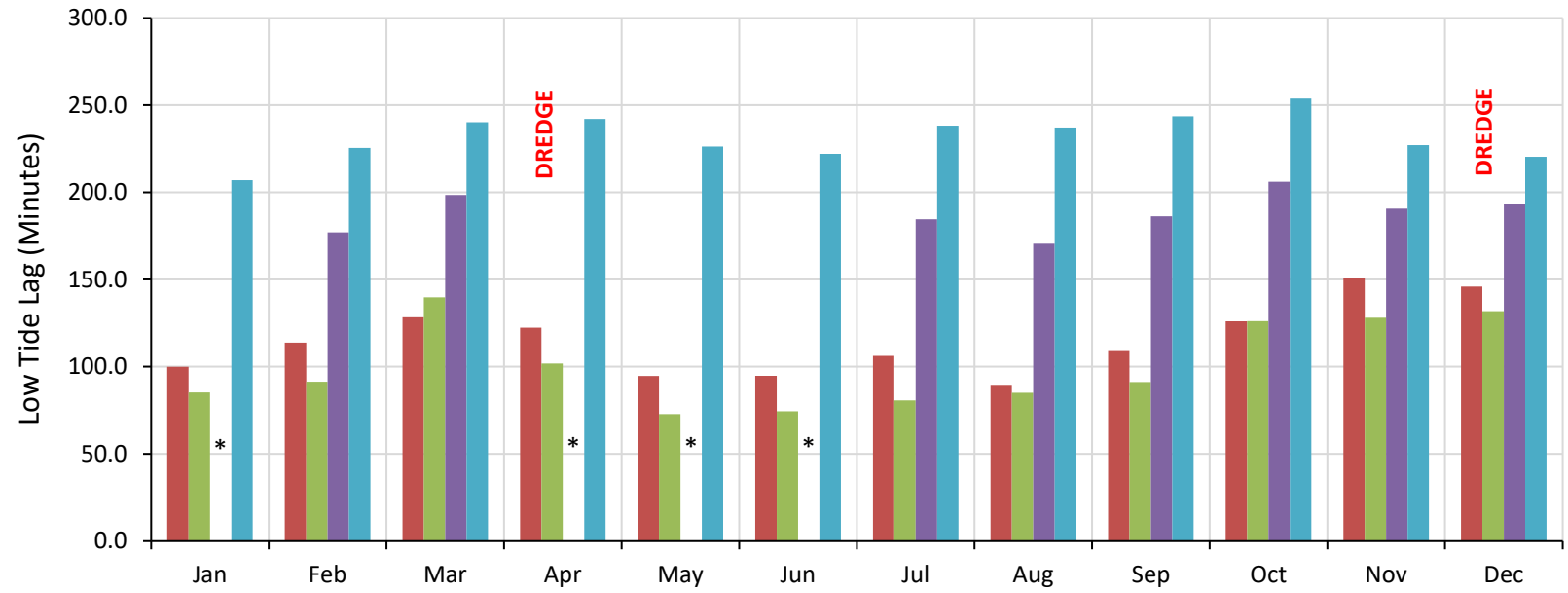


Figure 4 – Monthly Low & High Tide Time Lag Averages – 2020

Figure 5 – Yearly Low & High Tide Time Lag Averages – 2008 to 2020

3.4. TIDE RANGE

The tide range is also an important indicator of the flushing of Clam Bay and shoaling within the inlet. The tide range is the difference in elevation between high water and low water for a given tidal cycle which is an indicator of the tidal prism or volume of water flowing through the inlet at each tidal cycle. The bay tide range will always be smaller than the gulf tide range, however, a reduced bay tide range is an indicator of flow restriction through the inlet channel and shoal features (**Figure 6**).

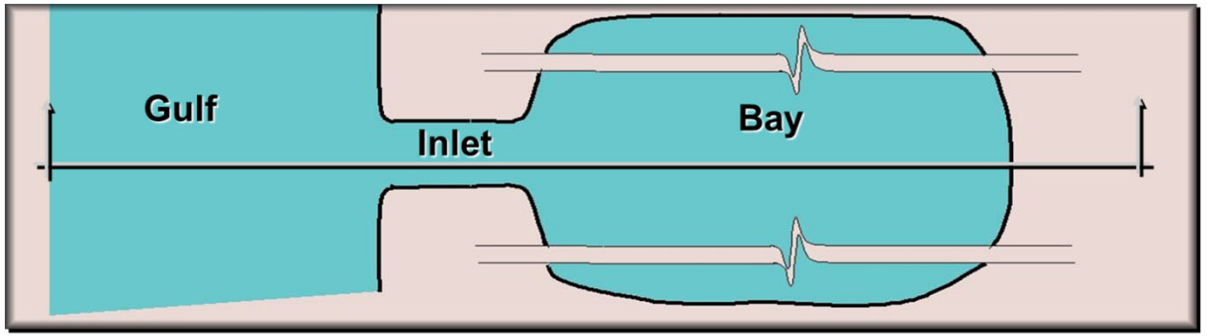
Figure 7 shows both the monthly average tidal ranges and tide ratios for the monitoring period of 2019. The Gulf tide range was around 2 feet, while the Marker 4 & 14 gauges (near the pass) tide ranges were near 1.5 feet. The tidal ranges at Marker 26 and 32 were consistent at around 0.5 feet and 0.2 feet respectively.

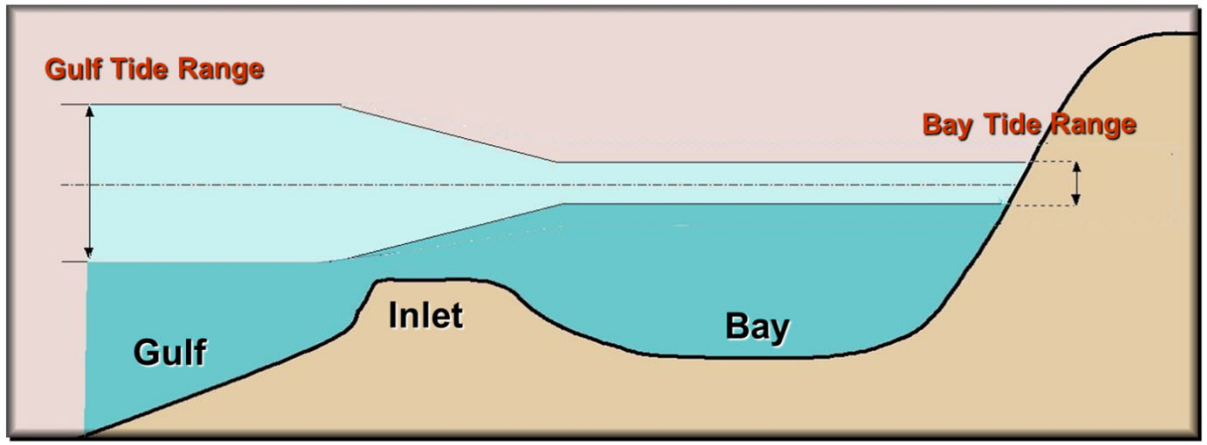
A review of ratios of the tidal range at each monitoring station to that of the gulf tide is used as the monitoring indicator for the flow through the inlet. The annual ratios of bay to Gulf tide from 1998 to date were used to establish a design tidal range ratio for Clam Bay. The available data indicates that when the inlet was hydraulically stable the ratio between the bay (Marker 4 & 14) and Gulf tide was between 0.6 and 0.7 over 90% of the time. The data also showed that this ratio was below 0.5 prior to 1999 dredging when the inlet was unstable and in 2012 prior to the inlet closure. The 2015 NRPA Management Plan set the critical ratio at 0.5, with additional monitoring conducted when the ratio drops below 0.6. The 2015 updated management plan uses the relative tidal range at the Marker 4 and Marker 14 gauges as indicators of hydraulic efficiency.

The plot of the monthly mean tide ratios shows ratios at Markers 4 & 14 dropped below the critical 0.5 ratio in March 2020 and October 2020, both events prompted maintenance dredging of the pass. The latest maintenance dredging event occurred during December 2020 and January 2021, subsequent monitoring indicates that the ratio went back above the critical threshold in 2021.

Average annual tidal ranges and ratios for Clam Pass are presented in **Figure 8** for the time period between 2008 and 2020. The average annual tidal ranges remain within the range of typical values. The average ratios for 2020 at Marker 4 and 14, were within the critical range of 0.5 to 0.6 and lower than the previous year, this is due to the nearshore sand movement which resulted in the maintenance dredging of the entrance of the pass in April and December 2020.

Overall, monthly and annual tide ranges and range ratios indicated a critically stable inlet requiring observation. Two maintenance grading operations were required to maintain the pass open due to shoaling at the mouth.





