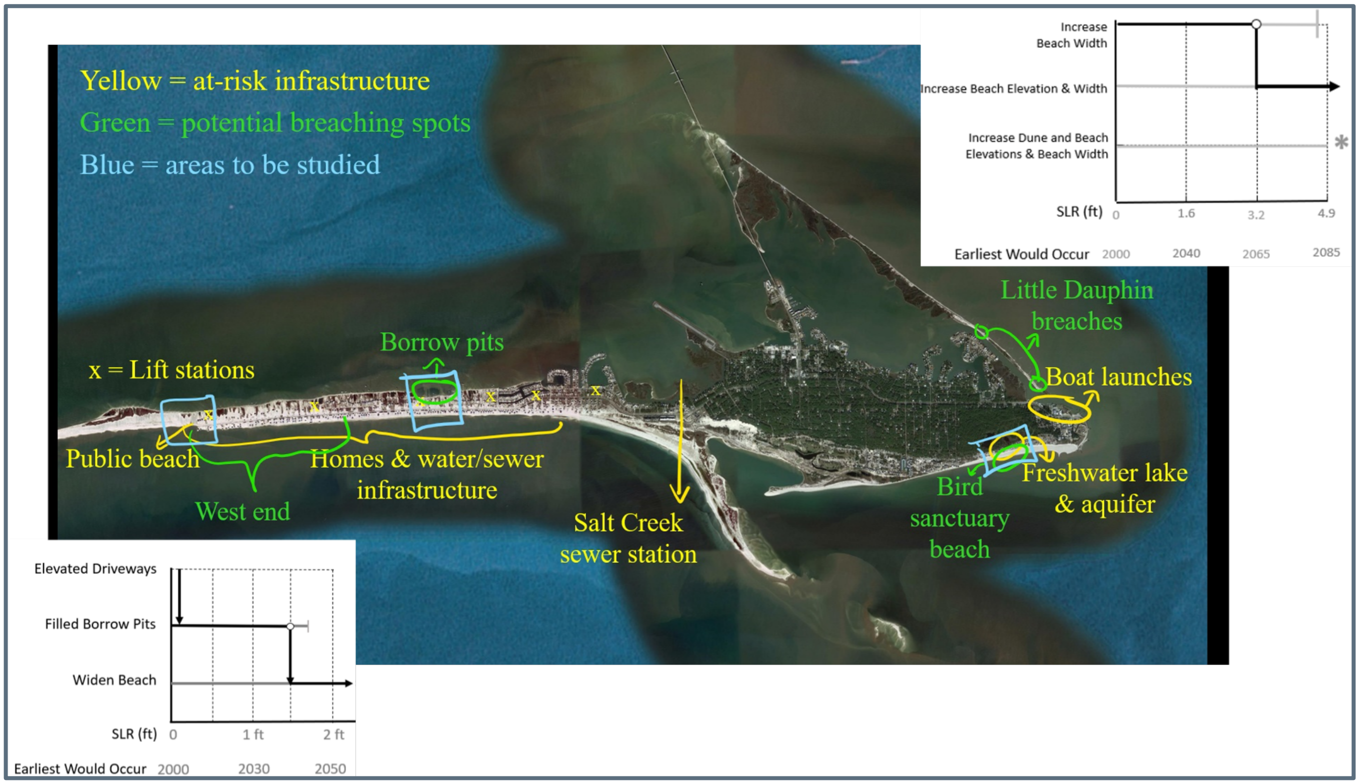

DAUPHIN ISLAND ADAPTATION PATHWAYS PROJECT

FINAL REPORT

U.S. COASTAL RESEARCH PROGRAM

AWARD W912HZ-20-200-02

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1 Introduction

This project developed adaptation pathways for a barrier island community by employing morphodynamic modeling and science extension methodologies, and engaging community leadership and members throughout the two-year project. Pathways are comprised of several alternatives for barrier island adaptation to future hurricanes and sea-level rise (SLR). The alternatives, termed adaptation strategies, are sequentially arranged based on their effectiveness in protecting the island from damage during a hurricane under future sea levels. "Tipping points" are identified as the amount of SLR that causes a strategy to no longer meet its original objective of mitigating storm damage, necessitating the implementation of another strategy; thus, the pathway is created. The pathway informs coastal management officials of the critical moment to implement a certain adaptation strategy based on observed SLR rather than uncertain long-term predictions, thereby reducing unnecessary costs. The adaptation pathways developed from this work identify best practices for increasing barrier island resilience to hurricanes under varying levels of SLR scenarios while also improving the understanding of developed barrier island responses to future storms.

1.1 Study Site

Dauphin Island, AL served as the example barrier island community to create two scientifically-based, community-informed adaptation pathways. Dauphin Island was selected for this study because it is a highly-vulnerable community at risk of severe economic and ecologic damage during a hurricane. Dauphin Island is a low-lying barrier island that sustains about 1,200 permanent and 3,100 seasonal residents (Fig. 1). The 22.5-km-long microtidal barrier island varies in width from about 3,000 m at its eastern end, which has dunes up to 15 m in height and a maritime forest, to less than 300 m on its western end, which has a typical elevation of 2 m above MSL. About 12.5 km of the western end is largely undeveloped (Fig. 1). Due to its location and unique characteristics, Dauphin Island's marine ecosystems support a high diversity of ecologically important species including endangered and protected species. Recreationally, the island supports boating, fishing and beach activities for tourists and residents. During hurricanes, Dauphin Island protects nearly 10,000 acres in and around Mobile Bay by serving as a buffer for waves and surge and reducing flooding to communities behind it. However, the barrier island is also extremely vulnerable to damage by storm surge and waves (Douglass, 1994; Froede, 2006; Froede, 2008). This vulnerability is expected to increase as sea levels continue to rise.

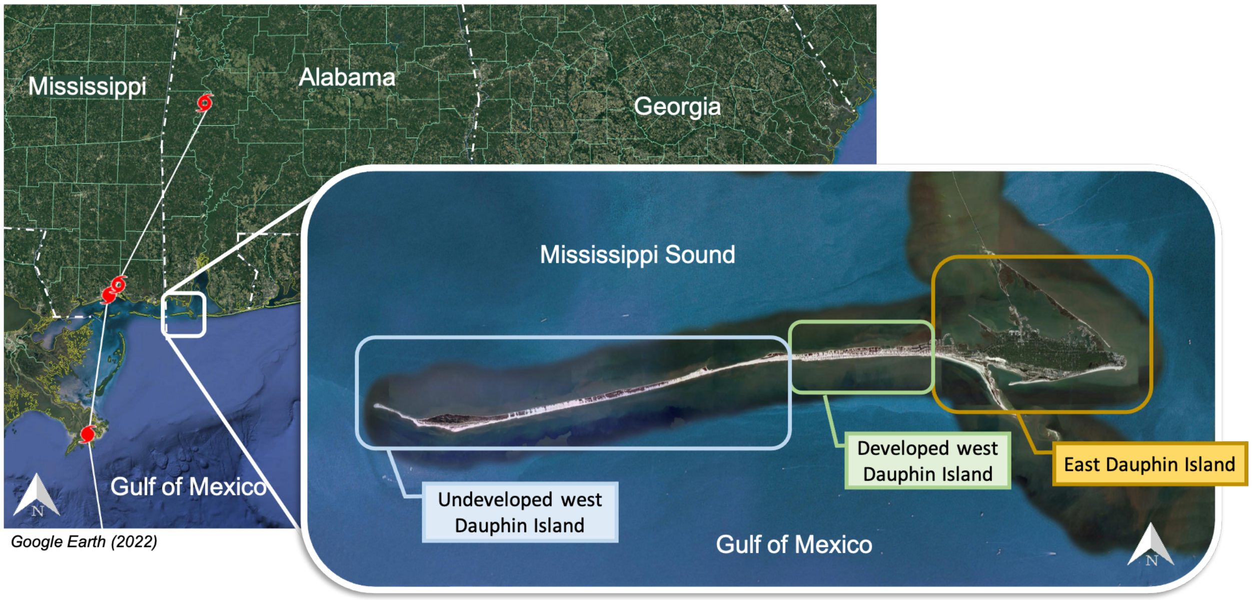


Figure 1. Dauphin Island is located in south Mobile County in Alabama. Hurricane Nate track is shown on the larger map (Google Earth, 2022).

Over the last 60 years, Dauphin Island has experienced an average SLR rate of 4.25 mm/yr, nearly double that of global estimates ("Sea Level Trends," 2022; Sweet et al., 2017). From 1993 to 2017, the SLR rate was 5.08 mm/yr, suggesting an accelerating trend ("Sea Level Trends," 2022). Significant increases in sea level (up to an additional 2.5 m) are projected over the next century (Sweet et al., 2017). Although the uncertainty in the estimates is substantial, it is certain that the economic loss potential of future hurricanes is in the billions, which could cripple the local economy.

On Dauphin Island, the pathways were developed for a location near a freshwater aquifer on the east end and near borrow pits on the developed west end (Fig. 1). These two sites are referred to as the "aquifer site" and the "middle west end site", respectively. Model calibration was performed using a site at the west end public beach, referred to as the "west end site" hereafter.

1.2 Project Objectives

As described in the funded proposal, this project aimed to meet three main objectives:

1. Summarize the present state-of-knowledge on adaptation methods of coastal communities;

2. Develop conceptual models for determining alternative adaptation pathways for an example barrier island community;
3. Test, revise, and validate approaches on an example barrier island community using an open-source numerical model.

This final report describes the methodologies employed to meet the three objectives, results from numerical modeling and extension efforts, and a discussion of the outputs resulting from this project. Through this project, we achieved the following expected outcomes:

- Enhanced capacity for the example barrier island community to utilize limited resources to protect their community in the face of rising sea levels;
- Advanced the coastal community's body of knowledge on the morphological changes of developed barrier islands during a hurricane and SLR, influences of ocean- and bay- side hydrodynamics on those morphological changes, and strategies to mitigate storm impacts;
- Expanded the extension community's body of knowledge on best practices for successful engagement in the complex communities found on barrier islands, particularly when discussing climate change.

2 Methodology

Numerical modeling was used to estimate the physical changes of barrier island topography to storms and SLR, and the modeling was informed by results from community engagement. These methodologies are described in the following subsections.

2.1 Morphodynamic Modeling

The process based, numerical model, XBeach, was used to simulate morphological change on Dauphin Island due to Hurricane Nate (2017), SLR scenarios, and whether or not an adaptation strategy was implemented. XBeach has been used to model storm impacts on complex topographies in several studies. In this study, we calibrated XBeach using survey data collected after Hurricane Nate. This storm was chosen as the study's storm of record due to: i) the quality of data collected during the storm and available for simulation and calibration and ii) the level and type of damage sustained by Dauphin Island. Because of the damage characteristics, using Hurricane Nate in this adaptation research produces relevant results for the Town of Dauphin Island (referred to as the Town hereafter) to consider; whereas, a more severe storm, like Hurricane Katrina, would devastate this community regardless of the adaptation strategies implemented.

