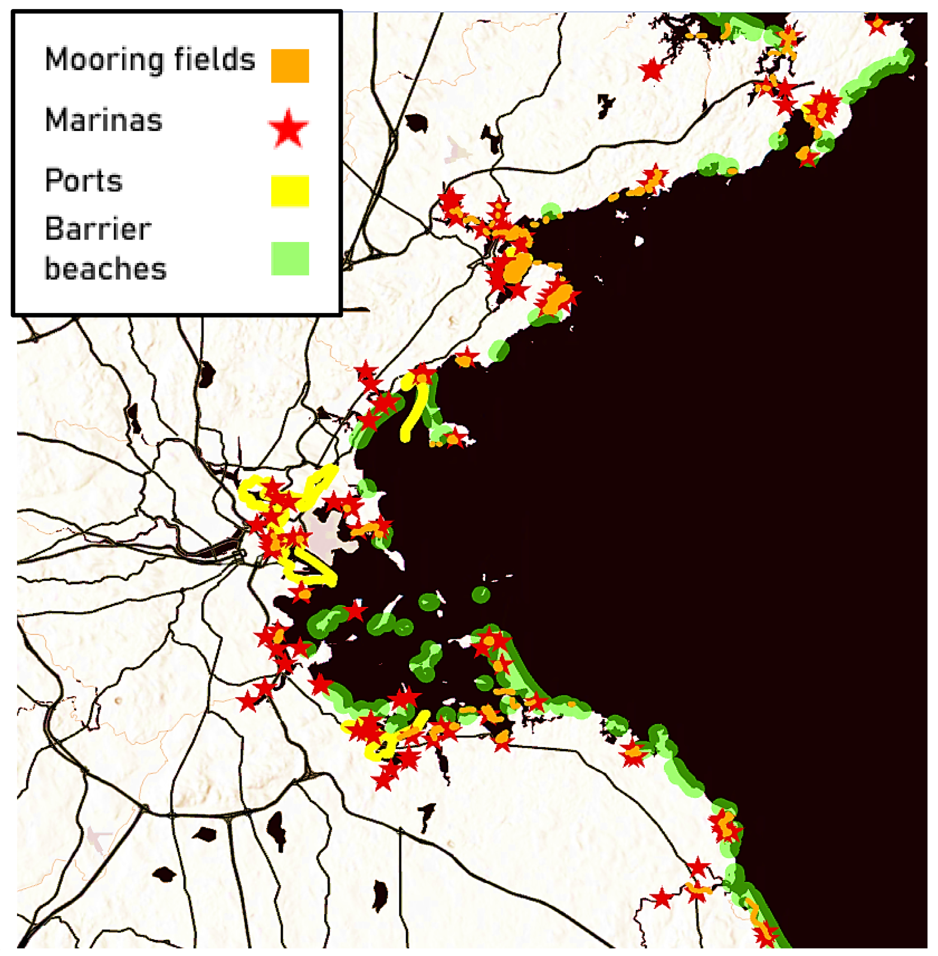
Optimizing Nourishment Strategies: A Multi-Model Approach for a Massachusetts Barrier Beach

Pontiki, Maro [a*], Whitmore, Eamon [a], Karp, Alex [a], Smith, Dave[a], and Bjarngard, Anders [a]

[a] GZA GeoEnvironmental, Inc., * Correspondence email: maria.pontiki@gza.com

1. Motivation

Massachusetts barrier beaches defend coastal communities and marine facilities (e.g., South Shore, Figure 1), reducing wave energy by up to 70% [1]. Nourishing these beaches near marshes is challenging as sediment mismatch and altered water flow can harm the ecosystem.



Advanced coastal numerical modeling helps us:

- ✓ Predict sediment movement
  → Minimizing marsh impact.
- ✓ Optimize nourishment
  → Balancing beach resilience & marsh health.
- ✓ Assess wave reduction
  → Protecting both marshes and marine facilities.

Figure 1. Map showing the location of marine facilities adjacent to barrier beaches in Greater Boston area.