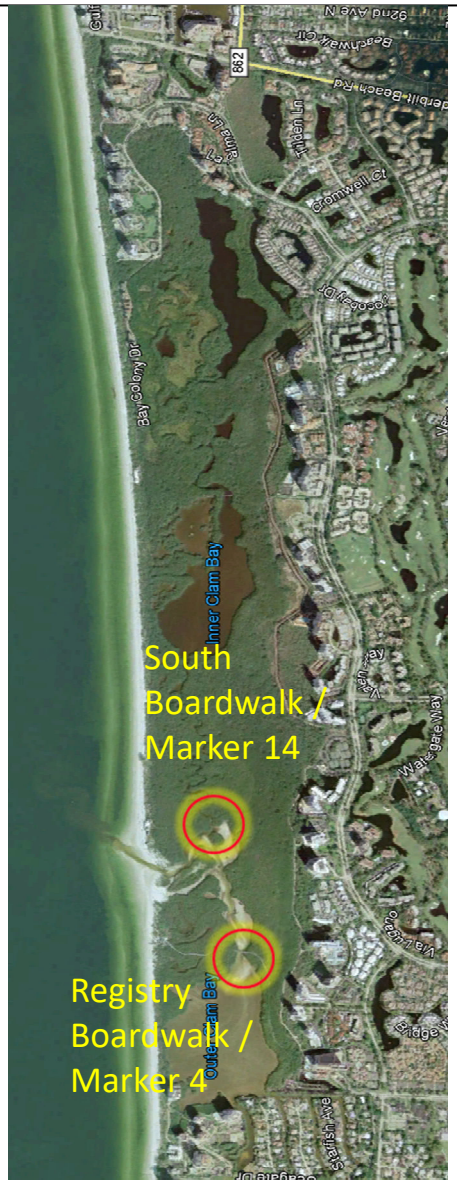


Figure 6. Gulf and Bay Tide Range Illustration

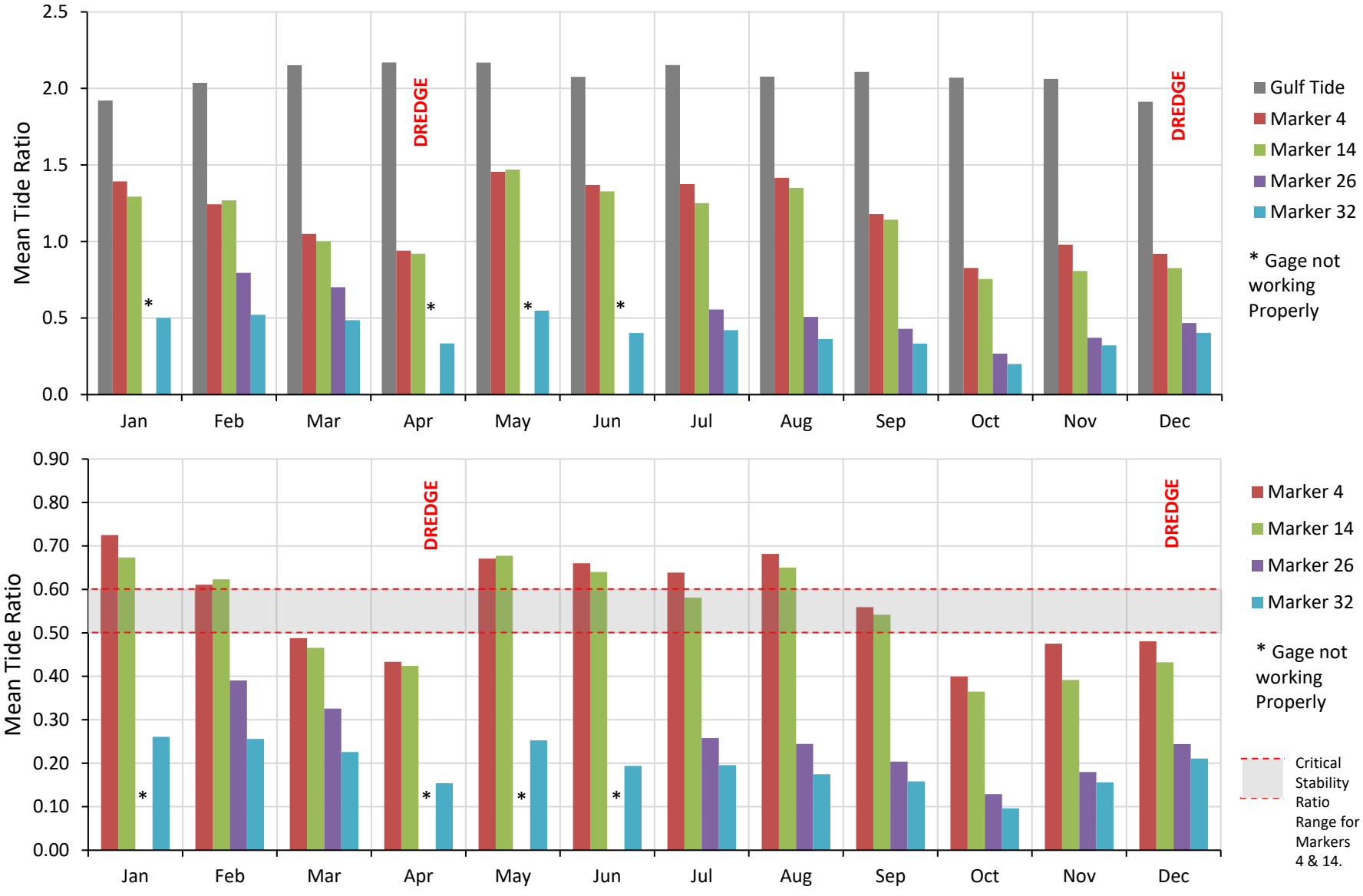


Figure 7 – Monthly Average Tide Range and Tide Range Ratio - 2020

Figure 8 – Annual Average Tide Range and Tide Range Ratio – 2008 to 2020

4. SUMMARY OF RESULTS & RECOMMENDATIONS

The condition of Clam Pass was documented by monthly oblique aerial photography, four complete bathymetric surveys, and tidal flow monitoring throughout 2020. These datasets were processed to monitor the condition of the pass. **Table 1** summarizes the design criteria indicators based on the 2020 survey data.

Table 1: Design Criteria and Present Conditions

Criteria	Target		Monitoring Condition				
			Nov '19	Mar '20	May '20	Dec '20	Jan '21
Section A – Average Cross Section (square feet)	>	300	370	--	290	330	631
Section A – Minimum Cross Section (square feet)	>	250	290	--	260	234	339
Section B – Average Cross Section (square feet)	>	450	510	--	440	348	636
Section B – Minimum Cross Section (square feet)	>	350	440	--	360	246	372
Section B – Volume in Template (cubic yards)	<	2,500	1,700	--	2,100	3,466	670
Section C – Average Cross Section (square feet)	>	450	660	--	610	--	565
Section C – Minimum Cross Section (square feet)	>	350	220	--	300	--	285
Section C – Volume in Template (cubic yards)	<	4,000	2,240	--	3,100	--	3,728
Annual Tide Ratio – Marker 4	>	0.5	0.73[1]	0.61[2]	0.59[3]	0.57[4]	0.78[5]
Annual Tide Ratio – Marker 14	>	0.5	0.69[1]	0.59[2]	0.57[3]	0.54[4]	0.77[5]
Monthly Tide Ratio – Marker 4	>	0.5	0.78	0.49	0.67	0.48	0.81
Monthly Tide Ratio – Marker 14	>	0.5	0.73	0.47	0.68	0.43	0.80
Seaward Extent of Ebb Shoal (feet)	>	250	283	--	240	--	230
Ebb Shoal Area (square feet)	>	200,000	190,000	--	235,000	--	205,000

The condition of Clam Pass at the time of the most recent survey (January 2021) is stable. The January 2021 data and analysis indicates that most inlet stability indicators are within the stable range. Hydraulic monitoring indicates that the tidal exchanges are in a healthy range, above critical levels.

The following recommendations for monitoring on a continuous basis are:

1. Tidal monitoring should continue to be collected and studied on a monthly basis as it has been shown to indicate the state of hydraulic efficiency in the pass.
2. Continue physical monitoring by conducting an annual hydrographic survey. Based on the existing condition at the end of 2020, an annual survey be conducted towards the end of 2021 is recommended to document the physical condition of the pass following the 2021 tropical season and in time for the 2021 annual report.

REFERENCES

Humiston & Moore Engineers (2018) Clam Pass Physical and Tidal Monitoring Report. Prepared for Pelican Bay Services Division, Collier County, Florida. December 2018.

Humiston & Moore Engineers (2019) Review of Inlet Management. Prepared for Pelican Bay Services Division, Collier County, Florida. August 2019.

Turrell, Hall & Associates, Inc.(2014) Clam Bay NRPA Management Plan. Prepared for Pelican Bay Services Division, Collier County, Florida. November 2014.

APPENDIX A

Clam Pass

Monthly Aerial Photos 2020

Figure A1 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A2 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A3 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A4 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A5 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A6 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A7 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A8 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A9 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

Figure A10 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

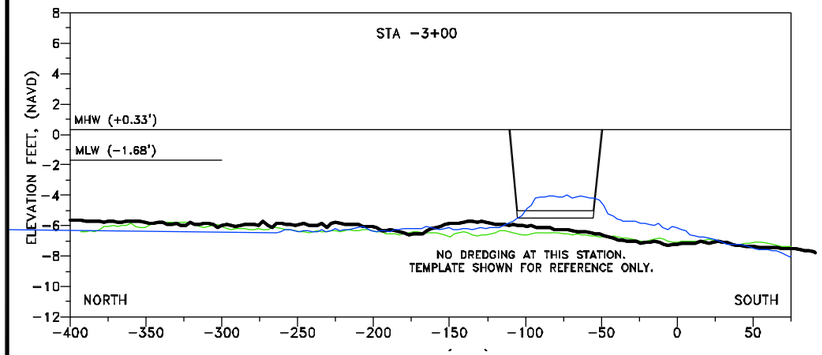
Figure A11 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

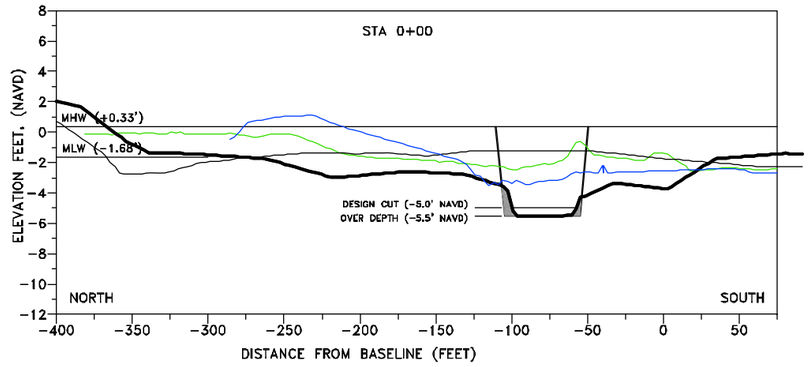
Figure A12 - Clam Pass Aerial Photograph (Photo Taken by Aerial Innovations)

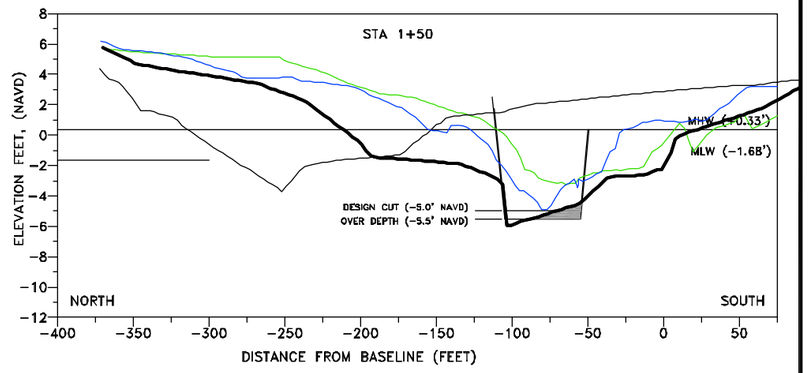
APPENDIX B

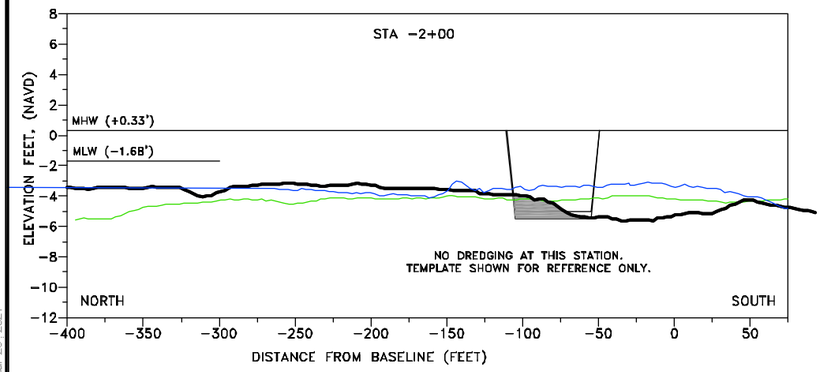
Clam Pass Surveys
Profile Cross Sections

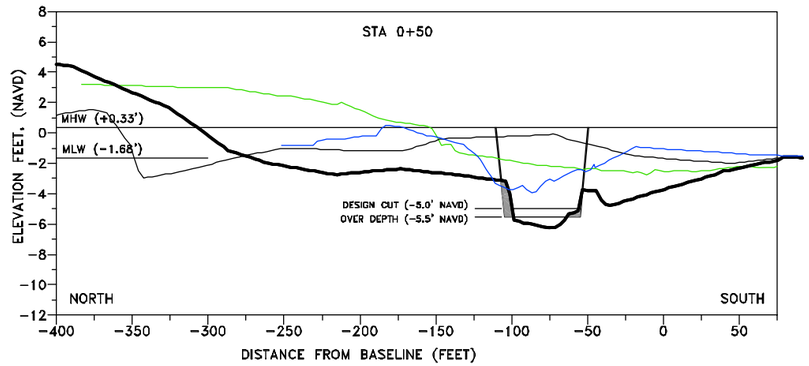
May, 2019
May, 2020
December, 2020
January, 2021

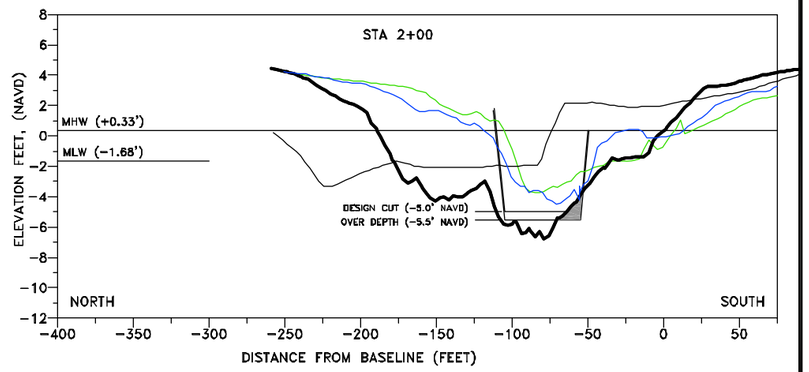


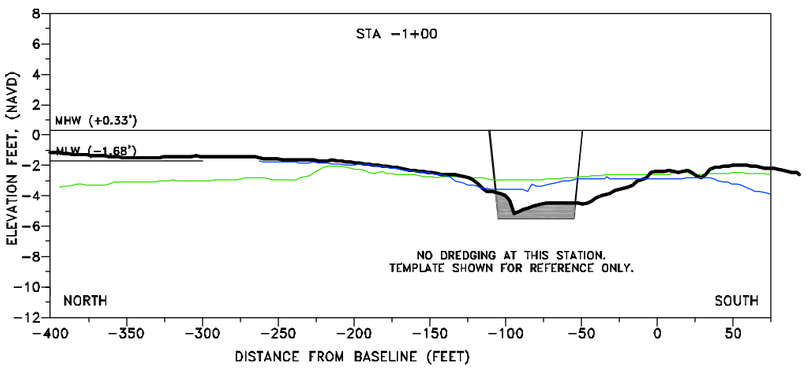


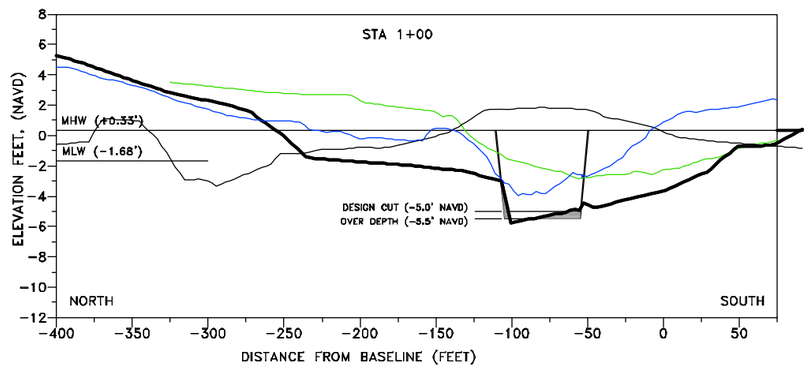


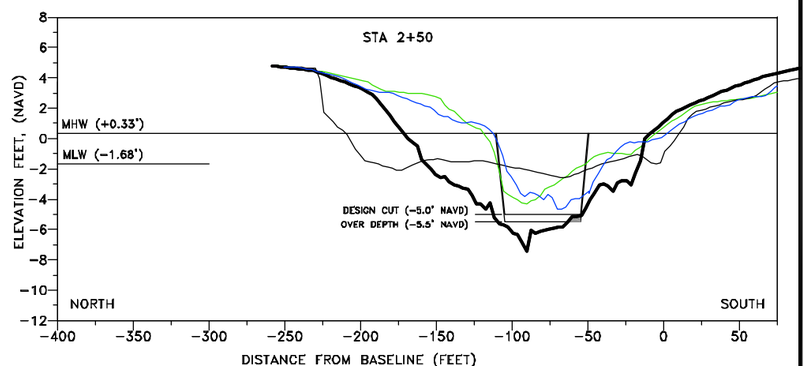












LEGEND

- MAY 2019 SURVEY
- MAY 2020 POST CONSTRUCTION
- DECEMBER 2020 PRE-CON
- JANUARY 2021 POST CON

NOTES:

1. ELEVATIONS SHOWN ARE IN FEET BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
2. DISTANCES SHOWN IN FEET.
3. STATIONS -1+00 THROUGH -3+00 SHOWN FOR REFERENCE ONLY
4. PROFILES BASED ON SURVEYS CONDUCTED BY PARK COASTAL SURVEYING.

HUMISTON & MOORE ENGINEERS
COASTAL ENGINEERING DESIGN AND PERMITTING

CLAM PASS - ANNUAL SURVEY INLET CROSS SECTIONS		
FOR: PELICAN BAY SERVICES DIVISION		
DATE: 3/26/21	FILE: PLAN	SCALE: SHOWN
JOB: 23-065	DATUM: NAVD88	SHEET: 2

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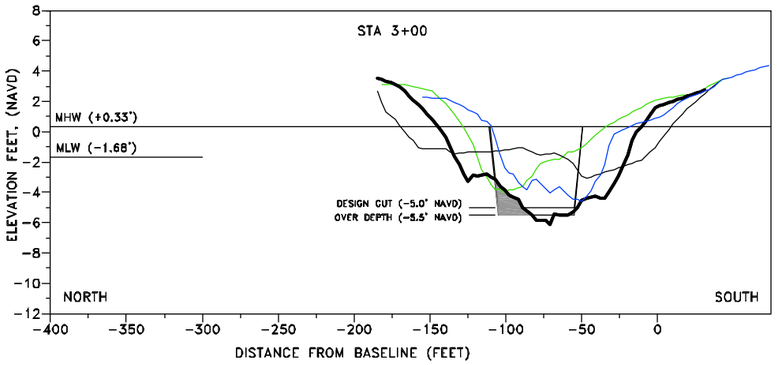

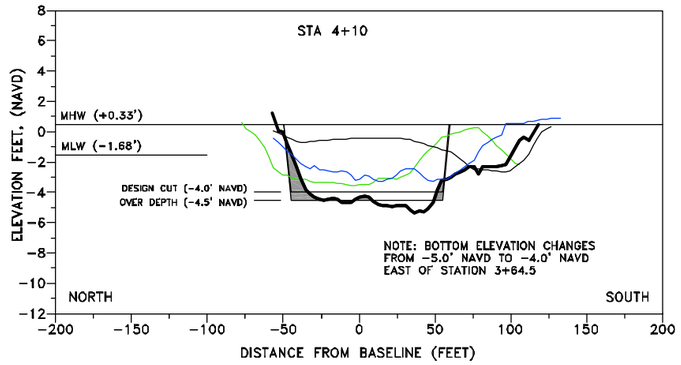

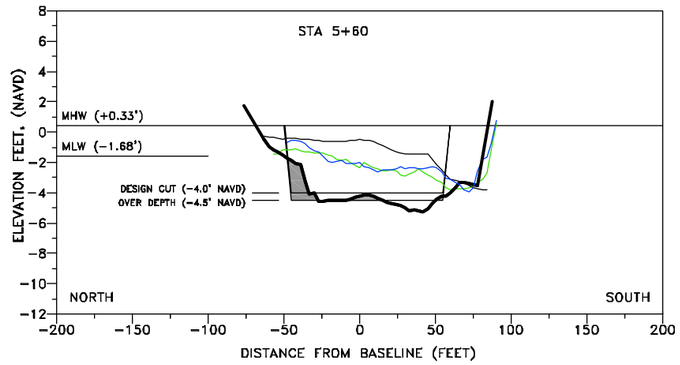

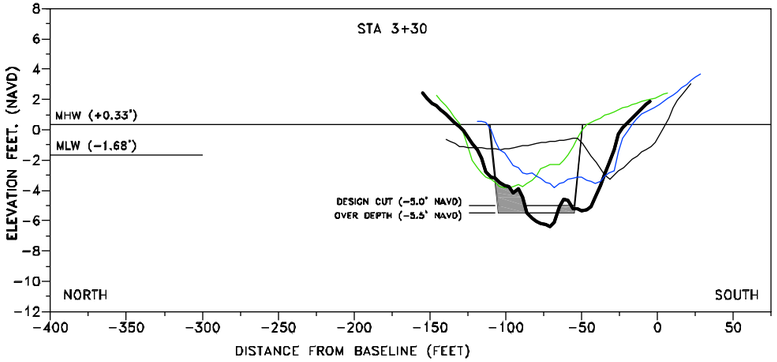

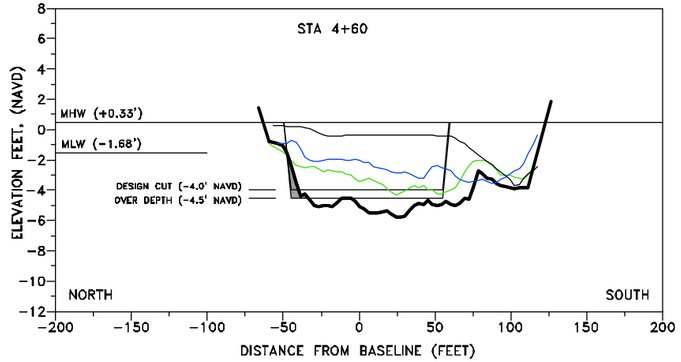

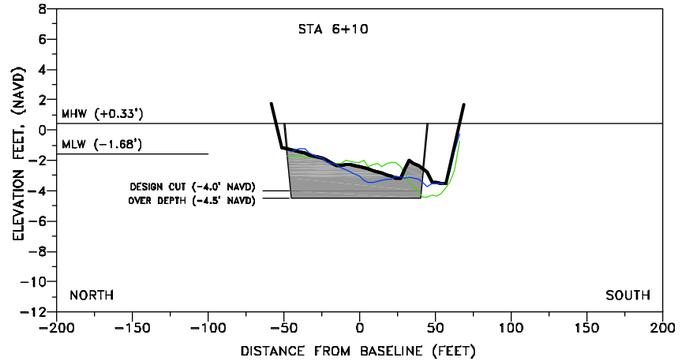

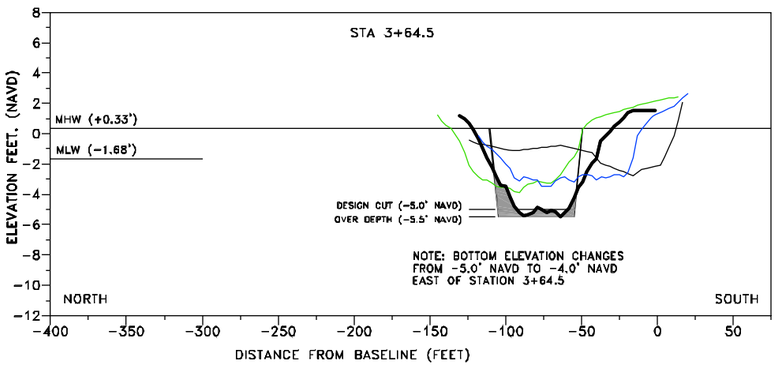

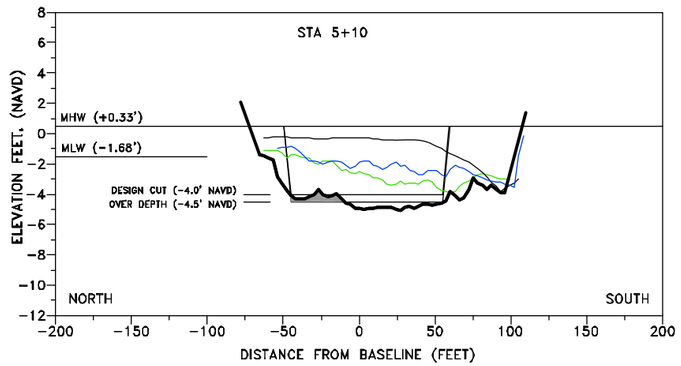

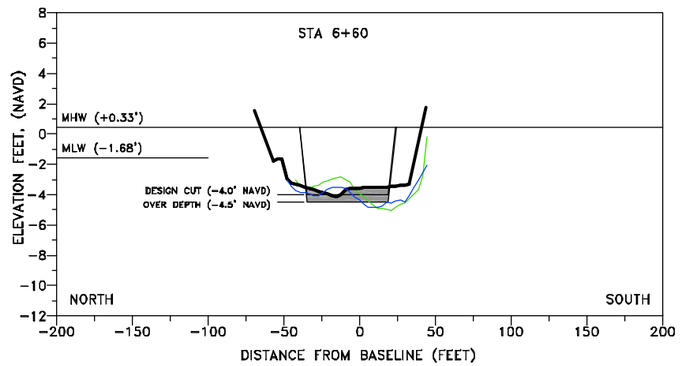

LEGEND

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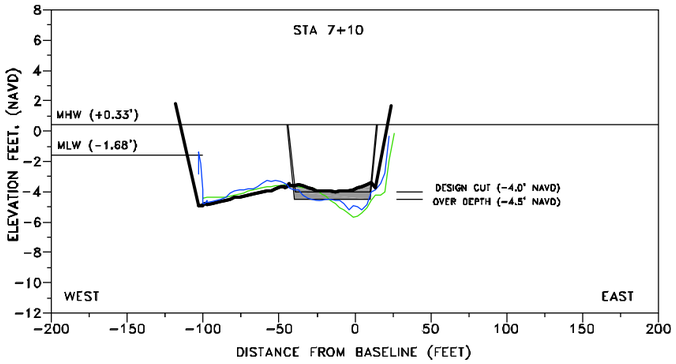