2.1.1 XBeach

XBeach is a two-dimensional horizontal (2DH) model that resolves infragravity waves and simulates hydrodynamics and morphology in the complex nearshore and coastal environment (Roelvink et al., 2009). Since XBeach cannot resolve individual waves in standard mode or three-dimensional processes, some processes are parameterized, resulting in the need for model calibration. User-defined model parameters were set at default in all instances except for the following: grain sizes were set to a D50 of 0.22 mm and D90 of 0.35 mm D90 (Buhring, 2017); *facua,* which accounts for wave skewness and governs onshore sediment transport, was set to 0.01; and wave bins were specified as 20° with waves approaching from 30 degrees to 310 degrees (nautical convention).

The 2D bathymetric grids used in the simulations were developed using the 2016 LiDAR survey for topography and Digital Elevation Model (DEM) for bathymetry. The grids are spatially varying in both the *x* and *y* directions with 1 m cell size in the high-resolution area to 30 m cell size in the low-resolution areas (on lateral ends and offshore boundary; an example grid is shown in Fig. 3). Friction factors were specified for changes in land cover in the model grid to simulate the difference in behavior of materials (sand, vegetation, roadway, open water, etc.). Manning's roughness coefficients for Dauphin Island, AL determined by

Passeri et al. (2018) were used (Table 2). Hard structures such as the seawall at the west end site are specified in the model grid by setting the corresponding grid cells as “nonerodable” such that no bed level changes are simulated in those cells.

Table 1. Manning's *n* coefficient values specified in model grids (Passeri et al. 2018).

Land Cover Class	Manning’s *n*
Open Water	0.022
Unconsolidated Shore	0.03
Open Space Development	0.035
Shrub Vegetation	0.08
Low Development	0.12

On the east and middle west end grids, adaptation strategies were implemented in the grid by altering topographic and bathymetric elevations and spatially varying friction factors due to changes in land cover. Adaptation strategies were determined through community engagement and outreach, ongoing project efforts, and by the project team. East end adaptation strategies include two design beach templates to prevent saltwater from overtopping the dunes and intruding the freshwater source for the aquifer. Beach template #1 widened the beach 70 m, whereas beach template #2 reflected the ongoing beach nourishment project on the east end by widening the beach 70 m and raising the elevation to 1.83 m NAVD88. Middle west end adaptation strategies include one design beach template, a linear dune system behind Gulf-front homes, and infilling borrow pits on the north side of the island. This beach template restored the shoreline to a historical location by widening the beach 50 m. The linear dune system was achieved by “elevating” driveways to nearly the same elevation as surrounding dunes. The borrow pits were filled by increasing those elevations to an average of surrounding topography, approximately 1 m. Adaptation pathways were created by evaluating the effectiveness of each strategy in protecting the barrier island community from damage during future storm scenarios using XBeach.

2.1.2 Hurricane Nate

In 2017, Hurricane Nate made US landfall near Gulfport, MS on Oct 8 at 00:20 CDT as a Category 1 hurricane (Fig. 1, hurricane track). While Hurricane Nate was considered a relatively minor tropical event and produced little structural damage, there was extensive morphological damage on western Dauphin Island. The entire western reach experienced morphological damage, some areas only being partially overwashed while others experienced overwash across the entire island width (Coogan et al. 2019).

The hydrodynamic forces used in the XBeach simulations are Hurricane Nate storm surge measured by the Dauphin Island tide gauge (NOAA Tides and Currents, 2017) and spectral waves measured by the NDBC's Station 42012 (NDBC, 2017; see Fig. 2). The wave angle, θ, is given in nautical convention. It is assumed that the water levels in the Gulf of Mexico and Mississippi Sound are equal. While that assumption is likely inaccurate, the data available for sound water levels is limited.

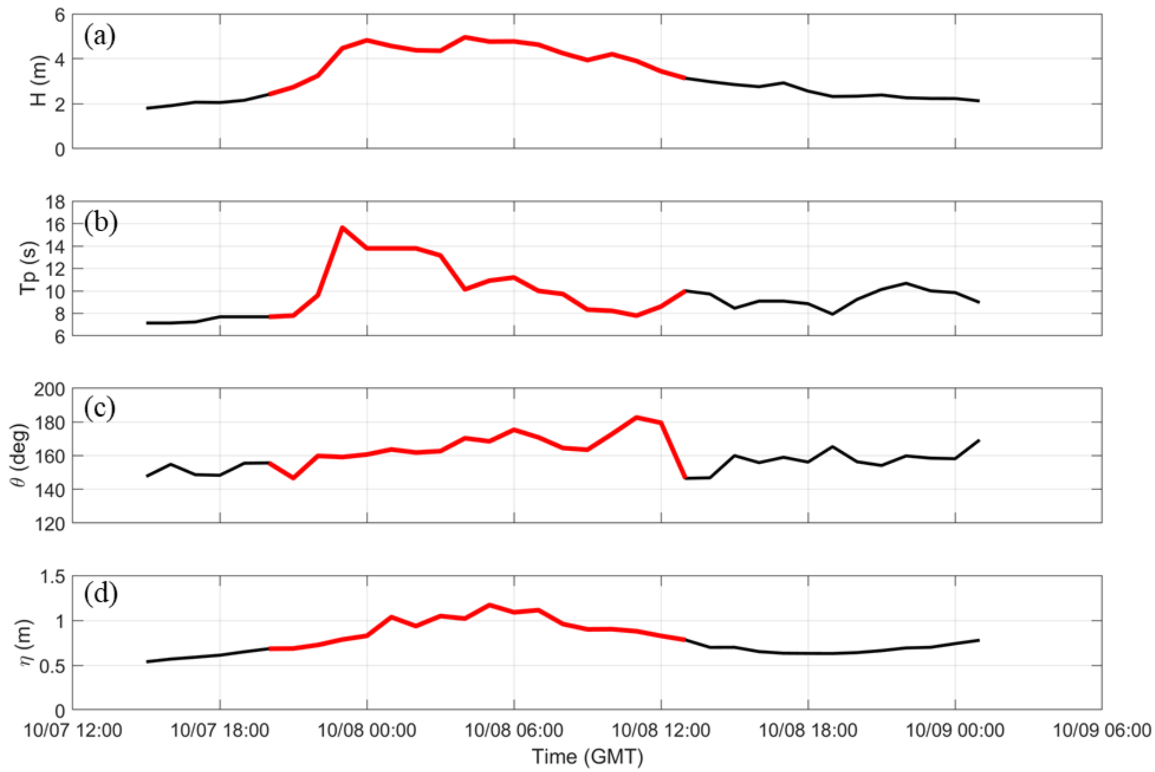


Figure 2. XBeach hydrodynamic inputs at the 25.9 m water depth contour for Hurricane Nate where (a) is spectrally significant wave height, H, (b) is peak period, Tp, (c) is mean wave directions, θ, in nautical convention and (d) is water level, η. The red line represents the shortened storm used for simulation.

2.1.3 Sea-level Rise Scenarios

Based on the stakeholder input, the SLR analysis consisted of simulating the following Sweet et al. (2017) Dauphin Island, AL RSLR projections for 2100: Low (0.53 m), Intermediate-Low (0.66 m), Intermediate (1.26 m), and Intermediate-High (1.93 m). Three other SLR values were simulated to provide higher resolution of analysis of the Sweet et al. (2017) RSLR projections: 0.4 m, 0.75 m, and 1.0 m. Sea level rise is included in the simulations by superimposing the amount of SLR onto the Gulf of Mexico and Mississippi Sound water levels using the initial bathymetry (i.e. before any morphological change is simulated). When applying the methods for simulating SLR, the "bathtub" approach is used such that the barrier island has not evolved in response to SLR.

2.1.4 Survey Data

Pre- (6 October 2017) and post- (9 October 2017) storm survey data were collected along seven transects at the west end public beach using a real-time kinematic (RTK) Trimble R8 global positioning system (GPS) (Coogan et al. 2019). Data were collected in Universal Transverse Mercator (UTM) zone 16 with respect to the North American Vertical Datum of 1988 (NAVD88) (Coogan et al. 2019). Pre- and post-storm drone imagery were also collected by the reconnaissance team.

2.2 Extension and Outreach

Several meetings were held with the Town leadership and community members to ensure this adaptation research can be utilized in making the island more resilient to hurricanes and SLR. An in-person meeting was held on 23 January 2020 with leaders of the Town to familiarize them with the project and gain insight into their concerns, ideas, and planning perspectives. In attendance were Mayor Jeff Collier of Dauphin Island, members of the Dauphin Island Planning Commission, a representative of the Dauphin Island Water and Sewer Board, a representative of Alabama Power, and the project team. Vulnerable locations and potential adaptation strategies were discussed to identify which strategies would be agreeable to the residents of Dauphin Island. Planning perspectives for Dauphin Island were discussed to obtain information on the existing critical infrastructure and what timelines were being considered.

Exceedance probabilities that correspond to the Sweet et al. (2017) RSLR projections under Representative Concentration Pathway (RCP) 8.5 (Table 1) were discussed to gain insight on the island leadership's risk tolerance. Exceedance probabilities, rather than quantities of SLR, were presented to prevent bias. The probabilities associated with RCP8.5 were used because the most recent observations are reflected most accurately by RCP8.5 (Terando et al. 2020) and using only one RCP (as opposed to several) focuses the presentation of and dialogue around the exceedance probabilities and risk tolerance. The range of SLR scenarios, Low through Extreme, cover the amount of SLR that is scientifically plausible by 2100 (Sweet et al., 2017). Probabilities communicate the likelihood of each scenario being exceeded under a specific RCP. For example, under RCP8.5, it is 100% likely that there will be at least 0.3 m of SLR by 2100, while it is much less likely that at least 2.5 m of SLR will occur by 2100 (Table 1) (Collini et al. 2018). Each attendee was able to vote for the two scenarios they thought were most appropriate for planning on Dauphin Island. This leadership meeting framed discussion with the broader community on vulnerable locations, adaptation strategies, and SLR scenarios to consider.

Table 2. SLR scenarios and their corresponding likelihood of exceedance under RCP8.5 (Sweet et al. 2017) as presented during the community outreach.

Sea Level Rise Scenario	Likelihood
Low	100%
Intermediate-low	96%
Intermediate	17%
Intermediate-high	1.3%
High	0.3%
Extreme	0.1%

A final, hybrid meeting was held on 30 June 2022 to describe modeling results and discuss the final adaptation pathways for the east end and middle west end locations.

2.2.1 Virtual Community Engagement

The initial plan was to hold in-person meetings with members of the Dauphin Island community to inform residents about the project, contextualize the project to other ongoing projects on the island, share the areas that will be researched, discuss any additional vulnerable areas and SLR risk tolerance, and answer any questions. However, due to COVID-19 and safety protocols, we changed the Dauphin Island resident outreach plan to be carried out over a virtual platform. We created a Facebook Page for our project, "DI Adaptation Pathway: Minimizing chances of future breaching" (with permission from the funding agency), and used the platform to communicate with the Dauphin Island community. Two Facebook Live events, two Zoom sessions, and two call-in events were held in lieu of in-person meetings to introduce the project, answer questions, and advertise the opportunity to weigh in on the research scope. Those events were advertised through the project's Facebook page and mailed flyers.

