ERDC/CHL TR-21-15

Coastal and Hydraulics Laboratory

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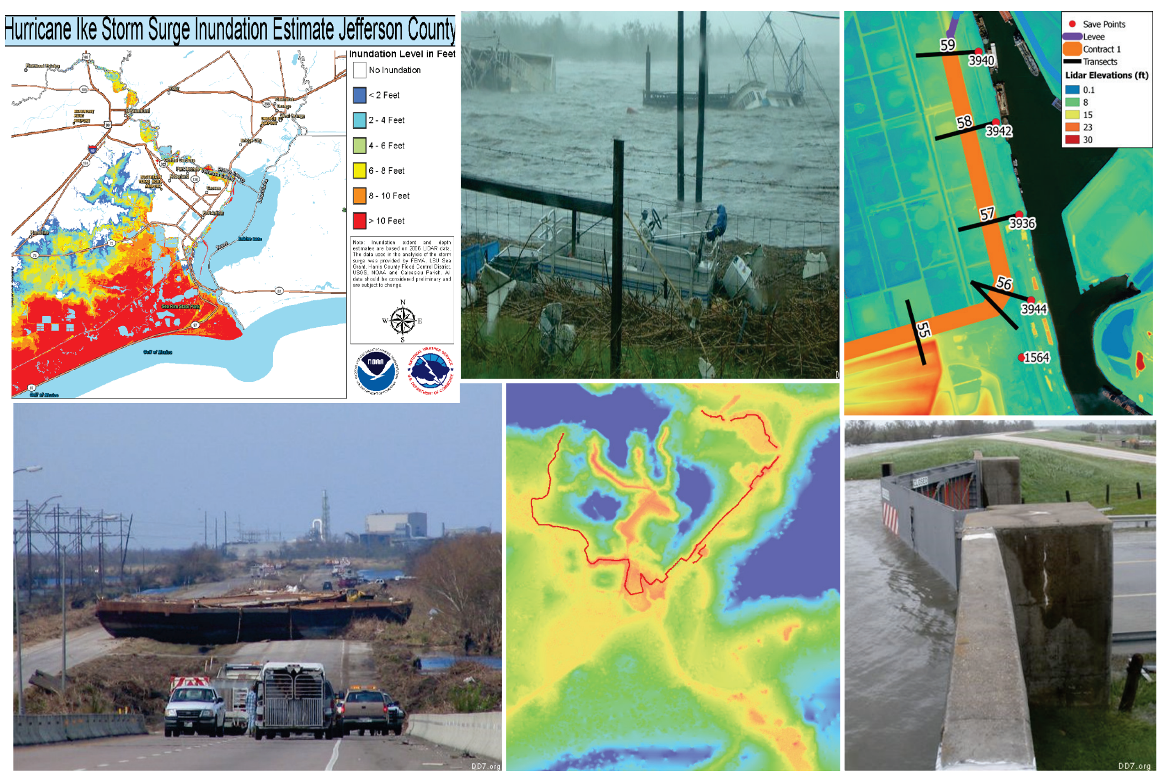
Sabine Pass to Galveston Bay, TX Pre-Construction, Engineering, and Design (PED): Coastal Storm Surge and Wave Hazard Assessment

Report 2 – Port Arthur

Abigail L. Stehno, Jeffrey A. Melby, Shubhra Misra, Norberto C. Nadal-Caraballo, and Victor Gonzalez

November 2021



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Under Galveston District CCLC

Abstract

The US Army Corps of Engineers, Galveston District, is executing the Sabine Pass to Galveston Bay Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design phase. This report documents coastal storm water level and wave hazards for the Port Arthur CSRM structures. Coastal storm water level (SWL) and wave loading and overtopping are quantified using high-fidelity hydrodynamic modeling and stochastic simulations. The CSTORM coupled water level and wave modeling system simulated 195 synthetic tropical storms on three relative sea level change scenarios for with- and without-project meshes. Annual exceedance probability (AEP) mean values were reported for the range of 0.2 to 0.001 for peak SWL and wave height (H_{mo}) along with associated confidence limits. Wave period and mean wave direction associated with H_{mo} were also computed. A response-based stochastic simulation approach is applied to compute AEP values for overtopping for levees and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic fluid pressures for floodwalls. CSRM crest design elevations are defined based on overtopping rates corresponding to incipient damage. Survivability and resilience are evaluated. A system-wide hazard level assessment was conducted to establish final recommended system-wide elevations.

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Preface

The study summarized in this report was conducted at the request of the US Army Corps of Engineers (USACE), Galveston District (SWG). Dr. Shubhra Misra was the primary engineering point of contact at SWG. The portion of the study reported herein was funded by SWG, under a Cross Charge Labor Code, and primarily conducted at the US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, during the period October 2018–May 2021.

SWG project leadership included Mr. Eddie Irigoyen, SWG Project Manager (PM) for Freeport; Mr. Charles Wheeler, SWG PM for Port Arthur; and Mr. Orlando Ramos-Gines, SWG PM for Orange County. Dr. Shubhra Misra was SWG project technical lead. At the time of this study, Mr. Robert Thomas was Chief, Engineering and Construction, SWG. At ERDC CHL, Mr. Chad Bounds was Chief of Harbors, Entrances, and Structures Branch within the Navigation Division, led by Ms. Ashley Frey, Acting Chief. Mr. Victor Gonzalez was Acting Chief of Coastal Processes Branch within the Flood and Storm Protection Division, led by Dr. Cary A. Talbot. At the time of publication of this report, Dr. Ty V. Wamsley was Director, CHL, and Mr. Keith Flowers was Deputy Director, CHL.

COL Teresa A. Schlosser was Commander of ERDC, and the Director was Dr. David W. Pittman.

Acknowledgement

This report underwent the US Army Corps of Engineers review process. Internal Galveston District (SWG) review, known as District Quality Control (DQC), included independent review by Dr. Himangshu Das and Mr. Chris Michalsky. In addition, Agency Technical Review (ATR) and Independent External Peer Review (IEPR) were thorough. All reviewers are gratefully acknowledged for improving this report.

Table of report review.

	Date	Changes
First Draft	01/31/2020	N/A
Post-DQC Revision	02/24/2020	Extensive changes and updates based on DQC comments
Post-ATR Revision	04/20/2020	Minor updates and revisions based on ATR comments
Post-IEPR Final	06/29/2020	Minor updates and revisions based on IEPR comments

DQC, ATR, and IEPR comments, responses, back-checks, and DQC certification are available from the SWG and in ProjNet.

Executive Summary

The US Army Corps of Engineers (USACE), Galveston District, is executing the Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design (PED) phase. As identified during the Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017), the S2G project CSRM formulated measures consist of reducing risks of tropical storm water level (SWL) impacts by constructing the new Orange 3 CSRM system in Orange County, and increasing the level of risk reduction and resiliency of the existing Port Arthur and Vicinity and Freeport and Vicinity Hurricane Flood Protection systems in Jefferson and Brazoria Counties, Texas.

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the Port Arthur CSRM and is part of a larger analysis focused on evaluation of the entire CSRM systems for Jefferson, Brazoria, and Orange Counties. Coastal SWL and wave loading and overtopping are quantified using state-of-the-art hydrodynamic modeling and stochastic simulations.

A multivariate probabilistic model of historical hurricane parameters was developed that spans the full range of tropical storm hazards from frequent, low-intensity storms to very rare, very intense storms. The probabilistic model describes the continuous spatial and temporal hazard. This probabilistic model was sampled efficiently to develop a suite of 195 synthetic tropical storms that effectively capture the flood hazard for the region from Freeport to the Louisiana-Texas border. Wind and pressure fields were developed for these 195 storms using the planetary boundary layer model.

The CSTORM coupled water level and wave modeling system was used to accurately quantify the SWL and wave hazards. New model meshes were developed from very-high-resolution land and sub-aqueous surveys for with- and without-project scenarios. With-project meshes include the new Orange CSRM, deepening of Sabine-Neches Waterway, and increased levee and floodwall elevations as authorized under the S2G feasibility study. The new meshes provide the highest-resolution regional water level and wave modeling done to date for the region. The CSTORM model was

validated against historical storms and then used to model the 195 synthetic tropical storms. The storms are run on three relative sea level change (RSLC) scenarios for with- and without-project meshes. These RSLC scenarios are (1) SLC0 corresponding to project completion in 2027 and an associated “Low” RSLC projection, (2) SLC1 corresponding to the end of a 50 yr[1] service lifecycle in 2077 and an associated “Intermediate” RSLC projection, and (3) SLC2 corresponding to the end of a 100 yr service lifecycle in 2127 and an associated “Intermediate” RSLC projection. A “High” RSLC projection over a period of 50 yr is approximately the same as an “Intermediate” RSLC projection over a period of 100 yr, so SLC2 corresponds closely with the end of a 50 yr service life in 2077 under a “High” RSLC projection.

Flood hazard exposure of the project features was quantified by computing hazard curves for the CSTORM output near the structures. Annual exceedance probabilities (AEP) were computed for the range of 1 to 0.0001 for peak SWL and wave height (H_{m0}) but is reported out in tables only between 0.2 to 0.001 AEP. Wave period (T_p) and mean wave direction associated with H_{m0} were also computed. Both mean values and confidence limits (CL) are summarized herein. In this case, CLs are used to describe epistemic uncertainty or levels of assurance. For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported. The 1% AEP (100 yr average recurrence interval) wave parameters H_{m0} and T_p describe small short waves that would be expected to characterize flood conditions inland, as occur in the area of the Port Arthur CSRM.

For the analysis, stochastic simulation uses a response-based approach, and overtopping responses are computed for each storm, and then hazard relations are computed from the results. The peaks-based response-based approach yielded a very accurate stochastic response with a reasonable computational requirement.

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[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Crest design elevations were based on overtopping rates corresponding to incipient damage. Limit states for overtopping rate for levees of q = 0.01 cfs/ft for the 50% CL and q = 0.1 cfs/ft for the 90% CL, and for floodwalls of q = 0.03 cfs/ft for the 50% CL and q = 0.1 cfs/ft for the 90% CL, were based on the start of erosion for a good-quality grass cover on a clay levee at 1% AEP. These limit states are accepted standard of practice both within the USACE and internationally. An additional survivability or resilience limit state of q = 1 cfs/ft was considered. While not used directly for design, the survivability limit state helped inform decisions by the project delivery team on final crest elevations. For vertical structures (e.g., floodwalls), overtopping nappe geometry and combined hydrostatic and hydrodynamic fluid pressures at various AEPs were computed. Optimized crest elevations for the 1% AEP hazard level satisfying overtopping criteria were also developed along with associated floodwall combined hydrostatic and hydrodynamic pressure and nappe geometry parameters. A system-wide hazard level assessment was conducted to establish final recommended system-wide elevations for both SLC1 and SLC2.

1 Introduction

1.1 Background

The US Army Corps of Engineers (USACE), Galveston District (SWG), is executing the Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design (PED) phase.

The Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017) identified measures of reducing risks of tropical storm inundation impacts. The S2G CSRM PED project incorporates additions and modifications of CSRM systems in Orange, Jefferson, and Brazoria Counties, Texas (Figure 1). The details of the complete S2G PED project analysis approach are described in Melby et al. (2021). This report describes the Port Arthur CSRM project (Figure 2), which consists of raising or reconstructing existing levees and floodwalls, replacing vehicular closure structures, constructing navigable surge gate structures, and increasing resiliency by installing erosion and scour protection as necessary. The recommended CSRM structure elevations from the feasibility study to the Port Arthur CSRM system are provided in Figure 3 and Table 1.

Figure 1. CSRM system for Brazoria (left), Orange (middle), and Jefferson (right) regions.

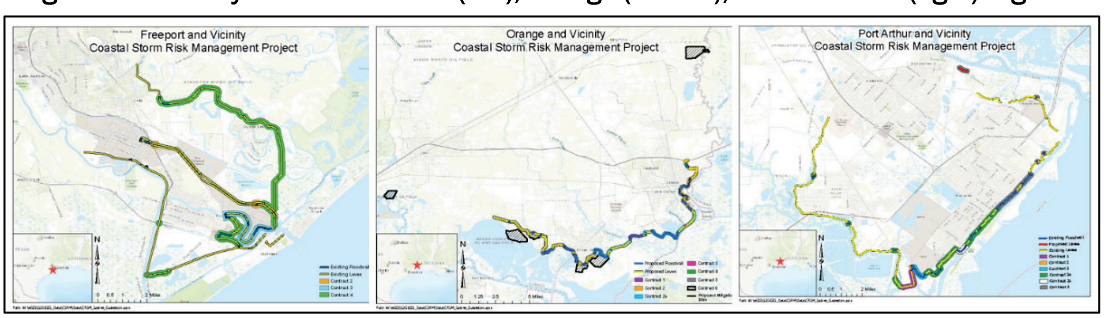
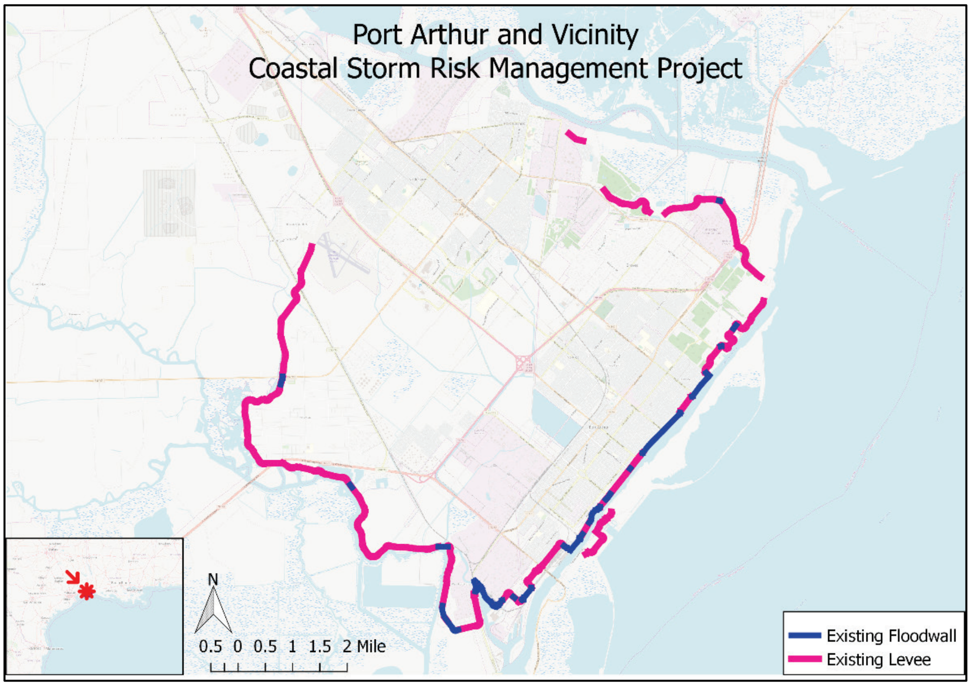


Figure 2. Port Arthur CSRM system.



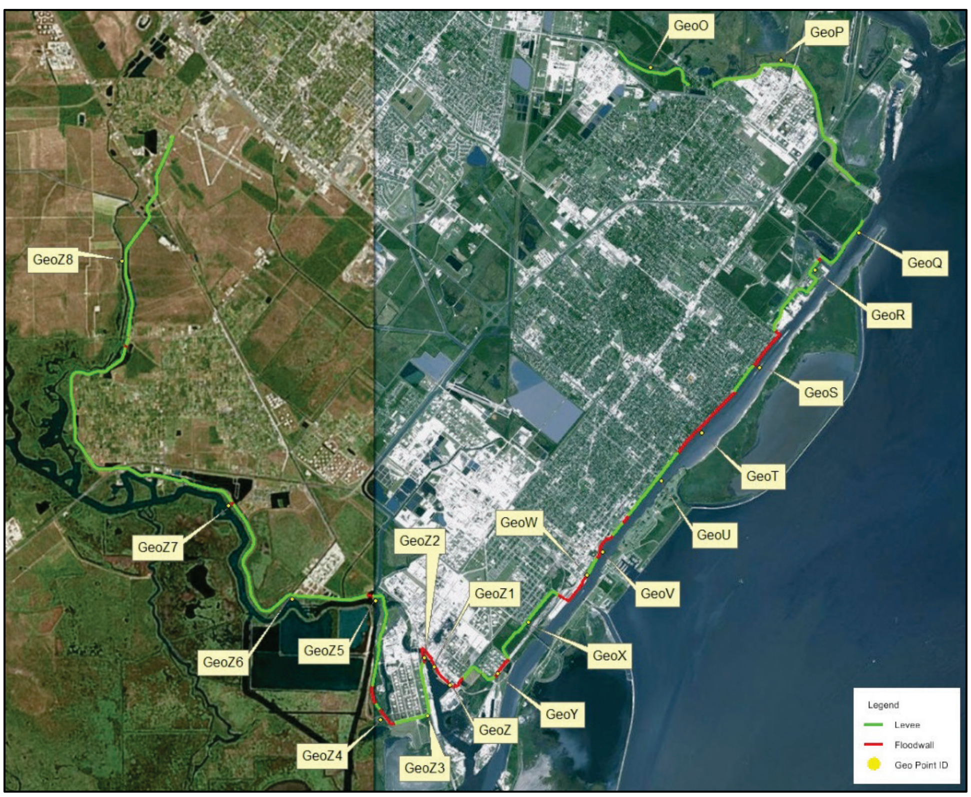


Table 1. Feasibility authorized (for design scenario associated with 50 yr[1] intermediate relative sea level change [RSLC]) CSRM structure elevations, in feet, NAVD88, for improvements to Port Arthur CSRM system (Geo Point IDs are shown in Figure 3).

Geo Point ID	Recommended Elevation (ft,NAVD88*)	
	Levee	Floodwall
O	14.5 – 14.8	
P	14.5 – 16.4	16.0
Q	15.4 – 15.9	16.85
R	15.5 – 15.8	15, 16.35
S	16.5	
T		19.5
U	16.0	17.0
V	16.5	17.5
W	16.5	17.5
X	17.0	
Y	17.0	17.0, 18.85
Z		18.00
Z1		19.50
Z2		19.50
Z3	17.50	
Z4	16.0 – 17.2	23.0, 25.5
Z5	16.0 – 16.8	21.5
Z6	16.0 – 17.4	
Z7	15.6 – 20.4	20.4
Z8	14.80 – 19.0	16.4

* North American Vertical Datum of 1988.

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

1.2 Objective

As part of the ongoing PED phase of the project, this report documents the methodology to analyze coastal storm inundation and wave hazards for Port Arthur and the vicinity and is part of a larger analysis focused on evaluation of the entire CSRM systems for Jefferson, Brazoria, and Orange Counties. Coastal storm inundation, wave loading, overtopping, and overflow are quantified using state-of-the-art hydrodynamic modeling and stochastic simulations.

1.3 Approach

This study was preceded by the S2G planning study and Coastal Texas Comprehensive Study (CTXCS[1,2]). The analysis used for this Port Arthur CSRM system investigation is summarized below. Melby et al. (2021) provide further details of the analysis methods. If the task was completed in prior studies, it is noted.

1. Characterize the CSRM system and components.
2. Characterize bathymetry and topography to 0.3 m accuracy. Described in Melby et al. (2021).
3. Gather Gulf of Mexico tropical cyclone (TC) data since 1938 from HURDAT II database. Completed in CTXCS.
4. Construct joint probability model (JPM) of TC parameters $\hat{x}$=(x_o=reference location, ΔP=central pressure deficit, R_{max}=radius of maximum winds, V_f=forward speed, θ=heading direction). Completed in CTXCS.
5. Efficiently sample JPM using optimal sampling methods to construct 660 TCs that effectively map practical probability space. Construct synthetic storm suite with parameterized TCs. Completed in CTXCS.
6. Construct numerical model meshes, validate with historical data, and quantify modeling uncertainties. Described in Melby et al. (2021).

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[1] Massey, T. C., R. Jensen, M. Cialone, Y. Ding, M. Owensby, and N. C. Nadal-Caraballo. 2019. *A Brief Overview of the Coastal Texas Protection and Restoration Feasibility Study: Coastal Storm Model Simulations of Waves and Water Levels*. ERDC/CHL LR-19-7. Vicksburg, MS: US Army Engineer Research and Development Center. NOTE: For access to this document, contact the author.

[2] Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report. Vicksburg, MS: US Army Engineer Research and Development Center.

7. Construct wind and pressure fields using planetary boundary layer (PBL) numerical model. Completed in CTXCS.
8. Model offshore waves with wave model (WAM) and surge and nearshore/inland waves with CSTORM (coupled ADCIRC and STWAVE) of all 660 TCs. Completed in CTXCS.
9. Create efficient subsample of 660 TCs using a genetic algorithm optimization that best matches the hazard with the fewest storms. New sample consisted of 195 storms, of which 189 storms were selected for design analysis. New storm rates were computed with metamodels. Described in Melby et al. (2021).
10. Model storm water levels and nearshore/inland waves with CSTORM for without- and with-project alternatives and three relative sea level scenarios for 189 synthetic TCs. Described in Melby et al. (2021). The with-project condition included CSRM system with feasibility authorized crest elevations.
11. Sample storms stochastically; extract storm water lever (SWL), wave height (H_{m0}), wave period (T_p), and mean wave direction and incorporate uncertainty; perform JPM integration to compute hazard curves for SWL, H_{m0}, and response parameters (e.g., q, the average overtopping rate). Also compute confidence limits (CL) (also called *level of assurance*). For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported. For USACE projects, q is computed at 50% and 90% upper CL and compared to overtopping limit states corresponding to start of damage and incipient failure. The details of the stochastic simulation approach and application of uncertainty are summarized in Appendix G of Melby et al. (2021).

The analysis took advantage of previous regional modeling completed under the Federal Emergency Management Agency, Flood Information Study that followed Hurricane Ike[1], S2G Feasibility Study[2] (USACE 2017), and Coastal Texas Comprehensive Study (see Melby et al. [2021], Appendix A for a summary of prior pertinent modeling and analysis

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[1] FEMA (Federal Emergency Management Agency). 2011 (Unpublished). *Flood Insurance Study: Coastal Counties, Texas. Intermediate Submission 2: Scoping and Data Review*. Joint Report prepared for Federal Emergency Management Agency by the Department of the Army, US Army Corps of Engineers, Washington DC.

[2] Melby, J. A., N. C. Nadal-Caraballo, J. Ratcliff, T. C. Massey, and R. Jensen. 2015 (Unpublished). *Sabine Pass to Galveston Bay Wave and Water Level Modeling*, ERDC/CHL Technical Report, Vicksburg, MS: US Army Engineer Research and Development Center.

studies). Additional hurricane SWL and wave hydrodynamic regional modeling, nearshore wave modeling, and overtopping modeling was completed for the S2G PED study. The extremal statistics were computed for the storm responses. The process used in the present analysis is described in Chapter 2 of Melby et al. (2021). Historical storms are described in Chapter 4, Appendix B, and Appendix D of Melby et al. (2021).

1.3.1 Storm hazard development

Probabilistic synthetic storm modeling is used to assess coastal storm hazards in hurricane-prone areas with a lack of adequate storm data. The joint probability method with optimal sampling was used to develop a total of 660 synthetic storms during the CTXCS study[1]. For the S2G PED study, a genetic algorithm was used to select an optimal subsample from the 660 CTXCS storms. The details of the approach are presented in Chapter 2 and Appendix C of Melby et al. (2021). The list of the 660 CTXCS model storms and 195 S2G model storms are in Appendix D of Melby et al. (2021). This set was further reduced to 189 storms. The six storms that were not used are noted in Appendix D of Melby et al. (2021).

1.3.2 Regional water level and wave modeling

Regional wind and surface pressure fields were generated with the PBL model and offshore waves with the third-generation wave model, WAM (Komen et al. 1994). Nearshore wave modeling was done with the STWAVE model. Circulation and water levels were generated with the ADCIRC model. The parameters used to set up ADCIRC, such as the Manning's *n* value, tidal constituents, river inflows, and the wind effects, are detailed in Chapter 4 of Melby et al. (2021). CSTORM modeling validation is summarized in Appendix B of Melby et al. (2021).

LiDAR topography data collected during 2018 was processed to construct a bare-earth digital elevation model (DEM) for the area. Excerpts from the metadata are given in Appendix E of Melby et al. (2021) that describe data collection, data processing, and quality control. Note that throughout this study, datum references followed requirements published in EM 1110-2-

[1] Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report, Vicksburg, MS: US Army Engineer Research and Development Center.

6056 (USACE 2010), including those specifically stated in Chapter 5 of that manual — *Standards and Procedures for Referencing Datums on Coastal Hurricane and Shore Protection Projects*. The SWL construction survey crew collected Taylor/Hillebrand Bayou bathymetric data in February 2019. Modeling and grid details of the WAM, STWAVE, and ADCIRC models for S2G are found in Chapter 3 of Melby et al. (2021). ADCIRC mesh and STWAVE grids were modified from the ones in CTXCS to more accurately capture the existing and proposed flood protection measures. The details of these modifications are in Chapter 3 of Melby et al. (2021).

Select spatial locations, called *save points* (SPs), were identified for CSTORM model parameter outputs. For S2G PED, a total of 5,148 SPs were identified in the Freeport, Port Arthur, and Orange CSRM regions. The SP selection process is detailed in Chapter 3 of Melby et al. (2021).

Tides were not included in the CSTORM synthetic storm modeling but rather included as epistemic uncertainty in the stochastic simulation modeling. This is consistent with other recent flood protection studies in the Gulf of Mexico. An error assessment was conducted to confirm that this approach was reasonable, and details are presented in Chapter 3 of Melby et al. (2021). Riverine flows from the Sabine River were not included in the CSTORM modeling, as described in Melby et al. (2021).

1.3.3 Design criteria

The criteria used for design of the levee and floodwall crest elevations are fundamentally based on a serviceability start-of-damage overtopping limit state at an annual exceedance probability (AEP) of 1%. This is consistent with present USACE practice and was followed for the planning phase of S2G and other recent regional projects such as Hurricane Storm Damage Risk Reduction System (HSDRRS) (USACE 2012).

Defining overtopping design criteria is empirical, and exact guidance does not exist. The Coastal Engineering Manual (USACE 2008) provides some general criteria, but there is considerable uncertainty due to a wide variation of potential structure configurations and surrounding ground cover. For example, a floodwall on a grass levee would likely be designed for overtopping rates consistent with grass levees, while a floodwall on a concrete wharf or quaywall would be designed for overtopping rates consistent with concrete armoring. The following conservative overtopping rate criteria were used for the HSDRRS project and was followed herein:

- For design levee elevation, overtopping rates of 0.1 cfs/ft at 90% CL and 0.01 cfs/ft at 50% CL were used as a limit state for initiation of damage.
- For design floodwall elevation, overtopping rates of 0.1 cfs/ft at 90% CL and 0.03 cfs/ft at 50% CL were used as a limit state for initiation of damage.

Damage here refers to the impact on surrounding soils near a structure due to overtopping. If the surrounding area is entirely concrete, the damage would be limited. Damage, in this sense, does not include settlement, damage to the wall, or geotechnical failure due to wall separation or levee slip circle failure. Herein, damage is defined only in relation to erosion of the leeside surrounding soil that supports the structure components. Implications of using these limit states over alternatives are described in Melby et al. (2021).

1.3.4 Coastal structure response hazard calculations

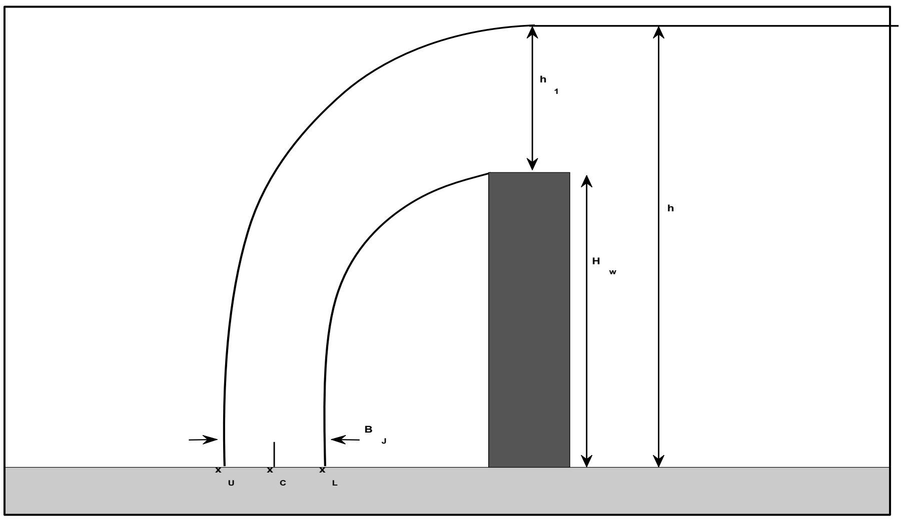
As described in Melby et al. (2021), two stochastic simulation approaches are commonly used for large-scale flood protection evaluation: event-based and response-based. Event-based approach is a partially probabilistic approach where the AEP values of water level and wave forcing parameters, such as the 1% AEP, are used to compute responses. Response-based approaches compute the structure response for each storm and then compute statistics from the peak responses. The design safety level used as a statistical basis for event-based approaches (e.g., AEP = 1%) is applied to the storm hydrodynamic response (e.g., SWL, H_{m0}) whereas the statistical basis for the response-based solution is the final response (e.g., overtopping). The result is that reliability (and risk) for the event-based approach will vary across the CSRM system because the response statistics will vary, whereas for the response-based approach, the reliability and risk will be more spatially consistent and will be consistent with the desired safety level. In addition, response-based approaches are more accurate because the multivariate probabilistic forcing and associated uncertainties are carried through the computational workflow along with uncertainties associated with the empirical equations used to compute overtopping and overflow, wave pressures on walls, and the characteristics of wall overtopping nappe. Melby et al. (2021) compared five different stochastic simulation approaches and showed that the response-based approach was much more accurate than event-based methods. Stehno (2021) showed that event-based methods for computing crest elevations based on overtopping rates often yield wildly inaccurate results. It was shown that there is no correlation between structure or storm forcing parameters and difference between event-based and response-based overtopping rate at 1% AEP. Therefore, herein, the response-based approach is used.

A simplification that was used is that the peak SWL and peak H_{m0} are assumed to occur at the same instant, and responses are computed using these values. This is not always true, so this is a conservative assumption. However, Melby et al. (2021) and Stehno (2021) showed that the added conservativeness from this assumption over the fully time-dependent approach was negligible. This is because the peaks align for the most intense storms, and these storms are much more influential in defining extreme response hazard.

Overtopping rates were computed for floodwalls and levees according to the EurOtop (2018) Manual, as summarized in Appendix F of Melby et al. (2021). An optimization step was completed to compute the required levee elevations that just exceed the no-damage limit states. The response-based stochastic simulation routine was initially used to compute the overtopping response of a relatively low crest elevation at each transect. If the overtopping response was greater than the no-damage limit states of q=0.01 cfs/ft for a 50% CL or q=0.1 cfs/ft for a 90% CL, the levee crest elevation was increased by 0.5 ft, and the response was recomputed. Similarly for floodwalls, if the overtopping response of a relatively low crest elevation exceeded q=0.03 cfs/ft for a 50% CL or q=0.1 cfs/ft for a 90% CL, the floodwall crest elevation was increased by 0.5 ft, and the response was recomputed. This crest raising and recomputation cycle was repeated with subsequent 0.5 ft crest height increments until both 50% and 90% CL no-damage limit states were satisfied, thus computing an "optimized" levee crest elevation. Additionally, if the optimized crest elevation was found to be lower than the 1% AEP SWL at 90% CL, then the 1% AEP SWL at 90% CL was selected as the optimized crest elevation. This simulation was completed using the with-project wave and water level responses. Results of the optimized crest elevation for each transect location are presented in Appendix C.

Overtopping nappe geometry characteristics, shown in Figure 4, were calculated for floodwalls. The inputs for SWL, H_{m0}, and q were taken at the corresponding AEP with a 90% CL for a conservative estimate. The equations for nappe geometry characteristics are described in Appendix F of Melby et al. (2021).

Figure 4. Floodwall nappe geometry characteristics.



Distances x_U, x_C, and x_L are measured from flood side of floodwall. For nappe computations, the floodwall is considered a sharp-crested structure with the peak structure crest coincident with the seaward face. The distance from the structure to the center of the jet impact x_C generally increases with the increase in water level (increasing RSLC conditions and decreasing AEP). The jet velocity and force on the impact location are minimal for low overtopping rates and increase as the overtopping rates increase with decreasing AEP.

The combined hydrostatic and hydrodynamic fluid pressures on floodwalls, shown in Figure 5 and Figure 6, were calculated. Elevation H_W denotes floodwall elevation, h_o denotes water depth five wave heights from the structure, h denotes storm water depth at structure toe, R_c denotes structure freeboard, and p_1, p_2, and p_3 are the Goda (1974) hydrodynamic pressures at the SWL, crest elevation, and structure toe, respectively. Hydrostatic pressures can be linearly added to the Goda hydrodynamic pressures. The equations for pressures are described in Appendix F of Melby et al. (2021).

Figure 5. Floodwall fluid hydrodynamic pressure characteristics when SWL is at or below the structure crest elevation (freeboard, *Rc*, is positive).

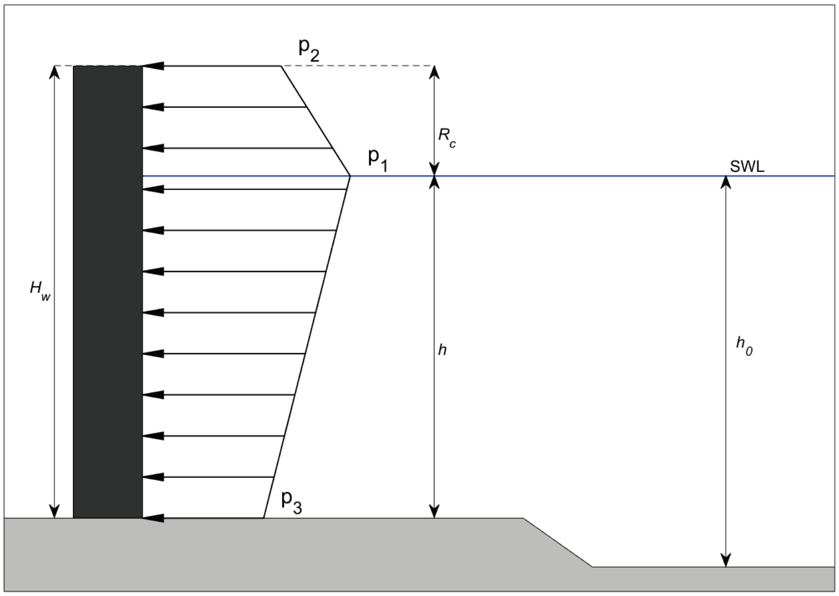
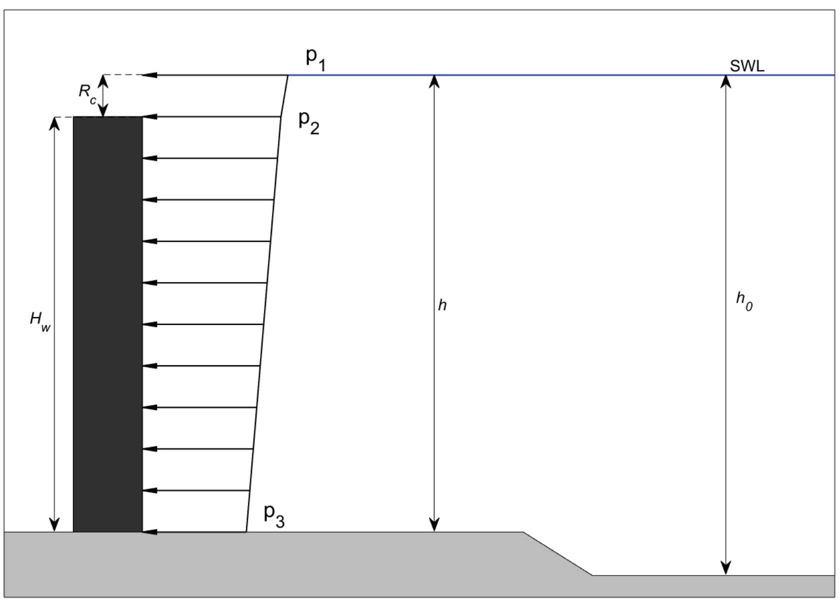


Figure 6. Floodwall fluid hydrodynamic pressure characteristics when SWL is higher than the structure crest elevation (freeboard, *Rc*, is negative).



1.3.5 Forcing and crest elevations

RSLC scenarios were defined according to guidance set forth in USACE ER 1100-2-8162 (USACE 2019a) and EP 1100-2-1 (USACE 2019b). The detailed calculations of RSLC and geoid offsets for CSTORM simulation scenarios are given in Appendix H and in Chapter 3 of Melby et al. (2021). The total RSLC and final geoid offsets for the CSTORM simulations were as follows:

- SLC0, Beginning of Service Life
  - RSLC=0.17 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL[1]-NAVD88)+0.17 ft=1.52 ft
- SLC1, 50 yr Service Life
  - RSLC=0.22 + 1.36 ft=1.58 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL-NAVD88)+1.58 ft=2.93 ft
- SLC2, 100 yr Service Life
  - RSLC=0.22 + 3.16 ft=3.38 ft
  - Geoid offset=0.39 ft steric+(0.96 ft LMSL-NAVD88)+3.38 ft=4.73 ft.

As only a single water level can be used as an initial water level over the entire model domain in the ADCIRC-STWAVE simulations, an average of the total RSLC and geoid offsets at Sabine Pass North and Freeport was used. The final design SWLs for a given project area were adjusted according to the difference between this average value and the values at the Sabine Pass North and Freeport gages for the Sabine and Freeport areas, respectively. According to Appendix H in Melby et al. (2021), the difference between the mean sea level (MSL) at Sabine Pass North gage and the average MSL (used to initialize the numerical model simulations) was 0.11 ft. As such, the final SWLs in the Sabine area include this additional 0.11 ft to reflect the larger “local” MSL compared to the “regional” average MSL used in the geoid offset of the CSTORM simulations.

The final list of forcing scenarios for CSTORM with geoid offset was as follows:

1. Without-project, SLC0.
2. Without-project, SLC1.
3. Without-project, SLC2.
4. With-project, SLC0, with Orange County CSRM system.
5. With-project, SLC1, with Orange County CSRM system.
6. With-project, SLC2, with Orange County CSRM system.

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[1] Local mean sea level vertical datum.

All with-project simulations were conducted with the feasibility "authorized" design elevations associated with the 50 yr intermediate RSLC scenario.

1.3.6 Forcing and crest elevation combinations

Multiple structure crest elevation scenarios were evaluated. The without-project (existing) elevations correspond to structure elevations from LiDAR collected in 2018 and from field measurements. The feasibility authorized design elevations (authorized) were defined in the feasibility study and were used as the structure elevations in the with-project CSTORM modeling. Structure crest elevations were optimized using design criteria under SLC1 and SLC2 with-project storm conditions and are referred to as "optimized" for the corresponding RSLC. The optimized crest elevation computation is described above. The feasibility authorized design elevations and optimized elevations informed the project development team (PDT) to define the "design elevations" corresponding to SLC1 and SLC2. Gates and pump station fronting protection crest elevations were set at the SLC2 design elevation. The combination of forcing and elevation scenarios presented herein are as follows:

1. Existing elevation/SLC0 forcing – Structure response evaluated for structure with existing without-project crest elevation and exposed to SLC0 without-project forcing scenario.
2. Design elevation SLC1/SLC1 forcing – Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to SLC1 with-project forcing scenario.
3. Design elevation SLC1/SLC2 forcing – Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to SLC2 with-project forcing scenario.
4. Design elevation SLC2/SLC2 forcing – Structure response evaluated for structure with design crest elevation computed under SLC2 condition and exposed to SLC2 with-project forcing scenario.

Additional combinations were provided to the sponsor but are not included herein.

1.3.7 Taylor/Hillebrand Bayou bathymetric data

In February 2019, the SWG survey crew collected single-beam bathymetric depths along cross sections within the Hillebrand and Taylor Bayous

(Figure 7 and Figure 8). The echo sounder used was a Hydrolite attached to a flat-bottom boat linked with a Trimble receiver for horizontal location of the depth readings. These points were reported relative to NAVD88 State Plane Texas South Central (feet) Geoid12B. Nature ground real-time kinematic Global Positioning System elevations were measured from boat on bank to tie field data with LiDAR. When these ground elevations were compared to the DEM derived from LiDAR, there was an average difference of under 0.1 ft with a standard deviation of 1 ft. The bathymetric and topographic data collected from the LiDAR surveys were incorporated in the ADCIRC and STWAVE mesh.

Figure 7. Extent (in blue) of 2019 bathymetric surveys of Taylor and Hillebrand Bayous.

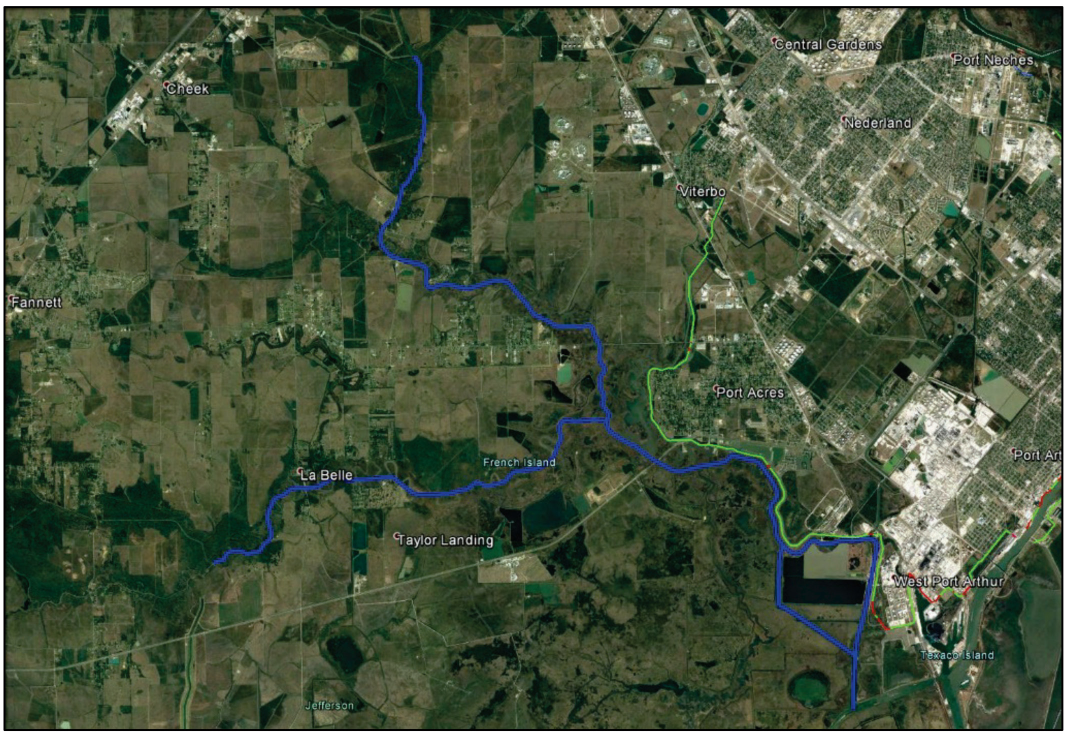
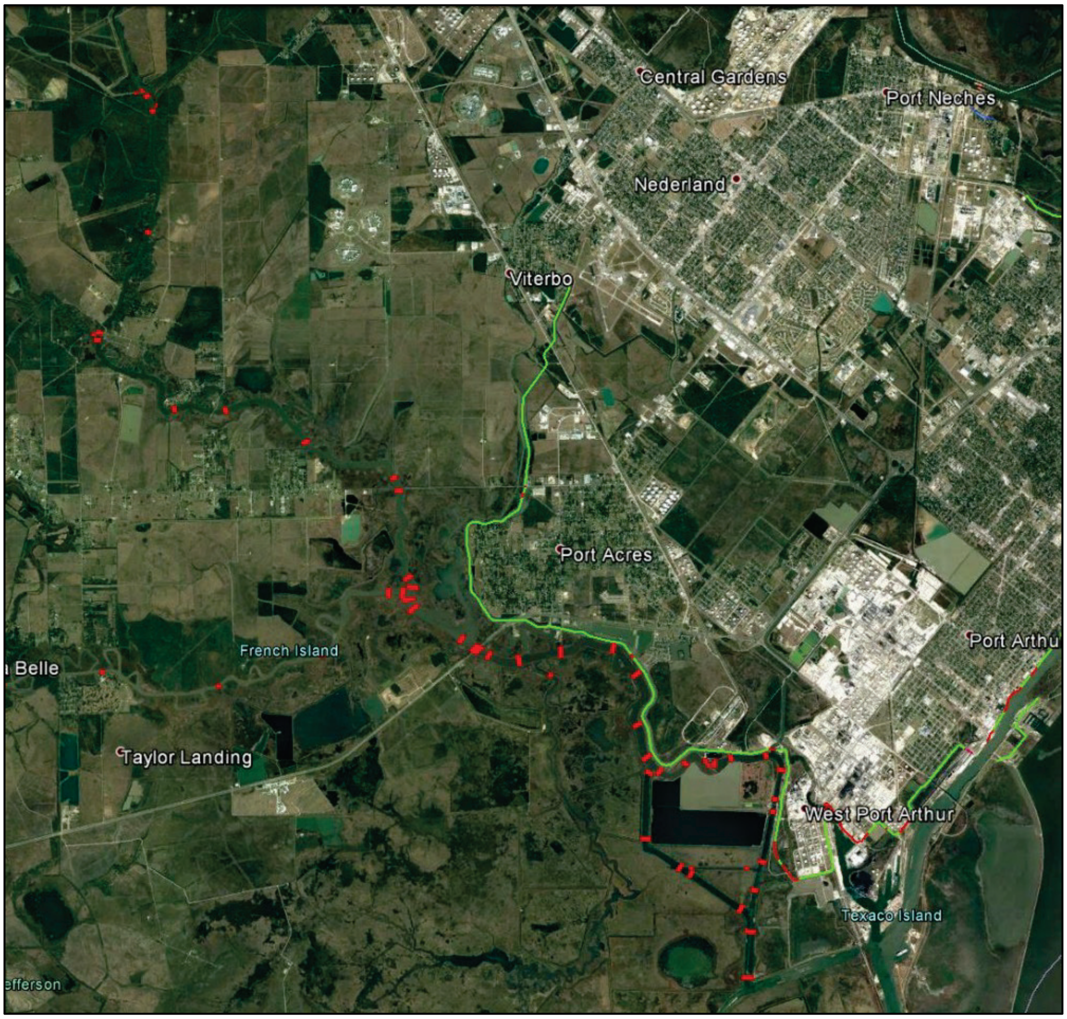


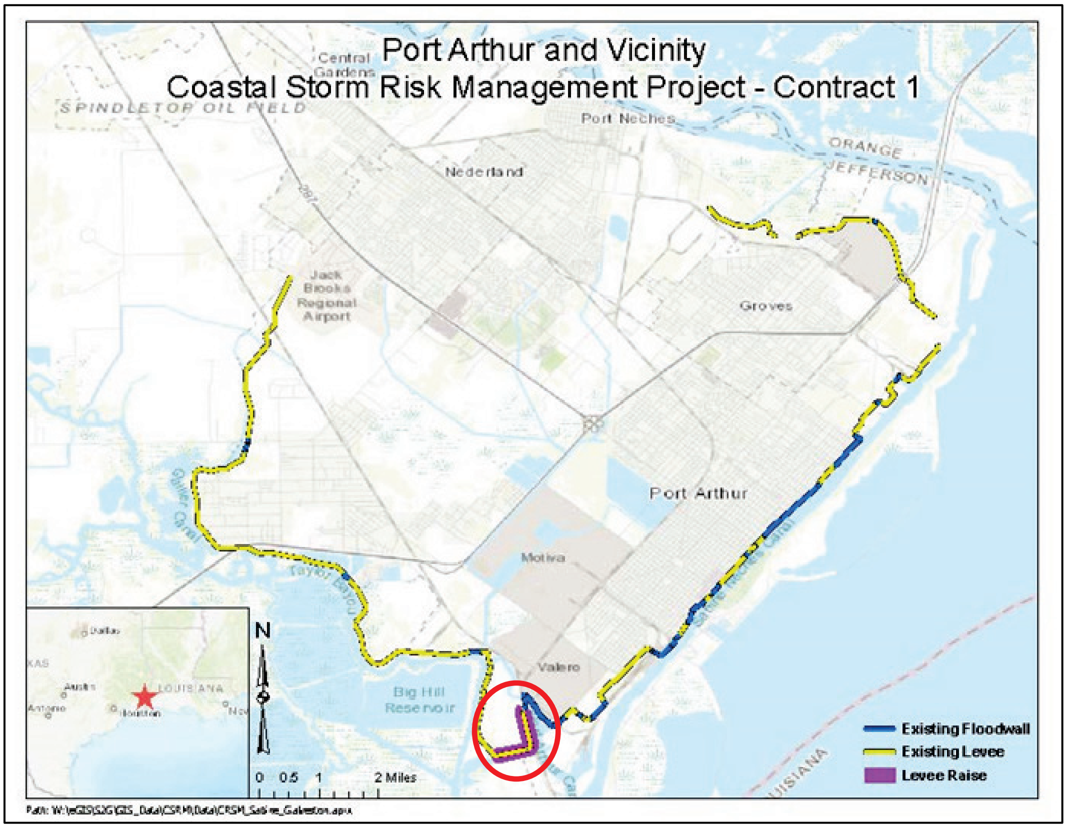
Figure 8. Survey cross section for 2019 bathymetry surveys of Taylor and Hillebrand Bayous.



2 Contract 1

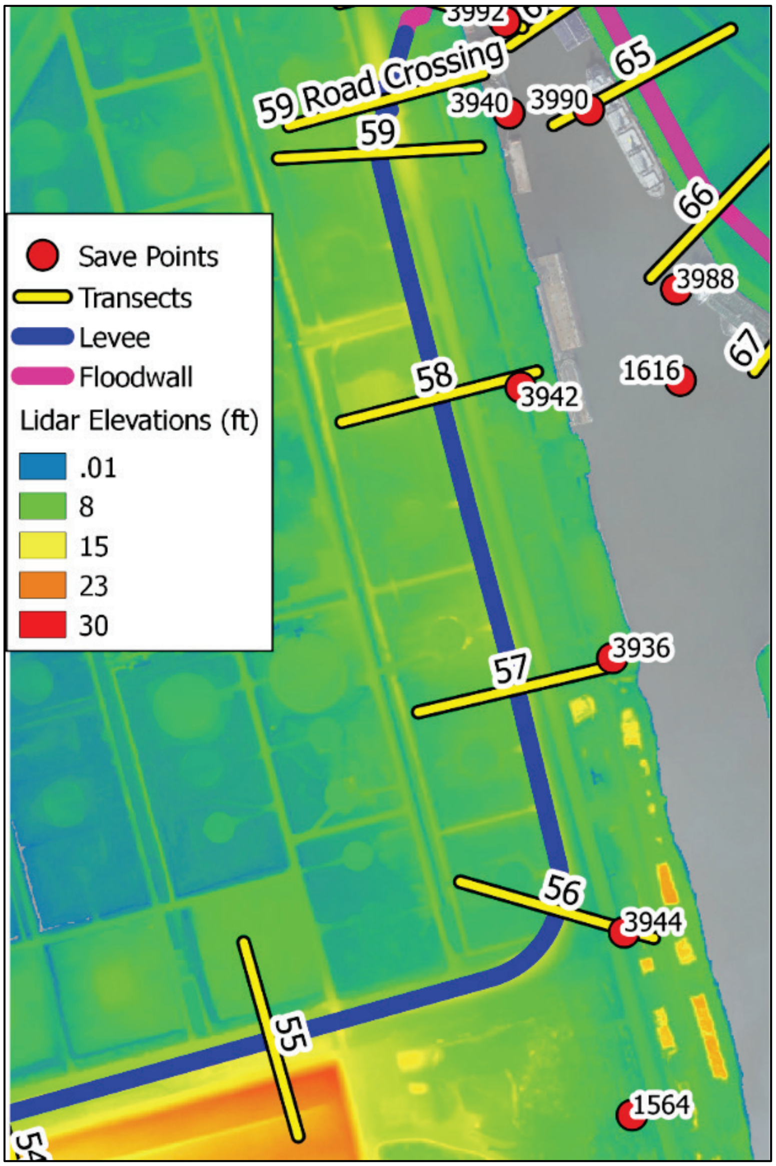
Contract 1 designates the first construction contract of the Port Arthur CSRM system (Figure 9 and Figure 10). Contract 1 consists entirely of levees. Coastal SWL, wave loading, and overtopping and overflow are quantified using hydrodynamic modeling and stochastic simulations described in Chapter 1.

Figure 9. Contract 1 levee replacement for Port Arthur CSRM (highlighted in purple and circled in red).



Contract 1 for Port Arthur includes a section of the existing CSRM system of approximately 1.1 mi of levee along the Chevron tank facility. The levee reach begins at STA. 872+78.35, which is adjacent to the west side of the Highway (HWY) 87 crossing and proceeds west to STA 933+80. Modifications include levee raising and reconstruction of portions of the levee that contain oyster shell as its erosion protection. The shell is approximated to be more than 1–2 ft in thickness and has shown excessive erodibility. It is anticipated that the levee cross section will be excavated and rebuilt to original design with a clay core and good grass cover, as well as incorporate a raise of the levee to the design elevations. Some additional features of this levee reach are (1) an all-weather access roadway on the crest that runs the entire length of the levee reach and (2) nine ramps that cross the levee near STA 877+40, STA 881+60, STA 884+60, STA 887+20, STA 892+20, STA 897+25, STA 902+30, STA 907+75, and STA 919+40.

Figure 10. Details of Contract 1 for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (ft, NAVD88).



2.1 Local wave and water level response

The peaks of the top 10 synthetic storms ranked by SWL are listed for SP 3936 (see Figure 10 for SP location) in Table 2 for without-project and with-project forcing conditions. The “MWD” column is mean wave direction (MWD) and is in Euclidean format (0 is east; counterclockwise is positive). Peak wave period (T_p) and MWD are values associated with significant wave height (H_{m0}) peak. Additional information regarding the water level response is found in Chapter 4 of Melby et al. (2021).

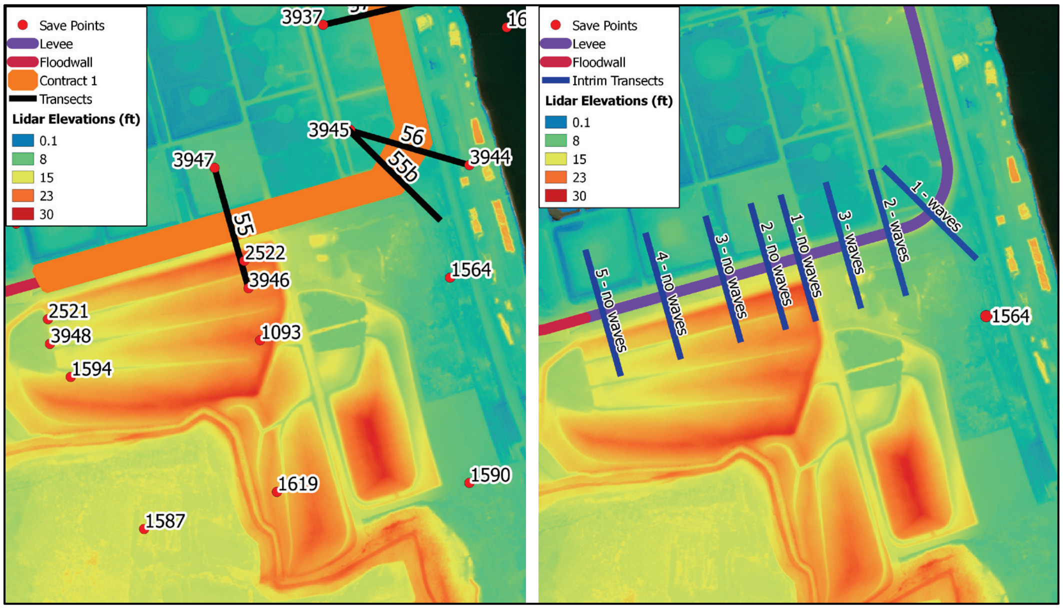
Peak SWL and H_{m0} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 forcing scenarios for each SP in the Contract 1 analysis are summarized in Appendices A and B.

Table 2. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 3936.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	19.01	4.02	3.24	127.9	461	18.16	4.16	3.91	127.9
633	18.46	3.13	3.24	161.9	447	17.64	2.2	2.94	141.7
357	17.96	2.63	2.94	140.7	633	17.48	3.22	3.56	161.8
447	17.88	2.25	2.94	141.7	357	17.45	2.43	2.94	140.7
464	16.36	2.19	2.94	139.4	589	16.69	2.09	2.94	109.3
342	16.17	1.66	2.94	146.6	464	16.51	2.19	2.94	139.4
598	15.96	2.36	2.94	138.1	342	16.38	1.76	2.94	146.6
589	15.88	1.94	3.24	115.9	598	16.16	2.38	2.94	138.1
159	15.04	1.96	2.94	127.3	529	15.9	1.82	3.24	118.6
529	14.64	1.85	3.24	118.6	634	15.51	2.15	3.56	178.3
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	20.14	4.28	3.56	127.9	461	19.52	4.28	3.56	127.9
633	19.38	3.87	3.56	163.8	447	19.46	2.46	2.94	144.5
447	19.27	2.47	2.94	141.7	357	19.21	2.73	2.94	140.7
357	19.08	2.75	2.94	140.7	633	19.19	3.75	3.56	163.8
589	18.64	2.25	2.94	97.5	589	18.5	2.14	2.94	126
598	18.45	2.87	2.94	138.1	464	18.01	2.59	2.94	139.4
342	18.29	2.02	2.94	149.4	342	17.93	2	2.94	149.4
464	18.27	2.67	3.24	154.7	598	17.82	2.86	3.24	148.7
529	16.52	2.28	3.24	118.6	529	16.97	2.25	3.24	118.6
159	16.4	2.19	2.94	129.6	159	16.64	2.24	2.94	129.6
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	21.76	5.01	3.56	147.3	416	21.79	4.79	3.56	147.3
366	21.4	4.43	3.56	163.8	447	21.54	2.72	3.24	150.2
447	21.37	2.67	3.24	152.9	357	21.36	3.02	3.24	148.7
357	21.17	2.97	3.24	152.4	366	21.35	4.47	3.56	163.8
589	20.38	2.51	2.94	97.5	589	20.49	2.5	2.94	97.5
464	20.22	3.03	3.24	154.7	464	20.28	3.03	3.24	154.7
598	20.14	3.36	3.24	148.7	598	20.08	3.35	3.24	148.7
342	19.96	2.3	2.94	152.5	342	20.04	2.32	2.94	152.5
529	19.5	2.6	3.56	129.5	529	19.24	2.65	3.24	118.6
595	19.21	3.77	3.56	118.6	532	18.74	2.22	2.94	145.2

For the southern leg of the levee corresponding to area from transect 55 west to end of Contract 1 reach (Figure 11), the CSTORM SLC0 scenarios did not inundate the area because there is a high mound seaward of the levee that is above the highest SLC0 SWL elevation. The topography seaward of that levee reach is higher than the levee crest. Several storms inundate the area just seaward of the levee between the mound and the levee, but no significant wave energy can get to the area even under elevated RSLC scenarios. The highest SWL in Table 2 is approximately 22 ft for SLC2 whereas the mound is over 25 ft. Therefore, the hazard exposure for the levee behind the mound (transect 55 to the western end of Contract 1 levee) is based on SWL only with no waves whereas transect 56 has the full wave impact associated with SP 1564. An analysis of the reach between transect 55 and transect 56 was done to determine the hazard exposure for this transitional reach. Note that the without-project structure slope varies along this reach, which also influences overtopping. The response analysis required the levee reach west of transect 56 to be refined into eight transects for without-project conditions, three of which are influenced by waves and five that are only influenced by water levels. The five that are only influenced by water levels are shoreward of the higher topography area. Figure 11 shows that the intermediate transect labeled as “3-waves” is the last transect in this reach that has any wave exposure, and even then, wave exposure is only from the southeast, and waves pass over relatively high topography that is approximately 15 ft in elevation. Transect “2-waves” has approximately the same wave exposure as transect 56. In the following, a new transect called “55b” is used to describe the maximum response occurring between transects 55 and 56 and the resulting levee crest elevation for this reach. SP 1564 is used as forcing for this section. The maximum without-project overtopping response for this reach occurs just west of transect 56.

Figure 11. Transect 55 and intermediate transects.



With-project SWL peaks for all storms are plotted against without-project conditions in Figure 12, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 13. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 12. With-project SWL peaks for all storms plotted against without-project conditions for SPs 3936 (left) and 3944 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

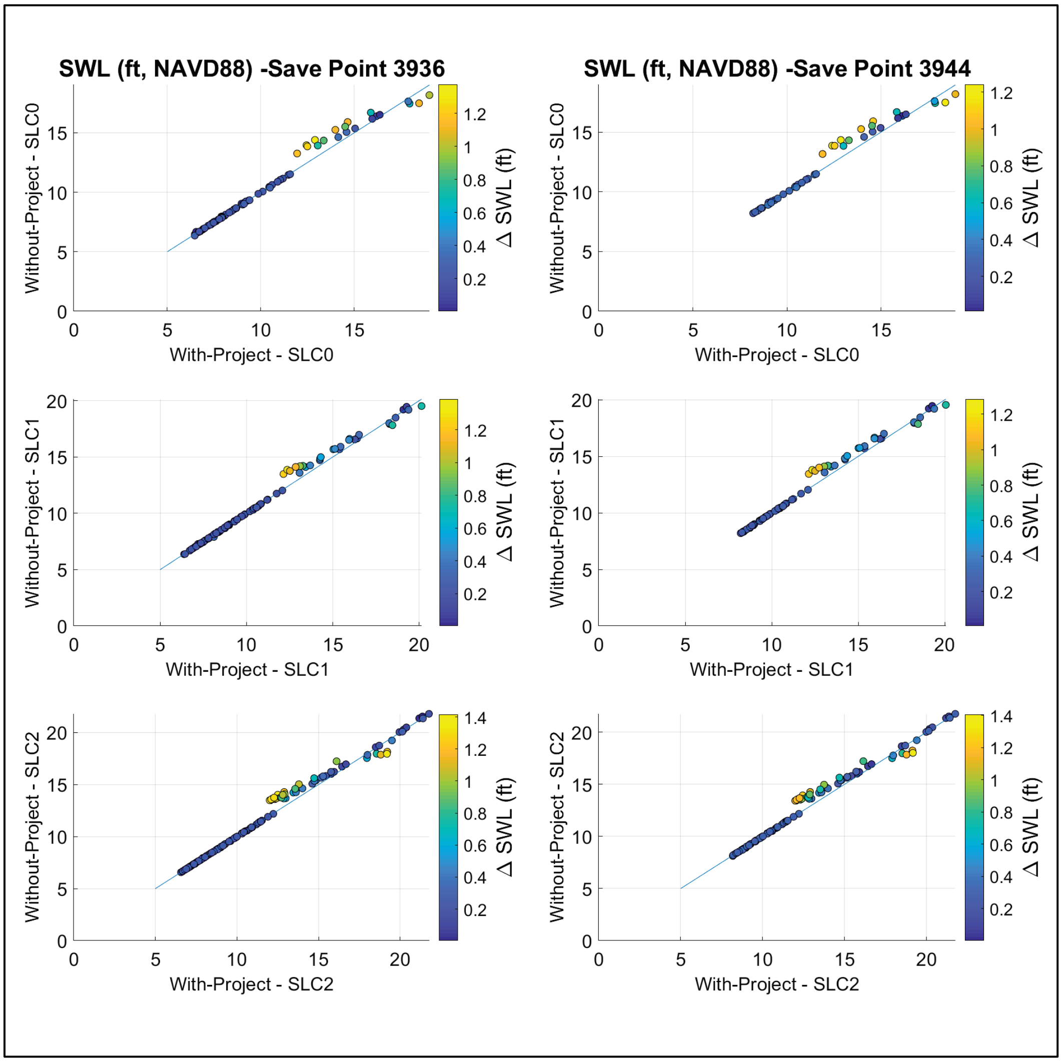
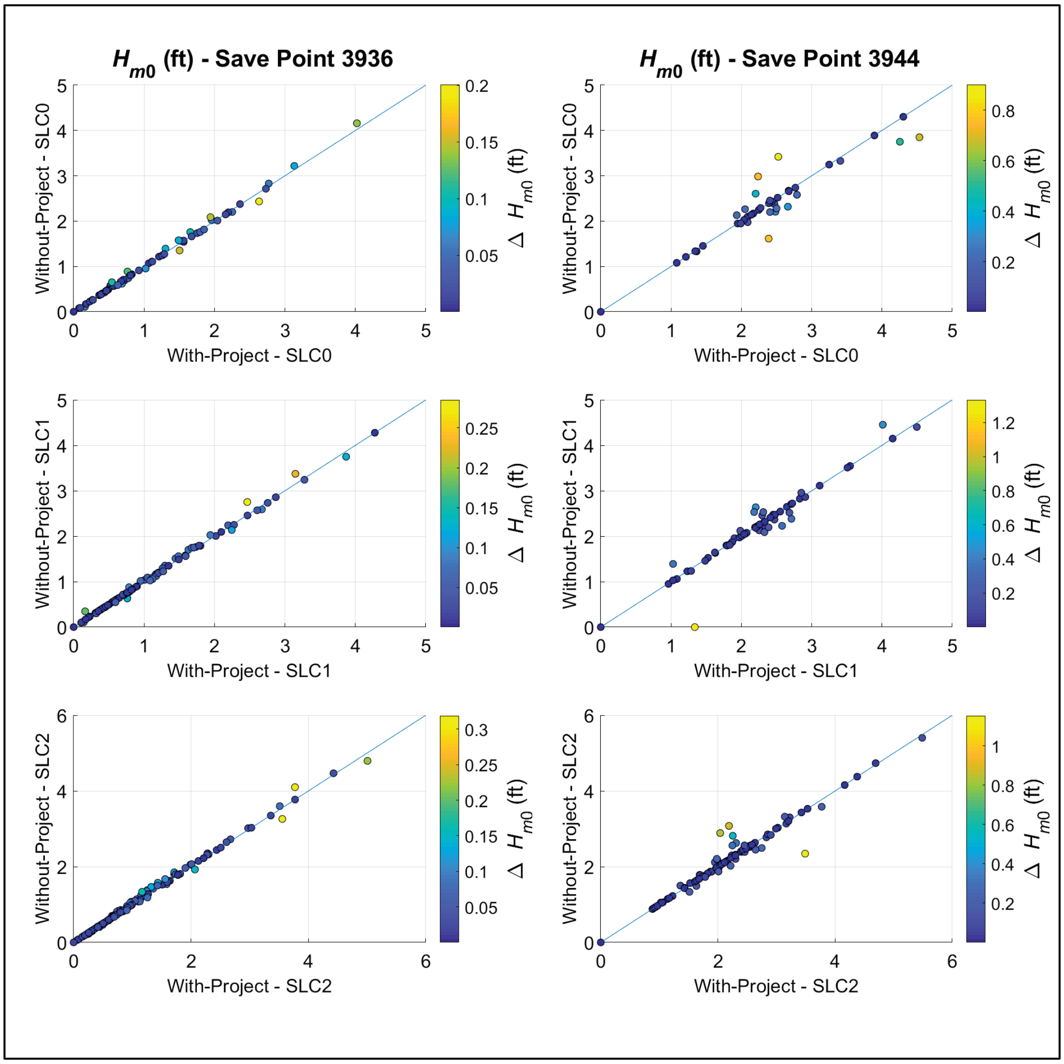


Figure 13. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 3936 (left) and 3944 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Probability masses were computed from the JPM analysis of CTXCS modeling output for 660 storms and 18332 SPs[1] and recomputed for the 189 S2G storms and 5,148 SPs using the methods discussed in Melby et al. (2021). The associated added uncertainty is described in Chapter 4 and Appendices A and G of Melby et al. (2021).

Figure 14 and Figure 15 show SWL and H_{m0} hazard curves, respectively, at SPs 3936 and 3944 for without- and with-project SLC0, SLC1, and SLC2

[1] Nadal-Caraballo, N. C., A. B. Lewis, V. M. Gonzalez, T. C. Massey, and A. T. Cox. Draft. *Coastal Texas Protection and Restoration Feasibility Study, Probabilistic Modeling of Coastal Storm Hazards*. ERDC/CHL Technical Report. Vicksburg, MS: US Army Engineer Research and Development Center.

scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in the link presented in Appendix D for without-project SLC0 and with-project SLC1 and SLC2 conditions. The 1% AEP waves are relatively small (generally, approximately H_{m0}=3 ft).

Figure 14. AEP vs. SWL for SP 3936 (left) and SP 3944 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

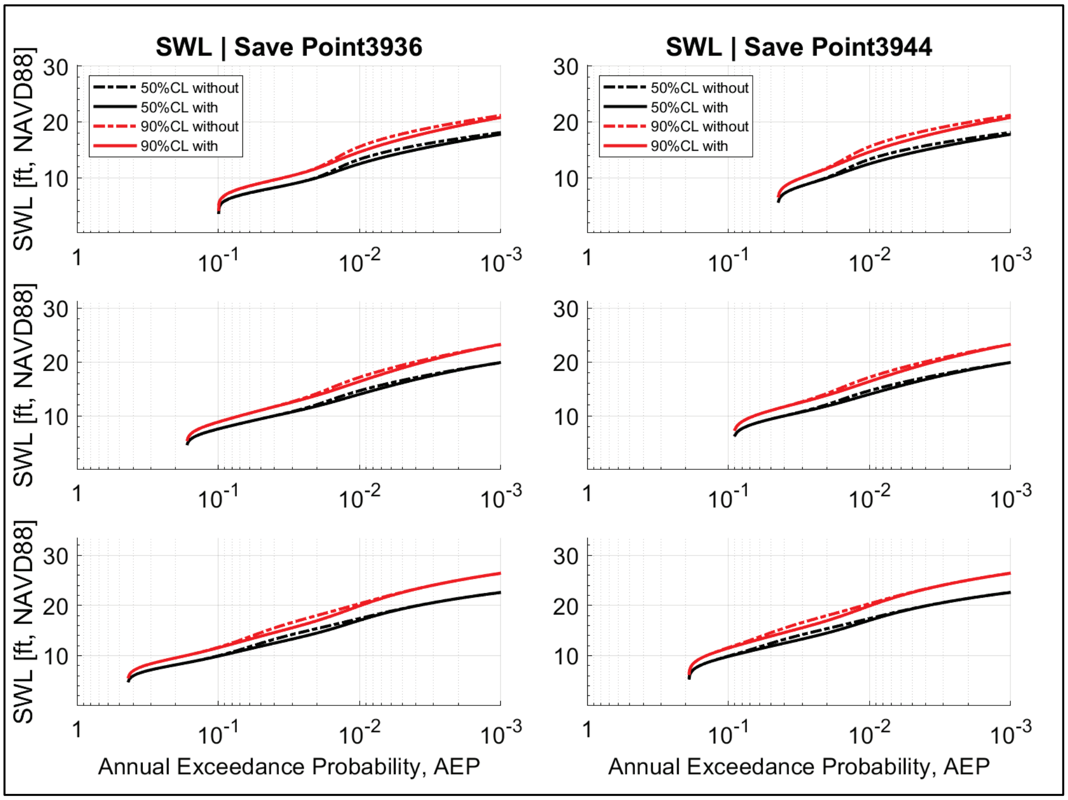
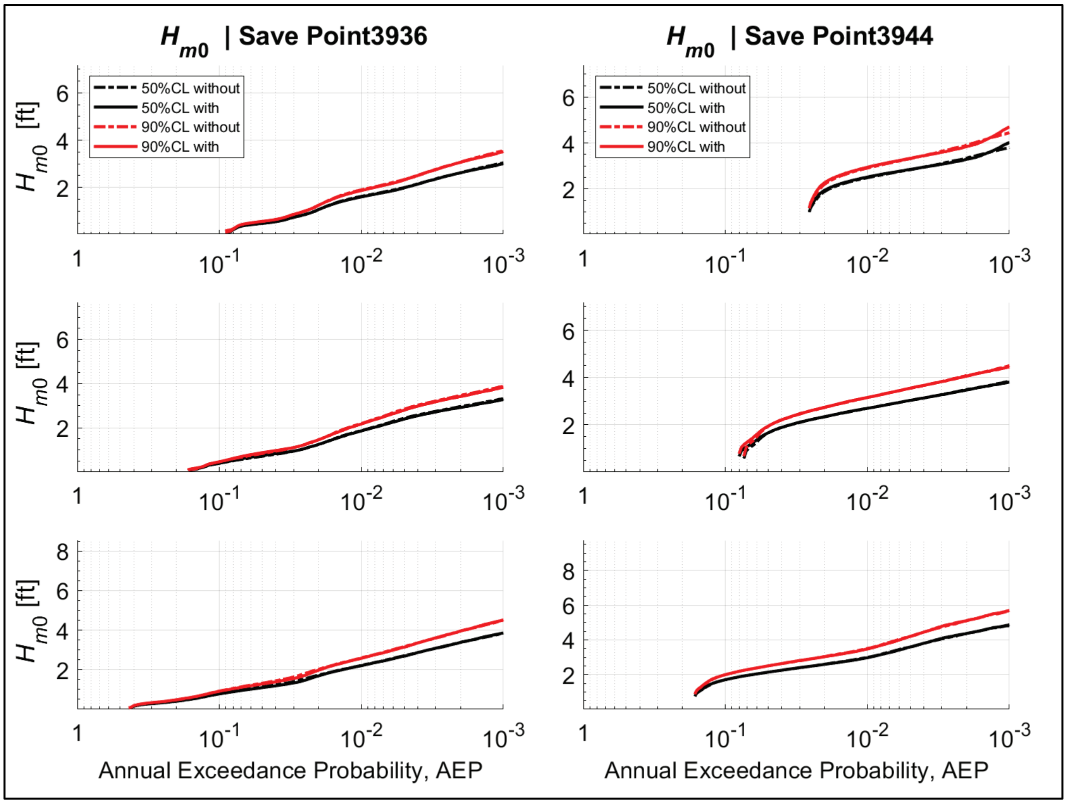


Figure 15. AEP vs. H_{m0} for SP 3936 (left) and SP 3944 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazards for SWL and H_{m0}, it can be seen that while there are some differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences for individual storm responses may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

2.2 Historical storm annual recurrence intervals

An analysis of historical tropical cyclones was conducted to determine the annual recurrence interval associated with the peak SWL. Each storm was modeled using CSTORM with geoid set to model the steric water level at the time of the storm. Tidal fluctuations were included. The storm modeling of historical storms is described in Chapter 4 and Appendix B of Melby et al. (2021). The peak SWLs from CSTORM were compared to National Oceanic and Atmospheric Administration (NOAA) water level gage measurements near the area, and they were within 1 ft. The results were consistent with the hazard curves from synthetic storms discussed above.

2.3 Minimum water level probabilistic hazard

An analysis of minimum water level probabilistic hazard was conducted to provide input for geotechnical stability related to drawdown. To compute the probability distribution of water level minima, the combination of relatively frequent localized minima from extreme tides and general weather systems and the infrequent extremes due to tropical cyclones must be combined. The continuous recorded hourly and monthly water levels near Contract 1 were obtained from NOAA Tides and Currents website for the Sabine Pass North Gage (8770570). This gage had a 33 yr record. SP 1094, in the center of Taylors Bayou Turning Basin (TBTB), was selected to analyze the JPM synthetic TC minimum water levels.

Figure 16 shows the measured SWL and resulting minima hazard curve. Note that the tropical storms were removed from the record on the left before computing the distribution on the right. Also, values in the time series in the left plot have not been inverted, but values in the distribution on the right have been. Figure 17 shows time series of two synthetic TCs with extreme minima where the time series minima have been highlighted. Here, extreme minima are the result of SP being on the left side of storm where winds are blowing offshore. Minima for all 189 TCs are shown in Figure 18 for with-project SLC0 scenario. Figure 19 shows the resulting TC minima hazard curves for with- and without-project SLC0 scenarios. Figure 20 shows the combined hazard curve where the measured curve (left figure) is combined with that for TC (right figure). Select values of drawdown at varied AEPs are shown in Table 3.

Figure 16. Water level gage 877570 recorded 33 yr time series and minima hazard curve where TCs have been excluded.

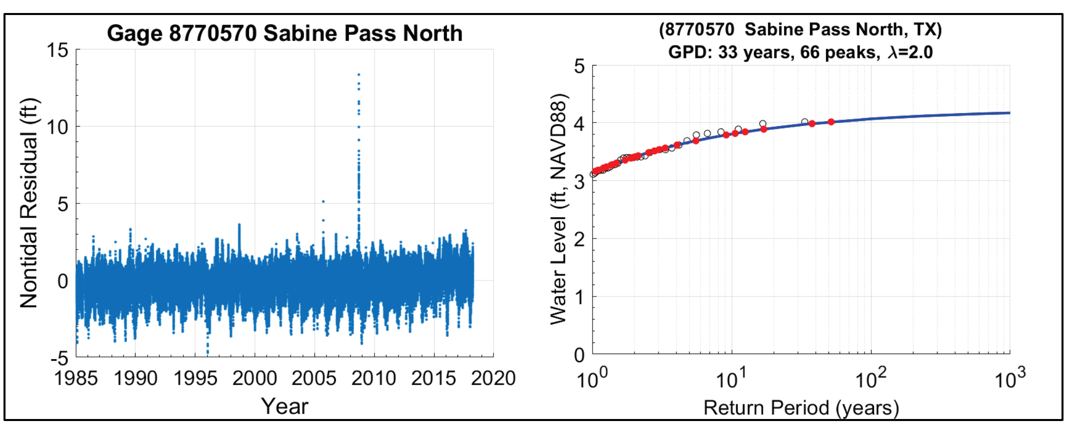


Figure 17. Example SWL time series and minima (red circle) for synthetic TC at SP 1094 for with-project SLC0 scenario.

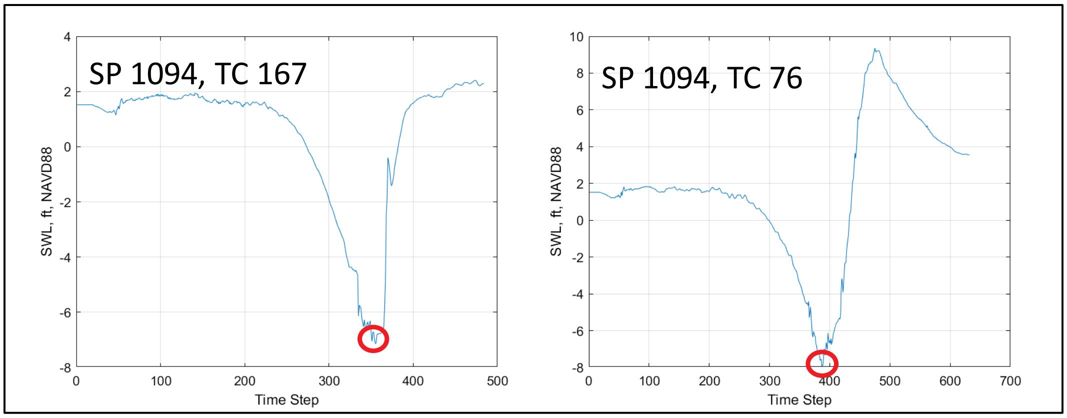


Figure 18. All TC minima for synthetic TCs at SP 1094 for with-project SLC0 scenario.

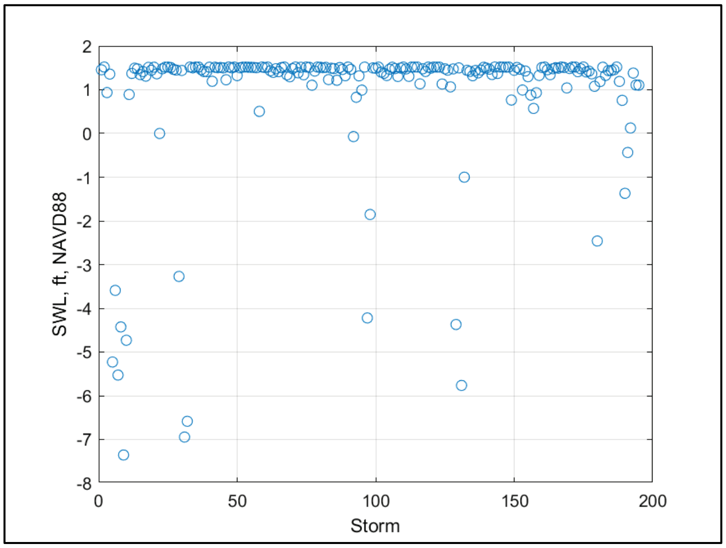


Figure 19. Hazard curves for synthetic TC minima at SP 1094 for without-project (left) and with-project (right) and SLC0 scenarios. Negative values have been inverted. SWL is in feet, NAVD88.