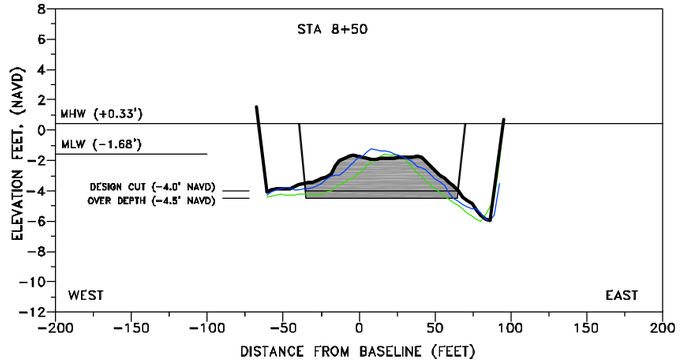

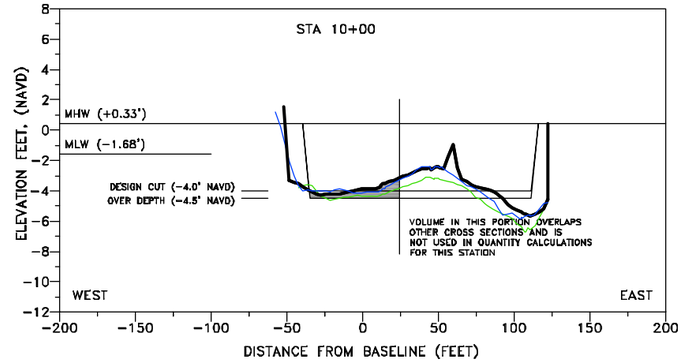

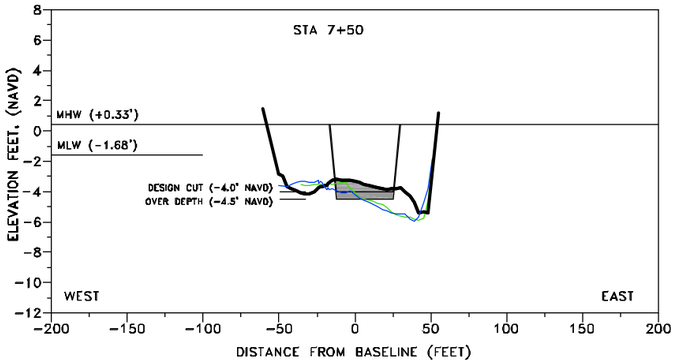

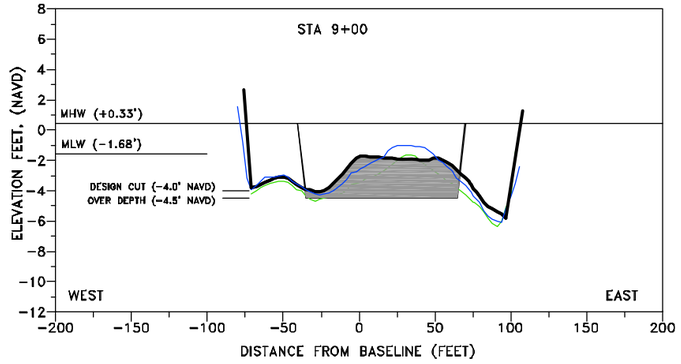

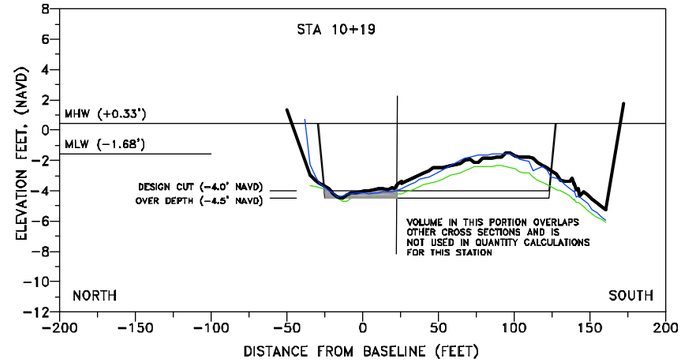

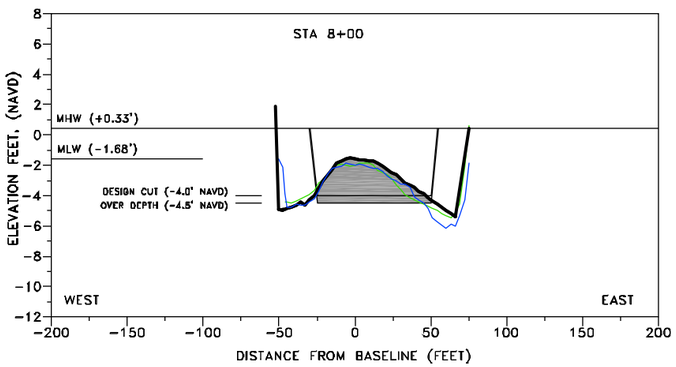

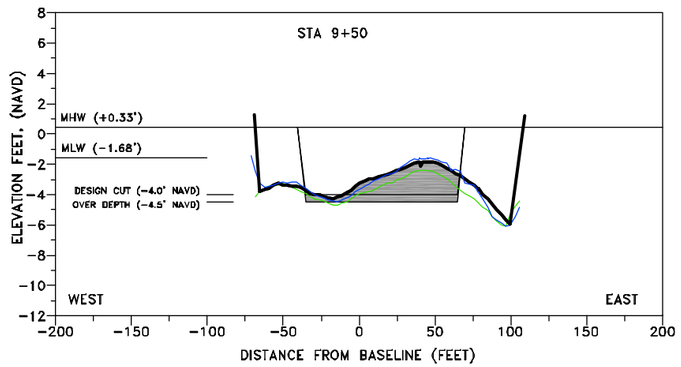

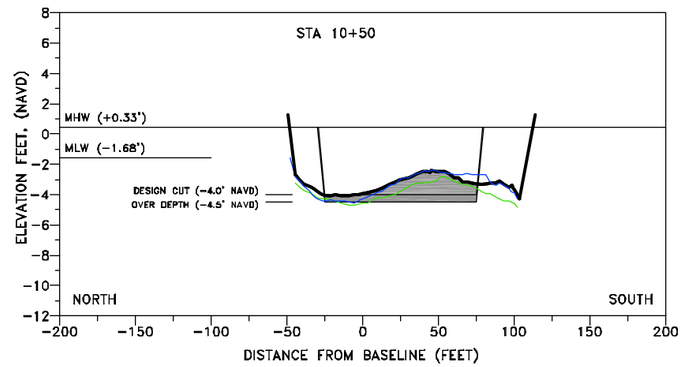

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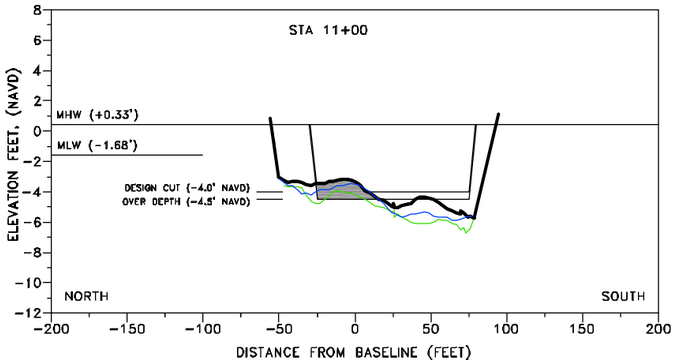

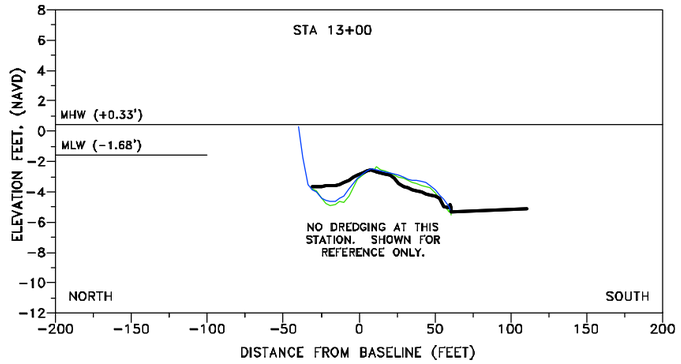

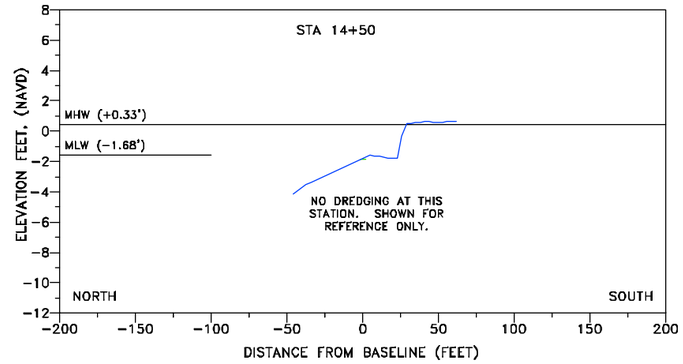

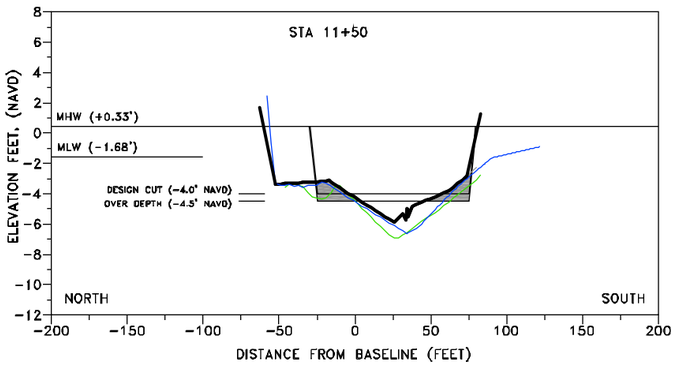

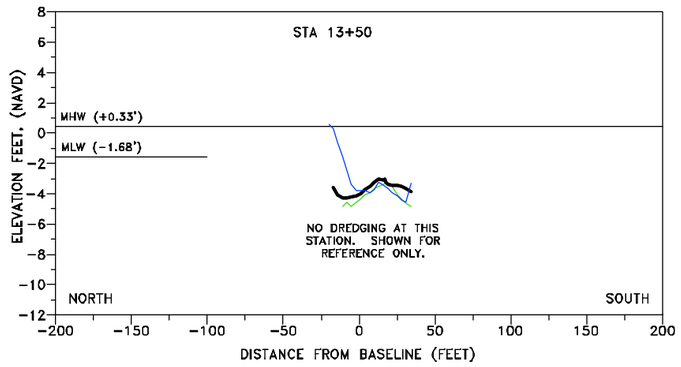

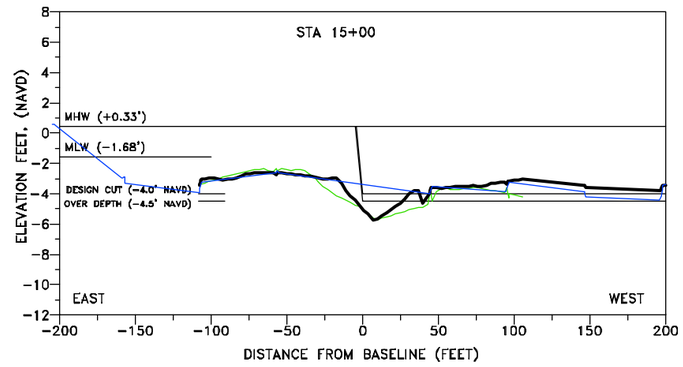

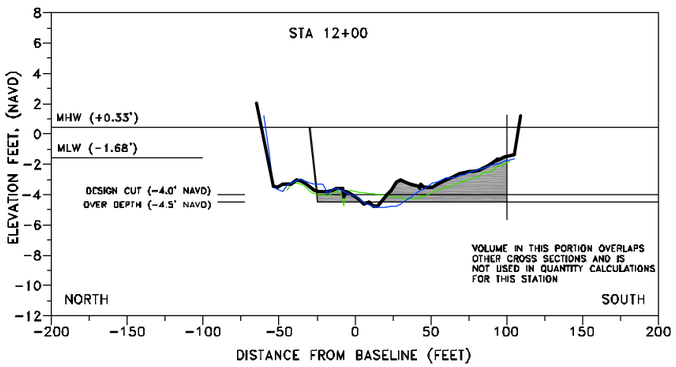

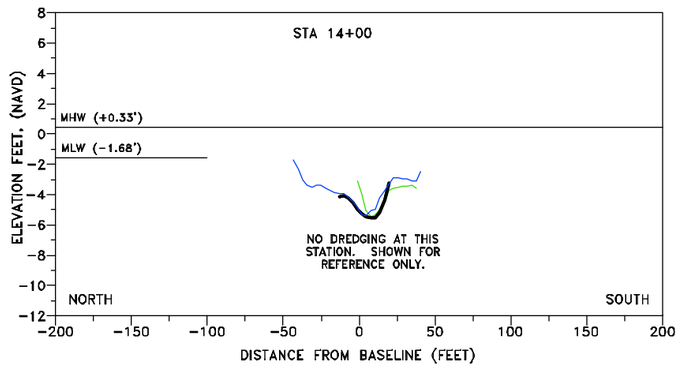

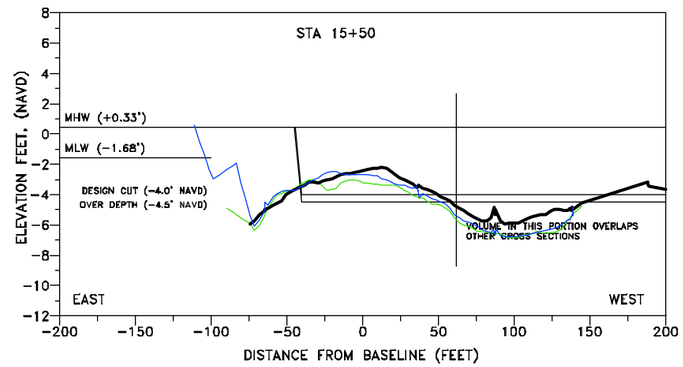

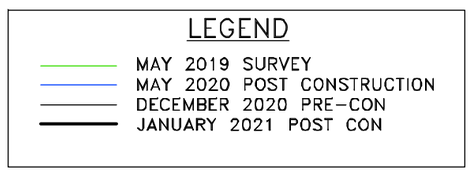

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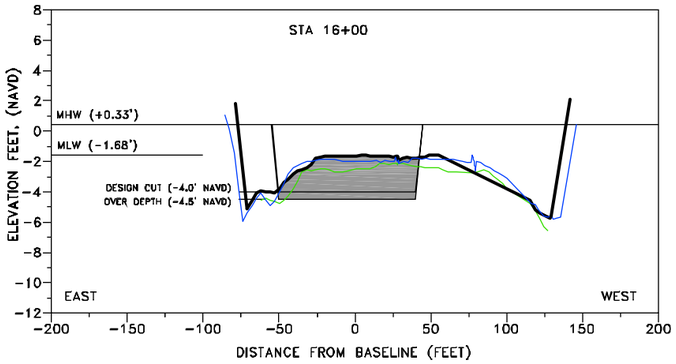