Following the community events, follow-up surveys were either mailed or emailed, depending on the recipient's preference (Appendix A). The surveys asked participants to identify additional vulnerable locations, vote for adaptation strategies they were in favor for, make suggestions for strategies not considered, identify their risk-tolerance to SLR, and ask any additional questions for follow-up. Two follow-up Zoom meetings were also held where participates could participate in the survey. Throughout the project, we provided updates, such as "About Me" posts by team members and a Year In Review post (Appendix B) on our Facebook page to maintain engagement with the community.

3 Results and Discussion

The success of this project was dependent on effective communication with community leadership and members who informed the modeling effort, which was used to produce two adaptation pathways. Separating the model results from the extension results as done below is to improve readability of this report; however, the two parts of this project were integrated in one another and cannot be truly separated.

3.1 Model Results

3.1.1 Calibration: West End Site

The accuracy of the model setup was evaluated using both quantitative and qualitative data. XBeach results were compared to survey, drone, aerial imagery, and satellite data. Brier Skill Scores (BSS) were calculated for each elevation survey transect taken by Coogan et al. (2019) in the west end site model domain using the method described by Van Rijn et al. (2003). A BSS equal to 1 indicates perfect model performance, a value of 0 occurs when modeling the baseline condition, and a negative value means the model performs worse than predicting no change. Our model simulated morphological change due to Hurricane Nate with BSS of 0.84 to 0.96 in the high-resolution region of the grid (shown in Fig. 3). Detailed calibration results can be found in Posey (2021).

Simulations indicate erosion in the swash zone and overwash fans in the backbarrier area (Fig. 3). The borrow pit located east of transect T1 breaches to Mississippi Sound on the north side of the island in the model, which was supported by drone imagery collected immediately after the storm and aerial imagery collected days after landfall (Fig. 4). The aerial imagery shows the breach starting to close up, suggesting barrier island recovery begins immediately after a storm and topography changes relatively quickly. Satellite imagery collected approximately five weeks later on 18 Nov 2017 (not shown) does not reveal any indication the borrow pit breached during the storm, underscoring the importance of post-event reconnaissance.

From these results, the quantitative and qualitative comparisons between modeled data and field data indicate the model is well-calibrated. As indicated above and shown below, the model grid was altered to include adaptation strategies and input water level data were altered to include SLR. Otherwise, the same model setup is used for all simulations in this project.

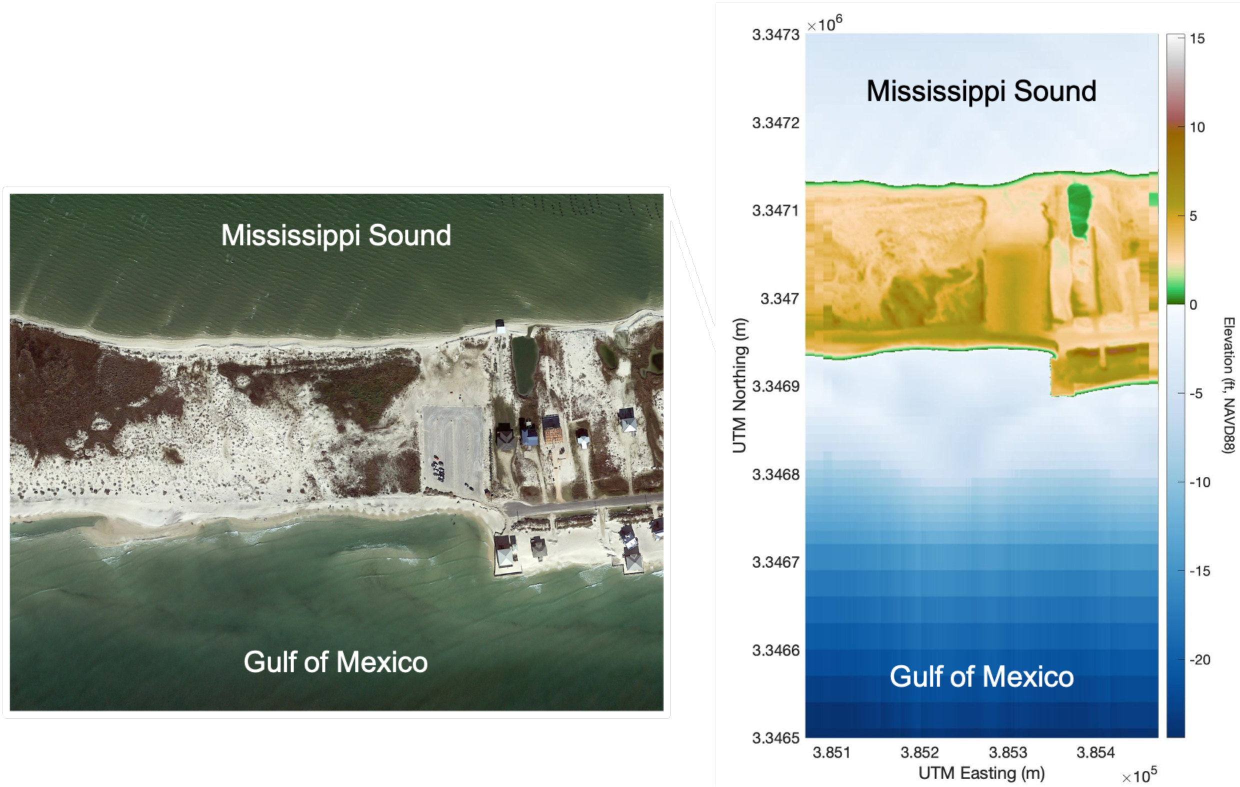


Figure 3. Satellite imagery (left) and initial bed elevations (right) in the high-resolution region of the model domain. Note, this figure was presented at community meetings so the vertical scale is in US customary units.

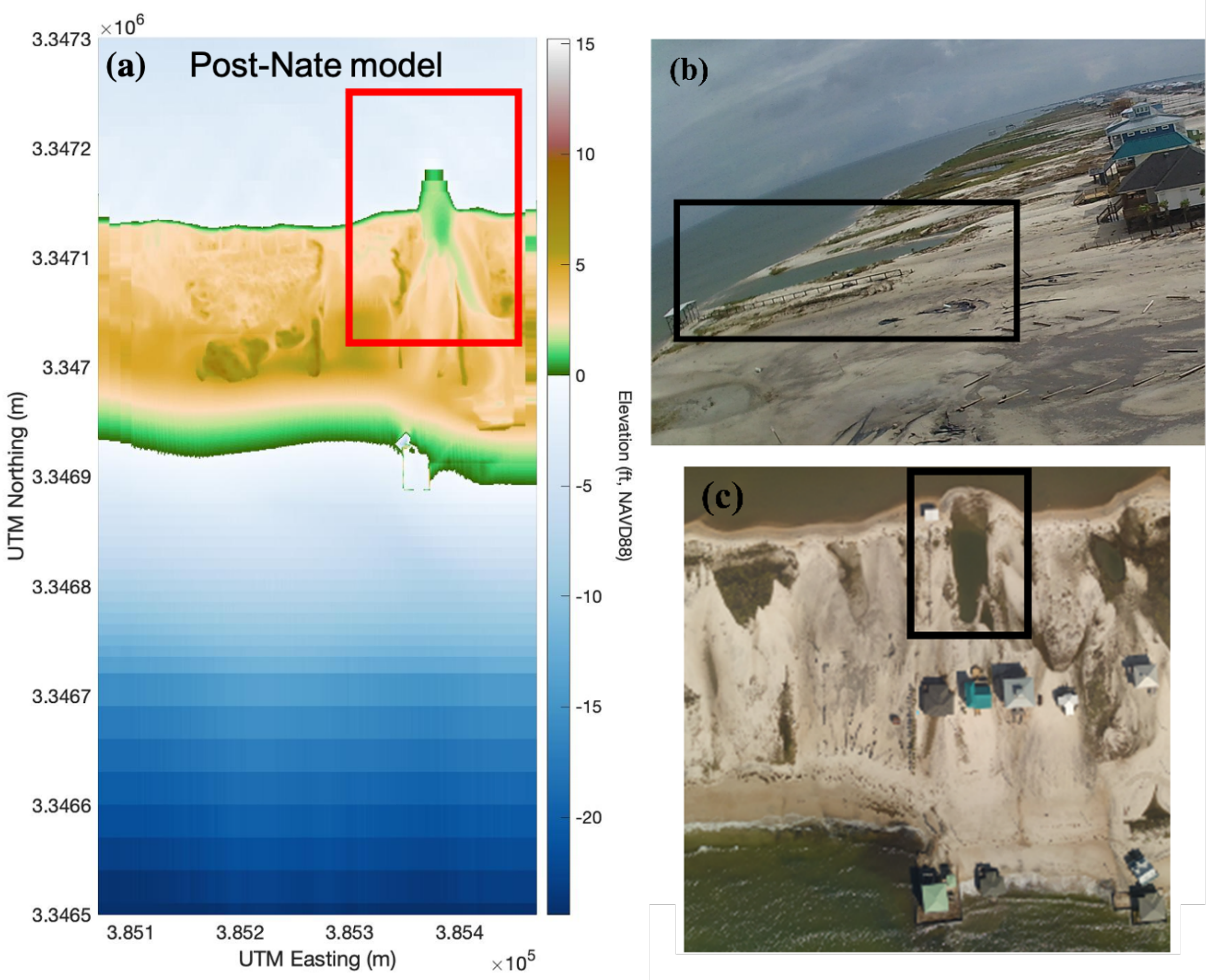


Figure 4. Post-storm west end site final simulated bed elevations (a) show the west end beach borrow pit (a, red box) breaching into Mississippi Sound. Drone imagery (b) collected two days post-Nate (Coogan et al. 2019) and aerial imagery (c) collected three days post-Nate (NGS 2017) show the same breach (black boxes). Note, this figure was presented at community meetings so the vertical scale is in US customary units.

3.1.2 Simulations: East End Site

The east end site initial grid was altered to include two beach design templates, the more robust of which is ongoing on Dauphin Island (shown in Fig. 5). Results show minor overtopping for the intermediate-high and extreme SLR scenarios for the eastern transect T3E when an adaptation strategy was not implemented. Beach templates #1 and #2 Detailed model setup and results for the east end site can be found in Bellais (2022).

