Novel Hybrid Coastal Evolution and Storm Modeling Framework for Beach Nourishment

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Outline

1.0 Questions and Needs

2.0 Approach

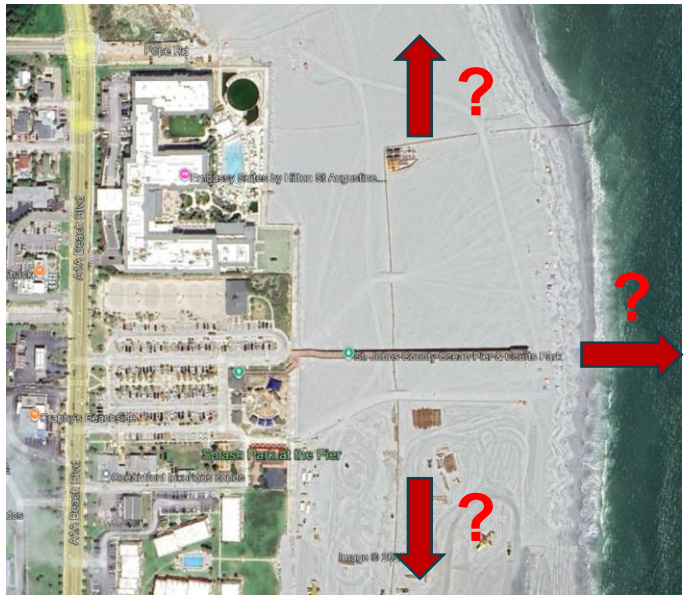
3.0 Application

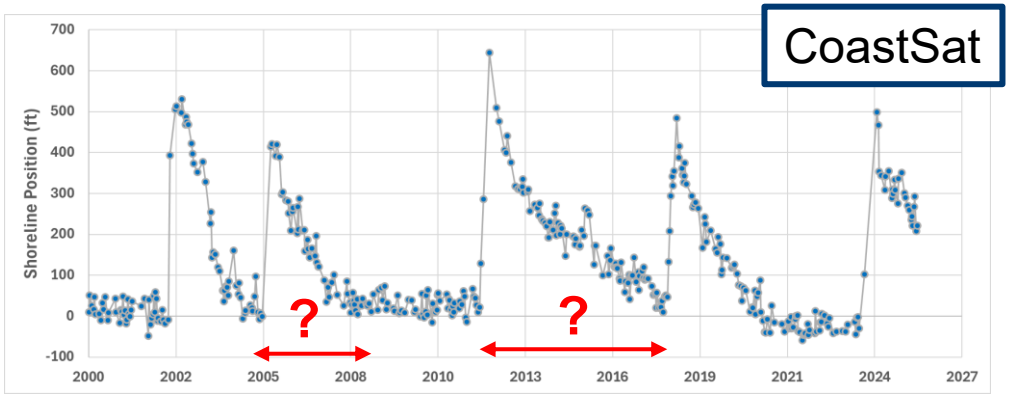
4.0 Summary

1.0 Questions and Needs

Questions

- How will the beach nourishment perform?
  - How does the nourished beach sand move?
  - How will the nourished beach evolve over the long-term and under storms/hurricanes?
- How much sand should be placed in a nourishment project?
- What spatial extents should be nourished?
- How to determine the uncertainties in storms and hurricanes?
- How to plan re-nourishment cycles?





Need

- A physics-based framework accounting for:
  - Beach nourishment design specifications, including nourishment profile and spatial extents.
  - Long-term littoral movement of nourished sand driven by nearshore processes
  - Short-term beach erosion of nourished sand under storms and hurricanes

2.0 Approach

Approach

- Developed a physics-based framework for modeling of long-term shoreline evolution along with storm-induced short-term shoreline erosion

- Evaluating the performance of beach nourishment design

- Informing:
  - Beach nourishment design quantities
  - Planning re-nourishment cycles

Modeling Approach

GenCade Modeling

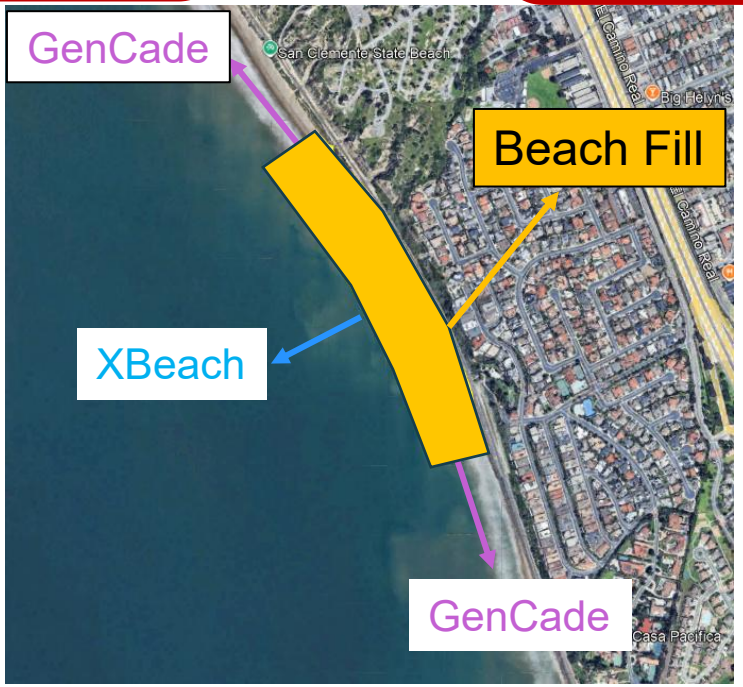
- 1-D shoreline evolution model simulating longshore sediment transport driven by waves