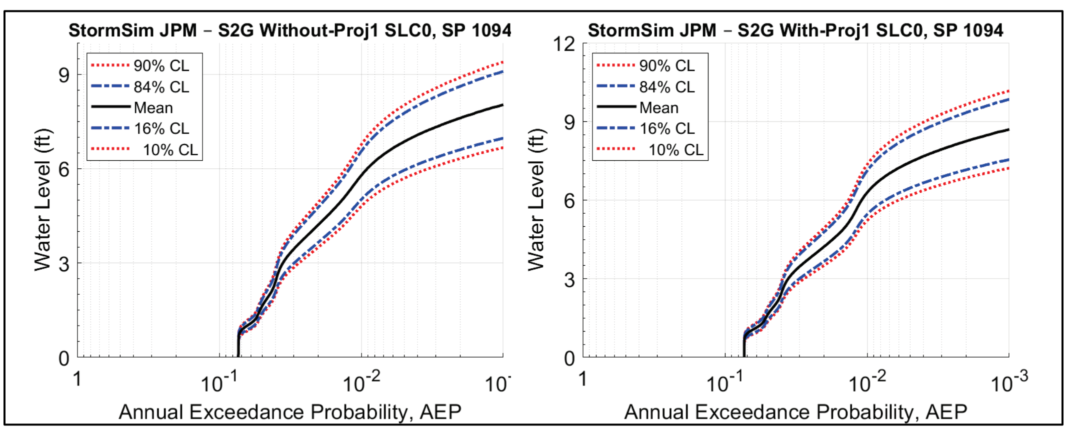


Figure 20. Hazard curves for combined measured SWL and TC minima at SP 1094 for with-project SLC0 scenario.

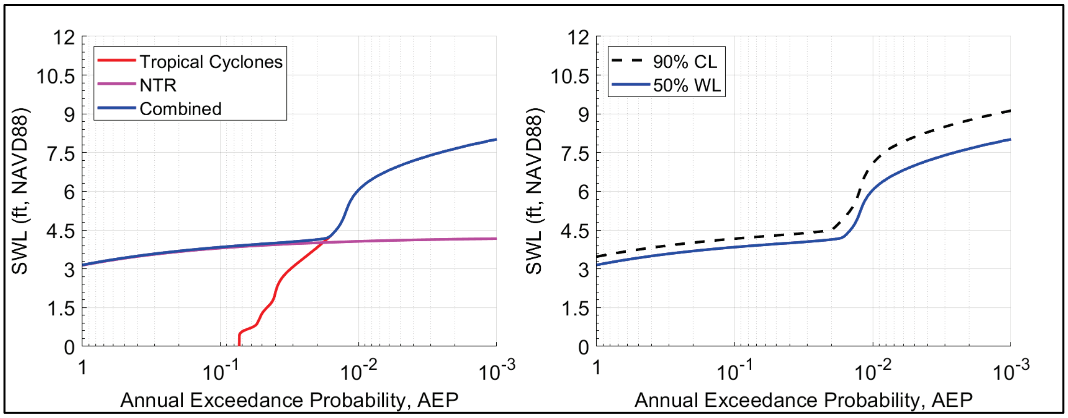


Table 3. Drawdown in feet, NAVD88, for various values of AEP in TBTB.

Scenario	Annual Exceedance Probability					
	1	0.1	0.02	0.01	0.002	0.001
Without-Project SLC0 50% CL	3.1	3.8	4.1	5.5	7.1	7.5
Without-Project SLC0 90% CL	3.5	4.2	4.5	6.4	8.2	8.6
With-Project SLC0 50% CL	3.1	3.8	4.2	6.0	7.6	8.0
With-Project SLC0 90% CL	3.5	4.2	4.5	7.1	8.7	9.1

2.4 Local Coastal Storm Risk Management (CSRM) system response modeling

The features of the without-project and feasibility authorized elevation CSRM system corresponding to Contract 1 are listed in Table 4 and Table 5, respectively. The existing topography for much of the area around Port Arthur CSRM system is from LiDAR and SWG (field surveys). Figure 21 shows the along-structure, without-project levee crest elevations for the TBTB reach, and Figure 22 shows the along-structure, without-project elevations for the west leg reach. The without-project levees were evaluated using the same overtopping limit states as the design elevation levees; however, the oyster shell on the without-project levee will have a lower failure level than an equivalent structure with grass cover and topsoil layer on clay subsoil.

Figure 21. TBTB reach without-project levee crest elevations relative to NAVD88.

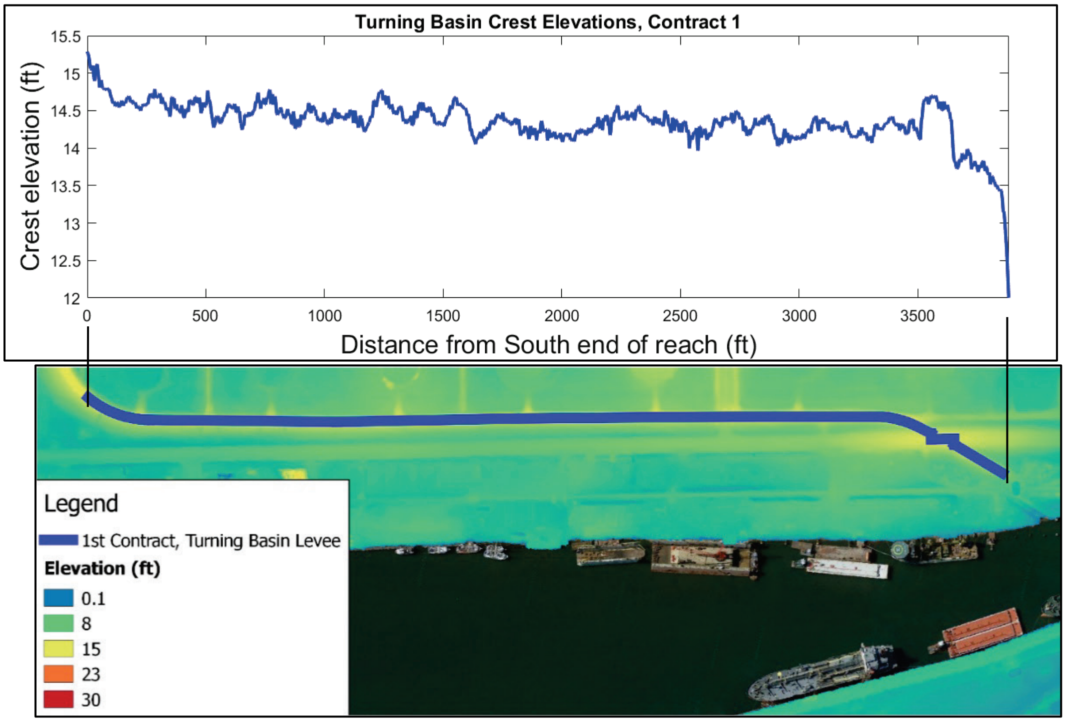


Figure 22. West reach without-project levee crest elevations relative to NAVD88.

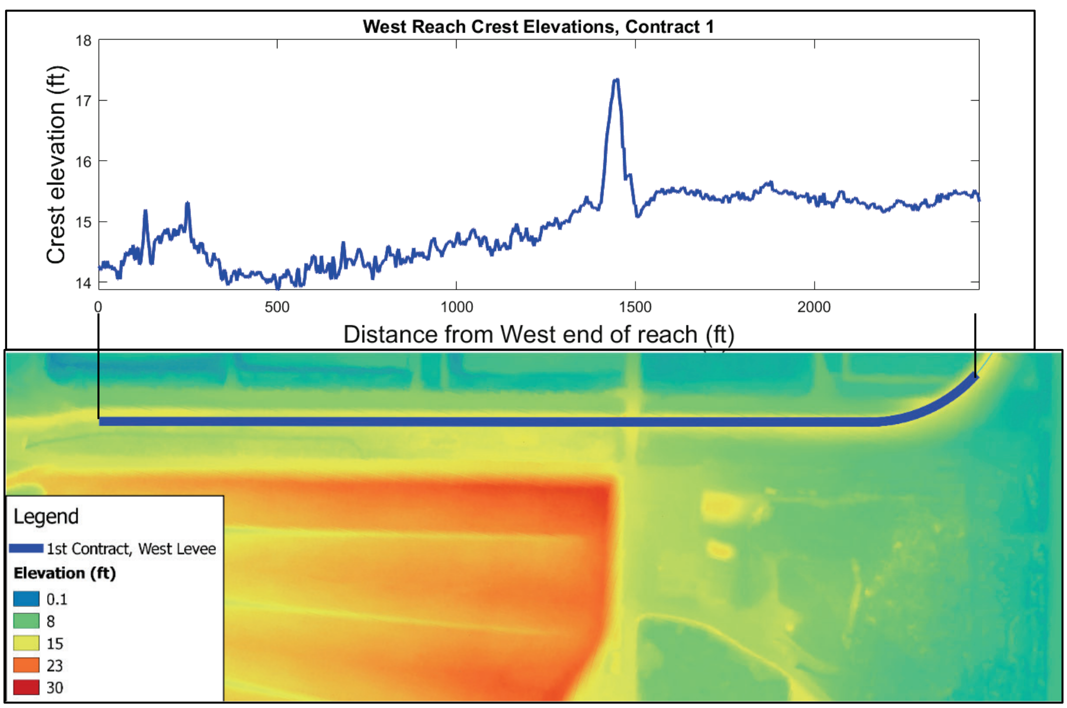


Table 4. Features of without-project CSRM system in Contract 1 area.

Transect Number	GeoID	Reach Start	Reach End	Average Reach Elevation (ft, NAVD88)	Type	Crown Width (ft)
55b	Z4	920+00.00	933+80.00	15.5	Levee, oyster shell exterior, Bermuda grass interior	25
56	Z3	903+77	920+00.00	14.5	Levee, oyster shell exterior, Bermuda grass interior	25
57	Z3	895+00.00	903+77.00	14.5	Levee, oyster shell exterior, Bermuda grass interior	25
58	Z3	883+78.00	895+00.00	14.2	Levee, oyster shell exterior, oyster shell interior	25
59	Z3	872+78.35 875+75.00	875+75.00 883+79.00	14.2	Levee, oyster shell exterior, oyster shell interior	25

Table 5. Features of feasibility authorized CSRM system in Contract 1 area.

Transect Number	GeoID	Associated SP	Reach Start	Reach End	Elevation (ft, NAVD88)	Average Slope	Crown Width (ft)
55b	Z4	1564	920+00.00	933+80.00	16.0	Exterior:10:1 Interior 2.5-3:1	10
56	Z3	3944	903+77	920+00.00	17.5	Exterior:8:1, Interior: 3:1	10
57	Z3	3936	895+00.00	903+77.00	17.5	Exterior:8:1, Interior: 3:1	10
58	Z3	3942	883+78.00	895+00.00	17.5	Exterior:6:1, Interior: 3:1	10
59	Z3	3940	872+78.35 875+75.00	875+75.00 883+79.00	17.5	Exterior:6:1, Interior: 3:1	10

Figure 23 shows without-project transects, and Figure 24 shows schematized analysis transects with without-project and with-project CSTORM modeled elevations. The location of the with-project transect in the figures is not the final design location. The visuals are showing the two structure cross-sections plotted with each other, but the final design may have them shifted so that, for example, the leeside or seaside slopes align. The feasibility authorized levee raises shown in Figure 24 have steeper slopes than without-project. These are shown in Appendix F of Melby et al.

(2021) to have lower overtopping than gentler slopes. They also result in reduced construction material quantities and therefore reduced cost.

Figure 23. Without-project levee transects in Contract 1 area. Elevations are measured in feet, NAVD88.

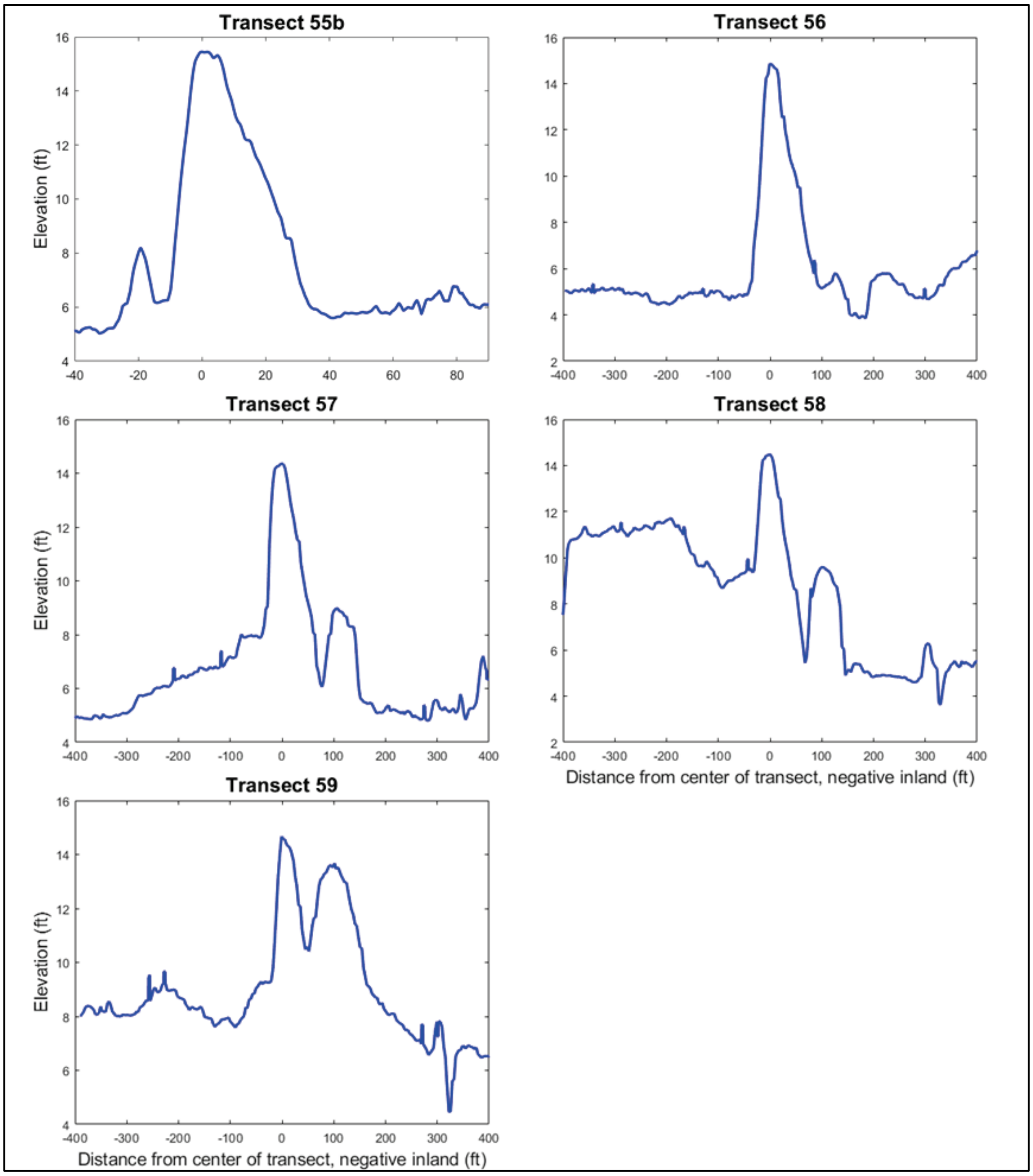
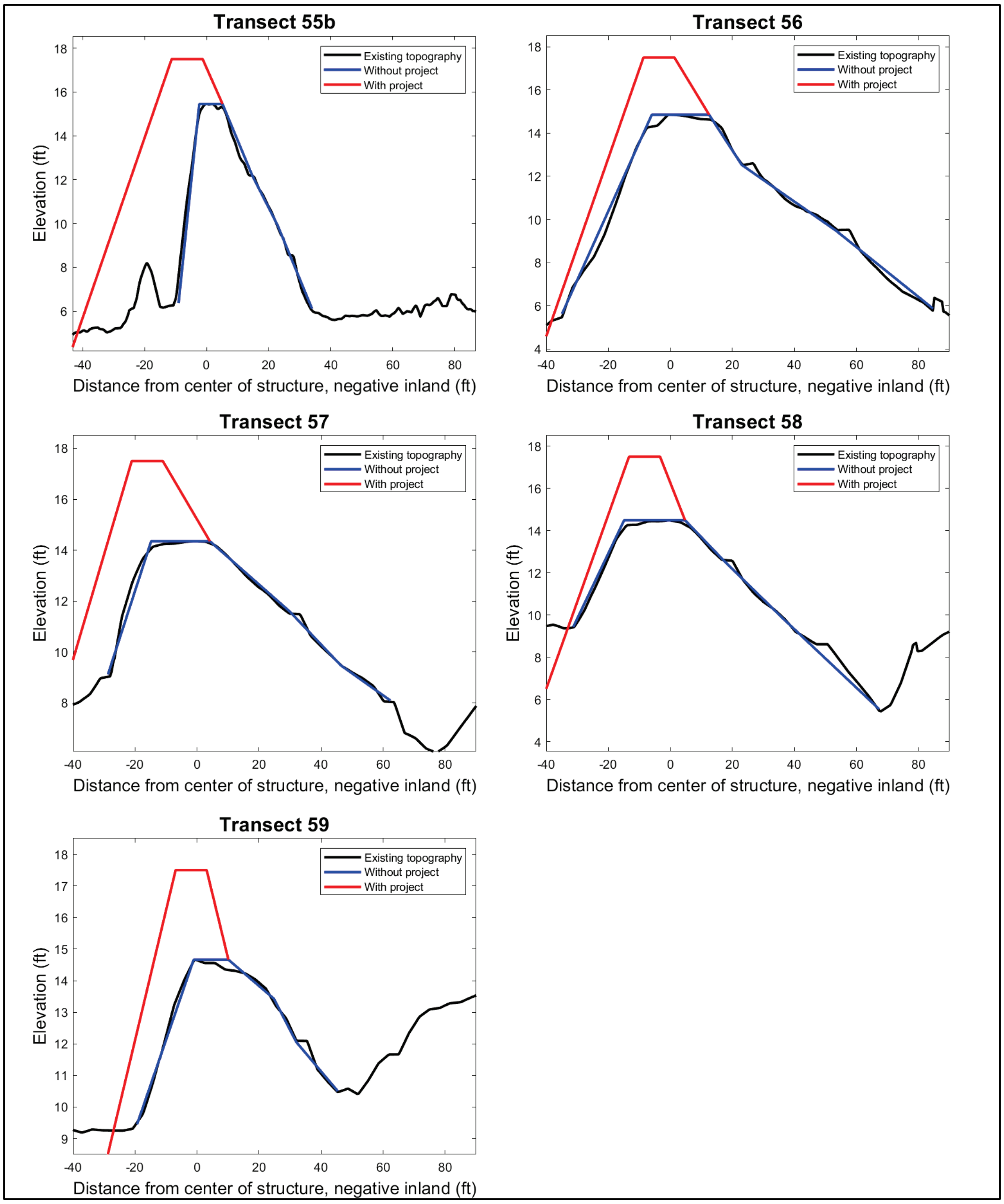


Figure 24. Measured existing topography (black), without-project idealized analysis transects (blue), and feasibility authorized (with-project) analysis transects with authorized elevation (red). Elevations are measured in feet, NAVD88.

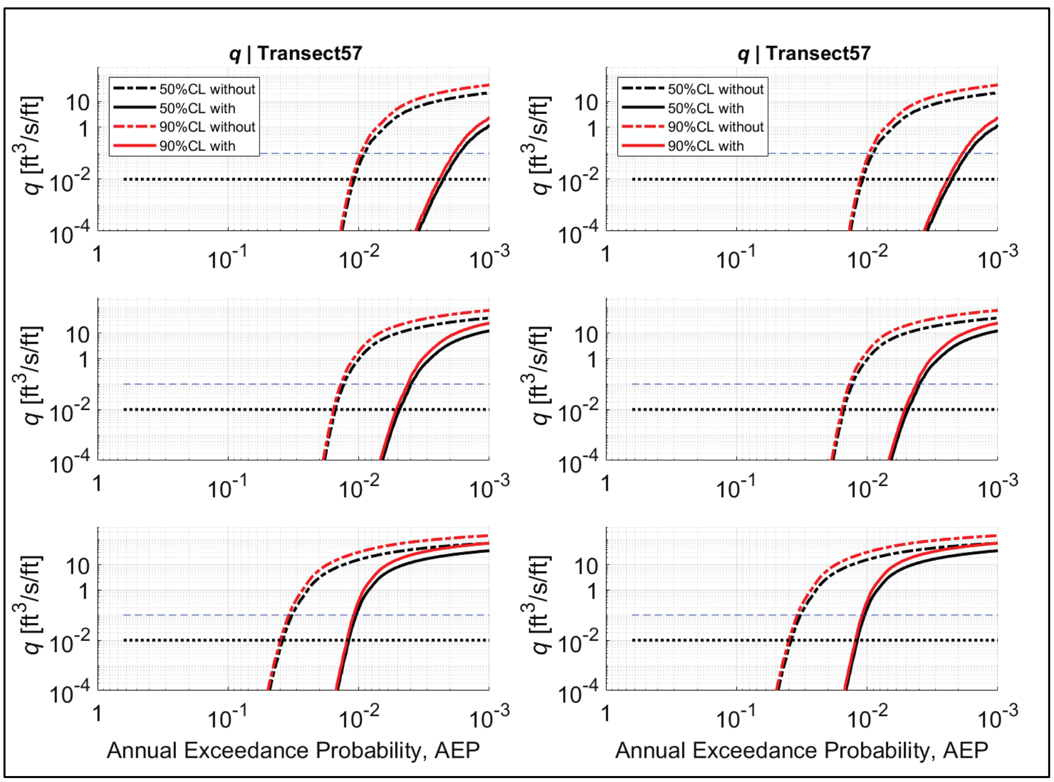


2.5 Results

Contract 1 CSRM system consists of levees, and the combined overtopping and overflow discharge rate was computed for the four forcing and crest elevation scenarios described in Chapter 1.

The analysis summarized below provides an illustration of the expected performance of both the without-project and feasibility authorized levees, to demonstrate the influence of increasing the levee crest elevation on overtopping. Overtopping results from response-based analysis are shown in Figure 25 for the without-project elevation and the feasibility authorized elevation. The without-project existing elevation overtopping response for SLC0 is summarized in Appendix D.

Figure 25. AEP vs. overtopping rate q for Transects 57 (left) and 59 (right), feasibility authorized elevations (with) are 17.5 ft, NAVD88. The without-project elevation is 14.5 ft, NAVD88 for transect 57 and 14.2 ft, NAVD88 for transect 59. Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. The horizontal lines represent limit states q=0.01 cfs/ft (gray, dotted line) and q = 0.1 cfs/ft (blue dashed line). The y-axis is in increments of 10^{-1}, with a lower limit of 10^{-4}.



The overtopping distributions above are generally steep over the higher frequency half and intersect the lower horizontal axis slightly less than the 1% AEP for with-project, suggesting that there is no overtopping for high frequency events. The curves flatten over the lower frequency half. Figure 25 makes a clear distinction between the without-project elevation and the feasibility authorized elevation. The without-project elevation does not satisfy the overtopping criteria of q = 0.01 cfs/ft for 50% CL and q = 0.1 cfs/ft for 90% CL for SLC1 or SLC2 at 1% AEP. The feasibility authorized elevations satisfy the overtopping criteria for SLC0 and SLC1 at 1% AEP. In summary, the without-project levees in Contract 1 area are inadequate, and without the authorized project improvements, would likely sustain damage at the 1% AEP under SLC1 and SLC2 conditions. Further, the feasibility authorized levee elevations are adequate for 1% AEP SLC0 and SLC1 but would likely sustain damage under scenario SLC2 at the 1% AEP.

Overtopping rate was computed as described in Chapter 1. Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1.The limit states assume that the oyster shell cover layer is replaced with clay and grass. The oyster shell cover layer provides little resistance to erosion from overtopping conditions. The results from the optimization routine are shown in Appendix C. The overtopping response for the elevation and forcing scenarios are summarized in Appendix D. Additionally, there is a road crossing (59-Road Crossing) at STA 875+75.00, for which the levee design elevation SLC1 is equal to design elevation SLC2.

2.6 Summary and conclusions for Contract 1

As part of the ongoing PED phase of the project, the coastal SWL and wave hazards for the Contract 1 portion of the Port Arthur CSRM system are documented. Coastal SWL, wave loading, and overtopping and overflow are quantified for the Contract 1 CSRM system consisting of levees using state of the art hydrodynamic modeling and stochastic simulations.

Without-project levee crest elevations in the Contract 1 area were shown to generally not meet the overtopping design criteria. The without-project levees in Contract 1 area are inadequate and would likely sustain damage under SLC1 and SLC2, and some may sustain damage under SLC0. Optimized crest elevations were found for SLC1 and SLC2 using overtopping criteria based on no damage limit states to inform the PDT during design.

3 Contract 2

Contract 2 designates the floodwall portion of the northwestern corner of TBTB (Figure 26 and Figure 27) of the Port Arthur CSRM system. Contract 2 CSRM system consists of floodwalls and one gate.

Contract 2 for Port Arthur includes a section of the existing CSRM system of floodwall along HWY 87 bordering TBTB and has a gate at the southern end. The contract begins at STA 860+57.93, which is adjacent to the Valero Port Arthur Refinery, and proceeds west to STA 872+78.35, which is adjacent to the east side of the HWY 87 crossing.

Figure 26. Contract 2 floodwall replacement for Port Arthur CSRM system within TBTB (in orange, circled in red).

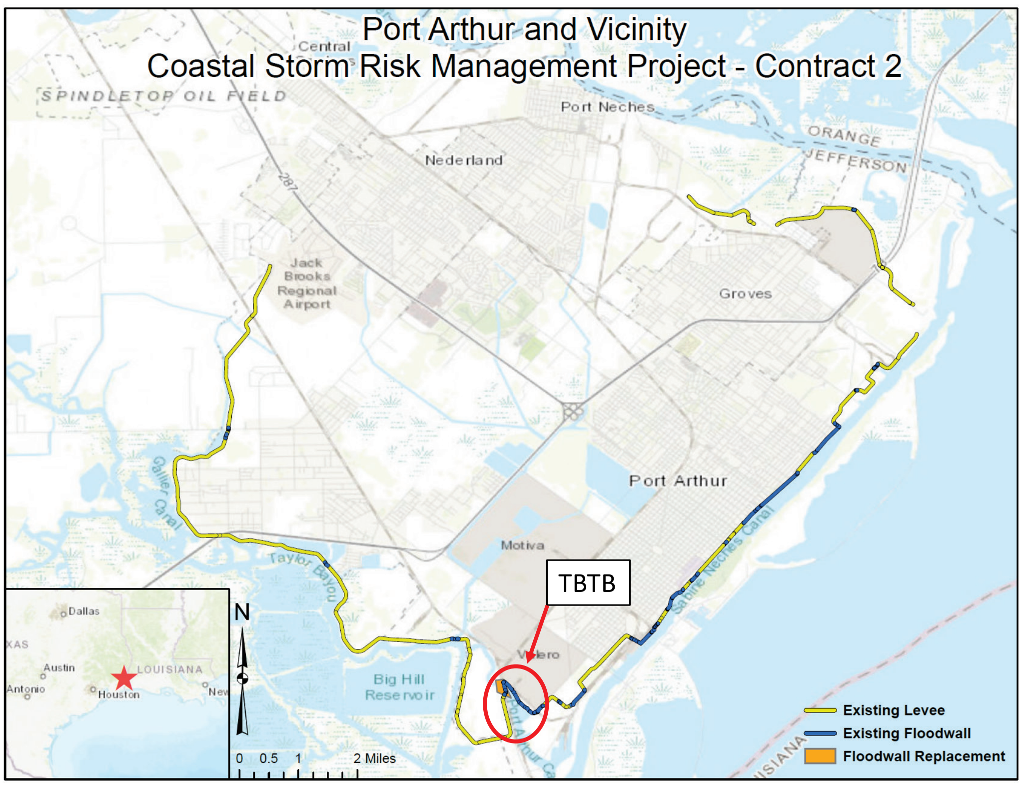
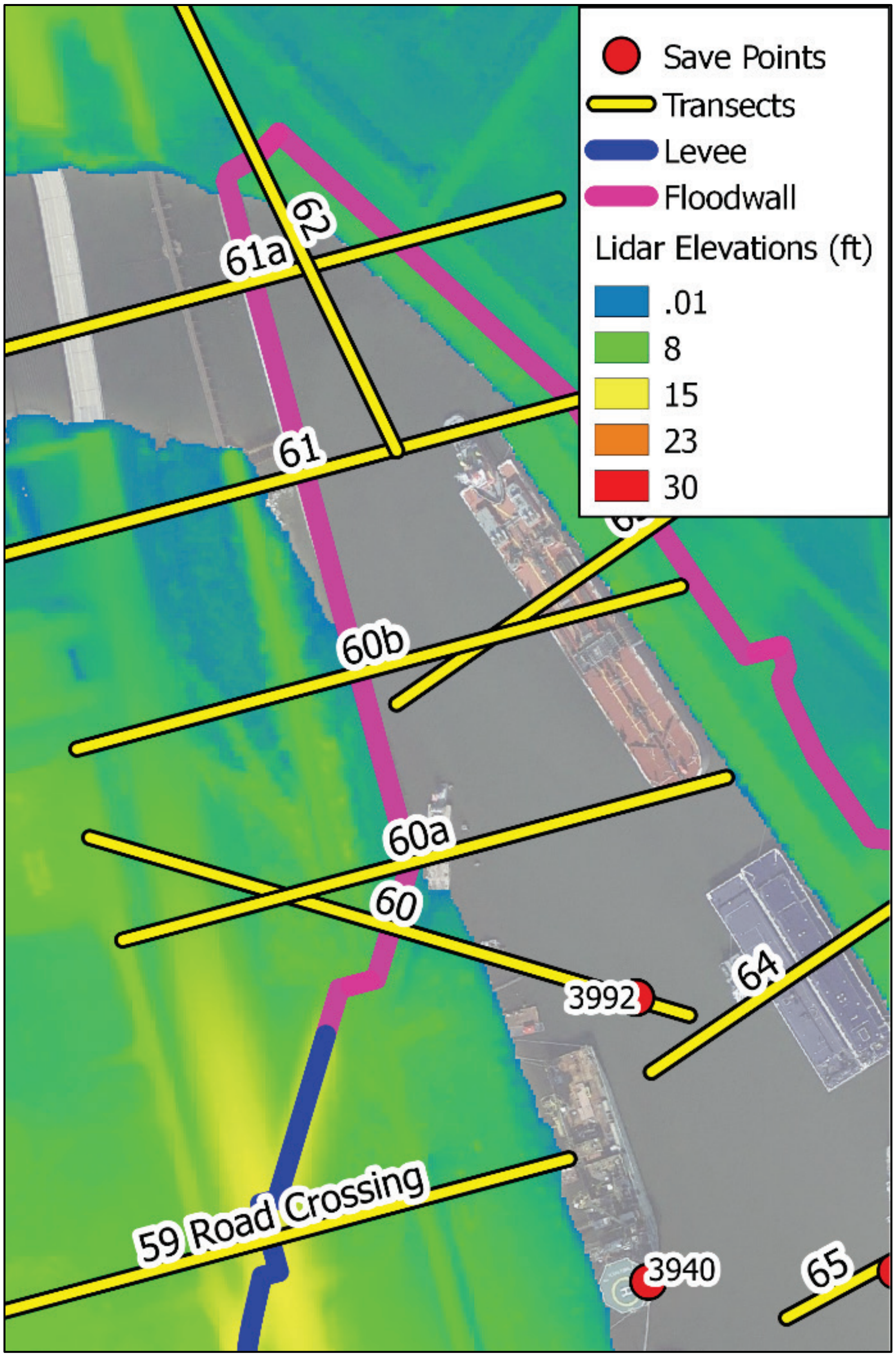


Figure 27. Details of Contract 2 for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots),and color-shaded LiDAR-based elevations (feet, NAVD88).



A 76 m portion of the floodwall shown in Figure 28 was damaged prior to hurricane Harvey in August 2017. The damage was attributed to scour on the floodside at the toe of the wall caused by propeller wash from berthing maneuvers of ships in the turning basin.

Figure 28. Damage to floodwall likely due to propeller wash-induced scour of floodside foundation.

3.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 3992 (see Figure 27 for SP location) in Table 6 for without-project and with-project forcing conditions. The highest SWL in the storm suite is approximately 22 ft for SLC2. Peak SWL and H_{m0} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 forcing scenarios are shown in Appendix A and B.

SPs in the back corner of TBTB did not show inundation or wave energy for all storms. The STWAVE cells are partially dry during lower water events because the cells straddle land at the narrow end of the basin. When the cell is partially dry, no wave energy is computed. SP 3992 is at a wider part of the basin and is always in water, so this SP included results for the full suite of storms. An analysis in Melby et al. (2021) showed that there was no difference in the hazard analysis between SPs in the center of TBTB and SPs nearby but on dry land and inundated by only a fraction of the storms.

Table 6. CSTORM output peaks for top 10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 3992.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	18.21	4.86	3.91	129	461	19.22	5.27	3.91	114
447	17.73	2.13	3.24	126.9	633	18.53	2.91	2.67	164.6
357	17.5	2.41	3.24	130.2	357	18.06	2.59	2.67	141
633	17.48	2.96	2.67	167.6	447	17.98	2.29	2.67	136.3
589	16.77	2.74	3.24	104	464	16.46	2.49	2.67	131.8
464	16.54	2.36	3.24	131.8	342	16.24	1.71	2.67	139
342	16.42	1.67	2.67	131.6	598	16.05	2.59	2.67	138.9
598	16.21	2.62	2.94	149.3	589	15.98	2.56	2.94	97.9
529	15.94	2.94	3.24	119.3	159	15.15	2.61	2.67	133.3
634	15.5	2.55	2.67	169.5	529	14.76	2.97	2.94	130.1
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	19.55	2.26	3.24	126.9	461	20.3	4.92	4.3	114
461	19.54	5.01	4.3	114	633	19.45	3.07	2.67	164.6
357	19.26	2.51	3.24	127.1	447	19.33	2.38	2.67	136.3
633	19.19	2.9	3.24	290.6	357	19.14	2.65	2.67	141
589	18.65	2.77	3.56	104	589	18.84	2.87	3.24	97.9
464	18.08	2.53	3.24	121.4	598	18.53	2.9	2.67	138.9
342	17.96	1.67	3.24	139	342	18.38	1.88	2.67	139
598	17.82	2.62	3.56	138.9	464	18.36	2.77	2.67	131.8
529	17.01	3.04	2.94	130.1	529	16.59	3.04	2.94	130.1
159	16.73	2.79	2.67	133.3	159	16.51	2.64	2.67	136.2
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	21.91	5.15	3.91	129	461	21.89	5.24	3.91	129
447	21.58	2.48	3.24	139.1	633	21.4	3.31	2.67	164.6
357	21.42	2.81	3.56	127.1	447	21.39	2.43	3.24	126.9
633	21.3	2.72	4.3	164.6	357	21.21	2.68	3.56	127.1
589	20.59	3.06	3.24	97.9	589	20.48	3.01	3.24	97.9
464	20.33	2.68	3.56	131.8	464	20.27	2.64	3.24	131.8
342	20.09	1.86	3.24	144.1	598	20.19	2.88	3.24	138.9
598	20.09	2.82	3.56	138.9	342	20.02	1.97	2.67	136.4
529	19.31	3.5	3.56	109.6	529	19.7	3.13	2.67	140
532	18.83	2.1	3.24	125.8	595	19.45	4.9	3.24	121.1

With-project SWL and H_{m0} peaks for all storms are plotted against without-project conditions in Figure 29. It can be seen that the SWL and H_{m0} differences between the two alternatives are small.

Figure 29. With-project SWL (left) and H_{m0} (right) peaks for all storms plotted against without-project conditions for SP 3992. Top row is SLC0, middle row is SLC1, and bottom is SLC2.

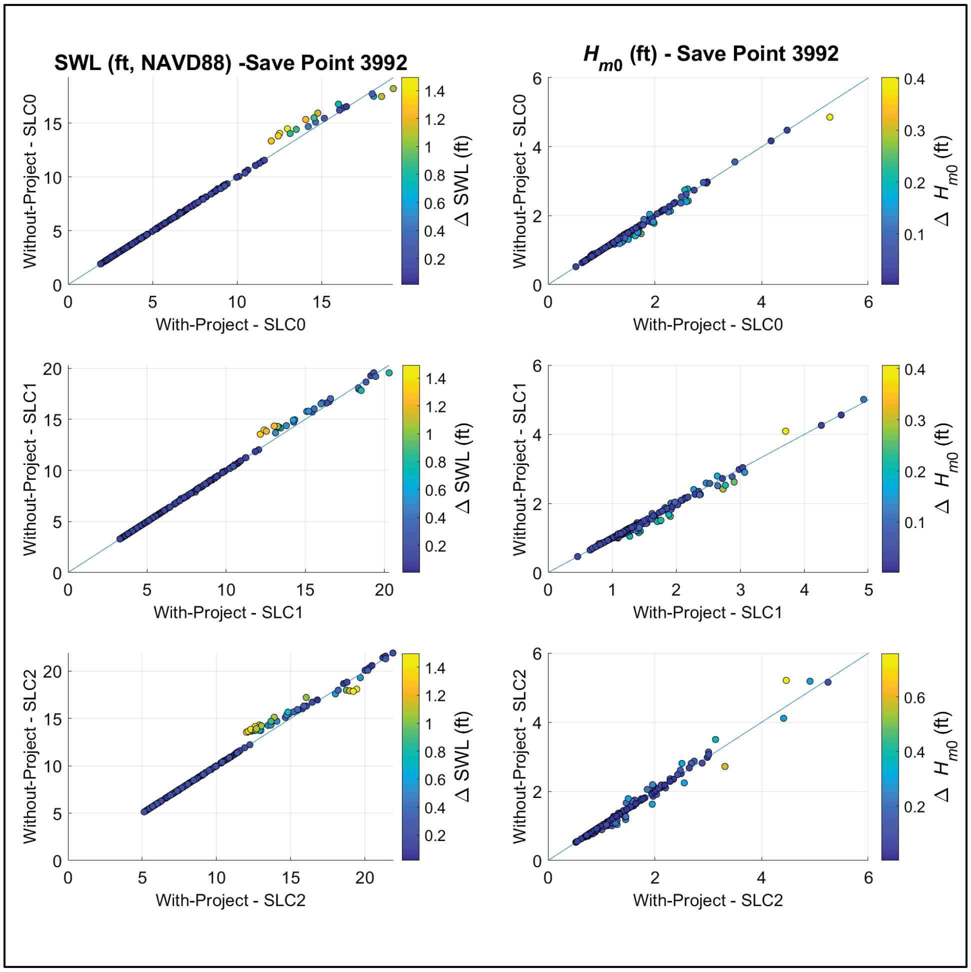
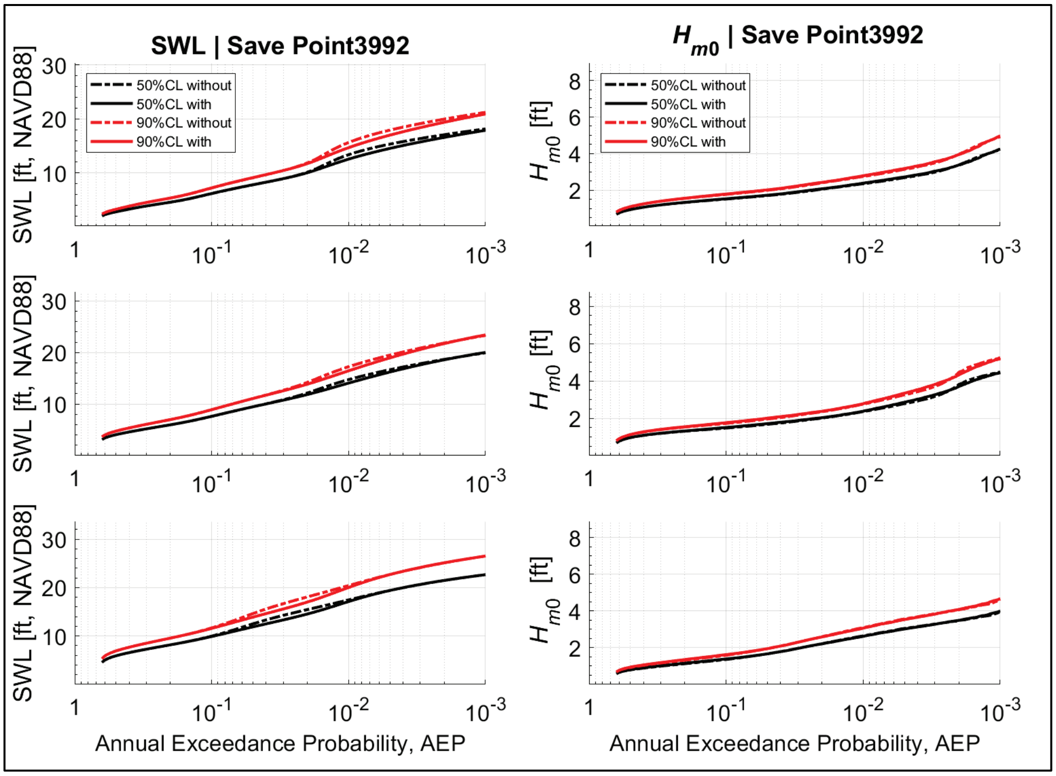


Figure 30 shows the SWL and H_{m0} hazard curves for without-project and with-project scenarios for SLC0, SLC1, and SLC2. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for without-project SLC0 conditions and for with-project SLC1 and SLC2 conditions. The 1% AEP waves are relatively small (generally $H_{m0} \leq 3$ ft).

Figure 30. AEP vs. SWL (left) and AEP vs H_{m0} (right) for SP 3992. Top row is SLC0, middle row is SLC1, and bottom is SLC2.



Comparing the hazards for SWL and H_{m0}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. There is some difference in SWL near 1% AEP. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

3.2 Local CSRM system response modeling

The features of the without-project and feasibility authorized CSRM system corresponding to the transects in Contract 2 are listed in Table 7. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG (field surveys). Figure 31 shows schematized analysis transects with without-project and with-project CSTORM modeled elevations.

Table 7. Features of CSRM system in Contract 2 area.

Transect Number	GeoID	Reach Start	Reach End	Crown Width (ft)	Toe Depth (ft, NAVD88)	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
60	Z2	867+41.85	872+78.35	2.67	4.09	14.85	19.5
60a	Z2	867+41.85	872+78.35	2.67	2.55	14.85	19.5
60b	Z2	867+41.85	872+78.35	2.67	1.64	14.85	19.5
61	Z2	860+57.93	867+41.85	3.17	1.19	14.85	19.5
61a	Z2	860+57.93	867+41.85	3.17	-5.75	14.85	19.5
62a	Z2	858+65.70	858+80.62	0	4.65	14.85	19.5

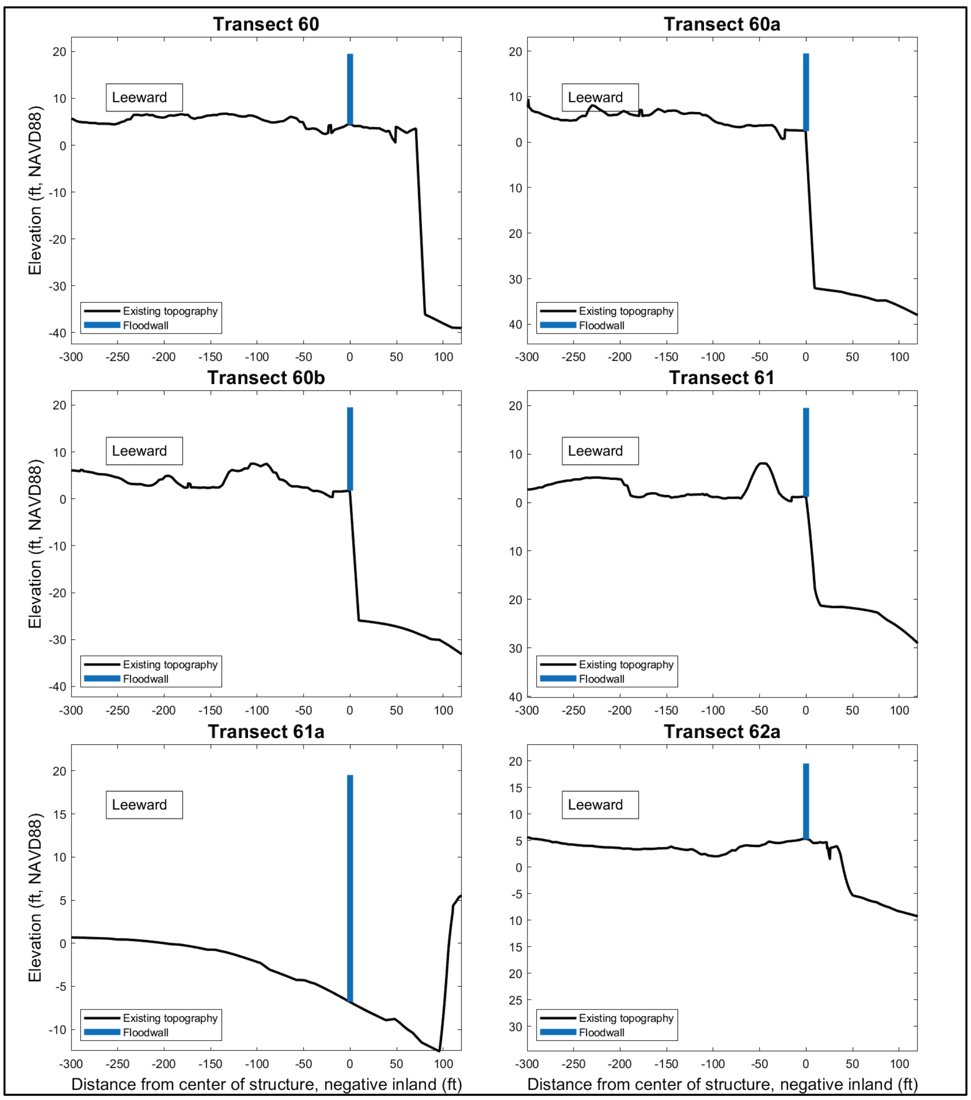
Transects for Contract 2 lie in the north corner of TBTB where there is a complex wave climate. Waves propagating from Taylor Bayou into the TBTB will be diffracted, reflected, and form mach stem waves. Reflection and the mach stem effect could increase the incident wave heights in the corners of TBTB. CSTORM (STWAVE) does not model some of these wave physics; therefore, there is a potential that the wave heights in TBTB are not conservative or are overly conservative and that the wave directions are not accurate. Analysis herein assumed that the wave crests are parallel to the floodwalls (waves are propagating shore-normal) to ensure conservatism of overtopping and pressures.

Transects in Contract 2 have unique surrounding topographies and bathymetries. The details for each transect are described in Table 8. Leeside material is the ground cover to the lee of the concrete pad. Transects 60, 60-a, and 62-a will have berm effects, so the hazard exposure may not be reliably estimated. To be conservative, berm effects that would reduce the wave hazard were not included in the hazard calculations. This assumption would be expected to have only a minor effect because the berms are well below the water surface for design-level surge cases and waves are relatively small and would have little effect from the berm. Transects 61 and 61-a have water on the leeside that is assumed to be at MSL.

Table 8. Characteristics of CSRM system in Contract 2 area.

Transect Number	Type	Berm width (ft)	Berm elevation (average) (ft, NAVD88)	Seaside Material	Leeside Material
60	Floodwall	115	3.8	Gravel/riprap	Grass/sand
60a	Floodwall	20	2.5	Riprap	Grass/sand
60b	Floodwall	0	N/A	Water	Grass/sand
61	Floodwall	0	N/A	Water	Water
61a	Floodwall	0	N/A	Water	Water
62a	Floodwall	75	4.8	Gravel	Gravel

Figure 31. Analysis transects with measured topography (black) and floodwalls feasibility authorized elevation at 19.5 ft, NAVD88 (blue).



3.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall portion of Contract 2. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

3.4 Summary and conclusions for Contract 2

As part of the ongoing PED phase of the project, this chapter documents coastal SWL and wave hazards and overtopping and overflow for the Contract 2 portion of the Port Arthur CSRM system. Optimized crest elevations were found for SLC1 and SLC2 using overtopping criteria based on no damage limit states. The overtopping and overflow, nappe geometry, and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect for the four forcing and crest elevation combinations.

4 Contract 3

Contract 3 describes the structure on the east side of TBTB and is part of the Port Arthur CSRM system (Figure 32 and Figure 33). Contract 3 extends along the Valero Port Arthur Refinery and consists mostly of floodwall, with a levee section for tie-in purposes and several road/railroad closure gates. The contract begins at STA 762+13.00, for a short portion of levee that is adjacent to the west end of W 7th street and the floodwall portion proceeds northwest to STA 858+80.62, which is at the northern end of the TBTB.

Figure 32. Contract 3 floodwall replacement for Port Arthur CSRM system (in light blue).

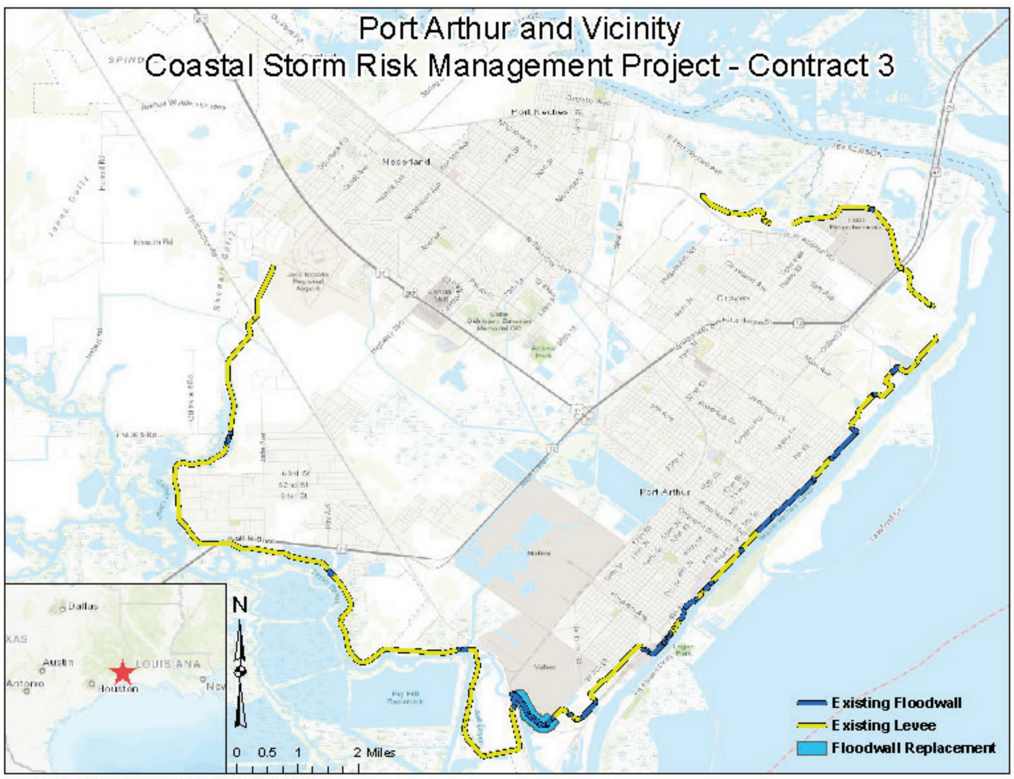
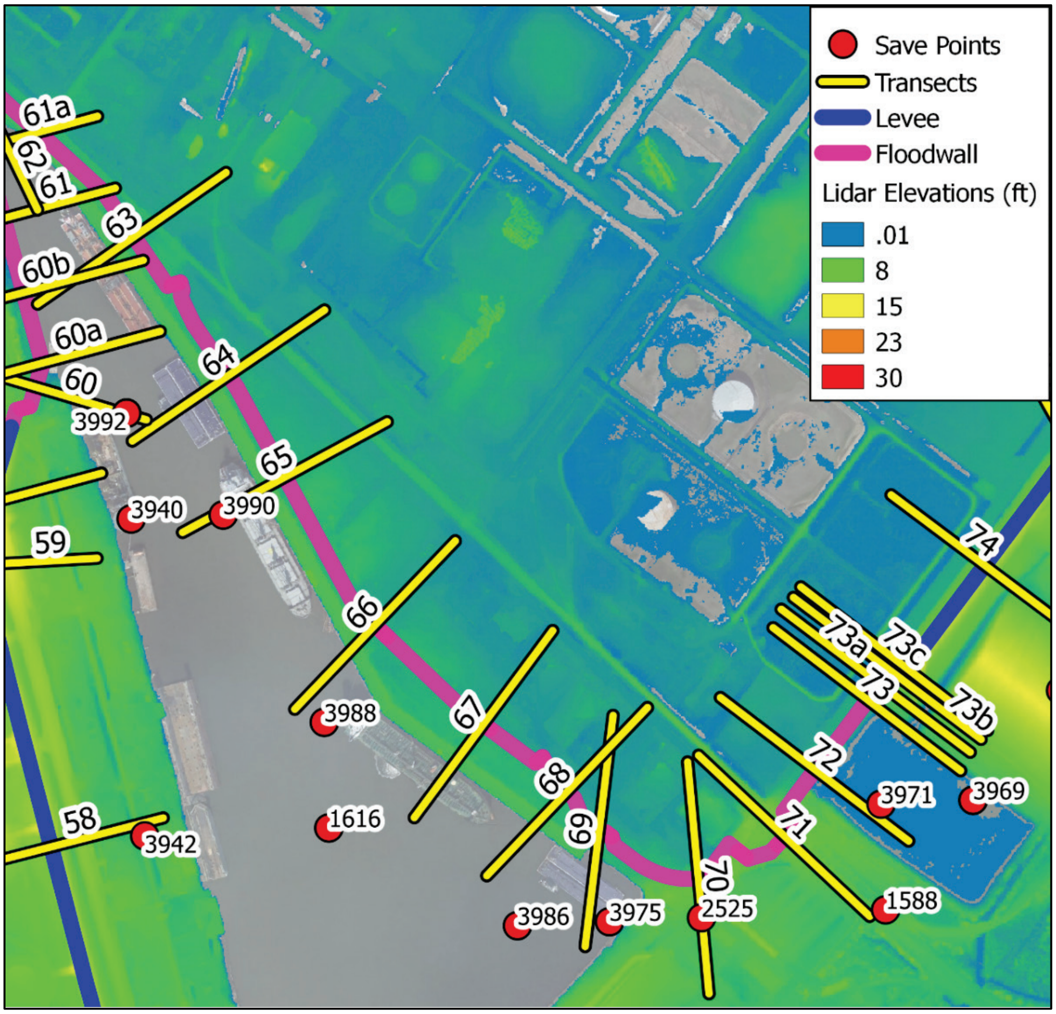


Figure 33. Details of Contract 3 for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



The quay area adjacent to the Valero Port Arthur Refinery is represented by transect 63a to transect 68. Transect 69 characterizes the retaining wall at the southern end of the quay. Transects 70 through 73c are not adjacent to the TBTB but are vulnerable to extreme flood forces. Transects 73a, 73b, and 73c characterize the tie-in portion of the levee.

4.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 3988 (see Figure 33 for SP location) in Table 9 for without-project conditions and with-project conditions. As can be seen, the highest SWL for SLC0 are approximately 18 ft, NAVD88.

Table 9. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 3988.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	18.2	5.53	3.56	148.1	461	19.12	5.56	4.3	113.7
447	17.67	2.51	3.24	139	633	18.47	3.54	2.67	164.3
357	17.47	2.84	3.24	140.9	357	18	3.02	3.24	140.9
633	17.46	3.23	3.91	164.3	447	17.91	2.59	2.94	141.9
589	16.74	3.1	3.24	116.2	464	16.4	2.74	3.24	139.8
464	16.53	2.76	3.56	131.6	342	16.2	1.9	2.94	139
342	16.4	1.96	2.94	146.7	598	15.99	3.09	2.67	149.1
598	16.18	2.94	3.24	149.1	589	15.93	3.04	3.24	116.2
529	15.92	3.61	3.24	119.1	159	15.09	2.87	3.24	133.1
634	15.49	2.81	2.67	169.1	529	14.72	3.61	3.24	119.1
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	19.54	5.66	4.3	113.7	461	20.22	5.61	3.91	128.6
447	19.48	2.69	3.24	136.2	633	19.39	3.66	2.67	164.3
357	19.24	3.01	3.24	130.1	447	19.28	2.72	3.24	141.9
633	19.19	3.3	3.91	164.3	357	19.11	3.11	3.24	140.9
589	18.56	3.2	3.24	97.8	589	18.75	3.35	3.24	97.8
464	18.02	2.94	3.56	131.6	598	18.47	3.38	3.24	138.7
342	17.91	2.08	3.24	141.3	342	18.34	2.11	2.94	141.3
598	17.83	3.21	3.56	138.7	464	18.31	3.02	3.24	139.8
529	17.02	3.65	3.24	119.1	529	16.56	3.66	3.24	119.1
159	16.68	3.14	2.94	141.2	159	16.45	3.04	2.94	141.2
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
461	21.86	6.02	3.91	128.6	461	21.84	6.09	3.91	128.6
447	21.59	3.01	3.24	136.2	633	21.38	4.04	2.94	164.3
357	21.38	3.35	3.56	137.5	447	21.37	2.86	3.24	130.4
633	21.33	3.48	4.3	162.4	357	21.19	3.22	3.56	137.5
589	20.53	3.44	3.56	97.8	589	20.42	3.42	3.56	103.9
464	20.31	3.2	3.56	131.6	464	20.23	3.13	3.56	131.6
598	20.09	3.46	3.56	138.7	598	20.16	3.47	2.67	149.1
342	20.04	2.27	3.24	144.1	342	19.99	2.18	2.94	139
529	19.26	4.01	3.24	119.1	529	19.63	3.89	3.24	119.1
532	18.77	2.49	2.94	125.7	595	19.37	5.64	3.56	120.4

As with Contract 2, some SPs in the northern corner of TBTB did not show inundation or wave energy for all storms because the cells were partially dry for some storms. SPs were selected at a wider part of the basin where there is always water, so the SP included results for the full suite of storms. Peak SWL and H_{m0} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendices A and B.

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 34, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 35. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 34. With-project SWL peaks for all storms plotted against without-project conditions for SPs 1616 (left) and 3990 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

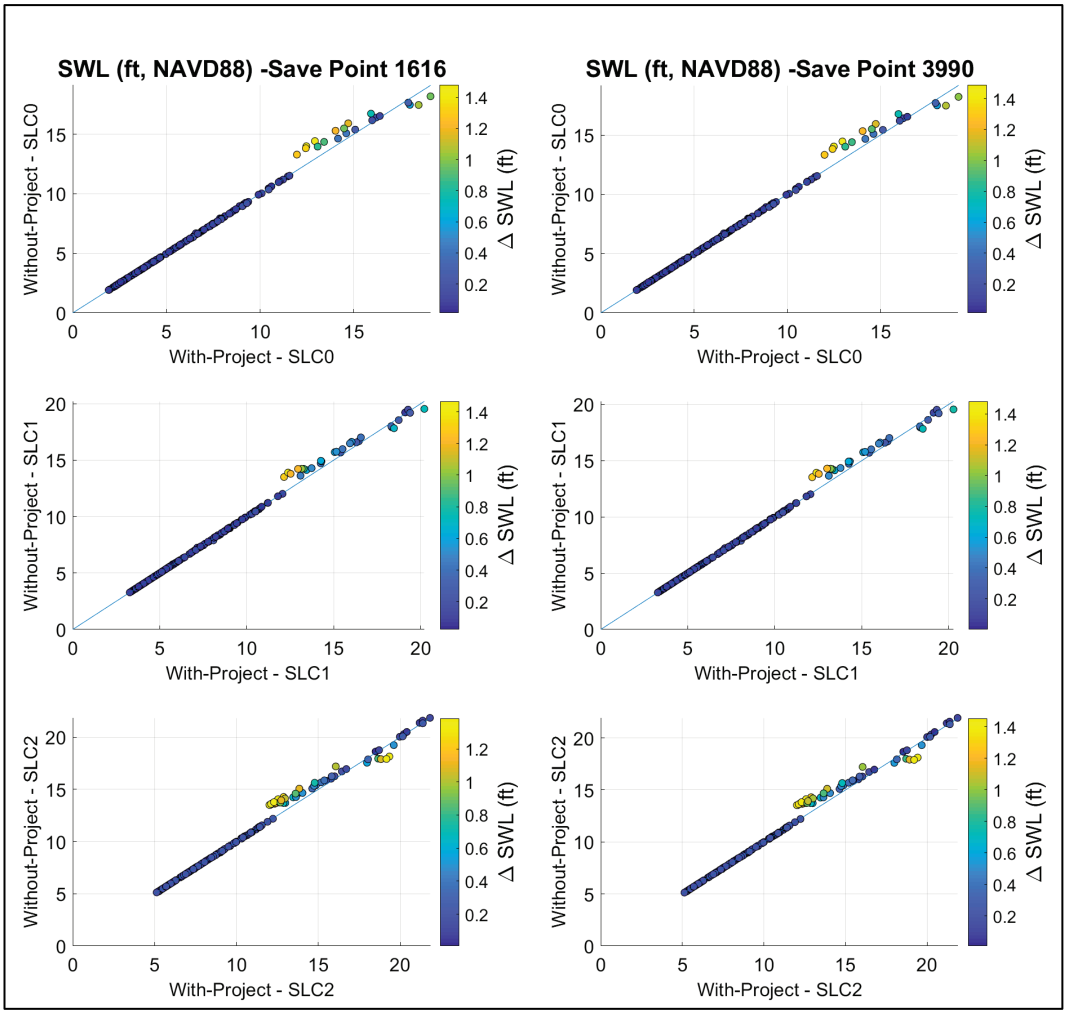


Figure 35. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 1616 (left) and 3990 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

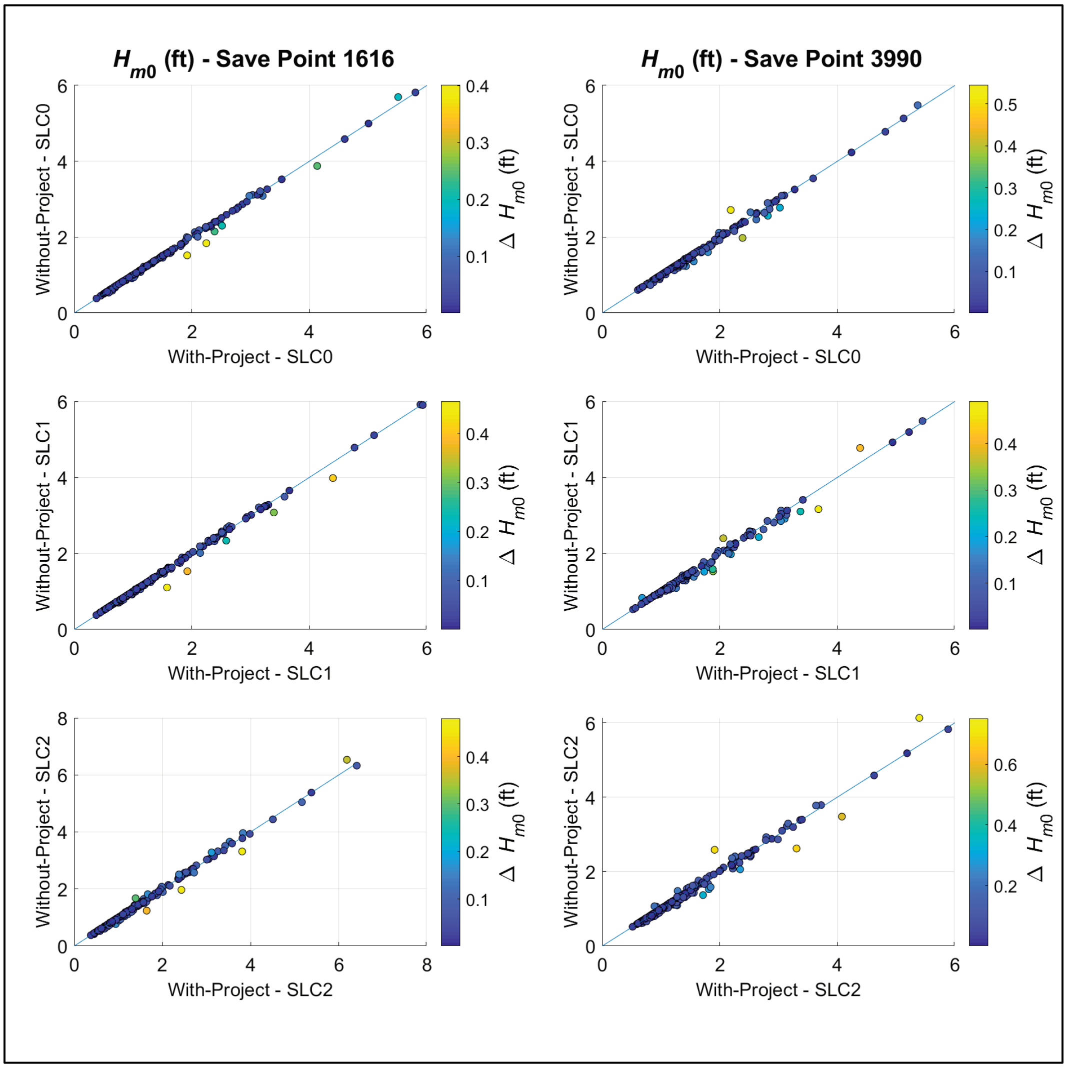


Figure 36 and Figure 37 show SWL and H_{mo} hazard curves, respectively, for SPs 3990 and 1616 for without-project and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two locations are very similar. SWL and H_{mo} values for a range of AEPs are listed with their corresponding transects in Appendix D for SLC0 without-project and SLC1 and SLC2 with-project conditions. The 1% AEP waves are relatively small (generally, $H_{mo} \leq 3$ ft).

Figure 36. AEP vs. SWL for SP 1616 (left) and SP 3990 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

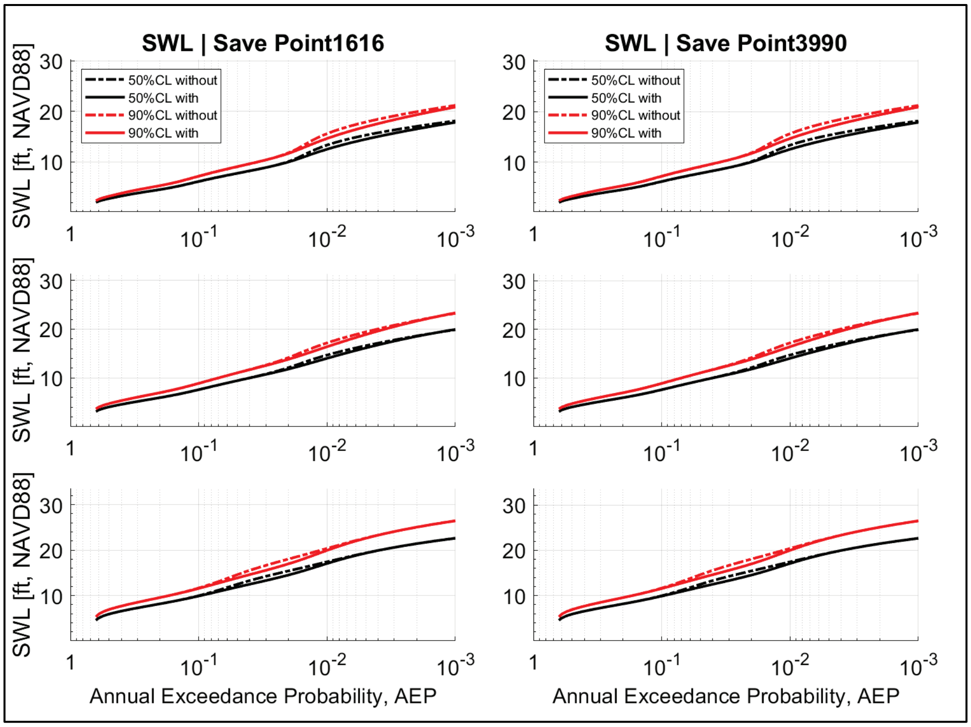
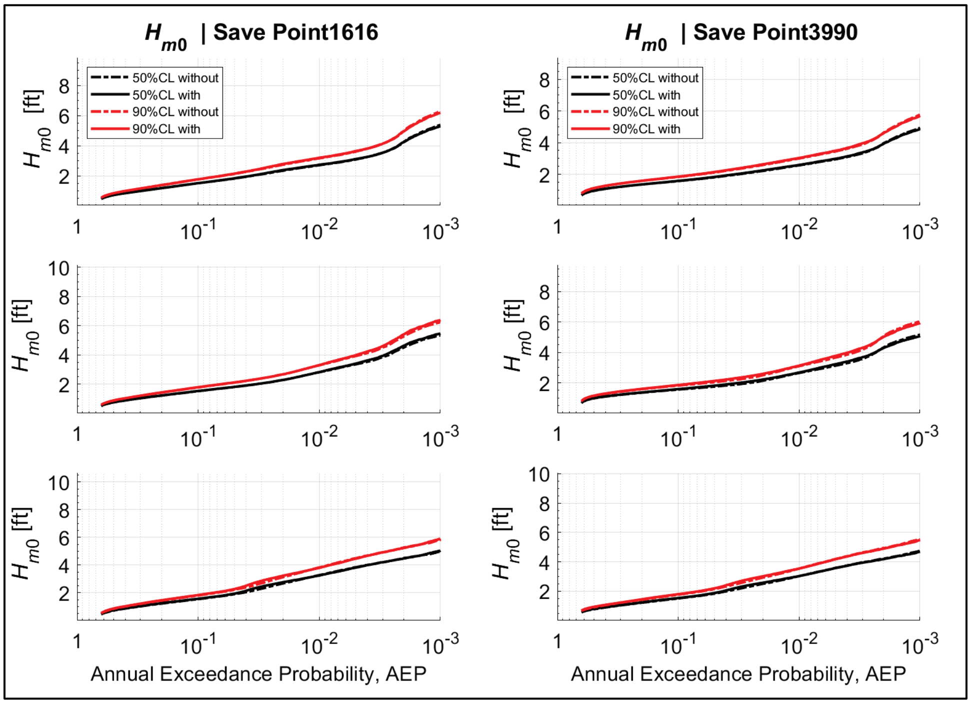


Figure 37. AEP vs. H_{m0} for SP 1616 (left) and SP 3990 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazard curves for SWL and H_{mo}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

4.2 Local CSRM system response modeling

The features of the CSRM system corresponding to the transects in Contract 3 are listed in Table 10. The existing topography and CSRM structure elevations for the area around the Port Arthur CSRM system are from LiDAR and SWG field surveys. Figure 38 through Figure 40 show schematized analysis transects with without-project and with-project modeled elevations.

Table 10. Features of CSRM system in Contract 3 area.

Transect Number	GeoID	Reach Start	Reach End	Toe Depth (ft, NAVD88)	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
63a	Z2	849+11.66	858+28.57	4.4	14.85	19.5
64	Z2	845+77.85	848+83.66	4.54	14.85	19.5
65	Z2	845+77.85	848+83.66	4.11	14.85	19.5
66	Z2	834+68.49	845+53.85	3.13	14.85	19.5
67	Z2	830+53.94	834+44.49	4.29	14.85	19.5
68	Z2	824+32.60	830+58.25	2.84	14.85	19.5
69	Z1	777+77.15	778+13.17	3.08	14.85	19.5
70	Z1	773+60.16	777+77.15	7.29	14.85	18.0
71	Z	769+61.00	773+60.16	8.08	14.85	18.0
72	Z	766+12.00	769+61.00	4.49	14.85	18.0
73	Z	763+28.71	766+12.00	5.89	14.85	18.0
73a	Z	762+87.00	763+33.34	6.79	14.85	18.0
73b	Z	762+62.93	762+87.00	14.28	14.85	18.0
73c	Y	762+13.00	762+88.73	8.5	15.4	17.0

Transects for Contract 3 lie along the northeast edge of TBTB where there is a complex wave climate that may not be accurately modeled by STWAVE, so conservative assumptions were employed, as discussed for Contract 2.

Transects in Contract 3 have unique surrounding topographies and bathymetries. The details for each transect are described in Table 11. Leeside material is the ground cover to the lee of the concrete pad. All of the transects except 70 through 73c will have berm effects that would be negligible for high water events, so these were not included in the calculation, as described in Chapter 2. The pressure distributions were individually calculated for each transect because the pressures on the floodwall depend on the toe elevations, which vary between transects.

Table 11. Characteristics of CSRM system in Contract 3 area.

Transect Number	Associated SP	Type	Berm Width (ft)	Berm Elevation (average) (ft, NAVD88)	Seaside Material	Leeside Material
63a	3992	Steel Sheet Pile	100	4.75	Concrete	Gravel
64	3992	Steel Sheet Pile	100	4.75	Concrete	Gravel
65	3990	Steel Sheet Pile	100	5	Concrete	Gravel
66	3988	Steel Sheet Pile	140	4.5	Concrete	Gravel
67	1616	Steel Sheet Pile	180	4.5	Concrete	Gravel
68	3986	Steel Sheet Pile	160	4.5	Concrete	Gravel
69	3975	Steel Sheet Pile	80	3.5	Gravel	Gravel
70	2525	Steel Sheet Pile	No Berm	N/A	Gravel	Gravel
71	1588	Steel Sheet Pile	No Berm	N/A	Gravel	Gravel
72	3971	Steel Sheet Pile	No Berm	N/A	Grass	Grass
73	3969	Steel Sheet Pile	No Berm	N/A	Grass	Grass
73a	3969	Steel Sheet Pile	No Berm	N/A	Grass	Grass
73b	3969	Steel Sheet Pile	No Berm	N/A	Grass	Grass
73c	3969	Levee	No Berm	N/A	Grass	Grass

Figure 38. Analysis transects 63a–68 with measured topography (black) and floodwalls with feasibility authorized elevation (blue). Elevations are in feet, NAVD88.

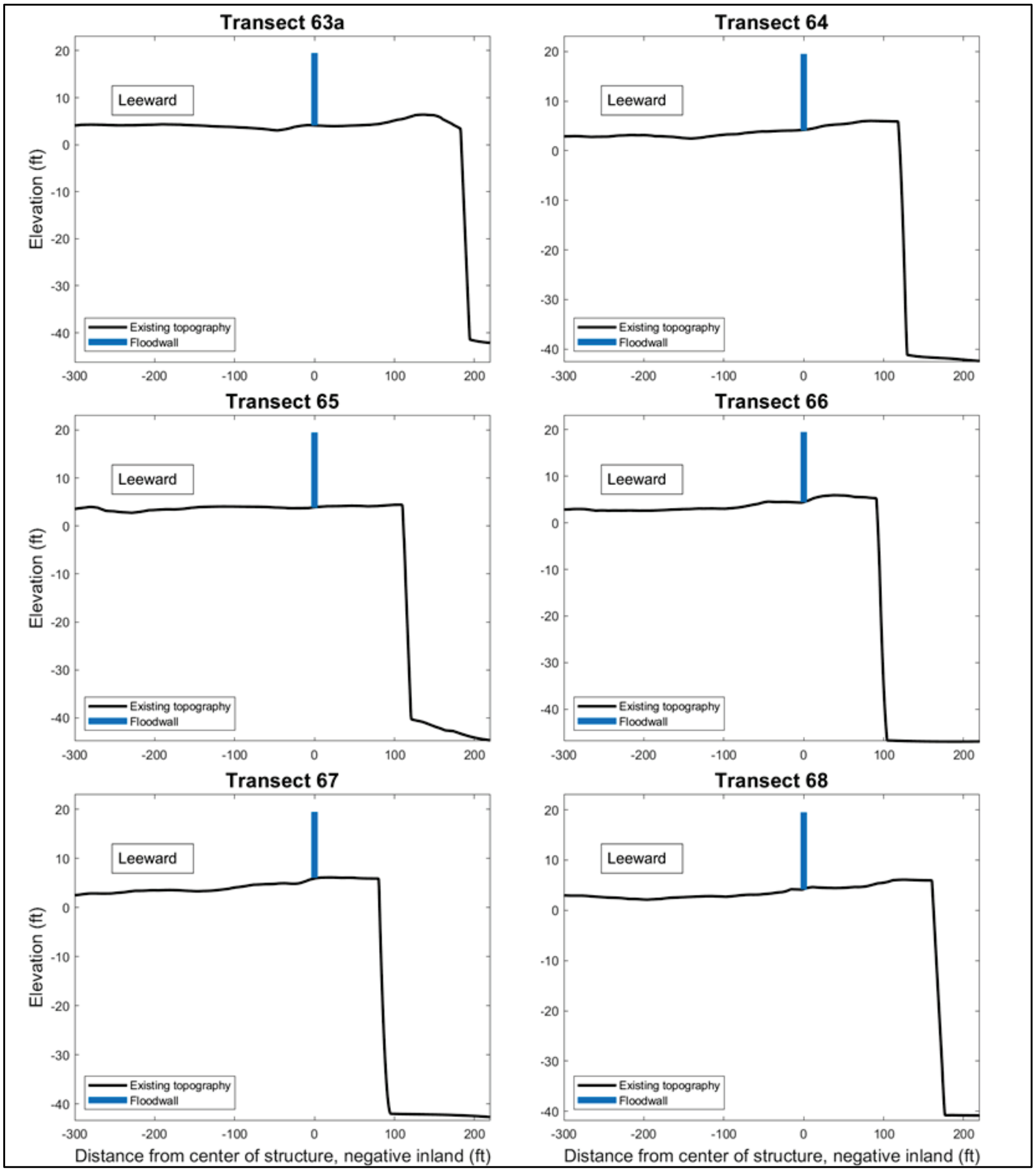


Figure 39. Analysis transects 69–73a with measured topography (black) and floodwalls with feasibility authorized elevation (blue). Elevations are in feet, NAVD88.

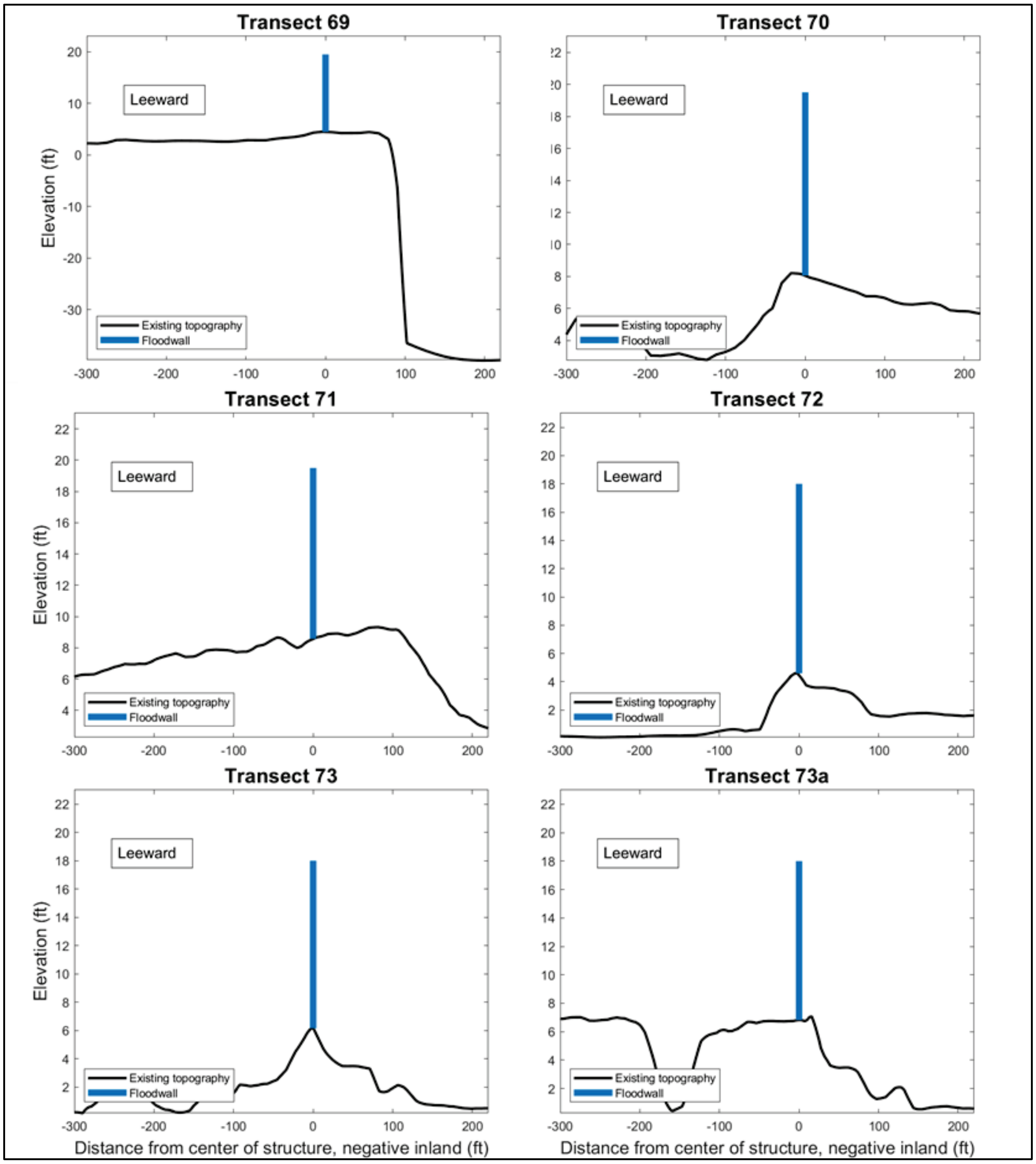
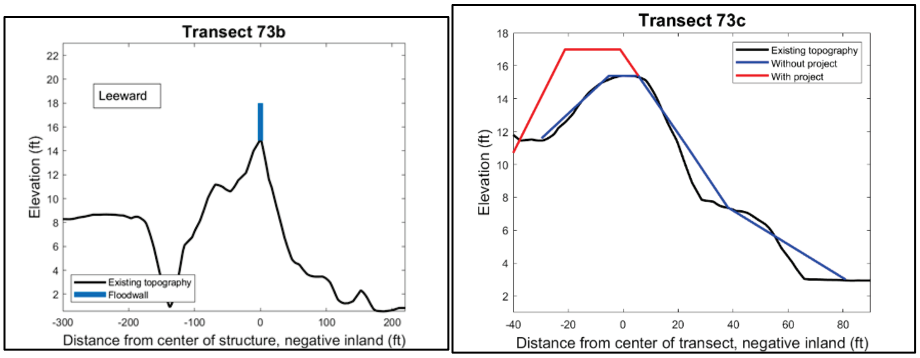


Figure 40. Analysis transect 73b (left) with measured topography (black) and floodwall with feasibility authorized elevation (blue) and analysis transect 73c (right) with measured topography (black), idealized without-project structure (blue), and with feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



4.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of Contract 3, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall portion of Contract 3. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

4.4 Summary and conclusions for Contract 3

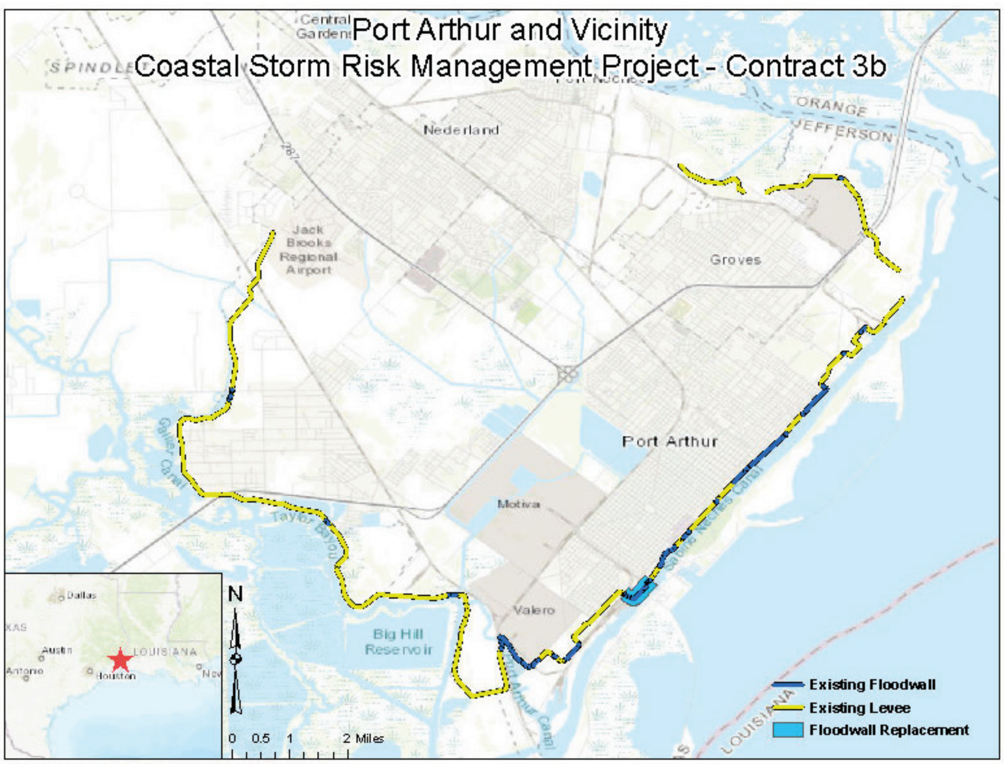
As part of the ongoing PED phase of the project, this chapter documents coastal SWL and wave hazards and coastal structure responses for the Contract 3 portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and overtopping and overflow are quantified. Optimized crest elevations were found for SLC1 and SLC2 using overtopping criteria based on no-damage limit states. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect for the four forcing and elevation combinations.