Project Scope

1) To develop and evaluate optimized beach nourishment strategies for marsh barrier beaches considering ecological impacts and economic feasibility.
2) To provide data-driven insights that empower decision-makers for the adoption of sustainable and effective coastal protection measures

2. Methodology

SWAN modeled nearshore wave transformation using NOAA buoy data for winter storms and Nor'easters. Significant wave height, Hs = 7-9 m, and peak wave period, Tp = 9-14 sec.

XBeach simulated the barrier beach response using measured profiles. Forcing included SWAN-derived waves and storm surges with 10-year peak surges of ~1.5 m NAVD88, 50-year ~2.1 m, and 100-year ~2.7 m Nor'easters. Sea-level rise projections of 0.3 m (2050) and 0.7 m (2070) above MSL (2022 NOAA inter-high) were included.

SWAN (Simulating WAves Nearshore)
spectral, phase-averaged wave model

Initial wave energy → Addition, transformation and dissipation of energy → New wave energy

↓

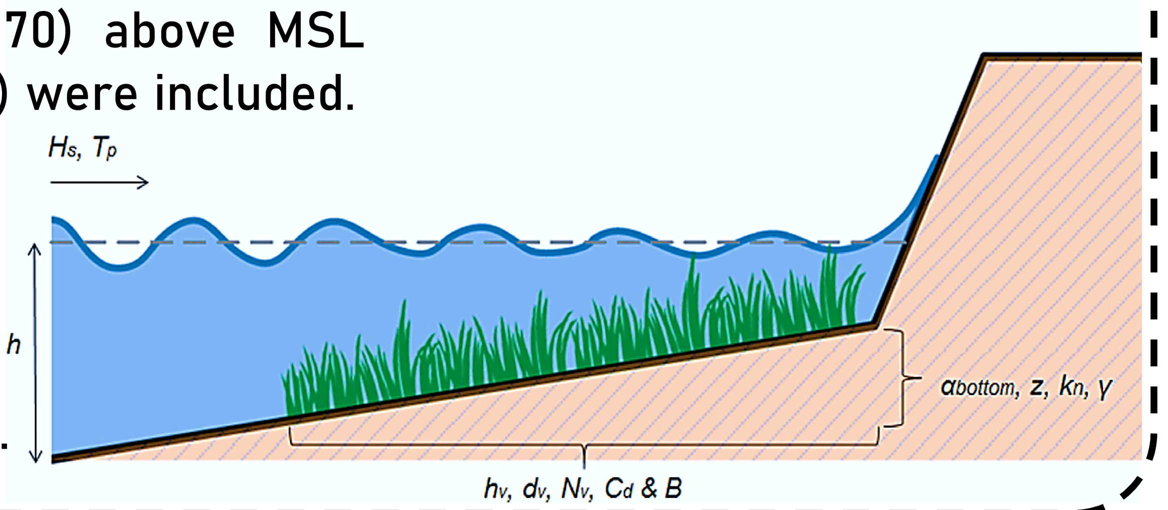
XBeach (eXtreme Beach behavior)
phase-resolving, non-hydrostatic model

Runup, morphodynamics, nourishment response to forcing conditions.

↓

Adjustment of beach nourishment design parameters

Various nourishment scenarios were simulated, involving sediment volumes (10,000 m³ - 30,000 m³).