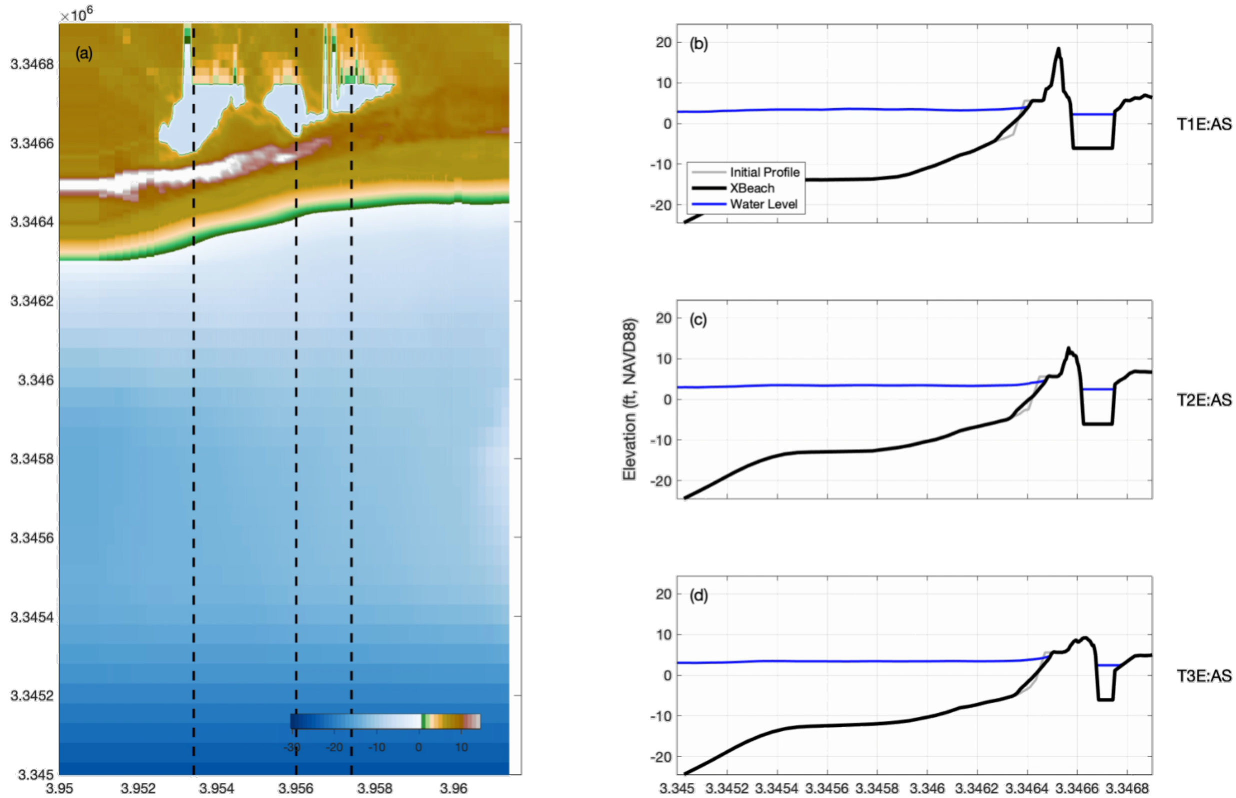


Figure 5. Example of simulation at the peak of the storm and no SLR on the beach template #2 adaptation strategy grid (left) and transects (right) of the initial profile and the bed levels and water levels at this time in the simulation. Note, this figure was presented at community meetings so the vertical scale is in US customary units.

3.1.3 Simulations: Middle West End Site

The original focus of this site was to determine under which SLR scenario the middle west end site would breach. A breach at this location would sever areas containing residential and municipal infrastructure from the island and prevent emergency operations west of the breach. However, for Hurricane Nate conditions, simulation results did not show a breach occurring under any SLR scenario. Instead, the island overwashes and rolls over as it is inundated with higher sea levels.

Since breaching was not observed in the simulations at this site, we shifted our focus to determine the effectiveness of adaptation strategies at mitigating morphological damage due to a hurricane and SLR scenarios. Implementing the adaptation strategies previously described, the linear dune system prevented sand from overwashing onto Bienville Boulevard, a priority distinguished by the Town (Fig. 6). However, as sea levels rise, the backbarrier (north side) of the island is inundated. The linear dune system starves the back barrier of sediment and prevents sound side water levels from draining to the Gulf side, exacerbating backbarrier inundation by bay-side water levels. Filling the borrow pits prevents the backbarrier from inundating for SLR scenarios less than 1 m (approximately 3 ft). Beach nourishment is observed to be the most effective strategy at mitigating morphological damage on the Gulf side of the island; however, it does not provide protection to the backbarrier. Detailed results of the middle west end site can be found in Delaney (2022).

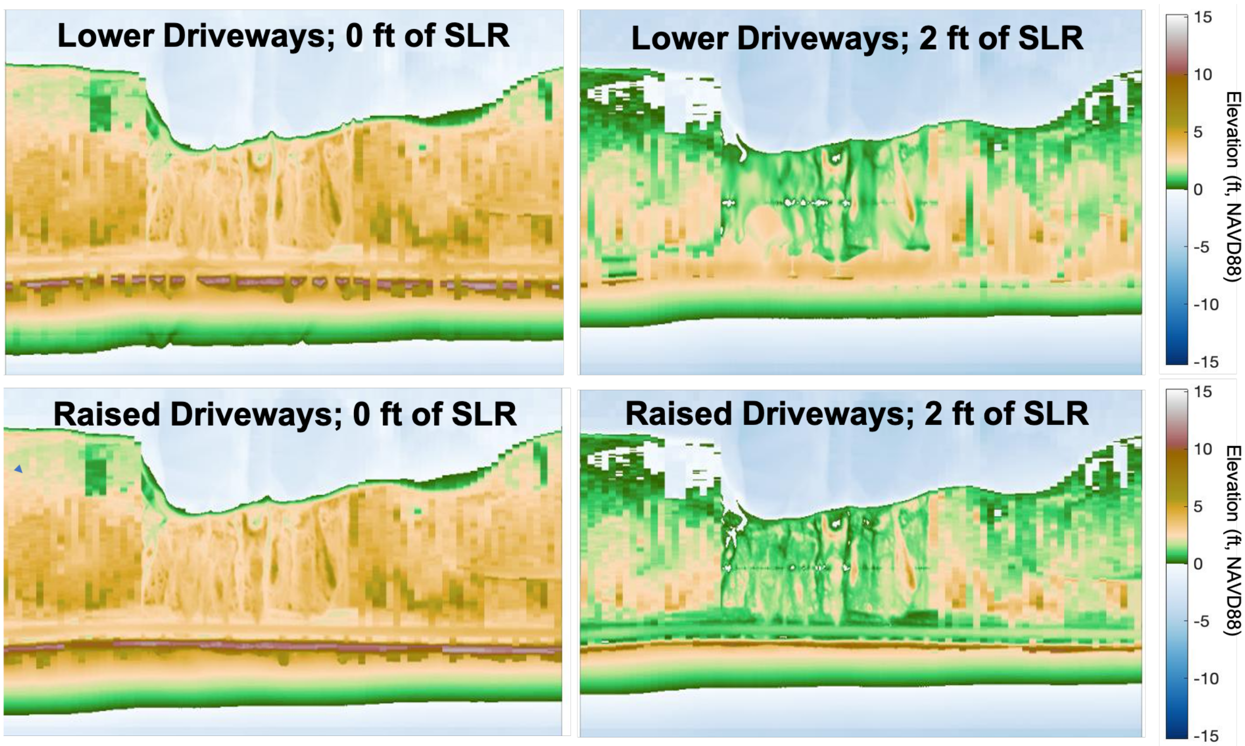


Figure 6. Final simulated morphological change for (top) without the linear dune system ("lower driveways"); (bottom) with the linear dune system for (left) no SLR and (right) with 2 ft of SLR. Note, this figure was presented at community meetings so the vertical scale is in US customary units.

3.2 Extension Results

Vulnerable locations to be analyzed in this study and locations of critical infrastructure were identified and agreed upon by the island's leadership and project team. We collected and quantified results from the follow-up surveys and meetings and shared the results with the community through our project Facebook page. The three locations described herein, the west end site, the middle west end site, and the east end site, were selected with the input of the Town of Dauphin Island's leadership and residents (Fig. 7; blue boxes). Based on community input, the east end site was included in our project and highlights the importance of engaging the community at the onset of research – we had not previously considered the east end site as a critically vulnerable location. The infrastructure that could directly or indirectly be impacted by either storm surge or breaching were identified (Fig. 7, yellow). The Dauphin Island leadership chose the Sweet et al. (2017) intermediate and intermediate-high SLR scenarios as the most appropriate for planning on Dauphin Island based on the exceedance probabilities. The Dauphin Island Community chose the Sweet et al. (2017) low and intermediate-low as the most appropriate for planning on Dauphin Island based on the exceedance probabilities. These results showed that the town leadership (who chose less likely scenarios) are more risk averse than the community members. Since most island residents are concerned with shorter planning horizons (e.g., 30-year mortgage) compared to those of island leadership (e.g., 50-year water treatment facility design life), it was expected the residents would choose SLR scenarios with higher likelihoods of occurrence lower values of SLR). The full reports on the meetings with the town's leadership can be found in Collini et al. (2020) and with the town's residents in Heming et al. (2021).

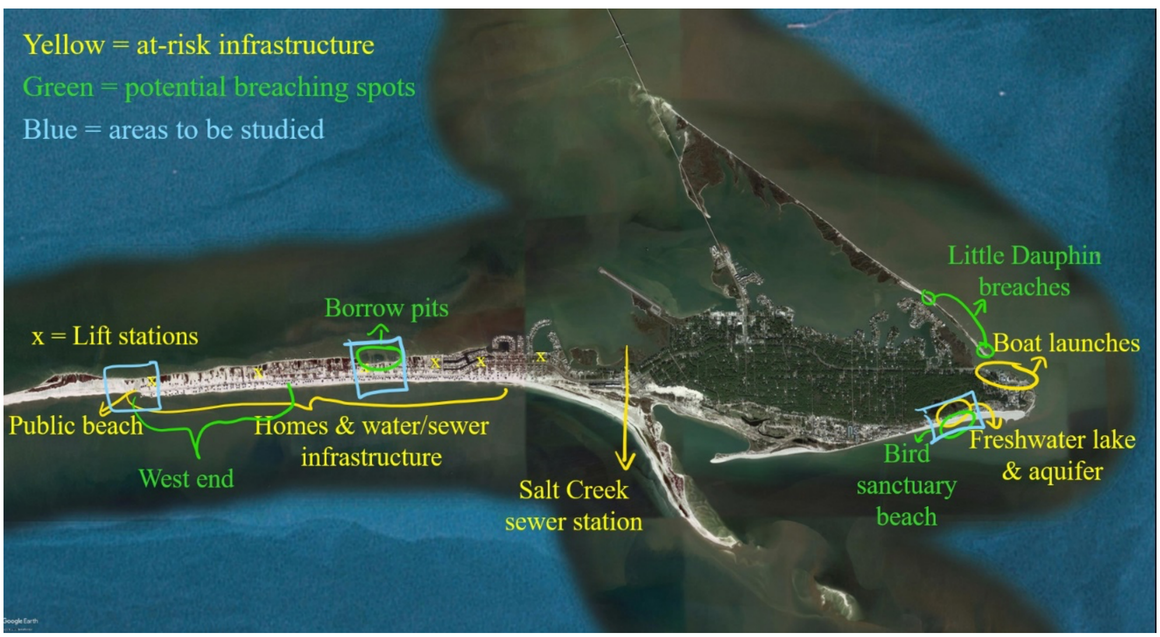


Figure 7. Results figure from the Dauphin Island Adaptation Pathway Meeting with the Town of Dauphin Island's leadership (Collini et al. 2020). Three locations (blue boxes) were chosen as at-risk areas to be analyzed in the overall project. The areas highlighted in green are locations deemed vulnerable to breaching by the Dauphin Island leadership. The areas highlighted in yellow are critical infrastructure on the island.