5 Contract 3b

This chapter documents coastal SWL, wave hazards, and coastal structure responses for the Contract 3b portion of the Port Arthur CSRM system ("Port Arthur – Contract 3b"; Figure 41 and Figure 42). The existing Contract 3b area consists mostly of floodwall, with levee sections at the ends for tie-in purposes and several road and railroad closure gates, shown in Figure 42. The floodwall portion of Contract 3b begins at STA 617+53.11 and proceeds northeast to STA 653+00.00.

Based on design and real estate constraints, during PED the project team made the decision to revise the alignment in this project area as shown in Figure 42. This was approved by the larger Sabine-to-Galveston team and SWG leadership. Transect locations shown in Figure 43 were selected to characterize both gate and floodwall portions of Contract 3b.

Figure 41. Contract 3b floodwall replacement along the Sabine-Neches Waterway (SNWW) (in light blue).



Path: W:\eGIS\S2G\GIS_Data\CSRM\Data\CRSM_Sabine_Galveston.aprx

Figure 42. Details of the Port Arthur proposed Contract 3b existing floodwall alignment (pink), new floodwall alignment (red), and color-shaded LiDAR-based elevations (feet, NAVD88).

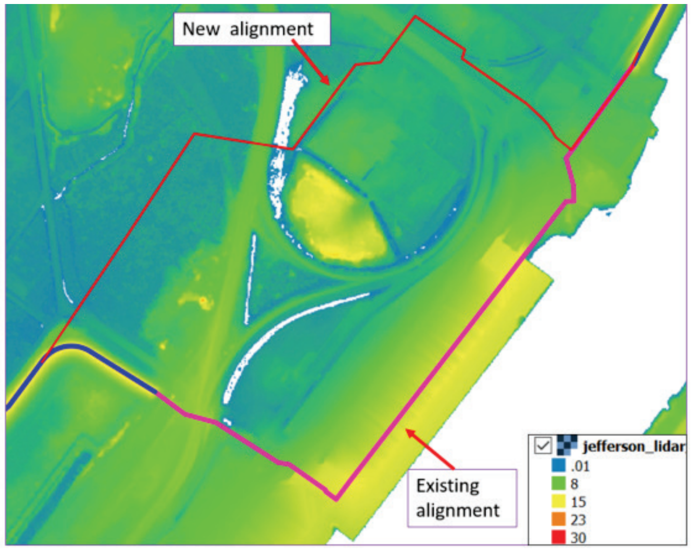
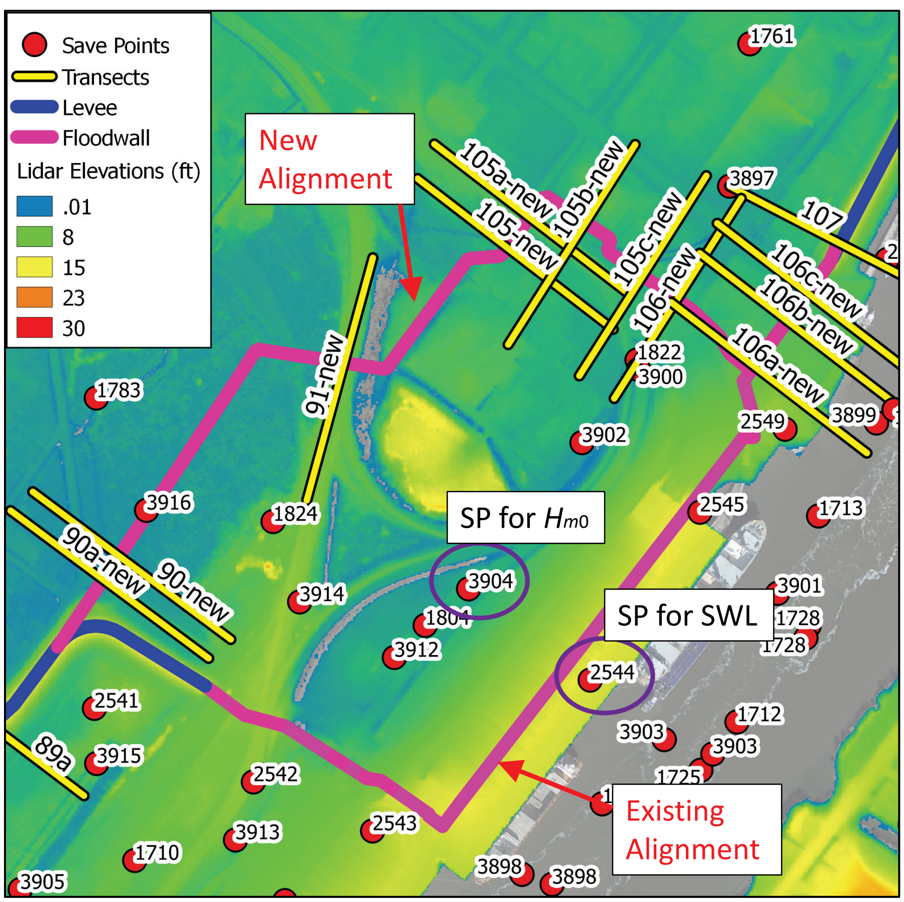


Figure 43. Details of the new Contract 3b for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



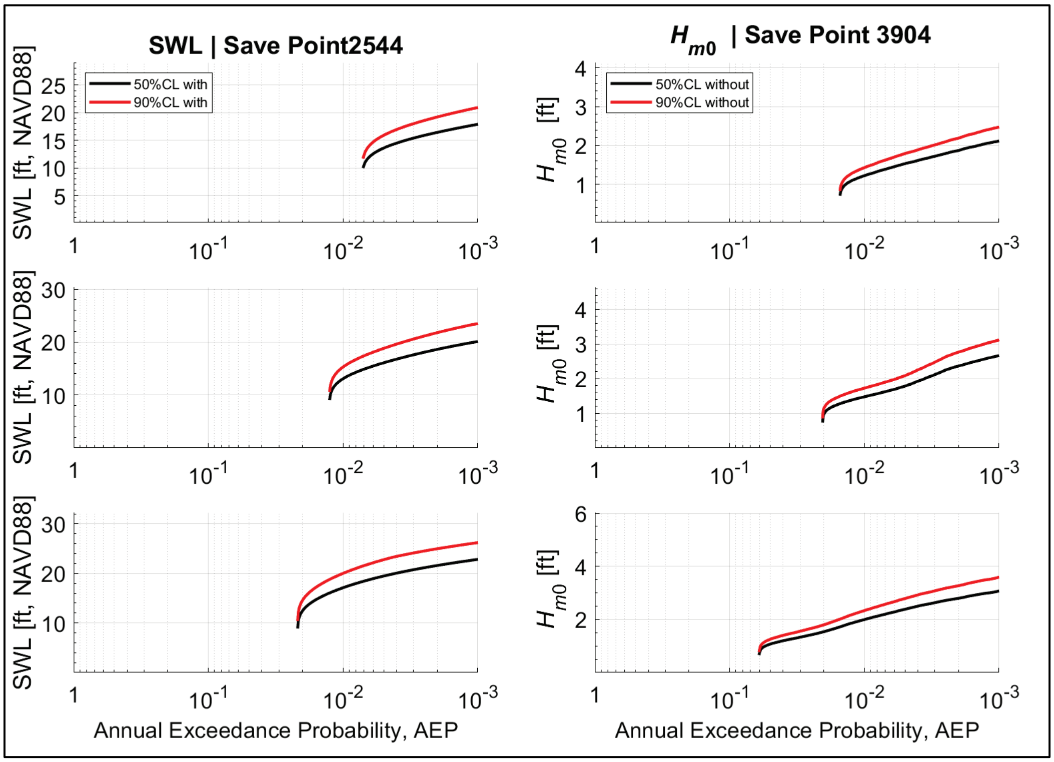
5.1 Local wave and water level response

SPs along the edge of the SNWW did not show inundation or wave energy for all storms. For the new alignment, forcing from SPs within the SNWW, such as SP 3903, does not represent the incident SWL and wave conditions. It could be argued that the extreme SWLs are appropriate because the SWLs would be gradually varying in the area, but the waves in the SNWW would be overly conservative. A comparison of SWL hazard curves between SP 2455 and SP 3903 showed that the extreme statistics were identical, but SP 2544 better represented the higher frequency conditions where the quaywall will limit inundation. An analysis of waves for all of the area SPs showed that many SPs had few storm wave conditions. The STWAVE cells are partially dry during lower water events because the cells straddle the higher elevation land on the quay. When the cell is partially dry, no wave energy is computed. The SPs in the area of SP 3904 are at a lower elevation that is flooded during storm events, so this SP included results for a large suite of storms. In addition, the SPs in the area of SP 3904 showed reasonably similar wave conditions and showed wave conditions that were reasonable for that somewhat sheltered area, being similar to other similar semi-sheltered areas around Port Arthur.

Therefore, two SPs were selected to describe the forcing hazards; SP 2544 was used for SWL and SP 3904 was used for H_{m0} and T_p. The with-project SWL at SP 2544 described the flood depths that exceed the elevation of the existing quaywall. The quaywall is not planned to be removed. SP 3904 was selected for waves based on the above discussion. An analysis in Melby et al. (2021) showed that there was very little difference in the limit state region of hazard curves between SPs that are always in water and nearby SPs on dry land that are inundated by only a fraction of the storms. Because the with-project conditions contained an increased structure crest elevation, the without-project wave conditions at SP 3904 were used. Peak SWL and H_{m0} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendix A and B.

Figure 44 shows SWL and H_{m0} hazard curves for SPs 2544 and 3904 for with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for with-project SLC1 and SLC2 conditions.

Figure 44. AEP vs. SWL for SP 2544 (left) and AEP vs. H_{m0} for SP 3904 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.



5.2 Local CSRM system response modeling

Features of the CSRM system corresponding to transects in Contract 3b are listed in Table 12. Contract 3b has both gates and floodwalls, with unique surrounding topographies and bathymetries. Transects for Contract 3b are along the SNWW where there is a long southwest to northeast fetch. Therefore, waves may be able to form down the length of the SNWW at high wind speeds and propagate into the Contract 3b area. However, these waves will be traveling along the SNWW and are likely to be highly oblique to the floodwall. In addition, there is an island approximately 700 ft southeast of the floodwall. The island will block waves propagating northwest at low water levels and reduce the waves at water levels greater than the elevation of the barrier island. At high water levels where the island is entirely submerged, there may be waves propagating from the Gulf of Mexico directly into the SNWW and to the project site. These waves will still be dramatically reduced because even at the highest water levels corresponding to the most severe storms, the water across the barrier island is shallow. CSTORM (STWAVE) does not model the physics of wave reflection nor does it account for wave diffraction within SNWW; therefore, these effects impact the estimated wave height uncertainty. Analysis herein assumed that the wave crests are parallel to the floodwalls (waves are propagating shore-normal) to ensure conservatism of overtopping and pressures. Berm effects were not included in the analysis.

Table 12. Characteristics of CSRM system in Contract 3b area.

Transect Number	Type	Toe Elevation (ft, NAVD88)	Seaside Material	Leeside Material
90a-new	Gate	2.0	Roadway	Roadway
90-new	Floodwall	1.3	Grass	Grass
91-new	Gate	7.7	Railroad	Railroad
105-new	Floodwall	3.8	Gravel	Gravel
105a-new	Gate	5.5	Roadway	Roadway
105b-new	Gate	3.5	Grass	Grass
105c-new	Floodwall	4.4	Gravel	Gravel
106-new	Gate	4.2	Roadway	Roadway
106a-new	Floodwall	6.7	Gravel	Gravel
106b-new	Floodwall	6.1	Gravel	Gravel
106c-new	Floodwall	5.9	Gravel	Gravel

5.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall and gate portions of Contract 3b. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

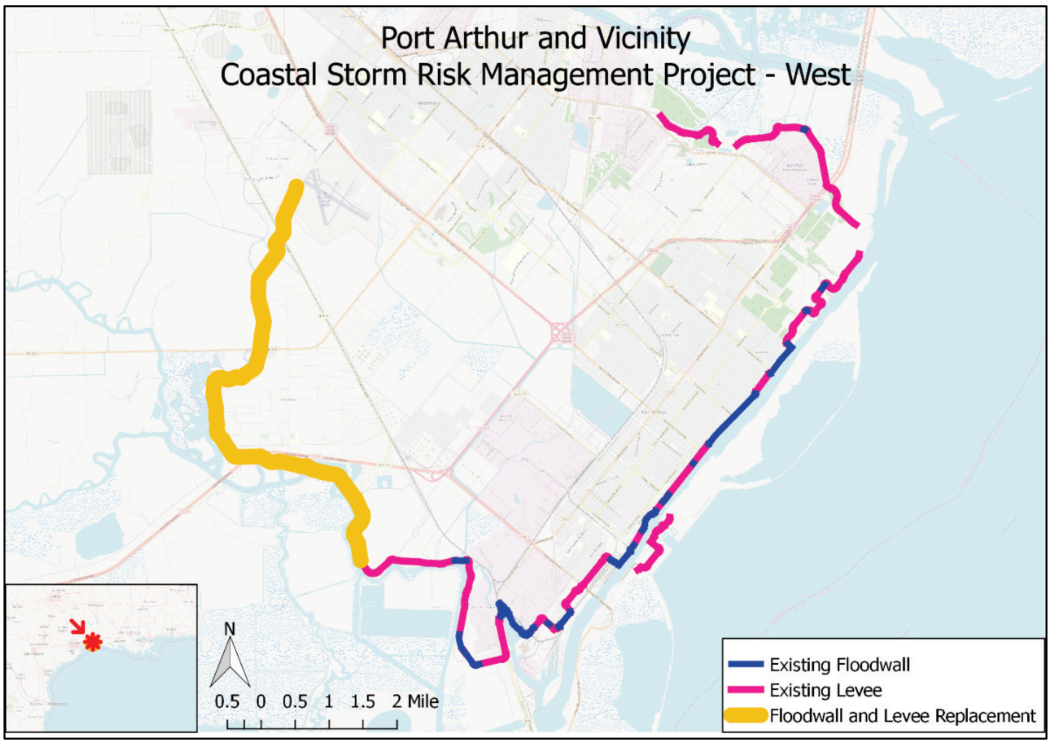
5.4 Summary and conclusions for Contract 3b

As part of the ongoing PED phase of the project, this chapter documents coastal SWL and wave hazards for the Contract 3b portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and overtopping and overflow are quantified for the Contract 3b CSRM structure consisting of floodwalls and gates. Optimized crest elevations were found for each RSLC using overtopping criteria based on no-damage limit states. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect for the four forcing and elevation combinations described in the introduction.

6 Port Arthur – West (PA-W)

PA-W designates the western leg of the Port Arthur CSRM system (PA-W; Figure 45 through Figure 47). PA-W consists primarily of levees, with floodwall sections at gate locations and pump stations. Coastal SWL and wave hazards and coastal structure responses are quantified.

Figure 45. PA-W levee and floodwall location along Taylors Bayou (in yellow).



PA-W begins at STA 1139+50 and proceeds to STA 1609+00. Modifications include increasing levee, pump station fronting protection, and gate crest elevations.

Figure 46. Details of PA-W, north end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).

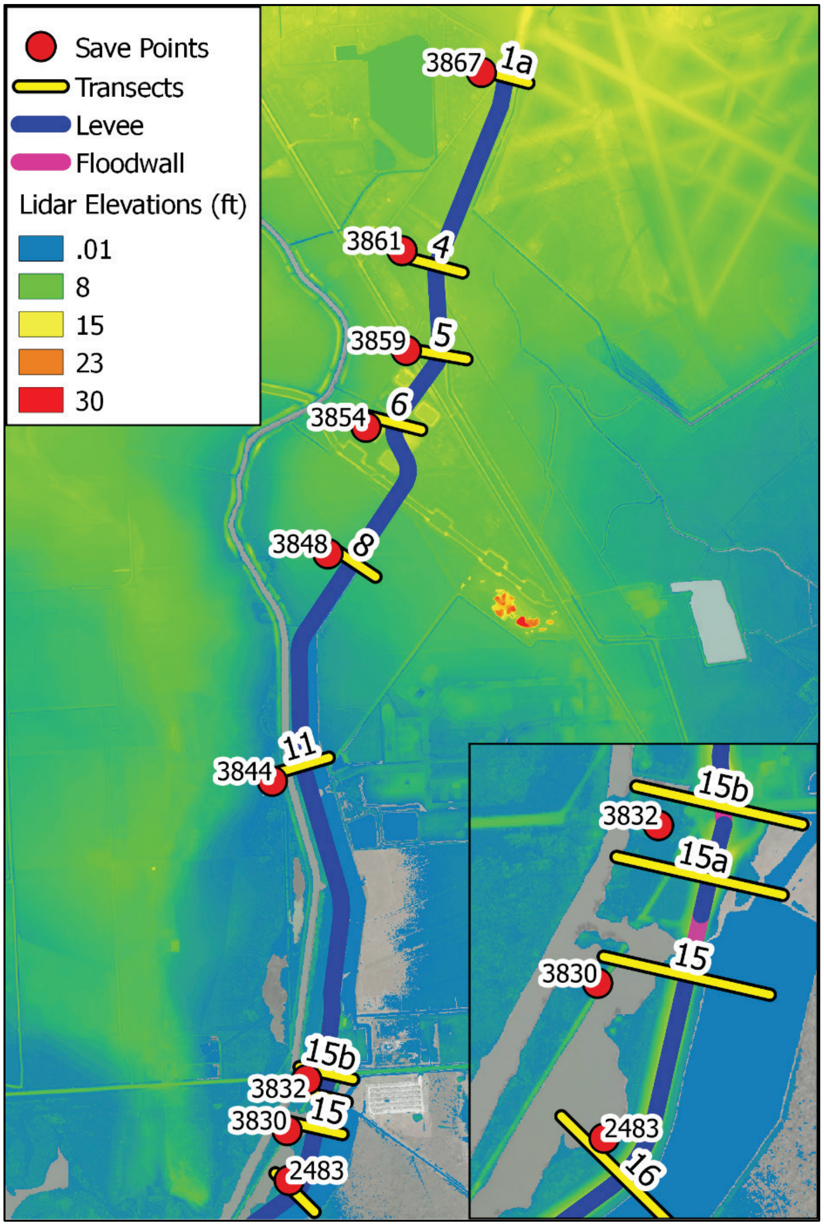
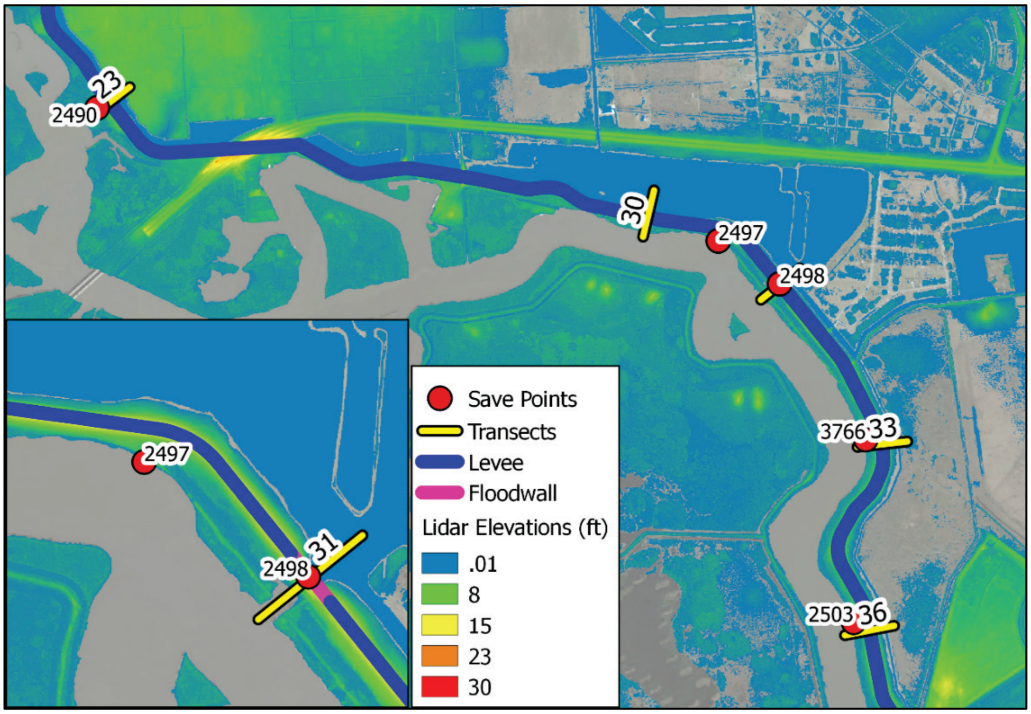


Figure 47. Details of PA-W, south end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



6.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 3766 in Table 13 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks for SLC0 are approximately 18 ft, NAVD88.

SPs along the edge of the Taylors Bayou channel did not show inundation or wave energy for all storms. The STWAVE cells are partially dry during lower water events because the cells straddle land along the edge of the channel. When the cell is partially dry, no wave energy is computed. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{mo} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 13. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 3766.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
589	18.35	4.08	3.91	57.4	589	18.29	4.07	3.91	57.4
447	18.12	1.72	2.67	86.7	447	18.06	1.72	2.67	86.7
464	17.8	3.38	3.91	73.9	464	17.74	3.37	3.91	73.9
357	17.64	1.95	2.67	131.8	461	17.6	4.5	2.94	75.2
461	17.54	4.5	2.94	75.2	357	17.5	1.95	2.67	131.8
342	16.52	1.56	2.67	132.3	342	16.46	1.56	2.67	134.8
628	15.87	2.76	3.91	21.5	628	15.76	2.74	3.91	21.5
159	15.6	1.77	2.67	130.3	159	15.48	2.07	2.43	152.8
532	15.55	2.6	3.56	63.2	352	15.45	2.59	3.56	63.2
598	15.29	3.21	3.91	7.6	598	15.22	3.19	3.56	7.6
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
589	19.78	4.26	3.91	57.4	589	19.77	4.26	3.91	57.4
447	19.53	1.75	2.67	86.7	447	19.32	1.76	2.43	140.4
461	19.3	4.54	4.3	75.2	461	19.24	4.53	4.3	75.2
357	18.91	1.85	2.67	143.1	357	18.71	1.85	2.67	143.1
464	18.72	3.5	3.91	71.3	464	18.64	3.47	3.91	64.5
342	17.94	1.57	2.67	132.3	342	17.9	1.57	2.67	132.3
628	17.43	3.09	3.91	21.5	628	17.36	3.02	3.91	21.5
598	17.24	3.57	3.91	7.6	598	17.25	3.55	3.91	7.6
352	16.93	2.75	3.56	60.8	352	16.89	2.72	3.56	63.2
159	16.85	2.07	2.43	152.8	159	16.76	2.07	2.43	152.8
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	21.57	2.23	3.56	128	447	21.46	2.19	3.56	128
589	20.98	4.36	3.91	54	589	20.95	4.41	3.91	54
357	20.94	2.02	3.56	125.7	461	20.76	4.67	3.24	81.2
461	20.83	4.36	4.3	71.3	357	20.75	1.92	3.56	125.7
464	20.15	3.43	3.56	60.9	464	19.94	3.42	3.91	69.2
342	19.85	1.88	2.94	156.6	342	19.67	1.58	2.43	156.6
529	19.4	4.02	3.91	59.7	529	19.4	4.02	3.91	59.7
598	19.06	4.03	3.91	7.6	598	18.98	4.01	3.91	7.6
628	18.88	3.4	3.91	21.5	628	18.78	3.42	3.91	21.5
352	18.63	2.94	3.56	60.8	352	18.51	2.99	3.56	60.8

With-project SWL peaks for all storms are plotted against without-project conditions for SPs 3844 and 3766 in Figure 48, and similarly, H_{m0} peaks for with-project and without-project conditions are plotted in Figure 49. It can be seen that the SWL and H_{m0} differences between the two alternatives are small.

Figure 48. With-project SWL peaks for all storms plotted against without-project conditions for SPs 3844 (left) and 3766 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

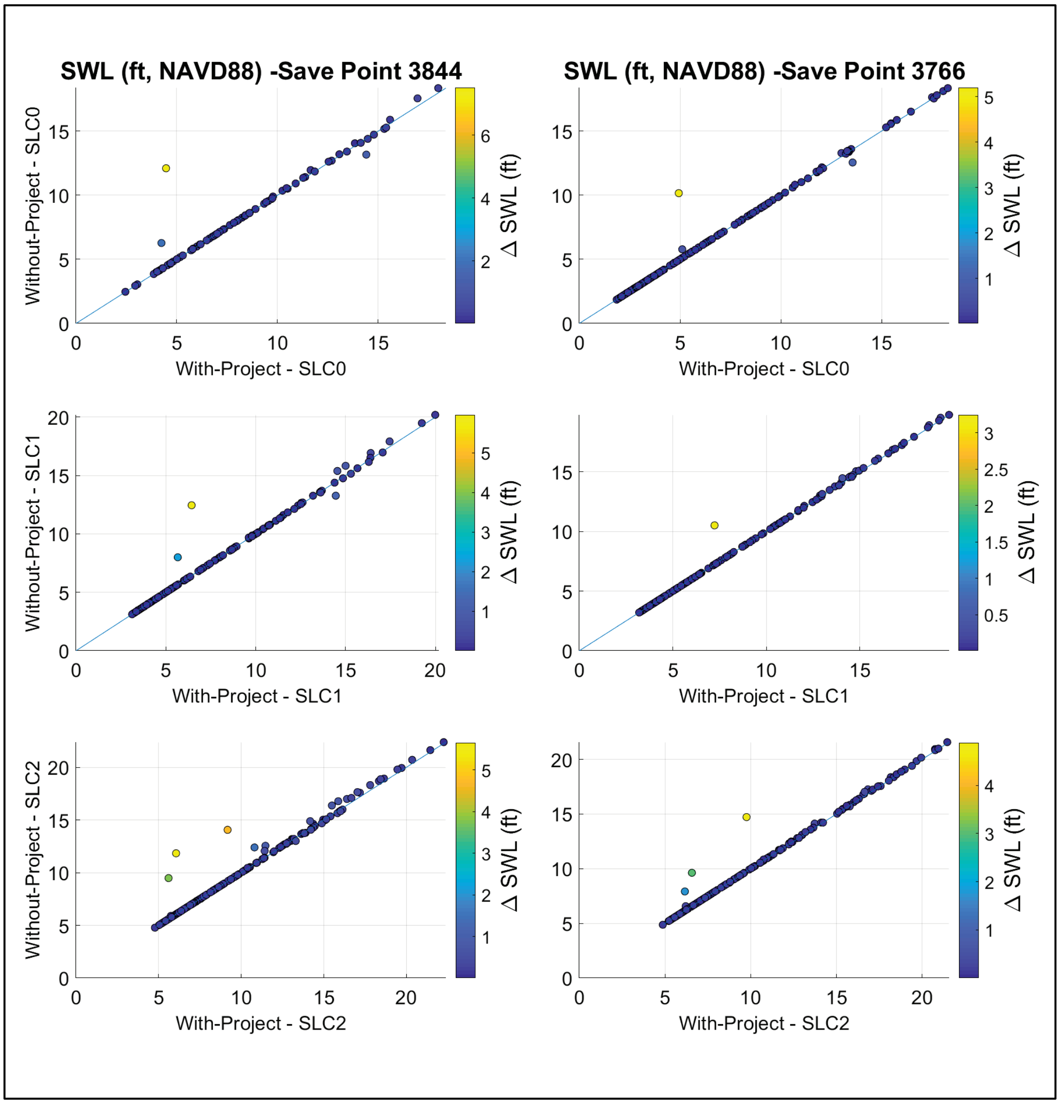


Figure 49. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 3844 (left) and 3766 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

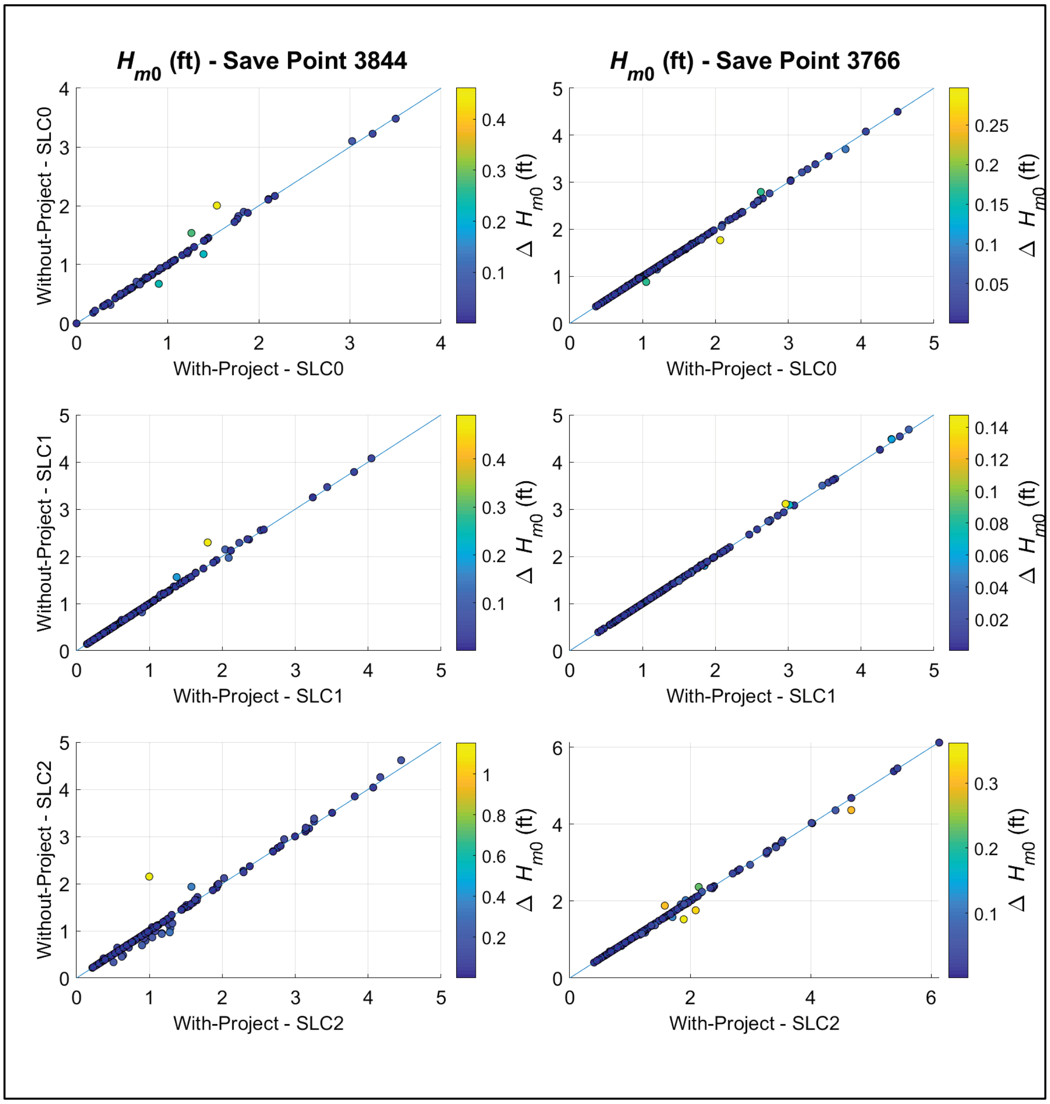


Figure 50 and Figure 51 show SWL and H_{m0} hazard curves, respectively, for SPs 3844 and 3766 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for with-project condition, but hazard curves for the two scenarios are very similar. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for without-project SLC0 and for with-project SLC1 and SLC2 for all of the analyzed SPs in PA-W. Waves in the area are relatively small.

Figure 50. AEP vs. SWL for SP 3844 (left) and SP 3766 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

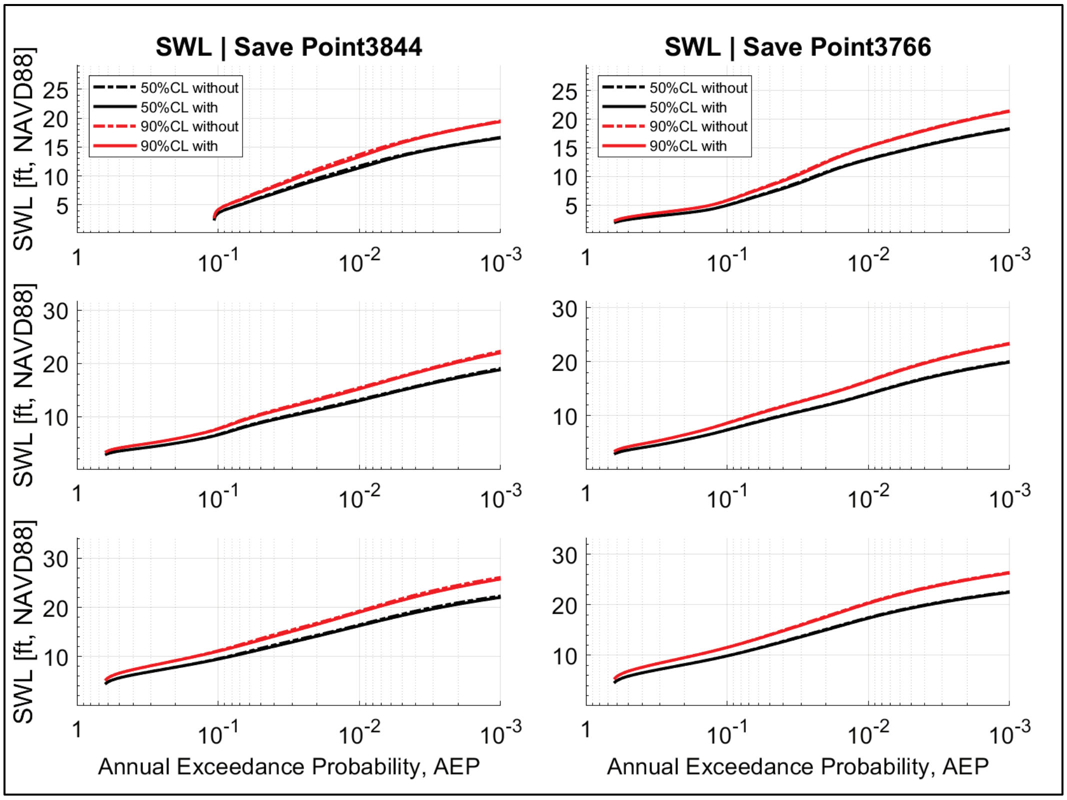
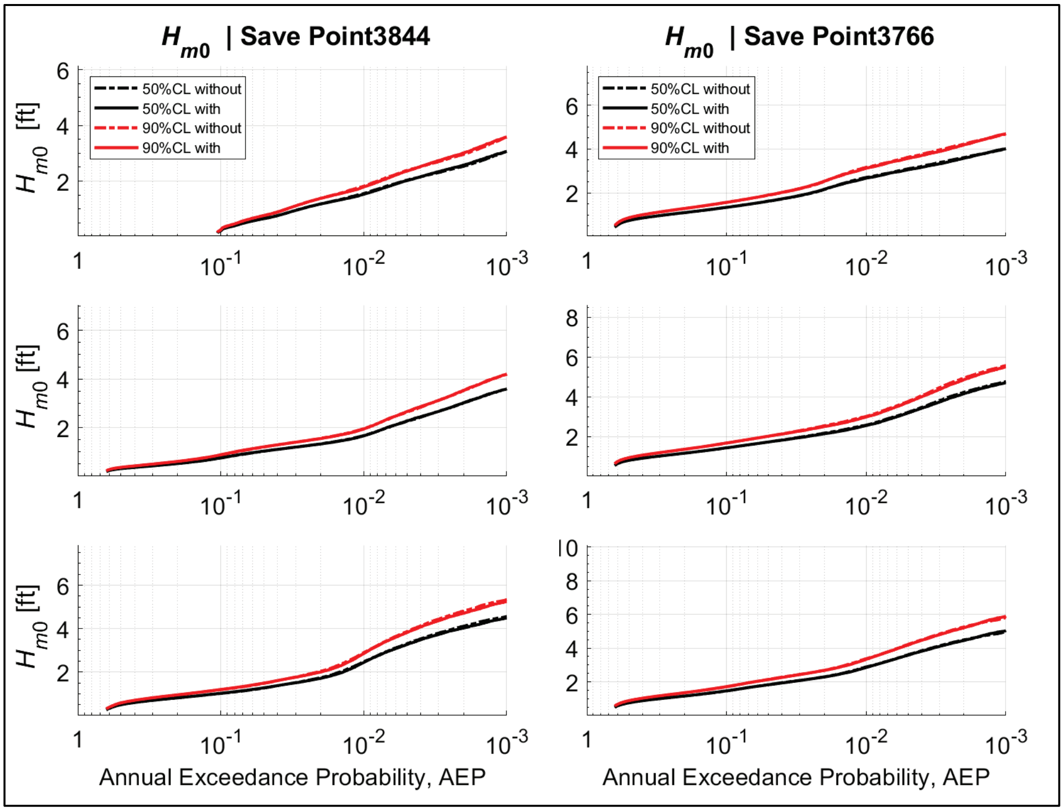


Figure 51. AEP vs. H_{m0} for SP 3844 (left) and SP 3766 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazard curves for SWL and H_{m0}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

6.2 Local CSRM system response modeling

PA-W CSRM system consists of levees and floodwalls/closure structures. The features of the CSRM system corresponding to the transects in PA-W are listed in Table 14. Transects 15b, 15, and 31 are gates or fronting protection while the rest of the transects are levees. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 52 through Figure 54 show schematized analysis transects with without-project and with-project modeled elevations.

Table 14. Features of CSRM system in PA-W area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
1	Z8	1608+00.00	1609+00.00	5	12.13	15
4	Z8	1570+00.00	1608+00.00	5	12.35	15
5	Z8	1557+50.00	1570+00.00	5	12.34	15
6	Z8	1540+00.00	1557+50.00	4	12.94	15
8	Z8	1512+50.00	1540+00.00	3	14.58	15
11	Z8	1453+89.00	1512+50.00	6	15.35	15.35
15b	Z8	1452+31.00	1453+89.00	N/A	16.4	16.4
15a	Z8	1447+95.00	1452+31.00	6	14.78	15
15	Z8	1444+54.00	1447+95.00	N/A	16.85	16.85
16	Z8	1380+00.00	1444+54.00	6	16.51	16.51
23	Z8	1322+84.82	1380+00.00	6	16.42	16.42
30	Z8	1216+20.00	1322+84.82	6	16.45	16.45
31	Z7	1211+00.00	1216+20.00	N/A	20.40	20.40
33	Z7	1160+00.00	1211+00.00	6	16.07	16.07
36	Z7	1139+50.00	1160+00.00	10	16.32	16.32

Transects for PA-W are along Taylors Bayou. There is a long wetlands area to the southwest of the CSRM system, so at high water levels waves may be able to form across this fetch. However, these waves will be dramatically reduced by shallow water effects, even at the highest water levels. CSTORM (STWAVE) does not model the physics of wave reflection, nor does it account for wave diffraction within Taylors Bayou; this results in added wave height uncertainty. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping.

Transects in PA-W have unique surrounding topographies and bathymetries. The details for each transect are described in Table 15. Berm effects were not included in the analysis, as described in prior chapters. The combined hydrostatic and hydrodynamic pressure distributions were calculated for each gate and pump station transect.

Table 15. Characteristics of CSRM in PA-W area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
1	3867	Levee	N/A	Grass	Grass
4	3861	Levee	N/A	Grass	Grass
5	3859	Levee	N/A	Grass	Grass
6	3854	Levee	N/A	Grass	Grass
8	3848	Levee	N/A	Grass	Grass
11	3844	Levee	N/A	Grass	Grass
15b	3832	HWY 365 Closure Gate	13.45	Concrete	Concrete
15a	3832	Levee	N/A	Grass	Grass
15	3830	Port Acers Pump Station	4.91	Concrete	Concrete
16	2483	Levee	N/A	Grass	Grass
23	2490	Levee	N/A	Grass	Grass
30	2497	Levee	N/A	Grass	Grass
31	2498	Lake Side Pump Station	14.85	Concrete	Concrete
33	3766	Levee	N/A	Grass	Grass
36	2503	Levee	N/A	Grass	Grass

Figure 52. Analysis transects 31–36 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

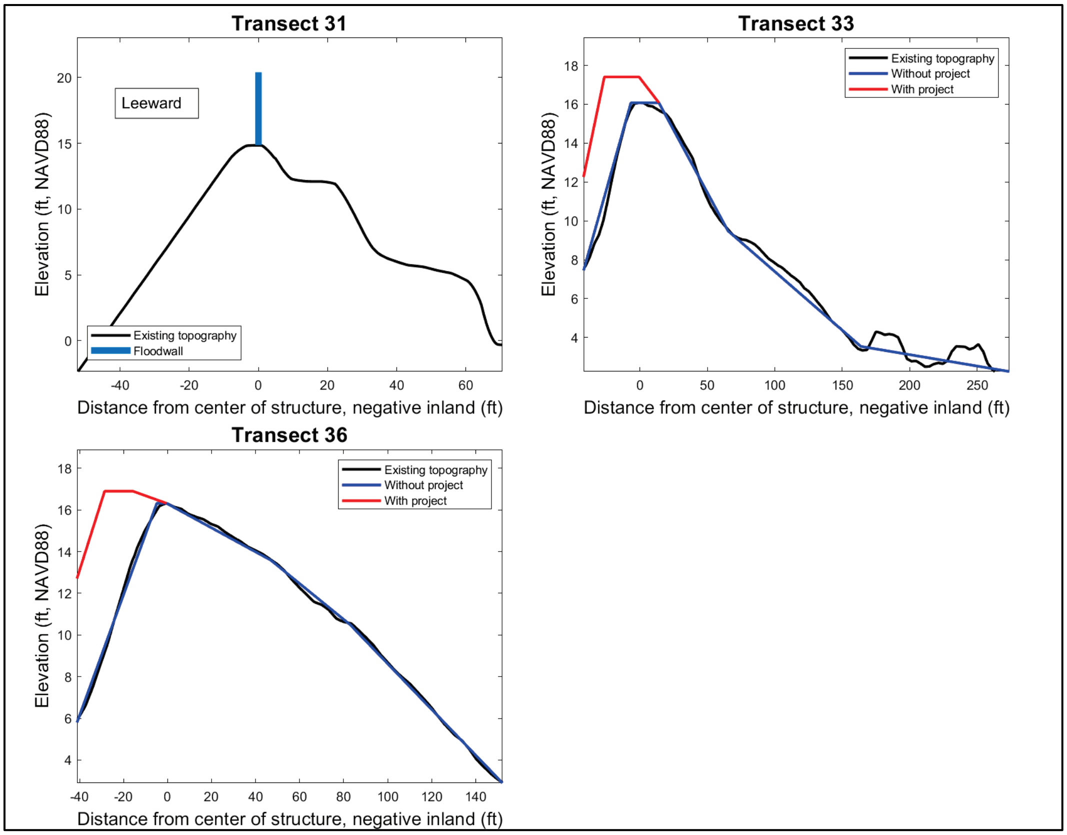


Figure 53. Analysis transects 1–11 with measured topography (black). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

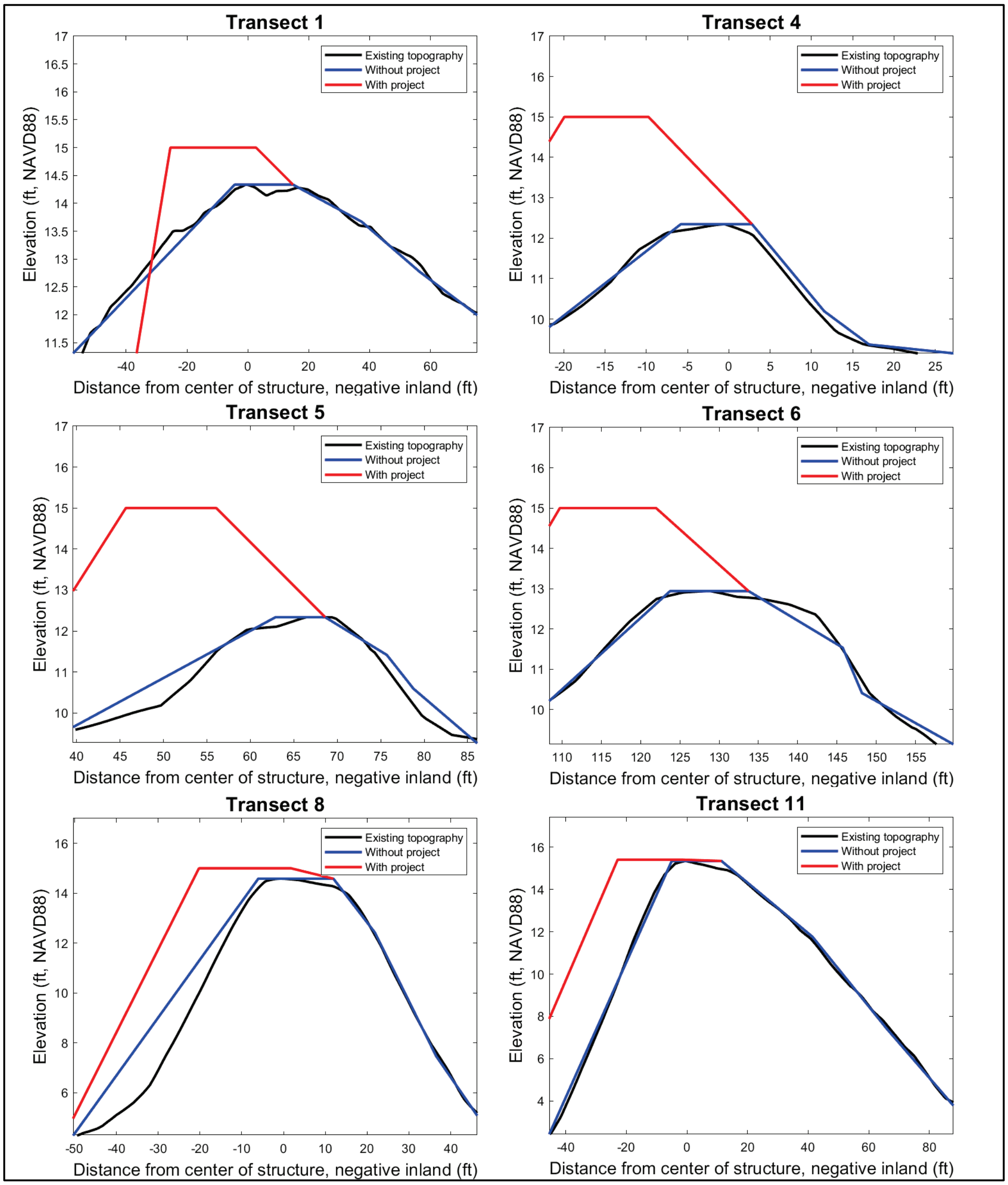
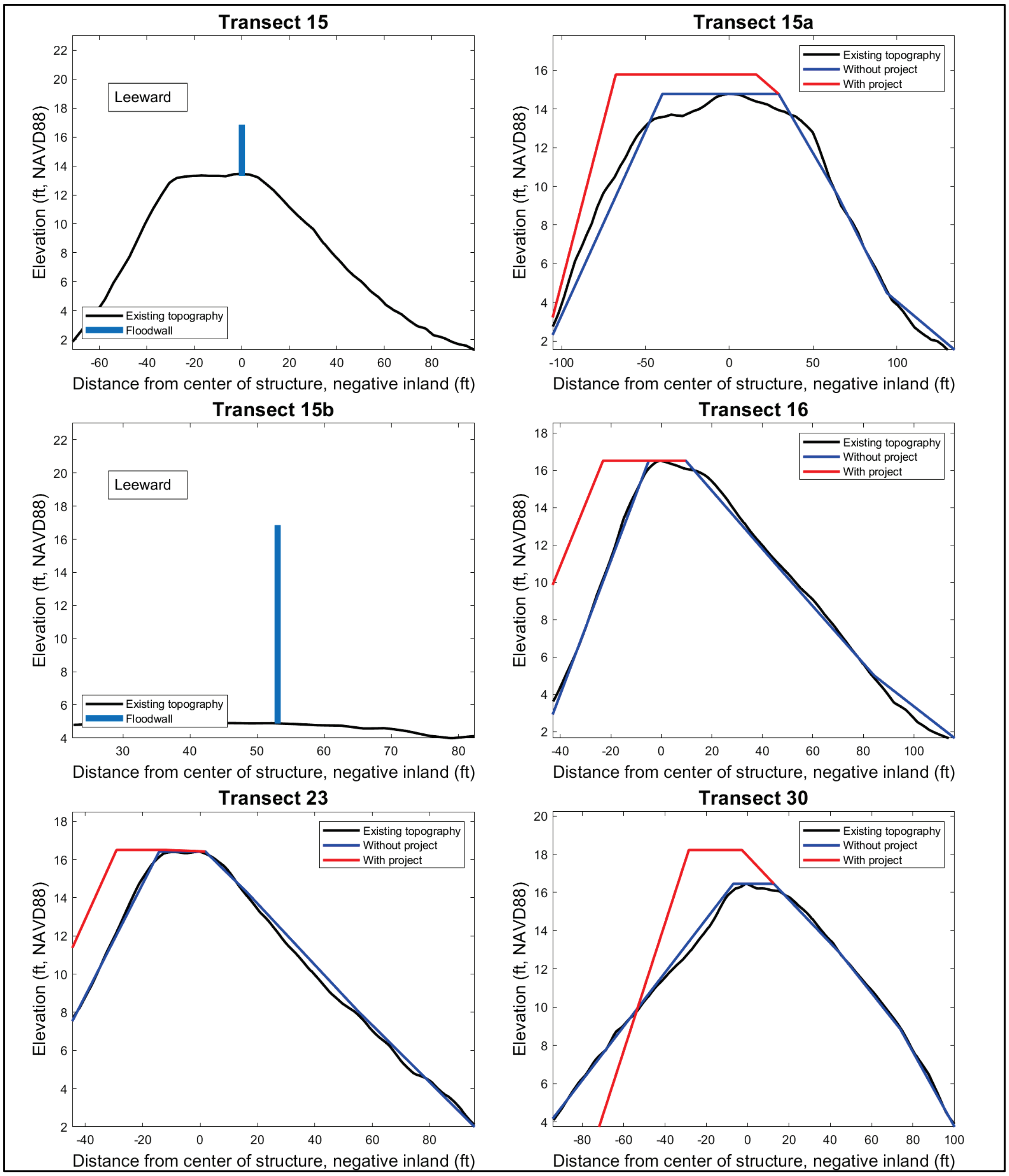


Figure 54. Analysis transects 15–30 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



6.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-W, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall and gate portions of PA-W. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

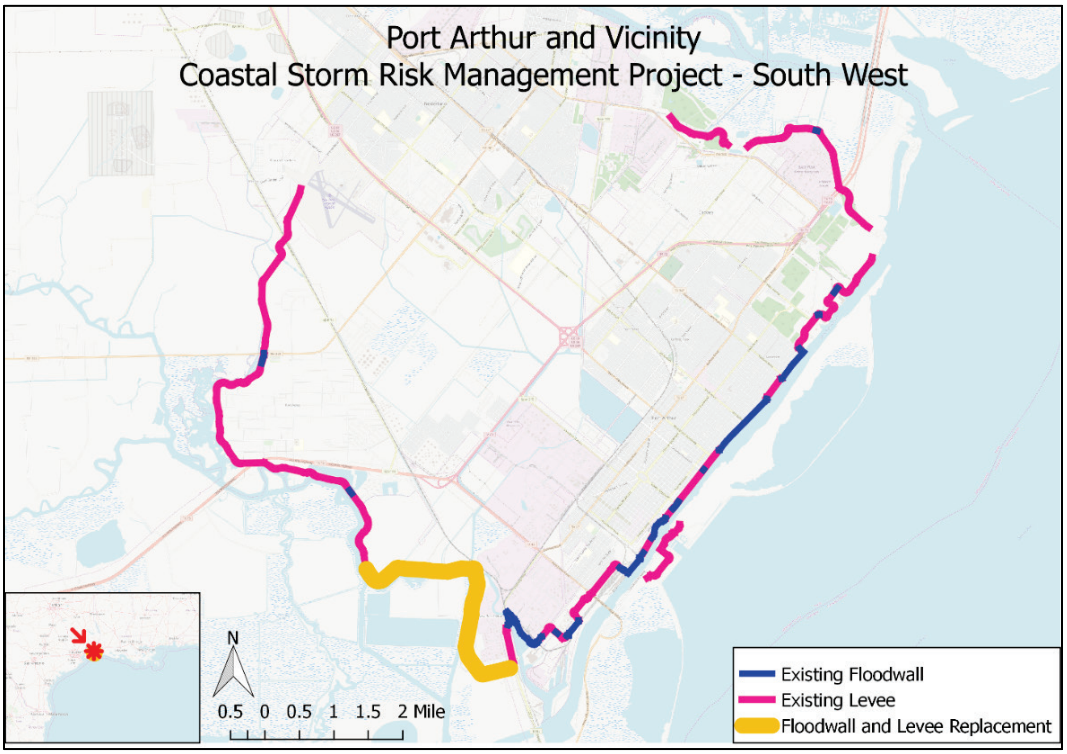
6.4 Summary and conclusions for PA-W

As part of the ongoing PED phase of the project, this chapter documents coastal SWL and wave hazards for the PA-W portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and combined overtopping and overflow are quantified for the PA-W CSRM system consisting of floodwalls and levees. Optimized crest elevations were found for SLC1 and SLC2 using overtopping criteria based on no-damage limit states. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall and gate transect.

7 Port Arthur – South West (PA–SW)

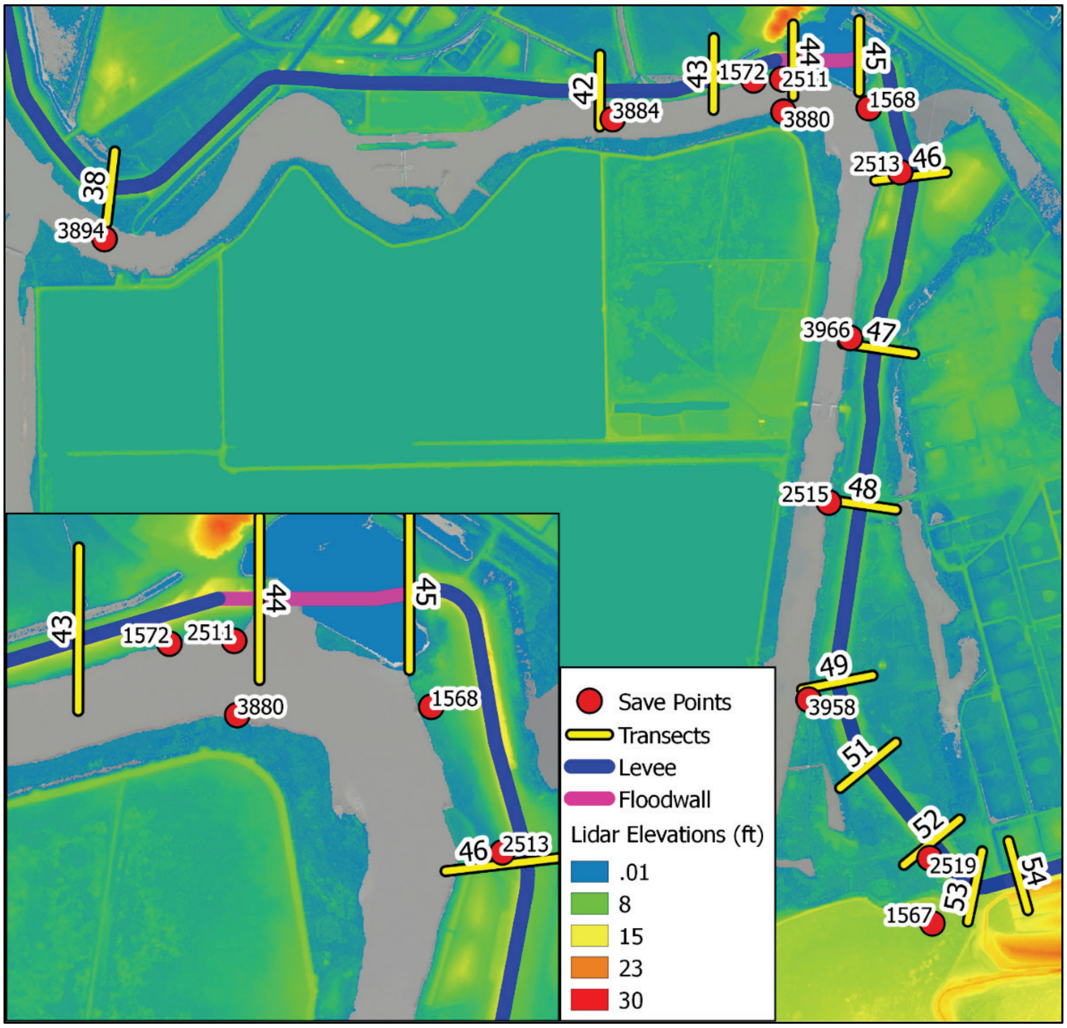
PA-SW designates the southwest portion of the Port Arthur CSRM system (Figure 55 and Figure 56). This chapter documents coastal SWL and wave hazards and coastal structure responses for the PA-SW portion of the Port Arthur CSRM system. PA-SW consists of both levee and pump station fronting protection sections.

Figure 55. PA-SW levee and floodwall location along Taylors Bayou (in yellow).



The PA-SW portion of Port Arthur includes a section of the existing CSRM system of floodwall pump station fronting protection and levee along the Port of Port Arthur, shown in Figure 56. The contract begins at STA 933+80.00 and proceeds to STA 1139+50.00.

Figure 56. Details of PA-SW for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



7.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 3884 in Table 16 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks are approximately 18 ft, NAVD88 for SLC0.

SPs along the edge of the Taylors Bayou channel did not show inundation or wave energy for all storms because STWAVE cells are partially dry during lower water events. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{mo} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 16. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 3884.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
589	18.25	3.82	3.24	61.8	589	18.2	3.82	3.24	61.8
447	17.71	3	3.56	136.9	461	17.65	4.78	3.56	90.8
461	17.57	4.75	3.56	90.8	447	17.61	3.01	2.94	139.7
464	17.57	3.31	3.24	71.6	464	17.52	3.31	3.24	71.6
357	17.23	3.14	3.24	135.2	357	17.14	3.14	2.94	135.2
342	16.26	2.46	2.94	147.2	342	16.19	2.38	2.94	139.4
532	15.46	2.61	2.94	63.7	532	15.35	2.6	2.94	63.7
628	15.34	2.78	3.24	101.7	628	15.23	2.79	3.24	101.7
598	15.21	2.84	2.94	140.5	598	15.14	2.75	2.94	140.5
159	15.15	2.63	2.94	124.9	159	15.02	2.59	2.94	124.9
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
589	19.6	3.9	3.24	97.9	589	19.6	3.87	3.24	61.8
447	19.2	3.33	3.56	133.9	461	19.08	5.02	3.56	101.1
461	19.17	5.12	3.56	101.1	447	18.98	3.18	3.56	131
357	18.66	3.4	3.56	127.9	357	18.42	3.4	3.56	142.1
464	18.49	3.38	3.24	71.6	464	18.4	3.36	3.24	67.1
342	17.69	2.39	3.24	139.4	342	17.62	2.63	3.24	147.2
598	17.15	3.35	3.24	140.5	598	17.11	3.3	3.24	140.5
529	16.88	3.56	3.24	60.5	529	16.86	3.55	3.24	60.5
628	16.85	2.81	3.24	101.7	628	16.79	2.82	3.24	101.7
352	16.79	2.74	2.94	61.4	352	16.75	2.71	2.94	61.4
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	21.28	3.87	3.56	136.9	447	21.18	3.84	3.56	136.9
589	20.84	4.23	3.56	104.1	589	20.81	3.97	3.24	55
461	20.82	5.82	3.91	101.1	461	20.67	5.34	3.91	115.7
357	20.79	3.99	3.56	131	357	20.58	3.9	3.56	131
464	20	3.51	3.56	103.9	464	19.8	3.43	3.24	71.6
342	19.68	2.83	3.56	139.4	342	19.48	2.78	3.24	139.4
529	19.29	3.92	3.24	71.4	529	19.29	3.9	3.24	71.4
598	18.98	3.76	3.91	140.5	598	18.85	3.8	3.56	140.5
352	18.53	2.89	3.56	126.7	352	18.37	2.86	2.94	61.4
628	18.34	3	3.24	117.9	628	18.22	2.9	3.24	117.9

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 57, and similarly, H_{m0} peaks for with-project and without-project conditions are plotted in Figure 58. It can be seen that the SWL and H_{m0} differences between the two alternatives are small.

Figure 57. With-project SWL peaks for all storms plotted against without-project conditions for SPs 1567 (left) and 3884 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

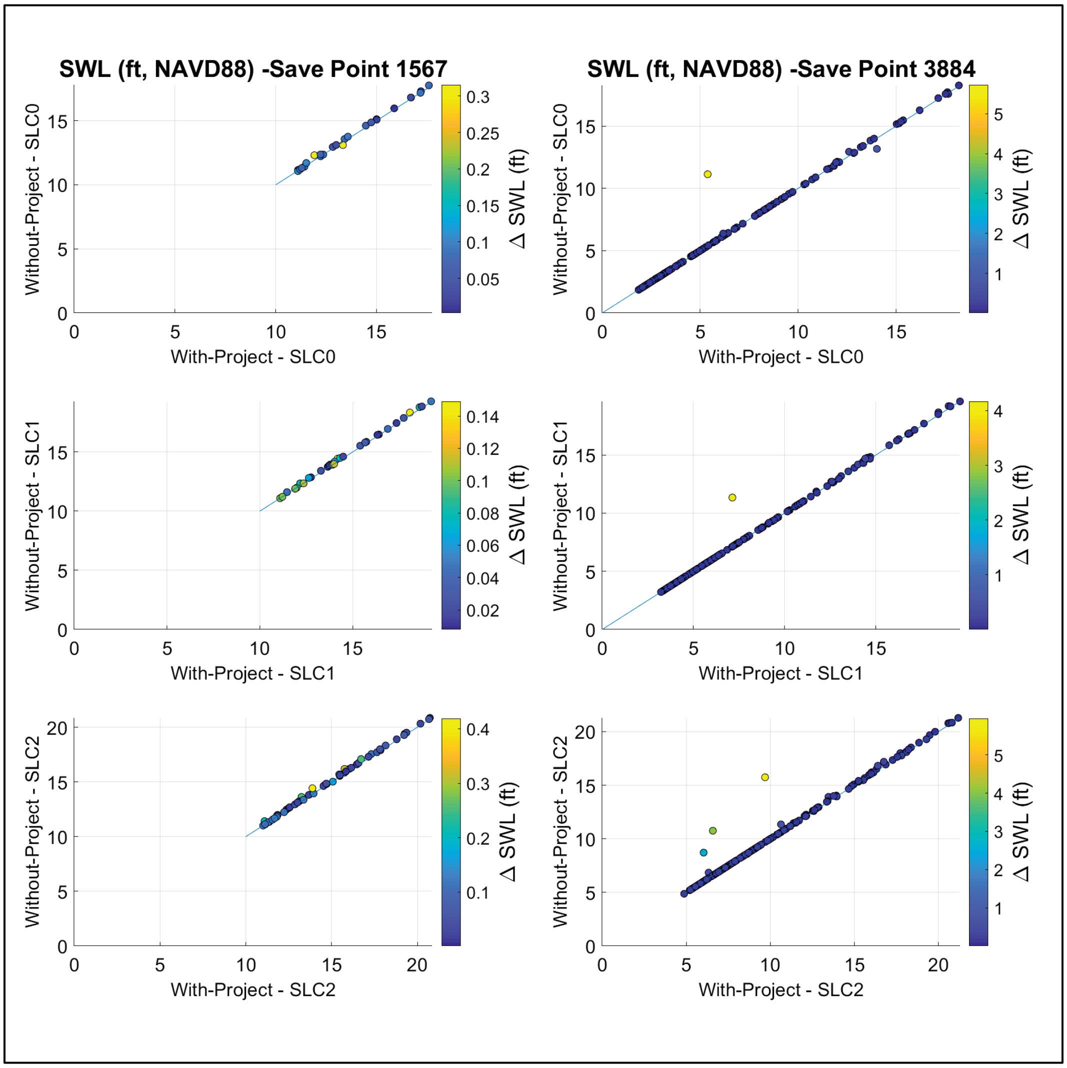


Figure 58. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 1567 (left) and 3884 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

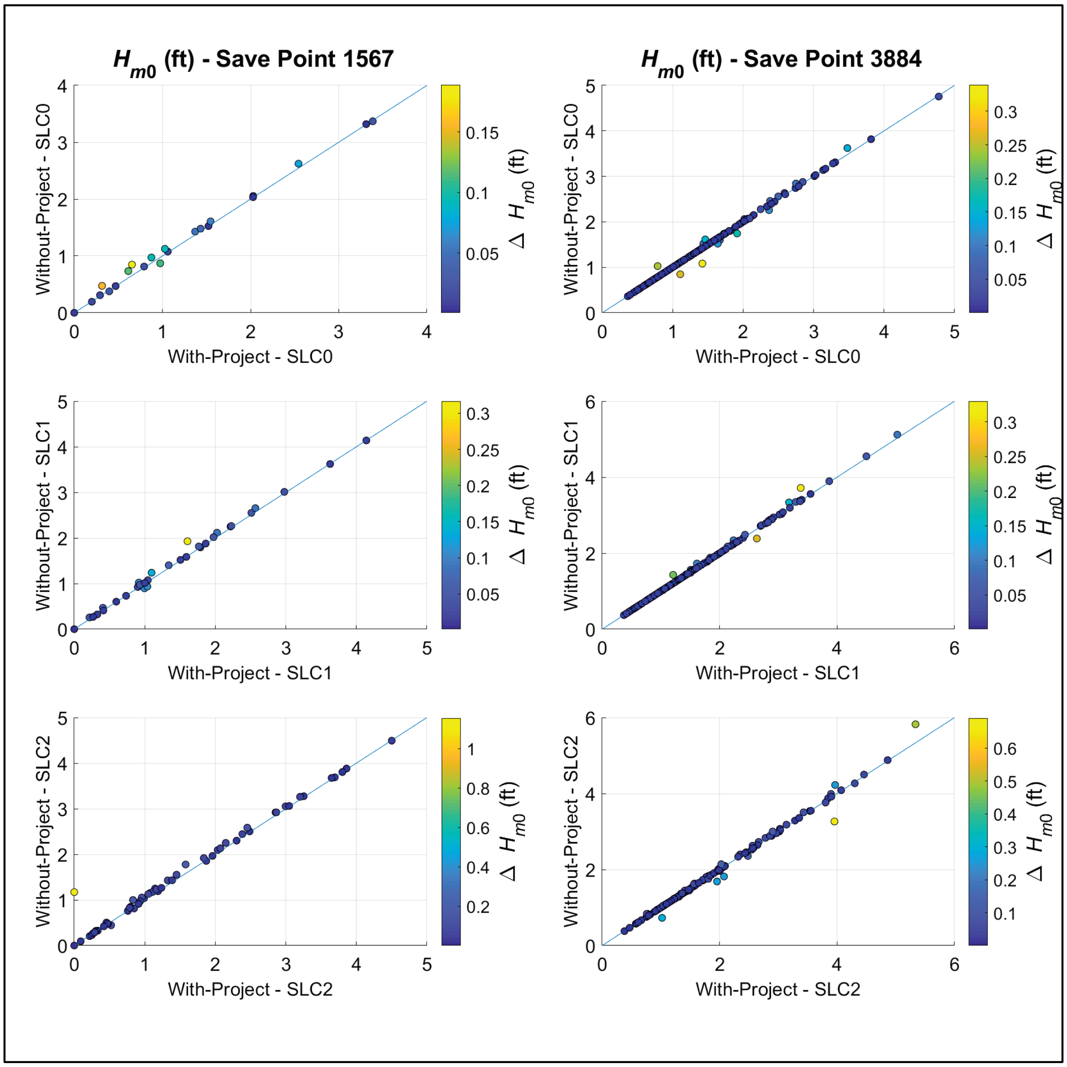


Figure 59 and Figure 60 show SWL and H_{mo} hazard curves, respectively, for SPs 1567 and 3884 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% confidence limits are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{mo} values for a range of AEPs are listed with their corresponding transects in Appendix D for SLC0 without-project and for SLC1 and SLC2 with-project conditions. The 1% AEP waves are relatively small.

Figure 59. AEP vs. SWL for SP 1567 (left) and SP 3884 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

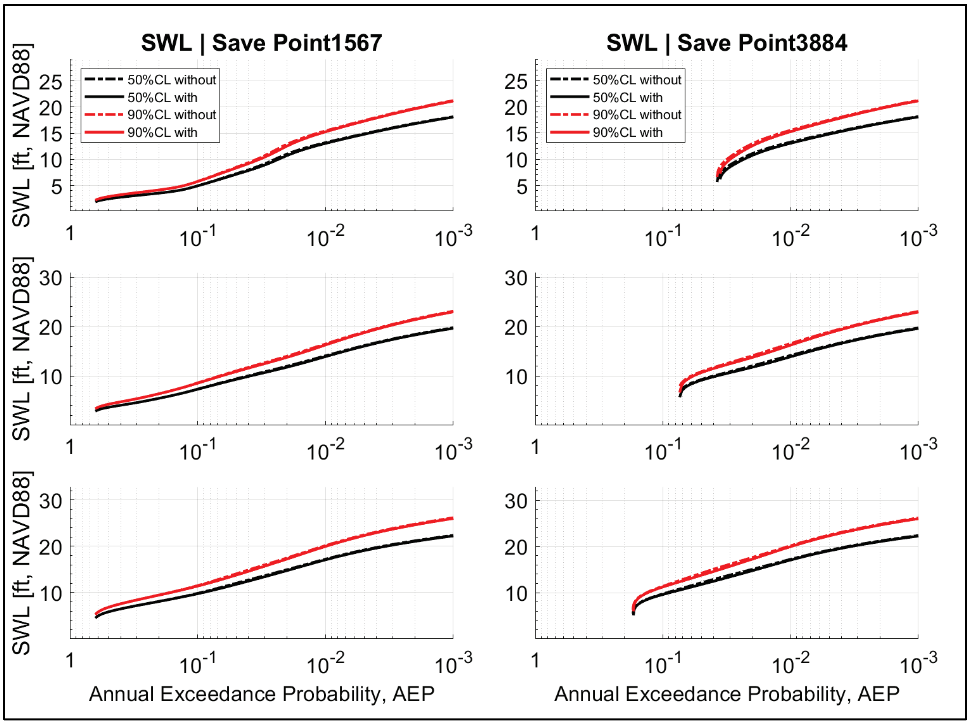
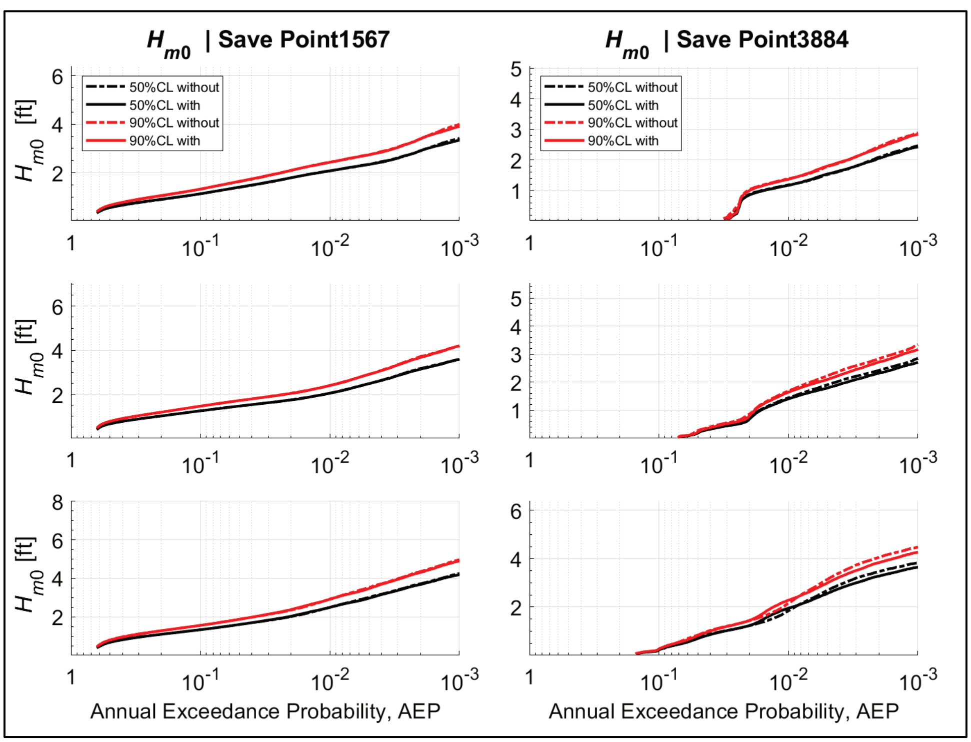


Figure 60. AEP vs. H_{m0} for SP 1567 (left) and SP 3884 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazard curves for SWL and H_{mo}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

7.2 Local CSRM system response modeling

PA-SW CSRM system consists of levees and floodwall pump station fronting protection. The features of the CSRM system corresponding to the transects in PA-SW are listed in Table 17. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 61 and Figure 62 show schematized analysis transects with without-project and with-project modeled elevations.

Table 17. Features of CSRM system in PA-SW area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
38	Z7	1110+00.00	1139+50.00	10	17.13	17.1
42	Z6	1057+50.00	1110+00.00	6	15.29	16
43	Z5	1047+04.00	1057+51.00	8	16.47	16.5
44	Z5	1039+34.00	1047+04.00	N/A	21.5	21.5
45	Z5	1037+72.92	1039+34.00	N/A	21.5	21.5
46	Z5	1020+00.00	1037+72.92	6	16.60	16.6
47	Z5	990+00.00	1020+00.00	10	16.64	16.6
48	Z4	970+00.00	990+00.00	6	17.58	17.6
49	Z4	955+96.67	970+00.00	N/A	23	16.5
51	Z4	952+00.00	955+96.67	N/A	23	16.5
52	Z4	945+10.00	952+00.00	N/A	23	16.5
53	Z4	934+53.89	945+10.00	N/A	23	16.5
54	Z4	933+80.00	934+53.89	N/A	23	16.5

Transects for PA-SW are along Taylors Bayou. The estimated wave heights are uncertain, as explained for PA-W. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure results are conservative. Additionally, berm effects were not included in the hazard calculations, as described for other regions. The combined hydrodynamic and hydrostatic pressure distributions were calculated for each floodwall pump station fronting protection transect because the pressures on the floodwall depend on the toe elevations, which vary between transects. See Table 18.