3. Results

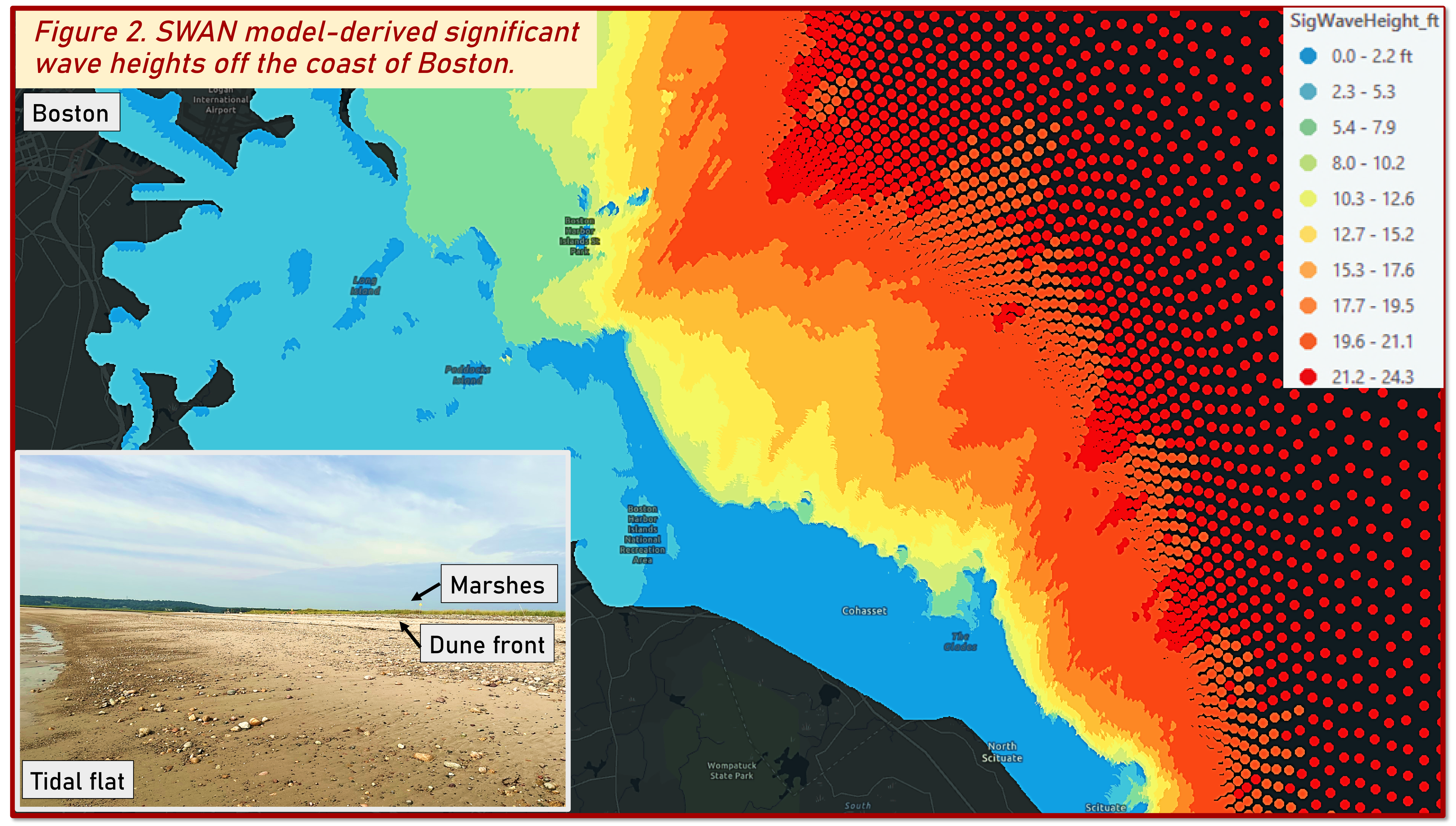