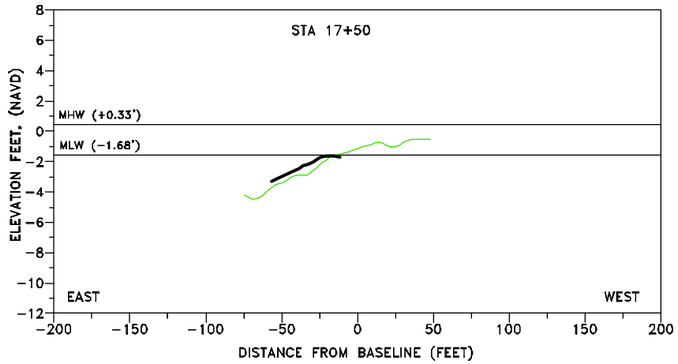

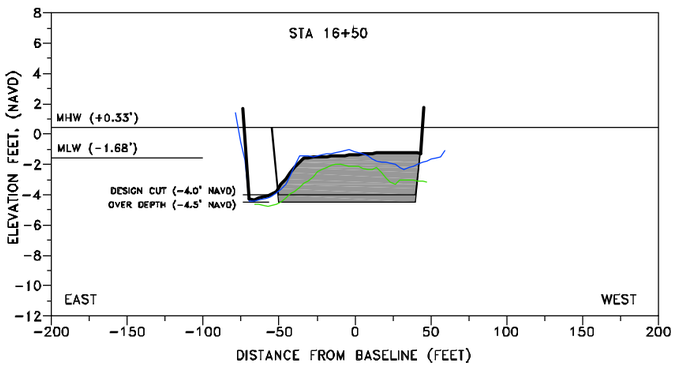

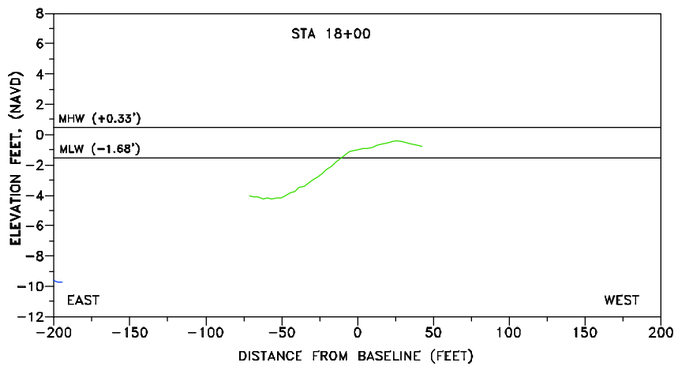

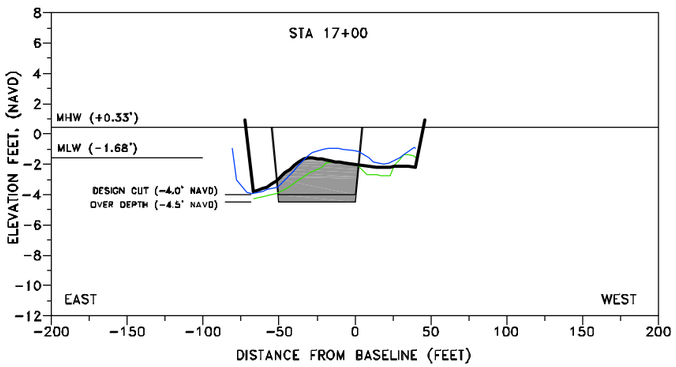

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APPENDIX C

Clam Pass Tidal Monitoring

Monthly Water Level Time Series

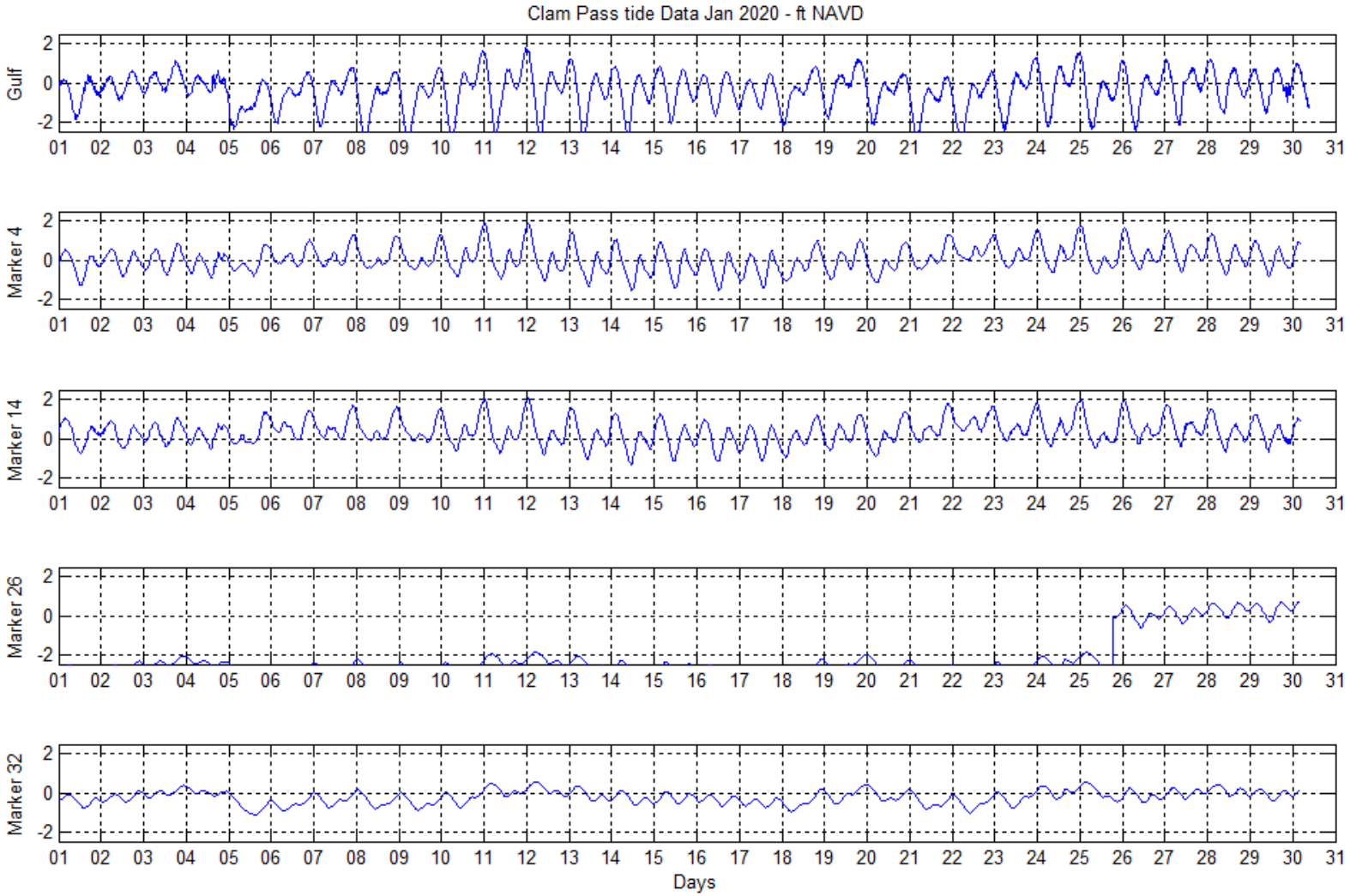

Figure C1 - Clam Pass Tide Gages Time Series – January 2020