Modeling how the beach nourishment will erode along the shore, and how the nourished shoreline will retreat over the next 5-10 years.

XBeach Modeling

- Grid-based morphodynamic model simulating shoreward wave propagation and cross-shore erosion under extreme storms

Modeling how the retreated shoreline might respond to extreme storms and provide protection.



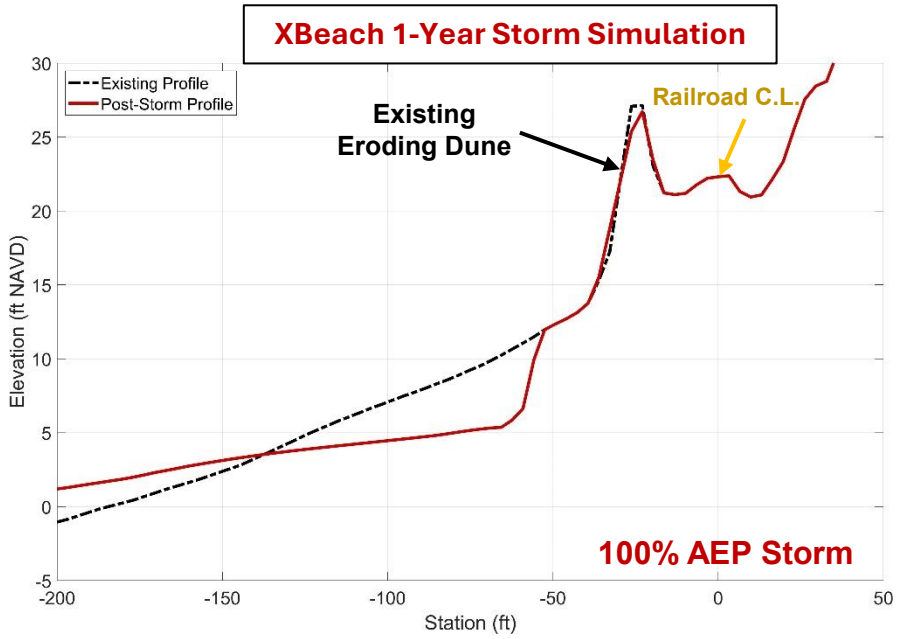
3.0 Application