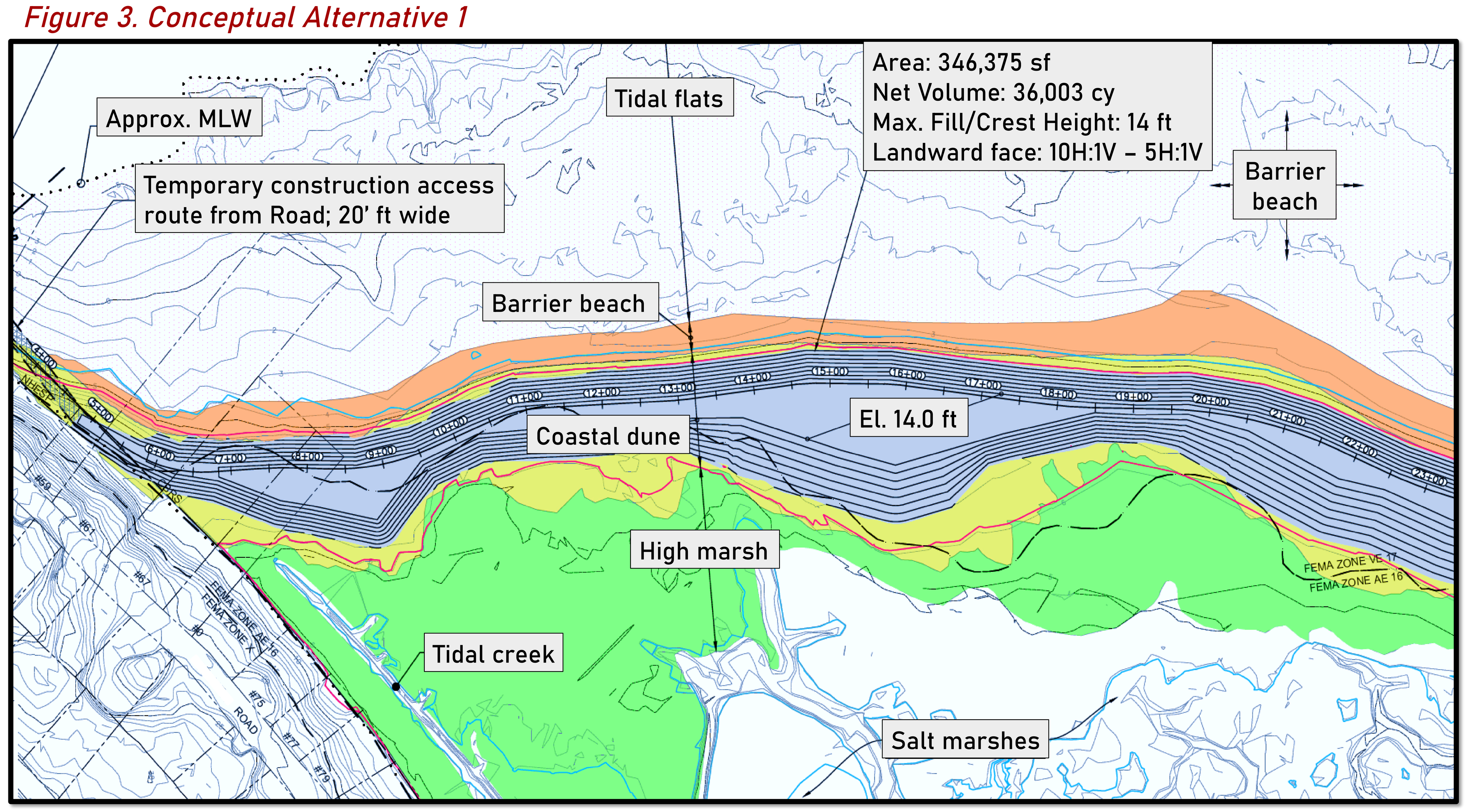