In the final meeting with the Town leadership, we explained our methodology, described the model results, and discussed the adaptation pathways created from this project. The east end beach nourishment (template #2) project is underway. Results from the middle west end provided insight on the effectiveness of the linear dune system at preventing sediment from depositing on Bienville Boulevard, and the Town is already pursuing opportunities to elevate driveways to create the linear dune system. The final meeting also brought to light the vulnerability of the back barrier and the need to pursue adaptation strategies to prevent inundation as sea levels rise. Handouts were provided to meeting attendees as "take-aways" from this project (Appendix C).

3.3 Adaptation Pathways

In total, three adaptation pathways were created from this project, and each of the three define "resilience" differently based on community input. One pathway was created for the east end (Fig. 8) and shows the ongoing project (orange asterisk) is an effective strategy to prevent saltwater from overtopping the dune and into the freshwater lake for every SLR scenario considered in this study.

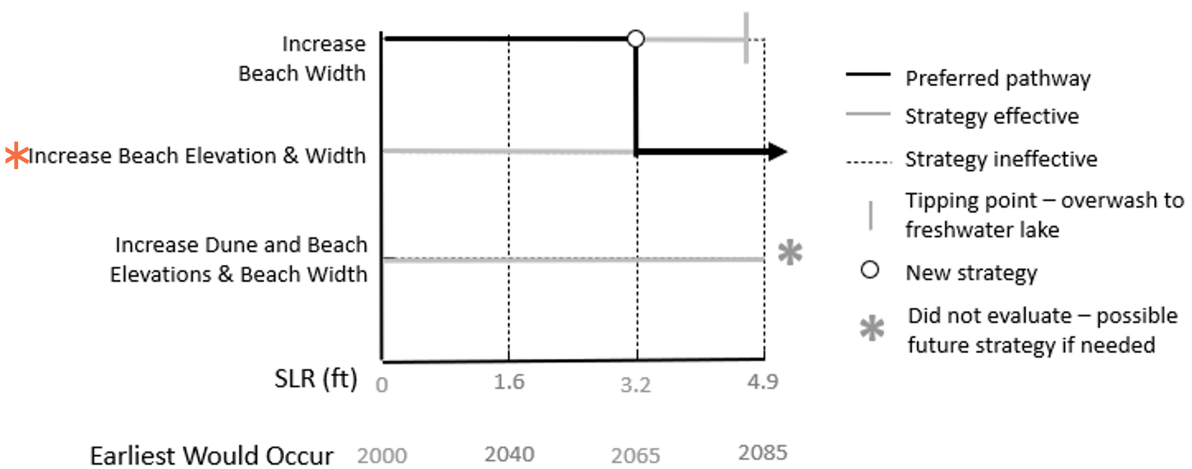


Figure 8. The east end site adaptation pathway shows the ongoing project (orange asterisk) is effective at preventing saltwater from overtopping the dune and into the freshwater lake for every SLR scenario considered in this study. Note, this figure was presented at community meetings so SLR quantity is in US customary units.

The middle west end results produced two adaptation pathways. The first defines an increase in resilience as preventing sand from overwashing onto Bienville Blvd. Up to 2 ft of SLR, the linear dune feature ("elevating driveways") is effective at increasing resilience because the amount of sediment deposited onto Bienville Blvd is drastically reduced (Fig. 9). As sea levels rise beyond 2 ft, beach nourishment is triggered and is effective at mitigating damage on the Gulf side of the island up to 3 ft under Hurricane Nate forcing. Beyond 3 ft of SLR, the island begins to inundate and roll over. However, the backbarrier is inundated during these scenarios. Therefore, a second adaptation pathway (Fig. 10) that takes a holistic approach to island resilience was created and shows elevating the driveways, while preventing sediment from depositing onto Bienville Blvd, does not prevent the backbarrier from flooding. The second adaptation pathway shows filling the borrow pits is a better strategy to increase overall island resilience because it prevents the backbarrier from inundating for SLR up to about 1.6 ft. At that sea level, beach nourishment is triggered and remains effective for up to 3 ft of SLR, at which point the island begins to inundate and roll over.

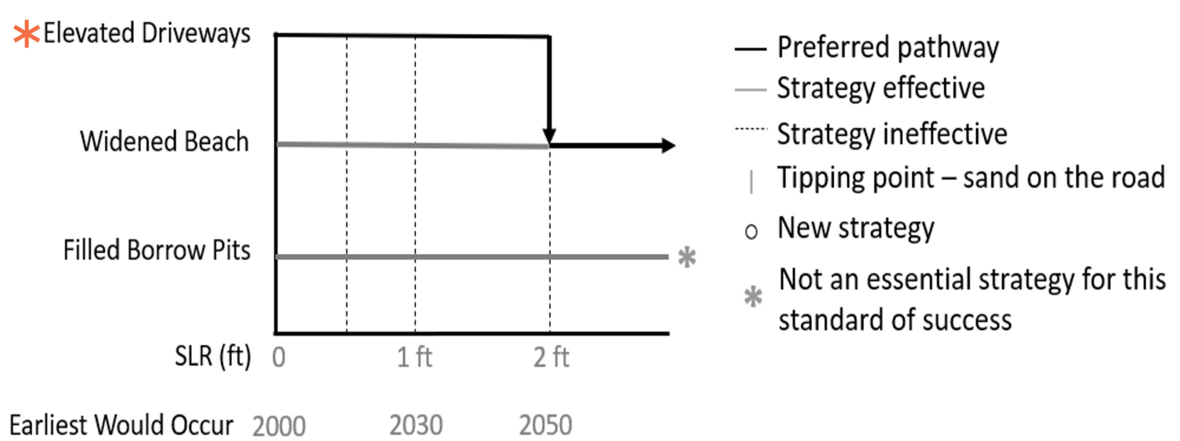


Figure 9. The first (of two) middle west end site adaptation pathway shows the linear dune system (orange asterisk) is effective at preventing sediment from overwashing onto Bienville Boulevard for up to 2 ft of SLR. Note, this figure was presented at community meetings so SLR quantity is in US customary units.

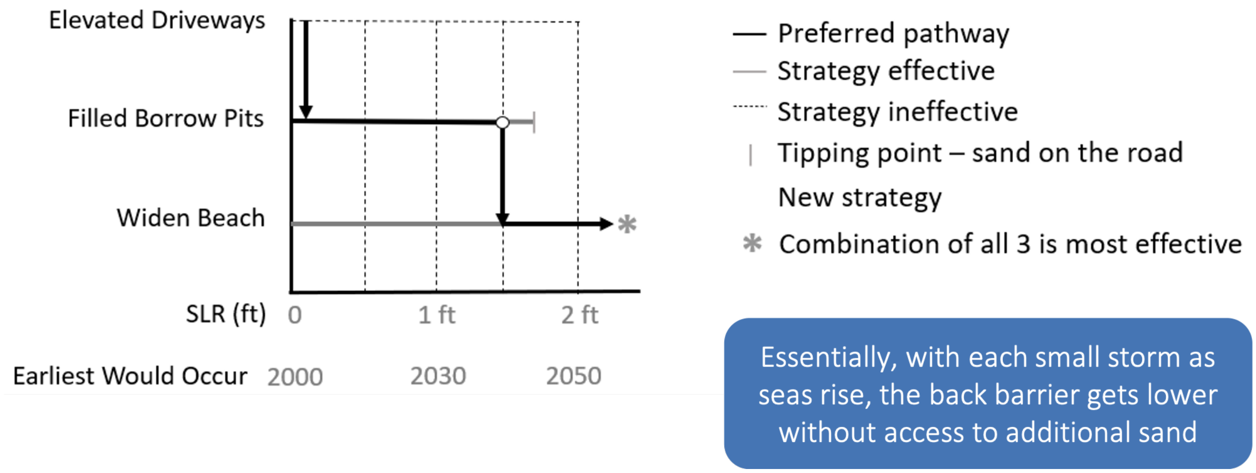


Figure 10. The second (of two) middle west end site adaptation pathway shows filling the borrow pits is effective at mitigating storm damage up to 1.6 ft of SLR, when a tipping point is reached and necessitates beach nourishment. Note, this figure was presented at community meetings so SLR quantity is in US customary units.

3.4 Study Limitations

While the results presented herein are useful for providing insight into barrier island morphological change to a storm and SLR scenarios, this study has several limitations:

- Hurricane Nate is the only storm considered for simulations. Additional storms should be simulated to obtain a holistic understanding of how Dauphin Island may be impacted in the future.
- Long-term barrier island evolution is not simulated in this study and each simulation starts with "today's condition". That means, as Dauphin Island topography and bathymetry change over time due to short and long-term processes, the results presented herein may not accurately reflect Dauphin Island's response to a similar storm.
- The "bathtub" approach was used to implement SLR scenarios in the model. It is known that SLR can have a non-linear interaction with storm surge and waves.

3.5 Project Outputs

Throughout the two-year project, extension specialists responsible for community engagement and coastal engineers responsible for numerical modeling maintained regular communication via monthly calls. We held four in-person meetings with Dauphin Island leadership and several virtual calls and video meetings with the community. This project supported three graduate student theses in the Civil, Coastal, and Environmental Engineering Department at the University of South Alabama, produced two manuscripts and conference proceedings with two more in preparation, four invited talks, eight conference presentations, and two technical reports. Our project was also featured in Dauphin Island's Town Crier and is being used to pursue funds for implementing adaptation strategies. We continue this work by expanding our numerical modeling simulations to include additional storms and simulated SLR impacts.

4 Conclusions

This project produces three adaptation pathways for two sites on Dauphin Island, AL, which served as the example barrier island community for this research. Integrating community engagement from the onset of this project and working closely as a team of extension specialists and coastal engineers proved critical to the success of this project. Using data collected before and after Hurricane Nate (2017), we calibrated an XBeach model and produced post-storm profiles that agreed with survey data with Brier Skill Scores up to 0.96. The calibrated model was then altered to incorporate adaptation strategies and SLR scenarios, determined from meetings with Dauphin Island leadership and community members. Model results were used to estimate the effectiveness of adaptation strategies to mitigate damage due to Hurricane Nate under rising seas. The model results were compiled into adaptation pathways, which show the which adaptation strategy to implement based on observed SLR and desired outcome (i.e. one pathway focuses on keeping sand off of the main thoroughfare whereas another pathway focuses on overall island resilience). The pathways show that, ultimately, beach nourishment is an effective strategy to mitigate damage to the Gulf-side of the island, but the backbarrier inundates as seas rise without raising backbarrier elevations.

5 References

Bellais, K., 2022. "Adaptation strategies to mitigate impacts of sea level rise on a freshwater aquifer supply on a barrier island." Master's Thesis. University of South Alabama.

Buhring, B., 2017. "Dauphin Island East End Beach and Barrier Island Restoration Project." Perdido Beach Resort.

Collini, R., Smallegan, S., Heming, M., Posey, S., Collier, J., Wood, C., Edwards, P., Fleming, H., Murril, S., 2020. *Report for the Dauphin Island Adaptation Pathway Meeting*. Mississippi-Alabama Sea Grant Consortium.

Collini, R., Sweet, W., Weaver, C., Roche, C., Fulford, C., Garfield, N., Hanisko, M., Hintzen, K., Luscher, A., Marcy, D., Scott, G., Spiegler, S., Stiller, H., Sudol, T. (2018). Sea Level Rise Two Pager Resource. masgc.org/northern-gulf-of-mexico-sentinel-site-co/two-pager.