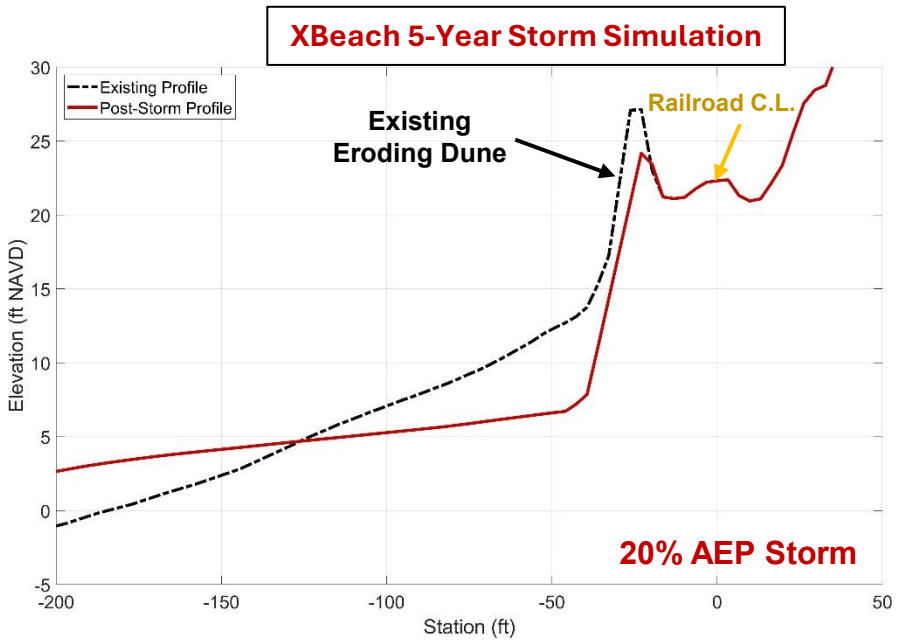
Study Area

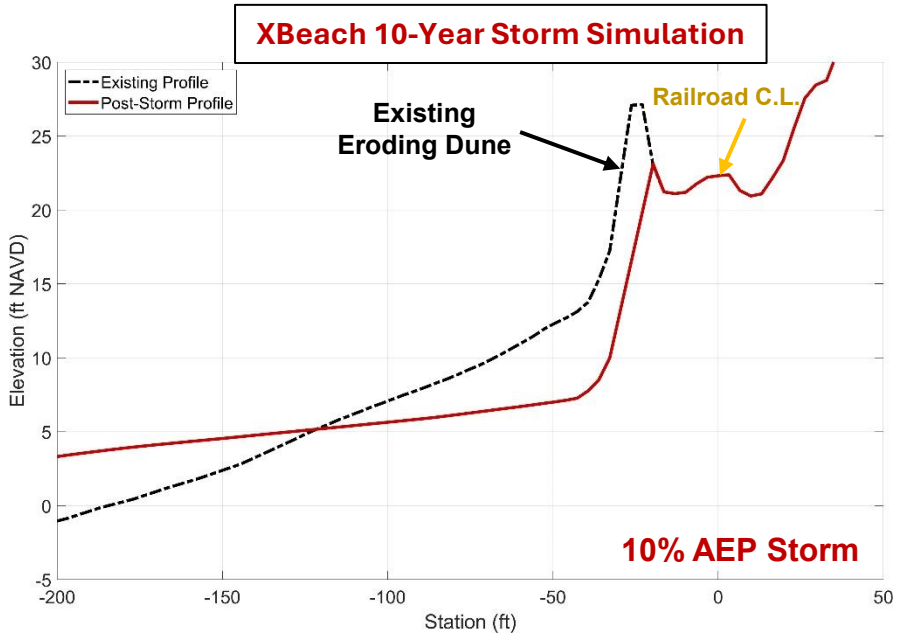
Photo taken in March 2025

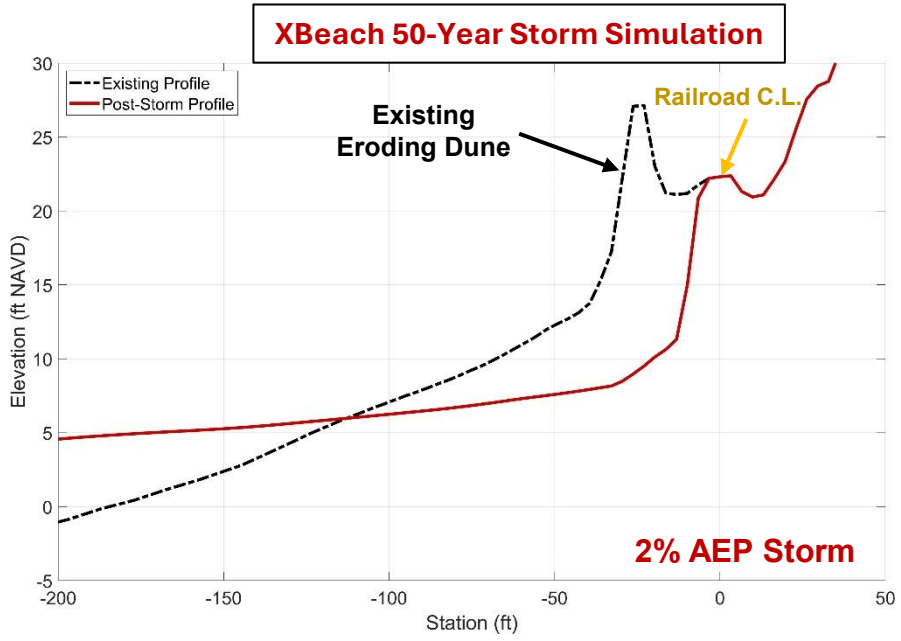
Existing Vulnerabilities

- XBeach simulations of existing shoreline under 1- to 50- Year storm events
- The existing shoreline is vulnerable to a 5-year storm
- Railroad failure under 10- to 50-year storms
- Created emergency condition in these area