Figure 2. SWAN model-derived significant wave heights off the coast of Boston.

Figure 3. Conceptual Alternative 1



Sediment transport (Q [m³/m/sec]) and bed level changes (derived from dune profile elevation differences) were estimated for three nourished profiles subjected to typical winter storms.

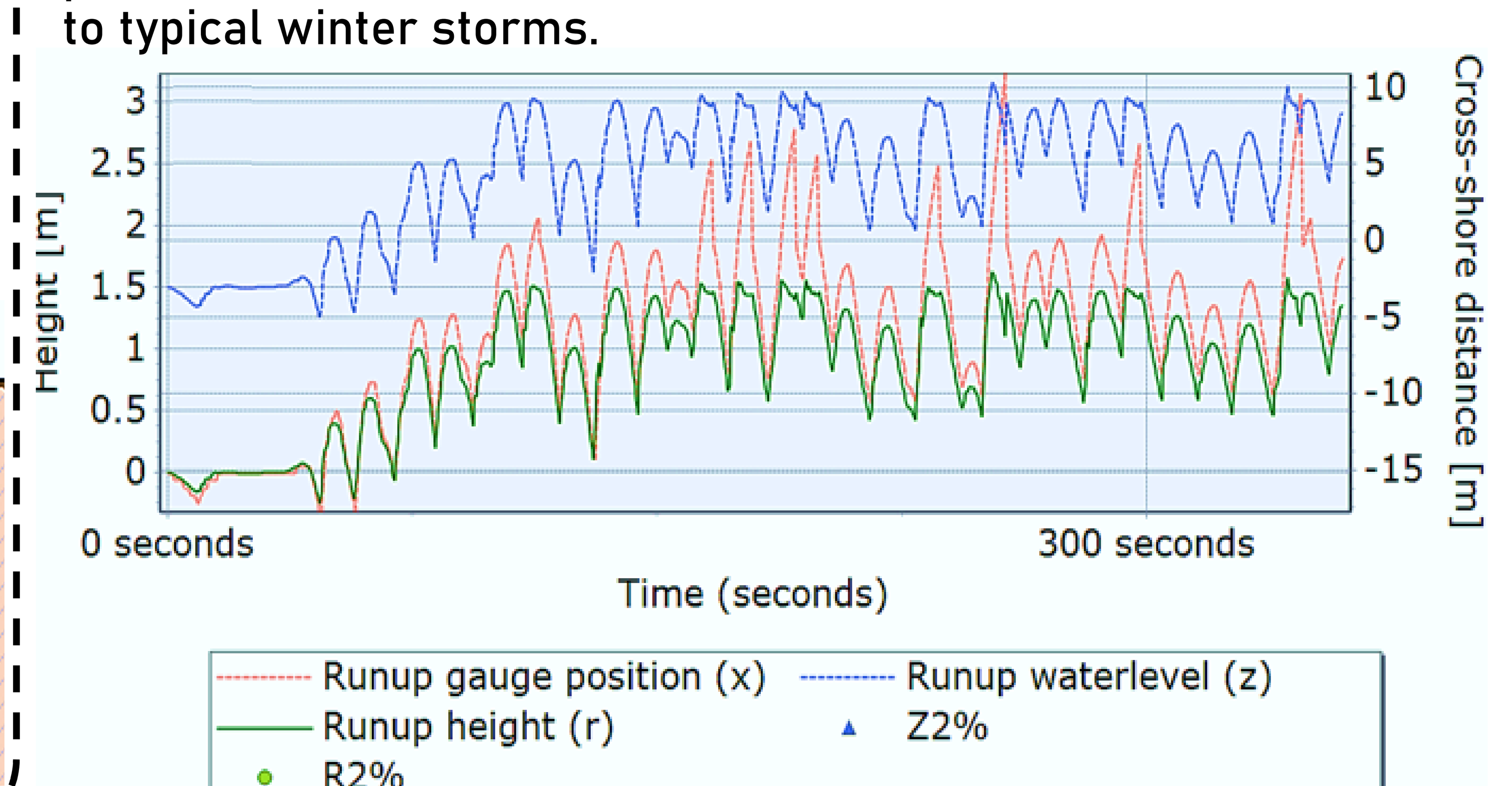
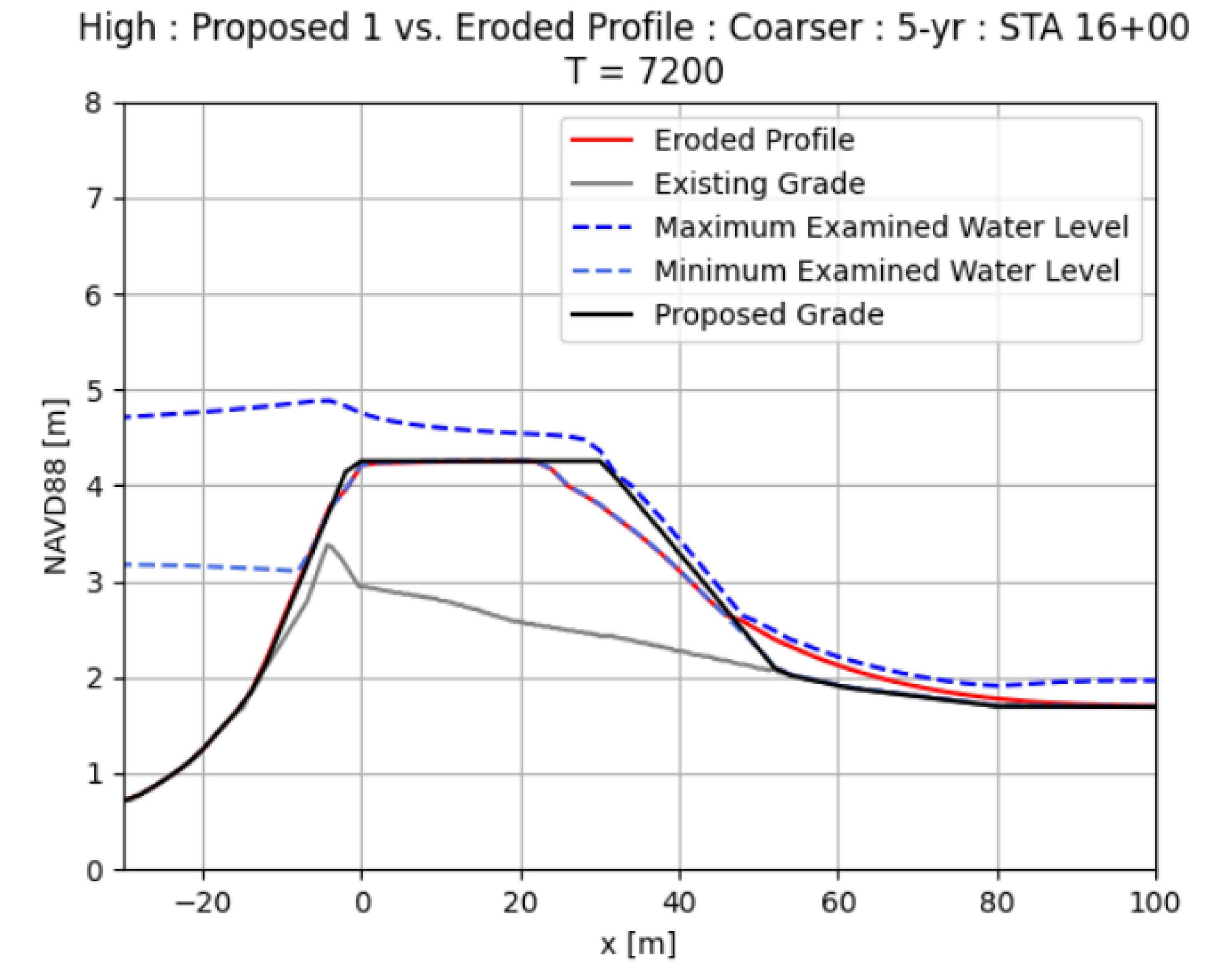
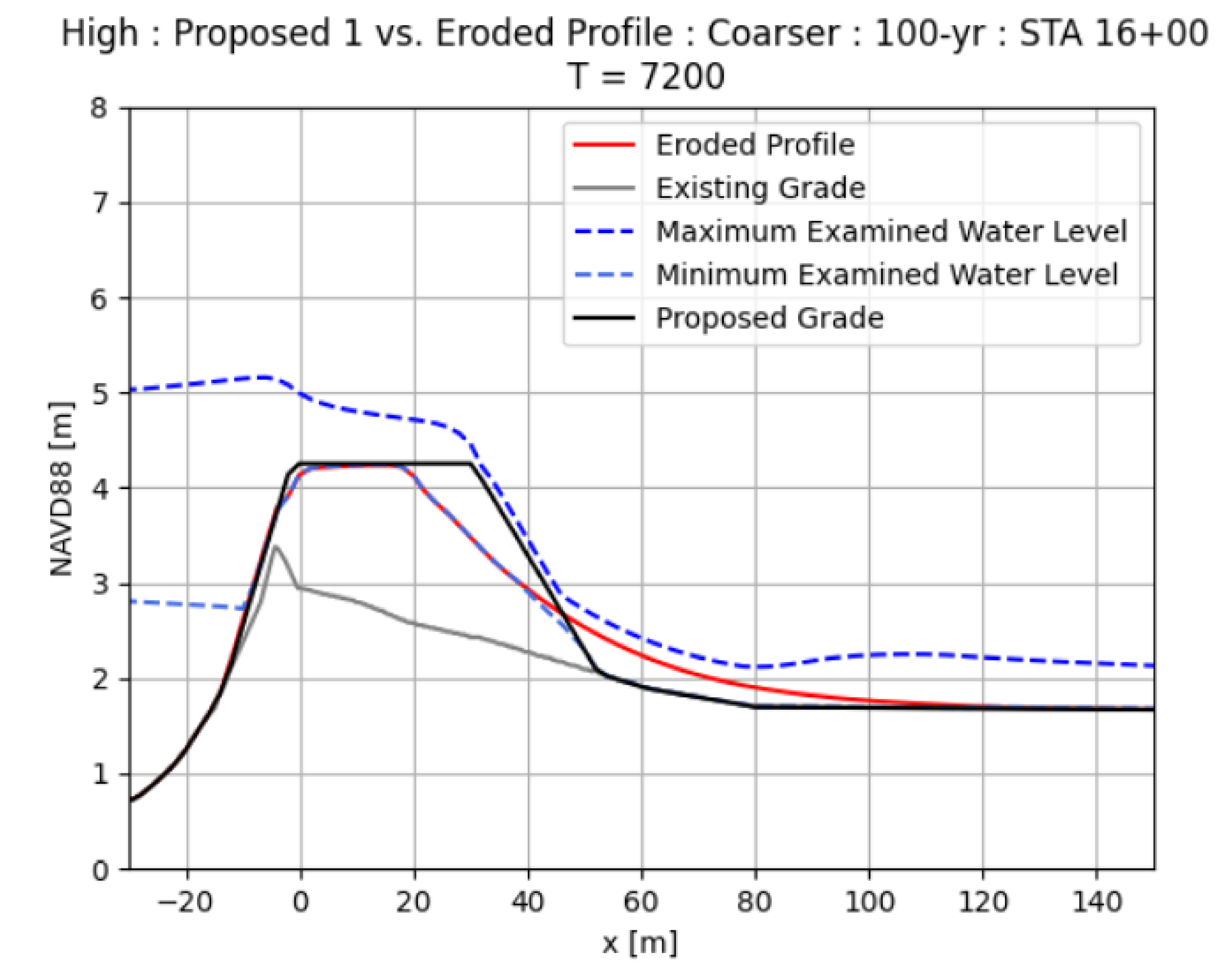


Figure 4. Example of XBeach wave runup levels on the beach.





Profile Section Loss

Design Storm	Grain-size Scenario	Section Loss (SF)
100 - year	Coarser	137
	Finer	669
5 - year	Coarser	59
	Finer	453

Conclusions – Ecological Considerations

Protecting Massachusetts salt marshes is a key consideration. Although traditional nourishment risks smothering with incompatible or thick sediment (> 15-20 cm), our proposed designs achieved minimal increase (less than 5%) in simulated daily inundation time in the low marsh zone, alongside providing protection to adjacent infrastructure and marine facilities.

References

[1] Massachusetts Department of Environmental Protection. 310 CMR 10.00: Wetlands Protection Act.
[2] Massachusetts Office of Coastal Zone Management (1994). Guidelines for Barrier Beach Management in Massachusetts
[3] Haney, R., Kouloheras, L., Malkoski, V., Mahala, J., & Unger, Y. (2016). Beach Nourishment. MassDEP's Guide to Best Management Practices for Projects in MA.