Coogan, J., Webb, B., Smallegan, S., and Puleo, J., 2019. "Geomorphic changes measured on Dauphin Island, AL, during Hurricane Nate." *Shore & Beach*, 87(4).

Delaney, B., 2022. "Adaptation strategies to mitigate morphological damage from future storms on Dauphin Island." Master's Thesis. University of South Alabama.

Douglass, S.L., 1994. Beach Erosion and Deposition on Dauphin Island, Alabama, U.S.A. J. Coast. Res. 10, 306–328.

Froede, C.R., 2006. The Impact that Hurricane Ivan (September 16, 2004) Made across Dauphin Island, Alabama. J. Coast. Res. 223, 561–573. https://doi.org/10.2112/05-0438.1

Froede, C.R., 2008. Changes to Dauphin Island, Alabama, Brought about by Hurricane Katrina (August 29, 2005). J. Coast. Res. 24, 110–117.

Heming, M., Collini, R., Schafer, C., Smallegan, S., Posey, S., 2021. *Report for the Dauphin Island Adaptation Pathway Virtual Engagement*. Mississippi-Alabama Sea Grant Consortium.

NOAA's National Data Buoy Center., 2017. Station 42012 – Orange Beach – 44 NM SE of Mobile, AL, https://www.ndbc.noaa.gov/station_history.php?station=42012, (accessed May 2019).

NOAA's Tides and Currents. (2017). Station ID: 8735180 – Dauphin Island, AL, https://tidesandcurrents.noaa.gov/waterlevels.html?id=8735180, (accessed May 2019).

Passeri, D.L., Long, J.W., Plant, N.G., Bilskie, M.V., Hagen, S.C., 2018. The influence of bed friction variability due to land cover on storm-driven barrier island morphodynamics. Coast. Eng. 132, 82–94. https://doi.org/10.1016/j.coastaleng.2017.11.005.

Posey, P., 2021. "Hurricane impacts on a barrier island under sea level rise scenarios using a calibrated model." Master's Thesis. University of South Alabama.

Roelvink, D., Reniers, A., van Dongeren, A., van Thiel de Vries, J., McCall, R., Lescinski, J., 2009. Modelling storm impacts on beaches, dunes and barrier islands. Coast. Eng. 56, 1133–1152. https://doi.org/10.1016/j.coastaleng.2009.08.006.

Sea Level Trends, 2022. NOAA Tides Curr. URL: https://tidesandcurrents.noaa.gov/sltrends/sltrends.html (accessed 11 August 2022).

Smallegan, S.M., Irish, J.L., Van Dongeren, A.R., Den Bieman, J.P., 2016. Morphological response of a sandy barrier island with a buried seawall during Hurricane Sandy. Coast. Eng. 110, 102–110. https://doi.org/10.1016/j.coastaleng.2016.01.005.

Sweet, W.V., Kopp, R.E., Weaver, C.P., Obeysekera, J., Horton, R.M., Thieler, E.R., Zervas, C., 2017. Global and regional sea level rise scenarios for the United States.

Terando, A., Reidmiller, D., Hostetler, S., Littell, J., Beard Jr., T.D., Weiskoph, S., Belnap, J., and Plumlee, G., 2020. Using Information From Global Climate Models to Inform Policymaking—The Role of the U.S. Geological Survey. https://pubs.usgs.gov/of/2020/1058/ofr20201058.pdf.

Van Rijn, L.,Walstra, D., Grasmeijer, B., Sutherland, J., Pan, S., Sierra, J., 2003. "The predictability of cross-shore bed evolution of sandy beaches at the time scale of storms and seasons using process-based profile models." *Coast. Eng.* 47, 295–327.

6 Appendices

Appendix A – Mailed Survey

Appendix B – Year in Review

Appendix C – Project “take-aways”

Join us at facebook.com/NoBreachDI

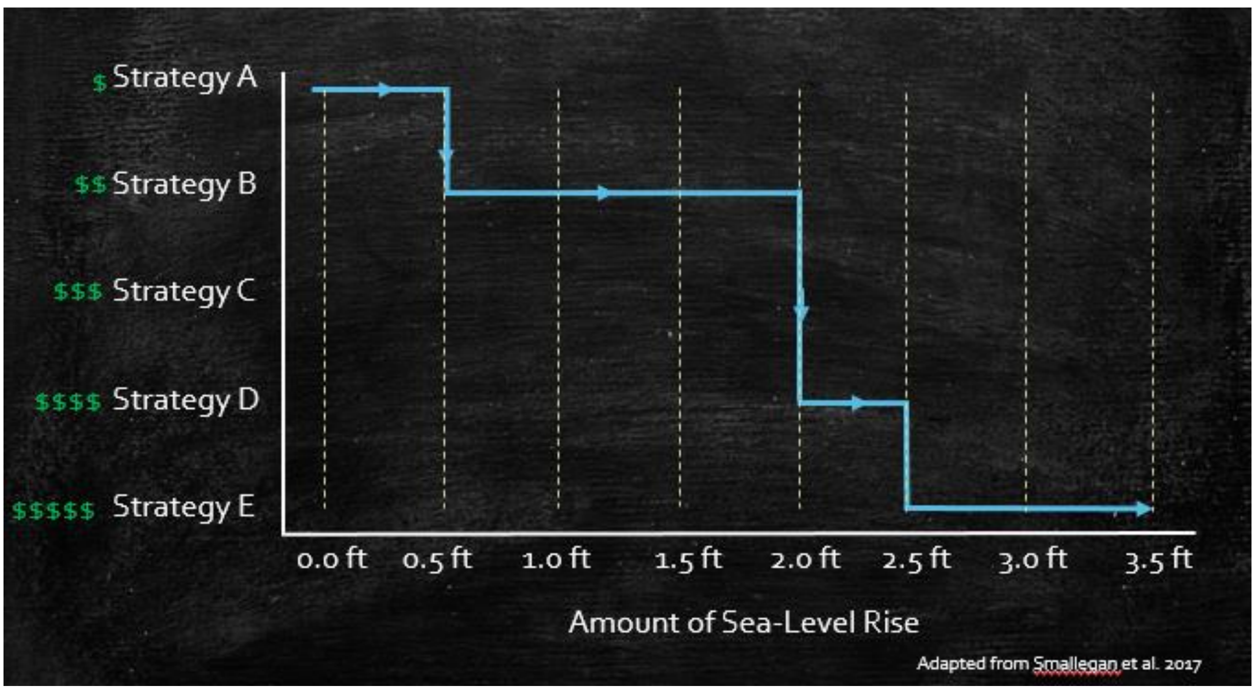
DI ADAPTATION PATHWAY

Minimizing chances of future breaching

This survey is to collect resident feedback on the DI Adaptation Pathway project being done in partnership with the Town of Dauphin Island and others.

The project is focused on minimizing our chances of future breaching of the island during smaller storms (like Hurricane Nate). This is especially a concern because as sea levels continue to rise around the island, these storms will have a larger impact.

Using a computer model, coastal engineers from the project team are looking at potential adaptation strategies that could be implemented over time at different locations on the island and what those strategies' effectiveness would be. This will help create a 'pathway' of strategies that can be taken as sea levels rise without unnecessarily spending too much money at one time.



DI ADAPTATION PATHWAY

Minimizing chances of future breaching

1. In which DI Adaptation Pathway event did you participate? (Select all that apply)

- ☐ Facebook Live (Wed, May 27 or Fri, May 29)
- ☐ Call-in Time (Thus, May 28 or Fri, May 29)
- ☐ Follow-Up Zoom (Wed, June 3 or Fri, June 5)
- ☐ None

2. Which best describes your connection to Dauphin Island? (Select all that apply)

- ☐ I do not own property on the island.
- ☐ I own one property on the island.
- ☐ I own more than one property on the island.
- ☐ I own a business on the island.

3. If you own property on Dauphin Island, which best describes your residency? (Select all that apply)

- ☐ I am a full-time resident.
- ☐ I am a part-time resident.
- ☐ Other (please specify in the space below)

4. How long have you been a resident of Dauphin Island?

- ☐ 0-1 years
- ☐ 2-5 years
- ☐ 6-10 years
- ☐ 11+ years
- ☐ N/A – not a resident

5. In what area of Dauphin Island do you live?

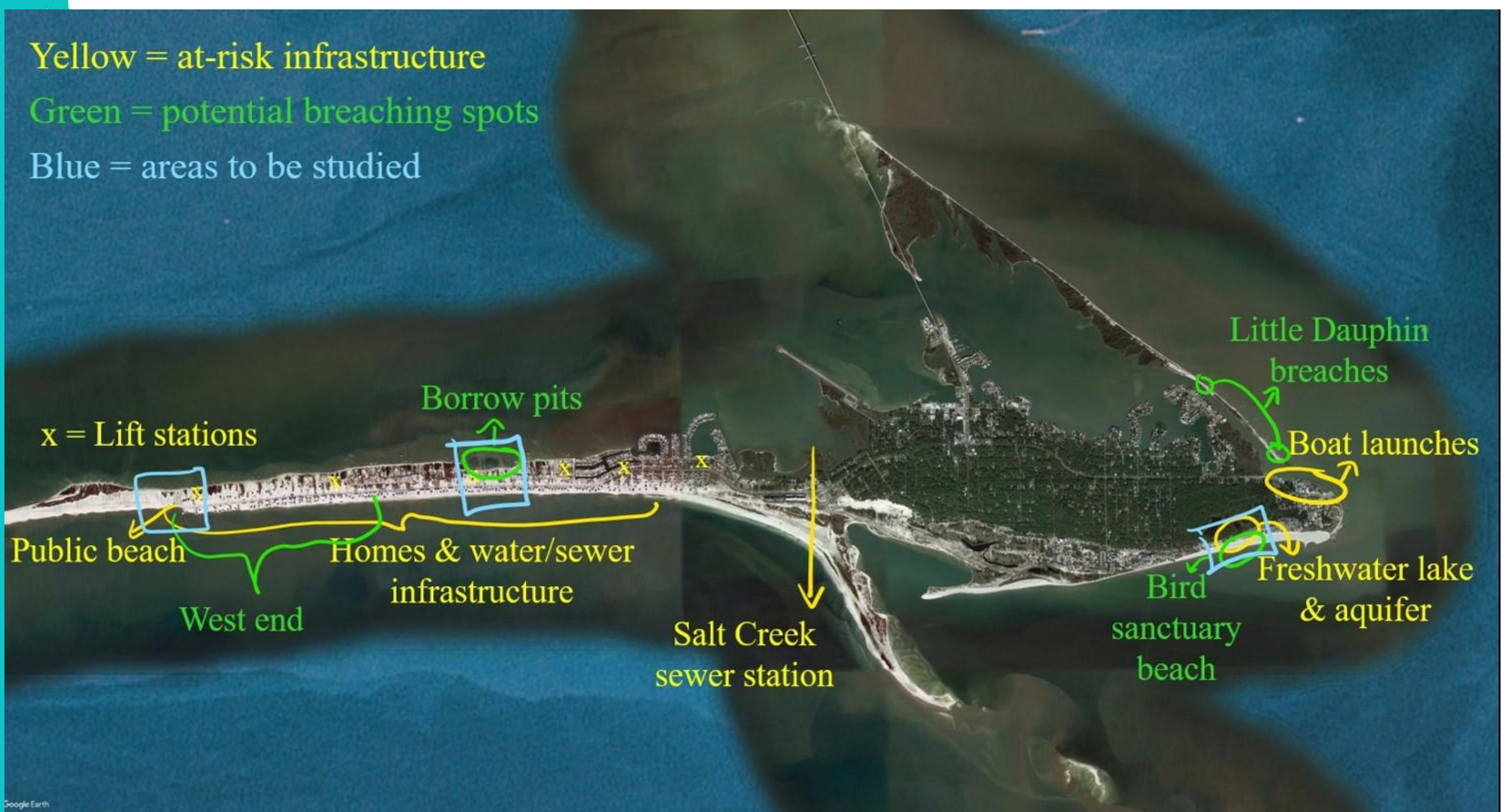
Feel free to provide an exact address, street, neighborhood, or whatever you're most comfortable with (e.g., The Village, Cadillac Ave – east end, 1011Bienville Blvd)

6. **Please identify what area(s) you believe are most at-risk to breaching due to a storm. Please be as specific as possible and explain why.**

   Note that we are currently planning to look at the sections identified in blue on the map below – the West End public beach, the borrow pits, and the bird sanctuary beach.