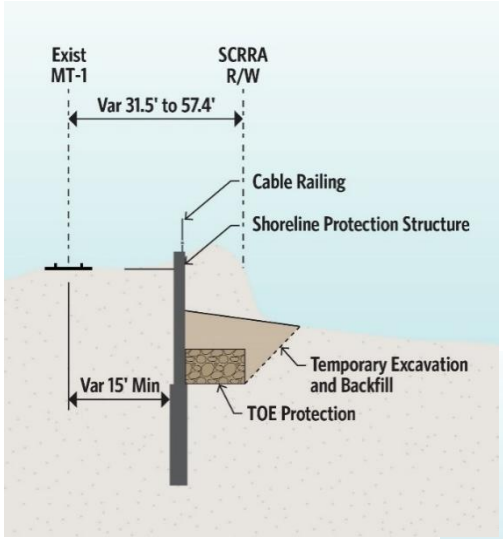




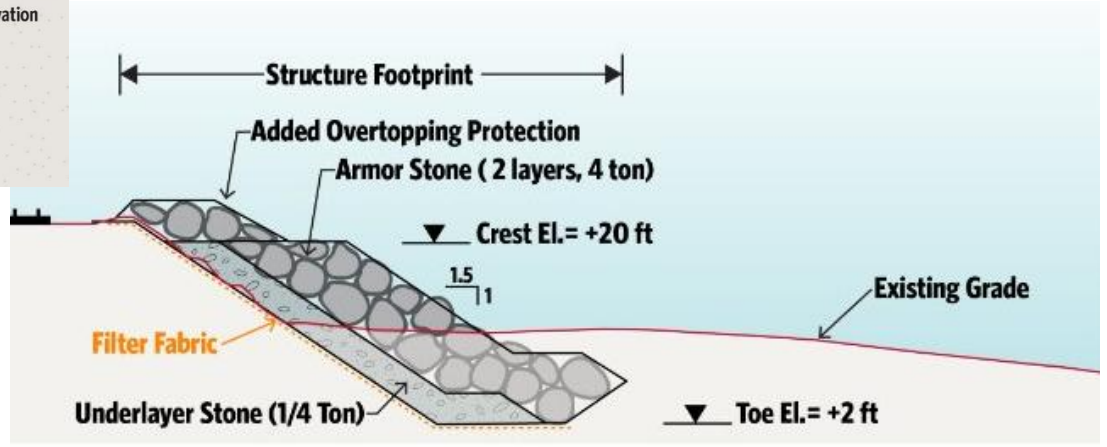


Alternatives

- **Seawall**



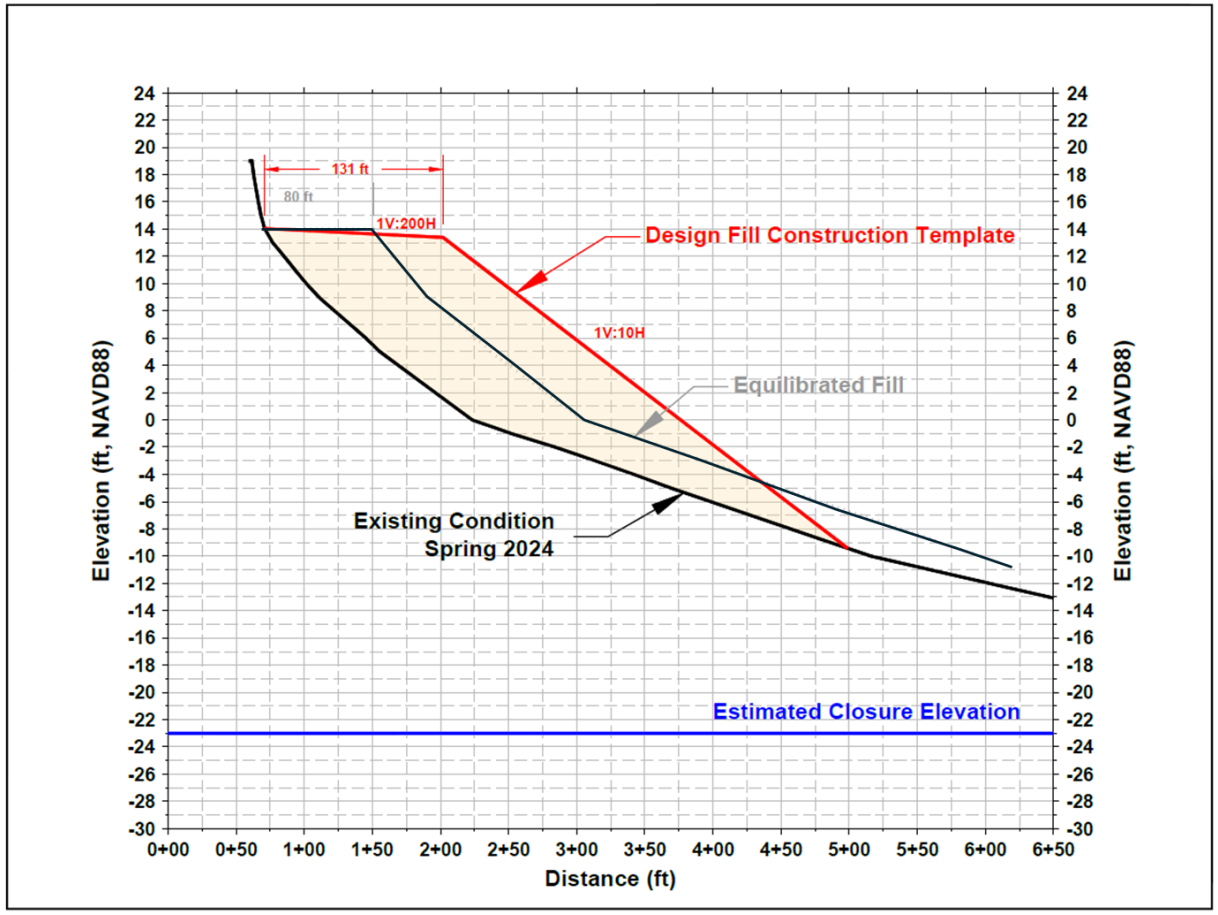
- **Rock Revetment**



- **Beach Nourishment**
  - How does the sand move?
  - How much sand will erode under extreme events?

Beach nourishment of North Beach in San Clemente, August 2024
Source: The Orange County Register

Preliminary Beach Nourishment Design

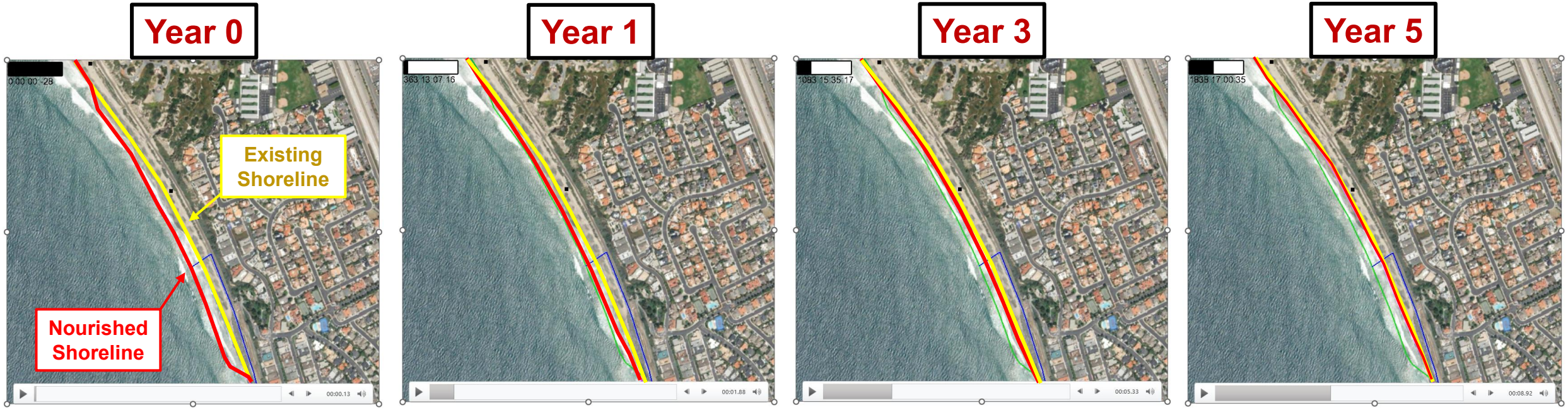