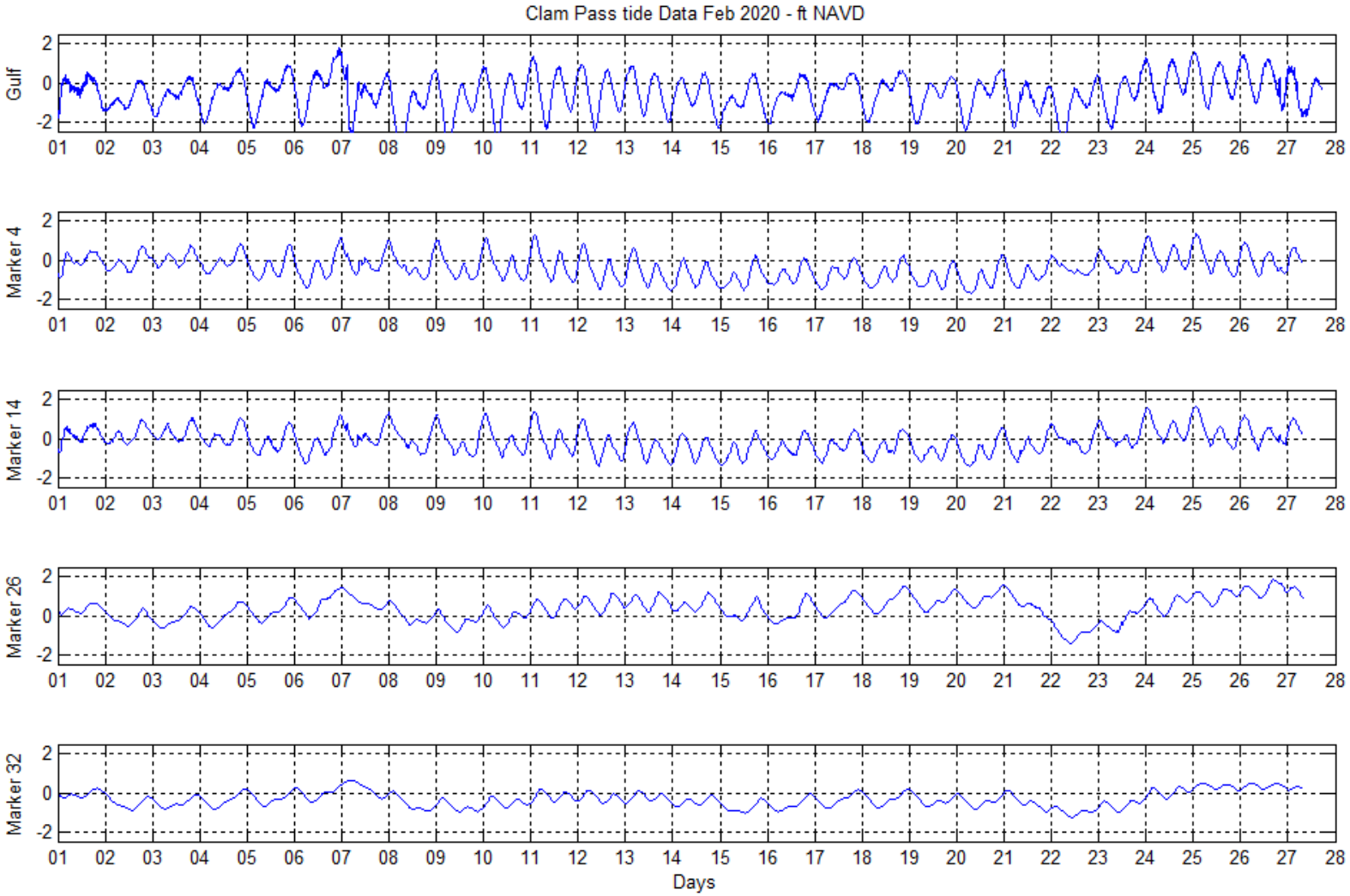

Figure C2 - Clam Pass Tide Gages Time Series – February 2020

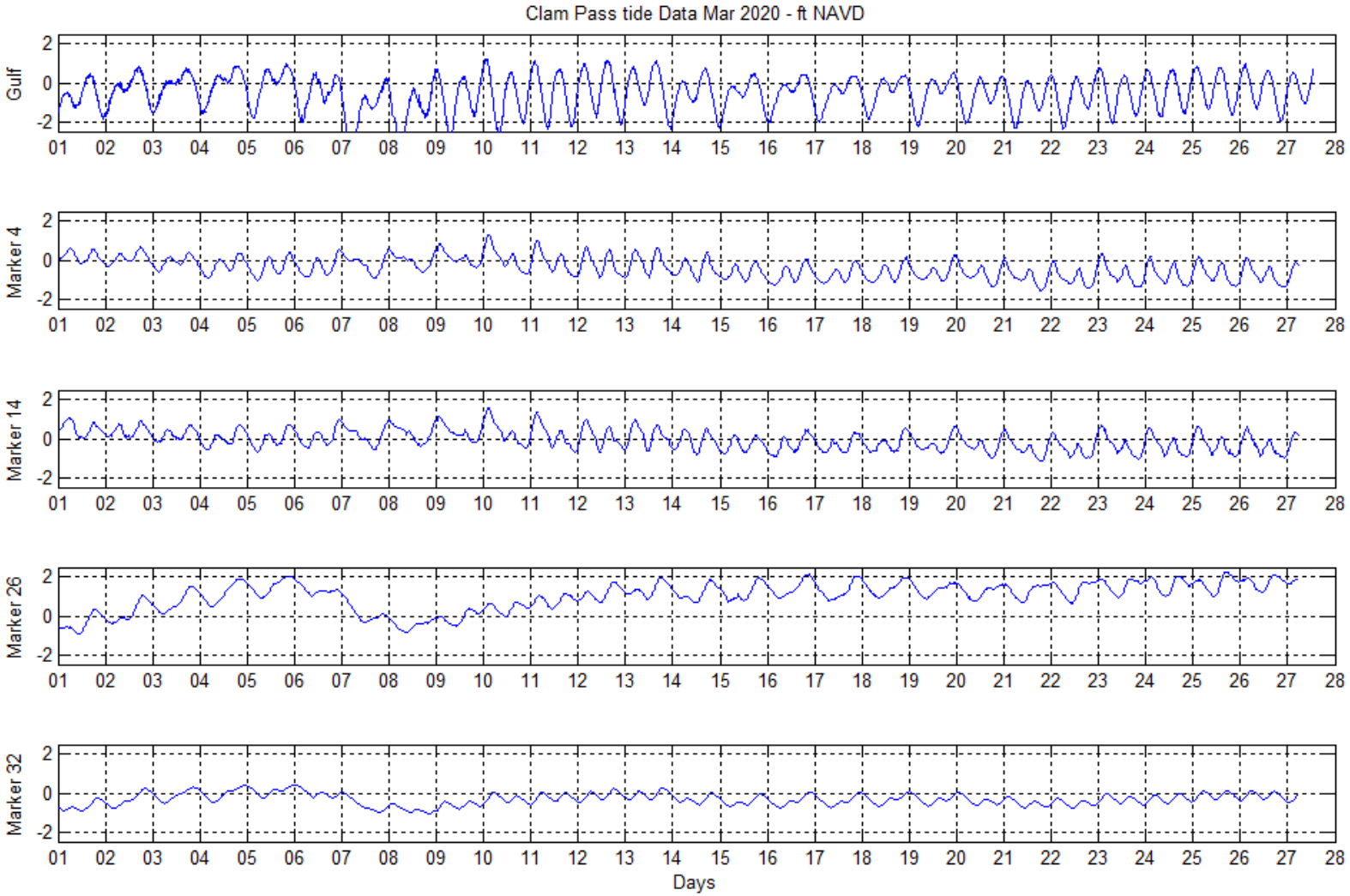

Figure C3 - Clam Pass Tide Gages Time Series – March 2020

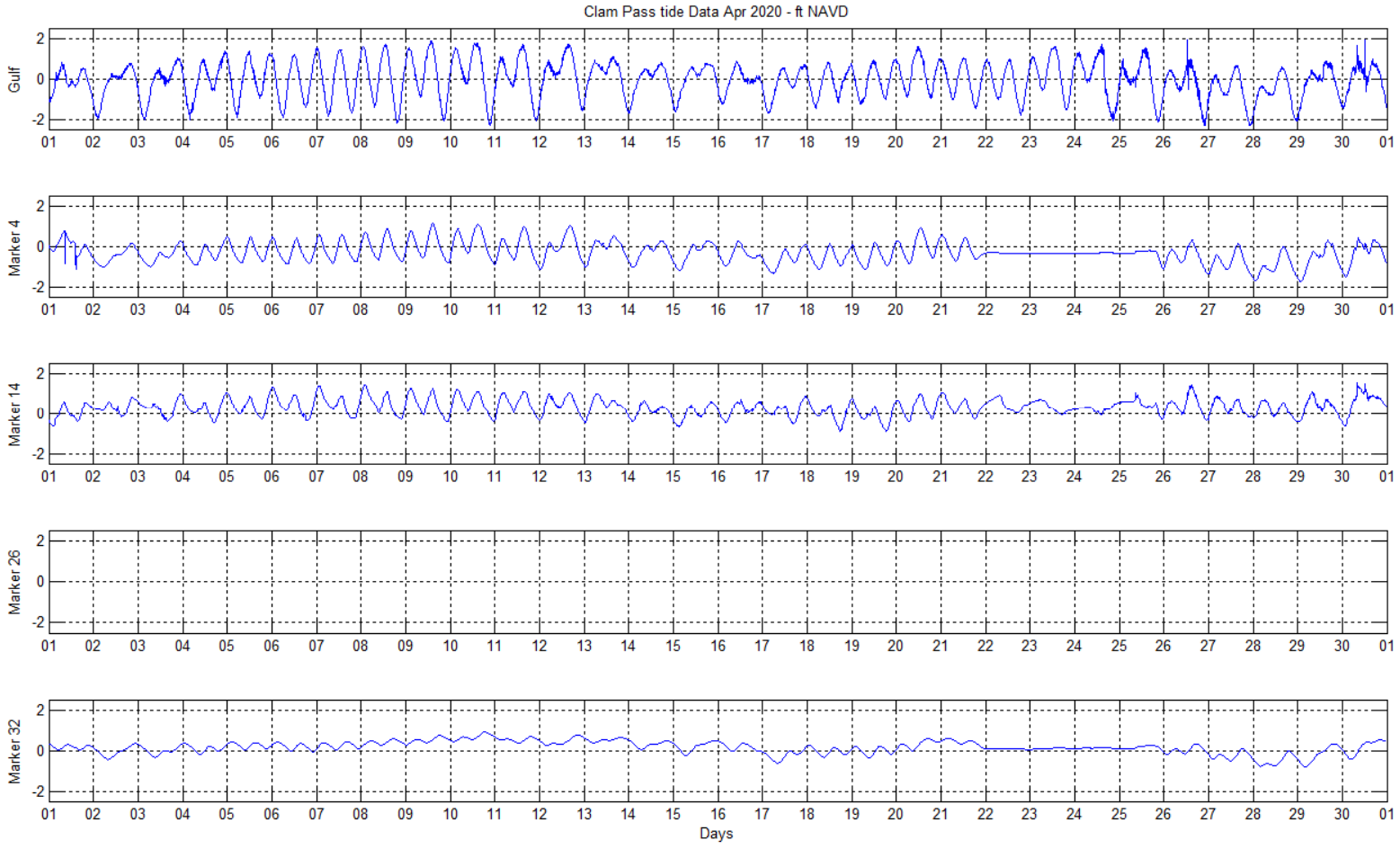

Figure C4 - Clam Pass Tide Gages Time Series – April 2020

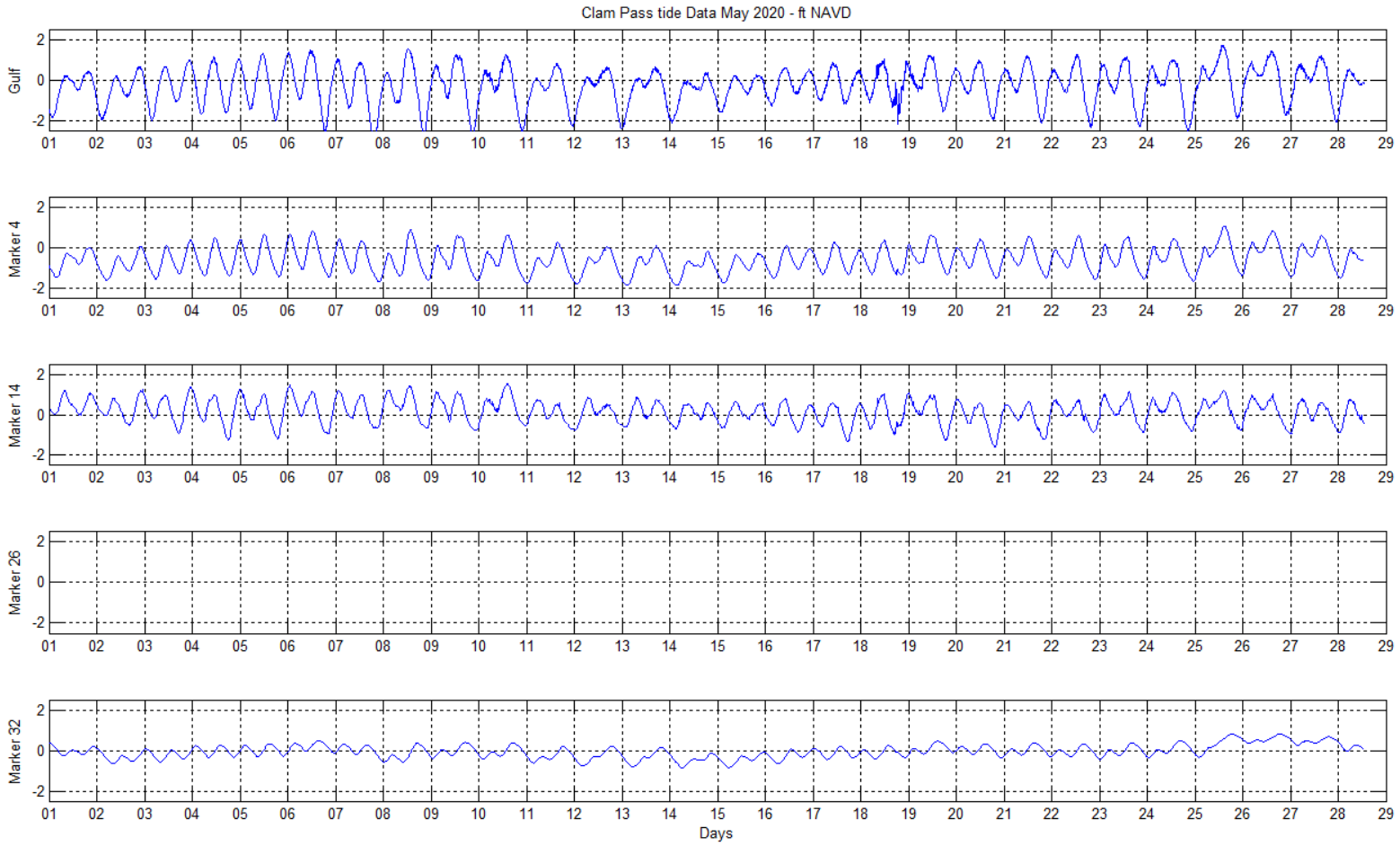