Table 18. Characteristics of CSRM system in PA-SW area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
38	3894	Levee	N/A	Grass	Asphalt
42	3884	Levee	N/A	Grass	Asphalt
43	1572	Levee	N/A	Grass	Asphalt
44	3880	Alligator Bayou Extension Pump Station	-14.00	Concrete	Concrete
45	1568	Floodwall – PS Fronting Protection	18.17	Concrete	Concrete
46	2513	Levee	N/A	Grass	Gravel
47	3966	Levee	N/A	Grass	Gravel/Grass
48	2515	Levee	N/A	Grass	Grass
49	3958	Levee	N/A	Grass	Grass
51	2519	Levee	N/A	Grass	Grass
52	2519	Levee	N/A	Grass	Grass
53	1567	Levee	N/A	Grass	Grass
54	1567	Levee	N/A	Grass	Grass

Figure 61. Analysis transects 38–46 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

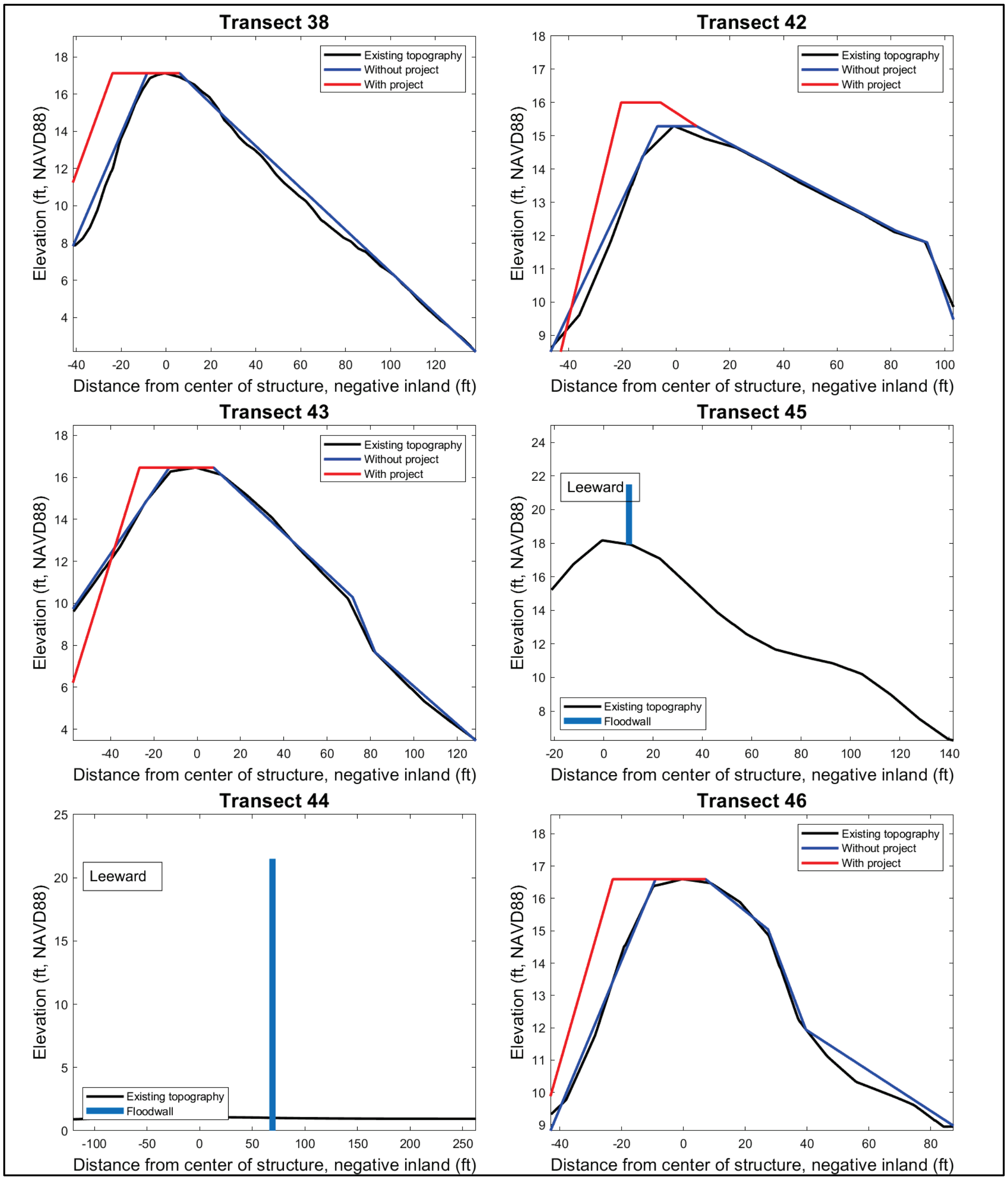
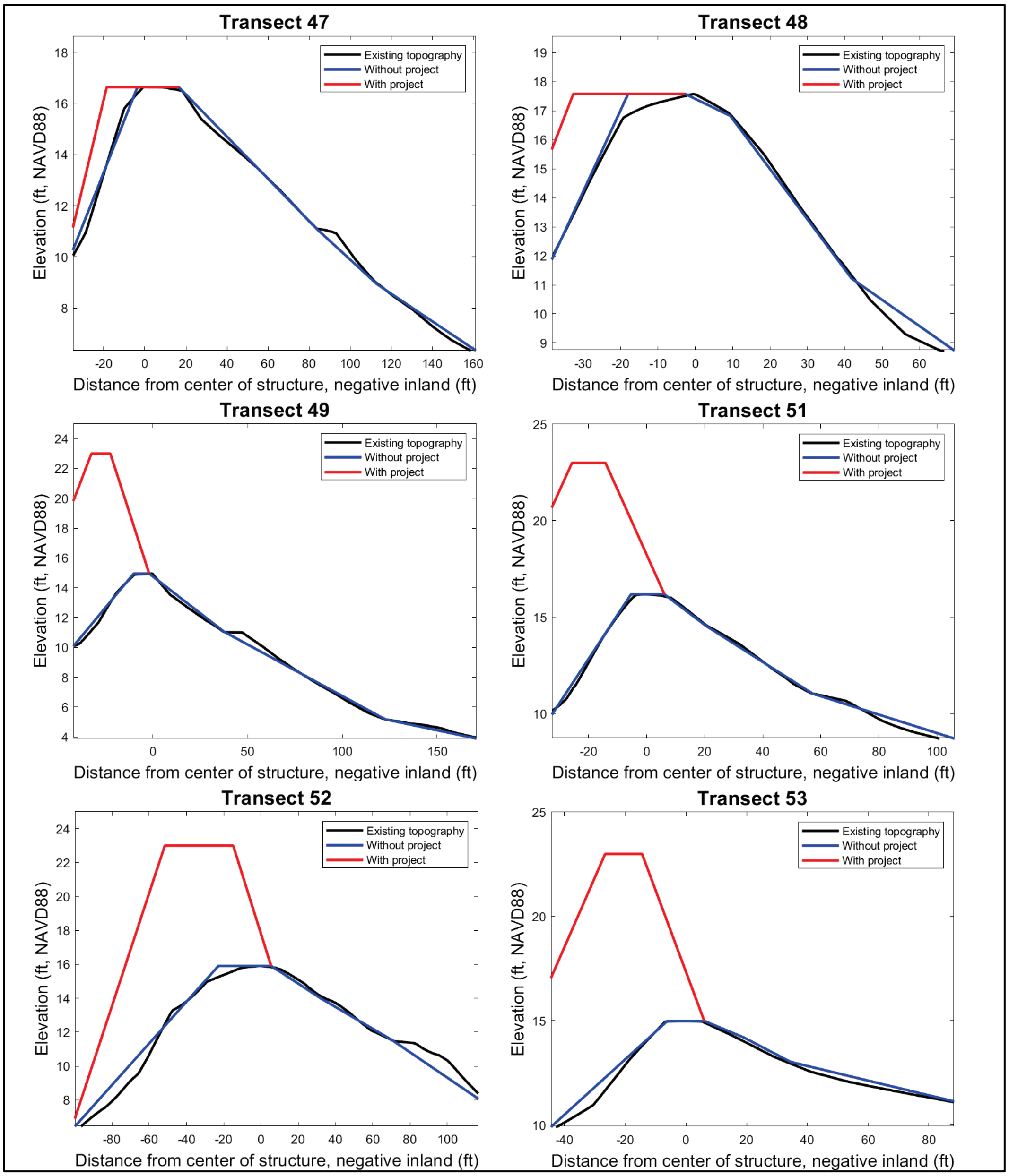


Figure 62. Analysis transects 47–53 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



7.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-SW, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall portion of PA-SW. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

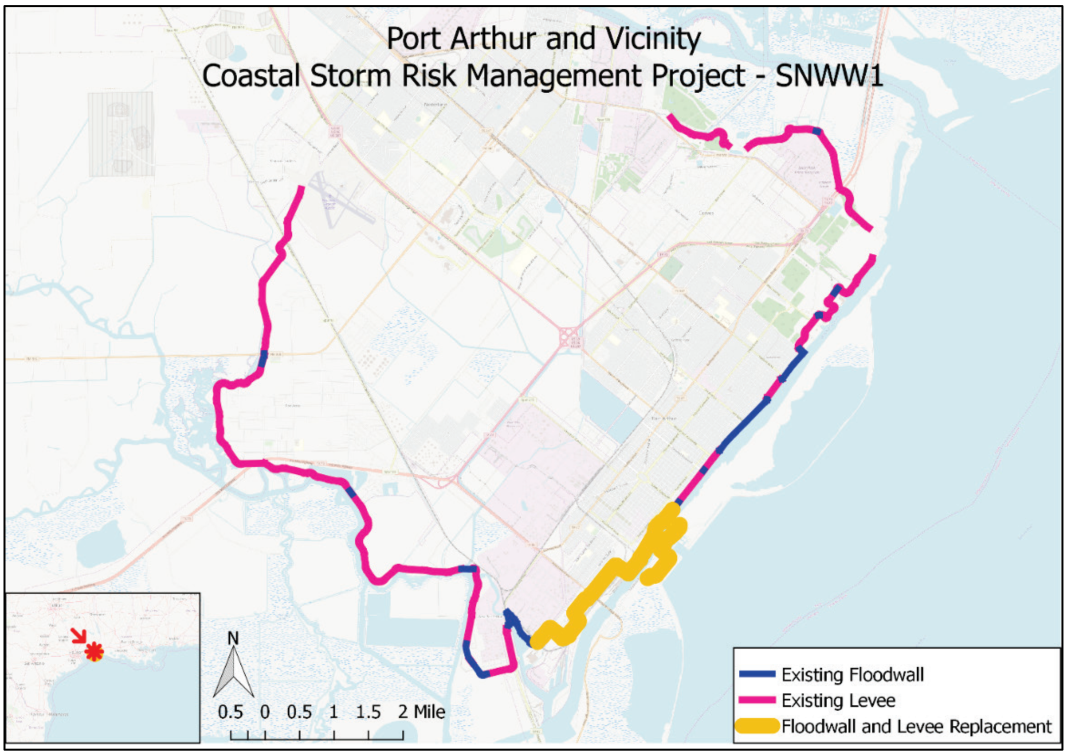
7.4 Summary and conclusions for PA-SW

As part of the ongoing PED phase of the project, this chapter documents coastal storm inundation, wave loading, and overtopping and overflow for the PA-SW CSRM system consisting of floodwall fronting protection and levees. Optimized crest elevations were computed based on no-damage overtopping criteria to inform the PDT during design. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect.

8 Port Arthur – SNWW1 (PA-SNWW1)

PA-SNWW1 designates the southern portion of the Port Arthur CSRM system along the SNWW. This chapter documents coastal SWL and wave hazards and structure responses for the PA-SNWW1 portion of the Port Arthur CSRM system (PA-SNWW1; Figure 63 through Figure 65). PA-SNWW1 consists of levees, floodwalls, and pump station fronting protection. PA-SNWW1 excludes the Contract 3b reach.

Figure 63. PA-SNWW1 levee and floodwall location along SNWW (in orange).



The south half of PA-SNWW1 begins at STA 653+00.00 and proceeds to STA 762+13.00. The northern half of PA-SNWW1 begins at STA 569+60.00 and proceeds to STA 617+53.11. Structure modifications include increasing the elevations of both the floodwall and levee.

Figure 64. Details of PA-SNWW1, south end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).

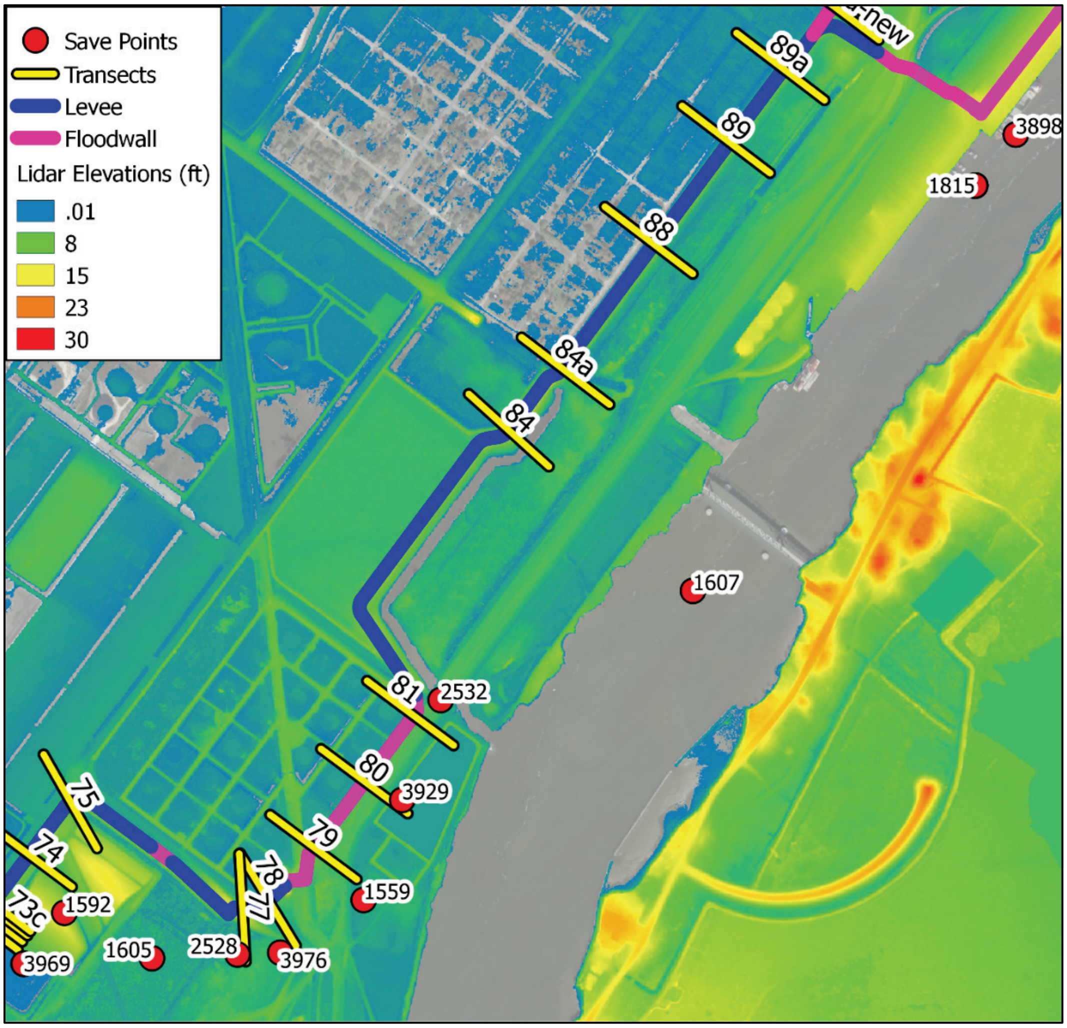
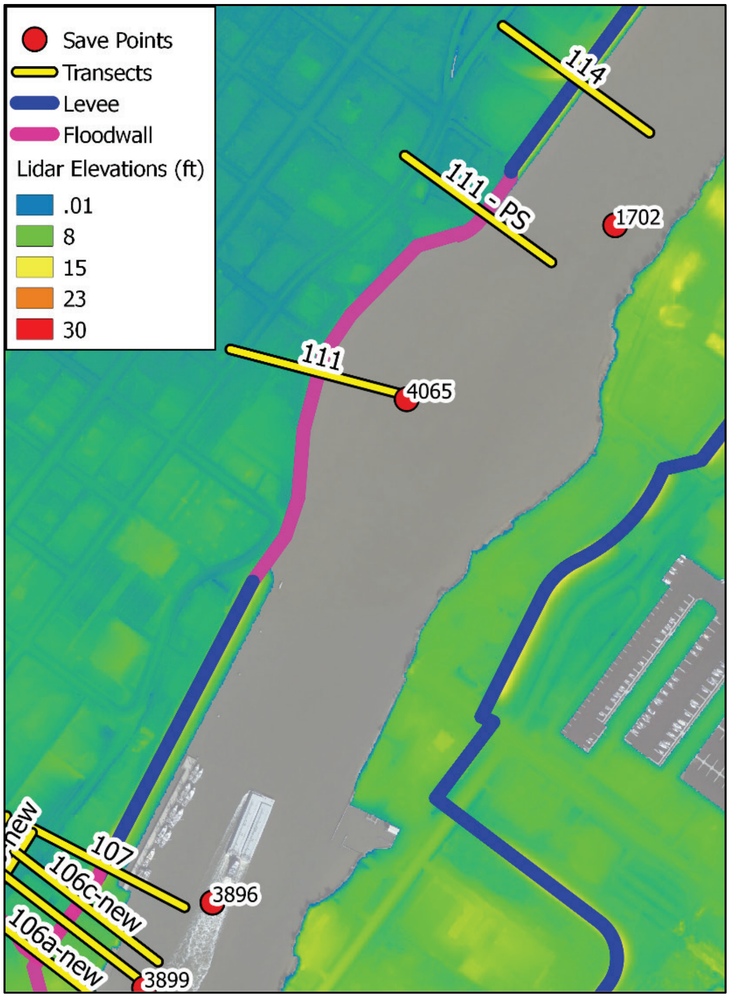


Figure 65. Details of PA-SNWW1, north end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



8.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 1815 in Table 19 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks for SLC0 are approximately 19 ft, NAVD88. SPs along the edge of the SNWW did not show inundation or wave energy for all storms because the STWAVE cells are partially dry during lower water events. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{m0} for 189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendix A and B.

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 66, and similarly, H_{m0} peaks for with-project and without-project conditions are plotted in Figure 67. It can be seen that the SWL and H_{m0} differences between the two alternatives are small.

Table 19. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 1815.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	18.33	2.2	2.67	150.3	633	19.26	3.31	2.67	161.1
633	17.98	3.03	2.67	161.1	461	18.61	3.83	2.94	102.9
357	17.96	2.51	2.67	141.3	447	18.58	2.25	2.67	144.7
461	17.78	3.8	2.94	102.9	357	18.47	2.42	2.67	141.3
464	16.93	2.48	2.67	113.8	464	16.82	2.47	2.67	113.8
342	16.41	1.77	2.67	144.1	342	16.15	1.76	2.67	144.1
598	16.16	2.58	2.67	150.1	598	15.67	2.58	2.67	150.1
159	16.14	2.53	2.67	141	159	15.53	2.53	2.67	141
589	15.93	2.69	2.67	94.1	589	15.02	2.72	2.67	94.1
634	15.77	3.03	2.94	167.2	153	14.54	1.95	2.67	152.2
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	20.2	3.09	2.67	164	633	20.07	3.07	2.94	164
447	20.04	2.27	2.67	153	447	19.9	2.26	2.67	153
357	19.77	2.52	2.67	152.7	461	19.71	3.91	2.94	102.9
461	19.41	3.9	2.94	102.9	357	19.5	2.51	2.67	152.7
464	18.57	2.46	2.67	154.8	464	18.56	2.49	2.67	154.8
342	18.05	1.88	2.67	144.1	598	18.51	2.57	2.67	150.1
589	17.75	2.71	2.67	94.1	342	18.37	1.8	2.67	144.1
598	17.74	2.74	2.67	150.1	589	18.22	2.73	2.67	94.1
159	17.61	2.56	2.67	141	159	16.82	2.54	2.67	141
532	16.66	1.98	2.67	95.7	532	16.32	1.97	2.67	95.7
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	22.61	3.25	2.67	161.1	633	22.55	3.24	2.67	161.1
357	22.02	2.6	2.67	141.3	357	21.88	2.61	2.67	141.3
447	21.93	2.23	2.67	147.6	447	21.88	2.33	2.67	136.6
461	21.83	3.91	2.94	102.9	461	21.74	3.91	2.94	102.9
464	21.14	2.55	2.67	148.7	464	20.97	2.55	2.67	113.8
598	20.53	2.72	2.67	150.1	598	20.36	2.71	2.67	150.1
342	20.41	1.91	2.67	152.6	342	20.29	1.79	2.67	144.1
589	20	2.74	2.94	94.1	589	19.7	2.74	2.94	94.1
159	19.49	2.58	2.67	141	159	19.19	2.57	2.67	136.3
532	19.21	2.22	2.67	95.7	532	19	2.23	2.67	103.3

Figure 66. With-project SWL peaks for all storms plotted against without-project conditions for SPs 1559 (left) and 1815 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

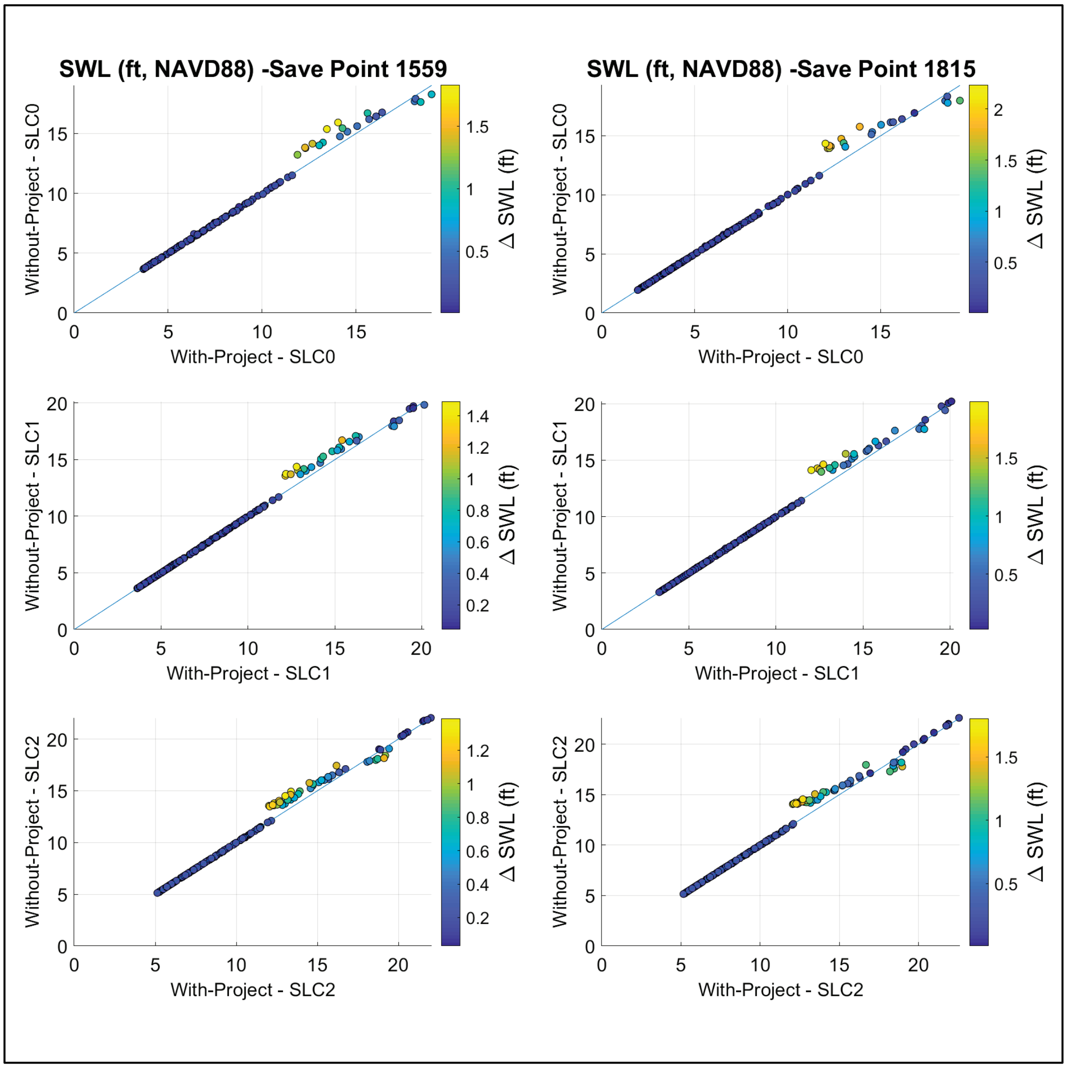


Figure 67. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 1559 (left) and 1815 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

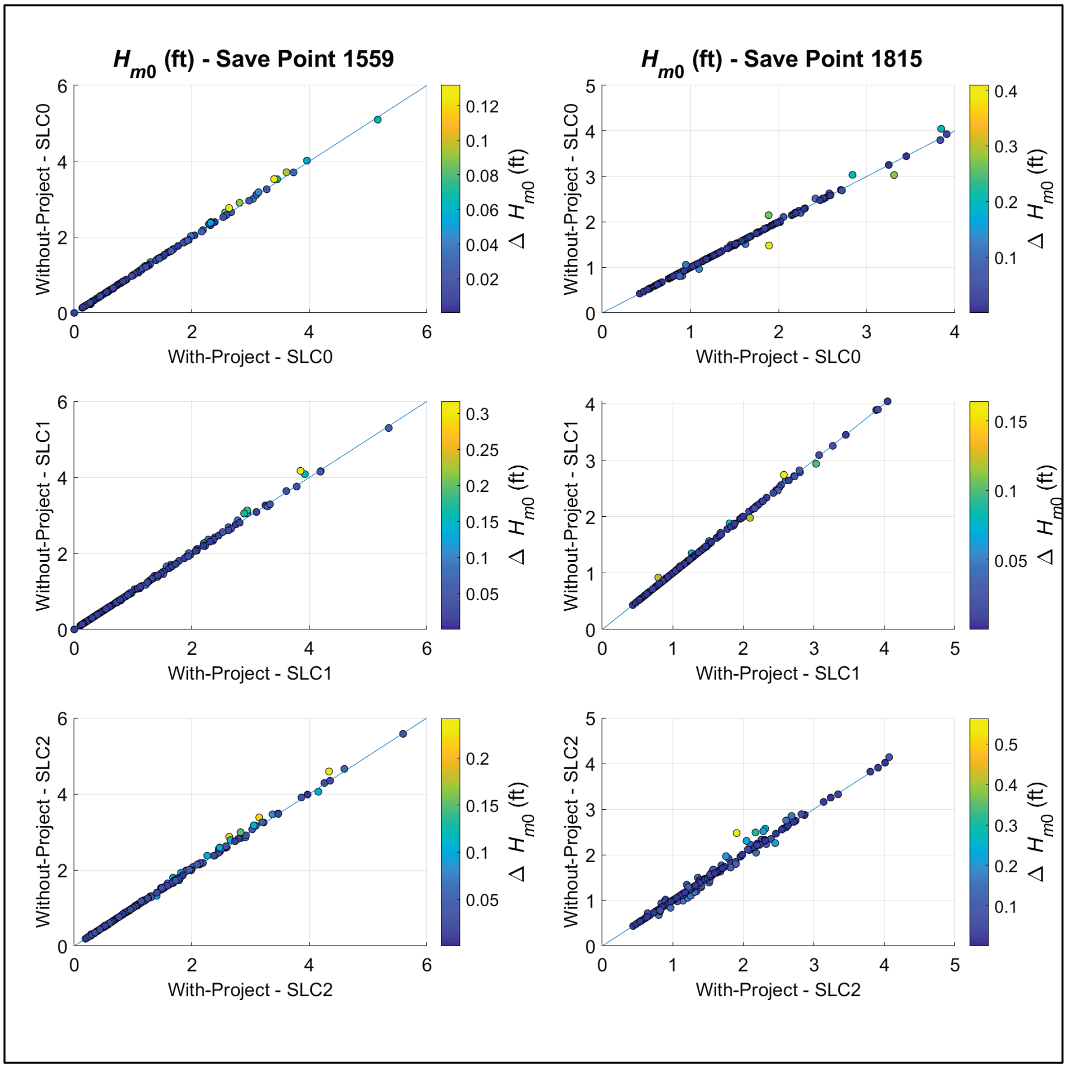


Figure 68 and Figure 69 show SWL and H_{m0} hazard curves, respectively, for SPs 1559 and 1815 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for SLC0 without-project and SLC1 and SLC2 with-project conditions.

Figure 68. AEP vs. SWL for SP 1559 (left) and SP 1815 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

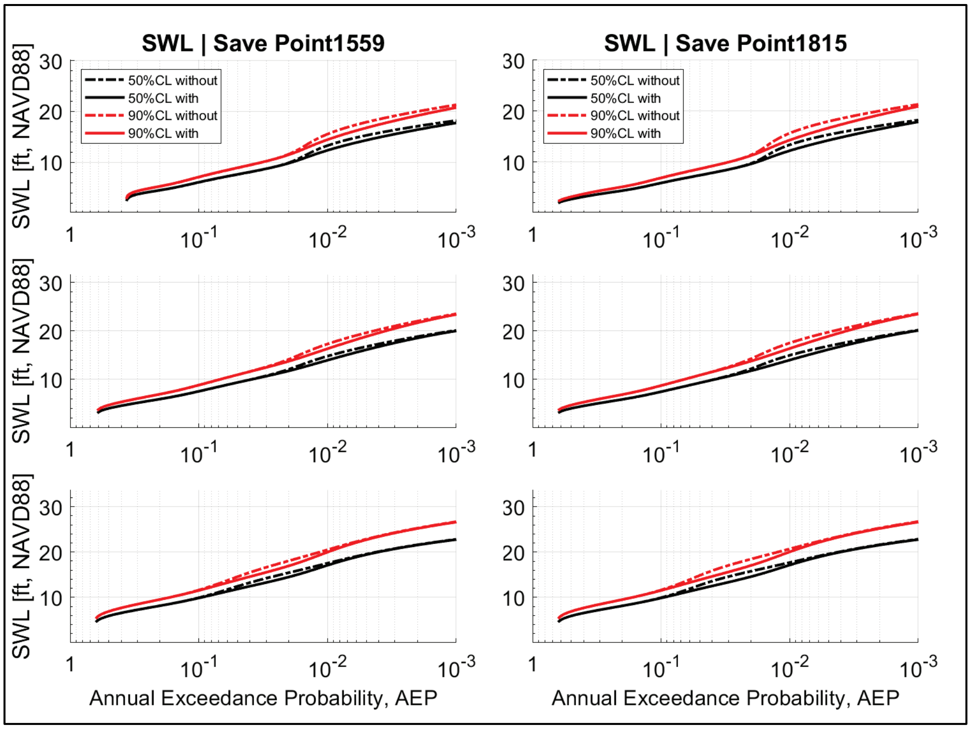
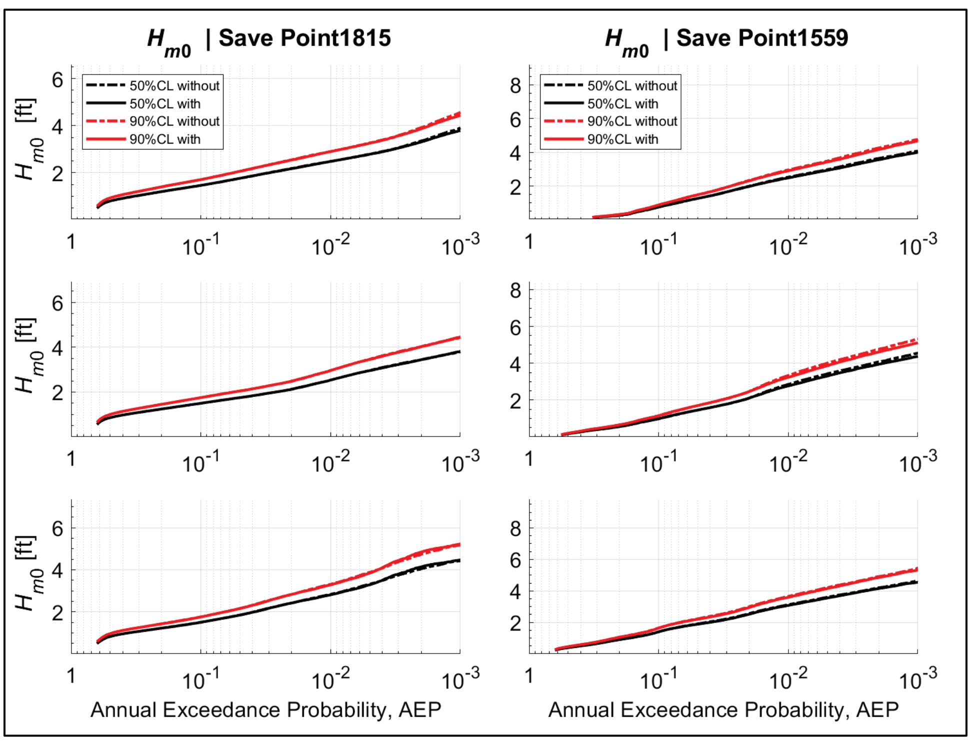


Figure 69. AEP vs. H_{m0} for SP 1815 (left) and SP 1559 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazard curves for SWL and H_{mo}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

8.2 Local CSRM system response modeling

PA-SNWW1 CSRM system consists of levees, floodwalls, and pump station fronting protection. The features of the CSRM system corresponding to the transects in PA-SNWW1 are listed in Table 20. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 70 through Figure 72 show schematized analysis transects with without-project and with-project modeled elevations. Transects 84a and 111a will have a similar cross section as transects 84 and 111, respectively.

Table 20. Features of CSRM system in PA-SNWW1 area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
74	Y	757+50.00	762+13.00	9	14.90	17.00
75	Y	744+00.00	757+50.00	6	15.90	17.00
77	Y	733+37.93	744+00.00	6	15.23	17.00
78	Y	733+37.93	744+00.00	6	15.84	17.00
79	Y	716+52.00	733+41.65	N/A	18.85	19.00
80	Y	716+52.00	733+41.65	N/A	18.85	19.00
81	Y	715+31.62	716+52.00	N/A	18.85	19.00
84	X	684+00.00	715+31.62	6	14.69	17.00
84a	X	684+00.00	684+00.00	6	14.69	17.00
88	X	653+00.00	684+00.00	6	16.79	17.00
89	X	653+00.00	684+00.00	6	16.96	17.00
89a	X	653+00.00	684+00.00	6	17.15	17.15
107	W	602+86.11	617+53.11	5	14.79	16.50
111	V	580+00.00 591+94.60	591+44.40 602+86.11	N/A	14.85	17.50
111 PS Fronting	V	591+44.00	594+94.60	N/A	14.85	17.50
114	V	569+60.00	580+00.00	2	14.31	16.50

Transects for PA-SNWW1 are along the SNWW, where there is a long southwest-to-northeast fetch. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore-normal) to ensure conservatism of overtopping and floodwall pressures, as described for Contract 3b.

Transects in PA-SNWW1 have unique surrounding topographies and bathymetries. The details for each transect are described in Table 21. Berm effects were not included in the hazard calculations, as described in prior chapters. The combined hydrodynamic and hydrostatic pressure distributions were individually calculated for each transect because the pressures on the floodwall depend on the toe elevations, which varies between transects.

Table 21. Characteristics of CSRM system in PA-SNWW1 area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
74	1592	Levee	N/A	Grass	Grass
75	1592	Levee	N/A	Grass	Grass
77	2528	Levee	N/A	Grass	Grass
78	3976	Levee	N/A	Grass	Asphalt
79	1559	Floodwall	5.14	Metal	Metal
80	3929	Floodwall	9.11	Metal	Metal
81	2532	Floodwall	15.98	Metal	Metal
84	1607	Levee	N/A	Grass	Grass
84a	1607	Levee – Folley PS Fronting Protection	N/A	Grass	Grass
88	1815	Levee	N/A	Grass	Grass
89	1815	Levee	N/A	Grass	Grass
89a	1815	Levee	N/A	Grass	Grass
107	3896	Levee	N/A	Grass	Grass
111	4065	Floodwall	4.91	Metal	Metal
111 PS Fronting	4065	Shreveport Ave PS Fronting Protection	4.91	Metal	Metal
114	1702	Levee	N/A	Grass	Grass

Figure 70. Analysis transects 107–114 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

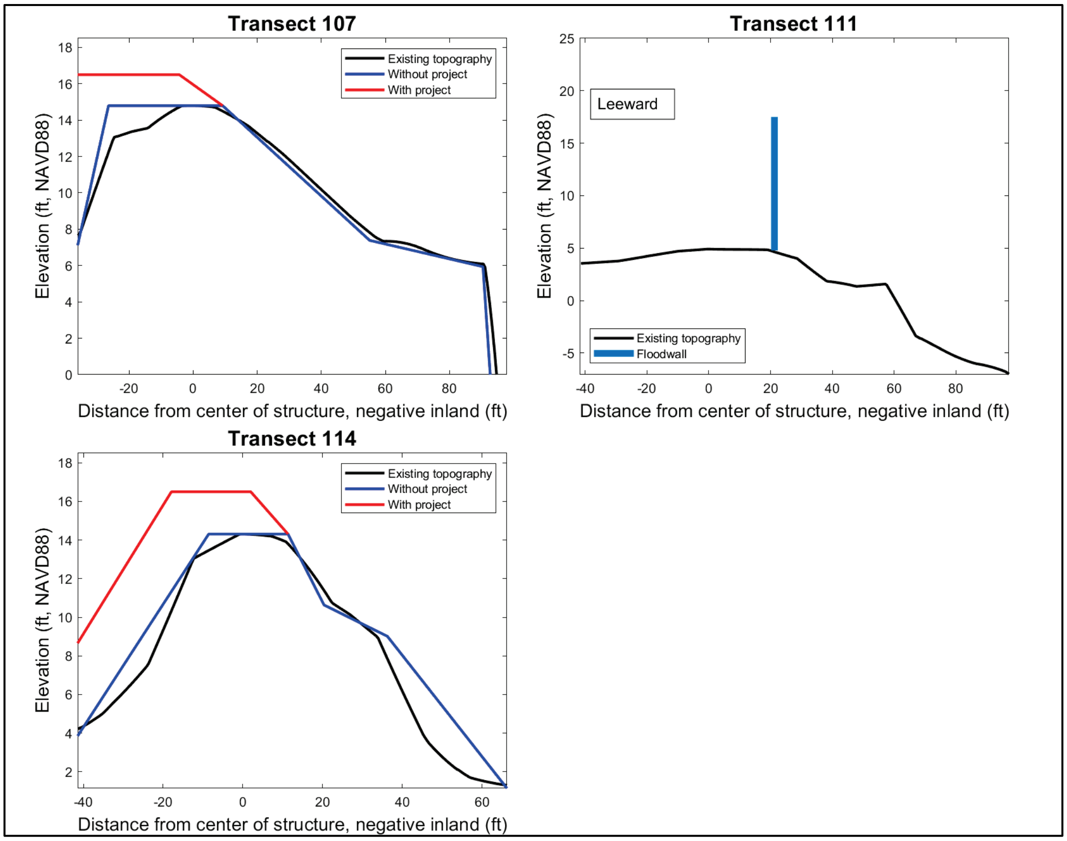


Figure 71. Analysis transects 74–79 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

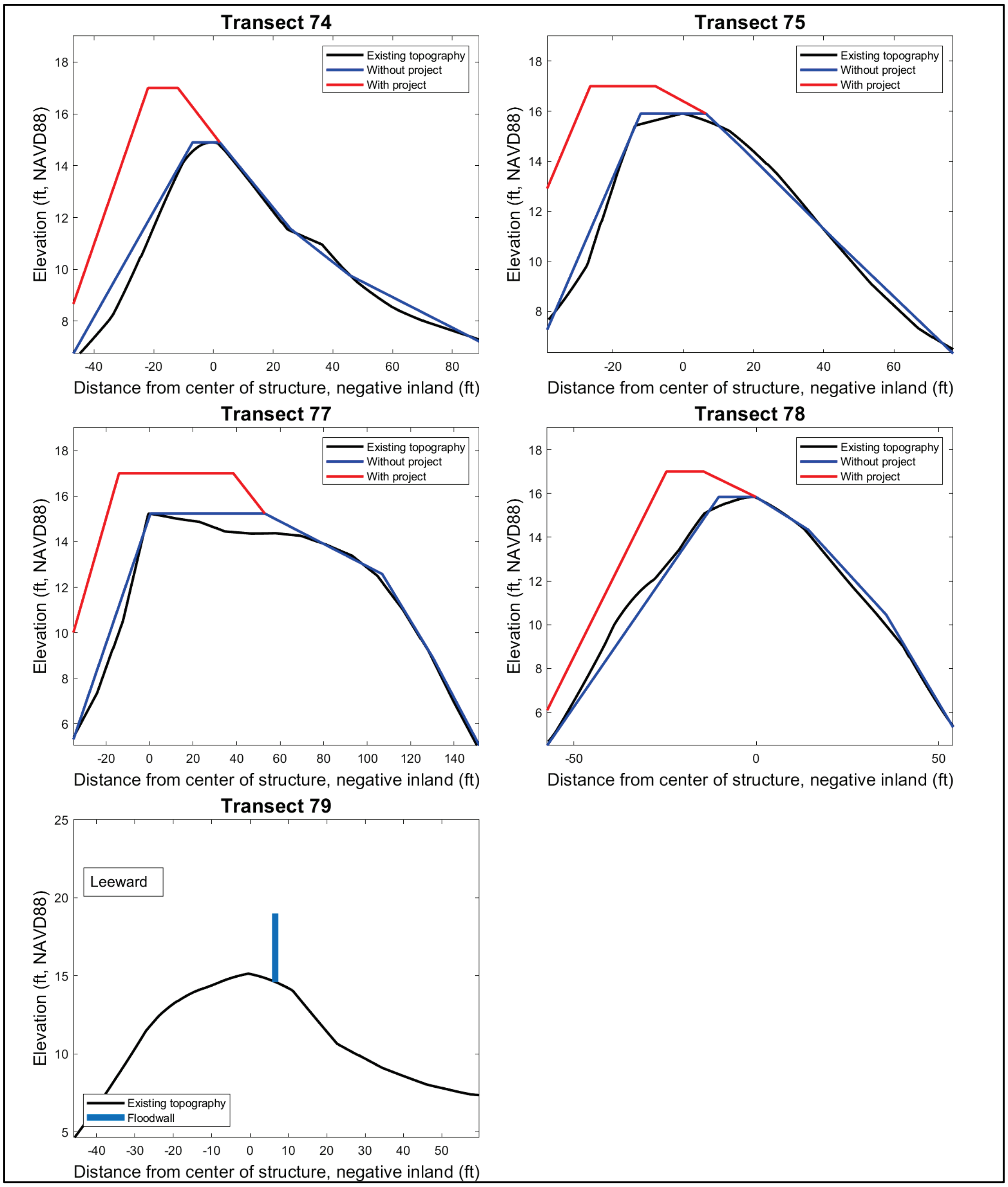
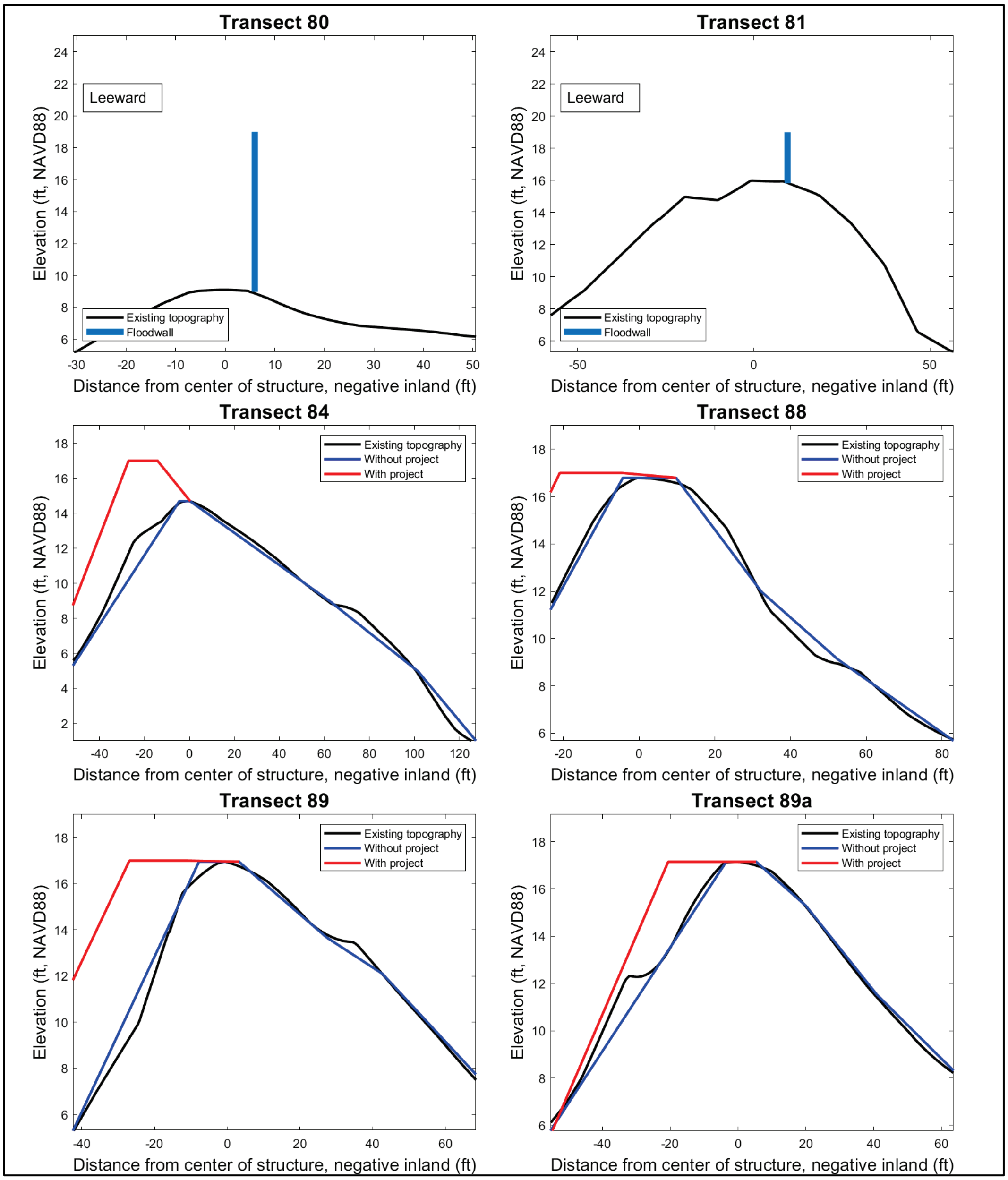


Figure 72. Analysis transects 80–89a with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



8.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-SNWW1 and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall portion of PA-SNWW1. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

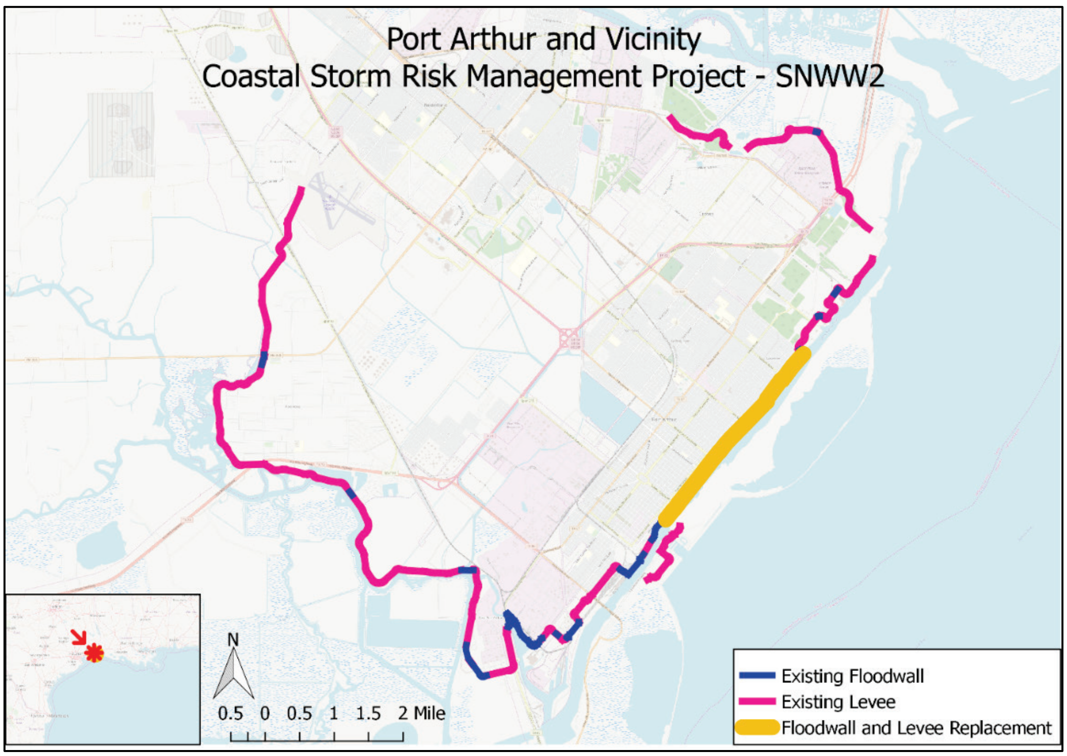
8.4 Summary and conclusions for PA-SNWW1

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the PA-SNWW1 portion of the Port Arthur CSRM. Coastal storm inundation, wave loading, and combined overtopping and overflow are quantified for the PA-SNWW1 CSRM system consisting of floodwalls and levees. Optimized crest elevations were computed to satisfy the no-damage overtopping criteria for floodwalls and levees. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect.

9 Port Arthur – SNWW2 (PA-SNWW2)

PA-SNWW2 designates the middle portion of the Port Arthur CSRM system along the SNWW (PA-SNWW2; Figure 73 and Figure 74). PA-SNWW2 consists of floodwalls, pump station fronting protection, and levees. Coastal SWL, wave loading, and coastal structure responses are quantified.

Figure 73. PA-SNWW2 levee and floodwall location along SNWW (in yellow).



The PA-SNWW2 area for Port Arthur includes a section of the existing CSRM system along the SNWW, shown Figure 74 and Figure 75. The contract begins at STA 385+12.00 and proceeds to STA 561+60.00. Structure modifications include increasing the elevations of both the floodwall and levee.

Figure 74. Details of PA-SNWW2, south end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).

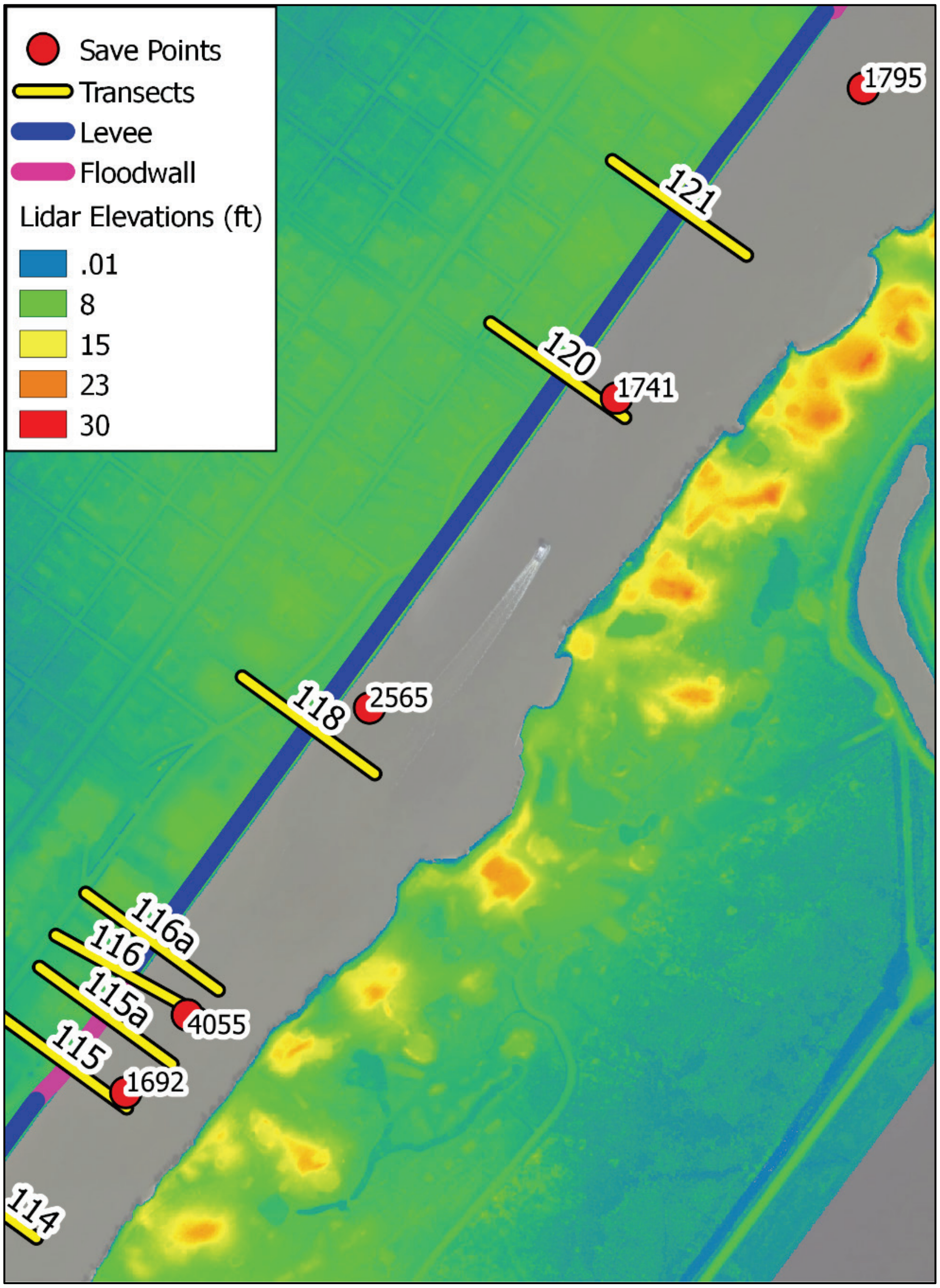
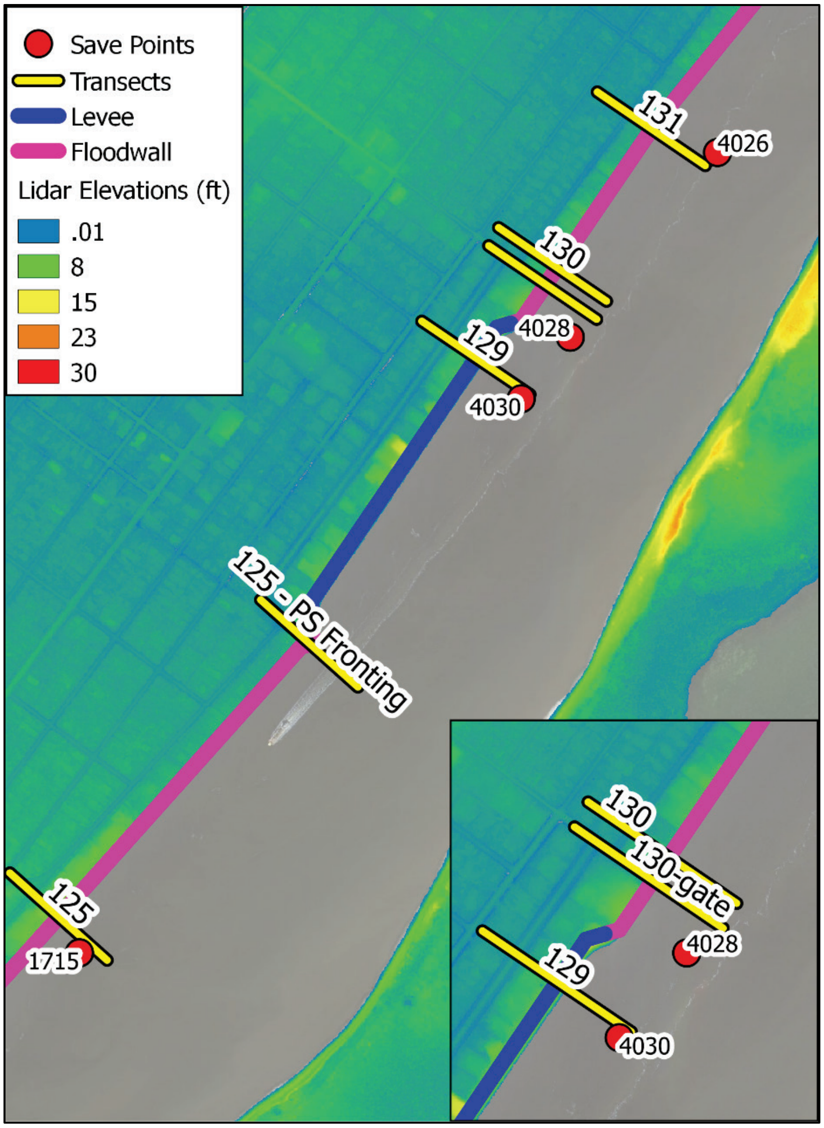


Figure 75. Details of PA-SNWW2, north end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



9.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 4028 in Table 22 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks for SLC0 are approximately 19 ft, NAVD88.

SPs along the edge of the SNWW did not show inundation or wave energy for all storms where the STWAVE cells are partially dry during lower water events because the cells straddle land along the edge of the channel. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{m0} for 189 S2G storms for SLC0 without-project and SLC1 and SLC2 with-project scenarios are shown in Appendix A and B.

Table 22. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 4028.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	19.05	5.5	4.3	163.8	633	18.9	5.5	4.3	163.8
447	18.3	3.68	3.24	140.5	447	18.56	3.67	3.24	140.5
357	18.17	4.16	3.56	143.6	357	18.34	4.15	3.56	143.6
461	17.91	5.86	4.3	101.5	461	17.9	5.67	4.3	101.5
464	17.26	4.45	3.56	142.6	464	17.41	4.44	3.56	142.6
159	16.57	3.95	3.24	127.7	159	16.9	3.97	3.24	127.7
342	16.21	3.06	3.24	144.8	342	16.38	3.06	3.24	144.8
598	15.7	4.55	3.56	144.9	598	16.02	4.58	3.56	144.9
153	15.05	3.04	3.24	151.3	153	15.7	3.06	3.24	151.3
532	14.59	3.27	3.24	136.4	532	14.73	3.28	3.24	136.4
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	21.24	6.08	4.3	163.8	633	21.29	6.34	4.3	163.8
447	20.62	4.14	3.56	143.3	447	20.23	4.11	3.56	143.3
357	20.32	4.73	3.56	143.6	357	19.88	4.73	3.56	143.6
461	19.6	6.33	3.91	125.6	461	19.59	6.45	3.91	125.6
464	19.48	4.66	3.56	118.8	464	19.06	4.66	3.56	118.8
159	18.34	4.21	3.56	137	342	17.98	3.19	3.24	147.4
342	18.17	3.18	3.24	147.4	159	17.96	4.21	3.56	137
598	17.97	4.8	3.56	144.9	598	17.95	4.84	3.56	144.9
153	16.81	3.2	3.24	151.3	532	16.58	3.52	3.24	129.5
532	16.78	3.52	3.24	129.5	153	16.56	3.18	3.24	151.3
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	24.04	7.39	4.3	163.8	633	23.77	7.39	4.74	163.8
357	22.71	5.56	3.56	140.3	357	22.51	5.33	3.56	143.6
447	22.47	4.63	3.56	140.5	447	22.29	4.62	3.56	140.5
461	22.36	7.42	4.3	125.6	461	22.28	7.45	4.3	125.6
464	22.09	5.75	3.91	126.3	464	21.69	5.73	3.91	126.3
598	20.93	5.81	3.91	144.9	598	20.64	5.45	3.56	144.9
342	20.76	3.87	3.24	144.8	342	20.45	4.04	3.24	144.8
159	20.37	4.66	3.56	139.5	159	19.9	4.59	3.56	139.5
532	19.83	4	3.56	129.5	532	19.1	3.9	3.56	129.5
589	19.31	4.61	3.56	99	589	18.8	4.69	3.56	99

With-project SWL peaks at SPs 1692 and 4028 for all storms are plotted against without-project conditions in Figure 76, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 77. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 76. With-project SWL peaks for all storms plotted against without-project conditions for SPs 1692 (left) and 4028 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

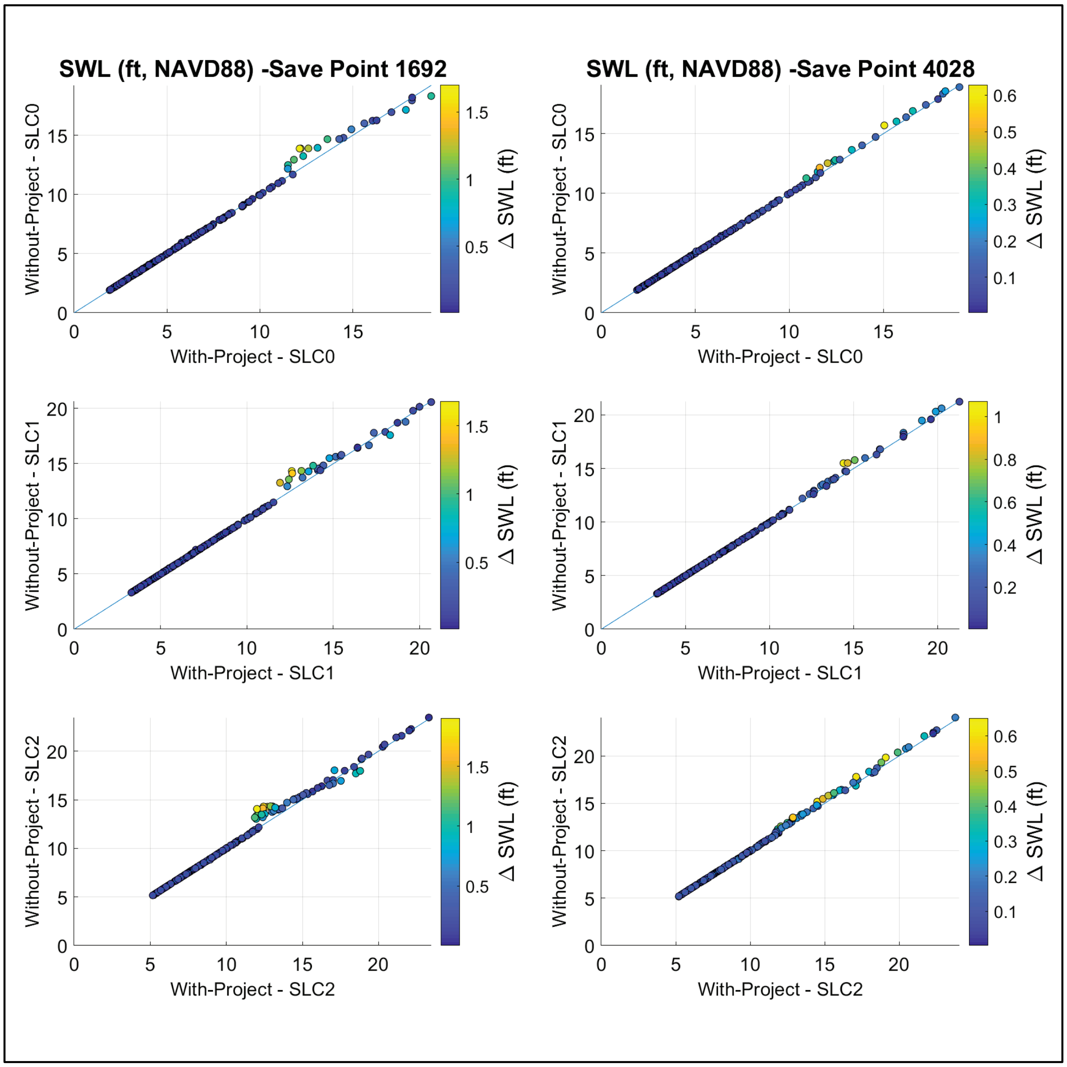


Figure 77. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 1692 (left) and 4028 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

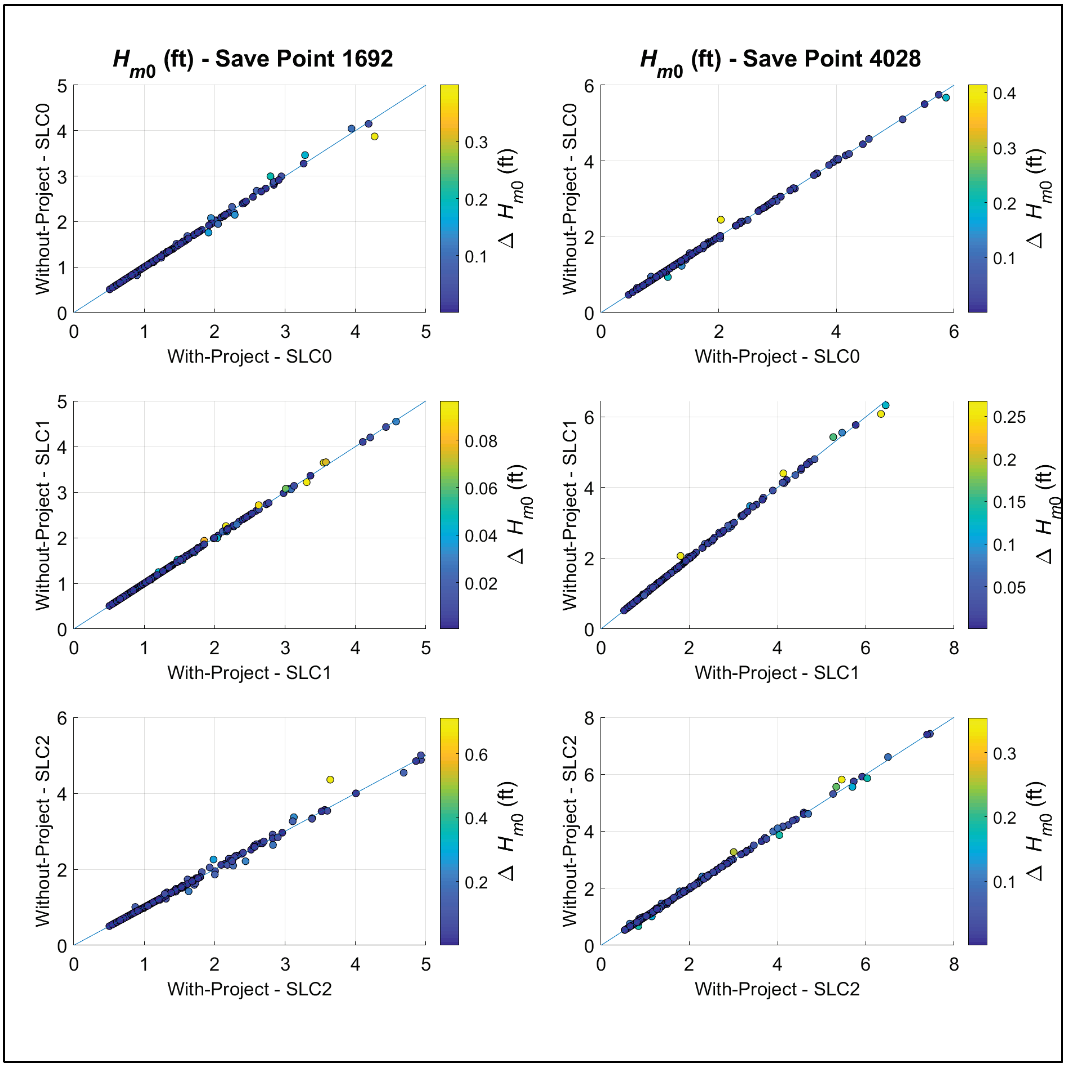


Figure 78 and Figure 79 show SWL and H_{m0} hazard curves, respectively, for SPs 1692 and 4028 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{m0} values for a range of AEPs are listed with their corresponding transects in Appendix D for without-project SLC0 and with-project SLC1 and SLC2.

Figure 78. AEP vs. SWL for SP 1692 (left) and SP 4028 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.

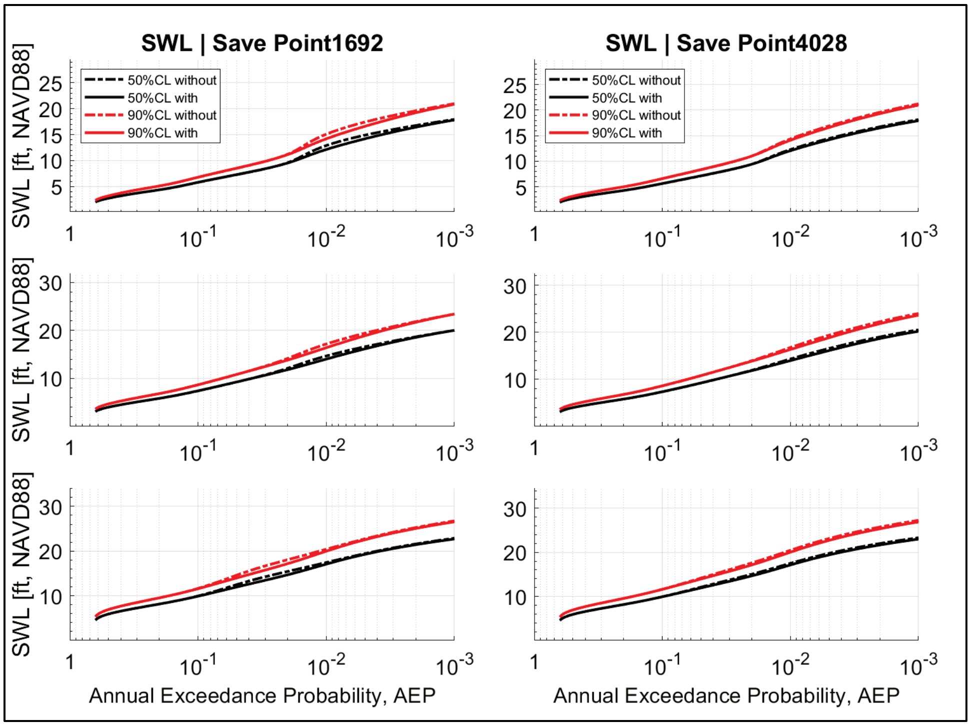
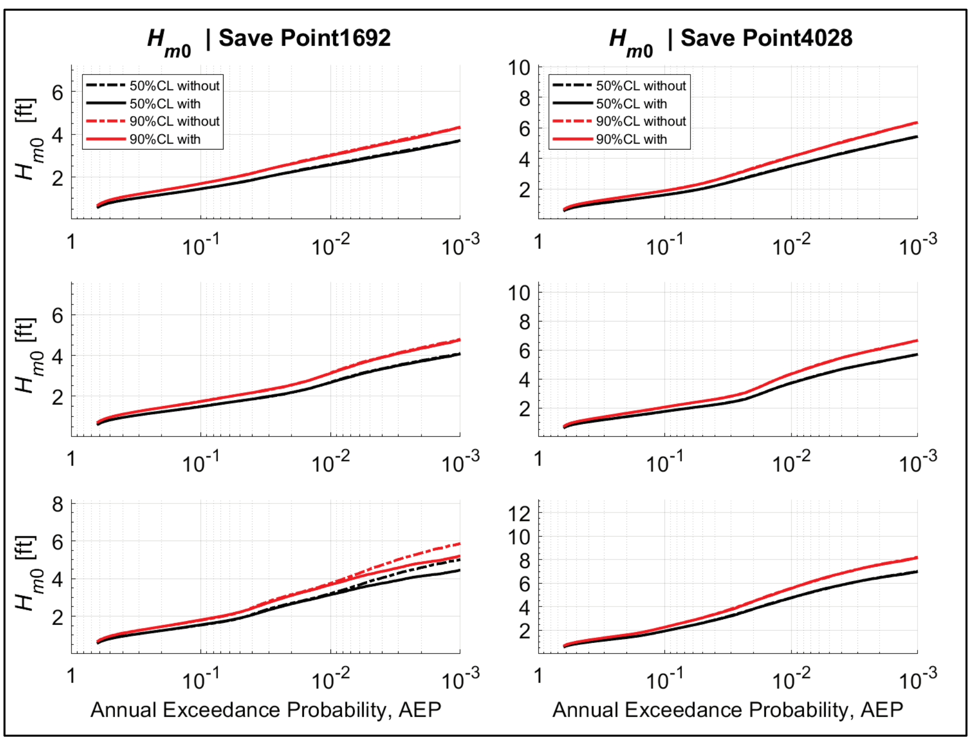


Figure 79. AEP vs. H_{m0} for SP 1692 (left) and SP 4028 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



Comparing the hazard curves for SWL and H_{mo}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards. These differences may be attributed to the change in flood patterns with the modifications of CSRM structures and local navigation channels.

9.2 Local CSRM system response modeling

PA-SNWW2 CSRM system consists of levees and floodwalls. The features of the CSRM system corresponding to transects in PA-SNWW2 are listed in Table 23. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 80 and Figure 81 show schematized analysis transects with without-project and with-project modeled elevations. Transects 125a and 130a will have cross sections similar to transects 125 and 130, respectively.

Table 23. Features of CSRM system in PA-SNWW2 area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
115	V	561+60.00	569+60.00	N/A	14.85	17.50
115a	V	561+60.00	569+60.00	N/A	14.85	17.50
116	V	561+60.00	569+60.00	N/A	14.85	17.50
116a	U	526+34.94	561+60.00	2	14.21	16.00
118	U	526+34.94	561+60.00	2	14.64	16.00
120	U	525+51.94	526+34.94	N/A	15.40	17.00
121	U	503+91.73	525+51.94	2	15.01	16.00
125	T	442+32.00 443+50.00	442+87.41 503+91.73	N/A	14.85	19.50
125 PS	T	0+00.00	0+76.95	N/A	14.85	19.50
129	S	419+85.50	442+32.00	2	14.55	16.50
130	S	390+01.00 416+75.00	416+75.00 419+85.50	N/A	14.85	19.50
130 gate		385+12.00 416+75.00	390+01.00 416+75.00	N/A	14.85	19.50
131	S	390+01.00 416+75.00	416+75.00 419+85.50	N/A	14.85	19.50

As described in prior chapters, Transects for PA-SNWW2 are along the SNWW where there is increased wave height uncertainty. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore-normal) to ensure conservatism of overtopping and pressures. Transects in PA-SNWW2 have unique surrounding topographies and bathymetries, shown in Table 24. Berm effects were not included in the hazard calculations, as described in prior chapters. The pressure distributions were individually calculated for each transect because the pressures on the floodwall depend on the toe elevations, which vary between transects.

Table 24. Characteristics of CSRM system in PA-SNWW2 area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
115	1692	Floodwall	13.91	Concrete	Concrete
115a	1692	Floodwall	6.74	Concrete	Concrete
116	4055	Floodwall	12.55	Concrete	Concrete
116a	4055	Levee	N/A	Grass	Grass
118	2565	Levee	N/A	Grass	Grass
120	1741	DeQueen Pump Station	9.53	Concrete	Concrete
121	1795	Levee	N/A	Grass	Grass
125	1715	Floodwall	4.34	Concrete	Concrete
125 PS Fronting	1715	Del Mar PS Fronting Protection	4.34	Concrete	Concrete
129	4030	Levee	N/A	Grass	Grass
130	4028	Floodwall	14.11	Concrete	Concrete
130 gate	4028	Lakeview and Stadium Rd PS	14.11	Concrete	Concrete
131	4026	Floodwall	5.71	Concrete	Concrete

Figure 80. Analysis transects 115–120 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

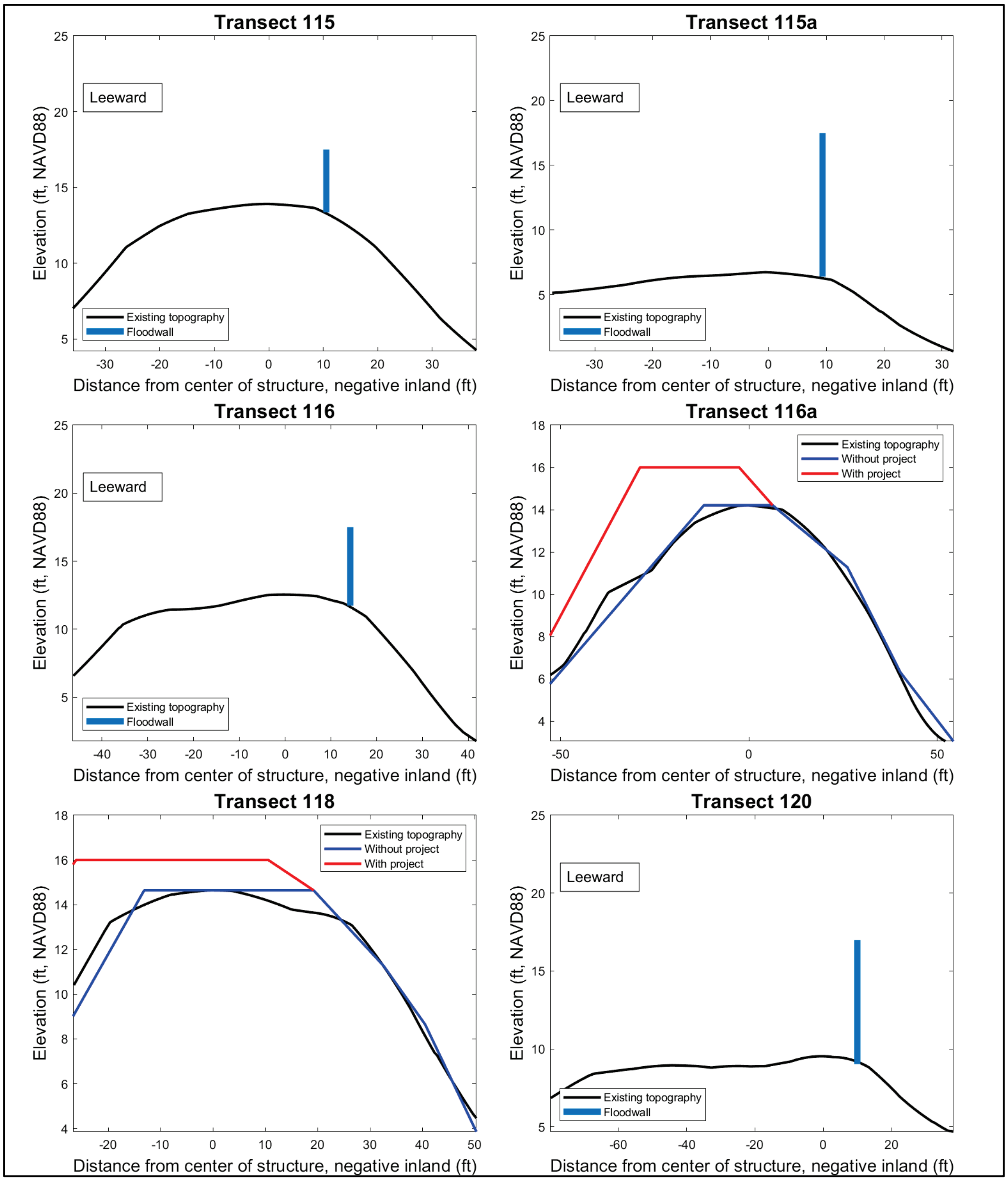
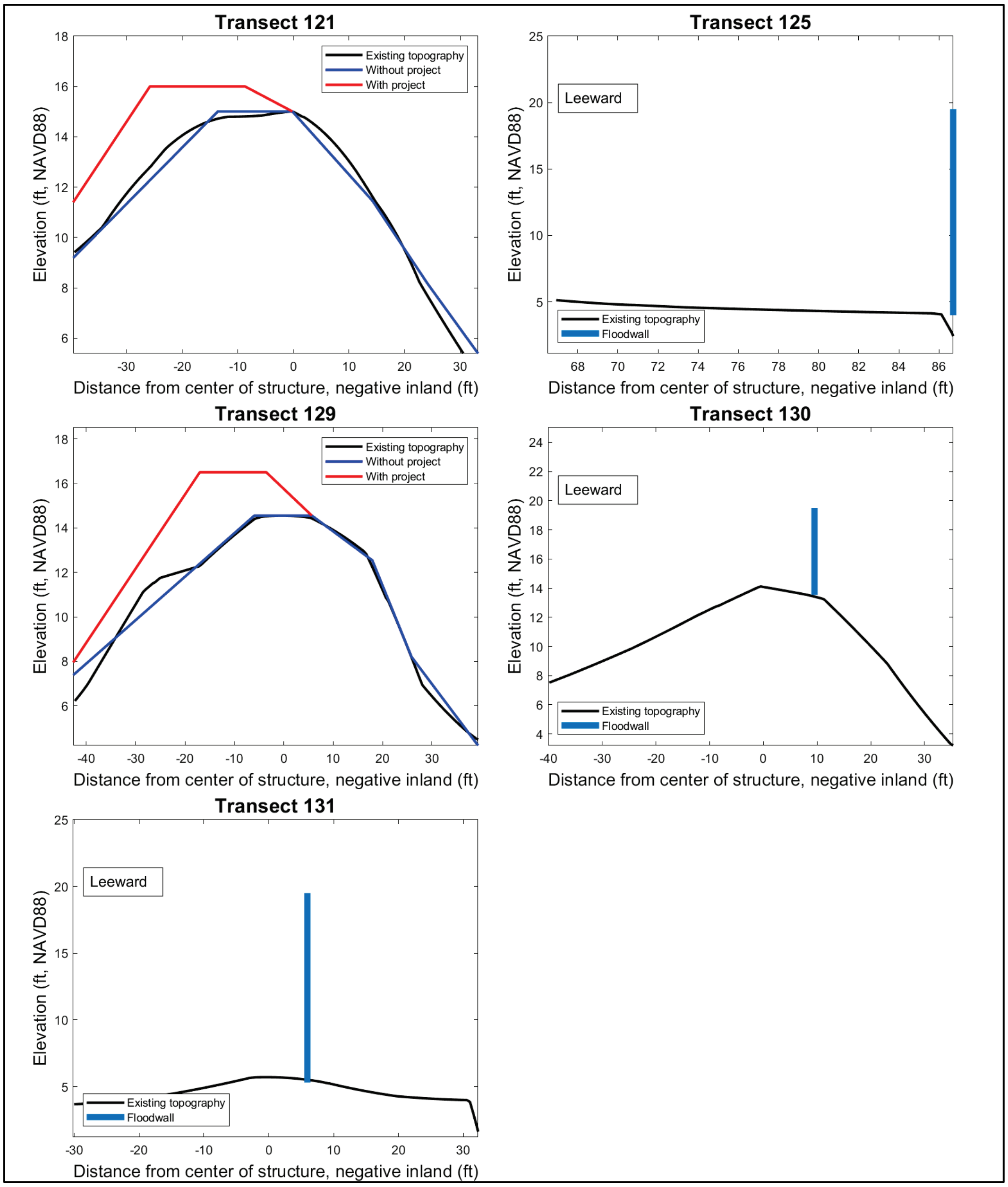


Figure 81. Analysis transects 121–131 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



9.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-SNWW2, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall portion of PA-SNWW2. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

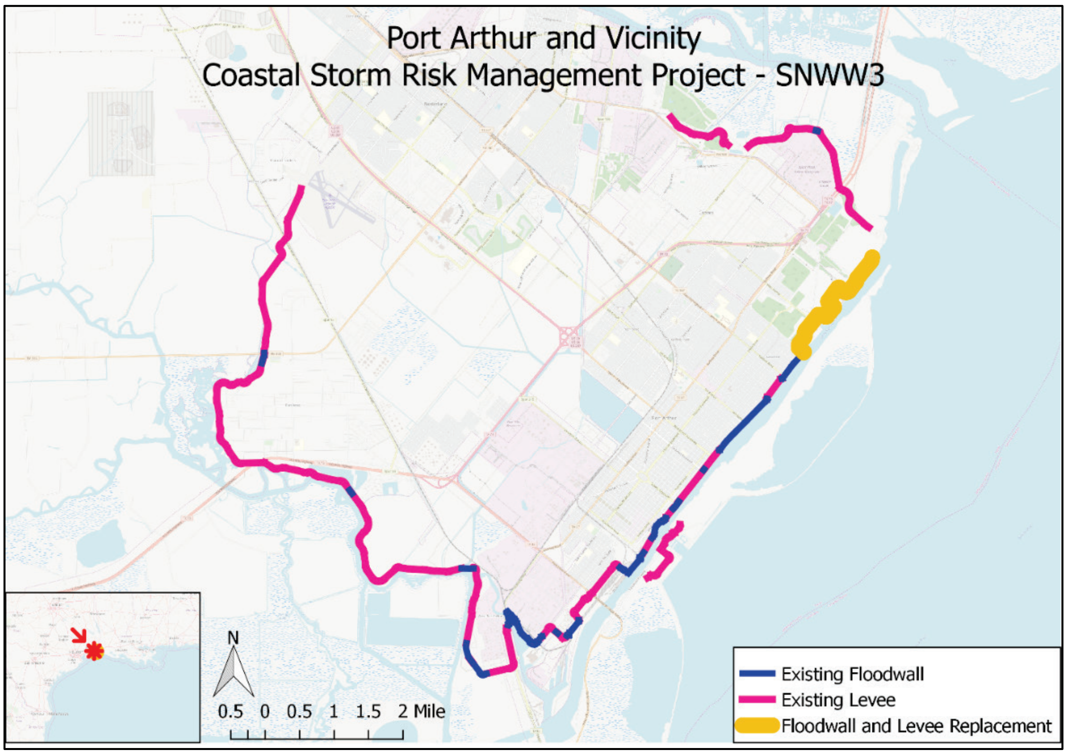
9.4 Summary and conclusions for PA-SNWW2

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the PA-SNWW2 portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and overtopping and overflow are quantified for the PA-SNWW2 CSRM system consisting of floodwalls and levees. Optimized crest elevations were computed that just satisfy the no-damage overtopping criteria. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall transect.