GenCade Model Domain

- 8 miles of shoreline from Doheny Beach to Trestles Beach
- 10-year simulation of shoreline evolution using the record of waves in the region

GenCade Model Results

- Modeling 270,000 cy of beach fill in Study Area

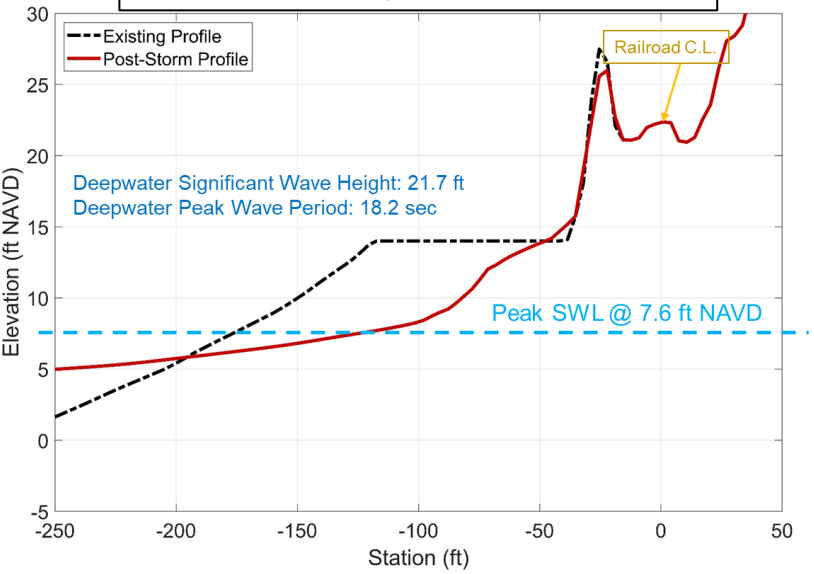


- Almost the entire beach fill will be eroded over the next 5 years
- The shoreline retreat after placement of beach fill is predicted as ~14 ft/year