Figure C5 - Clam Pass Tide Gages Time Series – May 2020

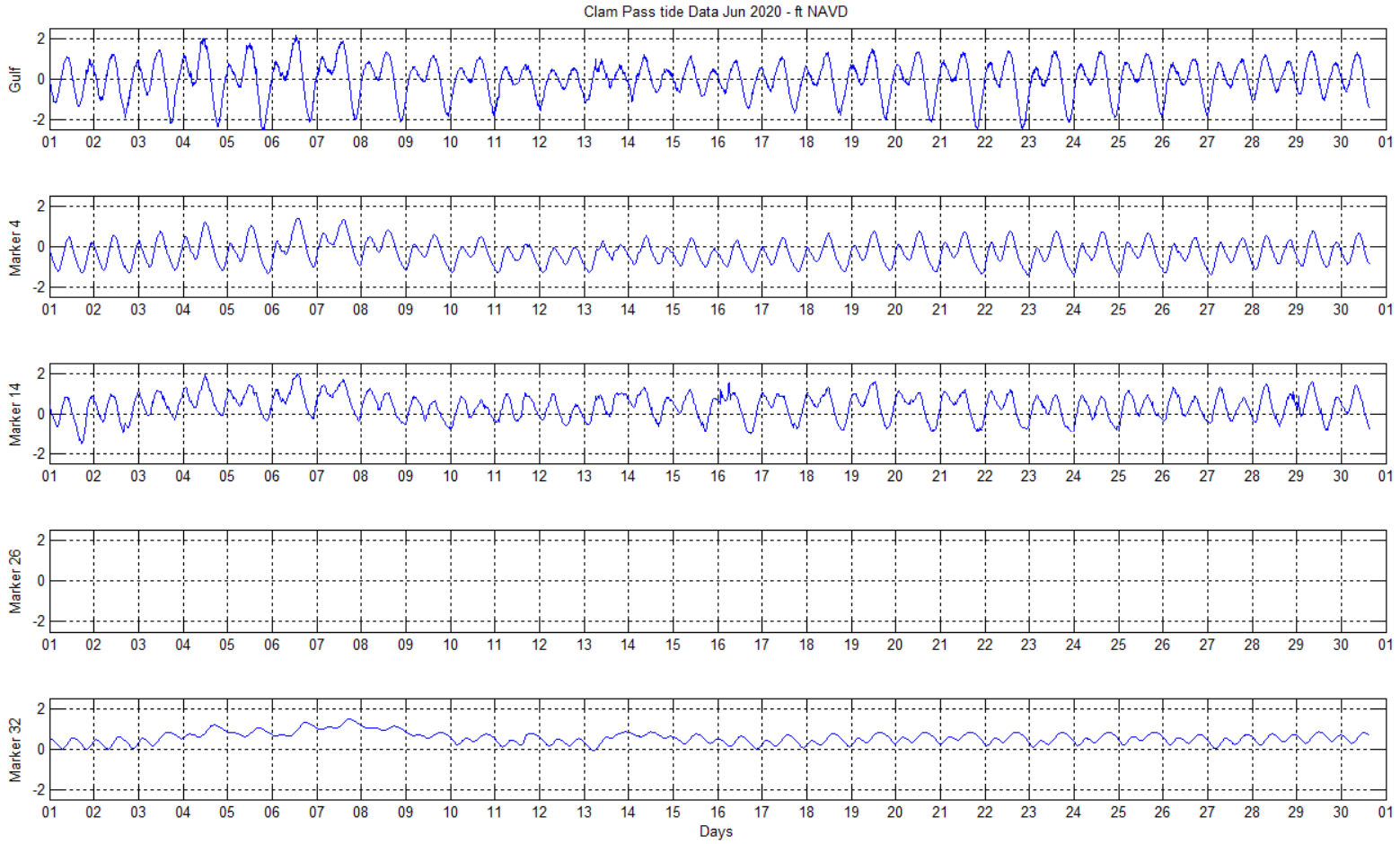

Figure C6 - Clam Pass Tide Gages Time Series – June 2020

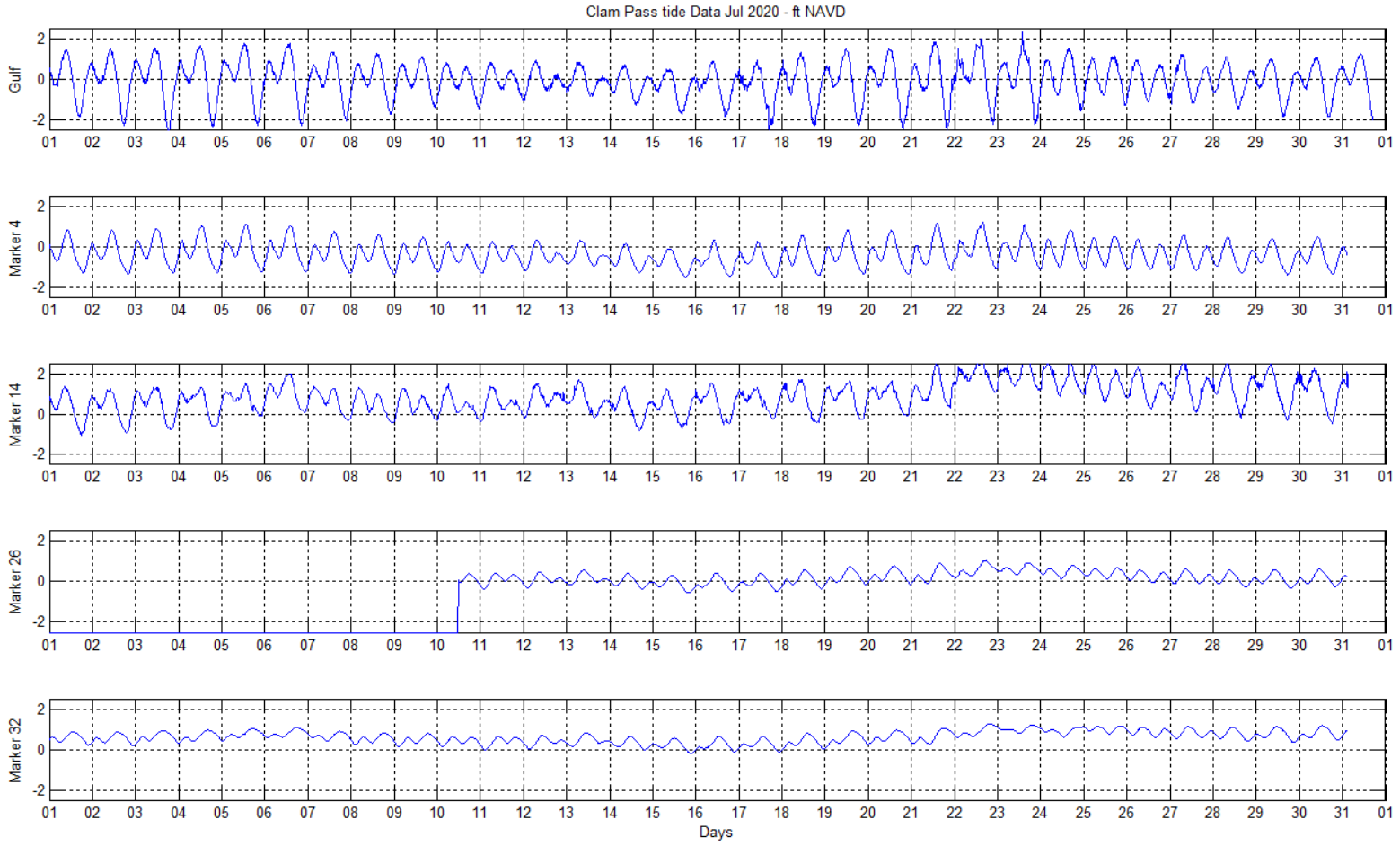

Figure C7 - Clam Pass Tide Gages Time Series – July 2020

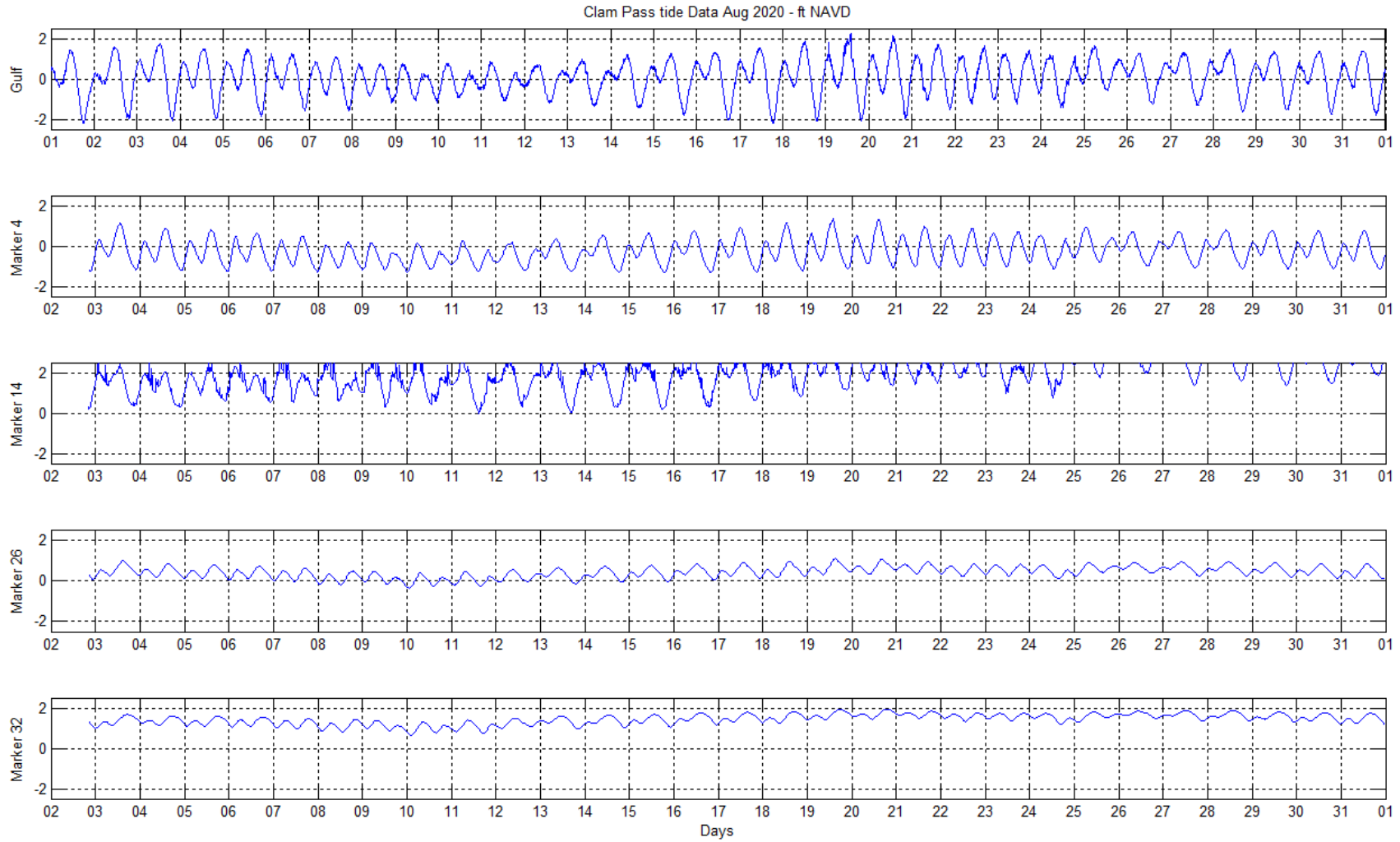

Figure C8 - Clam Pass Tide Gages Time Series – August 2020

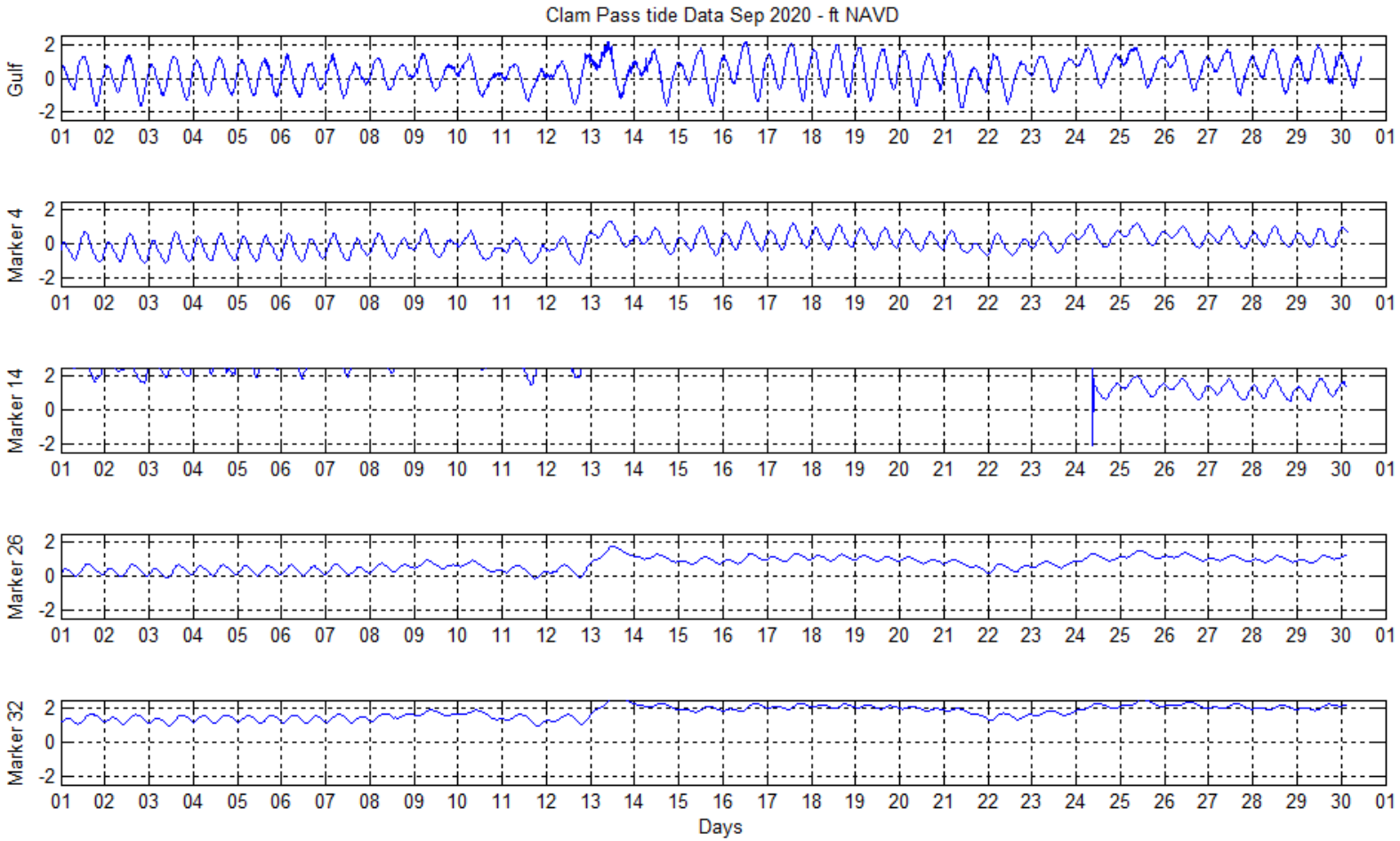