10 Port Arthur – SNWW3 (PA-SNWW3)

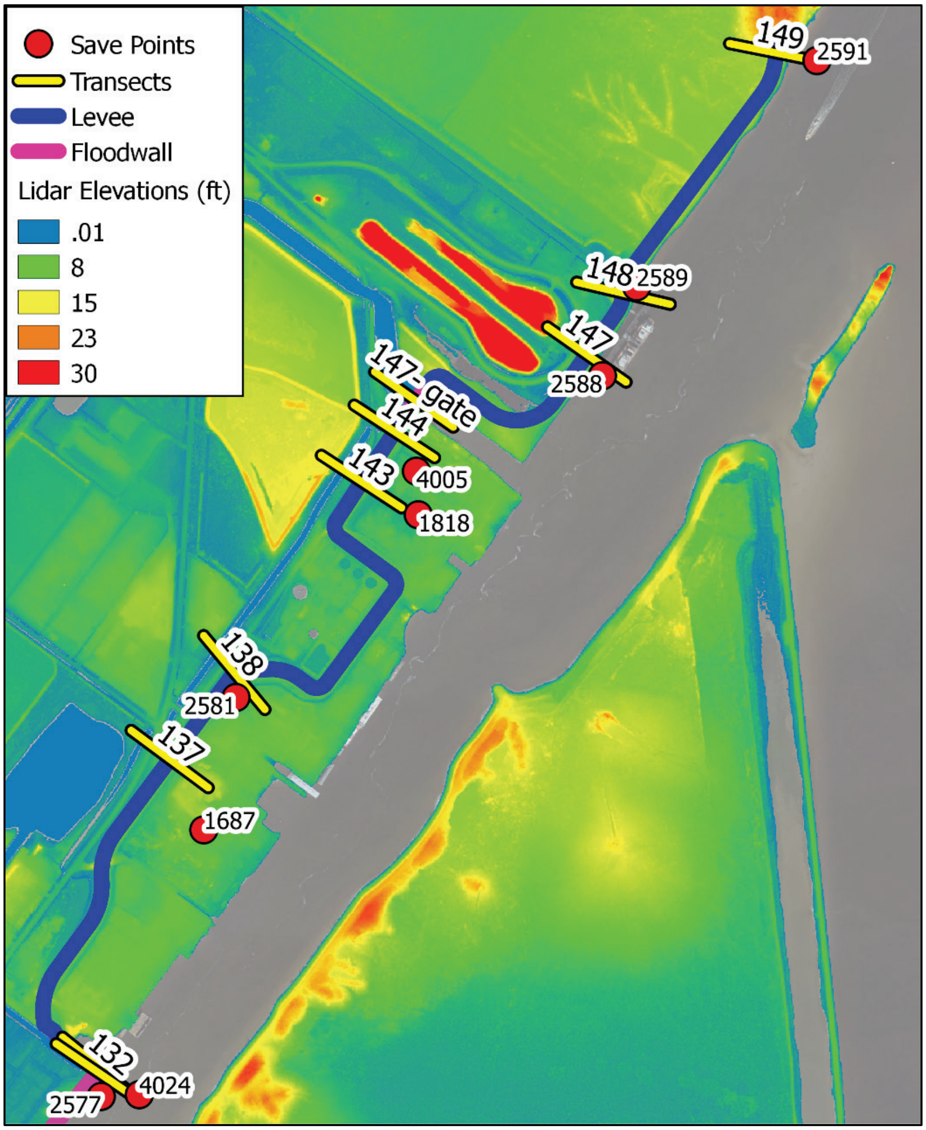
PA-SNWW3 designates the northern portion of the Port Arthur CSRM system along the SNWW (PA-SNWW3; Figure 82 and Figure 83). PA-SNWW3 consists of levee, pump station fronting protection, and closure gates. Coastal SWL, wave loading, and coastal structure responses are quantified.

Figure 82. PA-SNWW3 levee and floodwall location along SNWW (in yellow).



The PA-SNWW3 area for Port Arthur includes a section of the existing CSRM system along the SNWW, shown in Figure 83. The contract begins at STA 258+15.00+00 and proceeds to STA 381+30.00. Structure modifications include increasing the elevations of both the floodwall and levee.

Figure 83. Details of PA-SNWW3 for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



10.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 2589 in Table 25 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks for SLC0 are approximately 18 ft, NAVD88.

SPs along the edge of the SNWW did not show inundation or wave energy for storms where the STWAVE cells are partially dry during lower water events. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{mo} for

189 S2G storms for without-project SLC0 and with-project SLC1 and SLC2 scenarios are shown in Appendix A and B.

Table 25. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 2589.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	18.13	4.56	4.74	154.1	447	18.15	4.6	4.74	154.1
633	18.05	5.81	6.31	165.3	633	18.13	5.81	6.31	165.3
357	17.87	4.91	5.73	155.2	357	17.93	4.94	5.73	155.2
464	17.24	4.77	5.21	128.3	464	17.23	4.79	5.21	128.3
461	17.02	4.43	3.24	105.4	461	17.17	4.5	5.21	142.8
159	16.73	4.06	6.31	127.1	159	16.68	3.97	6.31	128.5
598	15.9	4.02	2.94	124.9	342	15.98	3.92	4.74	147.8
342	15.89	3.91	4.74	147.8	598	15.89	4.08	2.94	124.9
153	15.21	2.97	3.91	156.1	153	14.92	2.98	3.91	156.1
532	14.53	2.92	4.3	142.9	532	14.64	2.9	4.3	142.9
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	20.19	6.58	6.93	165.3	633	20.46	6.73	6.93	165.3
447	20.1	5.06	4.74	154.1	447	19.99	5.05	4.74	154.1
357	19.76	5.4	5.21	155.2	357	19.76	5.42	5.21	155.2
464	19.07	5.41	6.31	165	461	19.22	4.93	3.24	115.7
461	18.99	4.91	3.24	115.7	464	19	5.48	6.31	165
159	18.09	4.43	6.31	128.5	159	18	4.31	6.31	128.5
598	17.73	5.06	5.73	147.2	598	17.92	5.11	5.73	147.2
342	17.57	4.48	4.74	161.4	342	17.67	4.49	4.74	161.4
532	16.6	3.99	4.74	130.9	532	16.62	4.01	4.74	130.9
153	16.31	4.33	5.21	156.1	153	16.36	4.36	5.21	156.1
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
633	23.04	7.51	6.93	165.3	633	22.96	7.54	6.93	165.3
357	22.23	6.46	4.74	179.2	357	22.2	6.21	5.73	161.8
447	21.93	5.5	5.21	154.1	447	21.99	5.49	5.21	154.1
461	21.78	5.78	6.93	129.7	461	21.94	5.9	6.93	129.7
464	21.71	6.3	6.93	165	464	21.65	6.29	6.93	165
598	20.66	6.17	5.73	155	598	20.55	5.9	5.73	147.2
159	20.12	4.77	6.31	128.5	342	20.04	5.03	4.74	161.4
342	20.1	4.9	4.74	156	159	19.88	4.79	6.31	128.5
532	19.29	4.66	4.74	153.3	532	19.3	4.61	5.21	153.3
589	18.8	4.64	5.21	127.5	589	18.75	4.67	4.74	127.5

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 84, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 85. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 84. With-project SWL peaks for all storms plotted against without-project conditions for SPs 4026 (left) and 2589 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

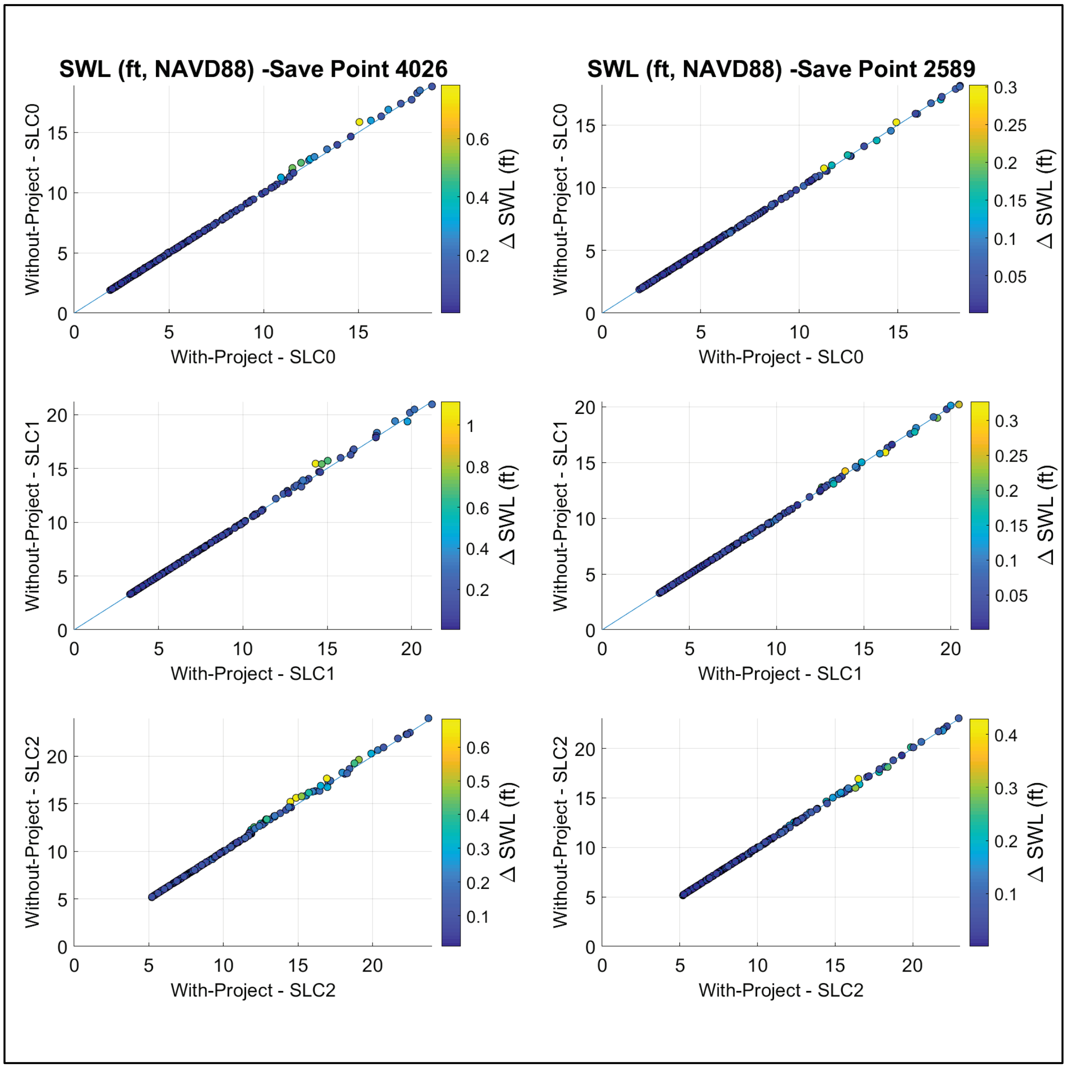


Figure 85. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 4026 (left) and 2589 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

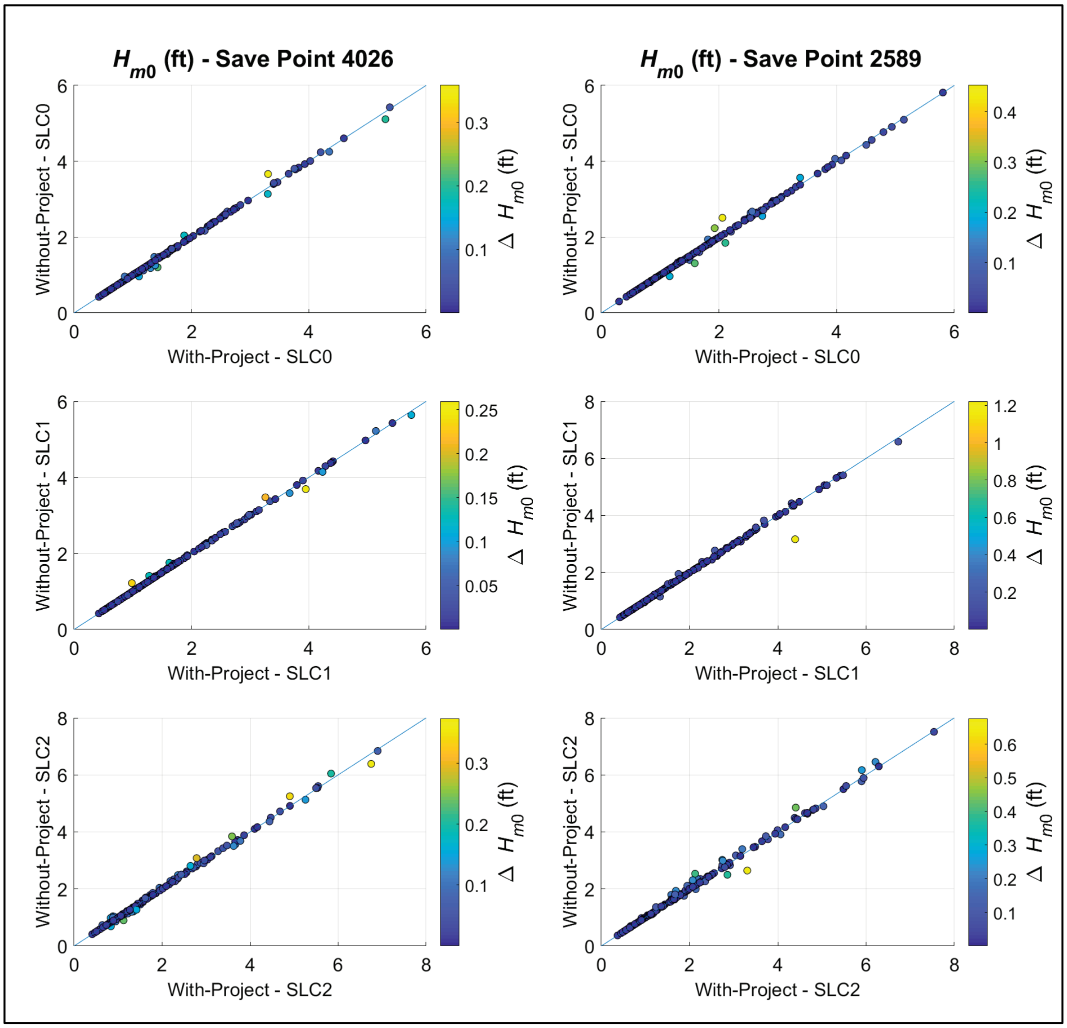
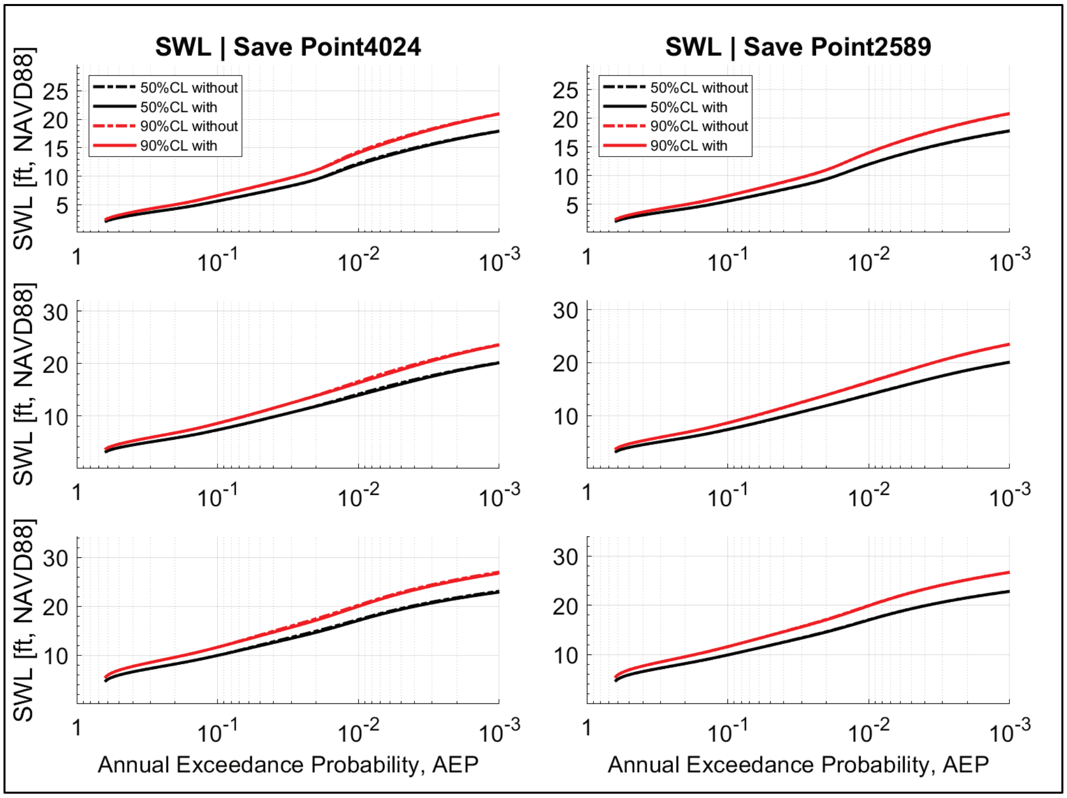


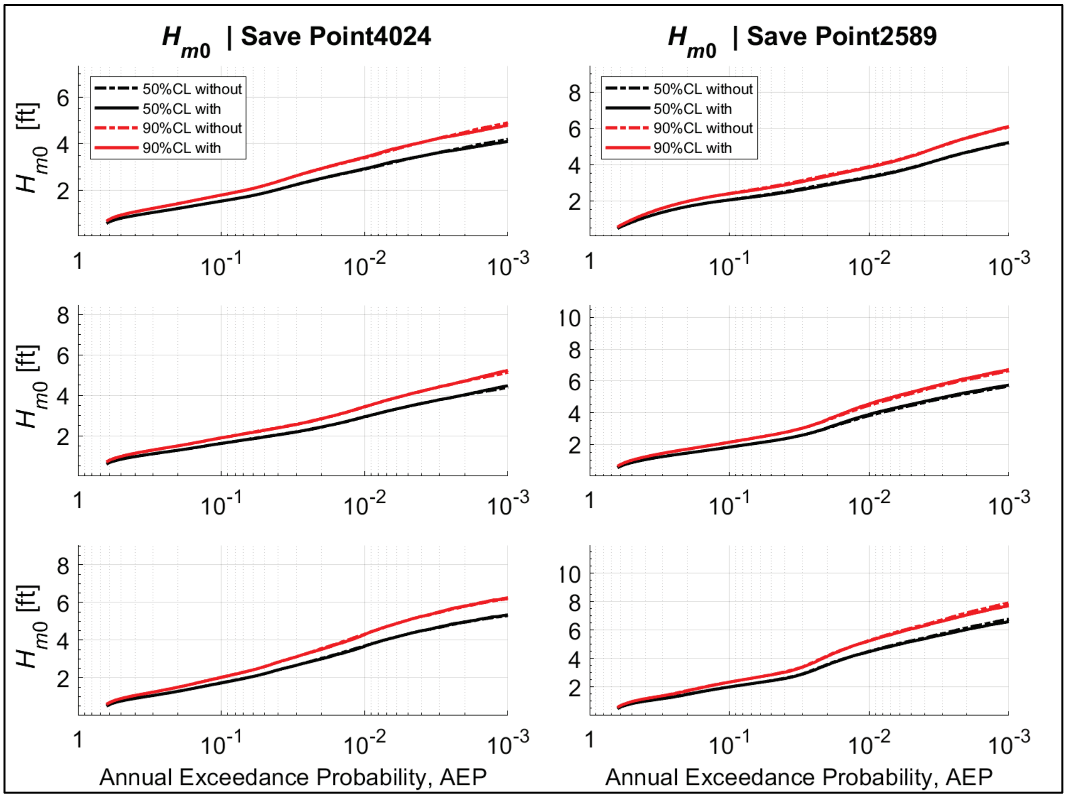
Figure 86 and Figure 87 show SWL and H_{mo} hazard curves, respectively, for SPs 4024 and 2589 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{mo} values for a range of AEPs are listed with their corresponding transects in Appendix D for without-project SLC0 and with-project for SLC1 and SLC2.

Figure 86. AEP vs. SWL for SP 4024 (left) and SP 2589 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.



Comparing the hazard curves for SWL and H_{mo}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards.

Figure 87. AEP vs. H_{m0} for SP 4024 (left) and SP 2589 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



10.2 Local CSRM system response modeling

PA-SNWW3 CSRM system consists of levees, closure gates, and pump station fronting protection. The features of the CSRM system corresponding to transects in PA-SNWW3 are listed in Table 26. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 88 and Figure 89 show schematized analysis transects with without-project and with-project modeled elevations. Transect 138 is currently a levee but will be replaced with a closure gate and floodwall tie-in. Transect 147a has a cross section similar to transect 147, but the with-project design will include a floodwall.

As described in the prior chapters, transects for PA-SNWW3 are along the SNWW where there is a potential that the estimated wave heights are uncertain. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore-normal) to ensure conservatism of overtopping and pressures. Transects in PA-SNWW3 have unique surrounding topographies and bathymetries. The details for each transect are described in Table 27. Berm effects were not included in the hazard calculations, as described in prior chapters.

Table 26. Features of CSRM system in PA-SNWW3 area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
132	R	381+30.00	385+12.00	N/A	14.85	19.50
137	R	345+83.00	381+30.00	6	15.51	15.51
138	R	344+61.00	345+83.00	N/A	15.97	15.97
143	R	316+00.00	344+61.00	6	15.71	15.75
144	R	310+93.10	316+00.00	6	15.25	15.75
147	Q	284+00.00 309+43.20	306+00.00 309+98.10	6	14.54	15.00
147 gate	Q	306+00.00 309+98.10	309+43.20 310+93.10	N/A	14.54	15.00
148	Q	280+00.00	284+00.00	6	15.59	15.59
149	Q	258+15.00	280+00.00	6	15.59	15.59

Table 27. Characteristics of CSRM system in PA-SNWW3 area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
132	4024	Floodwall	1.74	Concrete	Concrete
137	1687	Levee	N/A	Grass	Gravel
138	2581	Closure Gate / Floodwall	15.9	Grass	Gravel
143	1818	Levee	N/A	Grass	Gravel
144	4005	Levee	N/A	Grass	Gravel
147	2588	Levee	N/A	Grass	Asphalt
147 gate	2588	Crane Bayou PS Fronting Protection / Closure Gate/ Floodwall	14.5	Grass	Asphalt
148	2589	Levee	N/A	Grass	Asphalt
149	2589	Levee	N/A	Grass	Asphalt

Figure 88. Analysis transect 148 with measured topography (black). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

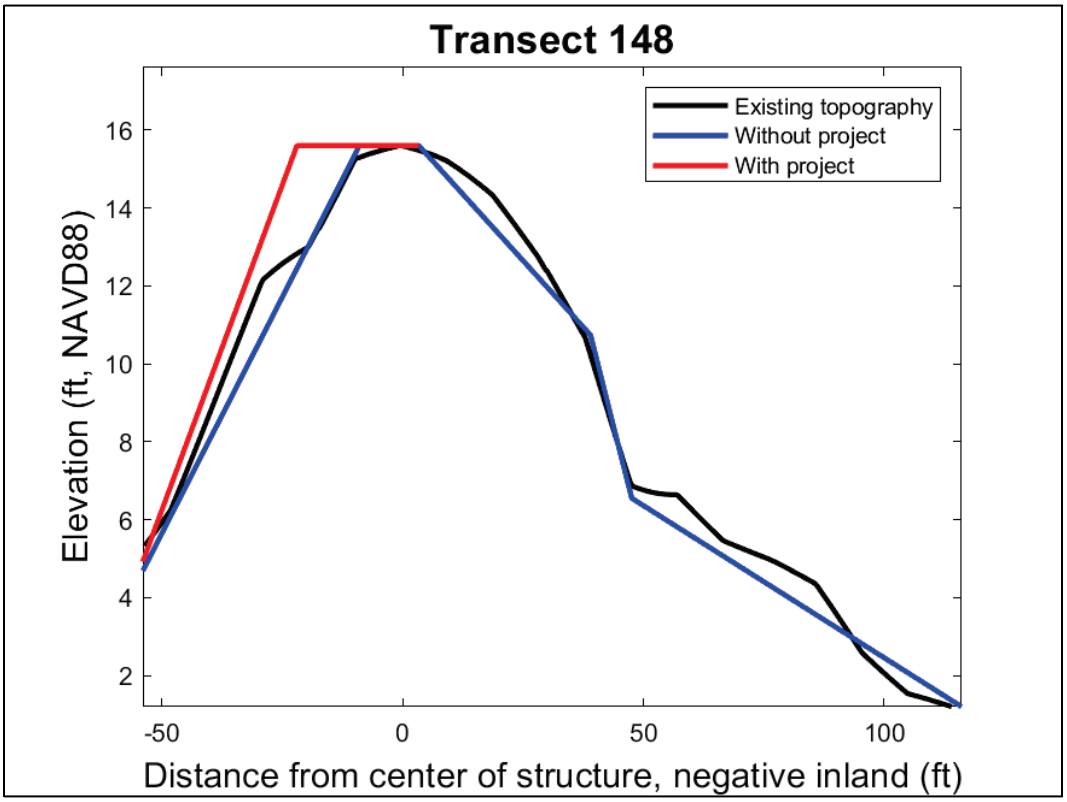
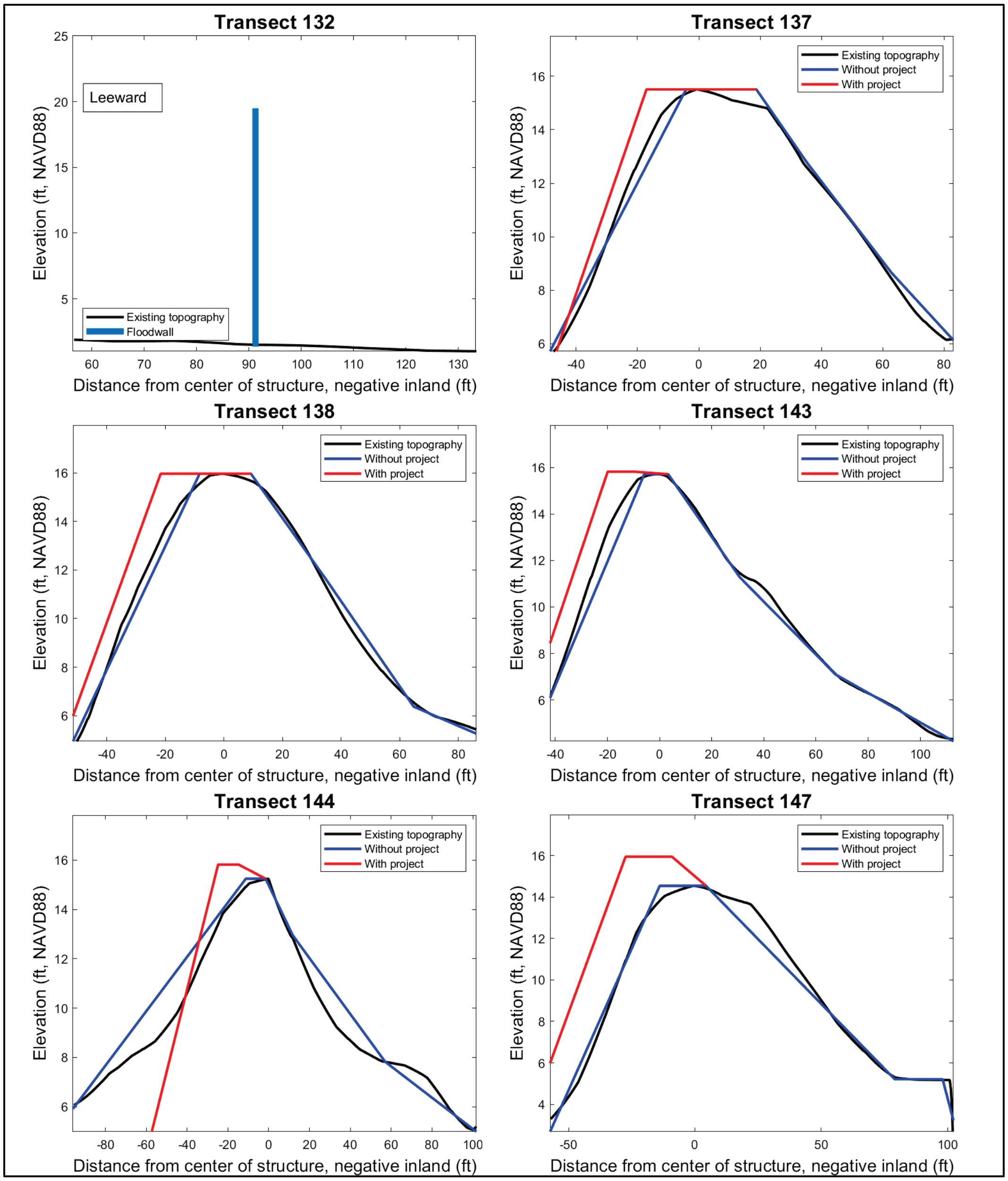


Figure 89. Analysis transects 132–147 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



10.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-SNWW3, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall and gate portions of PA-SNWW3. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

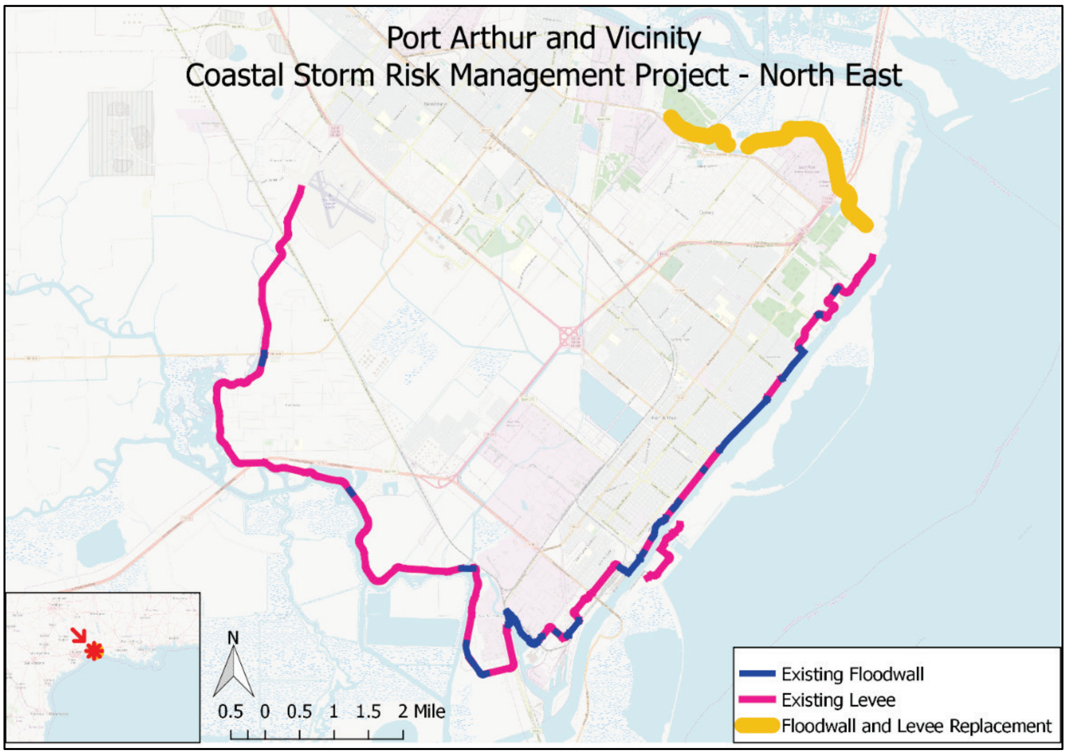
10.4 Summary and conclusions for PA-SNWW3

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the PA-SNWW3 portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and combined overtopping and overflow are quantified for the PA-SNWW3 CSRM system consisting of floodwalls and levees. Optimized crest elevations were computed at each transect location that just exceeded the no-damage overtopping criteria. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall and gate transect.

11 Port Arthur – North East (PA-NE)

PA-NE designates the northeast end of the Port Arthur CSRM system (PA-NE; Figure 90 through Figure 92). The PA-NE portion of the Port Arthur CSRM system consists mainly of levees, with one gate, levee pump station fronting protection, and high ground areas. Coastal SWL, wave loading, and coastal structure responses are quantified.

Figure 90. PA-NE levee and floodwall location near the Neches River (in orange).



The PA-NE area for Port Arthur includes a section of the existing CSRM system along the northeast edge of Port Arthur, shown Figure 91 and Figure 92. The contract begins at STA 00+00 and proceeds southeast to STA 230+55. The contract includes increasing structure crest elevations.

Figure 91. Details of PA-NE, east end, for Port Arthur floodwall (pink), levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).

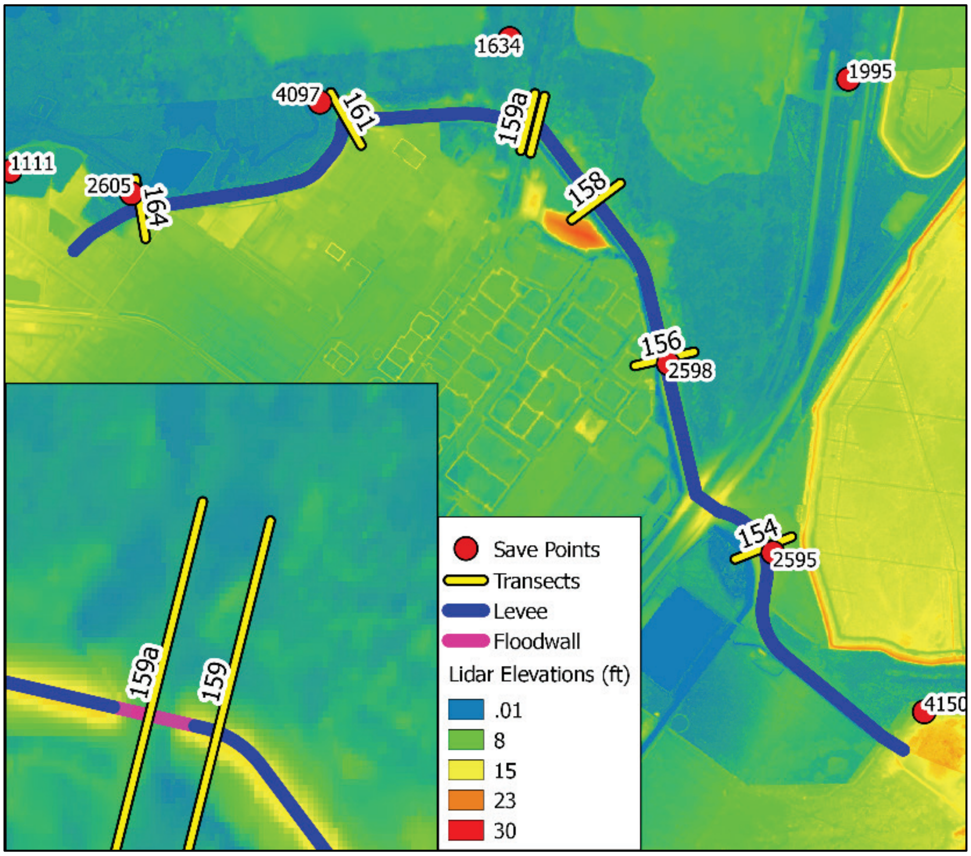
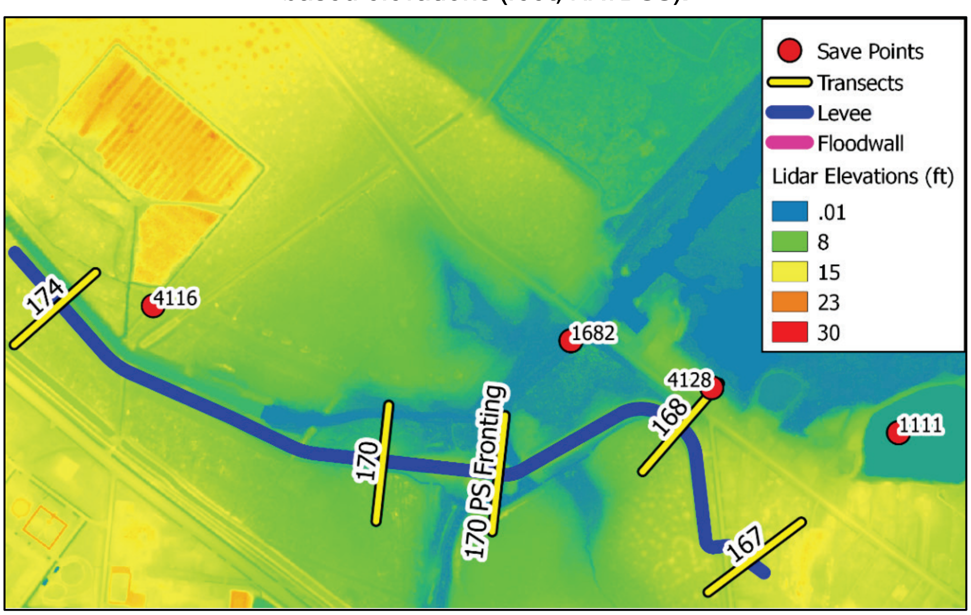


Figure 92. Details of PA-NE, west end, for Port Arthur levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color-shaded LiDAR-based elevations (feet, NAVD88).



11.1 Local wave and water level response

The peaks of the top-10 synthetic storms ranked by SWL are listed for SP 4128 in Table 28 for without-project conditions and with-project conditions. As can be seen, the highest SWL peaks for SLC0 are approximately 20 ft, NAVD88.

Table 28. CSTORM output peaks for top-10 synthetic storms ranked by SWL for without-project scenario (left side) and for with-project scenario (right side) at SP 4128.

SLC 0 - Without Project					SLC 0 – With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
357	19.84	1.89	3.24	186.7	357	19.83	2.02	3.56	177.9
447	19.51	1.6	2.43	115.5	447	19.46	1.6	2.43	115.5
464	19.18	2.05	3.56	178.9	464	18.93	2.18	3.56	178.9
159	18.23	1.5	2.67	129.3	633	18.02	2.95	2.94	292.1
633	18.1	2.84	3.56	184.7	159	17.93	1.48	2.67	129.3
342	16.22	1.25	2.94	174.8	461	15.83	1.78	2.43	108.4
153	16.04	1.39	2.94	171	342	14.26	1.29	2.94	174.8
532	15.75	1.4	2.43	103.2	532	13.92	1.23	2.67	126
598	15.65	1.52	2.94	173.2	153	13.91	1.46	2.94	171
461	15.54	1.87	2.43	97.5	598	13.85	1.42	2.67	129.7
SLC 1 - Without Project					SLC 1- With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	21.45	1.73	3.24	177.3	357	21.57	2.84	3.56	177.9
357	21.44	2.73	3.56	177.9	447	21.49	1.8	3.24	177.3
464	21.07	2.88	3.56	178.9	464	21.16	2.94	3.56	178.9
366	20.19	3.47	2.94	296.6	633	20.05	3.54	3.24	292.1
159	19.69	1.55	2.67	129.3	159	19.49	1.54	2.67	129.3
342	18.66	1.18	2.67	129.6	342	18.5	1.18	2.67	129.6
532	18.41	1.44	2.43	103.2	598	18.4	1.65	2.67	129.7
598	18.4	1.63	2.67	129.7	532	18.22	1.45	2.43	103.2
461	18.01	1.95	3.24	186.7	461	17.93	2.05	3.24	186.7
153	17.59	1.08	3.24	174.3	153	17.89	1.08	3.24	177.1
SLC 2 - Without Project					SLC 2 - With Project				
Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)	Storm ID	SWL (ft, NAVD88)	H_{m0} (ft)	T_p (s)	MWD (deg, Eucl)
447	23.54	2.33	3.24	177.3	447	23.77	2.33	3.24	177.3
357	23.53	3.33	3.56	181.4	357	23.72	3.4	3.56	184.1
366	23.31	4.03	4.3	292.1	464	23.49	3.56	3.91	182
464	23.3	3.59	3.91	185.9	366	23.21	3.93	3.91	176.8
159	21.53	1.59	2.67	129.3	159	21.59	1.58	2.67	129.3
598	21.4	1.78	2.67	129.7	598	21.35	1.77	2.67	129.7
342	21.15	1.94	3.24	177.1	342	21.27	2.07	3.24	179.1
532	21	1.61	2.67	118.5	532	21.05	1.63	2.43	118.5
461	20.4	2.83	3.56	186.7	461	20.44	2.94	3.56	181
589	20.06	1.78	2.43	95.9	589	19.94	1.81	2.43	102.4

SPs directly adjacent to along the edge of the CSRM system (rather than in the Neches river on the seaward side) did not show inundation or wave energy for all storms where the STWAVE cells are partially dry during lower water events because the cells straddle land along the edge of the channel. SPs were selected in the channel where there is always water, so the SPs included results for the full suite of storms. Peak SWL and H_{mo} for 189 S2G storms for SLC0 without-project and SLC1 and SLC2 with-project scenarios are shown in Appendix A and B.

With-project SWL peaks for all storms are plotted against without-project conditions in Figure 93, and similarly, H_{mo} peaks for with-project and without-project conditions are plotted in Figure 94. It can be seen that the SWL and H_{mo} differences between the two alternatives are small.

Figure 93. With-project SWL peaks for all storms plotted against without-project conditions for SPs 2598 (left) and 4128 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

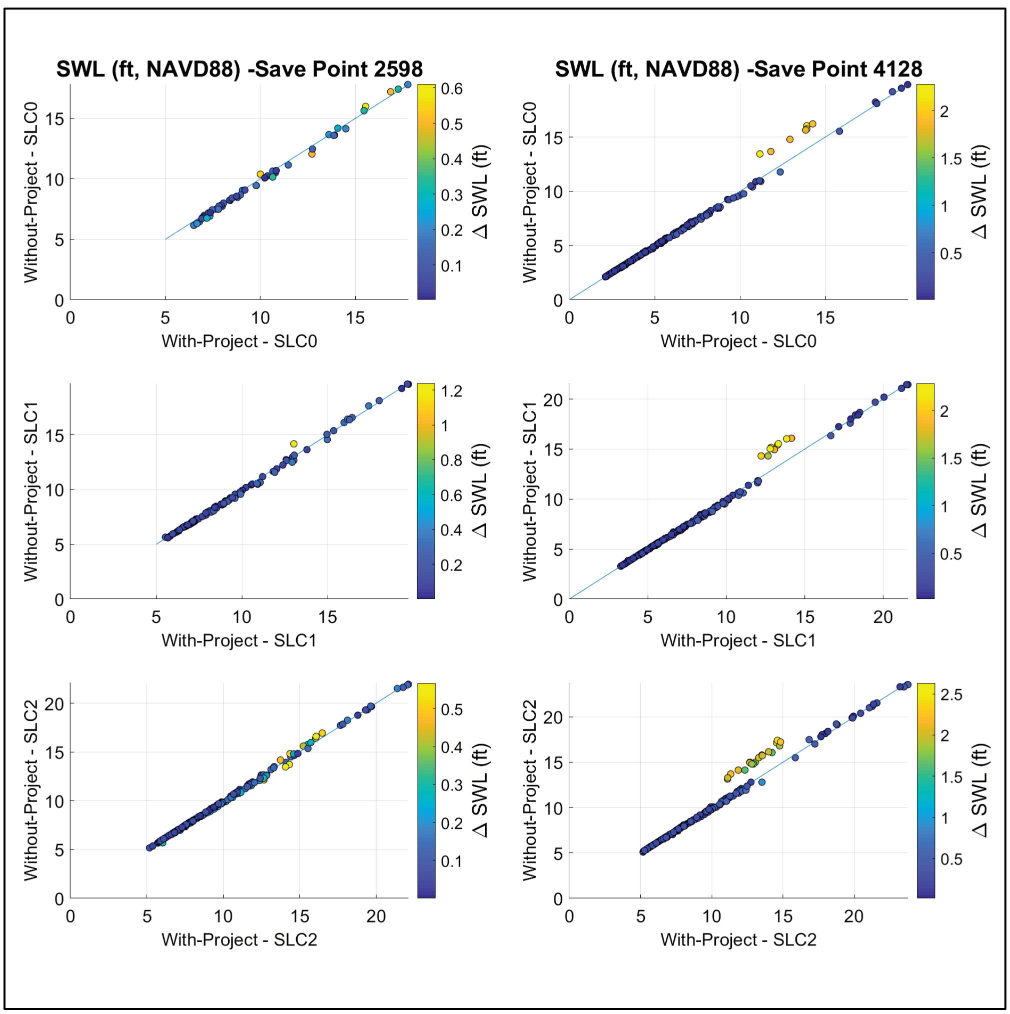


Figure 94. With-project H_{m0} peaks for all storms plotted against without-project conditions for SPs 2598 (left) and 4128 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.

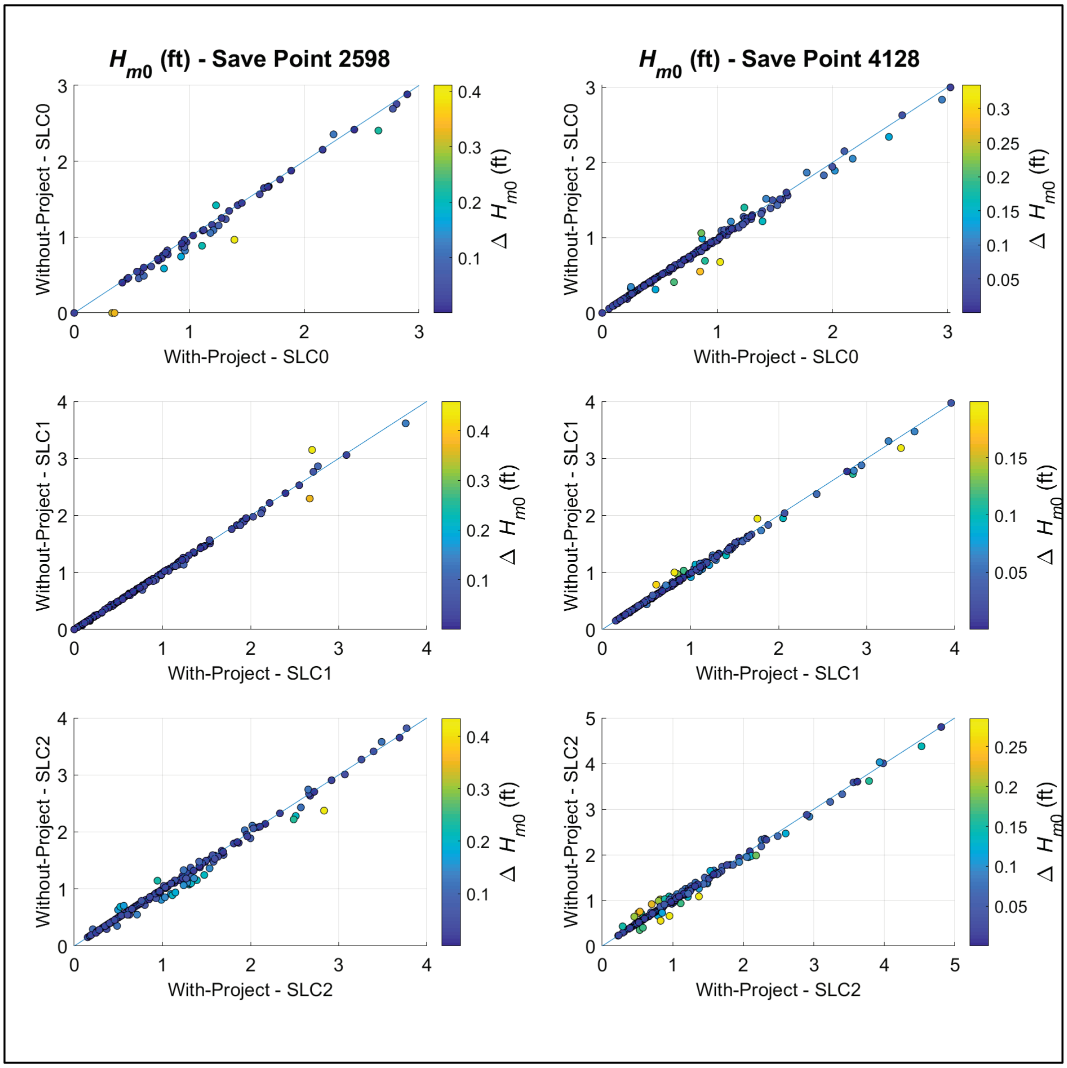
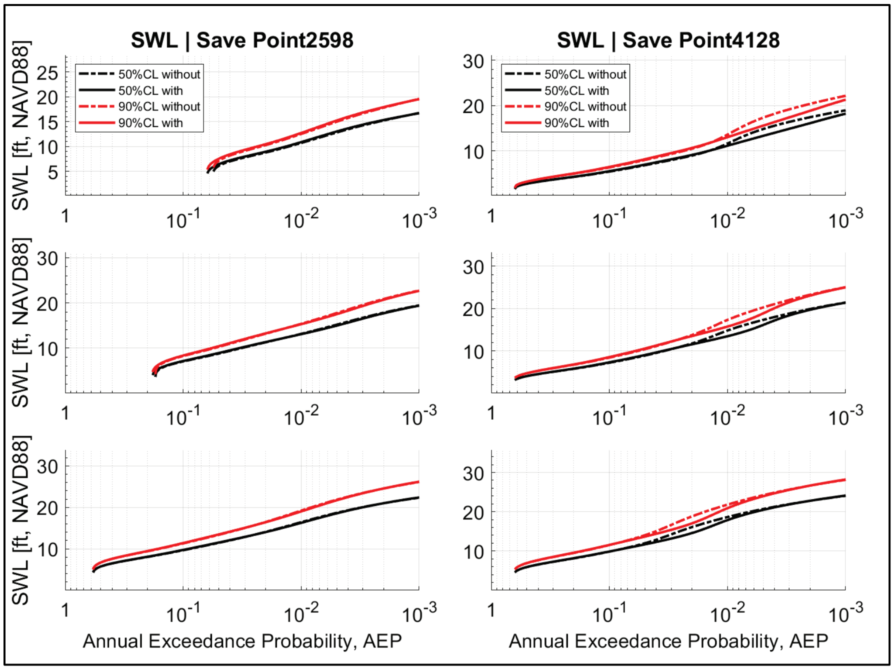


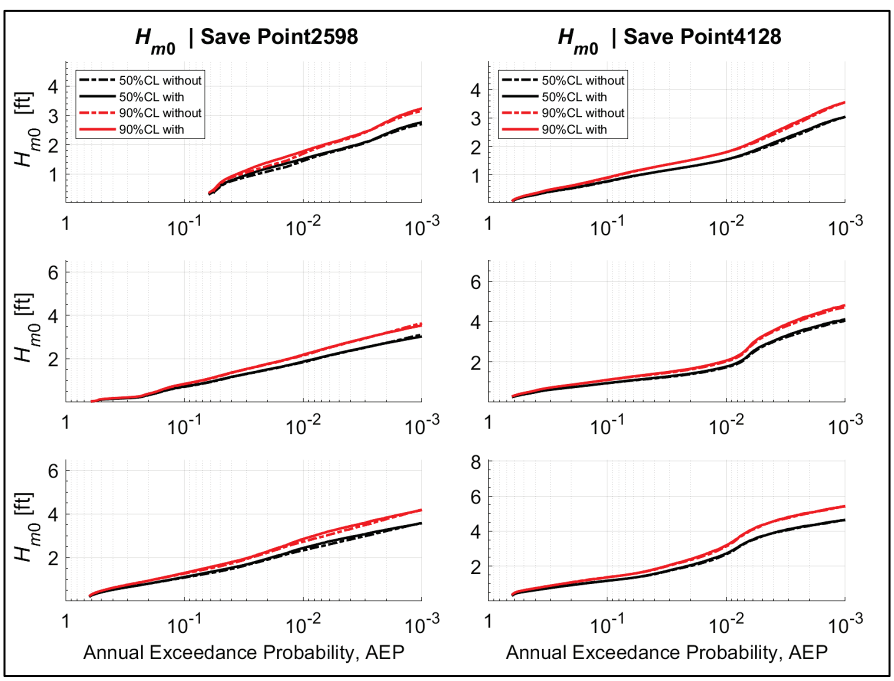
Figure 95 and Figure 96 show SWL and H_{mo} hazard curves, respectively, for SPs 2598 and 4128 for without- and with-project SLC0, SLC1, and SLC2 scenarios. In the figures, the 50% and 90% CLs are shown. As can be seen in the figures, SWL hazard curves are slightly lower for the with-project condition, but the hazard curves for the two scenarios are very similar. SWL and H_{mo} values for a range of AEPs are listed with their corresponding transects in Appendix D for without-project SLC0 and with-project SLC1 and SLC2.

Figure 95. AEP vs. SWL for SP 2598 (left) and SP 4128 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2. Elevations are in feet, NAVD88.



Comparing the hazard curves for SWL and H_{m0}, it can be seen that while there are differences between with-project and without-project individual storm responses, these differences have almost no effect on the hazards.

Figure 96. AEP vs. H_{m0} for SP 2598 (left) and SP 4128 (right). Upper row is SLC0, middle row is SLC1, and bottom row is SLC2.



11.2 Local CSRM system response modeling

PA-NE CSRM system consists of levees and floodwalls. The features of the CSRM system corresponding to the transects in PA-NE are listed in Table 29. The existing topography for much of the area around the Port Arthur CSRM system is from LiDAR and SWG field surveys. Figure 97 and Figure 98 show schematized analysis transects with without-project and with-project modeled elevations.

Table 29. Features of CSRM system in PA-NE area.

Transect Number	GeoID	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
154	P	183+50.00	230+55.00	6	13.37	14.50
156	P	129+89.83	183+50.00	6	16.72	16.7
158	P	129+89.83	183+50.00	6	16.29	16.3
159	P	129+89.83	183+50.00	6	16.36	16.4
159a	P	128+34.50	129+89.83	N/A	14.85	16.00
161	P	102+50.00	128+34.50	5	16.27	16.3
164	P	62+50.00	102+50.00	6	15.63	15.6
167	O	55+00.00	64+95.00	9	14.35	14.50
168	O	40+00.00	55+00.00	6	13.82	14.50
170	O	15+00.00 39+25.00	36+60.50 40+00.00	4	13.95	14.50
170 PS Fronting	O	36+60.50	39+25.00	N/A	13.95	14.50
174	O	0+00.00	15+00.00	3	13.81	14.50

Transects for PA-NE are adjacent to a large wetland area to the northeast of the structure, so at high water levels, waves may be able to form across this fetch. However, these waves will be dramatically reduced by shallow water effects even at the highest water levels. CSTORM (STWAVE) does not model the physics of wave reflection, nor does it account for wave diffraction within the adjacent channel or marsh; therefore, there is a potential that the estimated wave heights are uncertain. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping.

Transects in PA-NE have unique surrounding topographies and bathymetries. The details for each transect are described in Table 30. Berm effects were not included in the hazard calculations, as described above. The pressure distributions were calculated for transect 159a, which characterizes a gate.

Table 30. Characteristics of CSRM system in PA-NE area.

Transect Number	Associated SP	Type	Toe Depth (ft, NAVD88)	Seaside Material	Leeside Material
154	2595	Levee	N/A	Grass	Grass
156	2598	Levee	N/A	Grass	Gravel
158	1995	Levee	N/A	Grass	Gravel
159	1634	Levee	N/A	Grass	Gravel
159a	1634	Closure Gate / Floodwall	4.99	Concrete	Concrete
161	4097	Levee	N/A	Grass	Gravel
164	2605	Levee	N/A	Grass	Gravel
167	4128	Levee	N/A	Grass	Grass
168	4128	Levee	N/A	Grass	Gravel
170	1682	Levee	N/A	Grass	Gravel
170 PS Fronting	1682	Star Lake PS Fronting Protection	N/A	Grass	Gravel
174	4116	Levee	N/A	Grass	Gravel

Figure 97. Analysis transects 154–161 with measured topography (black). Floodwalls include feasibility authorized elevation (blue). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.

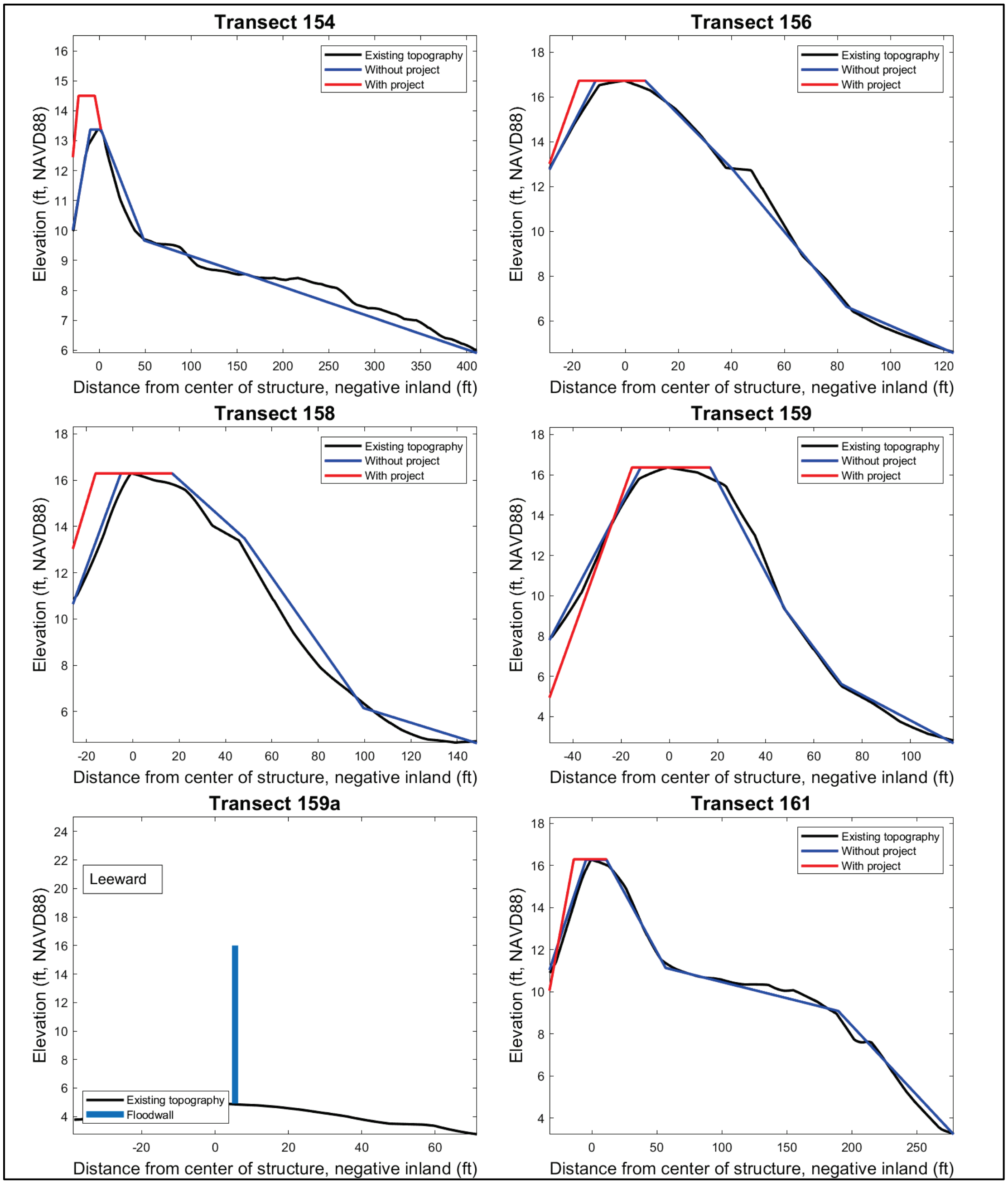
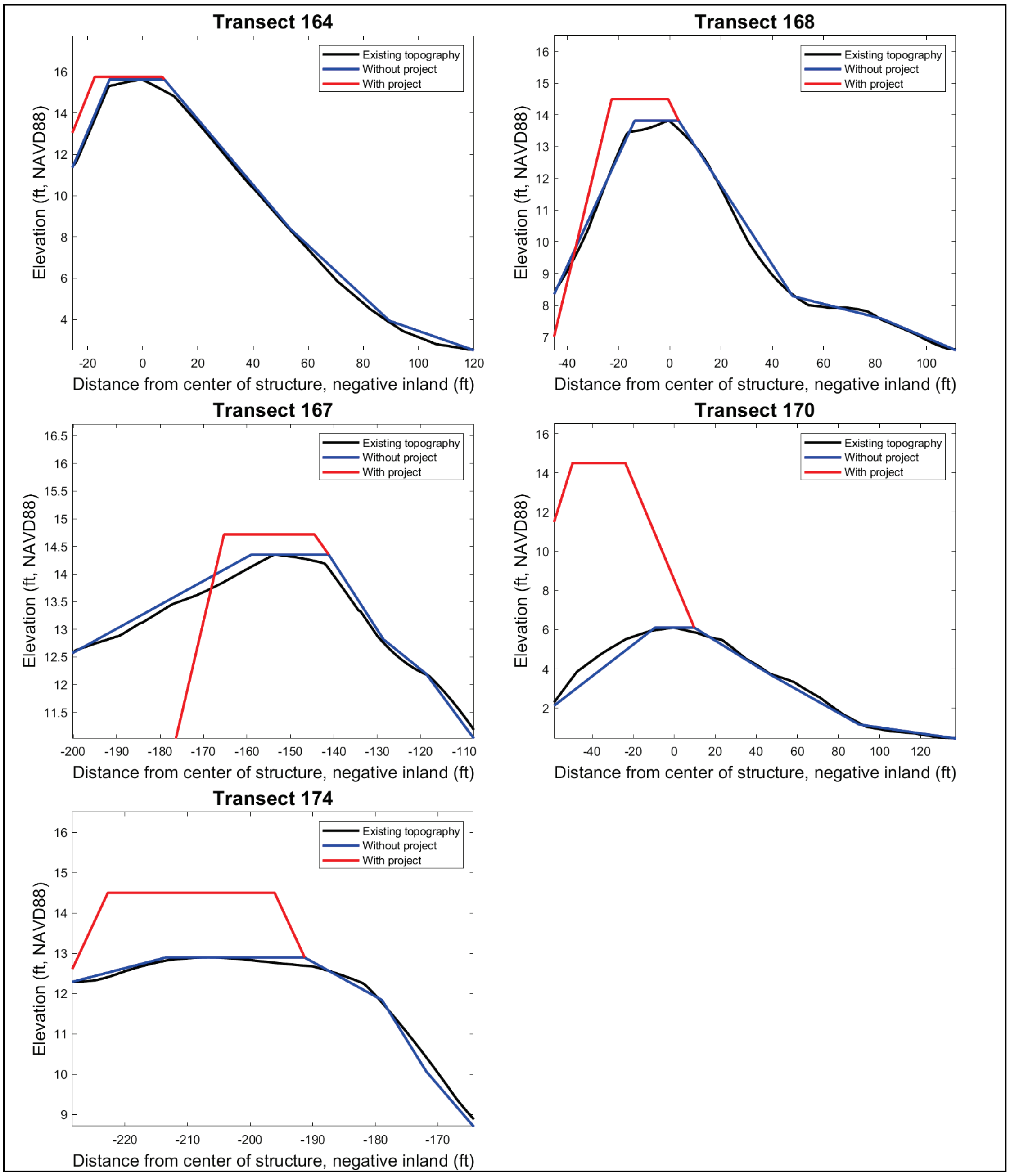


Figure 98. Analysis transects 164–174 with measured topography (black). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



11.3 Results

Design elevations were determined by the PDT, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-NE, and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic wall pressures were computed for the floodwall and gate portions of PA-NE. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

11.4 Summary and conclusions for PA-NE

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the PA-NE portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and combined overtopping and overflow are quantified for the PA- NE CSRM system consisting of floodwalls and levees. An optimized crest elevation was computed that just exceeded the no-damage overtopping limit states. Overtopping nappe geometry and combined hydrostatic and hydrodynamic pressures on the seaward face of the floodwall were calculated for each floodwall and gate transect.

12 Port Arthur – North East-extension (PA-NE-ext)

PA-NE-ext designates the proposed extension at the northeast end of the Port Arthur CSRM system (PA-NE-ext; Figure 99 and Figure 100). The PA-NE-ext portion of the Port Arthur CSRM system is proposed to consist of levees. Coastal SWL, wave loading, and overtopping and overflow are quantified.

Figure 99. PA-NE-ext levee location near the Neches River (in orange).

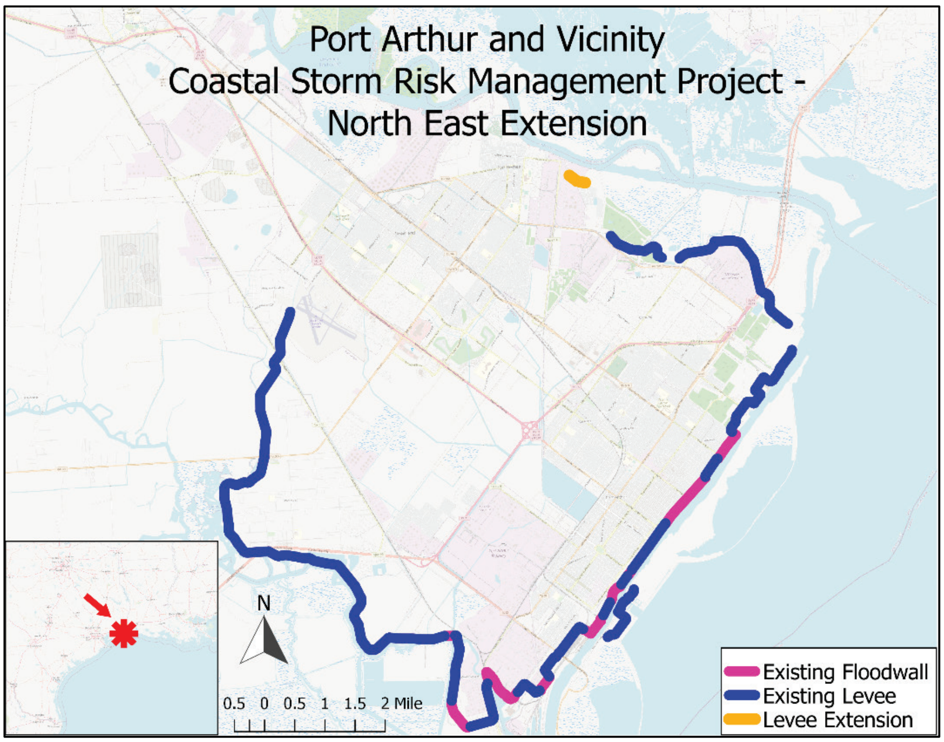
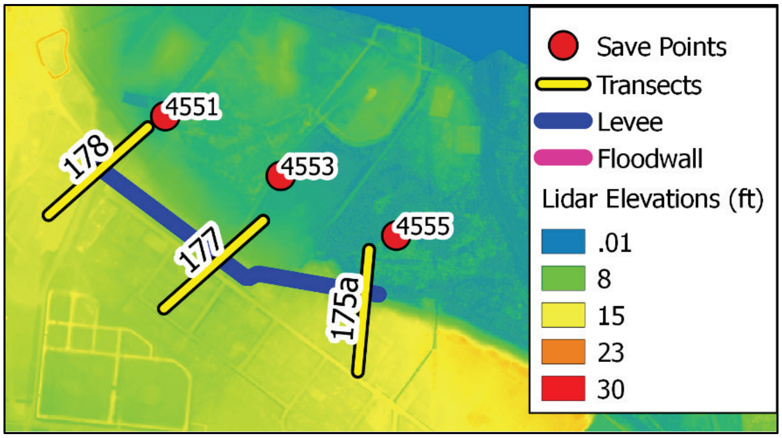


Figure 100. Details of PA-NE-ext for Port Arthur levee (blue), analysis sections (yellow lines), regional modeling output locations (red dots), and color shaded LiDAR-based elevations (feet, NAVD88).



12.1 Local wave and water level response

The PA-NE-ext was modeled using a 60-storm subsample that was selected from the 189 S2G synthetic tropical storms using the genetic algorithm iterative storm selection method discussed in Melby et al. (2021). From the 60 storms, 55 storms were analyzed for SLC1, and 57 storms were analyzed for SLC2. The storms were modeled with CSTORM with the S2G with-project mesh, which included the northeast extension. The subsample SWL hazard curves were compared to the 189-storm curves and were shown to both predict the hazard curve equally.

12.2 Local CSRM system response modeling

The proposed PA-NE-ext CSRM system consists of levees. The CSRM features corresponding to the transects in PA-NE-ext are listed in Table 31. The existing topography for much of the area around Port Arthur is from LiDAR and SWG field surveys. Figure 101 shows schematized analysis transects with without-project and with-project modeled elevations.

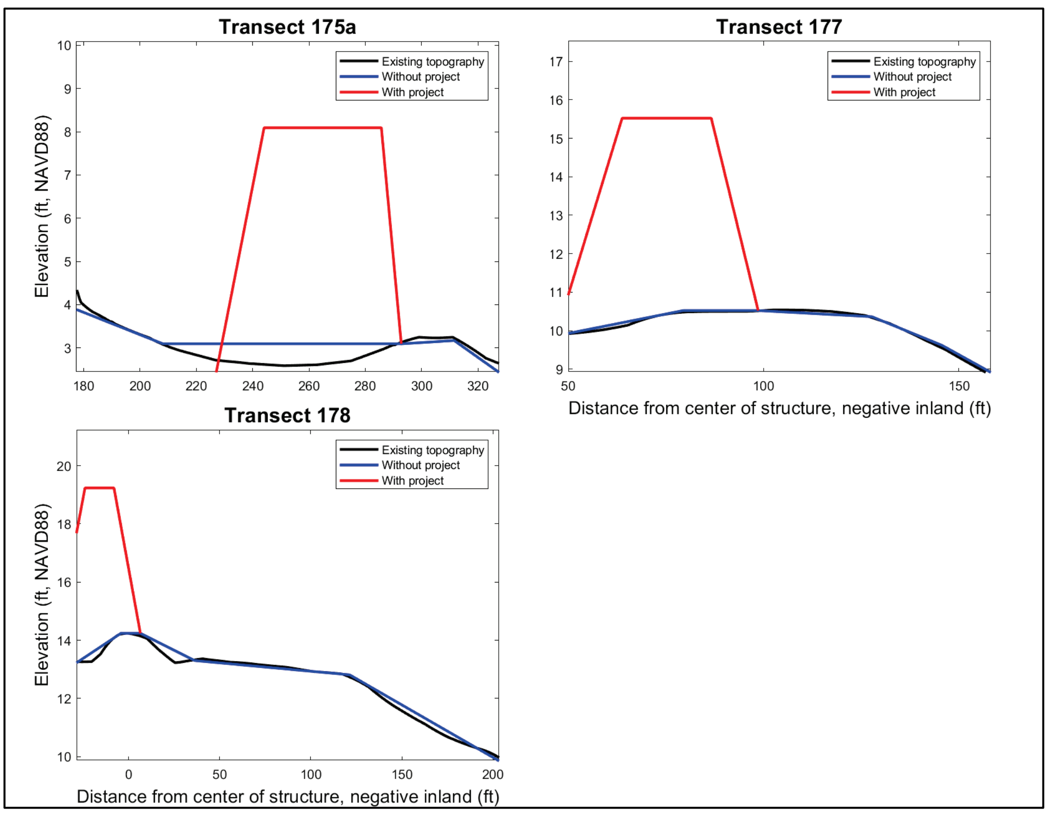
Table 31. Features of CSRM system in PA-NE-ext area.

Transect Number	Associated SP	Type	Reach Start	Reach End	Average Slope	Existing Average Reach Elevation (ft, NAVD88)	Authorized Elevation (ft, NAVD88)
175a	4555	Levee		18+30.00	3	3.09	8.09
177	4553	Levee			3	10.52	15.52
178	4551	Levee	0+00.00		3	14.23	19.23

Transects for PA-NE-ext are adjacent to a large wetland area to the northeast of the structure, so at high water levels, waves may be able to form across this fetch. However, these waves will be dramatically reduced by shallow water effects even at the highest water levels. CSTORM (STWAVE) does not model the physics of wave reflection, nor does it account for wave diffraction within the adjacent channel or marsh; therefore, there is a potential that the estimated wave heights are uncertain. Analysis herein assumed that the wave crests are parallel to the structure (waves are propagating shore normal) to ensure conservatism of overtopping.

Transects in PA-NE-ext are surrounded by grass. Berm effects were not included in the hazard calculations, as described in previous chapters.

Figure 101. Analysis transects 175a-178 with measured topography (black). Levees include idealized without-project (blue) and idealized feasibility authorized (with-project) elevation (red). Elevations are in feet, NAVD88.



12.3 Results

Design elevations were determined by the PDT team, which considered the optimized elevations required to just exceed the no-damage limit states under with-project forcing conditions, as described in Chapter 1. The results of the optimization are shown in Appendix C. Overtopping was computed for the levee portion of PA-NE-ext. The response results from the response-based analysis are shown in Appendix D for the four forcing and elevation combinations described in Chapter 1.

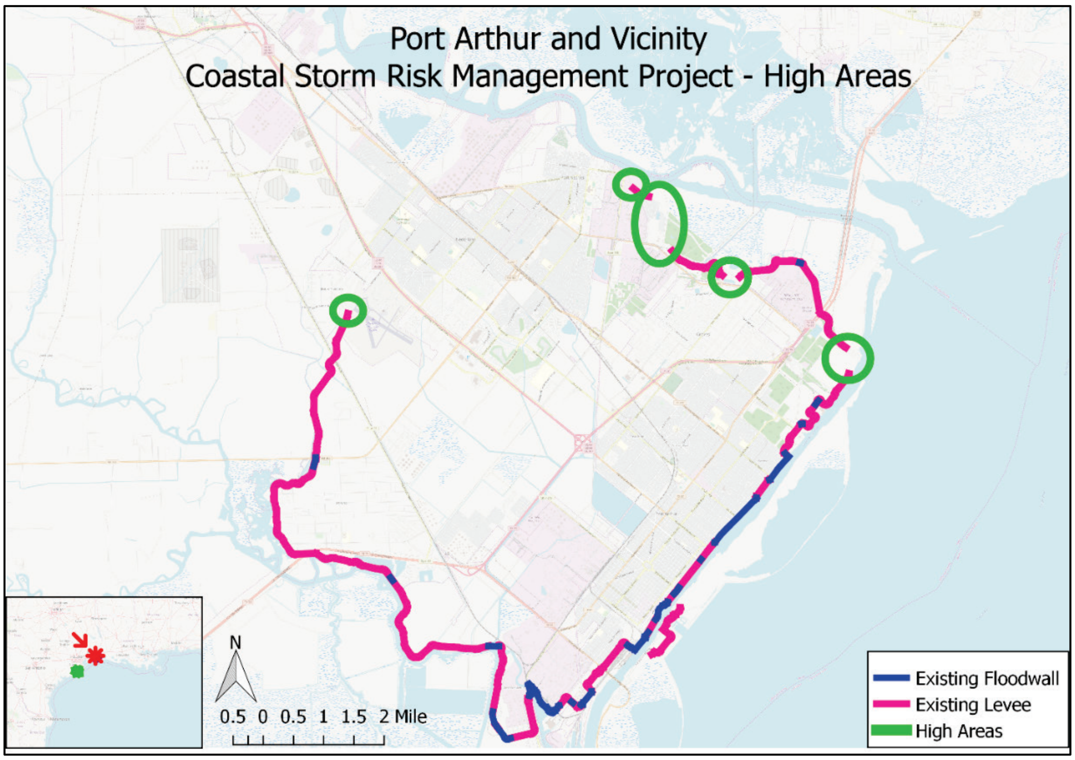
12.4 Summary and conclusions for PA-NE-ext

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the PA-NE-ext portion of the Port Arthur CSRM system. Coastal storm inundation, wave loading, and combined overtopping and overflow are quantified for the PA-NE-ext CSRM system consisting of levees. An optimized crest elevation was computed that just exceeded the no-damage overtopping limit states.

13 Port Arthur – High Grounds

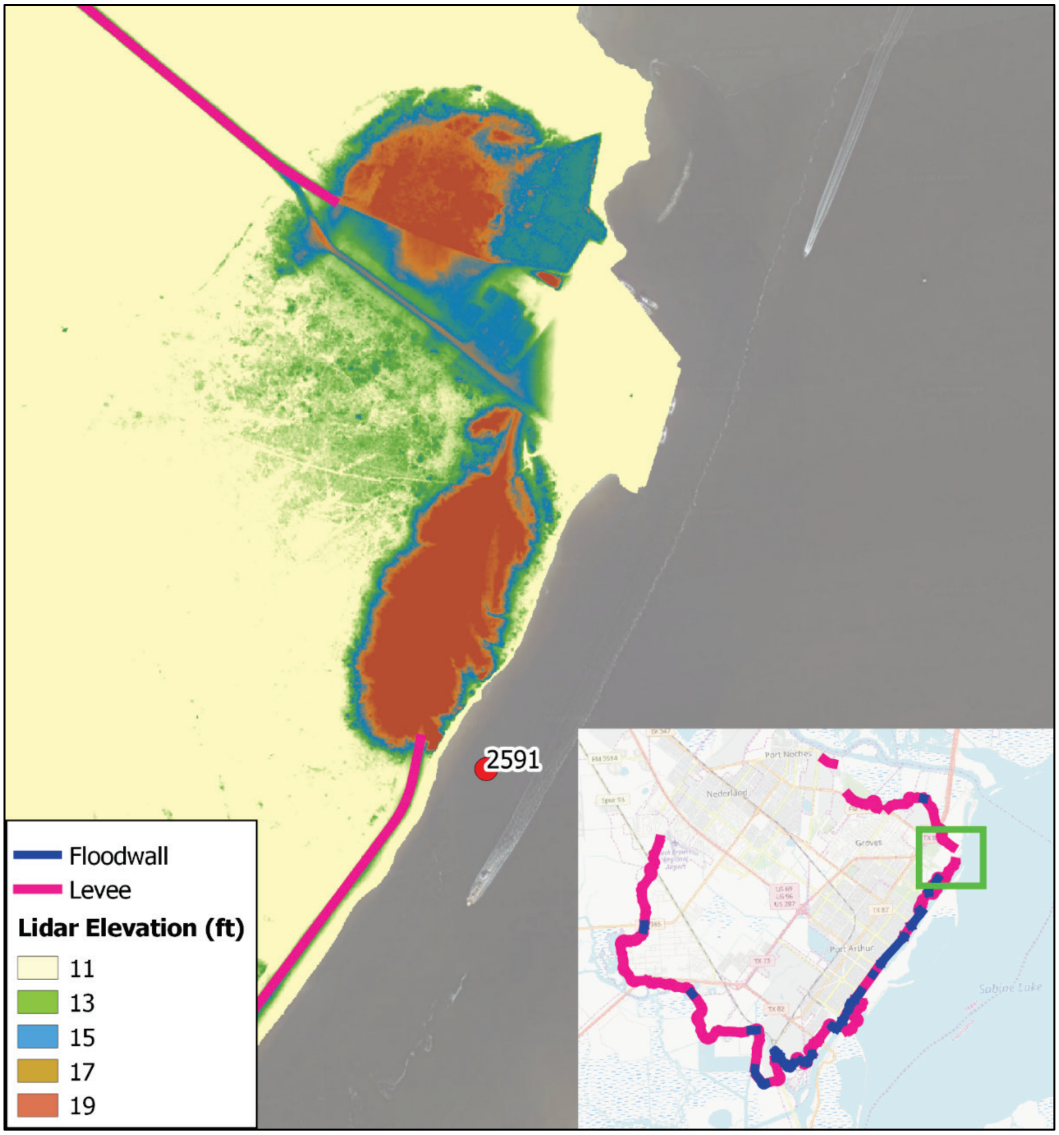
Port Arthur high grounds designate the areas adjacent to the Port Arthur CSRM system that, during the feasibility study, were determined to not require any CSRM system features due to existing high land elevation. This chapter documents coastal SWL and wave hazards analysis that has been performed in PED for the high ground regions near the Port Arthur CSRM system ("Port Arthur – high grounds"; Figure 102).