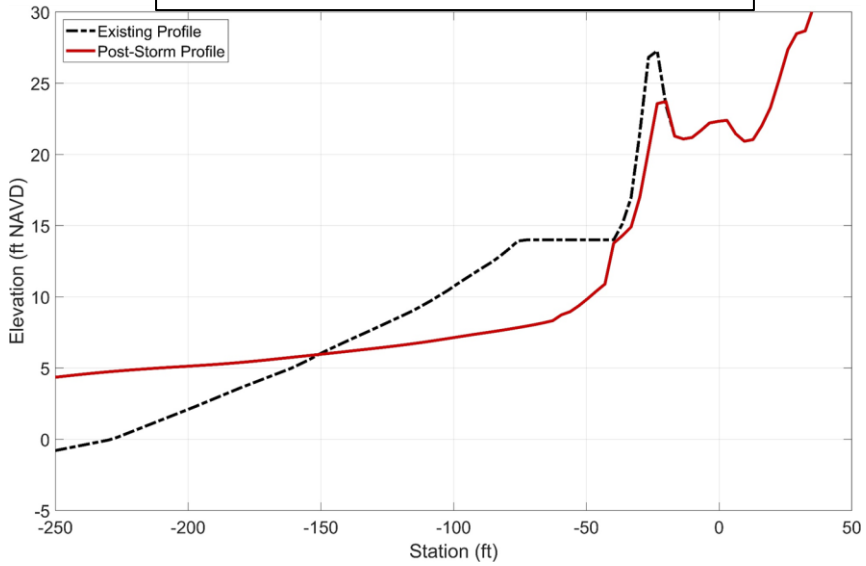
XBeach Simulation

- Modeling the **270,000 cy** nourished shoreline under a **50-year storm event**