   You may comment on these *and/or* other areas you believe are at-risk to breaching.

   If you're happy with these selections please let us know that too.



7. **What Gulf-side adaptation strategy/strategies would you like to see explored? (Select all that apply.)**

   Note that this project is focused on investigating whether or not these strategies would be beneficial as breach prevention measures. Future consideration will include concerns such as cost, feasibility, etc.; this stage of the project is identifying what strategies are worth moving to that future stage.

   ☐ Beach nourishment to maintain current width and height over time
   ☐ Beach nourishment to widen beach (to a previous historical width)
   ☐ Raising the dunes
   ☐ Adding a buried seawall beneath the dunes
   ☐ Elevating driveways where they intersect the berms
   ☐ Other (please specify)

8. **What sound-side adaptation strategy/strategies would you like to see explored? (Select all that apply.)**

   Note that this project is focused on investigating whether or not these strategies would be beneficial as breach prevention measures. Future consideration will include concerns such as cost, feasibility, etc.; this stage of the project is identifying what strategies are worth moving to that future stage.

   ☐ Filling borrow pits
   ☐ Adding back-bay bulkheads
   ☐ Raising back-bay bulkheads (Quivira, Port Royal, DelChamps)
   ☐ Adding a breakwater
   ☐ Other (please specify)

9. What other adaptation strategy/strategies would you like to see explored? (Select all that apply.)

Note that this project is focused on investigating whether or not these strategies would be beneficial as breach prevention measures. Future consideration will include concerns such as cost, feasibility, etc.; this stage of the project is identifying what strategies are worth moving to that future stage. w

- ☐ Raising the entire island
- ☐ Closing the "end" of Bienville
- ☐ Not clearing sand from the roads post-storm (this would elevate the roads)
- ☐ Other (please specify)

10. The numbers below represent the likelihood that we will see a certain amount of sea-level rise. **They are all possible** based on the best available science, but they are **not all as likely to happen**. For example, the low amount of sea-level rise is 100% likely to happen, but the extreme is very unlikely to happen.

For people who are **risk-adverse**, they may be more interested in planning for scenarios that are less likely to happen to make sure that they are not impacted (e.g., intermediate or intermediate-high).

For people who are **risk-tolerant**, they may only want to plan for what they are sure is going to happen (e.g., low or intermediate-low).

Based on your personal risk tolerance, what are you most comfortable planning for? Please select two.

- ☐ 100% - Low (will definitely happen)
- ☐ 96% - Intermediate-Low
- ☐ 17% - Intermediate (moderately likely to happen)
- ☐ 1.3% - Intermediate-High
- ☐ 0.3% - High
- ☐ 0.1% - Extreme (very unlikely to happen)

11. How far into the future do you see yourself or your family having your home/business on Dauphin Island? (i.e., how far into the future should we be planning for?)

- ☐ 20 years
- ☐ 30 years
- ☐ 50 years
- ☐ 80 years
- ☐ Other (please specify)

12. Is there anything else that you would like us to know as we proceed with this project?

Thank you so much for your time! This will help us make sure the study best meets the needs of all islanders!

DI ADAPTATION PATHWAY

Mininmizng chances of future breaching

2020

YEAR IN REVIEW: WHAT HAVE WE DONE?

HAD CONVERSATIONS

3 in-person meetings

4 virtual meetings

2 call-in sessions

Who we talked with:

DI residents & property owners

Those responsible for infrastructure & services on DI

What we talked about:

- Project goals
- Where the island is most vulnerable
- Which strategies could protect the island
- Risk tolerance - what is too risky?
- Planning - how far ahead?

SET PROJECT FOCUS

Picked 3 vulnerable locations

Identified 13 adaptation strategies

Set future conditions to research

COLLECTED DATA

Worked w/Town to collect elevation data & photos from 3 tropical systems!

Cristobal Sally Zeta

BUILT MODELS OF DI

Built models for 2 locations replicating sand movement during a hurricane

Using models to test adaptation strategy effectiveness at reducing likelihood of future breaching

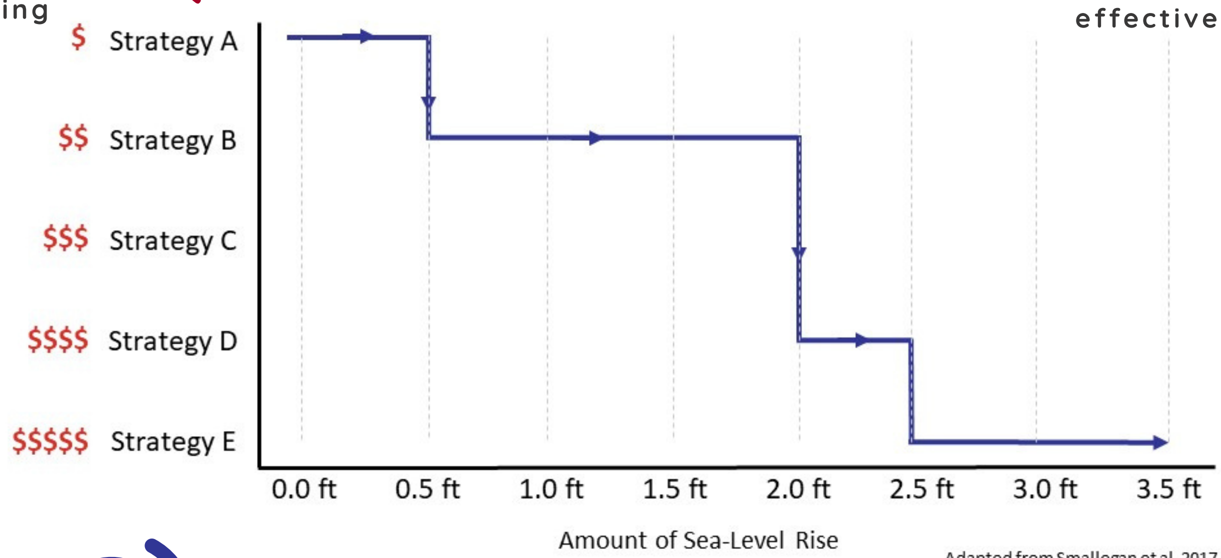
DAUPHIN ISLAND ADAPTATION PATHWAY

GOAL: Support Dauphin Island planning with adaptation pathways

Assess adaptation strategies to prevent breaching

Example Adaptation Pathway

Assemble pathway based on cost and effectiveness



Adapted from Smallegan et al. 2017

Evaluated strategies for Hurricane Nate

Considers sea-level rise up to 2 ft

WEST END BEACH

Beach nourishment

Dune elevation

MID WEST END

Filling borrow pits

Elevating driveways

Beach nourishment

EAST END

Beach nourishment

Beach elevation

Dune elevation

PROCESS:

Create model to accurately represent storm impacts

Use model to test effectiveness of adaptation strategies

Order strategies from least to most intensive regarding cost & effort

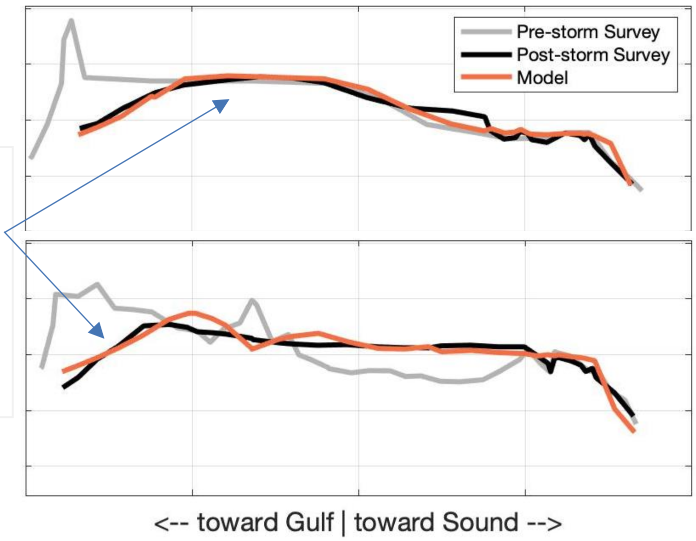
Town of Dauphin Island Planning Commission

STUDY FINDINGS

MODEL VALIDATION

- BUILT A MODEL
- MADE SURE THE MODEL REFLECTS REALITY
- TESTED USING HURRICANE NATE
- FOUND <u>VERY GOOD</u> AGREEMENT

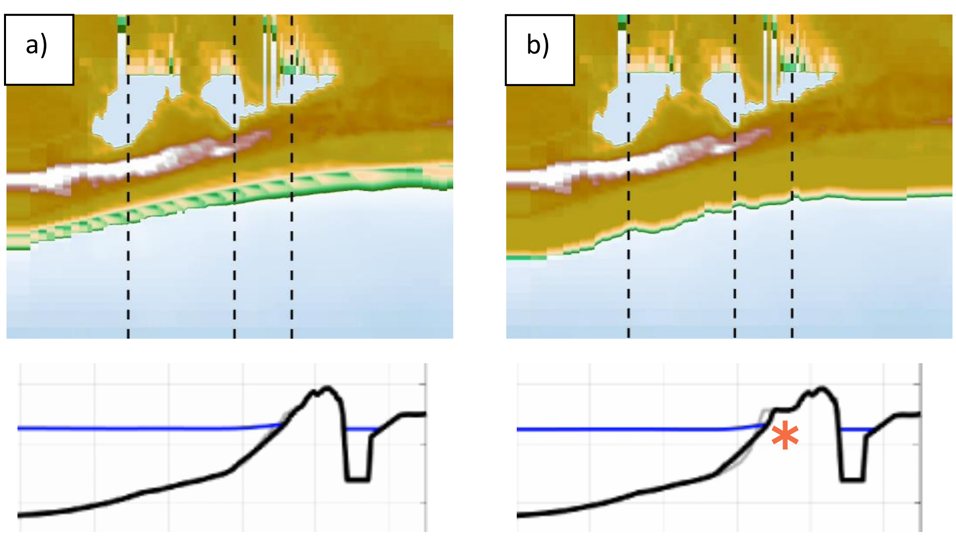
Overlapping lines means the model accurately predicted what happened.