Figure 102. High areas in the Port Arthur vicinity (circled in green).



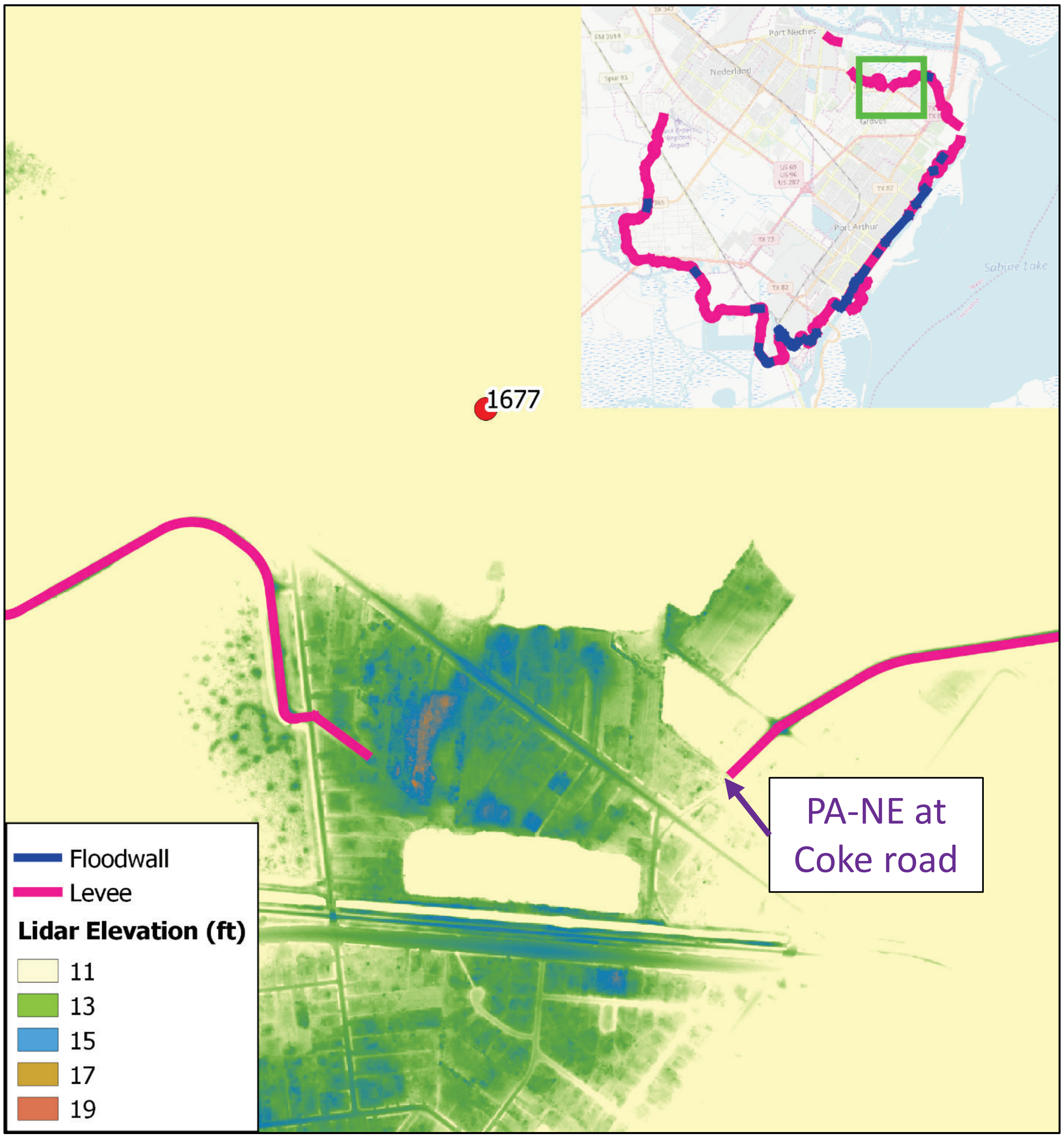
Port Arthur high grounds include the terminal ends of the CSRM system as well as three areas between CSRM system reaches in the PA-NE area. Details for these areas are shown in Figure 103 through Figure 106.

Figure 103. Details of high grounds in the east corner of Port Arthur CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).



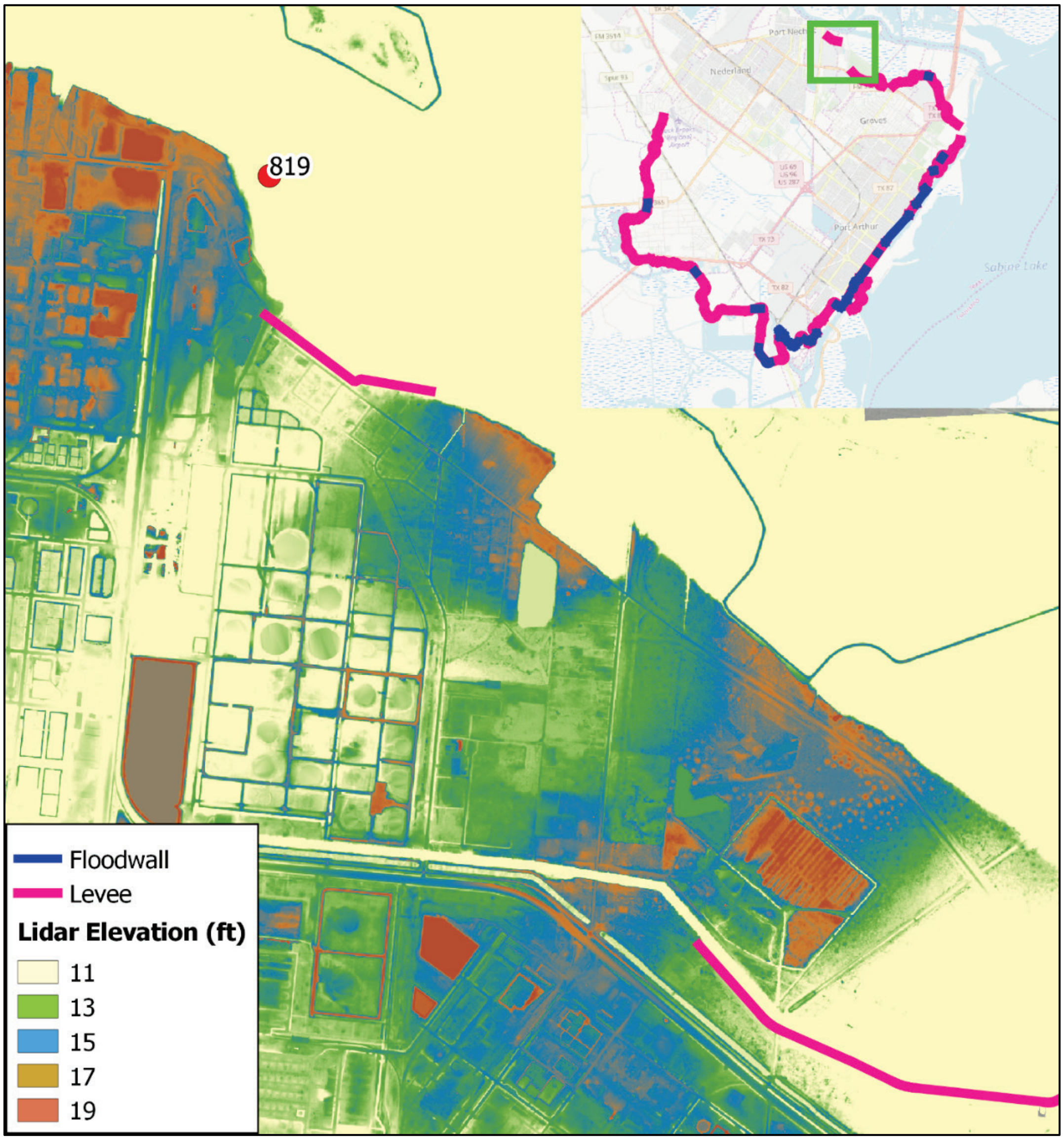
The east corner of the Port Arthur CSRM system shows an elevation greater than 19 ft, NAVD88, for the majority of the high ground area. However, in the middle of the east corner area, there is ground with an elevation of approximately 15 ft, NAVD88.

Figure 104. Details of high grounds between PA-NE at Coke Road and PA-NE western leg of Port Arthur CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).



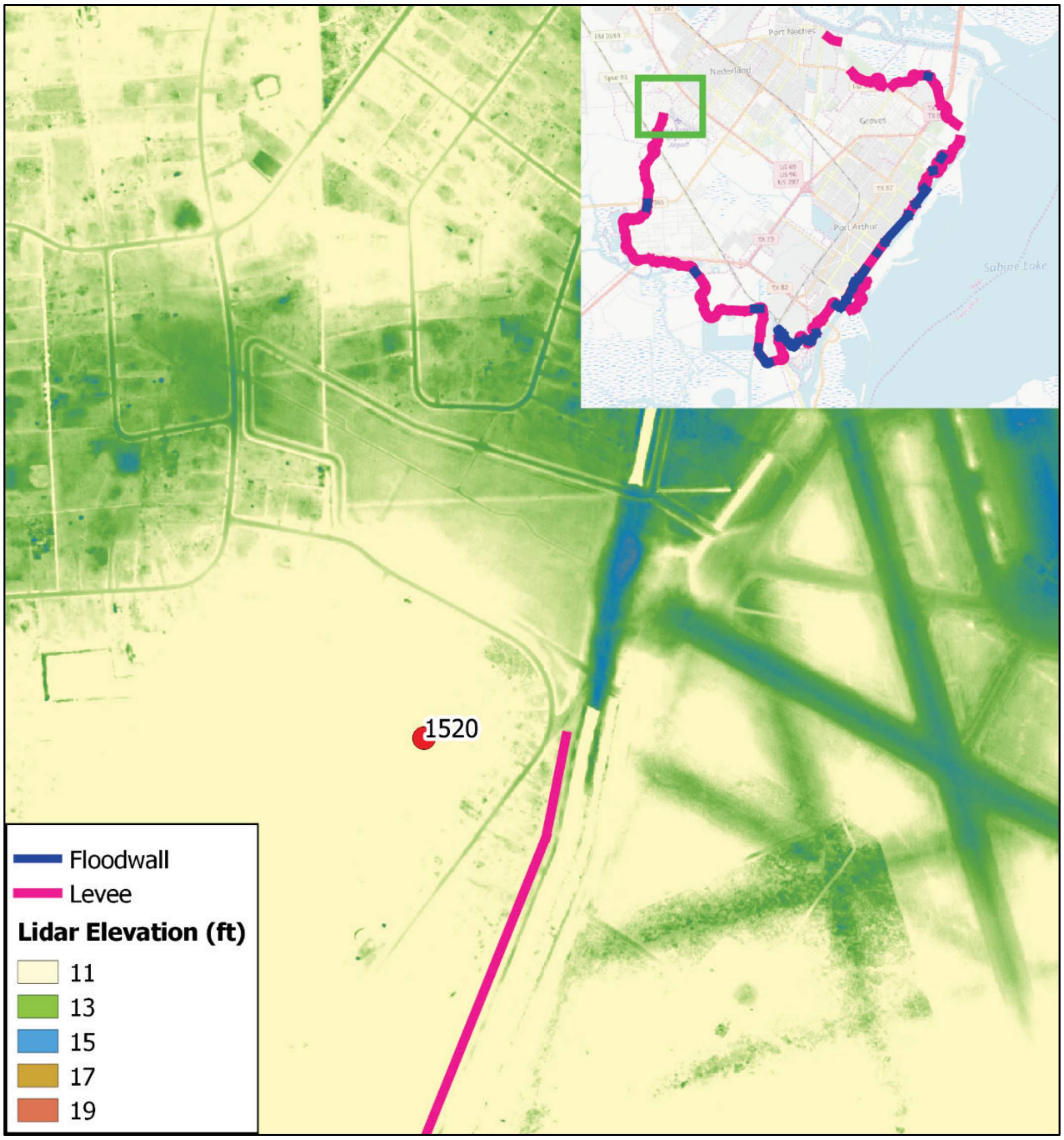
The high ground minimum elevation between PA-NE at Coke Road and the PA-NE western leg is approximately 13 ft, NAVD88, with some areas greater than 15 ft, NAVD88. The high ground near Coke Road is approximately 11 ft, NAVD88.

Figure 105. Details of high grounds at the terminal end of PA-NE and between existing structure and proposed extension of the Port Arthur CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).



The high ground minimum elevation adjacent to the existing PA-NE terminus and adjacent to the PA-NE extension is greater than 13 ft, NAVD88, with the majority of the area greater than 15 ft, NAVD88, and some areas having an elevation greater than 19 ft, NAVD88.

Figure 106. Details of high grounds adjacent to the western terminus of Port Arthur CSRM system and color-shaded LiDAR-based elevations (feet, NAVD88).



The high ground minimum elevation adjacent to the west terminus of the CSRM system is approximately 13 ft, NAVD88. There is an area that is 15 ft, NAVD88, but this is located 150 ft from the end of the CSRM system.

13.1 Local wave and water level response

The 1% AEP SWL and H_{m0} values were computed for SPs in each high ground area at both a 50% and 90% CL. The SP with the highest 1% AEP SWL at a 90% CL for SLC0 was used to characterize the local SWL and wave response for each of the RSLC conditions and are marked in Figure 103 through Figure 106. These values are listed in Table 32, and corresponding 1% AEP H_{m0} values are listed in Table 33. Only with-project SWL and wave responses were used in this analysis.

Table 32. SWL, in feet, NAVD88, for 1% AEPs for S2G high ground areas at 50% CL and 90% CL, with-project.

Scenario	East Corner (Maximum Existing Elevation = 15 ft, NAVD88)	Between PA-NE at Coke Road and PA-NE Western Leg (Maximum Existing Elevation = 11 ft, NAVD88)	PA-NE Terminus and Extension (Maximum Existing Elevation = 13 ft, NAVD88)	West Terminus (Maximum Existing Elevation = 13 ft, NAVD88)
SLC0 50% CL	11.95	11.07	11.27	10.16
SLC0 90% CL	13.98	12.95	13.18	11.88
SLC1 50% CL	13.91	13.28	13.47	13.01
SLC1 90% CL	16.27	15.54	15.75	15.21
SLC2 50% CL	17.12	16.48	16.59	16.51
SLC2 90% CL	20.03	19.27	19.40	19.31

Table 33. H_{m0}, in feet, for 1% AEPs for S2G high ground areas at 50% CL and 90% CL, with-project.

Scenario	East Corner	Between PA-NE at Coke Road and PA-NE Western Leg	PA-NE Terminus and Extension	West Terminus
SLC0 50% CL	4.80	1.60	1.80	0.40
SLC0 90% CL	5.62	1.87	2.11	0.47
SLC1 50% CL	5.04	2.02	2.28	0.61
SLC1 90% CL	5.90	2.36	2.66	0.71
SLC2 50% CL	6.14	2.98	2.89	1.24
SLC2 90% CL	7.18	3.48	3.38	1.45

A nodal hazard analysis showed inundation behind the authorized CSRM system at PA-NE at Coke Road for SLC1 at the 1% AEP, shown in Figure 107 for 50% CL and Figure 108 for 90% CL. Inundation was shown throughout the inside of the CSRM system for SLC2 at 1% AEP, shown in Figure 109 for 50% CL. The ADCIRC mesh within CSTORM did not show inundation within nearby channels for areas that were not flooded for SLC1 because the channels were smaller than the mesh refinement; however, the channels have banks that are greater than the 1% AEP SWL, so overbank flooding is not expected for the 1% AEP flood condition at SLC1. Figure 109 shows that the entire area floods at SLC2 so, again, the lack of flow in the channel was not influential.

Figure 107. Inundation shown behind levee at PA-NE Coke Road, color-shaded LiDAR-based elevations (feet, NAVD88), and colored regional nodal output locations corresponding to the SWL for SLC1 at 1% AEP, 50% CL.

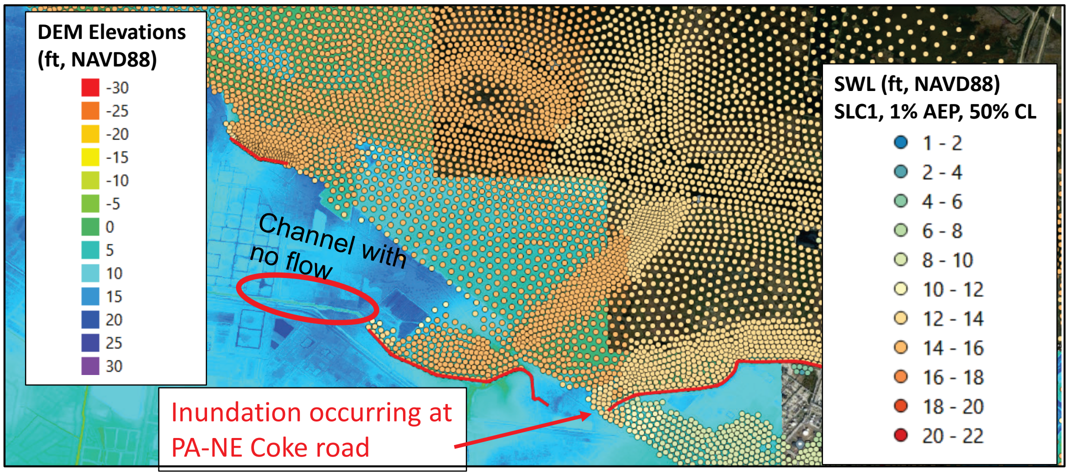


Figure 108. Inundation shown behind levee at PA-NE Coke Road, color-shaded LiDAR-based elevations (feet, NAVD88), and colored regional nodal output locations corresponding to the SWL for SLC1 at 1% AEP, 90% CL.

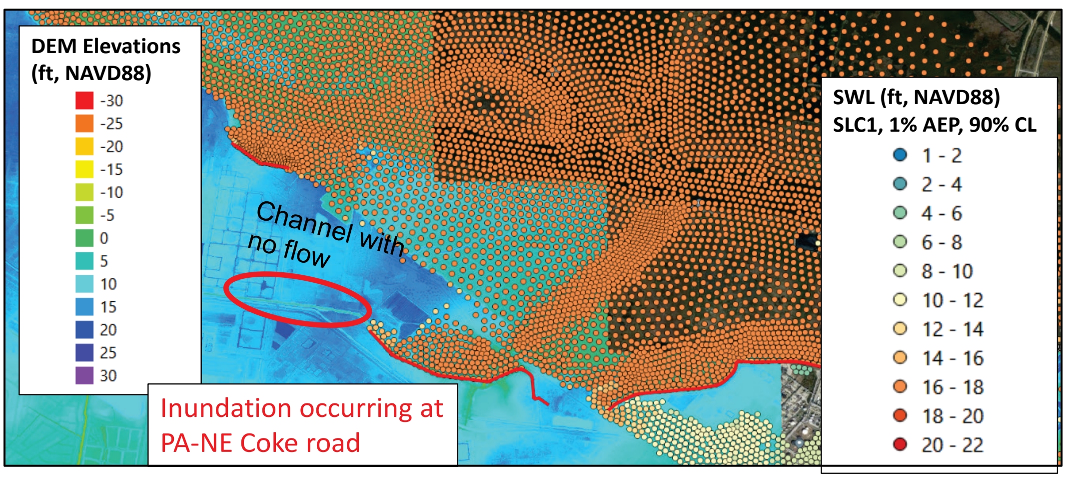
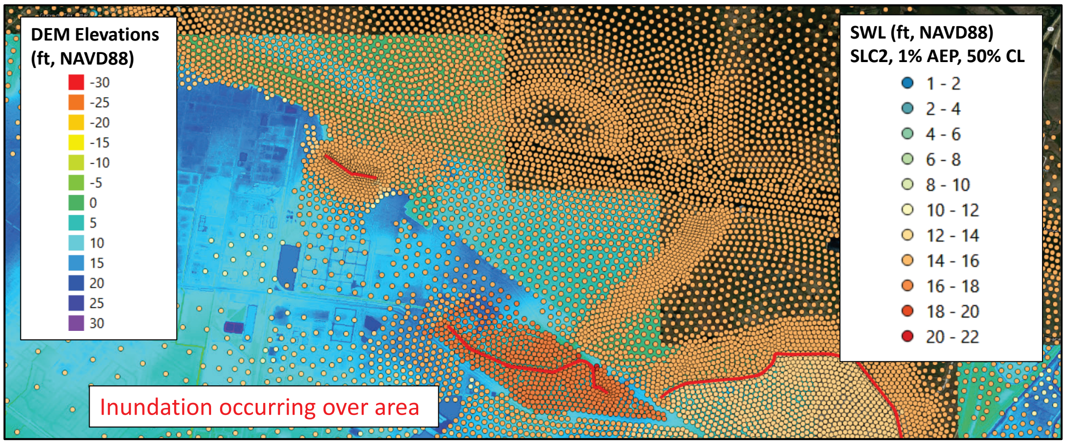


Figure 109. Inundation shown behind levee at the north end of PA-NE, color-shaded LiDAR-based elevations (feet, NAVD88), and colored regional nodal output locations corresponding to the SWL for SLC2 at 1% AEP, 50% CL.



13.2 Optimized levee elevation

An optimization step was completed to compute an optimized levee crest elevation required to just exceed the no-damage limit states in the high ground areas using the with-project wave and water level responses. The SP that produced the highest 1% AEP SWL at a 90% CL in the area for SLC0 was used with its associated wave conditions. As a representative geometry, the slope of the adjacent levee structures was used to compute overtopping rates. Results are summarized in Table 34.

It can be seen that only one of the existing elevations is lower than the optimized elevations for SLC0. For SLC1 and SLC2, all of the existing high ground elevations are lower than the optimized elevations, which indicates that additional CSRM features will be needed in these high ground areas to provide the same level of risk reduction as the rest of the CSRM system. These additional CSRM features will be designed by others, and their detailed local and regional SWL and wave response will be quantified in future efforts within the S2G project.

Table 34. Optimized levee crest elevations that most nearly match no-damage overtopping limit states. Elevations are in feet, NAVD88.

	Minimum Existing Elevation, feet, NAVD88	Adjacent Structure Slope	SLC0	SLC1	SLC2
East Corner	15	6	18.0	20.5	24.5
PA-NE middle	11	6	12.95	15.54	19.27
PA-NE end and addition	13	3	14.5	17.5	21.5
West end	13	5	11.88	14.0	19.31

As discussed in Melby et al. (2021), extensive riverine analysis (Sabine and Neches) has been conducted, and compound flooding impacts have been assessed separately. They note that design SWL elevations are dominated by hurricane storm surge and wave contributions, not by riverine flows or by the compounding effect of the two. The multivariate probabilistic combinations of surge and hydrologic impacts are much more rare than would be a consideration for CSRM design. If combined flooding of the 1% AEP SWL tropical storm occurs with rare Lower Neches River flows, there would likely be greater flooding; however, this was not investigated herein.

13.3 Summary and conclusions for high grounds

The 1% AEP SWLs were compared to the elevations in the high ground areas to determine if the high ground would provide adequate level of risk reduction comparable to the rest of the CSRM system. High ground elevations were generally greater than the 1% AEP SWL at a 50% CL corresponding to SLC0, but not for SLC1 and SLC2. Additionally, and considering overtopping hazards, all of the existing minimum high ground elevations adjacent to the CSRM structures were lower than the optimized elevations for SLC1 and SLC2, indicating that additional CSRM features will be needed in these areas.

14 Conclusions and Recommendations

The USACE SWG is executing the S2G CSRM project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the PED phase. As identified during the Final Integrated Feasibility Report – Environmental Impact Statement (USACE 2017), the S2G project CSRM formulated measures consist of reducing the risks of tropical SWL impacts by constructing the new Orange 3 CSRM system in Orange County and increasing the level of risk reduction and resiliency of the existing Port Arthur and Vicinity and Freeport and Vicinity CSRM systems in Jefferson and Brazoria Counties, Texas.

As part of the ongoing PED phase of the project, this report documents coastal SWL and wave hazards for the Port Arthur CSRM system. Coastal SWL and wave loading, and wave and SWL overtopping are quantified.

A multivariate probabilistic model of historical hurricane parameters was developed that spans the full range of tropical storm hazards. The model was sampled effectively to develop a suite of 189 synthetic tropical storms that efficiently capture the flood hazard for the region from Freeport to the Louisiana-Texas border. The CSTORM coupled circulation, water level, and wave modeling system was used to accurately quantify the SWLs and wave hazards. SWLs consist of storm surge, tides, wave setup, seasonal variations, and other local storm effects from currents and winds. The storms were run on three RSLC scenarios for the with- and without-project meshes. These RSLC scenarios are referred to as SLC0 corresponding to project completion in 2027 with associated “Low” RSLC rate, SLC1 corresponding to the end of a 50 yr service life in 2077 with associated “Intermediate” RSLC rate, and SCL2 corresponding to the end of a 100 yr service lifecycle in 2127 with associated “Intermediate” RSLC rate. Further details are provided in Melby et al. (2021).

The flood hazard exposure of the project features was quantified by computing hazard curves for the CSTORM output near the structures. AEPs were computed for the range of 1 to 0.0001 for peak SWL and H_{m0} at 50% and 90% CLs but reported out in tables only between 0.2 to 0.001 AEP. Wave direction and T_p associated with peak H_{m0} were also computed. In this case, CLs are used to describe epistemic uncertainty or levels of assurance. For hazard curves contained herein, the mean and median are indistinguishable. Therefore, only mean values are reported. Typically, the with-project SWL hazard curves are shown to be approximately the same as the without-project. Waves at 1% AEP are shown to be primarily small and short in length and characterize wind-wave conditions inland, as occur in the area of Port Arthur. As reported in Melby et al. (2021), a Boussinesq model of wave propagation in the Sabine area showed that the swell and infragravity wave energy is nearly entirely dissipated between the open coast and the CSRM structures, which are well inland. Therefore, the modeling does not include infragravity waves. An analysis of the nonlinear residual was completed in Melby et al. (2021) that illustrated the need for coupled circulation and wave modeling.

An analysis of stochastic workflows was completed for overtopping by Melby et al. (2021). It was shown that a peaks-based response-based approach yielded accurate stochastic response estimates, so this method was used to compute the design. No-damage limit states for overtopping a levee of q = 0.01 cfs/ft for the 50% CL and q = 0.1 cfs/ft for the 90% CL were based on previous studies. Limit states for overtopping a floodwall of q = 0.03 cfs/ft for the 50% CL and q = 0.1 cfs/ft for the 90% CL were based on previous studies. These limit states are accepted standard of practice both within USACE and internationally. An additional ultimate limit state of q = 1 cfs/ft was considered. While not used directly for design, the limit state helped inform decisions by the PDT on final crest elevations. The optimized levee and floodwall elevations were computed using the limit states. The PDT selected final design elevations based on the optimized elevations and local considerations. In addition to overtopping, combined hydrostatic and hydrodynamic pressures and overtopping nappe characteristics were calculated for floodwall reaches.

Flooding potential in natural high ground areas adjacent to the CSRM systems was identified, and associated additional CSRM features will be needed to provide a consistent system-wide level of risk reduction against coastal hazards.

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Appendix A: Peak Storm Water Level (SWL) by Storm

Contract 1

Figure A-1. Peak SWL for without-project and SLCO scenario for SPs in Contract 1 area. SWL is in feet, NAVD88.

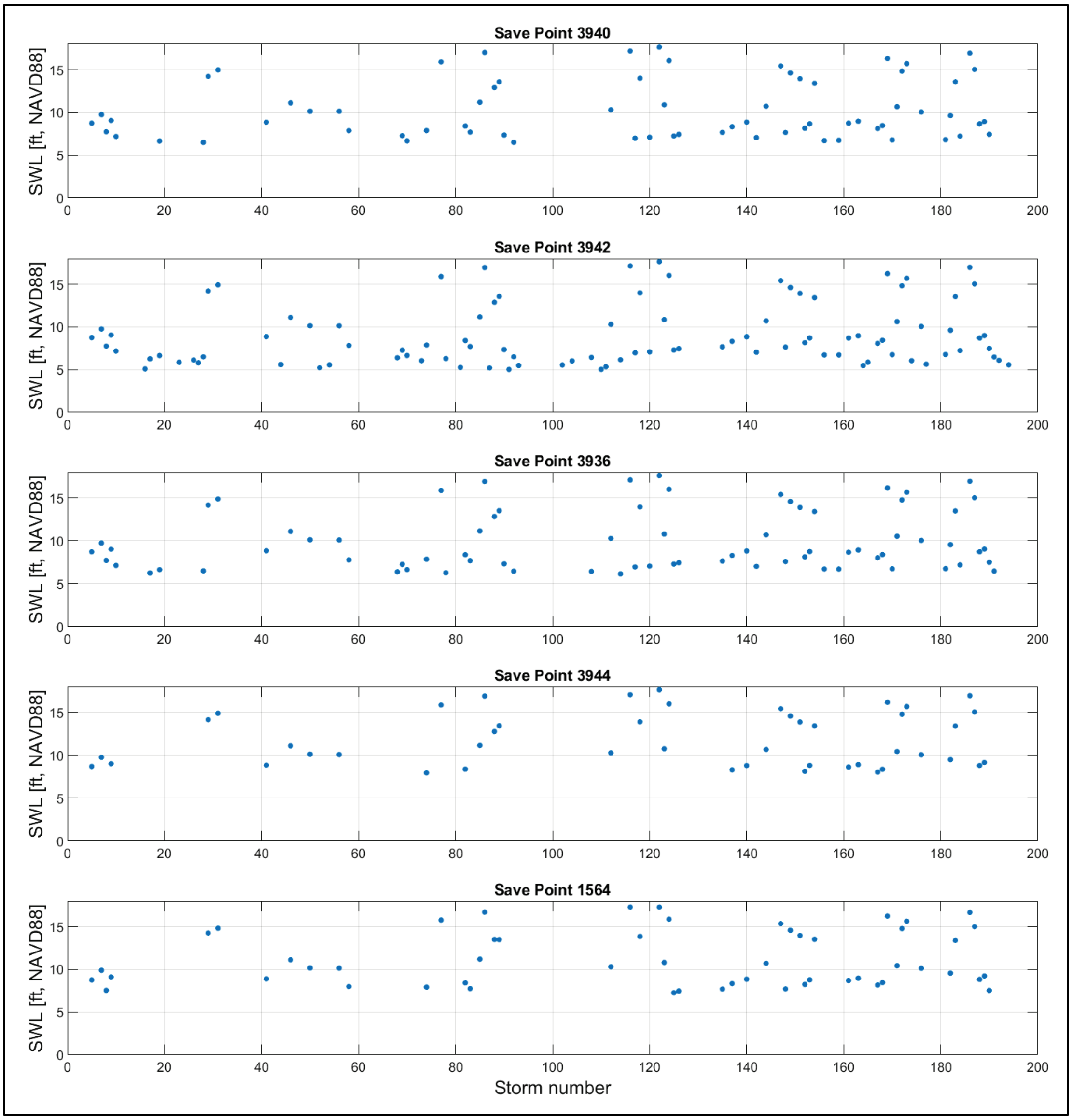


Figure A-2. Peak SWL for with-project and SLC1 for SPs in Contract 1 area. SWL is in feet, NAVD88.

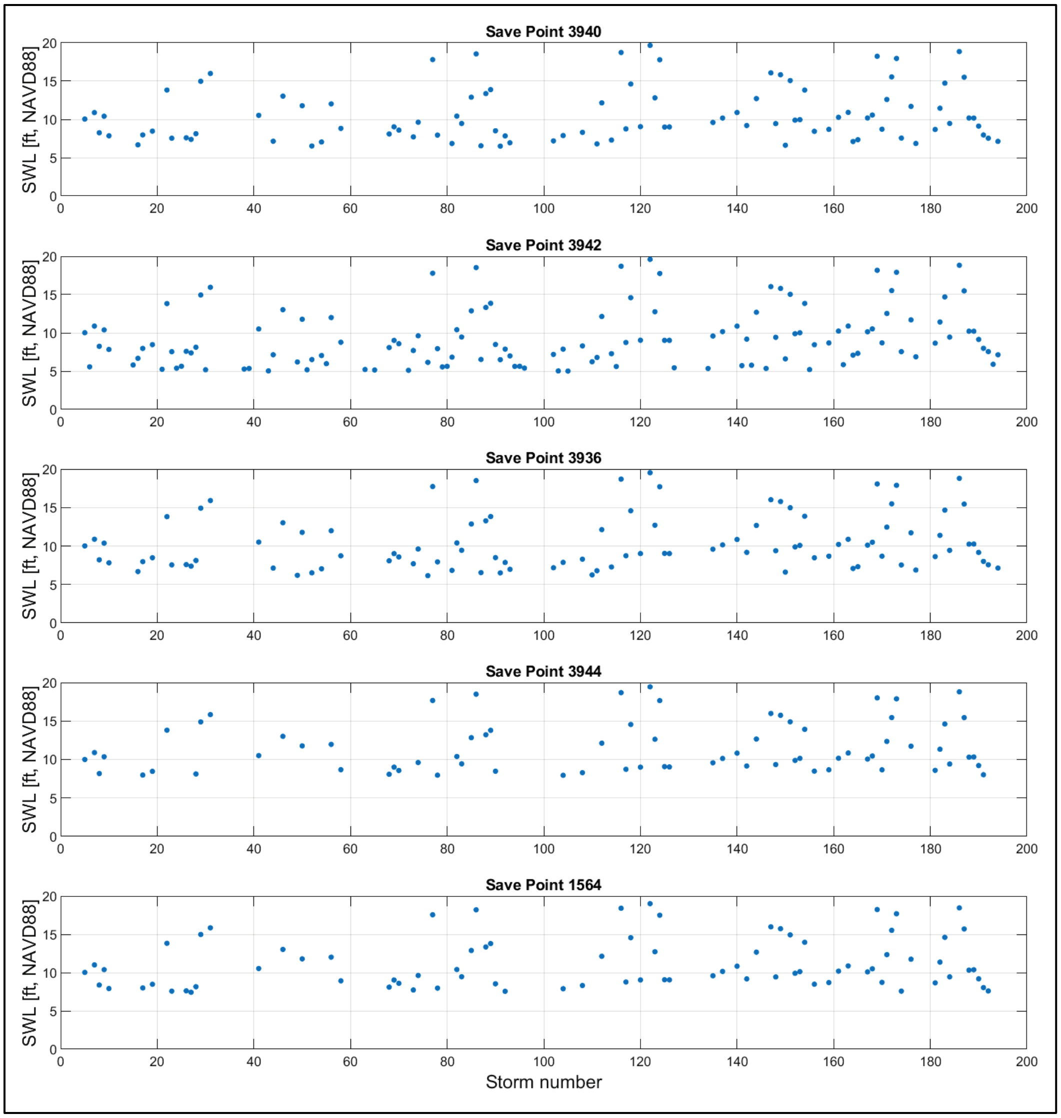
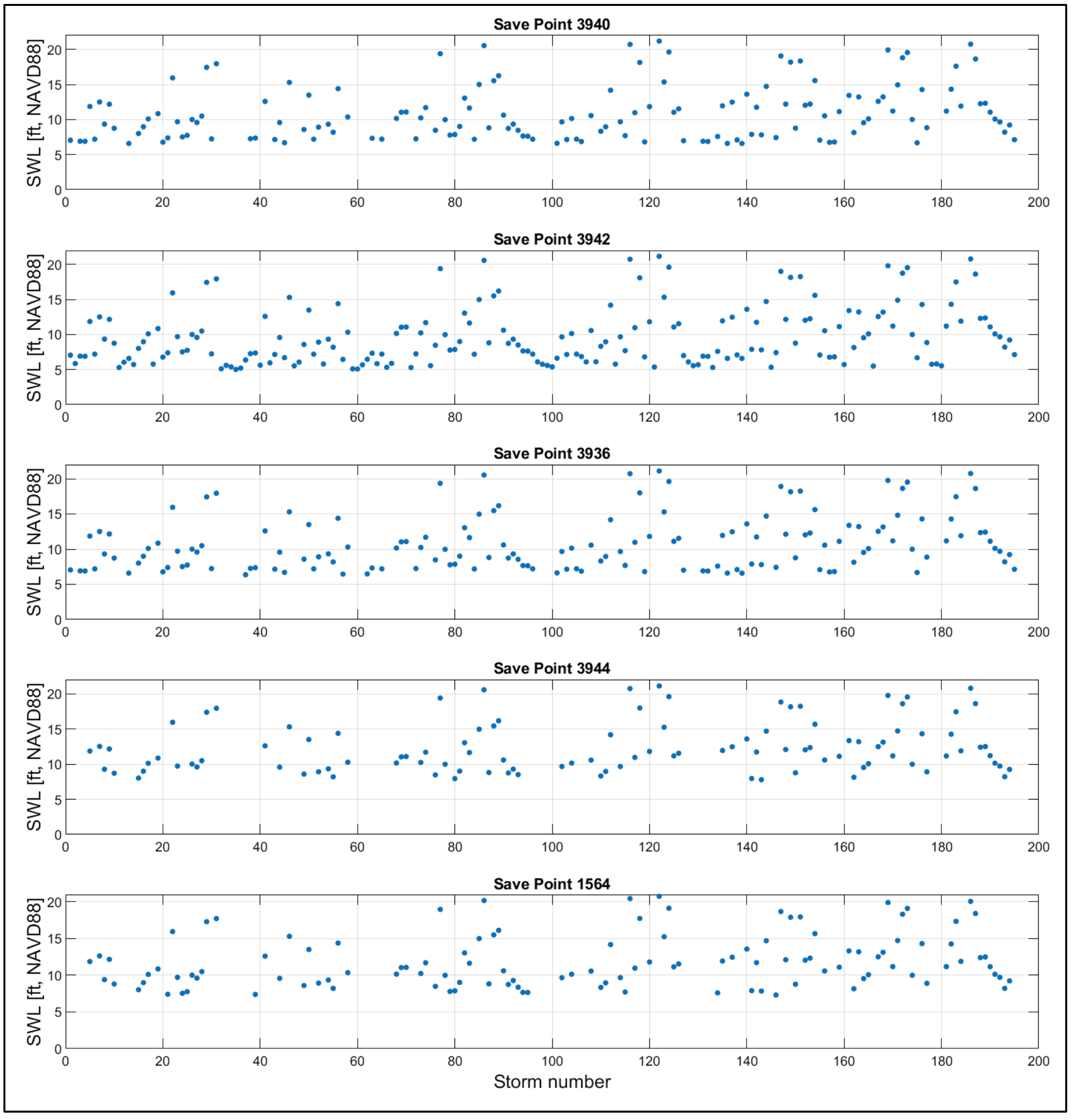
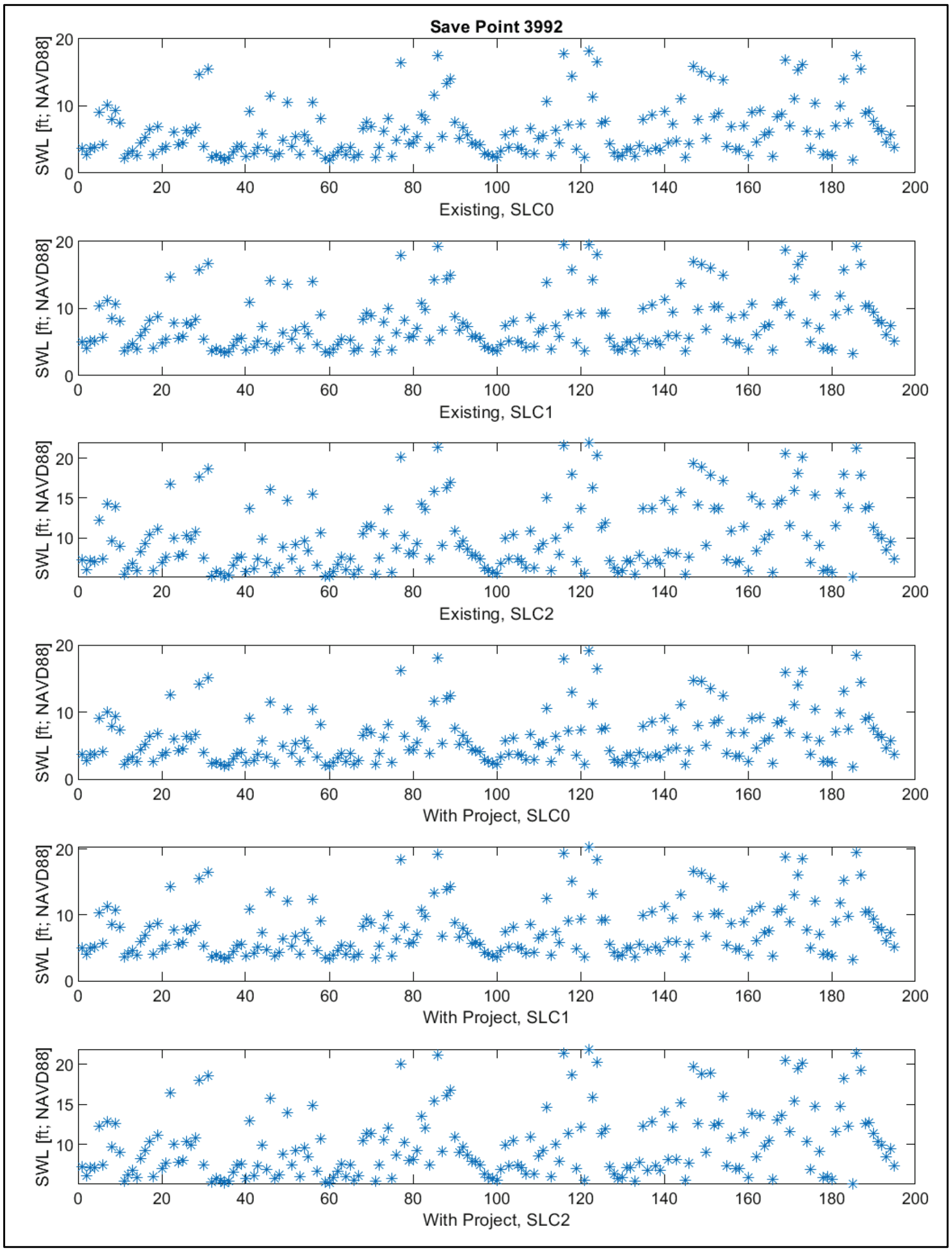


Figure A-3. Peak SWL for with-project and SLC2 for SPs in Contract 1 area. SWL is in feet, NAVD88.



Contract 2

Figure A-4. Peak SWL for SP 3992. The top three plots are for without-project conditions under scenarios SLC0, SLC1, and SLC2, respectively. The bottom three plots are for with-project conditions under scenarios SLC0, SLC1, and SLC2, respectively. SWL is in feet, NAVD88.



Contract 3

Figure A-5. Peak SWL for without-project and SLC0 scenario for SPs in Contract 3 area. SWL is in feet, NAVD88.

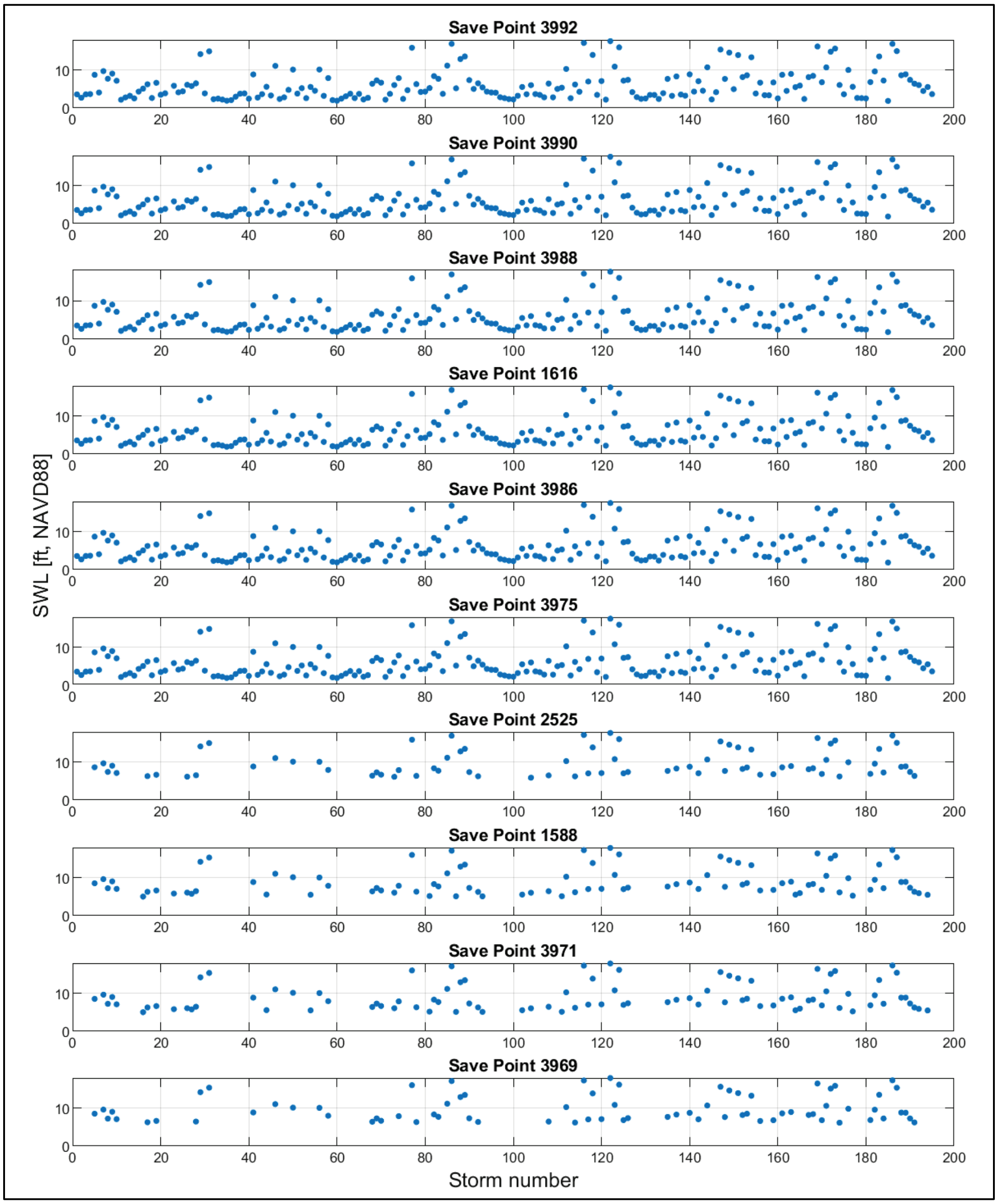


Figure A-6. Peak SWL for with-project and SLC1 for SPs in Contract 3 area. SWL is in feet, NAVD88.

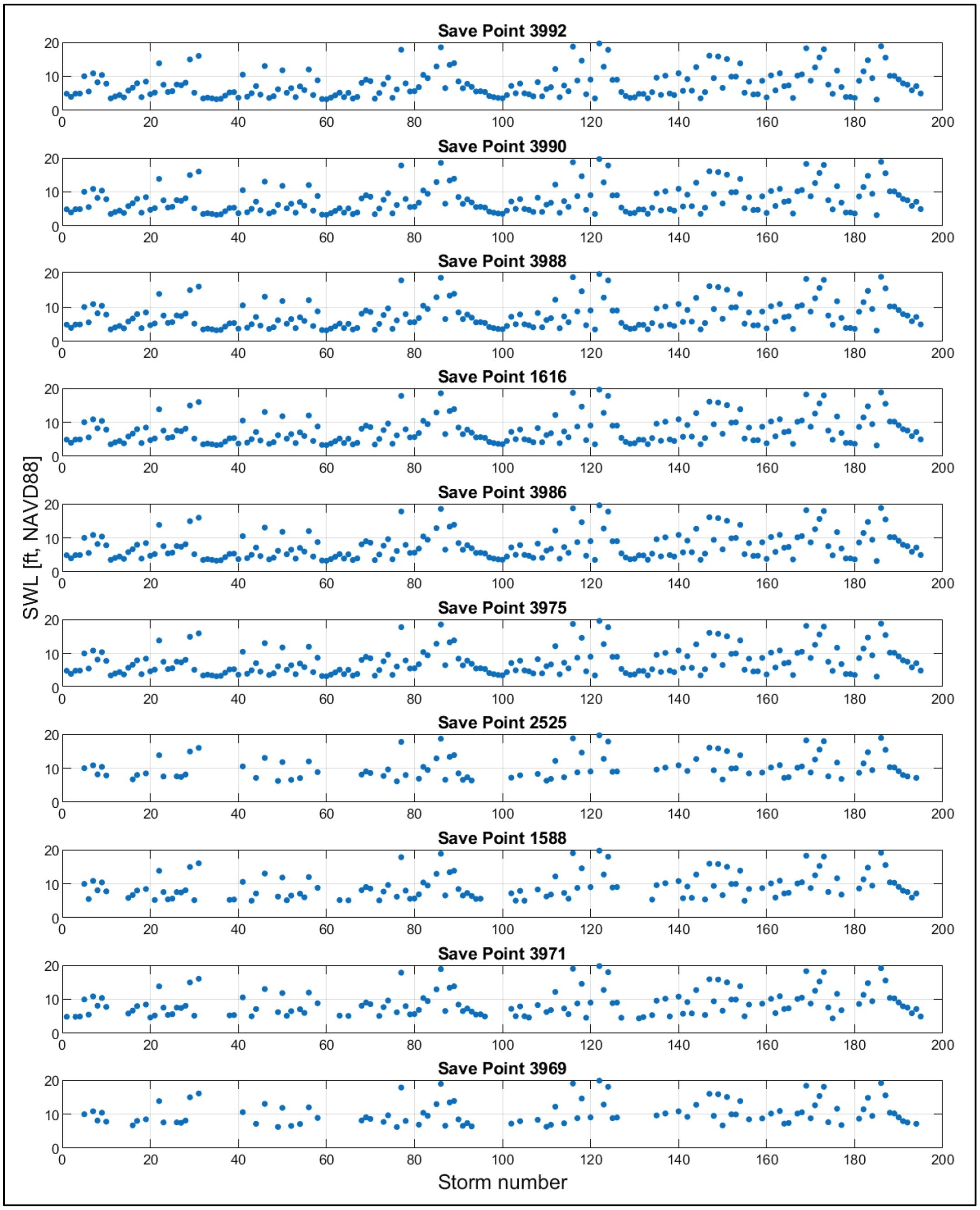
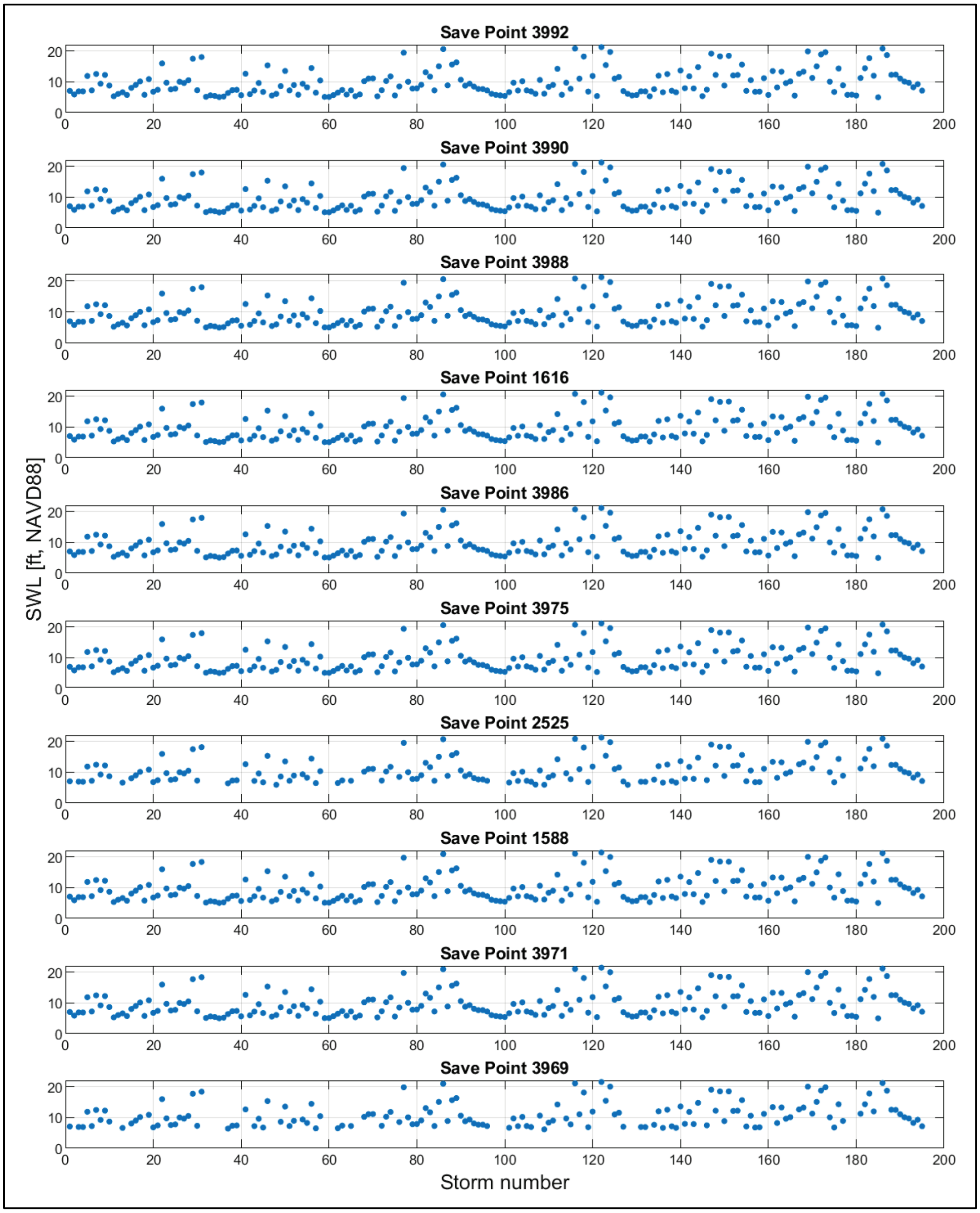
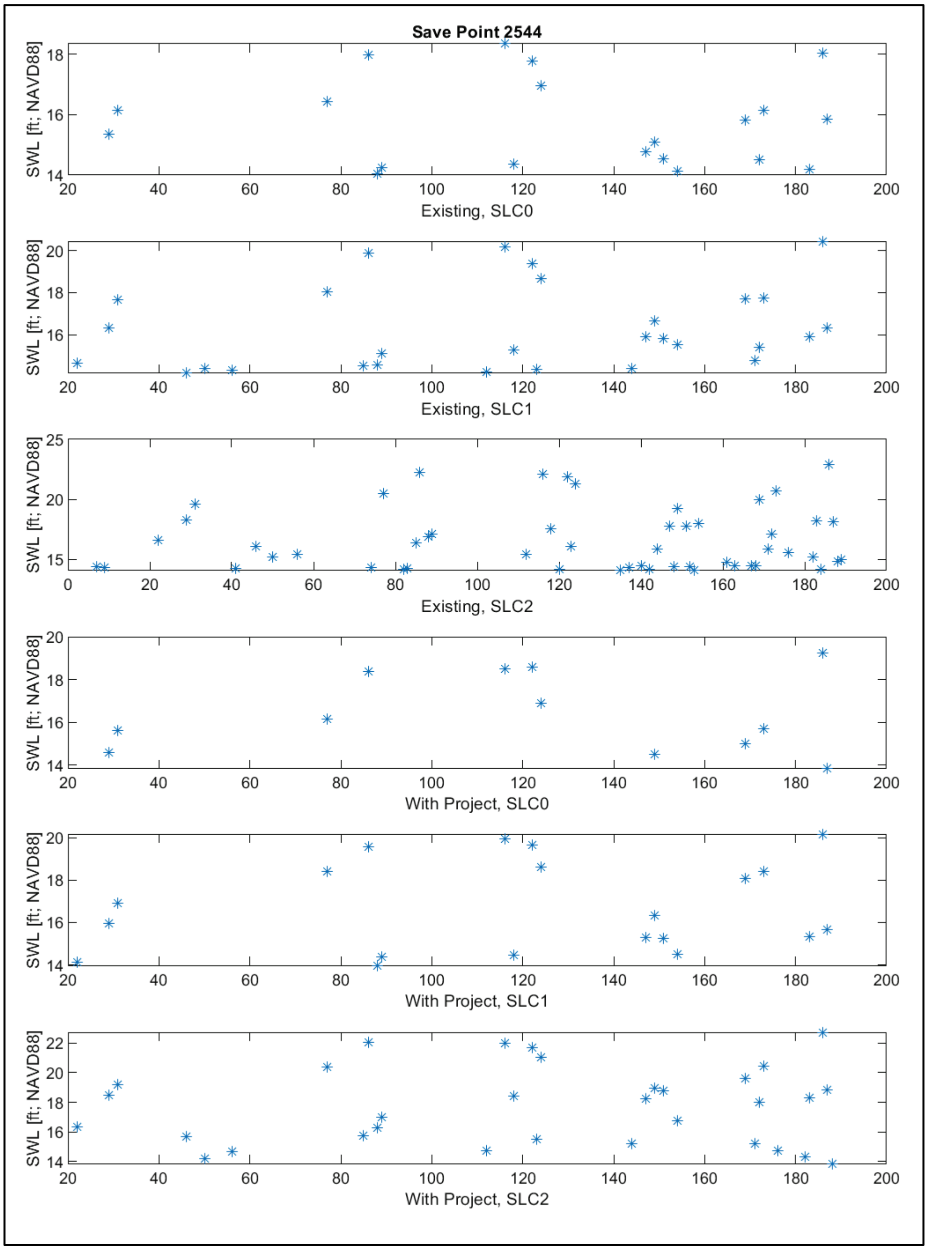


Figure A-7. Peak SWL for with-project and SLC2 for SPs in Contract 3 area. SWL is in feet, NAVD88.



Contract 3b

Figure A-8. Peak SWL for SP 2544 in Contract 3b area. SWL is in feet, NAVD88.



PA-W

Figure A-9. Peak SWL for without-project and SLC0 for SPs in PA-W area. SWL is in feet, NAVD88.

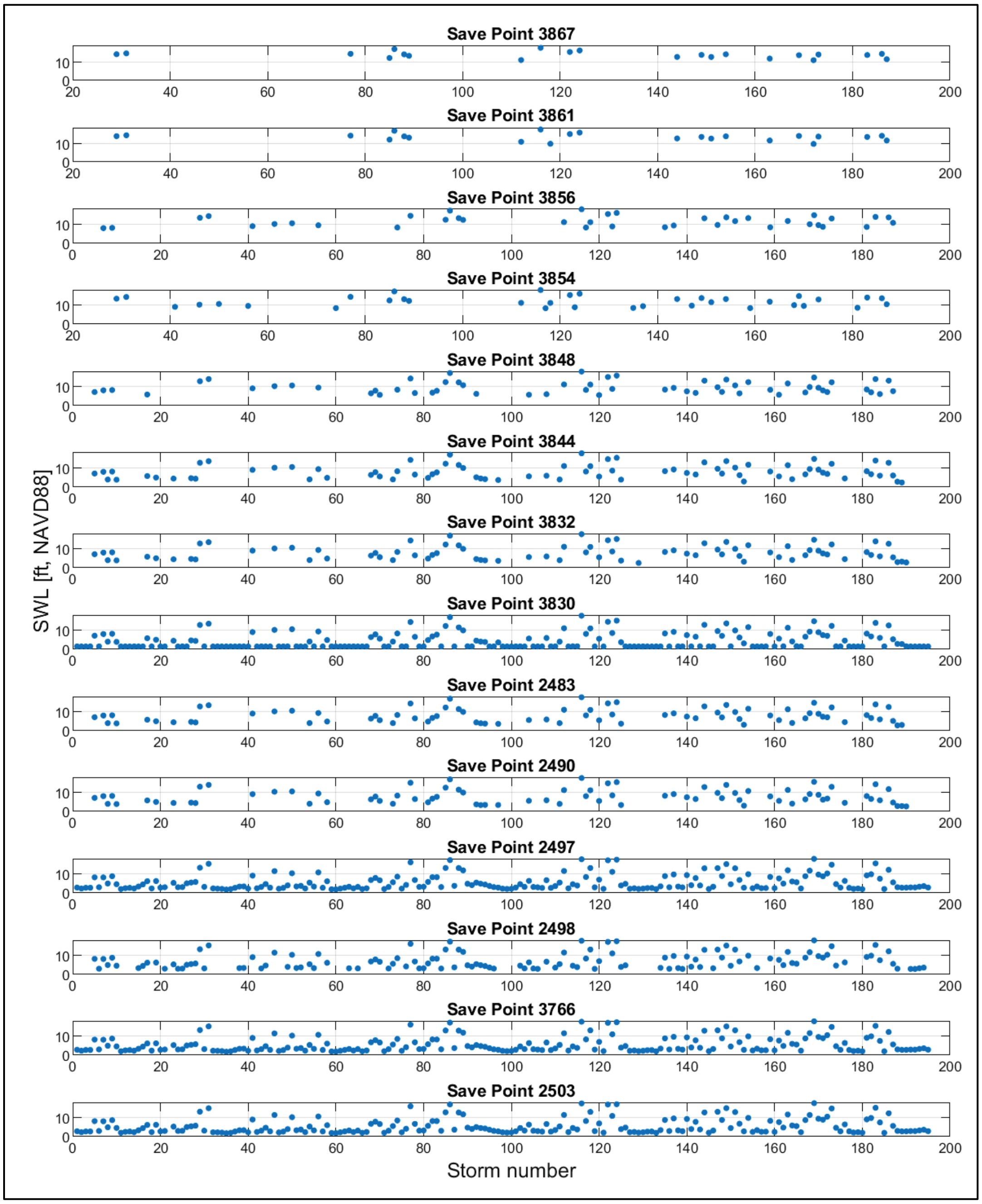


Figure A-10. Peak SWL for with-project and SLC1 for SPs in PA-W area. SWL is in feet, NAVD88.

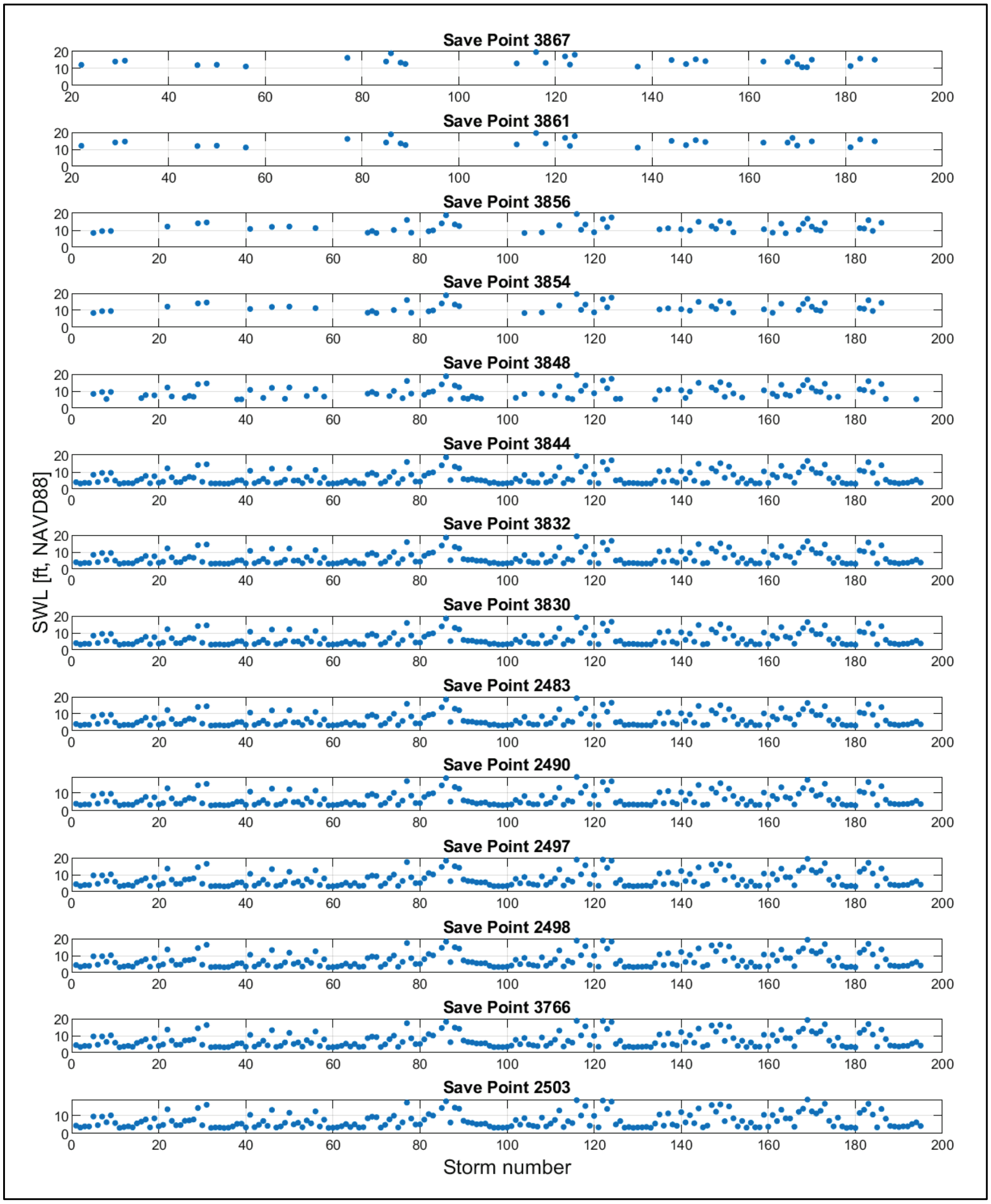
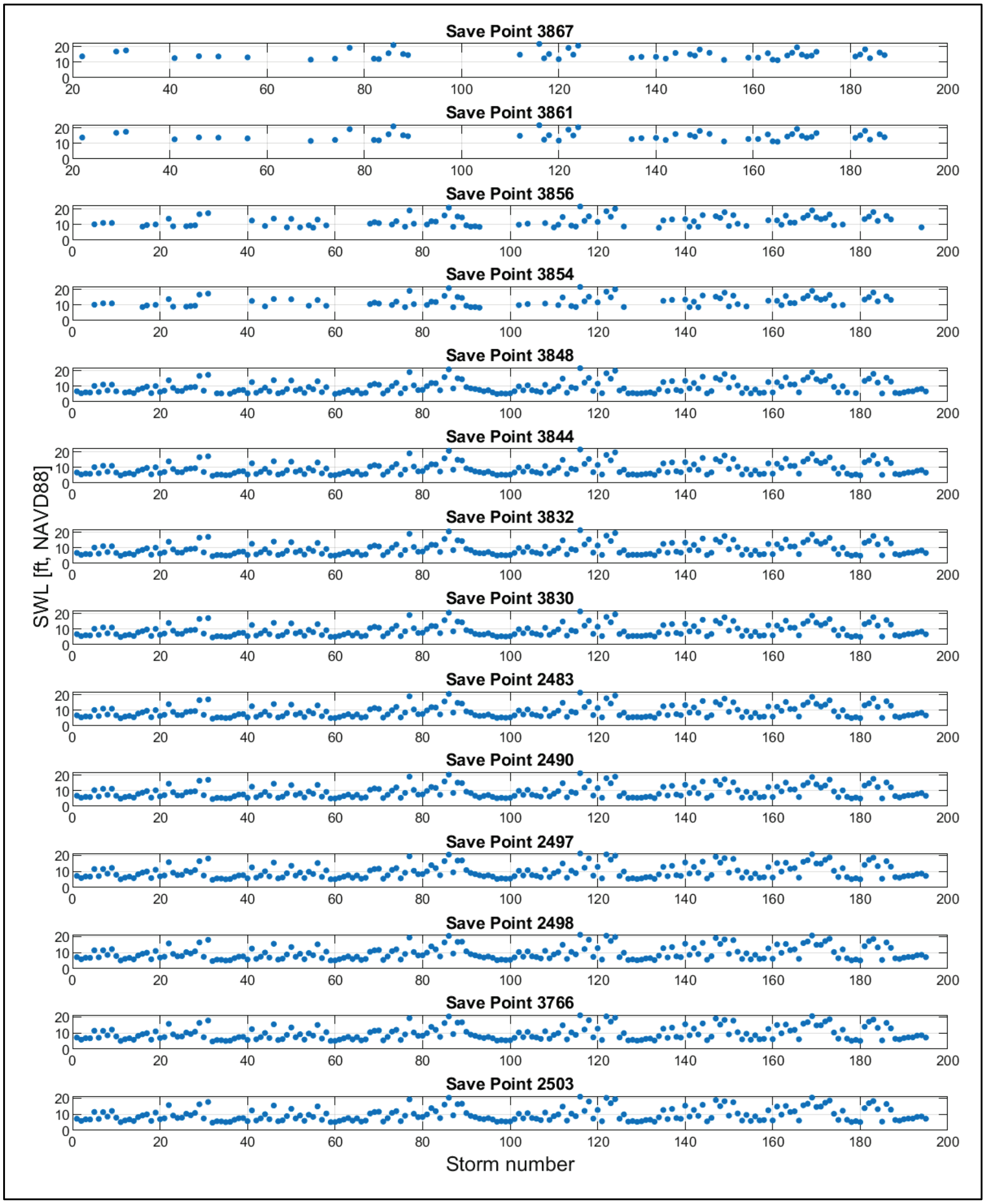


Figure A-11. Peak SWL for with-project and SLC2 for SPs in PA-W area. SWL is in feet, NAVD88.



PA-SW

Figure A-12. Peak SWL for without-project and SLC0 for SPs in PA-SW area. SWL is in feet, NAVD88.

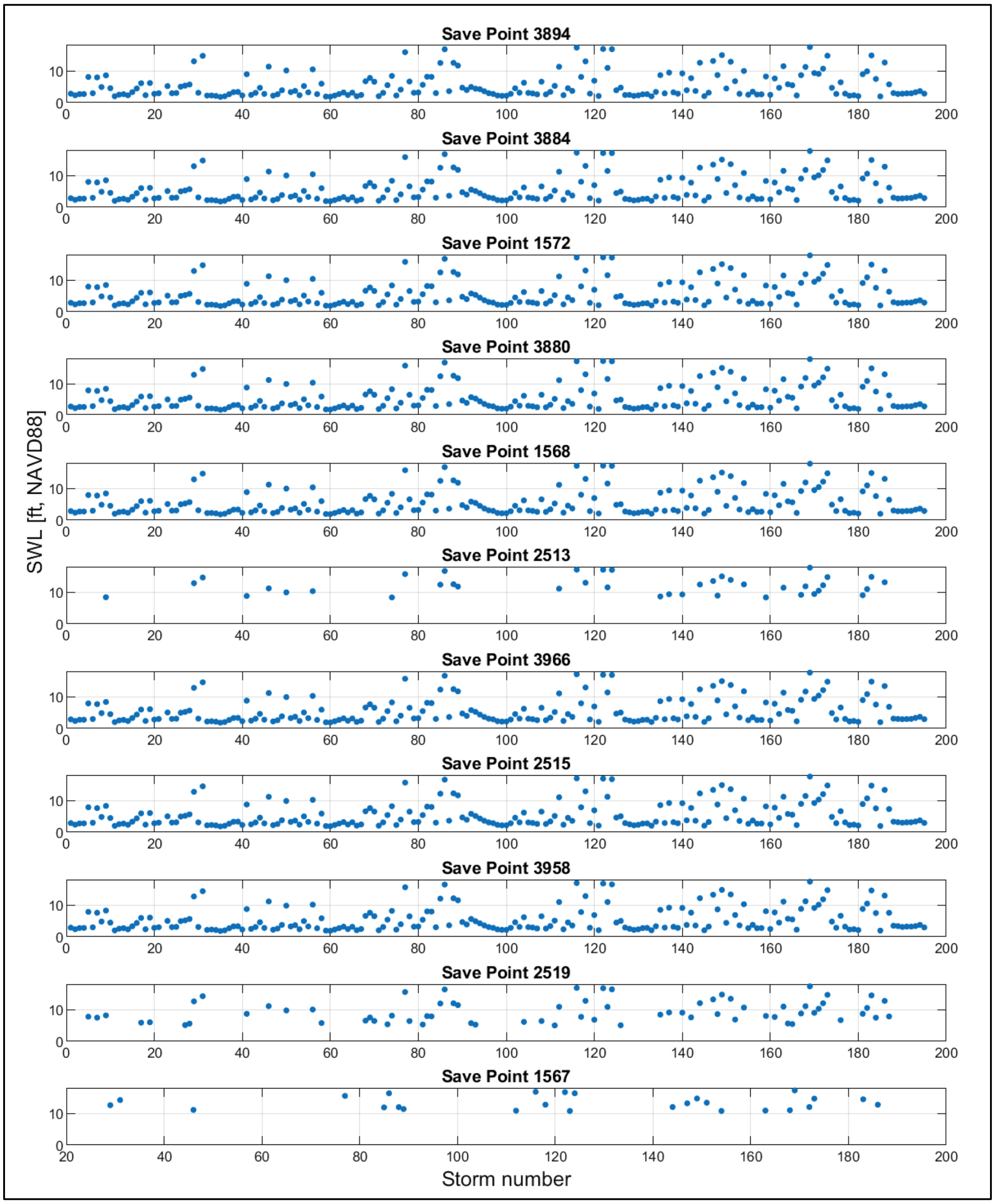


Figure A-13. Peak SWL for with-project and SLC1 for SPs in PA-SW area. SWL is in feet, NAVD88.

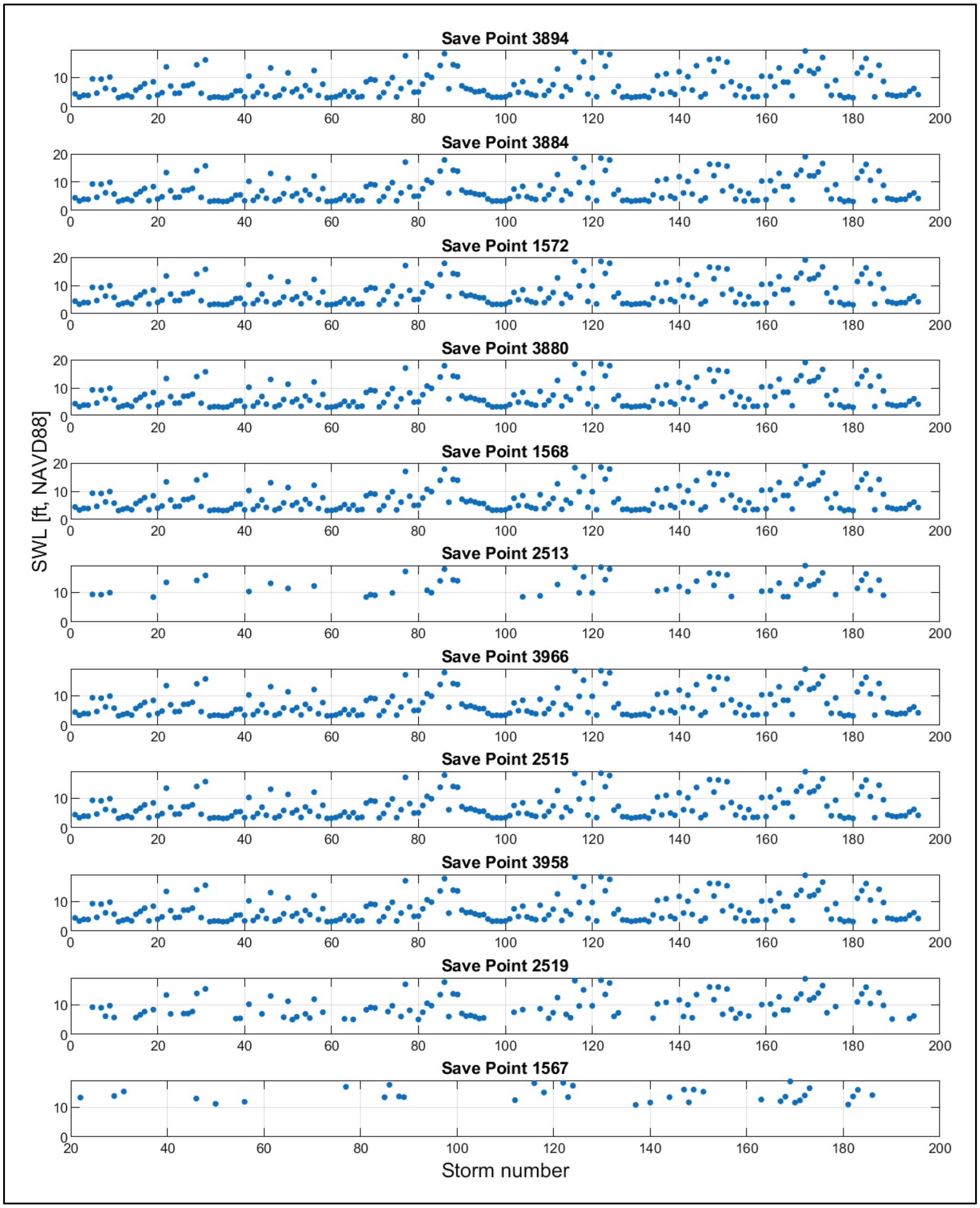
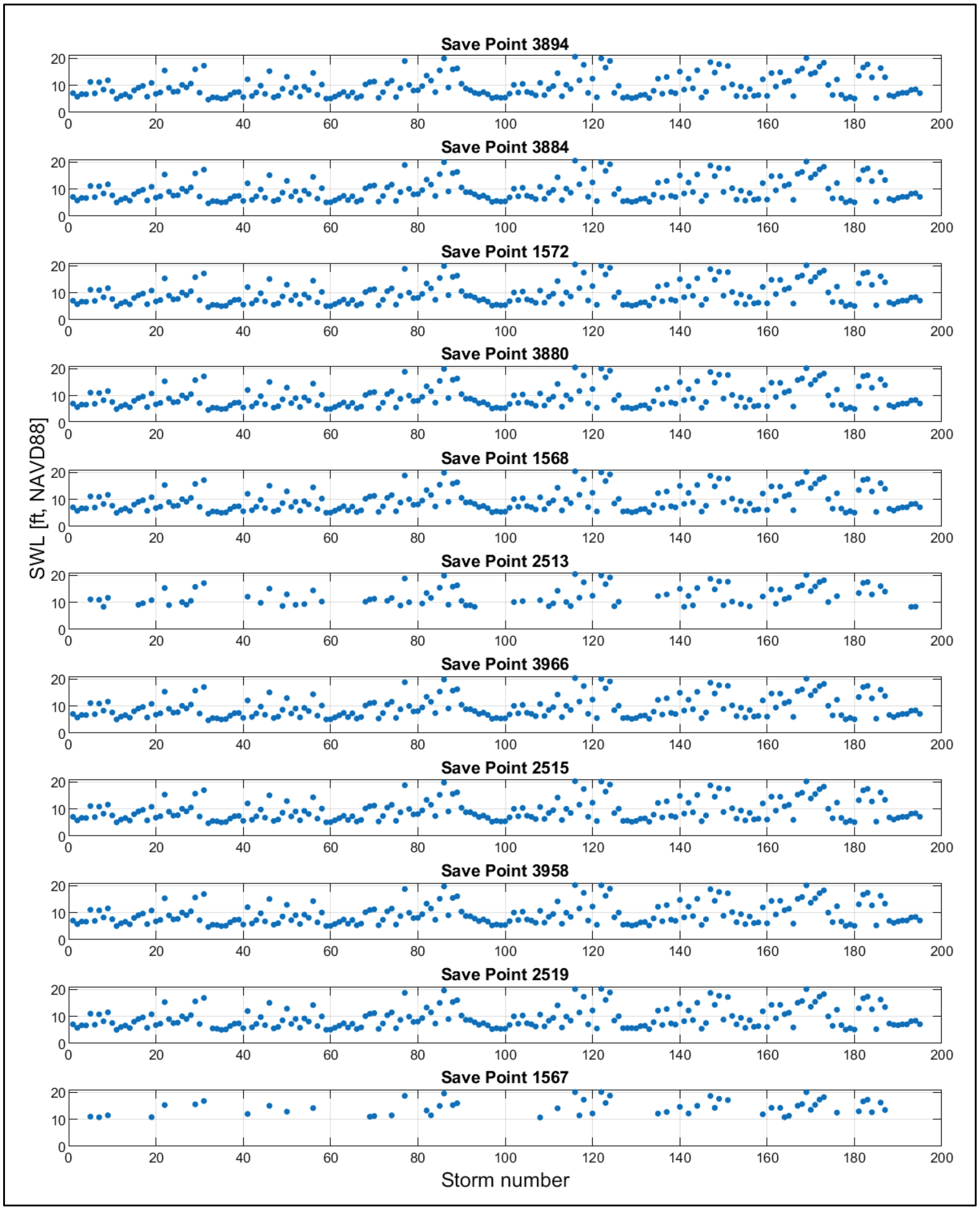


Figure A-14. Peak SWL for with-project and SLC2 for SPs in PA-SW area. SWL is in feet, NAVD88.



PA-SNWW1

Figure A-15. Peak SWL for without-project and SLC0 for SPs in PA-SNWW1 area. SWL is in feet, NAVD88.