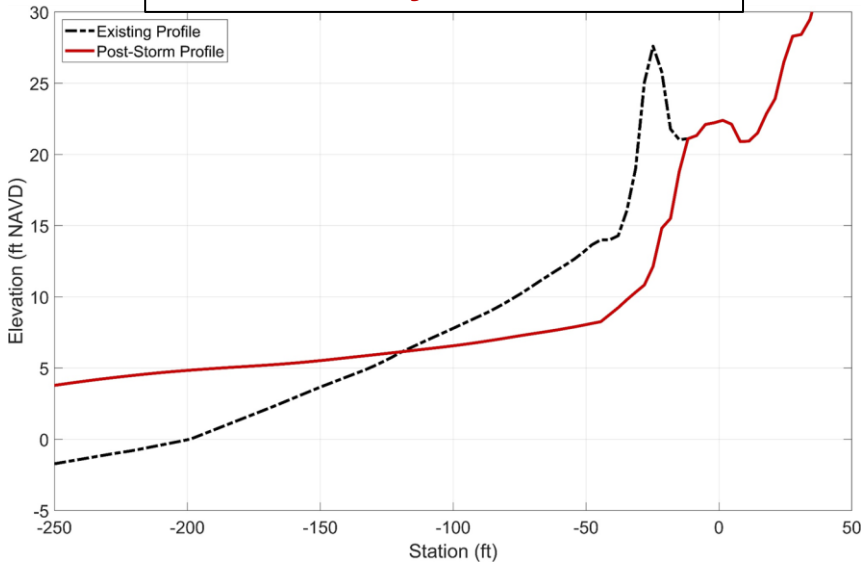
270,000 cy Fill – Year 0



270,000 cy Fill – Year 3



270,000 cy Fill – Year 5

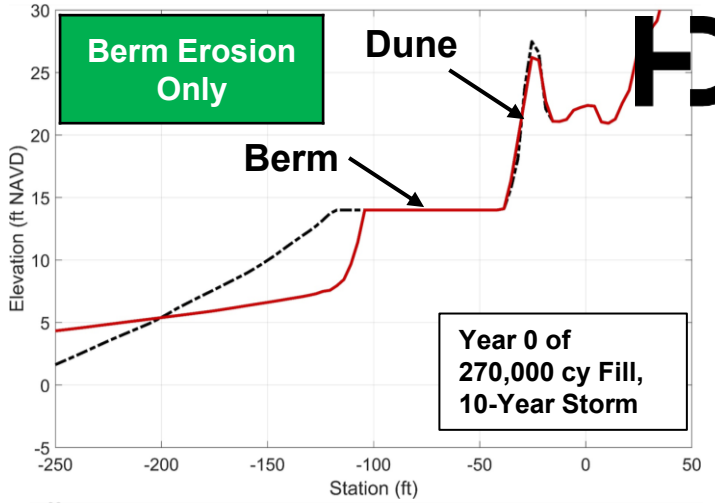


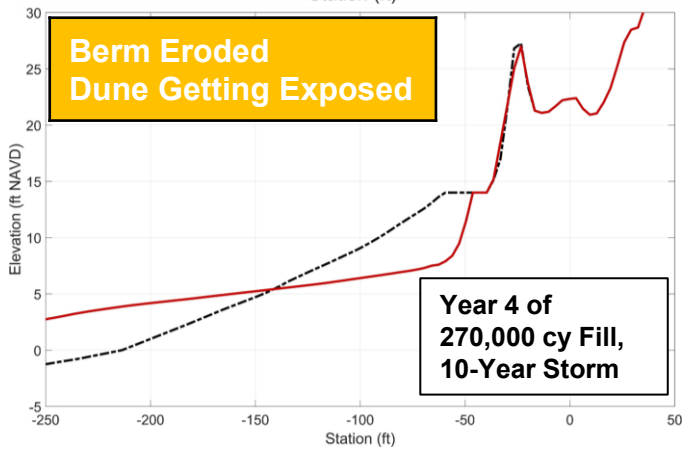
Beach Nourishment Modeling

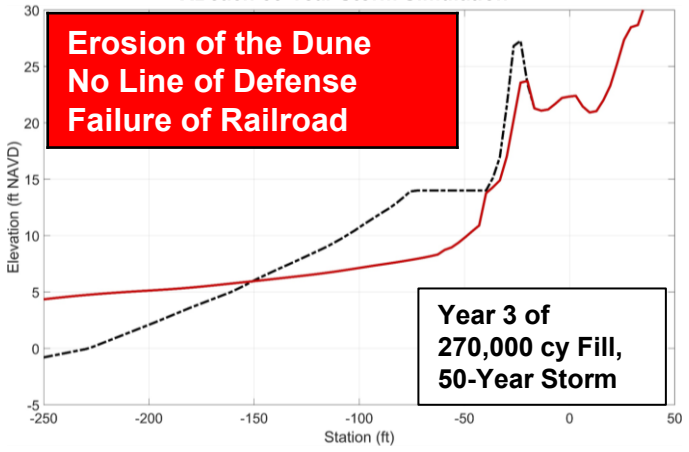
270,000 cy of Nourishment

	1-Year Storm	5-Year Storm	10-Year Storm	50-Year Storm
Year 0				
Year 1				
Year 2				
Year 3				
Year 4				
Year 5				

- The site is expected to be vulnerable if a single 50-year storm event occurs immediately following beach nourishment.
- The vulnerability worsens in time!
- Beach nourishment can provide protection under a 10-year storm event for up to four years following placement.







Beach Nourishment Modeling

540,000 cy of Nourishment

	1-Year Storm	5-Year Storm	10-Year Storm	50-Year Storm
Year 0				
Year 5				
Year 6				
Year 7				
Year 8				
Year 9				
Year 10				

- Expected to protect the site under a 50-year storm in Year 0.
- Not expected to provide protection under a 50-year storm through Year 5.
- Provides protection under a 10-year storm event for up to 8 years following placement.

810,000 cy of Nourishment

	1-Year Storm	5-Year Storm	10-Year Storm	50-Year Storm
Year 0				
Year 5				
Year 8				
Year 9				
Year 10				
Year 11				
Year 12				

- Expected to protect the site under a 50-year storm through Year 5
- Not expected to provide protection under a 50-year storm through Year 8.
- Provides protection under a 10-year storm event for up to 8 years following placement.

4.0 Summary

Summary

- A physics-based hybrid modeling framework was developed to evaluate the performance of beach nourishment design.
- The hybrid model simulates long-term shoreline evolution driven by nearshore processes, as well as short-term erosion during storm and hurricane events.
- The framework has proven effective in informing beach nourishment design, including nourishment quantities and spatial extents, as well as planning re-nourishment intervals.
- This framework can be implemented across a wide range of coastal environments and settings to support planning and design of beach nourishment projects.