Figure C9 - Clam Pass Tide Gages Time Series – September 2020

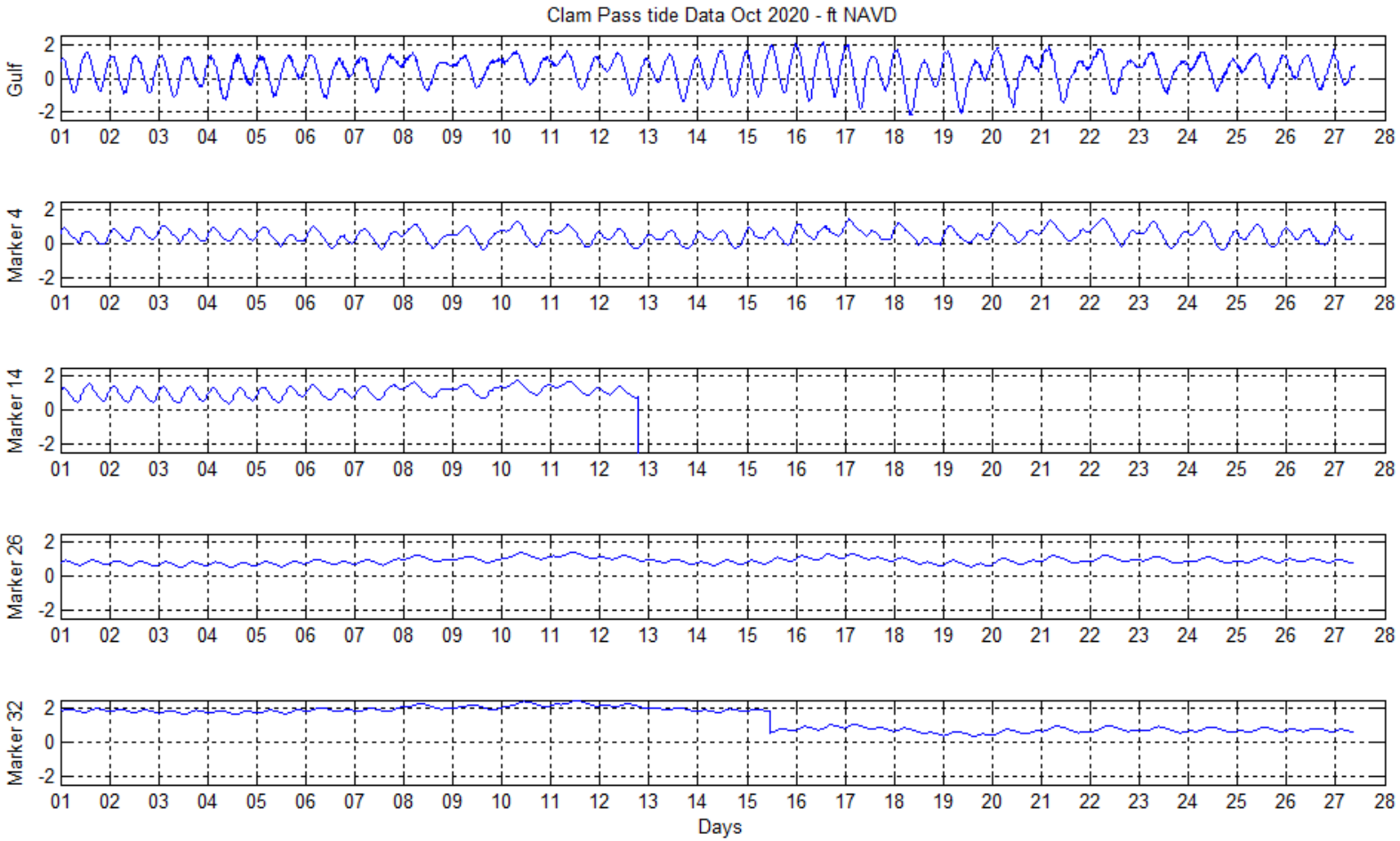

Figure C10 - Clam Pass Tide Gages Time Series –October 2020

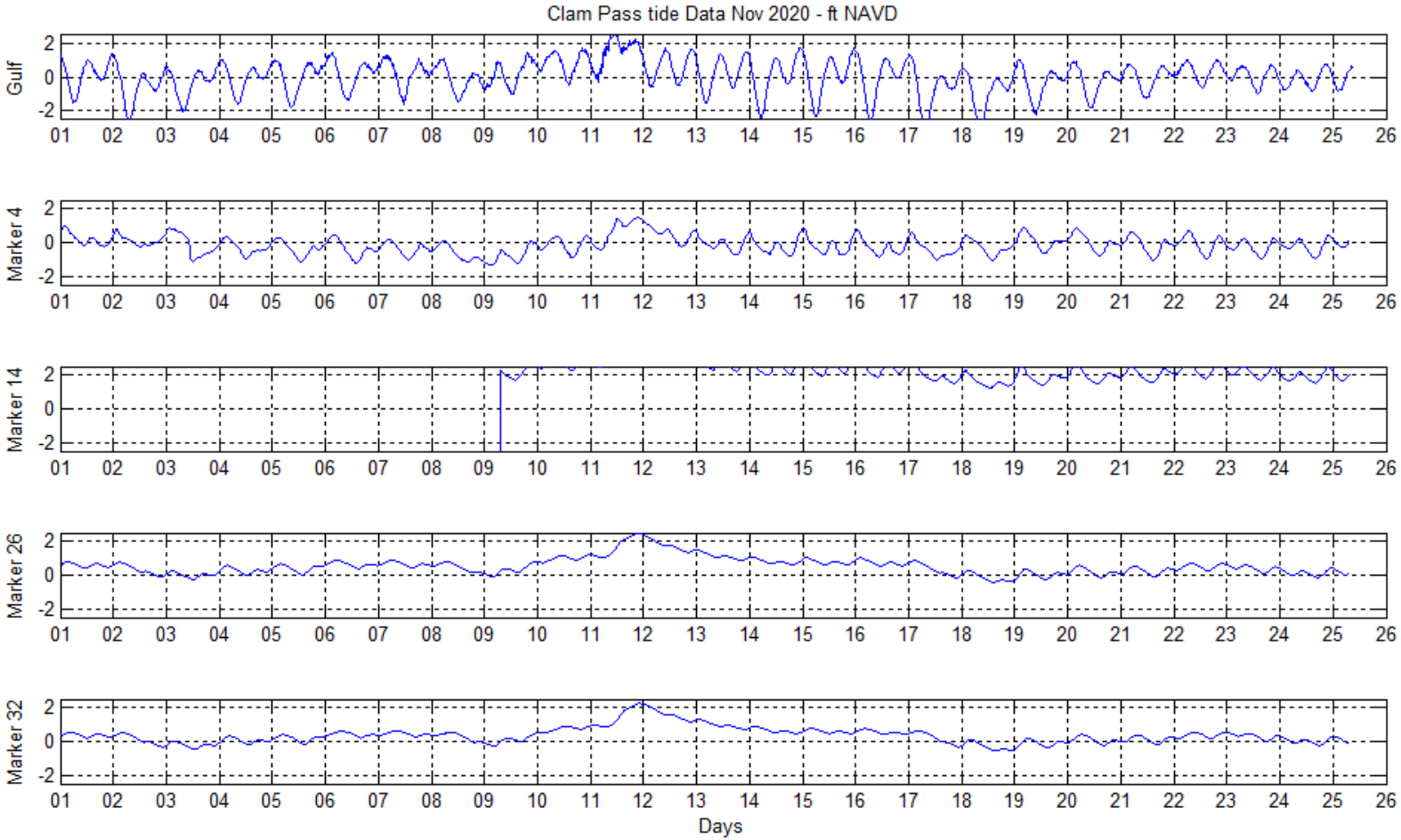

Figure C11 - Clam Pass Tide Gages Time Series –November 2020

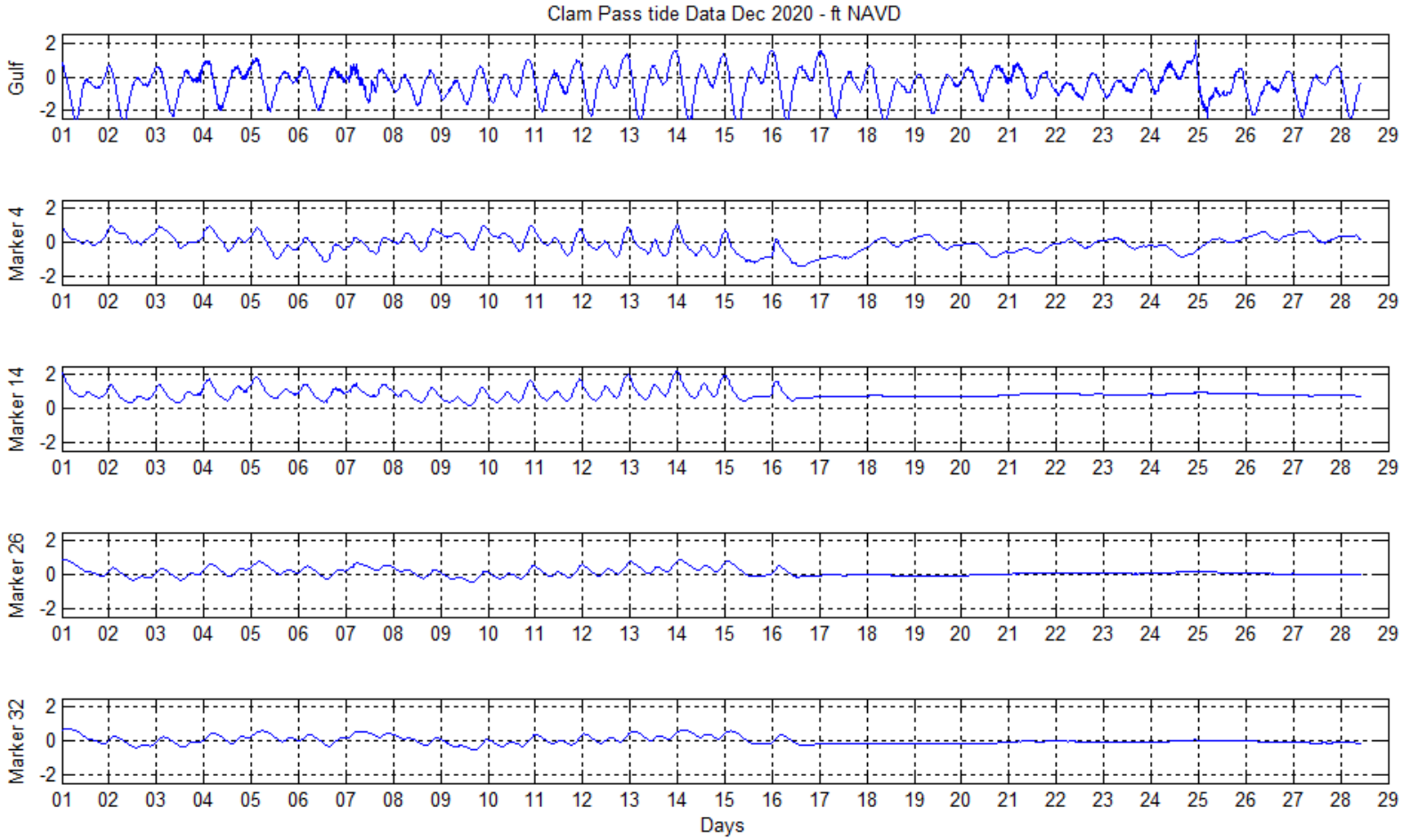

Figure C12 - Clam Pass Tide Gages Time Series –December 2020