TAKE AWAY – WE HAVE A MODEL THAT DOES A GOOD JOB PREDICTING HOW THE ISLAND WILL RESPOND TO STORMS

EVALUATE ADAPTATION STRATEGIES

- EVALUATE THE DIFFERENT ADAPTATION STRATEGIES UNDER DIFFERENT CONDITIONS
- IDENTIFY TIPPING POINTS WHEN STRATEGIES NO LONGER WORK BASED ON SEA-LEVEL RISE



a. Current conditions on the east end

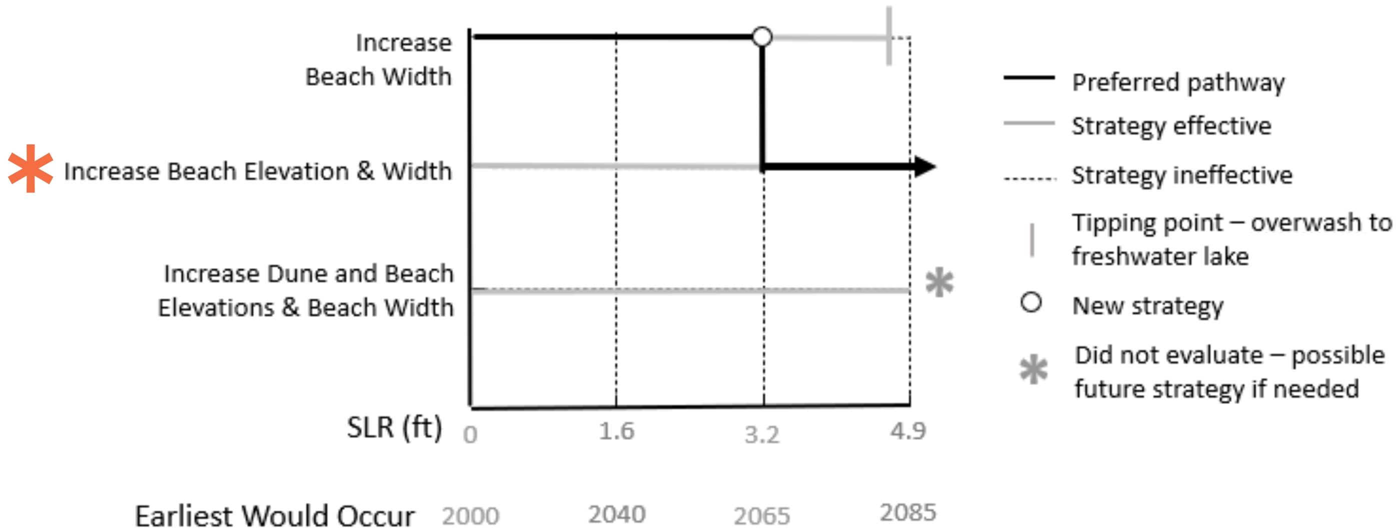
b. East end with the soon-to-be widener and higher beach

* Additional protection – less impact and risk from storms

TAKE AWAY – WE UNDERSTAND HOW WELL EACH STRATEGY AVOIDS BREACHING DURING LOW-INTENSITY STORMS EVEN AS SEAS RISE

STUDY FINDINGS

EAST END BEACH PATHWAY



TAKE AWAY – CURRENT ADAPTATION STRATEGY IS EFFECTIVE LONG-TERM, *IF BEACH WIDTH IS MAINTAINED*

MIDDLE WEST END

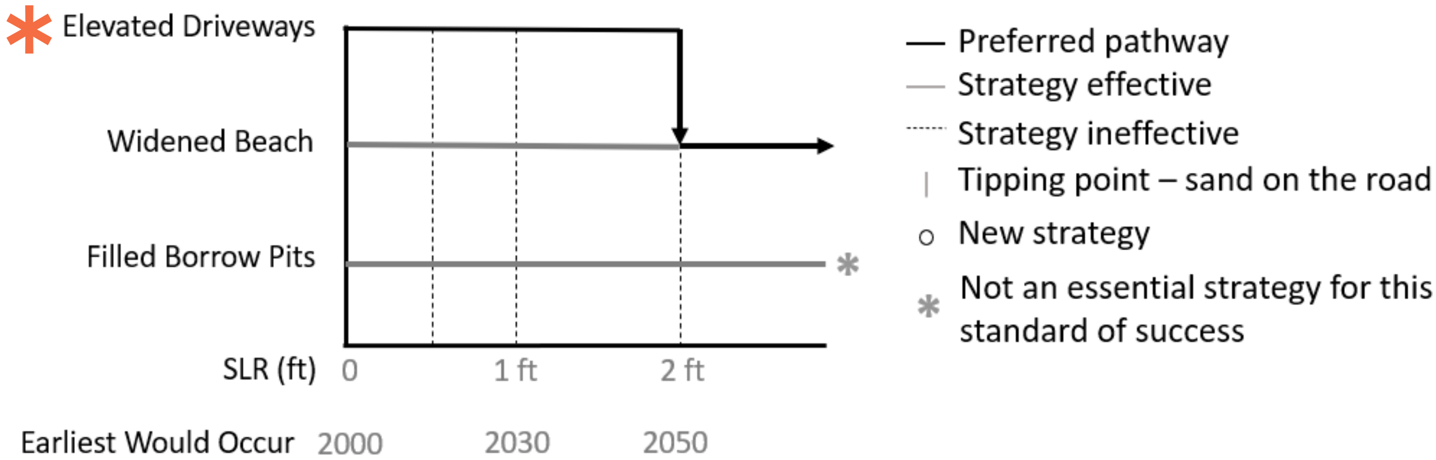
EVALUATED THE DIFFERENT ADAPTATION STRATEGIES UNDER DIFFERENT STANDARDS OF SUCCESS:

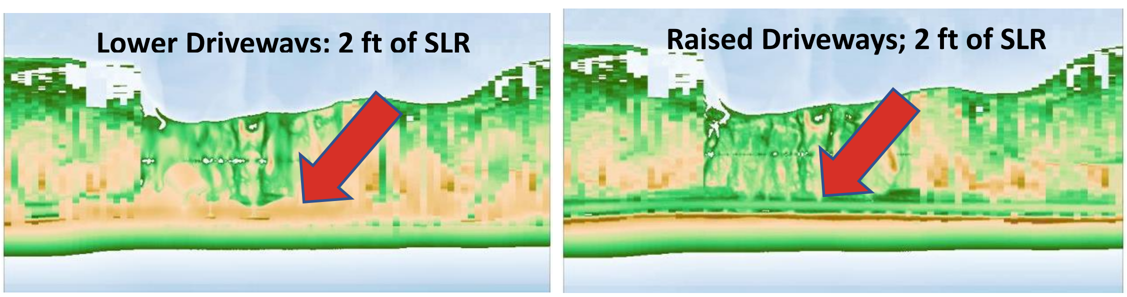
1. BREACHING
2. SAND ON BIENVILLE
3. SAND VOLUME AND ELEVATION ACROSS THE ISLAND

MIDDLE WEST END – BREACHING

TAKE AWAY – A LOW INTENSITY STORM LIKE NATE DOESN'T BREACH MIDDLE WEST END WITH 2 FT OF SLR

MIDDLE WEST END – SAND ON BIENVILLE



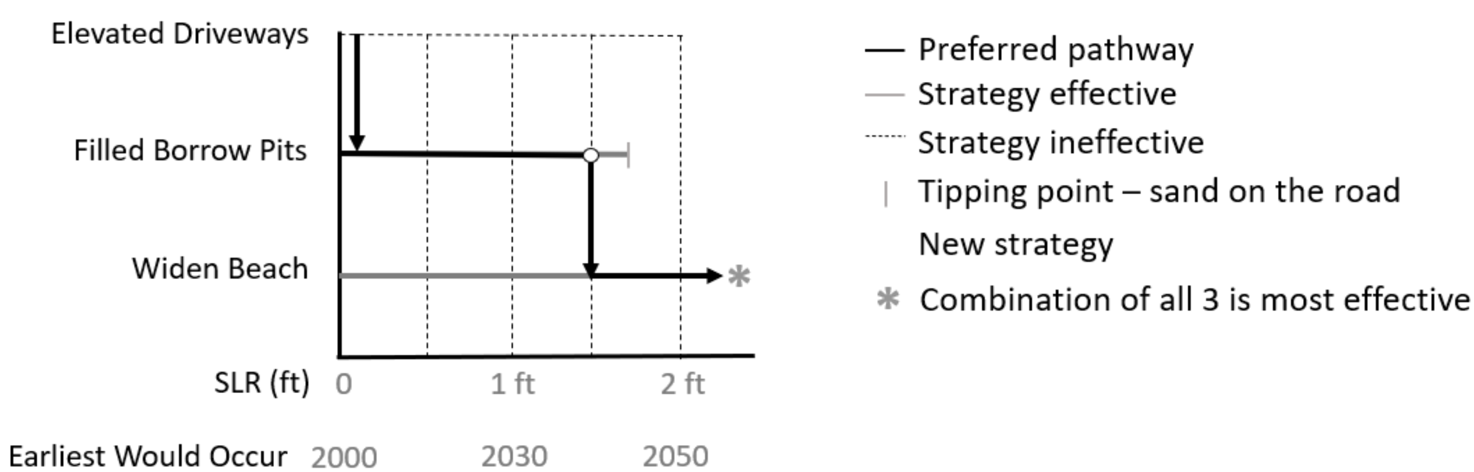


Model results showing how elevated driveways keep the road clear after a storm, even with SLR

TAKE AWAY – ELEVATED DRIVEWAYS ARE LIKELY TO SUCCESSFULLY PROTECT THE ROAD UNTIL 2 FT OF SLR OCCURS

MIDDLE WEST END – OVERALL RESILIENCE

EVALUATED BASED ON 1) BACK BARRIER ABOVE SEA-LEVEL & 2) MINIMUM ELEVATION STAYS THE SAME



TAKE AWAY – WITHOUT ADDITIONAL ACTION BACK BARRIER IS AT RISK TO PERMANENT FLOODING

STUDY FINDINGS

DISCUSSION CONSIDERATIONS

- Back Barrier challenges
    a. Bay side flooding
    b. breaching often instigated by back bay flooding
- Back Barrier Potential Solutions
    a. Strategically use stand during overwash – possible with new projects
    b. Consider natural shoreline protection to reduce bay side erosion & trap sediment during storms (e.g., living shorelines)
- Maintenance & monitoring are key
- Consider tipping points vs trigger points
- These are lower intensity, higher frequency storms – protecting against *future* low intensity storms is protecting against the high intensity storms of *today*

TAKE AWAY – THE TOWN IS DOING EXCELLENT WORK TO PROTECT THE ISLAND; ADDITIONAL CONSIDERATIONS, MONITORING, AND MAINTENANCE WILL HELP PRESERVE AND EXPAND ISLAND RESILIENCE