Thank You

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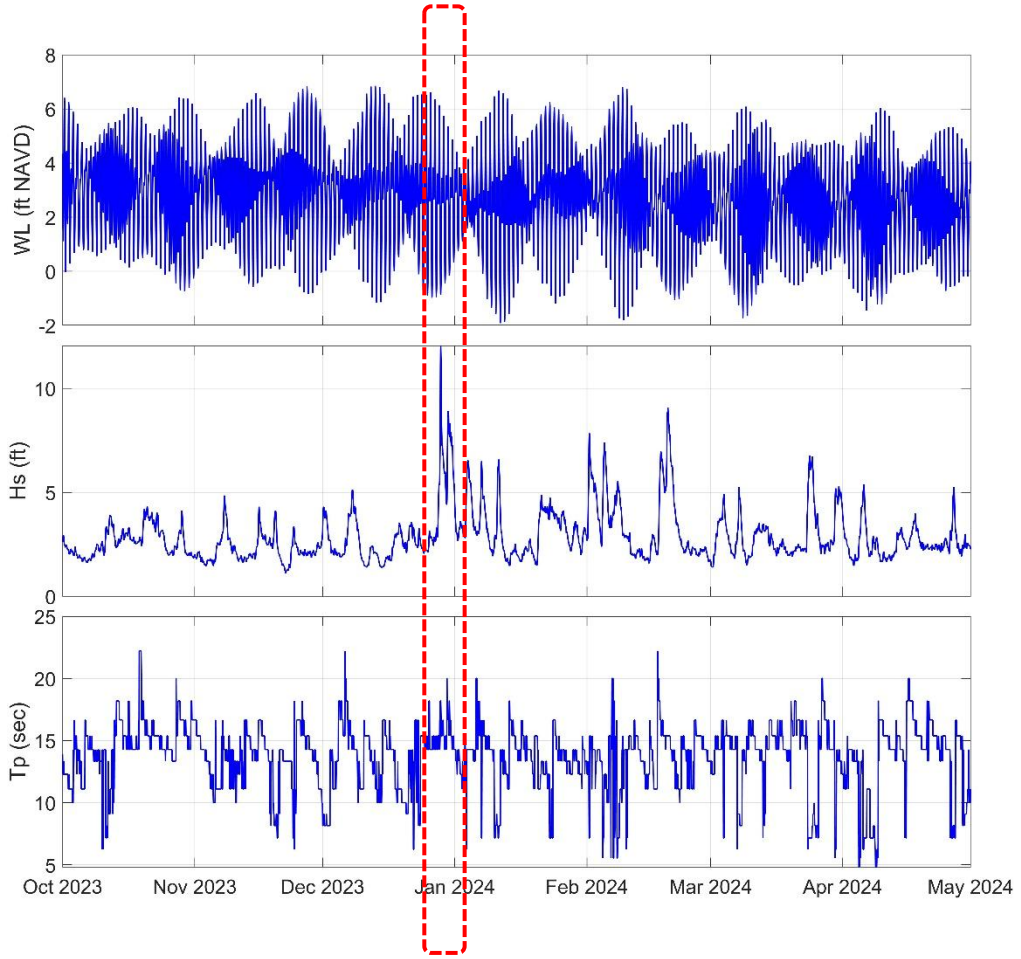
Backup Slides

XBeach Model Calibration

- Using beach profile measurements from October 2023 and May 2024



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Modeling the hydrodynamics and morphodynamics of sandbar migration events

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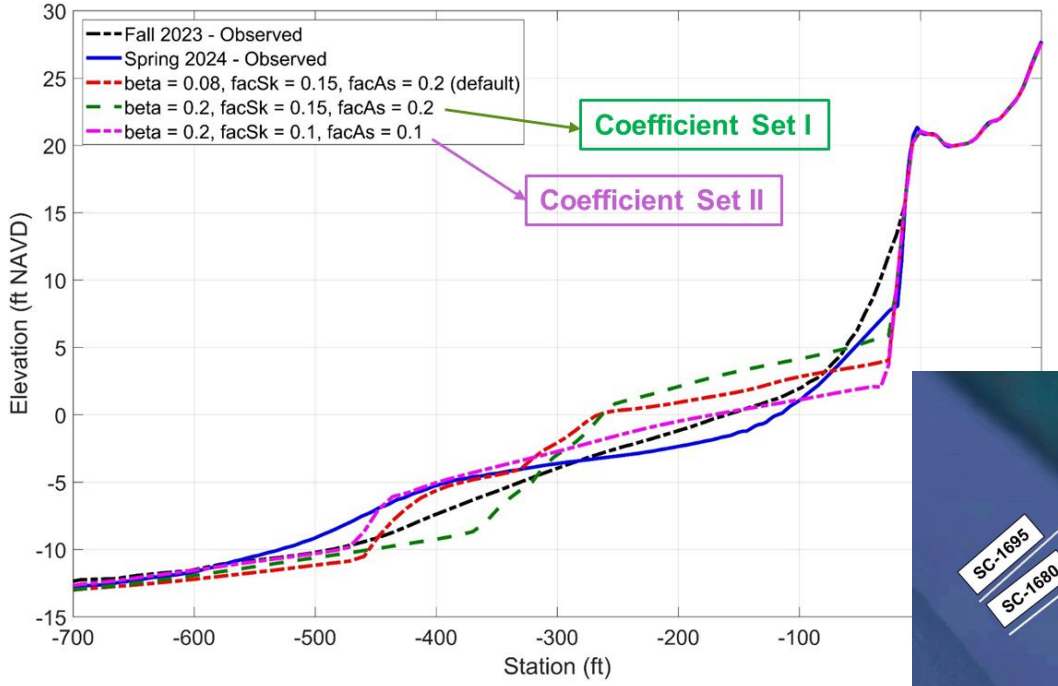

GenCade Model Calibration

- Using shoreline retreat obtained from CoastSat Database

Vos et al. (2019). CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. Coastal Engineering.