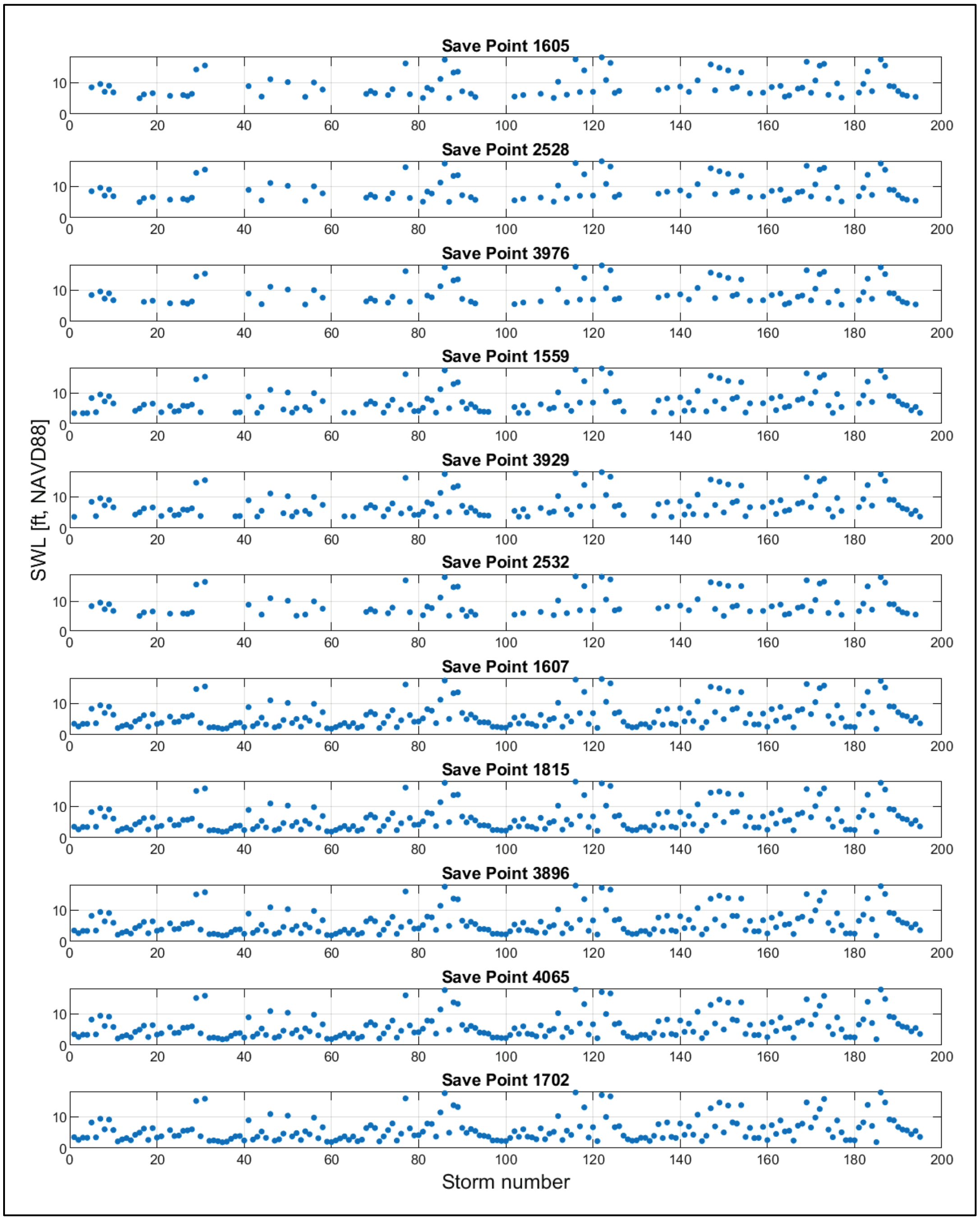


Figure A-16. Peak SWL for with-project and SLC1 for SPs in PA-SNWW1 area. SWL is in feet, NAVD88.

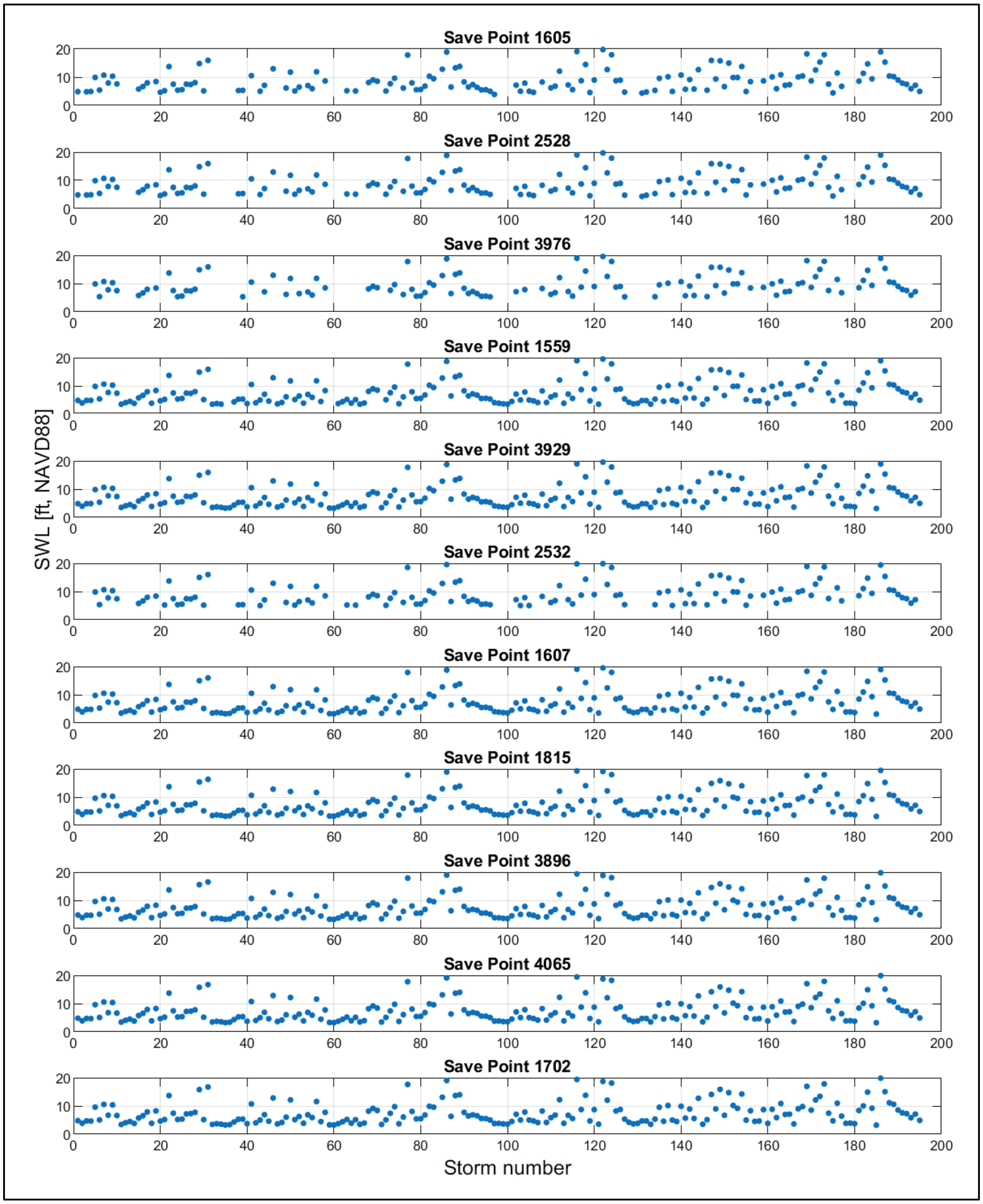
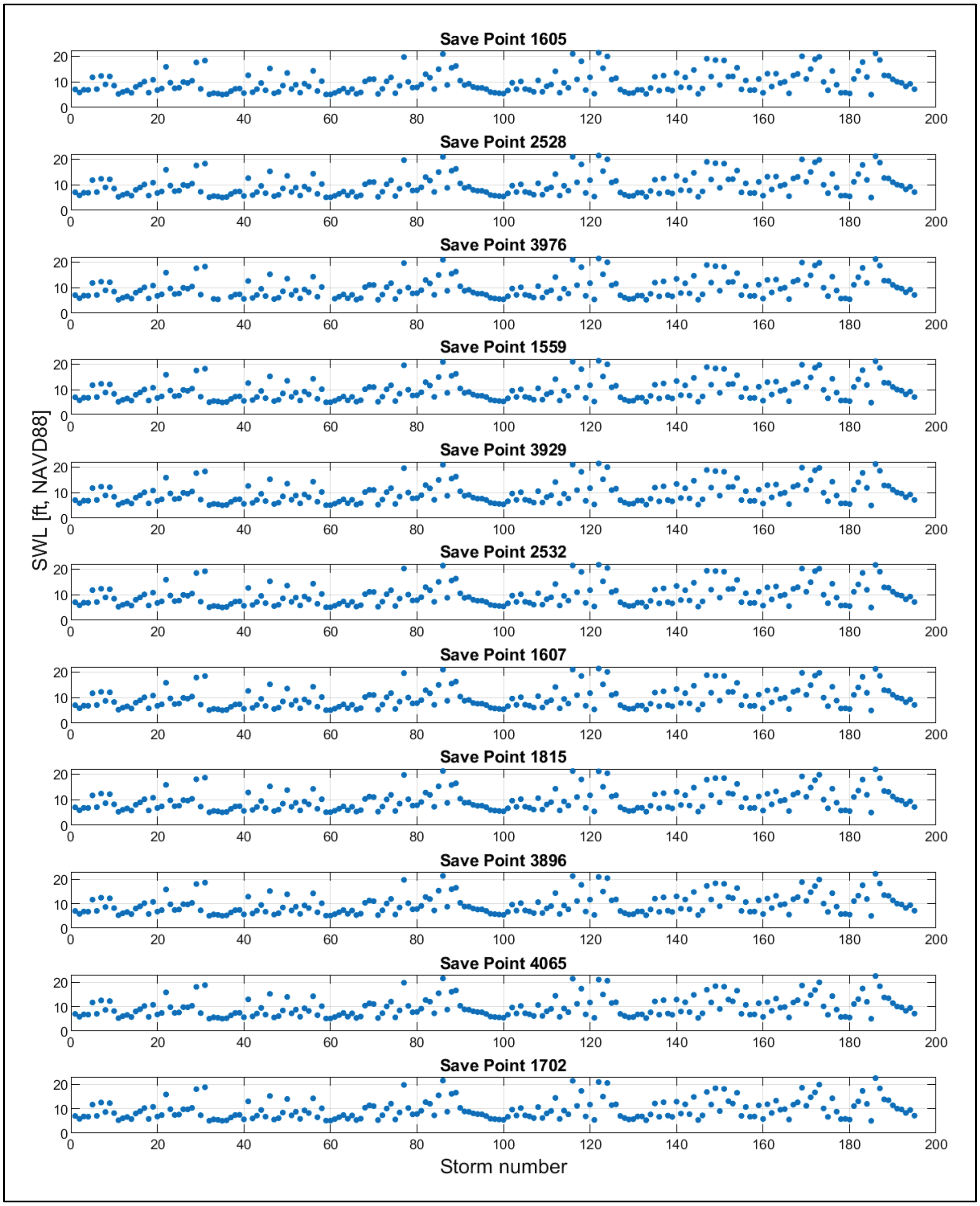


Figure A-17. Peak SWL for with-project and SLC2 for SPs in PA-SNWW1 area. SWL is in feet, NAVD88.



PA-SNWW2

Figure A-18. Peak SWL for without-project and SLC0 for SPs in PA-SNWW2 area. SWL is in feet, NAVD88.

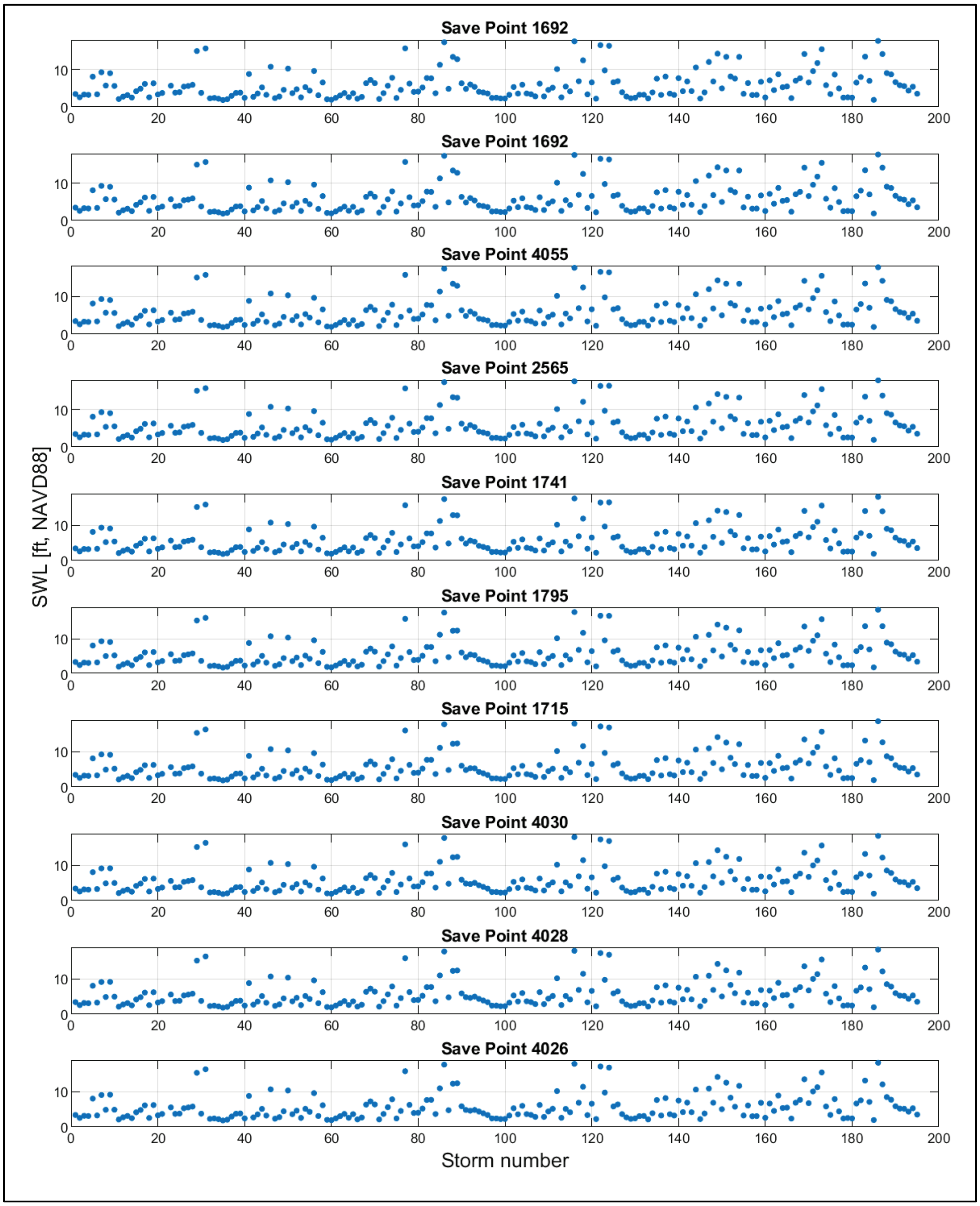


Figure A-19. Peak SWL for with-project and SLC1 for SPs in PA-SNWW2 area. SWL is in feet, NAVD88.

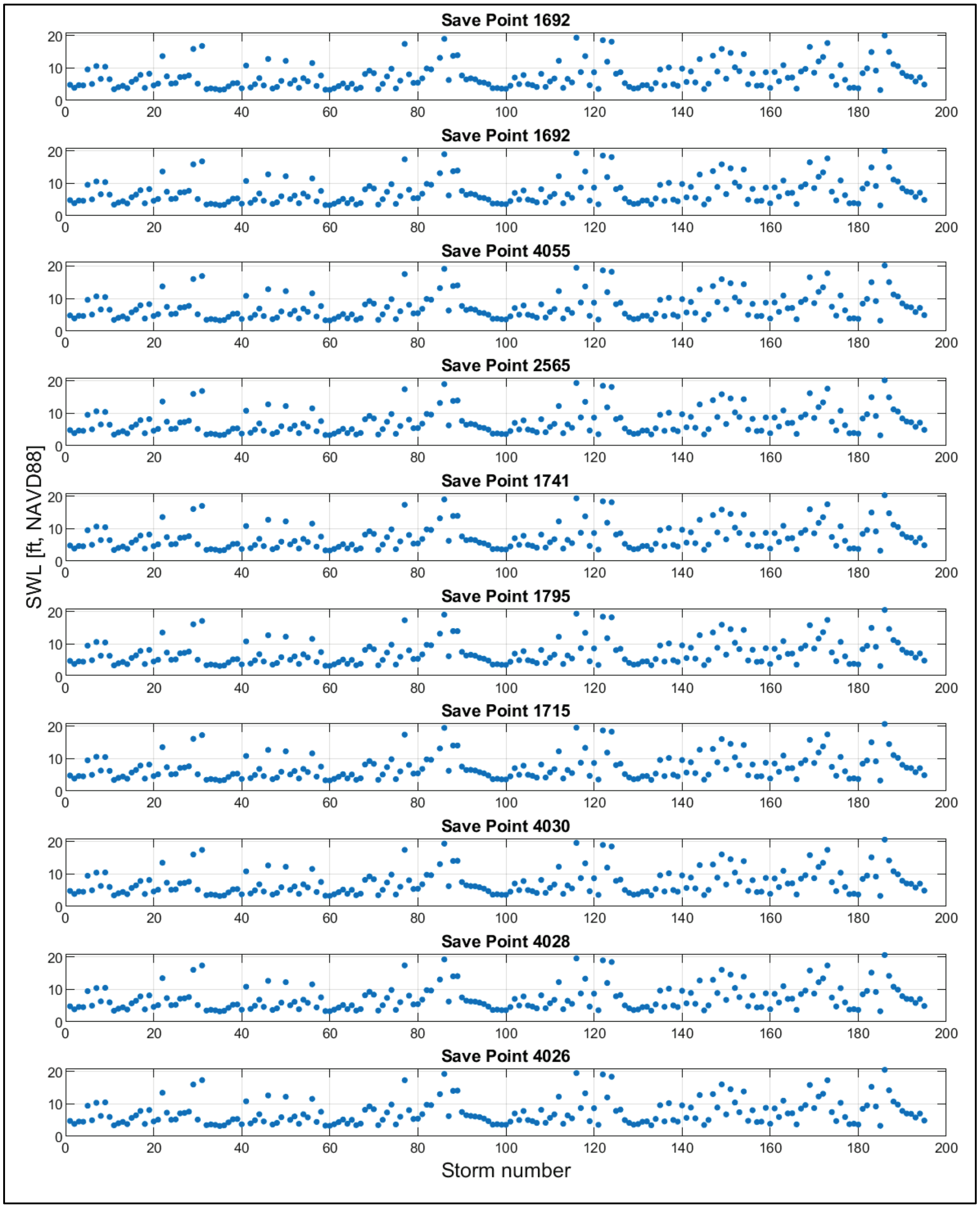
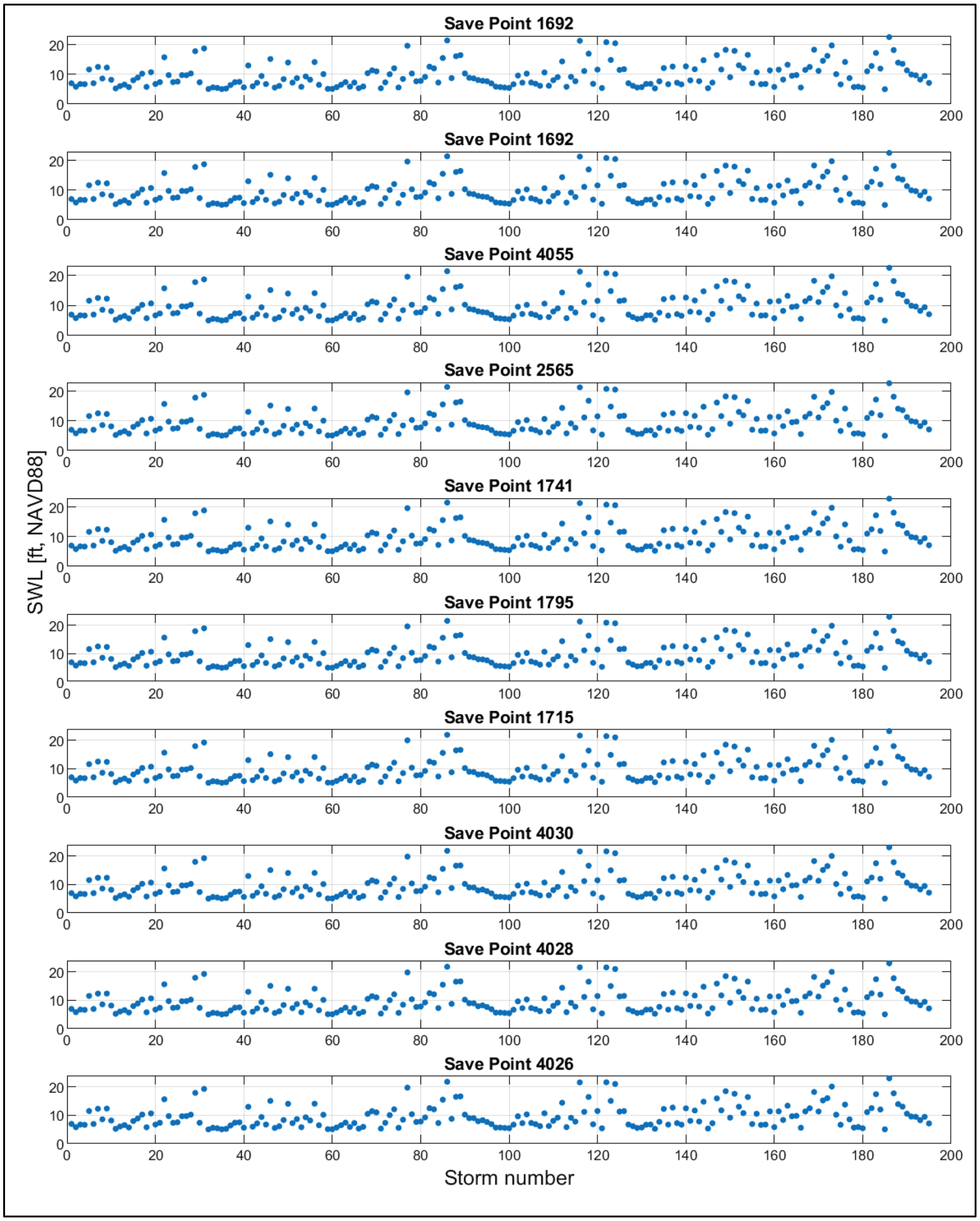


Figure A-20. Peak SWL for with-project and SLC2 for SPs in PA-SNWW2 area. SWL is in feet, NAVD88.



PA-SNWW3

Figure A-21. Peak SWL for without-project and SLC0 for SPs in PA-SNWW3 area. SWL is in feet, NAVD88.

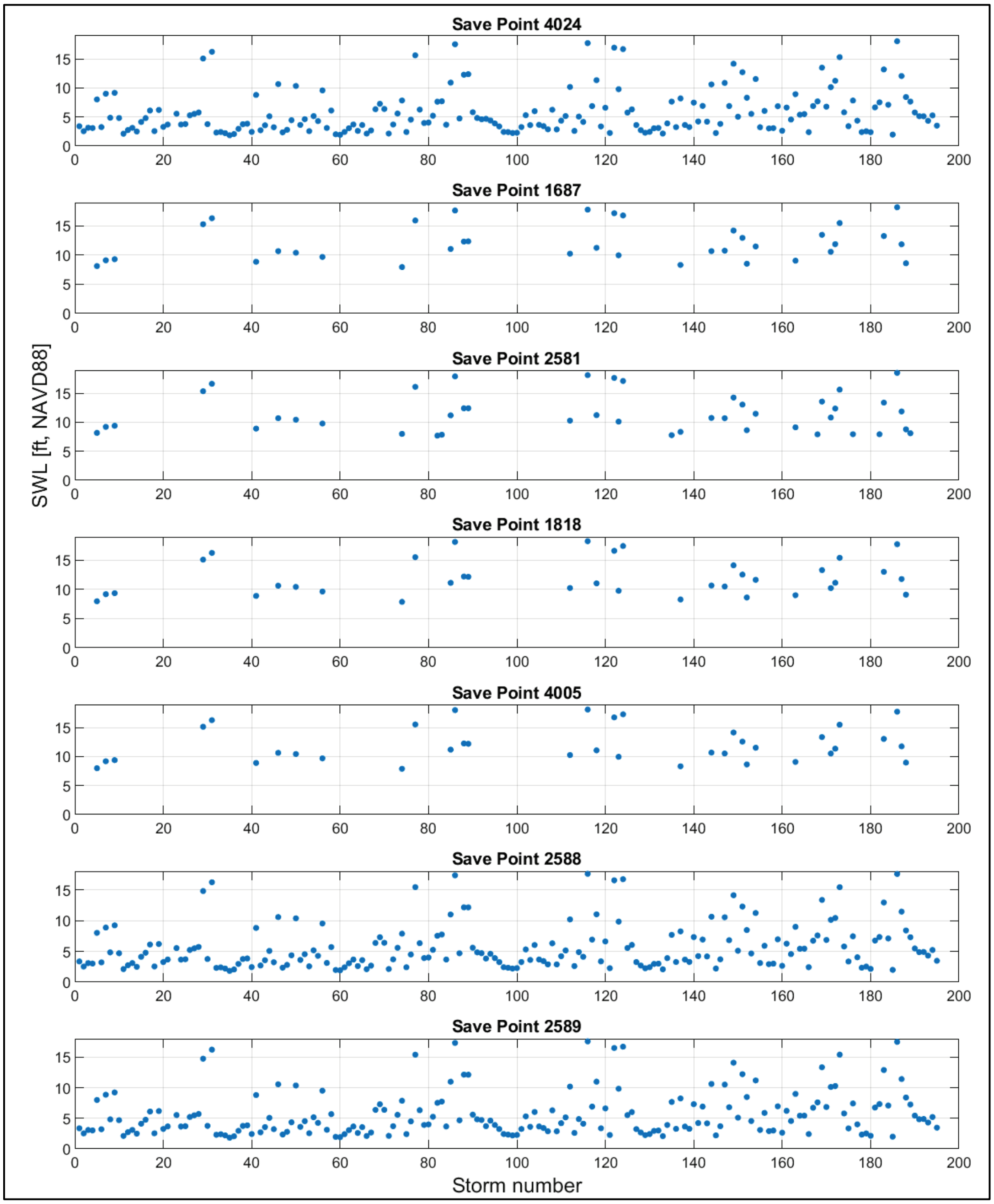


Figure A-22. Peak SWL for with-project and SLC1 for SPs in PA-SNWW3 area. SWL is in feet, NAVD88.

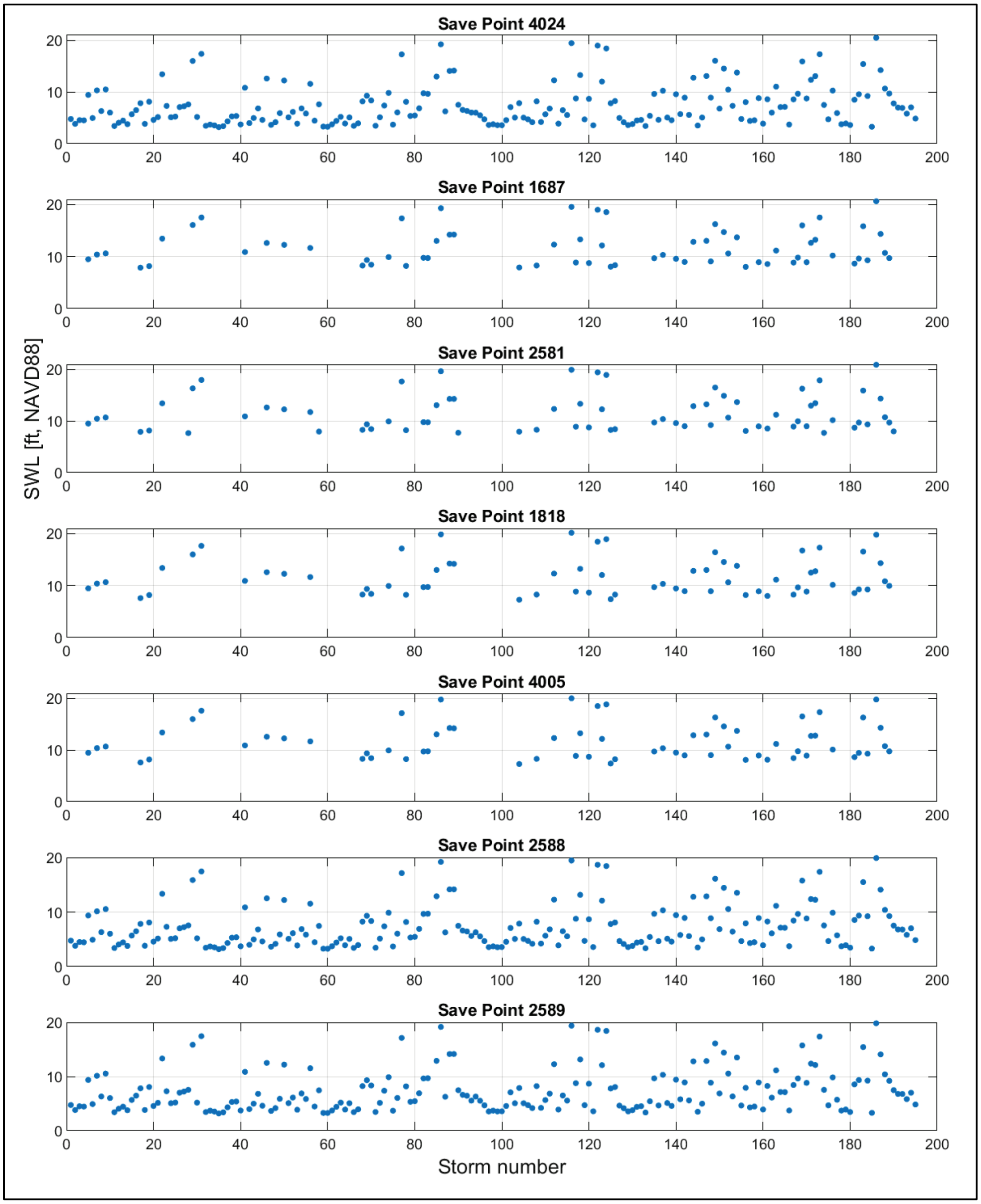
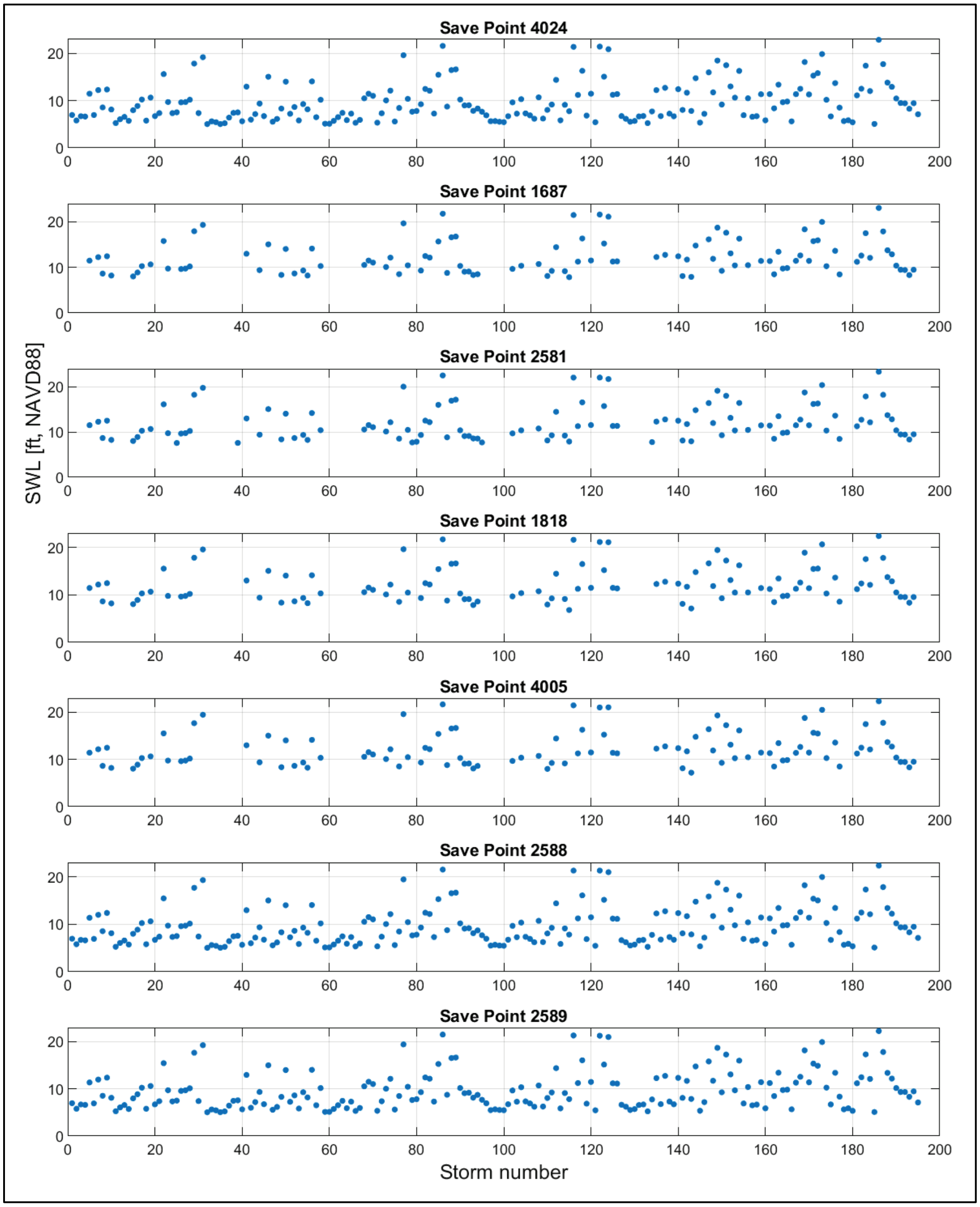


Figure A-23. Peak SWL for with-project and SLC2 for SPs in PA-SNWW3 area. SWL is in feet, NAVD88.



PA-NE

Figure A-24. Peak SWL for without-project and SLC0 for SPs in PA-NE area. SWL is in feet, NAVD88.

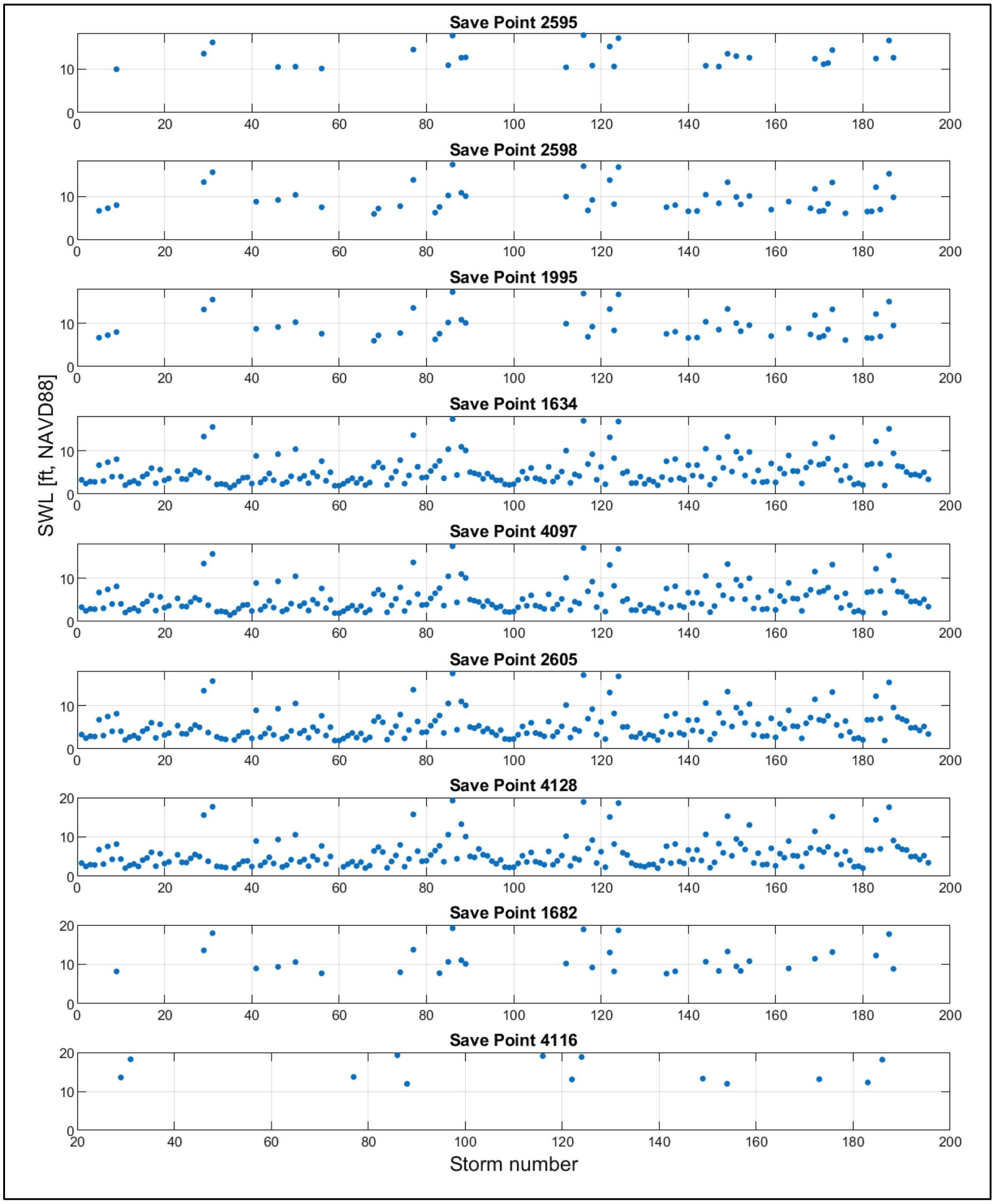


Figure A-25. Peak SWL for with-project and SLC1 for SPs in PA-NE area. SWL is in feet, NAVD88.

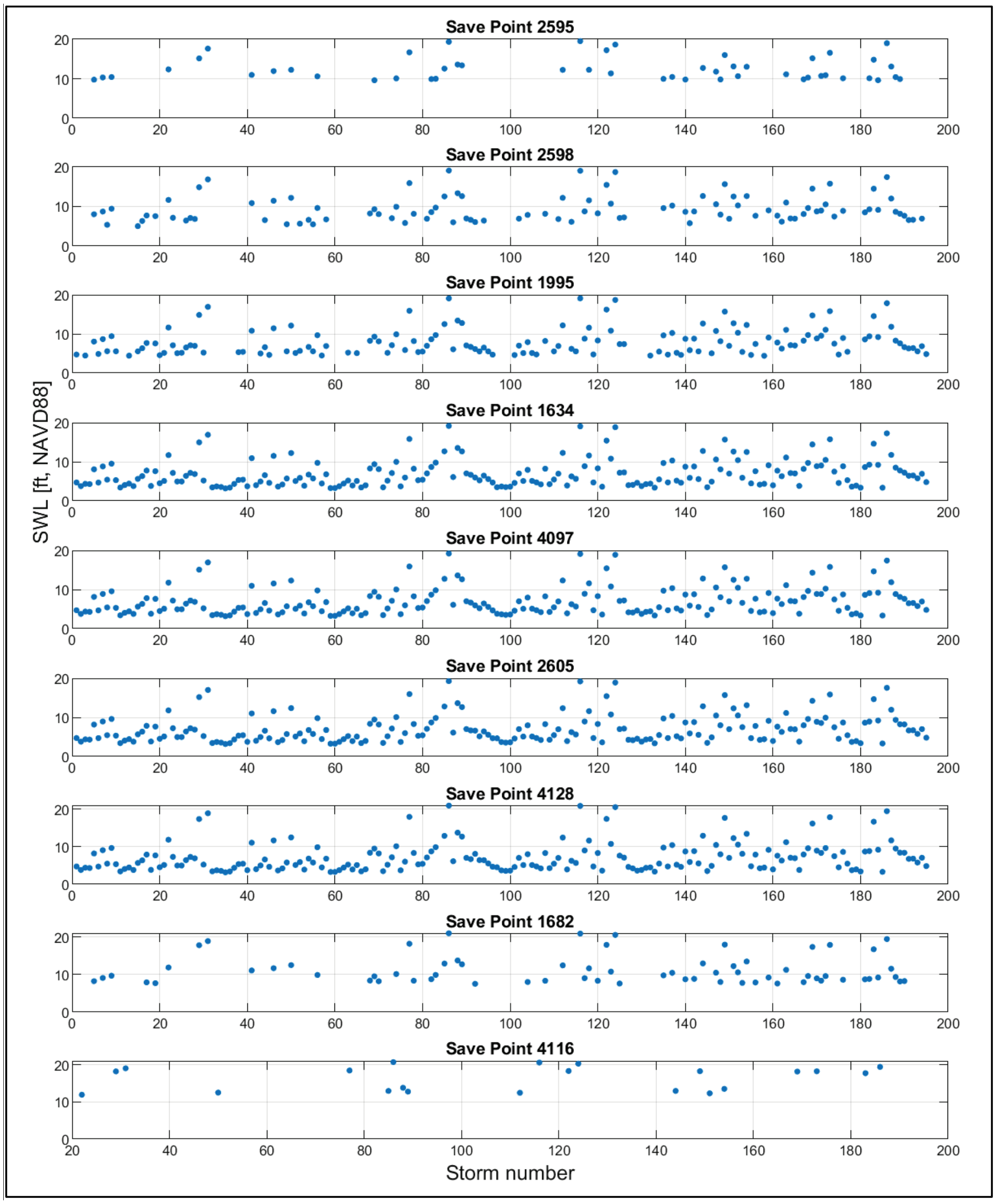
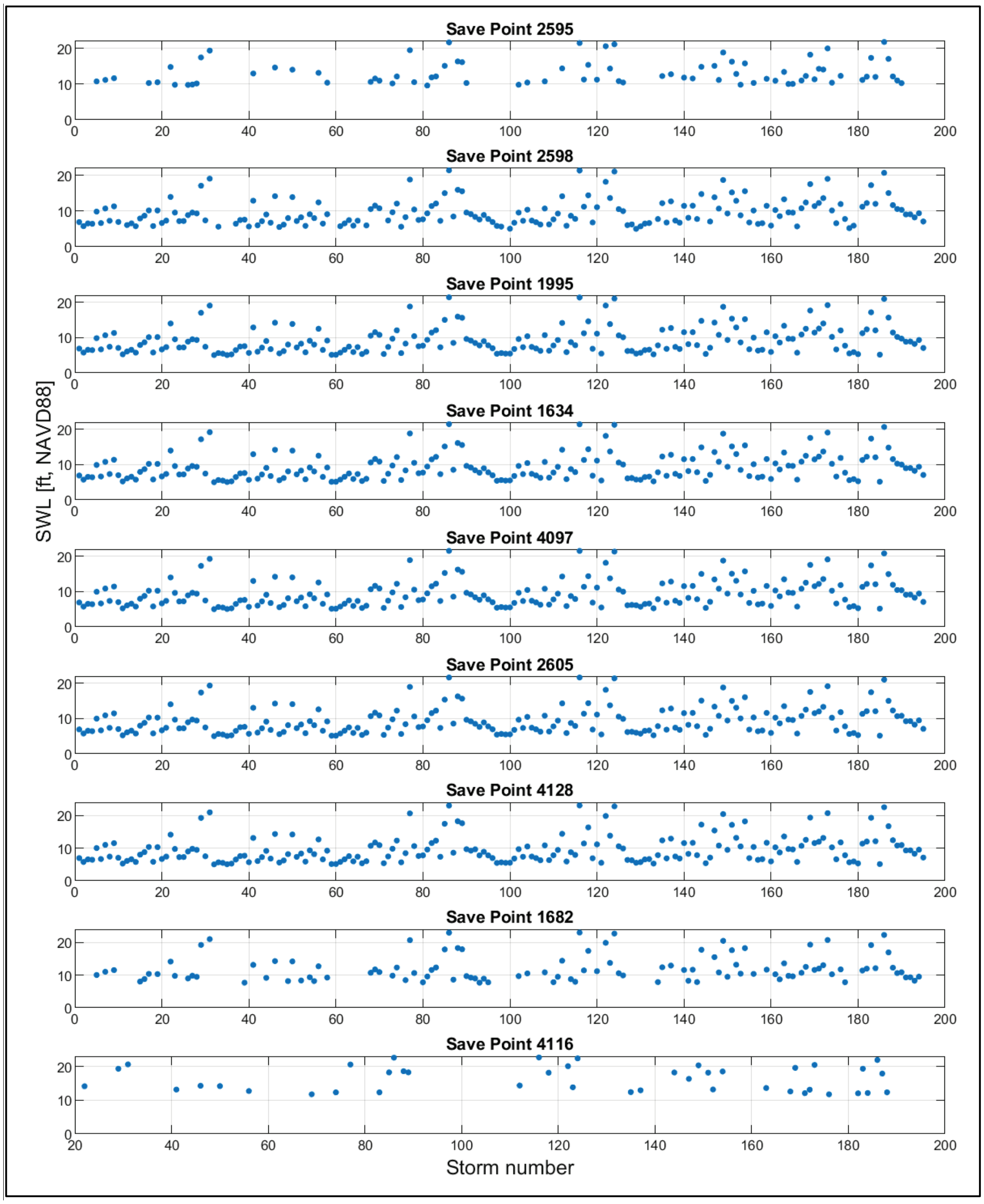


Figure A-26. Peak SWL for with-project and SLC2 for SPs in PA-NE area. SWL is in feet, NAVD88.



Appendix B: Peak Wave Height (H_{m0}) by Storm

Contract 1

Figure B-1. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in Contract 1 area.

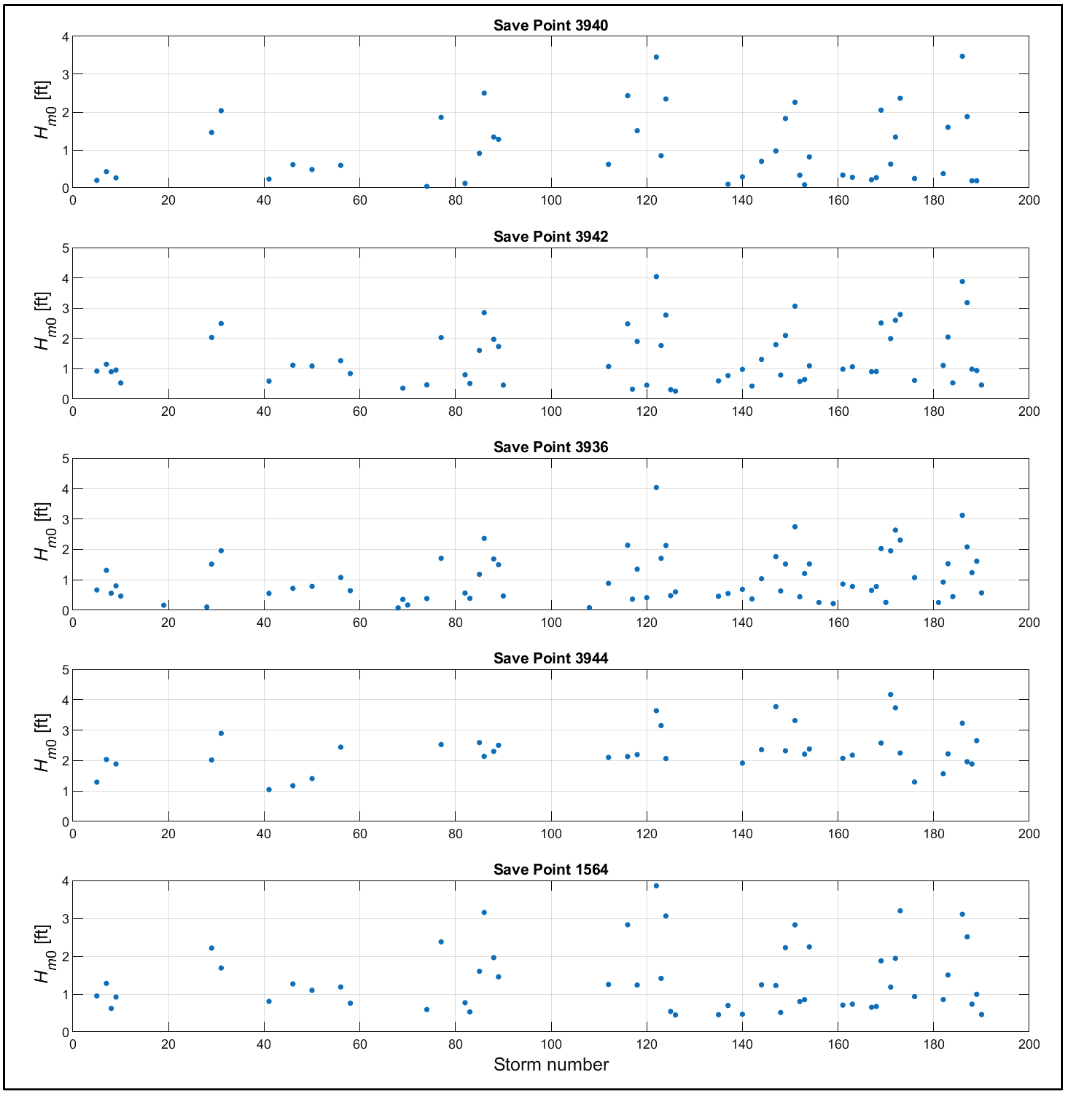


Figure B-2. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in Contract 1 area.

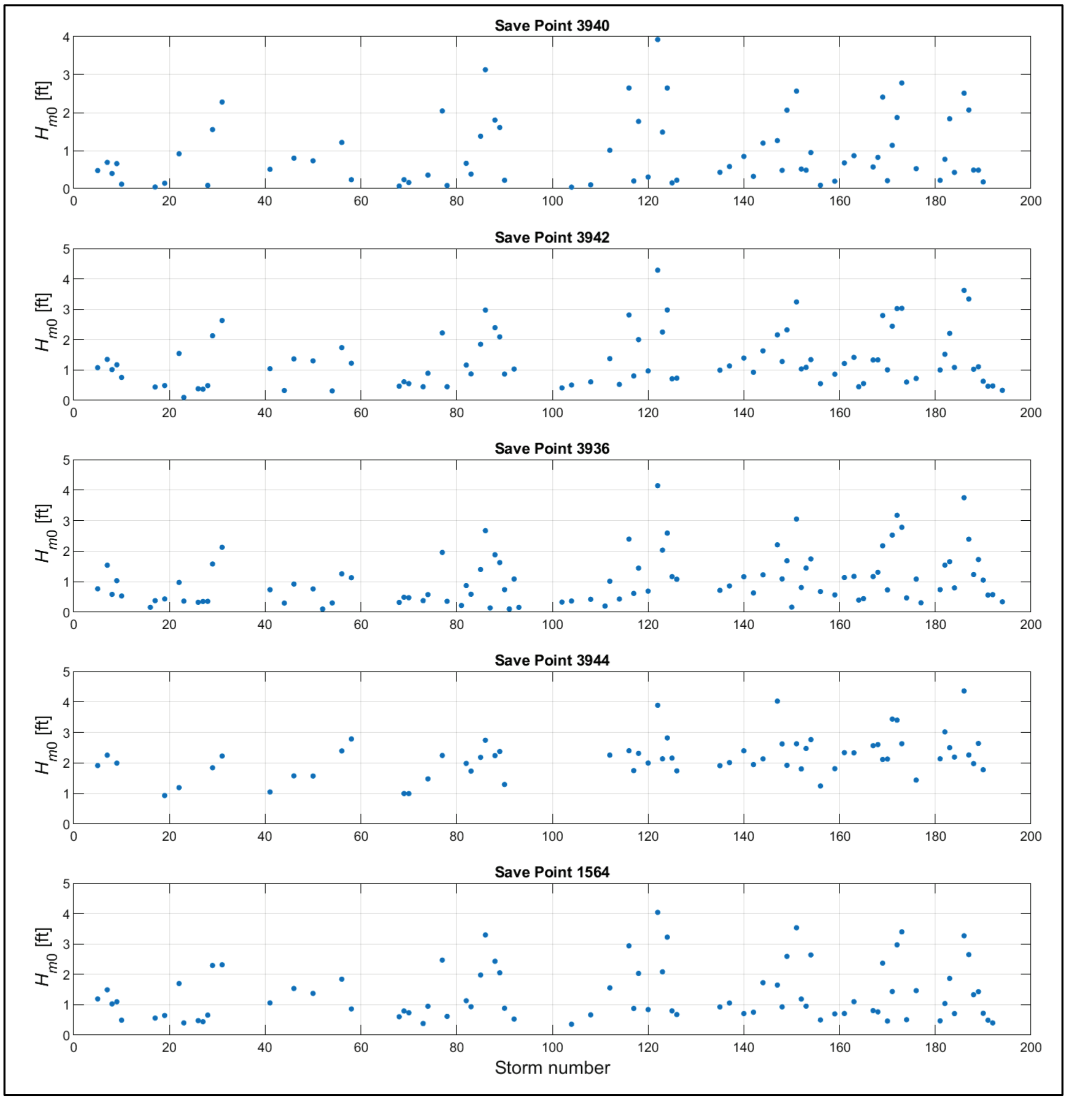
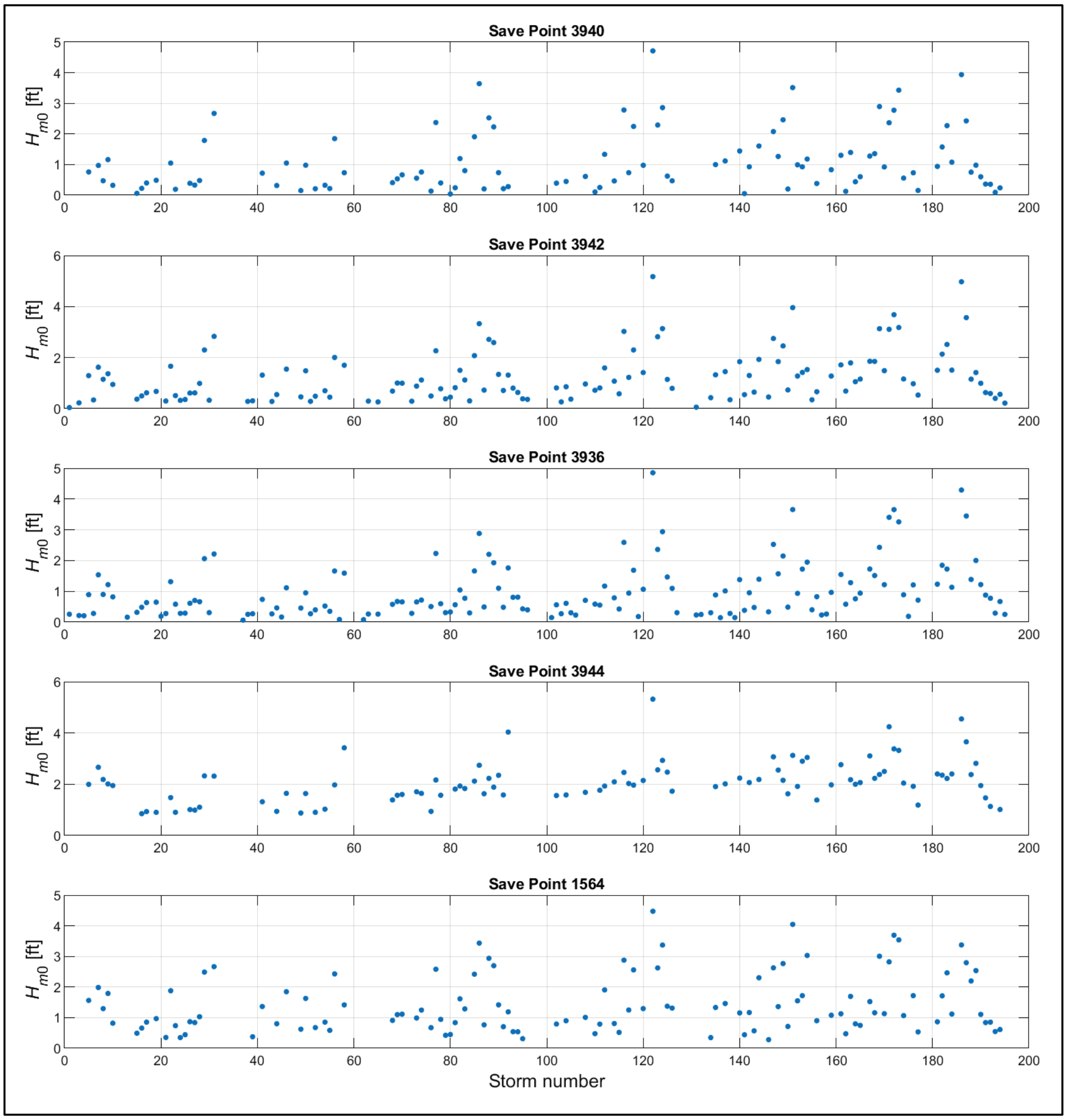
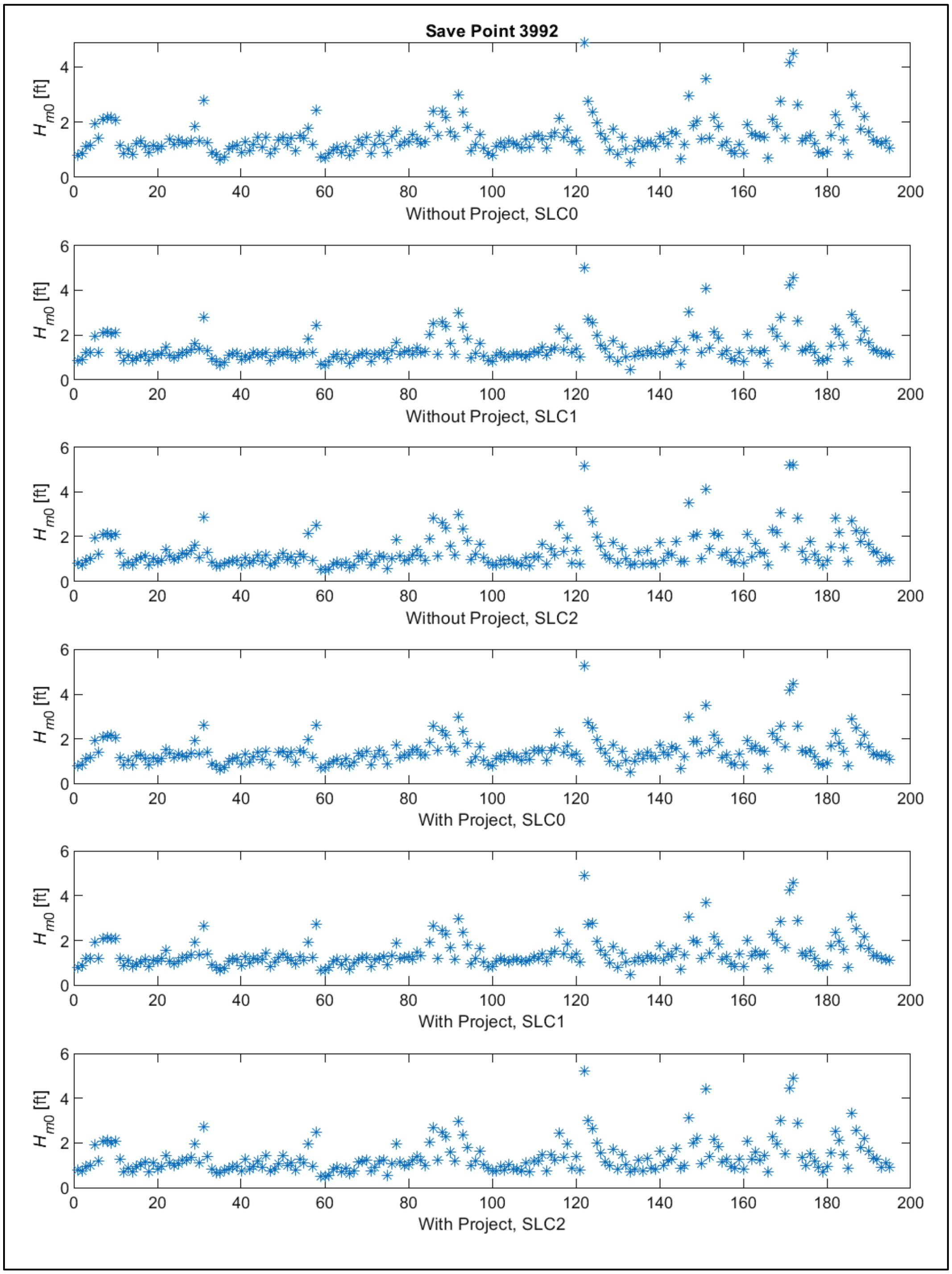


Figure B-3. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in Contract 1 area.



Contract 2

Figure B-4. Peak H_{m0}, in feet, for SP 3992. The top three plots are for without-project conditions under scenarios SLC0, SLC1, and SLC2, respectively. The bottom three plots are for with-project conditions under scenarios SLC0, SLC1, and SLC2, respectively.



Contract 3

Figure B-5. Peak H_{m0}, in feet, for without-project and SLCO for SPs in Contract 3 area.

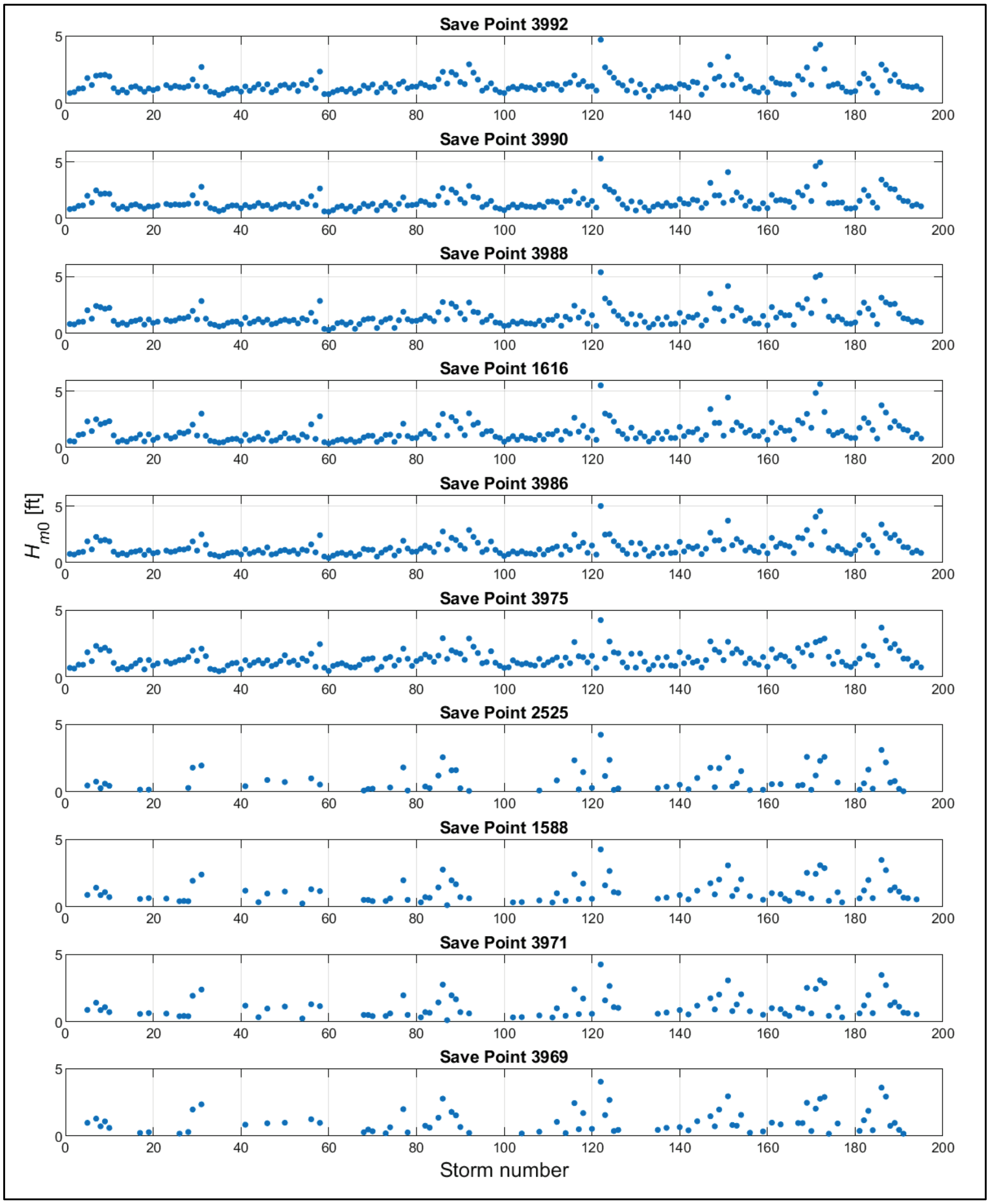


Figure B-6. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in Contract 3 area.

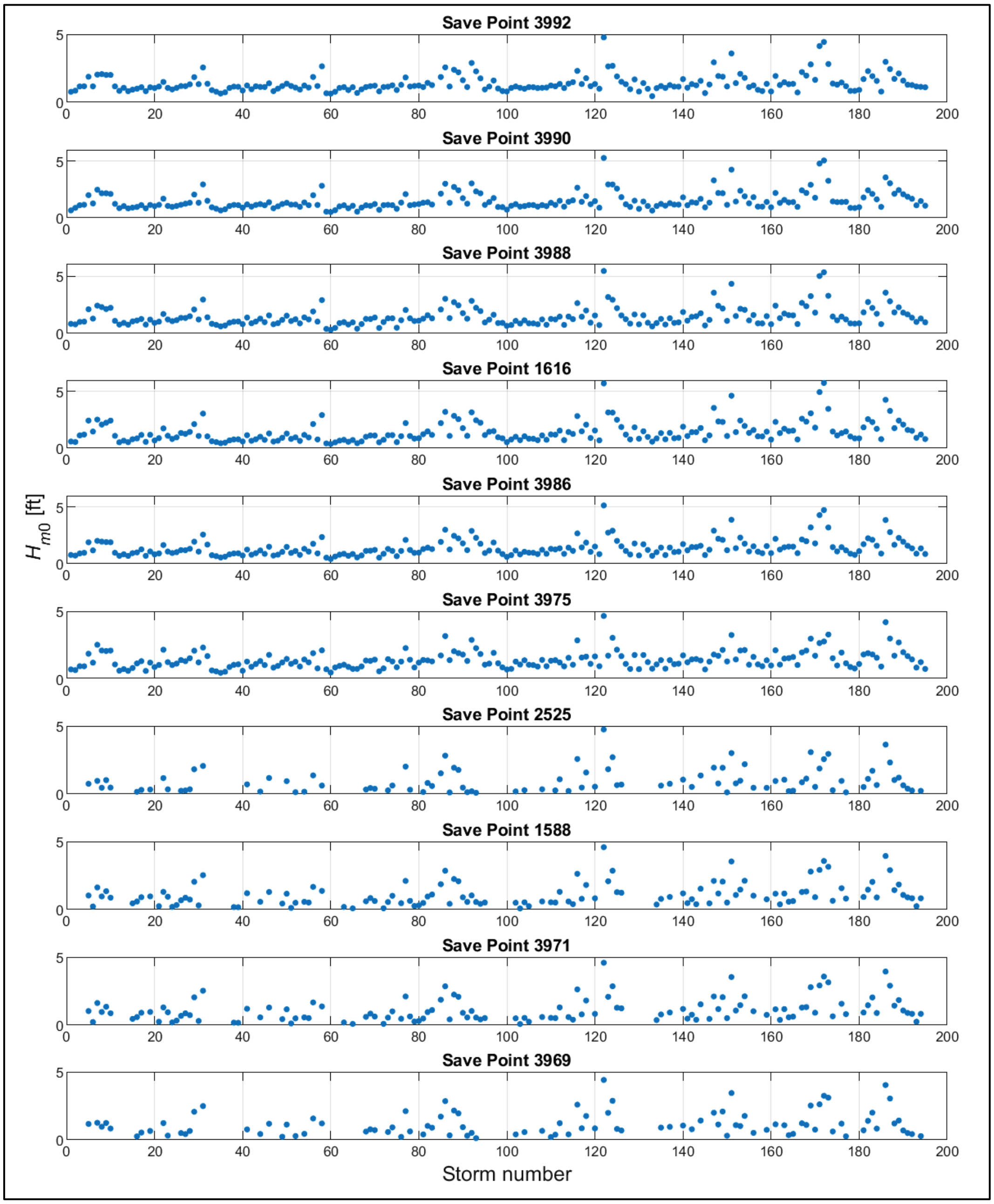
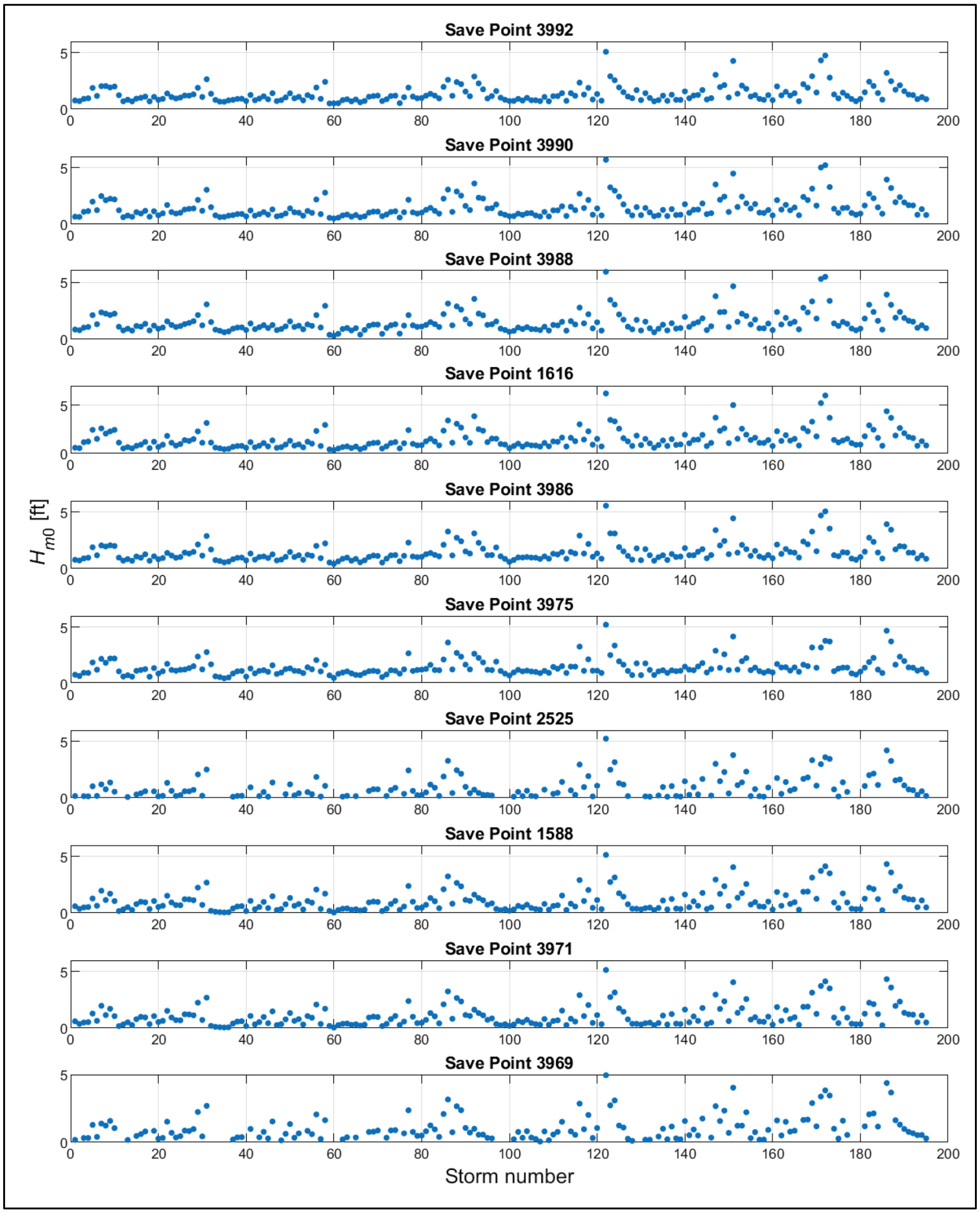
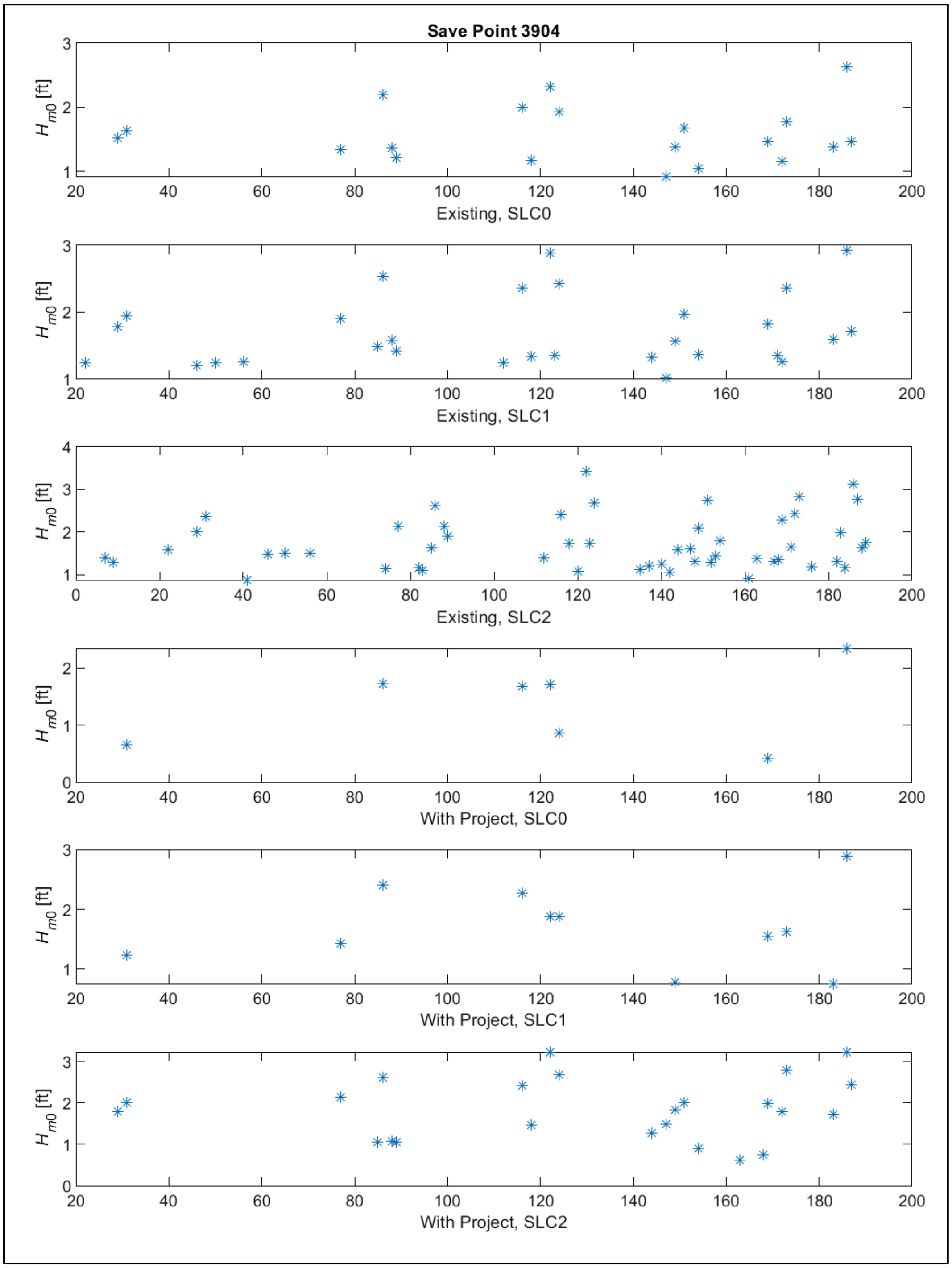


Figure B-7. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in Contract 3 area.



Contract 3b

Figure B-8. Peak H_{m0}, in feet, for SP 3904 in Contract 3b area.



PA- W

Figure B-9. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-W area.

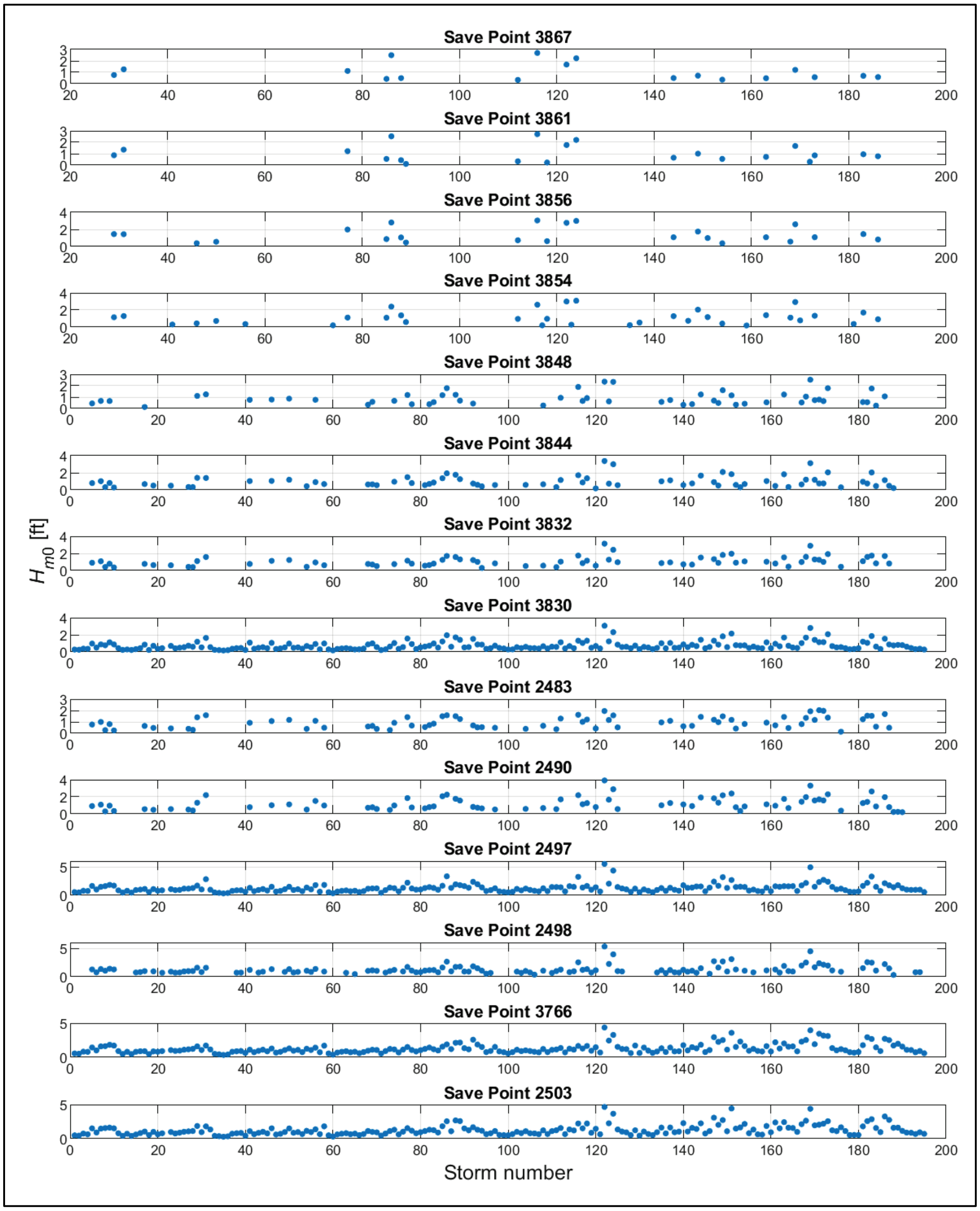


Figure B-10. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in PA-W area.

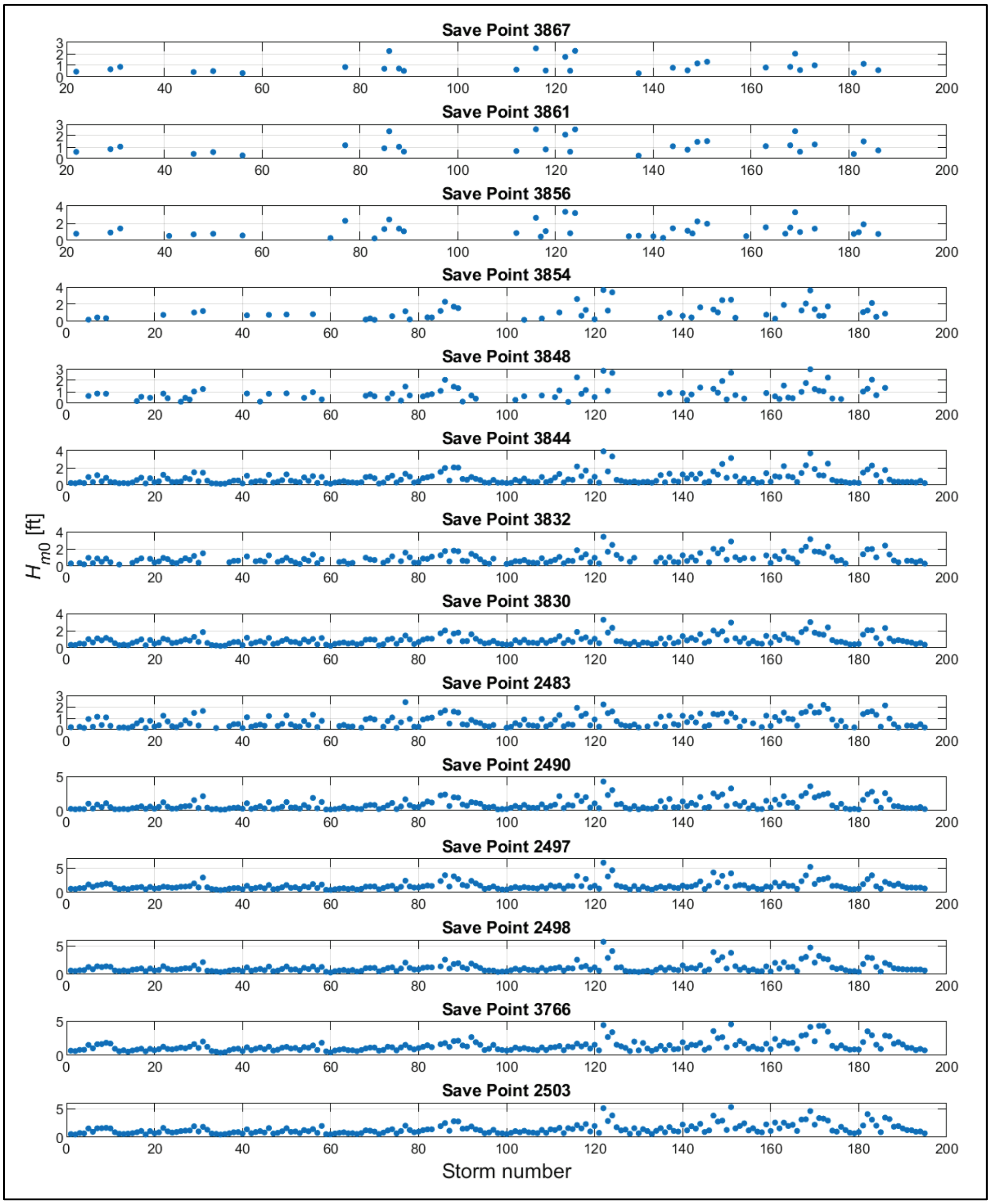
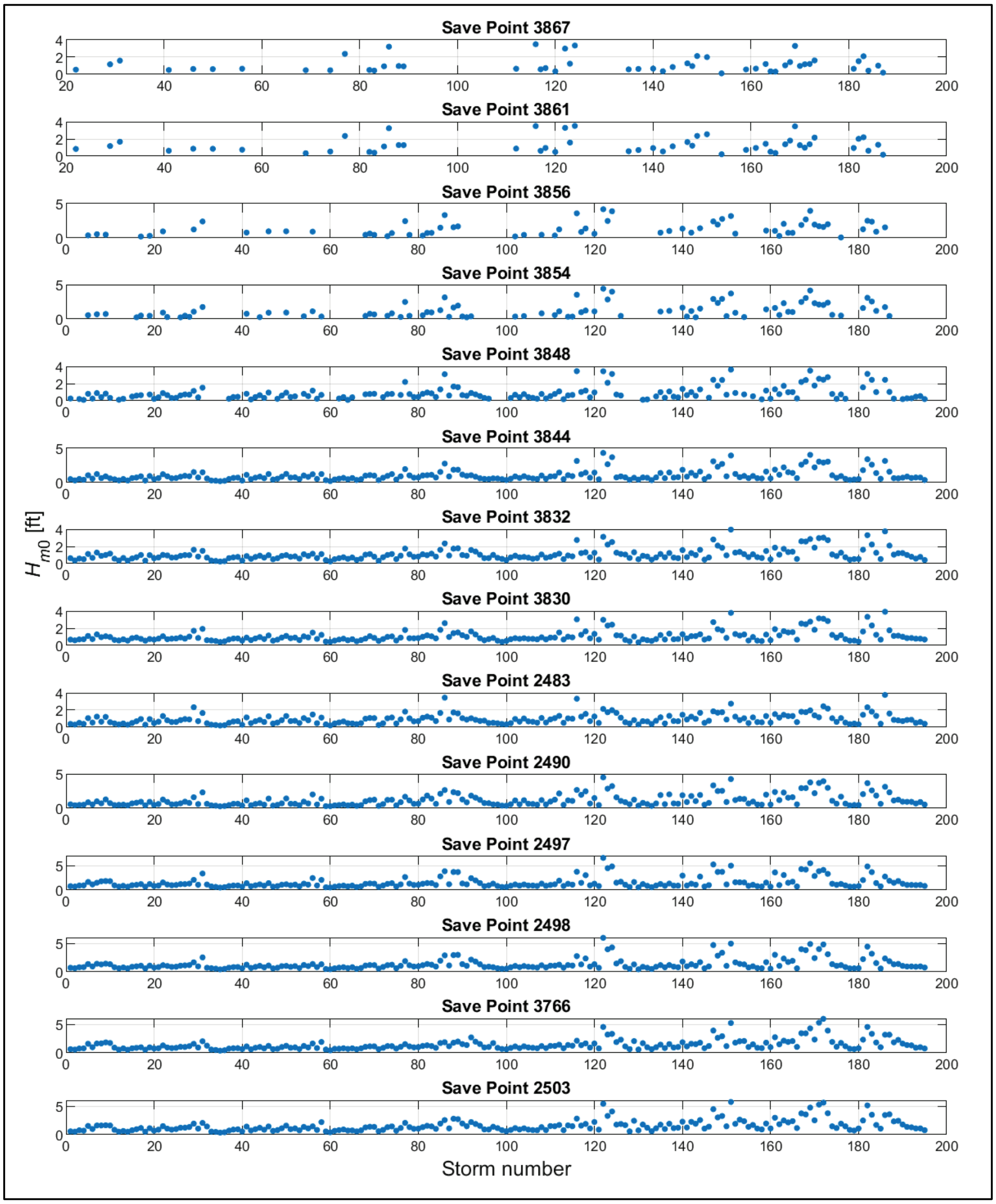


Figure B-11. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-W area.



PA-SW

Figure B-12. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-SW area.

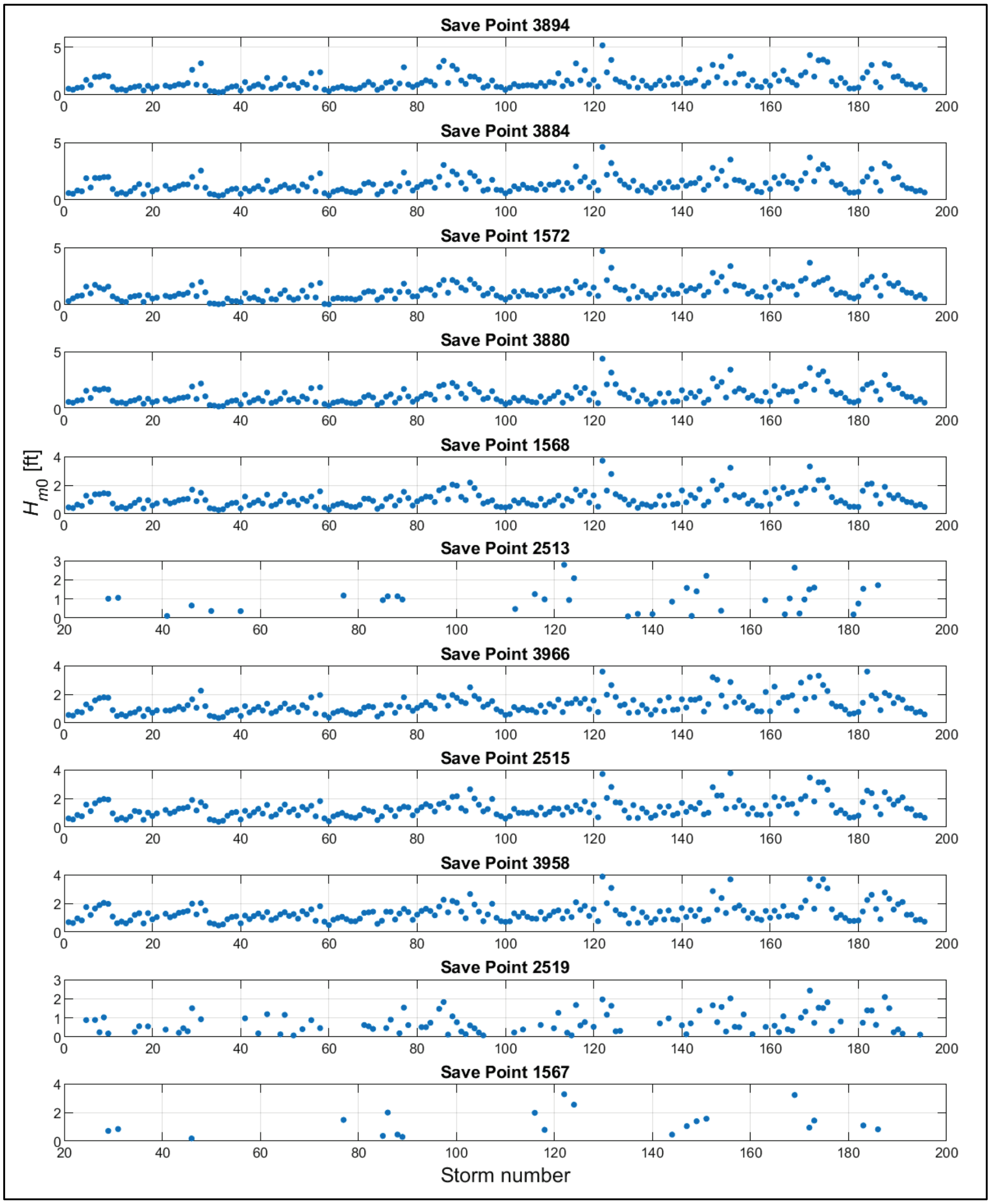


Figure B-13. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in PA-SW area.

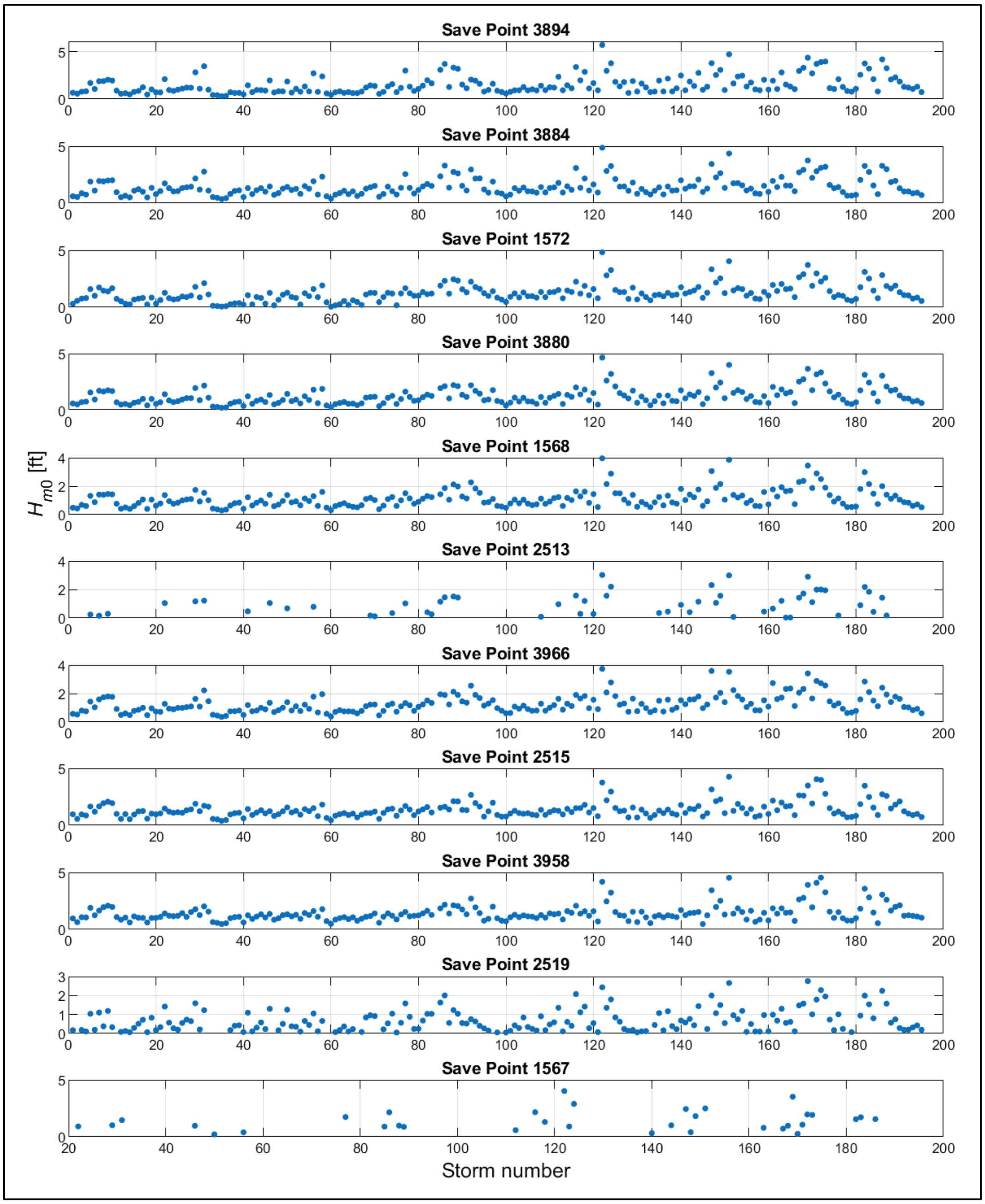
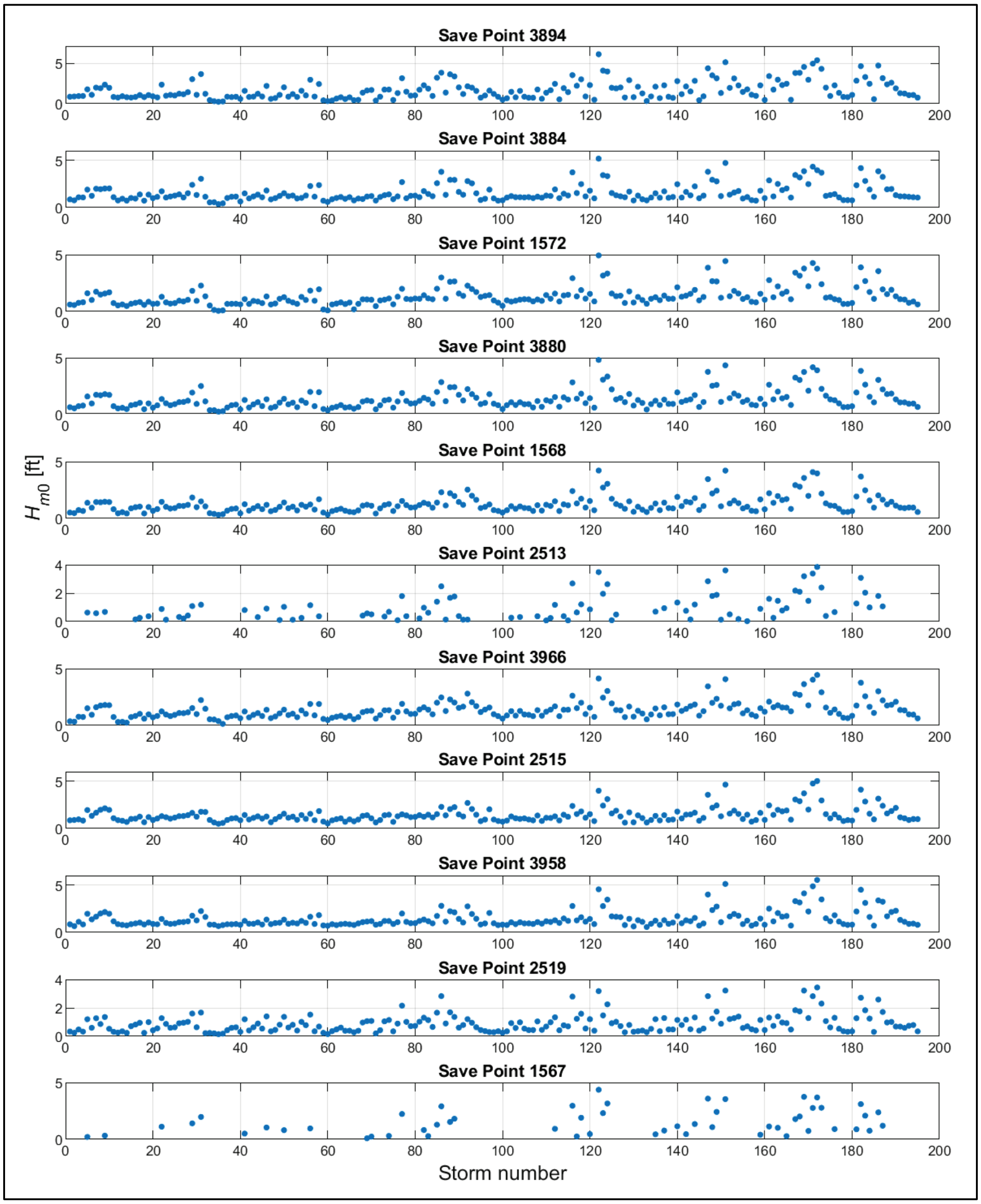


Figure B-14. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-SW area.



PA-SNWW1

Figure B-15. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-SNWW1 area.

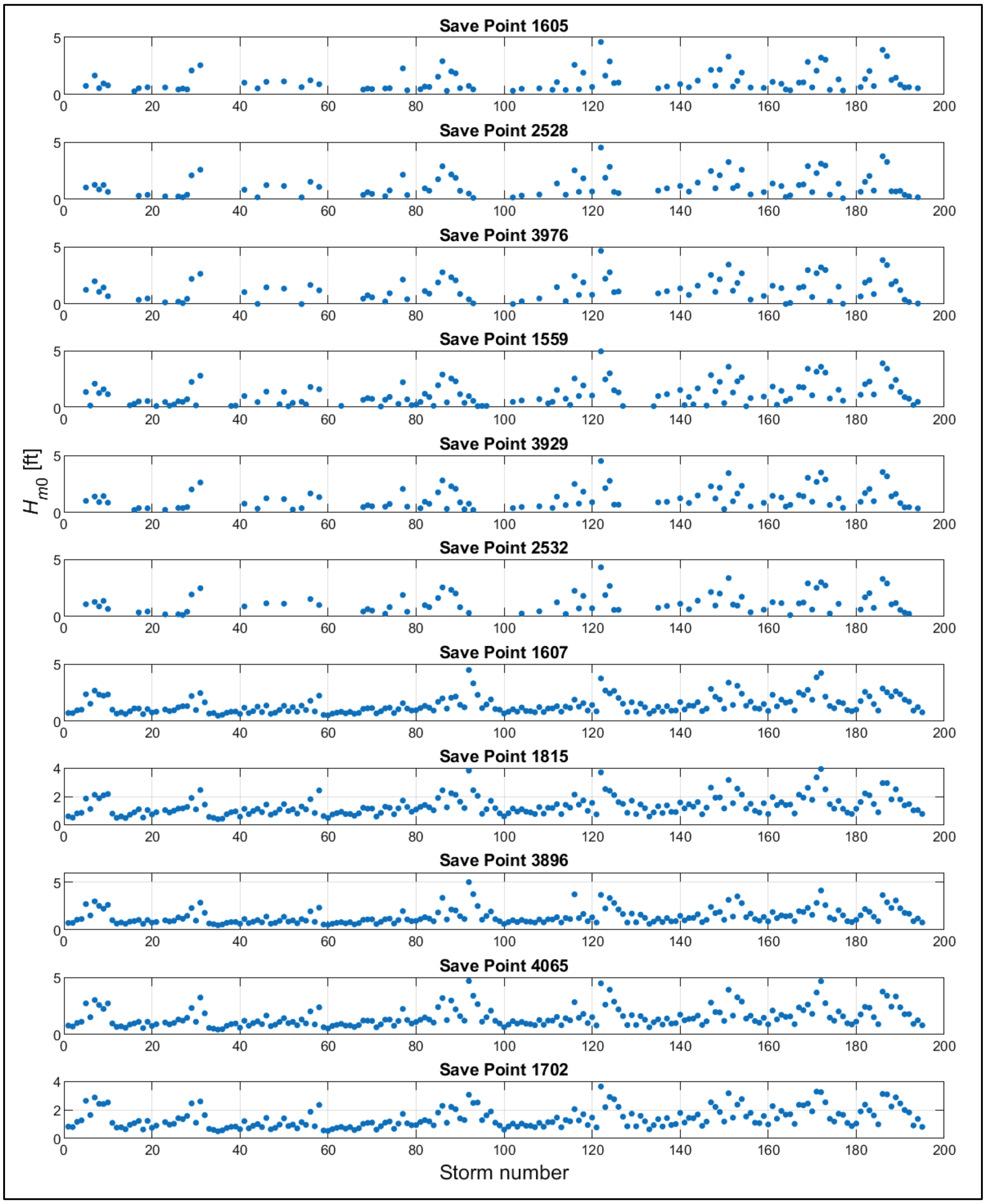


Figure B-16. Peak H_{m0}, in feet, for with-project and SLC1 for SPs PA-SNWW1 area.

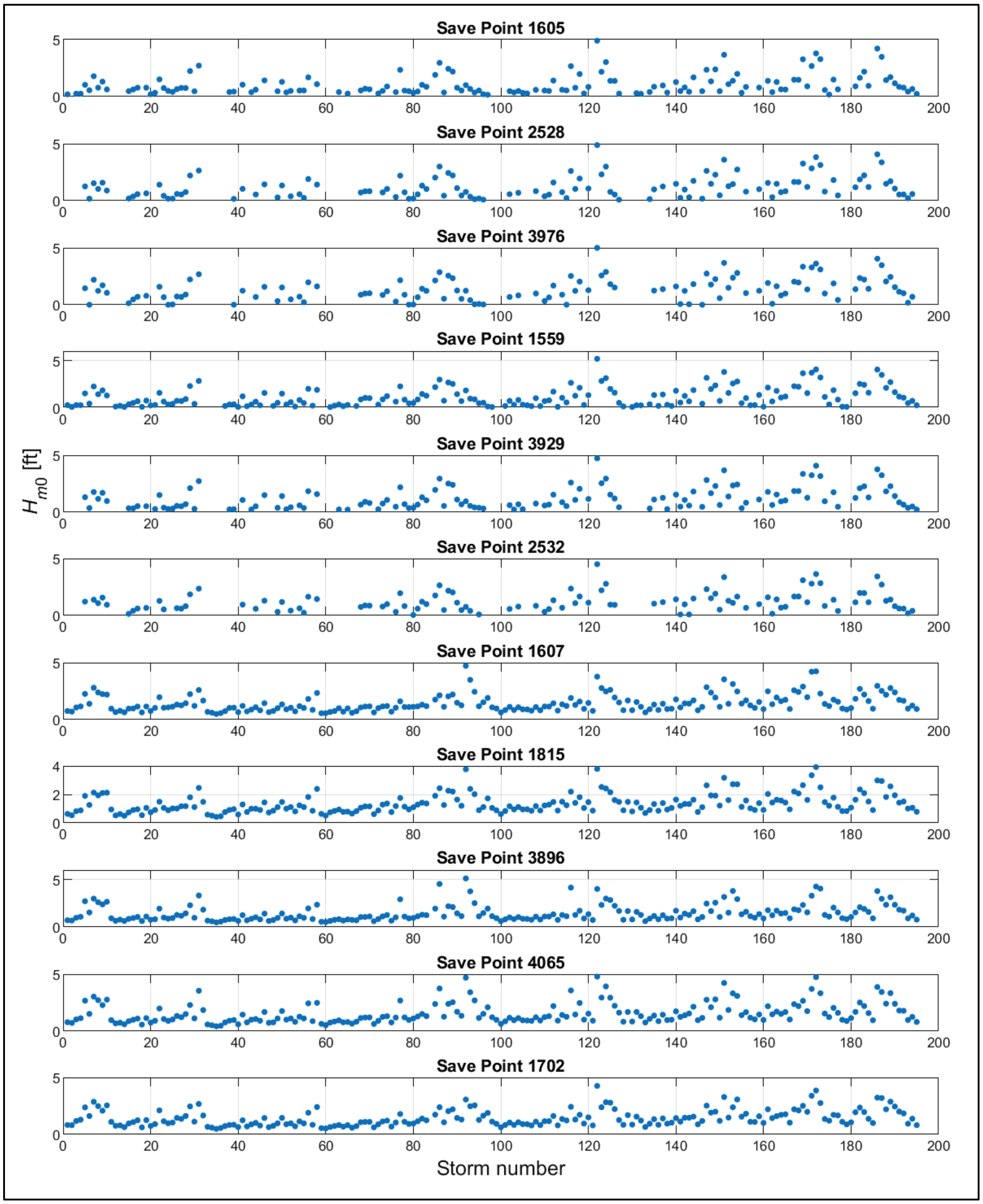
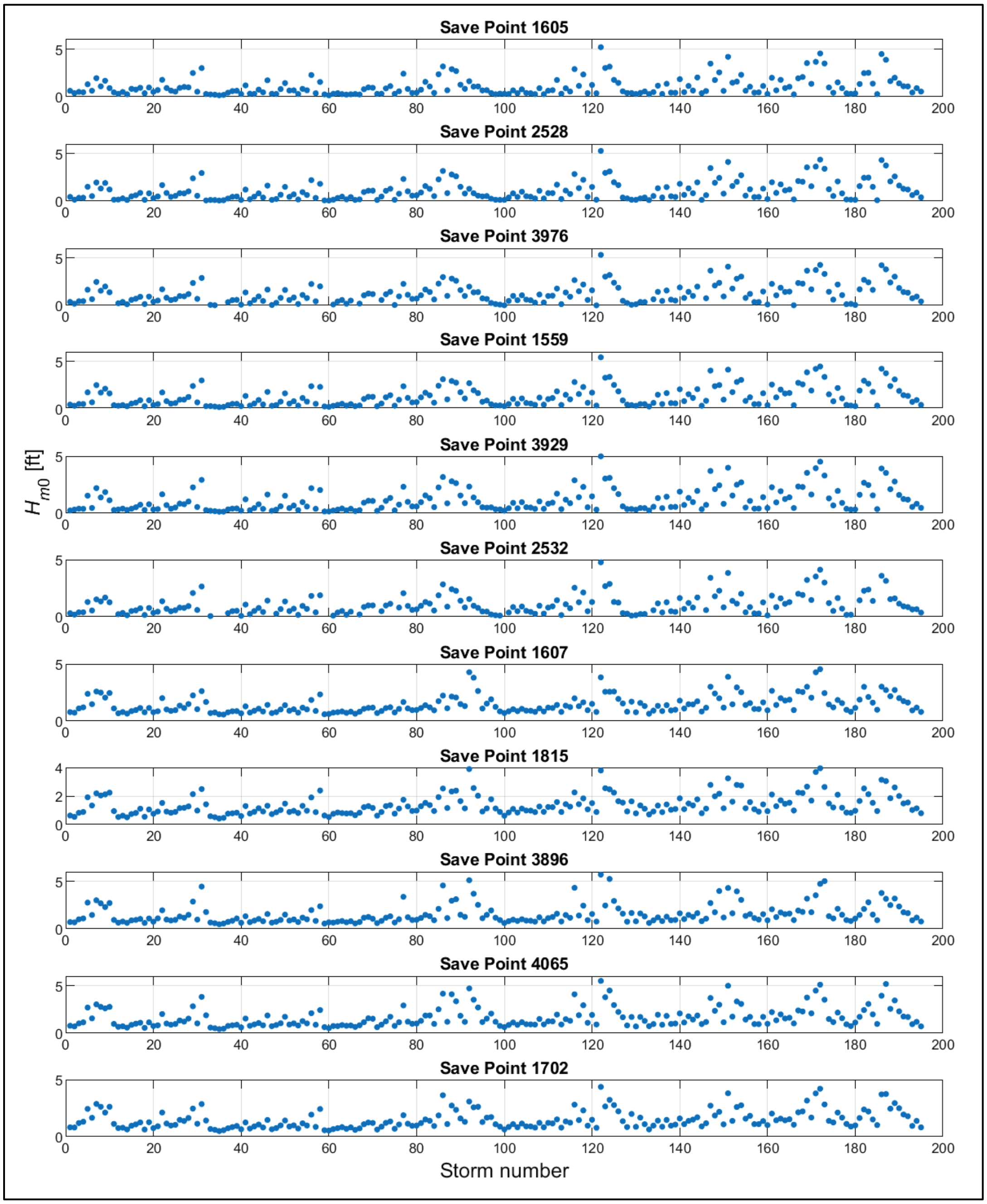


Figure B-17. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-SNWW1 area.



PA-SNWW2

Figure B-18. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-SNWW2 area.

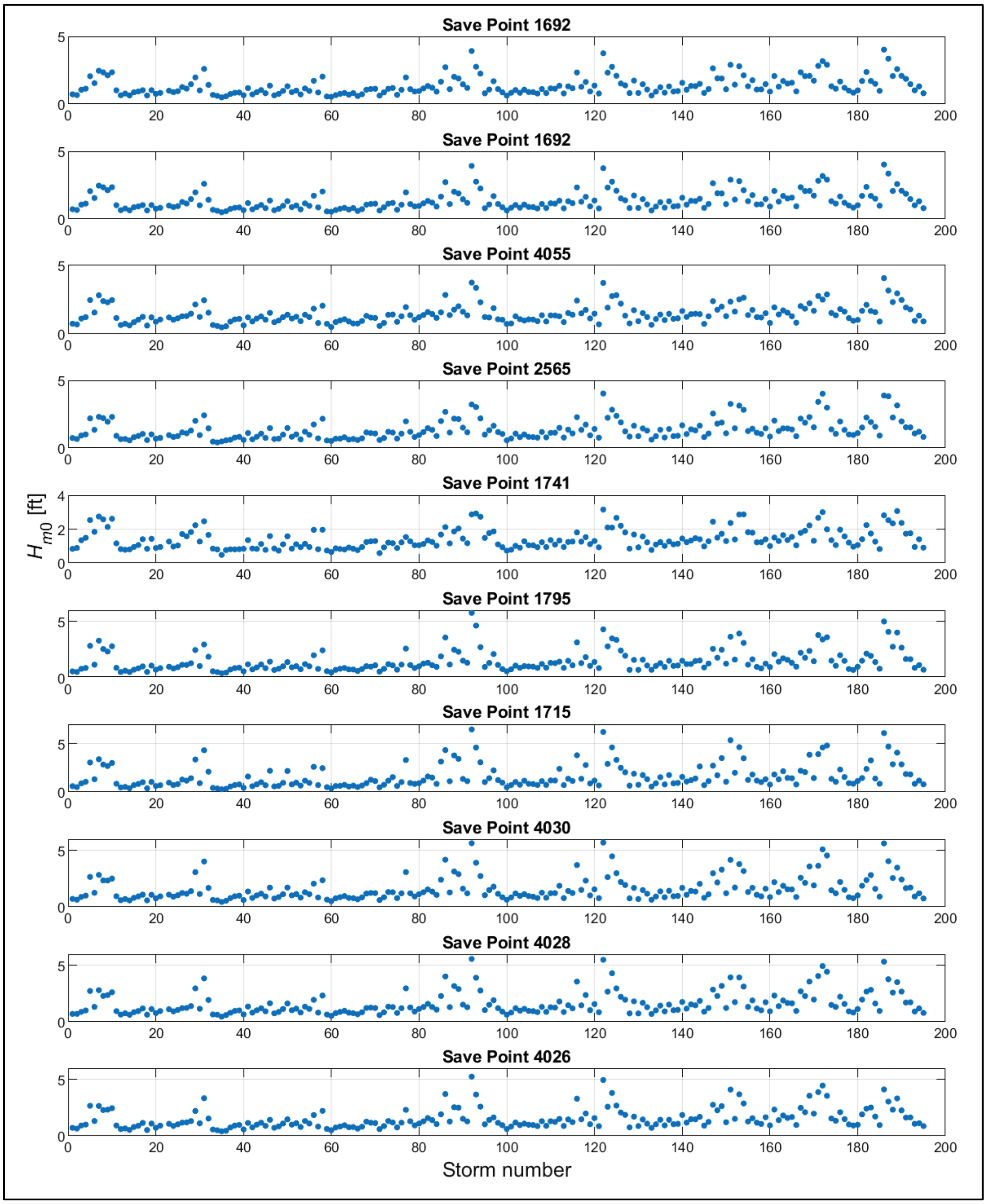


Figure B-19. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in PA-SNWW2 area.

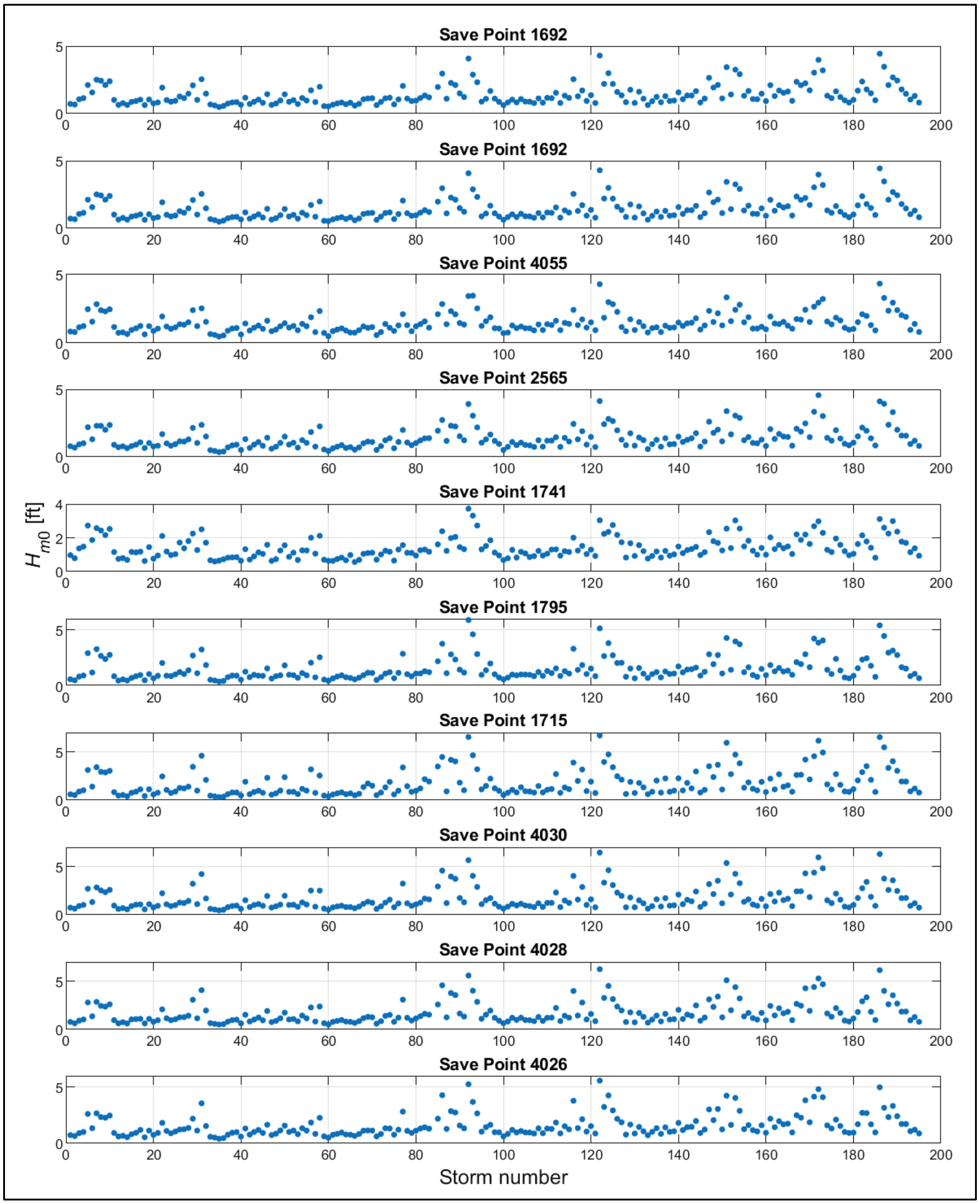
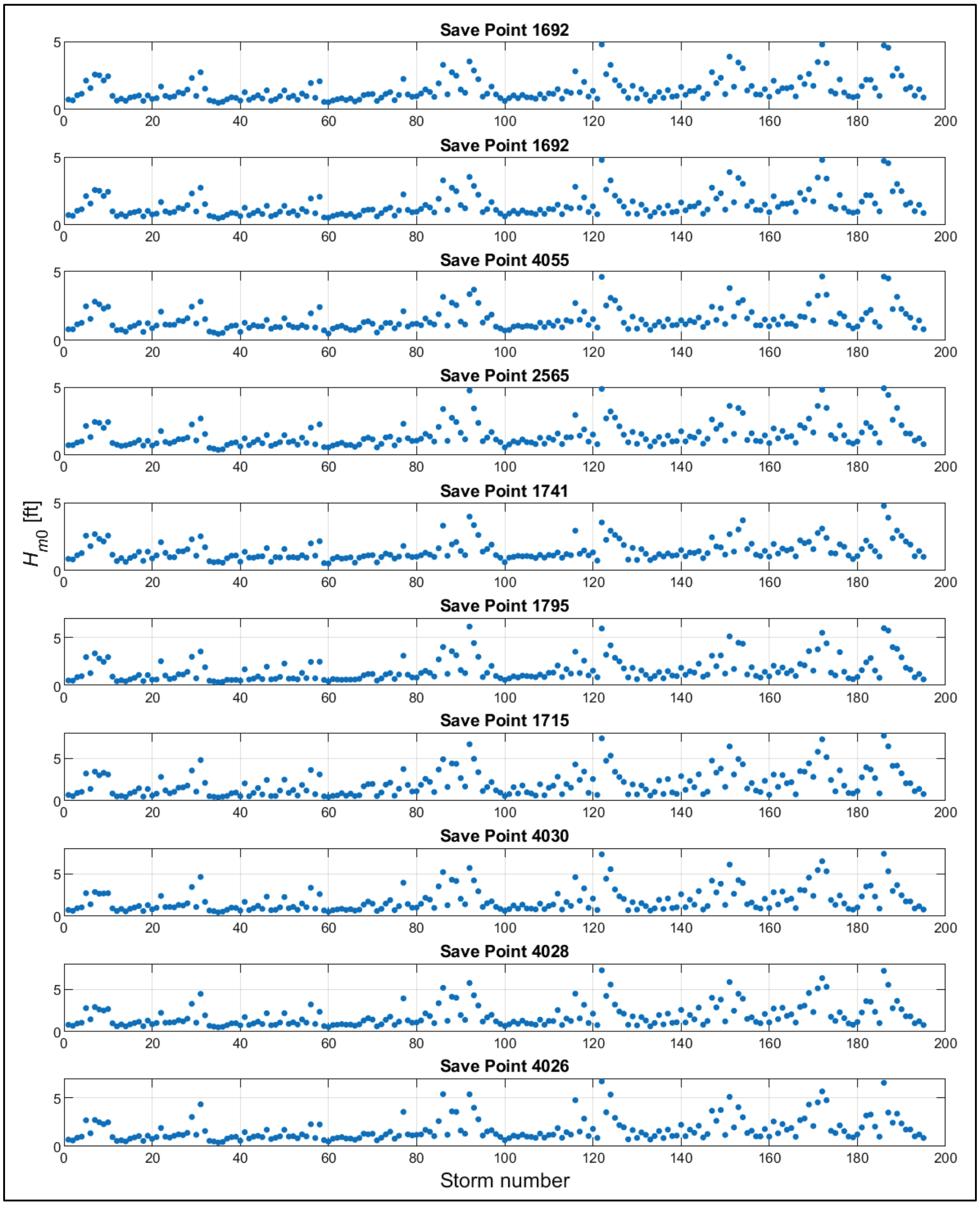


Figure B-20. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-SNWW2 area.



PA-SNWW3

Figure B-21. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-SNWW3 area.

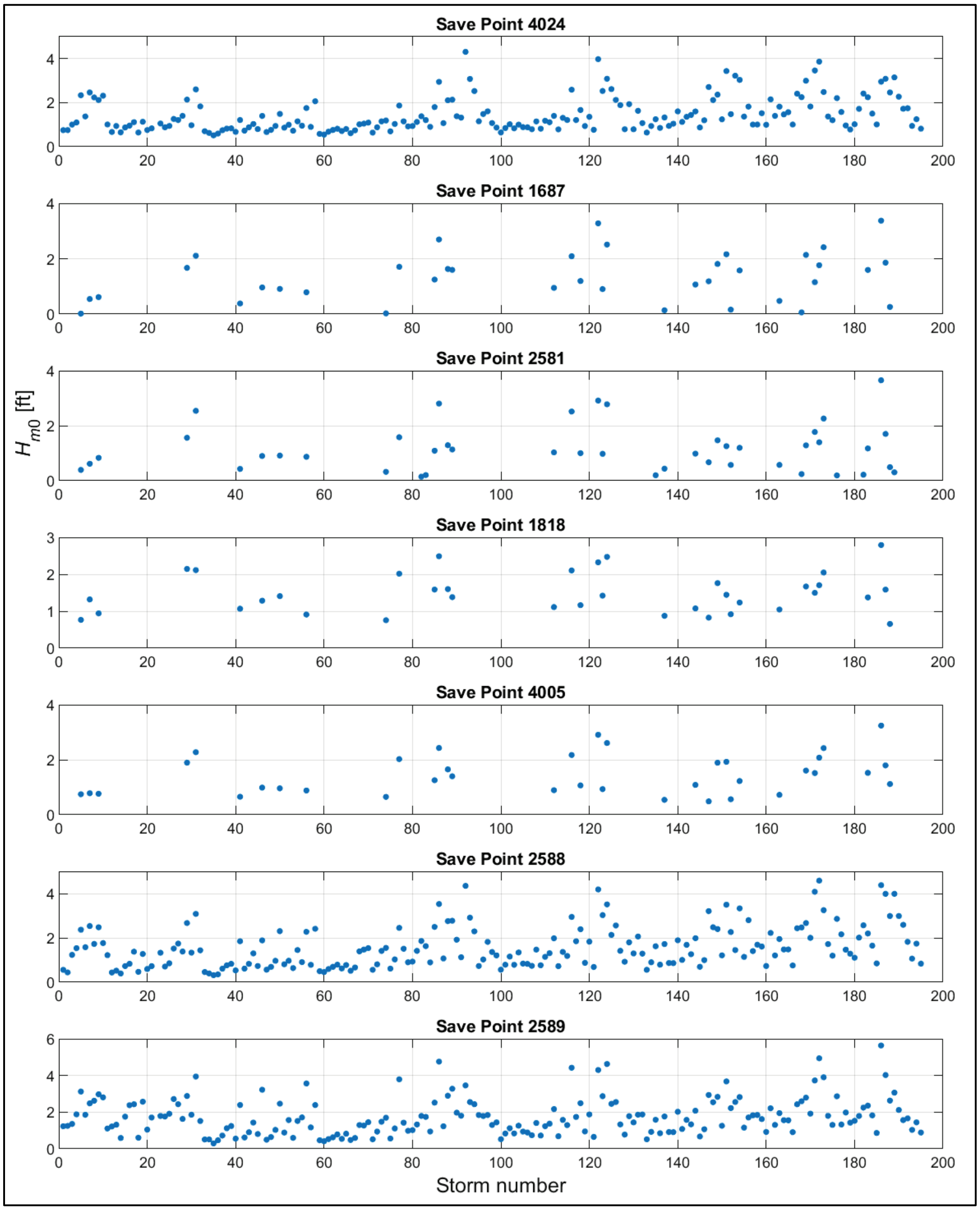


Figure B-22. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in PA-SNWW3 area.

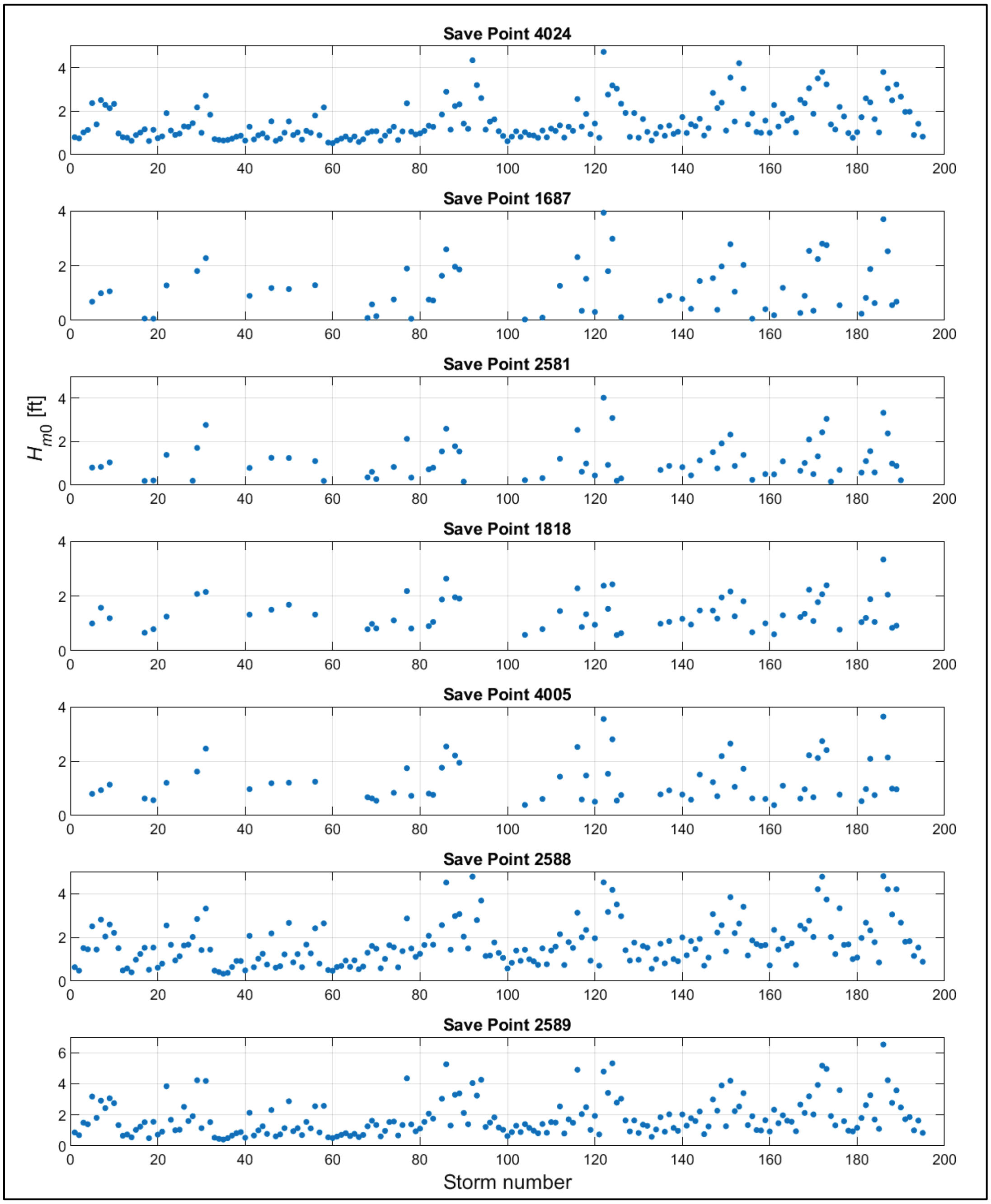
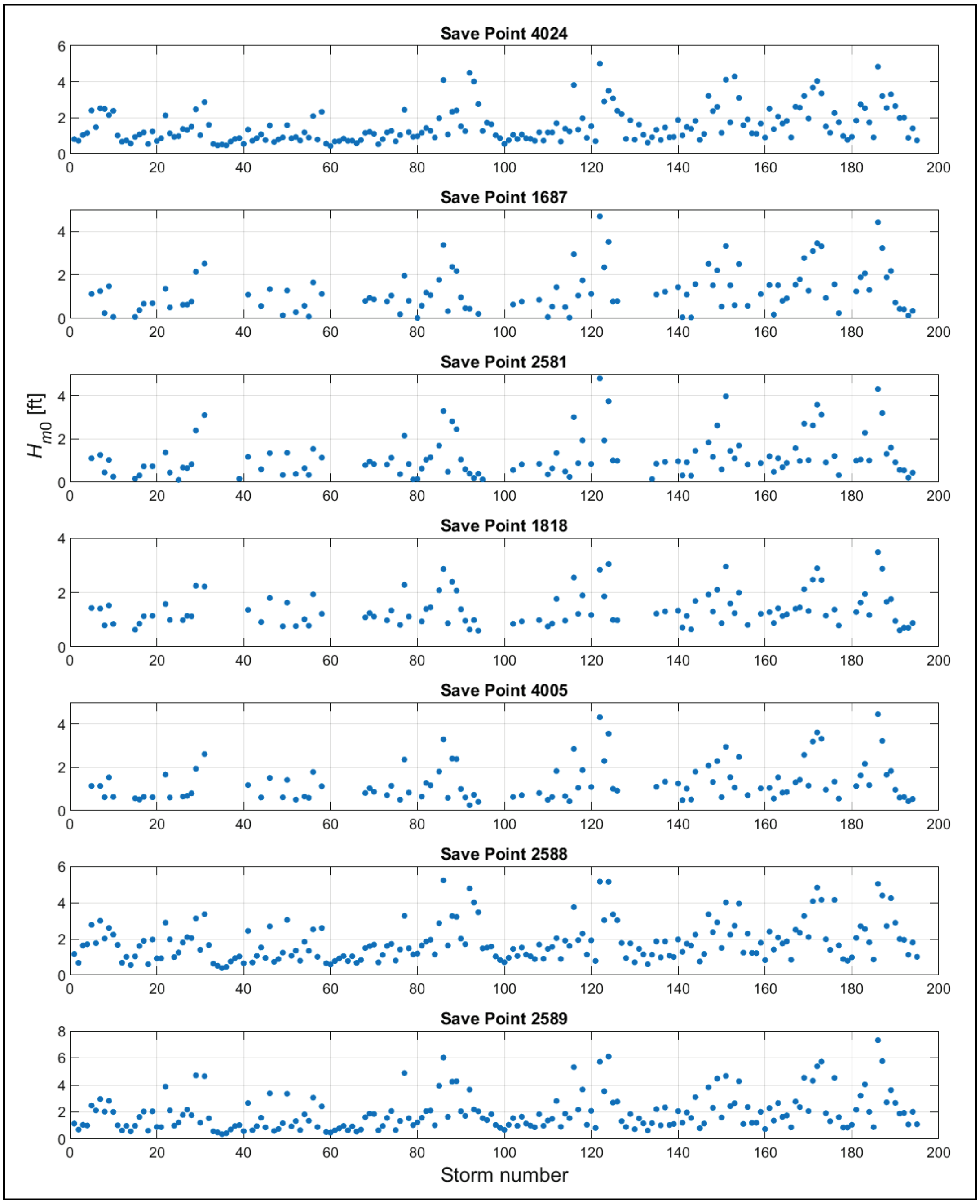


Figure B-23. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-SNWW3 area.



PA-NE

Figure B-24. Peak H_{m0}, in feet, for without-project and SLC0 for SPs in PA-NE area.

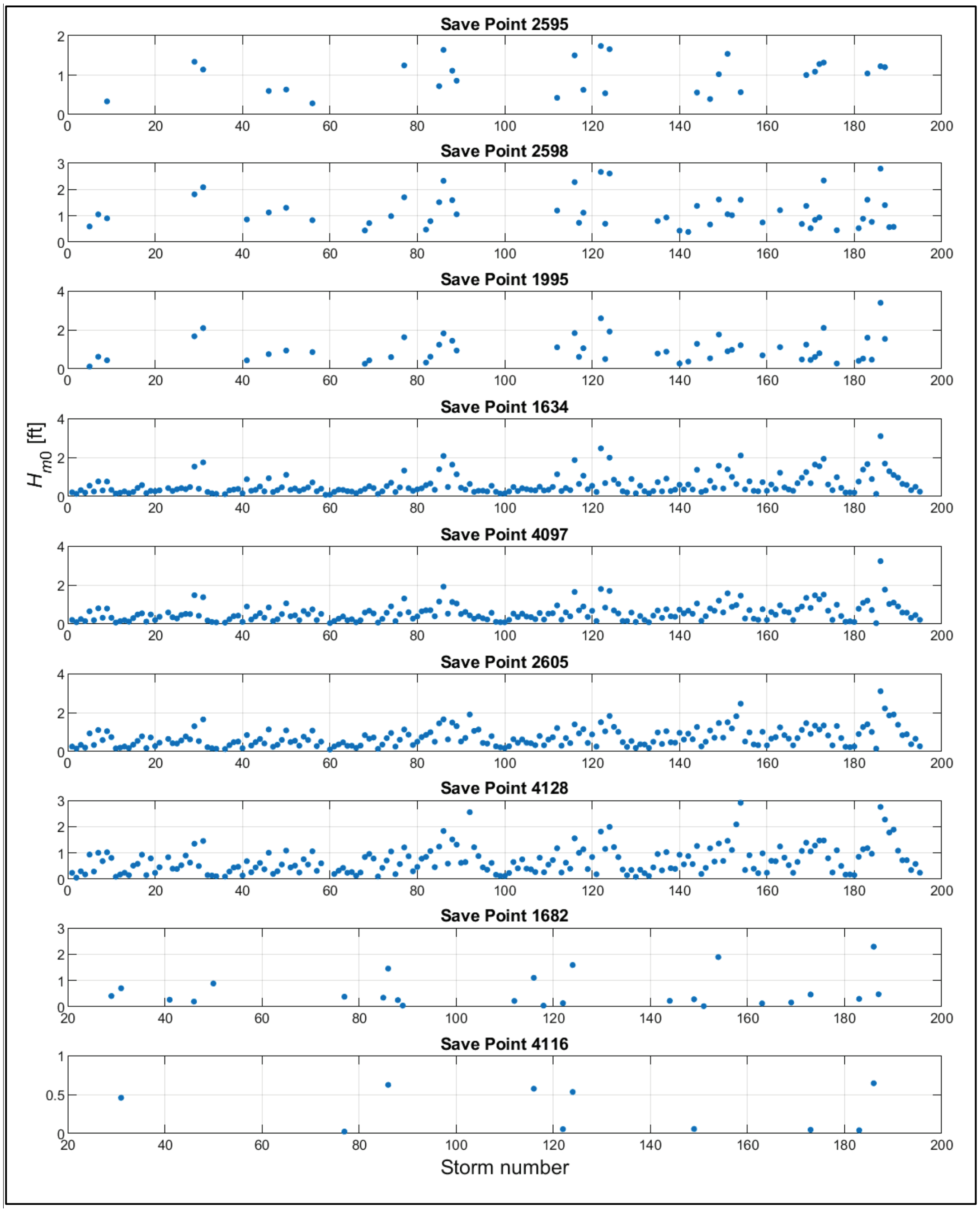


Figure B-25. Peak H_{m0}, in feet, for with-project and SLC1 for SPs in PA-NE area.

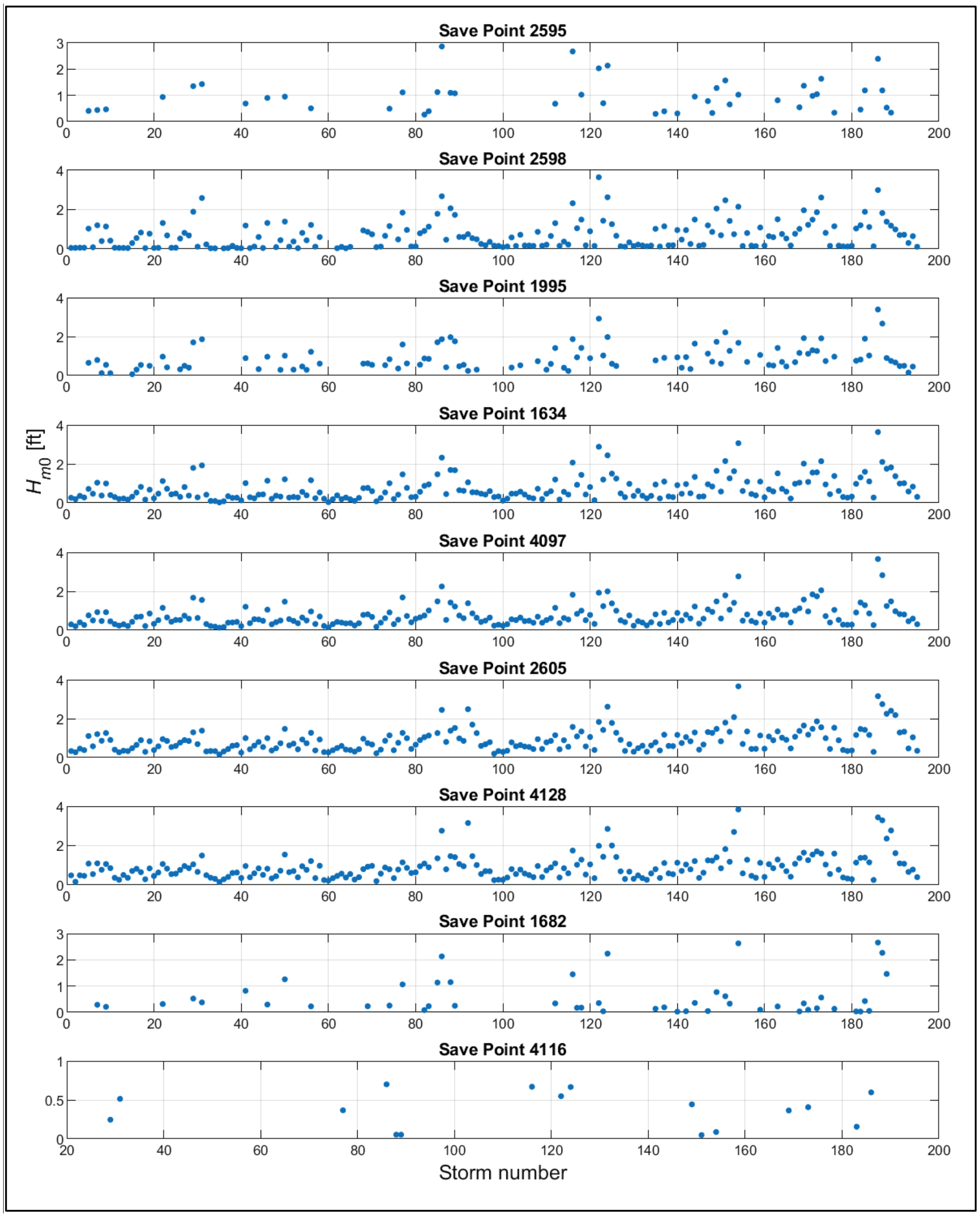
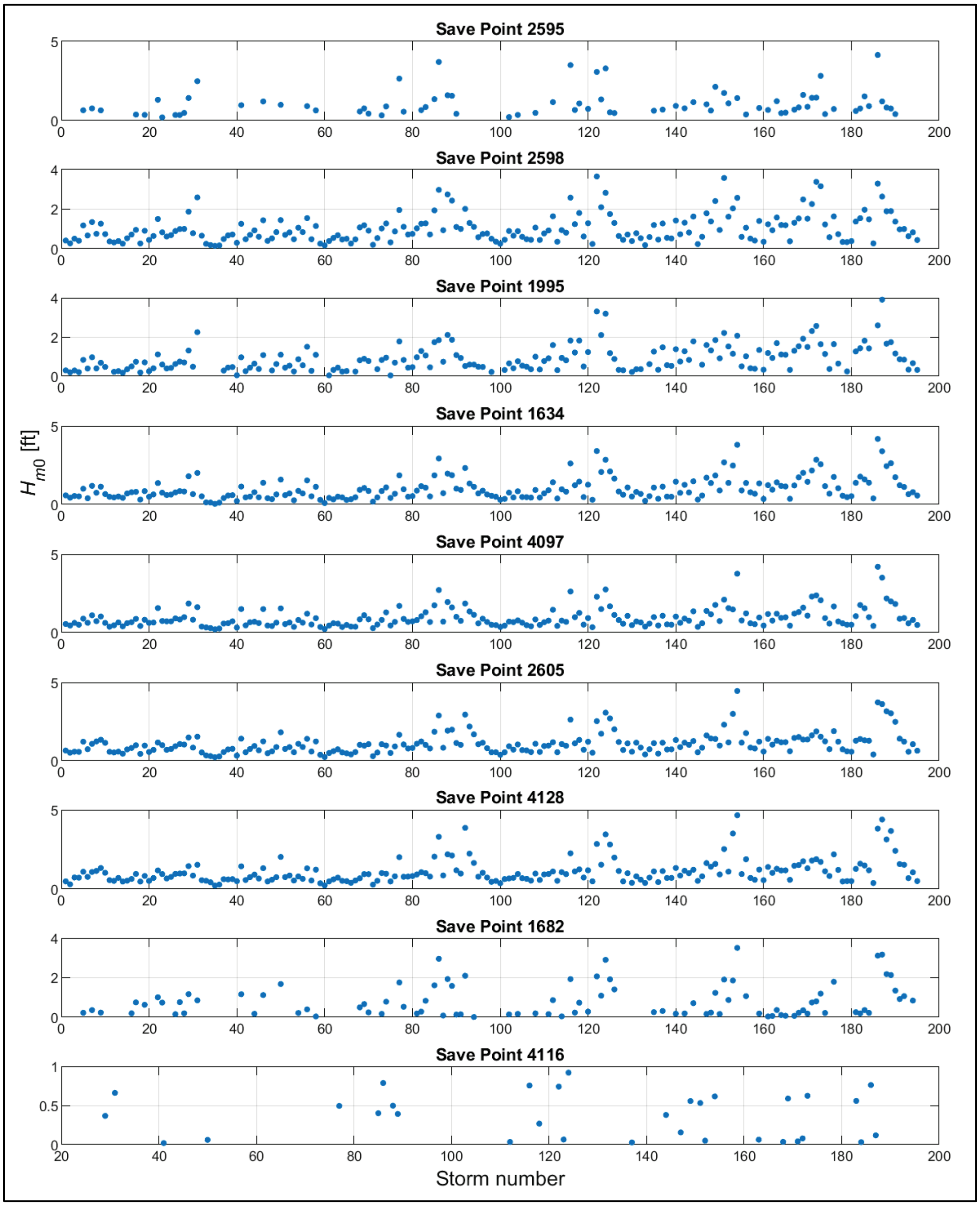


Figure B-26. Peak H_{m0}, in feet, for with-project and SLC2 for SPs in PA-NE area.



Appendix C: Optimized and Design Crest Elevations

This appendix presents the optimized elevations, computed as described in Chapter 1, for levees, floodwalls, fronting protection, and gates. The optimized crest elevations were used to inform the PDT during the selection of the final Design Elevations for SLC1 and SLC2. The final Construction and Design elevations for the levees, floodwalls, and gates are presented on the right side of the table. Gates and fronting protection were designed to the Adaptability Elevation, which is based on the SLC2 optimized crest elevation.

Table C-1. Optimized and design elevations for Port Arthur transects 154 to 178.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
178	0+00.00		Levee	17.50	22.50	17.50			22.50
177			Levee	15.00	21.50	15.00			21.50
175a		18+30.00	Levee	16.00	22.00	16.00			22.00
High Ground									
174	0+00.00	2+00.00	Levee	16.000	21.400	16.000			21.500
	2+00.00	9+00.00	Levee			16.000			21.500
	9+00.00	14+00.00	Levee			16.000			21.500
	14+00.00	15+00.00	Levee			16.000			21.500
170	15+00.00	24+00.00	Levee	15.800	21.200	16.000			21.250
	24+00.00	36+60.50	Levee			16.000			21.250
170 PS Fronting	36+60.50	39+25.00	Levee - Star Lake PS Fronting Protection			21.250			21.250
170	39+25.00	40+00.00	Levee			16.000			21.250
168	40+00.00	45+00.00	Levee	15.700	20.900	15.750			21.000
	45+00.00	55+00.00	Levee			15.750			21.000
167	55+00.00	64+95.00	Levee	15.700	20.900	15.750			21.000
High Ground									
164	62+50.00	63+00.00	Levee	15.50	19.20	15.50			19.25
	63+00.00	102+50.00	Levee			15.50			19.25
161	102+50.00	128+34.50	Levee	15.40	19.10	15.50			19.25
159a	128+34.50	129+89.83	Closure Gate/Floodwall	15.30	19.10		19.25	19.25	19.25
159/158/156	129+89.83	129+92.75	Levee	15.30	19.10	15.50			19.25
	129+92.75	183+50.00	Levee			15.50			19.25
154	183+50.00	190+00.00	Levee	15.80	19.60	16.00			19.75
	190+00.00	193+00.00	Levee			16.00			19.75
	193+00.00	207+44.50	Levee			16.00			19.75
	206+82.62	230+55.00	Levee			16.00			19.75
High Ground									

Table C-2. Optimized and design elevations for Port Arthur transects 125 to 149.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
149	258+15.00	280+00.00	Levee	20.50	24.50	20.50			24.50
148	280+00.00	284+00.00	Levee	18.00	22.50	18.00			22.50
147	284+00.00	306+00.00	Levee	17.00	20.00	17.00			20.00
147 gate	306+00.00	309+43.20	Floodwall - Crane Bayou PS Fronting Protection				20.00		20.00
147	309+43.20	309+98.10	Levee			17.00			20.00
147 gate	309+98.10	310+93.10	Closure Gate/Floodwall				20.00	20.00	20.00
144	310+93.10	316+00.00	Levee	16.40	20.10	16.50			20.25
143	316+00.00	344+61.00	Levee	16.40	20.20	16.50			20.25
138	344+61.00	345+83.00	Closure Gate/Floodwall	16.50	20.40		20.50	20.50	20.50
137	345+83.00	381+30.00	Levee	16.40	20.10	16.50			20.25
132	381+30.00	385+12.00	Floodwall	17.50	21.00		17.50		21.00
130 gate	385+12.00	390+01.00	Floodwall - Lakeview PS Fronting Protection	18.50	23.00		24.00		24.00
131/130	390+01.00	416+75.00	Floodwall	19.50	24.00		19.50		24.00
130 gate	416+75.00	416+75.00	Floodwall - Stadium Rd PS Fronting Protection				24.00		24.00
131/130	416+75.00	419+85.50	Floodwall				19.50		24.00
129	419+85.50	442+32.00	Levee	20.00	24.50	20.00			24.50
125	442+32.00	442+87.41	Floodwall	20.50	24.50		20.50		24.50
125 - PS Fronting	0+00.00	0+76.95	Floodwall - Del Mar PS Fronting Protection				24.50		24.50
125	443+50.00	503+91.73	Floodwall				20.50		24.50

Table C-3. Optimized and design elevations for Port Arthur transects 79 to 121.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
121	503+91.73	504+40.00	Levee	19.00	23.00	19.00			23.00
	504+40.00	504+87.00	Levee			19.00			23.00
	505+00.00	525+51.94	Levee			19.00			23.00
120	525+51.94	526+34.94	Floodwall - DeQueen PS Fronting Protection	17.00	20.00		20.00		20.00
116a/118	526+34.94	561+60.00	Levee	18.00	21.50	18.00			21.50
116/115a/115	561+60.00	569+60.00	Floodwall	17.50	21.00		17.50		21.00
114	569+60.00	580+00.00	Levee	18.00	21.50	18.00			21.50
111	580+00.00	583+75.00	Floodwall	18.50	22.50		18.50		22.50
	583+84.67	591+44.40	Floodwall				18.50		22.50
111 PS Fronting	591+44.00	591+94.60	Floodwall - Shreveport Ave PS Fronting Protection				22.50		22.50
111	591+94.60	602+86.11	Floodwall				18.50		22.50
107	602+86.11	617+00.00	Levee	16.50	21.50	16.50			21.50
	617+00.00	617+53.11	Levee			16.50			21.50
Contract 3b new	617+53.11	Corner; +100 ft	Floodwall/Gates	17.50	22.00		17.50	22.00	22.00
			Floodwall	15.30	20.00		15.50		20.00
			Gates					20.00	20.00
88/89/89a	653+00.00	684+00.00	Levee	16.40	20.10	16.50			20.25
84a	684+00.00	684+00.00	Levee - Foley PS Fronting Protection	16.30	20.10	19.00			20.25
84	684+00.00	715+31.62	Levee	16.30	20.10	16.50			20.25
81	715+31.62	716+52.00	Floodwall	17.00	21.00		18.00		21.50
79/80	716+52.00	731+71.87	Floodwall	18.00	21.50		18.00		21.50
	731+73.28	733+41.65	Floodwall				18.00		21.50

Table C-4. Optimized and design elevations for Port Arthur transects 63 to 78.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
77/78	733+37.93	744+00.00	Levee	16.50	20.00	16.50			20.00
75	744+00.00	757+50.00	Levee	16.20	20.10	16.25			20.25
74	757+50.00	762+13.00	Levee	16.20	20.10	16.25			20.25
73c	762+13.00	762+88.73	Levee	16.40	20.10	16.50			20.25
73b	762+62.93	762+87.00	Floodwall	16.50	20.50		18.00		21.00
73a	762+87.00	763+33.34	Floodwall	16.50	20.50		18.00		21.00
73	763+28.71	766+12.00	Floodwall	16.50	20.50		18.00		21.00
72	766+12.00	769+61.00	Floodwall/Gate	17.00	21.00		18.00	21.00	21.00
71	769+61.00	773+60.16	Floodwall/Gates	17.00	20.50		18.00	21.00	21.00
70	773+60.16	774+00.00	Floodwall	16.50	20.50		18.00		21.00
	774+00.00	777+77.15	Floodwall/Gate	16.50			18.00	21.00	21.00
69	777+77.15	778+13.17	Floodwall	17.00	21.00		18.00		21.00
68	824+32.60	827+74.40	Floodwall/Gate	17.50	21.00		18.00	21.00	21.00
	827+74.40	830+58.25	Floodwall/Gate	18.00			18.00	21.00	21.00
67	830+53.94	834+44.49	Floodwall	18.00	21.00		18.00		21.00
	834+44.49	834+68.49	Gate					21.00	21.00
66	834+68.49	845+53.85	Floodwall	18.00	21.00		18.00		21.00
	845+53.85	845+77.85	Gate					21.00	21.00
64/65	845+77.85	847+38.77	Floodwall	17.50	21.00		18.00		21.00
	847+24.79	848+83.66	Floodwall				18.00		21.00
	848+83.66	849+11.66	Gate					21.00	21.00
63	849+11.66	858+28.57	Floodwall	17.50	20.50		18.00		21.00
	858+38.95	858+65.70	Floodwall/Gate				18.00	21.00	21.00
	858+65.70	858+80.62	Floodwall				18.00		21.00

Table C-5. Optimized and design elevations for Port Arthur transects 49 to 62a.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
61/61a/62a	860+57.93	867+41.85	Floodwall	17.00	20.00		18.00		21.00
60/60a/60b	867+41.85	870+14.49	Floodwall	17.50	20.50		18.00		21.00
	870+14.49	871+76.93	Floodwall				18.00		21.00
	871+75.93	872+78.35	Floodwall/Gate				18.00	21.00	21.00
59	872+78.35	875+75.00	Levee	16.40	20.00	17.50			20.00
59-road crossing	875+75.00	875+75.00	Levee - HWY 87 Road Crossing			20.00			20.00
59	875+75.00	877+60.00	Levee			17.50			20.00
	877+60.00	883+79.00	Levee			17.50			20.00
58	883+78.00	887+00.00	Levee	16.40	20.00	17.50			20.00
	887+00.00	895+00.00	Levee			17.50			20.00
57	895+00.00	903+77.00	Levee	16.40	19.90	17.50			21.00
56	903+77.00	909+00.00	Levee	16.40	19.90	17.50			20.50
	909+00.00	912+50.00	Levee			17.50			20.50
	912+50.00	920+00.00	Levee			17.50			20.50
55	920+00.00	923+00.00	Levee	16.40	19.80	16.50			20.00
	923+00.00	930+00.00	Levee			16.50			20.00
	930+00.00	932+95.00	Levee			16.50			20.00
	932+95.00	933+80.00	Levee			16.50			20.00
54	933+80.00	934+53.89	Levee	15.70	19.60	15.75			20.00
53	934+53.89	945+10.00	Levee	15.70	19.60	15.75			19.75
52	945+10.00	952+00.00	Levee	15.80	19.60	16.00			19.75
51	952+00.00	955+96.67	Levee	15.80	19.60	16.00			19.75
49	955+96.67	963+98.64	Levee	17.00	20.50	17.00			20.50
	964+00.00	966+54.27	Levee			17.00			20.50
	966+70.90	970+00.00	Levee			17.00			20.50

Table C-6. Optimized and design elevations for Port Arthur transects 33 to 48.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
48	970+00.00	970+50.00	Levee	16.00	19.80	16.00			20.00
	970+50.00	990+00.00	Levee			16.00			20.00
47	990+00.00	1005+08.42	Levee	16.10	19.90	16.25			20.00
	1005+06.66	1008+00.00	Levee			16.25			20.00
	1008+00.00	1011+17.55	Levee			16.25			20.00
	1011+03.57	1012+00.00	Levee			16.25			20.00
	1012+00.00	1020+00.00	Levee			16.25			20.00
46	1020+00.00	1037+22.00	Levee	16.20	20.00	16.25			20.00
	1037+22.00	1037+72.92	Levee			16.25			20.00
45	1037+72.92	1039+34.00	Floodwall - PS Fronting Protection	16.50	20.00		21.00		21.00
44	1039+34.00	1040+69.85	Floodwall - PS Fronting Protection	17.00	21.00		21.00		21.00
	1039+34.00	1041+50.00	Floodwall - PS Fronting Protection				21.00		21.00
	1041+50.00	1047+04.00	Floodwall - Alligator Bayou PS Fronting Protection				21.00		21.00
43	1047+04.00	1047+54.00	Levee	16.30	20.00	16.50			20.00
	1047+54.00	1057+51.00	Levee			16.50			20.00
42	1057+50.00	1065+00.00	Levee	16.20	20.00	16.25			20.00
	1065+00.00	1068+00.00	Levee			16.25			20.00
	1068+00.00	1110+00.00	Levee			16.25			20.00
38	1110+00.00	1139+50.00	Levee	16.10	20.00	16.25			20.00
36	1139+50.00	1160+00.00	Levee	16.20	20.10	16.25			20.25
33	1160+00.00	1189+00.00	Levee	16.40	20.30	16.50			20.50
	1189+00.00	1192+00.00	Levee			16.50			20.50
	1192+00.00	1199+77.98	Levee			16.50			20.50
	1198+20.36	1211+00.00	Levee			16.50			20.50

Table C-7. Optimized and design elevations for Port Arthur transects 1a to 31.

ERDC Transect number	Contract Stationing		Feature Type Used For Modeling	PED Optimized Crest Elevation (1% AEP Risk Reduction) (ft, NAVD88)		Levee Embankment - Design Grade (SLC1/SLC2, ft)	Floodwall - Construction Elevation (SLC1/SLC2, ft)	Gates - Construction Elevation (SLC2, ft)	Adaptibility Elevation - (SLC2, ft)
	Begin	End		Design Scenario (SLC1)	Adaptability Scenario (SLC2)				
31	1211+00.00	1216+20.00	Floodwall - Lakeside PS Fronting Protection	17.00	22.00		22.00		22.00
30	1216+20.00	1216+70.00	Levee	16.50	20.50	16.50			20.50
	1216+70.00	1224+93.76	Levee			16.50			20.50
	1224+92.76	1322+84.82	Levee			16.50			20.50
23	1322+84.82	1321+03.94	Levee	15.30	19.10	15.50			19.25
	1322+84.82	1380+00.00	Levee			15.50			19.25
16	1380+00.00	1410+00.00	Levee	15.10	18.90	15.25			19.00
	1410+00.00	1444+00.00	Levee			15.25			19.00
	1444+00.00	1444+54.00	Levee			15.25			19.00
15	1444+54.00	1447+95.00	Floodwall - Port Acres PS Fronting Protection	15.10	18.90		19.00		19.00
15a	1447+95.00	1448+45.00	Levee	15.10	19.00	15.25			19.00
	1448+45.00	1451+80.00	Levee			15.25			19.00
	1451+80.00	1452+31.00	Levee			15.25			19.00
15b	1452+31.00	1453+89.00	Gate/Floodwall - HWY 365 Closure Gate	15.10	18.90		19.00	19.00	19.00
11	1453+89.00	1454+40.00	Levee	15.20	19.00	15.25			19.00
	1454+40.00	1464+94.63	Levee			15.25			19.00
	1465+00.00	1512+50.00	Levee			15.25			19.00
8	1512+50.00	1520+00.00	Levee	15.50	20.50	15.50			20.50
	1520+00.00	1532+00.00	Levee			15.50			20.50
	1532+00.00	1540+00.00	Levee			15.50			20.50
6	1540+00.00	1554+00.00	Levee	15.40	20.00	15.50			20.00
	1554+00.00	1557+50.00	Levee			15.50			20.00
5	1557+50.00	1570+00.00	Levee	14.50	19.10	14.50			19.25
4	1570+00.00	1608+00.00	Levee	15.10	19.30	15.25			19.50
1a	1608+00.00	1609+00.00	Levee	15.20	19.30	15.25			19.50

Appendix D: Final Product Development Team (PDT) Design and Adaptability

This appendix summarizes the hydraulic response parameters for AEPs that are associated with the Final Design and Adaptability elevations determined by the PDT. Note that the response-based stochastic simulation method was used to determine the elevations and this computation included epistemic uncertainties associated with both the forcing and response. Therefore, using these hydraulic response parameters in a pseudo-deterministic event-based computation will not yield the same results summarized herein.

The combination of forcing and elevation scenarios presented herein are as follows:

1. Existing elevation/SLC0 forcing – Structure response evaluated for structure with existing without-project crest elevation and exposed to SLC0 without-project forcing scenario.
2. Design elevation SLC1/SLC1 forcing - Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to SLC1 with-project forcing scenario.
3. Design elevation SLC1/SLC2 forcing - Structure response evaluated for structure with design crest elevation computed under SLC1 condition and exposed to SLC2 with-project forcing scenario.
4. Design elevation SLC2/SLC2 forcing - Structure response evaluated for structure with design crest elevation computed under SLC2 condition and exposed to SLC2 with-project forcing scenario.

The Appendix D file is available under "Files in This Item" located here: http://dx.doi.org/10.21079/11681/41901. The file name will indicate that it is an appendix.

Unit Conversion Factors

A sponsor requirement for this study was the use of English Customary units of measurement. Most measurements and calculations were done in International System (SI) units and then converted to English Customary. The following table can be used to convert back to SI units.

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
foot-pounds force	1.355818	joules
ounces (US fluid)	2.957353 E-05	cubic meters
pounds (force) per square foot	47.88026	pascals

Acronyms and Abbreviations

AEP	Annual exceedance probability
CL	Confidence limits
CSRM	Coastal Storm Risk Management
CTXCS	Coastal Texas Comprehensive Study
DEM	Digital elevation model
DQC	District Quality Control
HSDRRS	Hurricane Storm Damage Risk Reduction System
HWY	Highway
ID	Identifier
JPM	Joint probability model
LMSL	Local mean sea level vertical
MSL	Mean sea level
MWD	Mean wave direction
NOAA	National Oceanic and Atmospheric Administration
PA-NE	Port Arthur – North East
PA-NE-ext	Port Arthur North East extension
PA-SNWW1	Port Arthur – SNWW1
PA-SNWW2	Port Arthur – SNWW2
PA-SNWW3	Port Arthur – SNWW3
PA-SW	Port Arthur South West
PA-W	Port Arthur West
PBL	Planetary boundary layer
PDT	Project development team
PED	Pre-construction, Engineering, and Design
RSLC	Relative sea level change
S2G	Sabine Pass to Galveston Bay
SLC0	Sea level change corresponding to beginning of service life
SLC1	Sea level change corresponding to 50 yr service life
SLC2	Sea level change corresponding to 100 yr service life
SNWW	Sabine-Neches Waterway
SP	Save point

SWG	Galveston District
SWL	Storm water level
TBTB	Taylors Bayou Turning Basin
TC	Tropical cyclone
USACE	US Army Corps of Engineers
WAM	Wave model

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14. ABSTRACT
The US Army Corps of Engineers, Galveston District, is executing the Sabine Pass to Galveston Bay Coastal Storm Risk Management (CSRM) project for Brazoria, Jefferson, and Orange Counties regions. The project is currently in the Pre-construction, Engineering, and Design phase. This report documents coastal storm water level and wave hazards for the Port Arthur CSRM structures. Coastal storm water level (SWL) and wave loading and overtopping are quantified using high-fidelity hydrodynamic modeling and stochastic simulations. The CSTORM coupled water level and wave modeling system simulated 195 synthetic tropical storms on three relative sea level change scenarios for with- and without-project meshes. Annual exceedance probability (AEP) mean values were reported for the range of 0.2 to 0.001 for peak SWL and wave height (Hm0) along with associated confidence limits. Wave period and mean wave direction associated with Hm0 were also computed. A response-based stochastic simulation approach is applied to compute AEP values for overtopping for levees and overtopping, nappe geometry, and combined hydrostatic and hydrodynamic fluid pressures for floodwalls. CSRM crest design elevations are defined based on overtopping rates corresponding to incipient damage. Survivability and resilience are evaluated. A system-wide hazard level assessment was conducted to establish final recommended system-wide elevations.

15. SUBJECT TERMS
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