Integrated Assessment of Shoreline Protection Options

Di Jin (WHOI)

- **Worldwide, coastal communities face threats of shoreline change.**
- **A warming climate, rising sea levels have resulted in the permanent inundation of residences and businesses.**

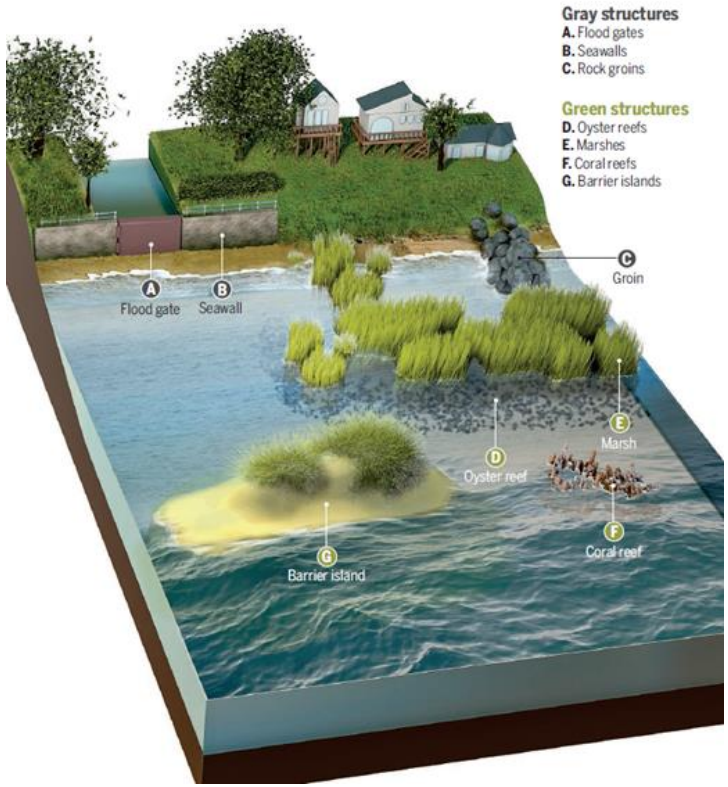
- **Coastal communities must consider whether**
  - **to stabilize the shoreline with gray or green methods, or**
  - **to leave the shoreline alone, implying a more rapid retreat from the coast.**

www.sunjournal.com

Green vs. Gray Options

stateofthecoast.noaa.gov

Shoreline armoring can accelerate erosion and loss of beaches and tidal wetlands (*Gittman et al. 2015*).



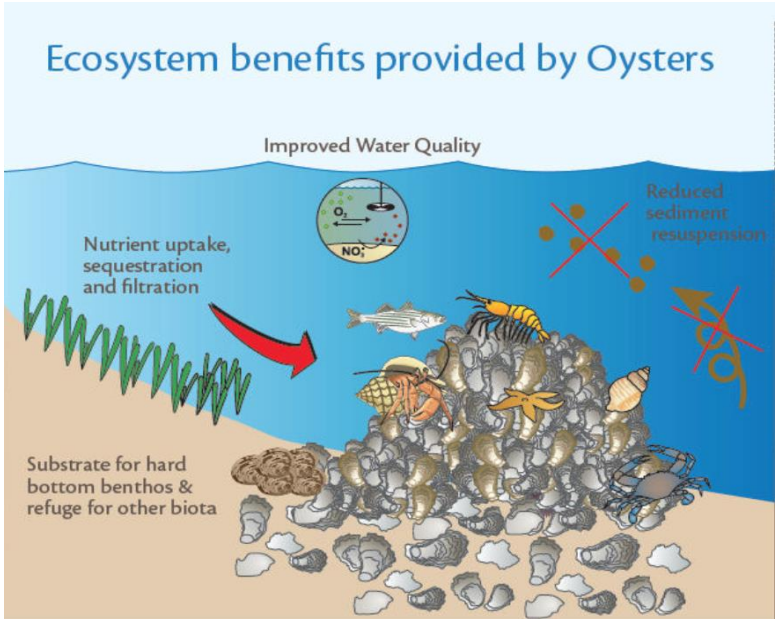
Green and gray and infrastructure for coastal protection
(Source: **Popkin**, G. 2015. Breaking the waves. *Science* 350(6262):756-759)**: Combining green and gray structures could create hybrid, layered defenses that offer both ecological and economic benefits.**

Ecosystem Services

https://www.delawarelivingshorelines.org/what-is-a-living-shoreline

- Water quality maintenance
- Nursery habitats
- Tourism and recreation
- Health benefits
- Symbolic of coastal heritage

- Protection of coastlines from storm surges and waves
- Reduction of shoreline erosion
- Cycling of nutrients
- Carbon sequestration

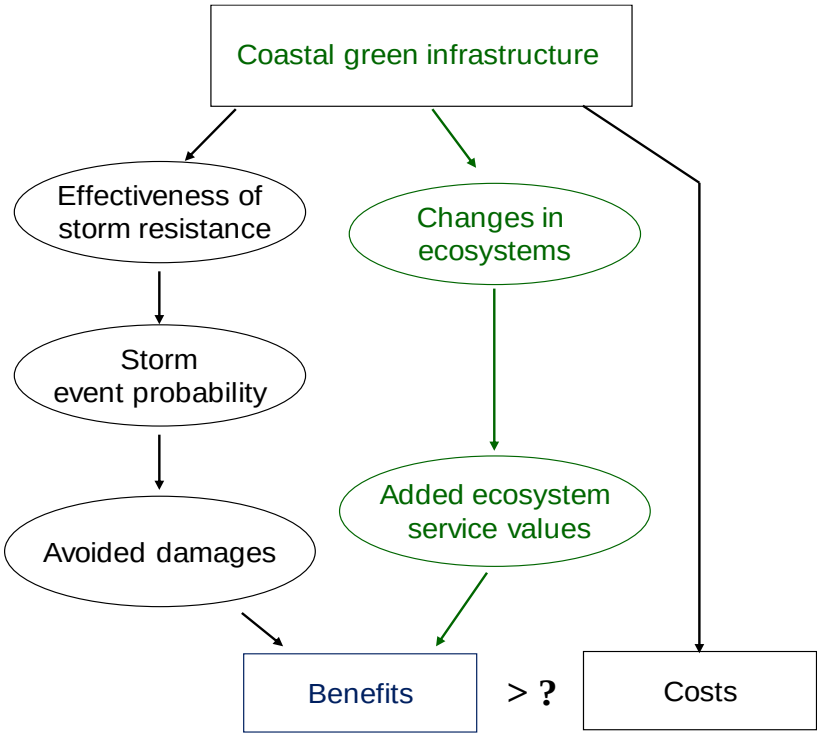


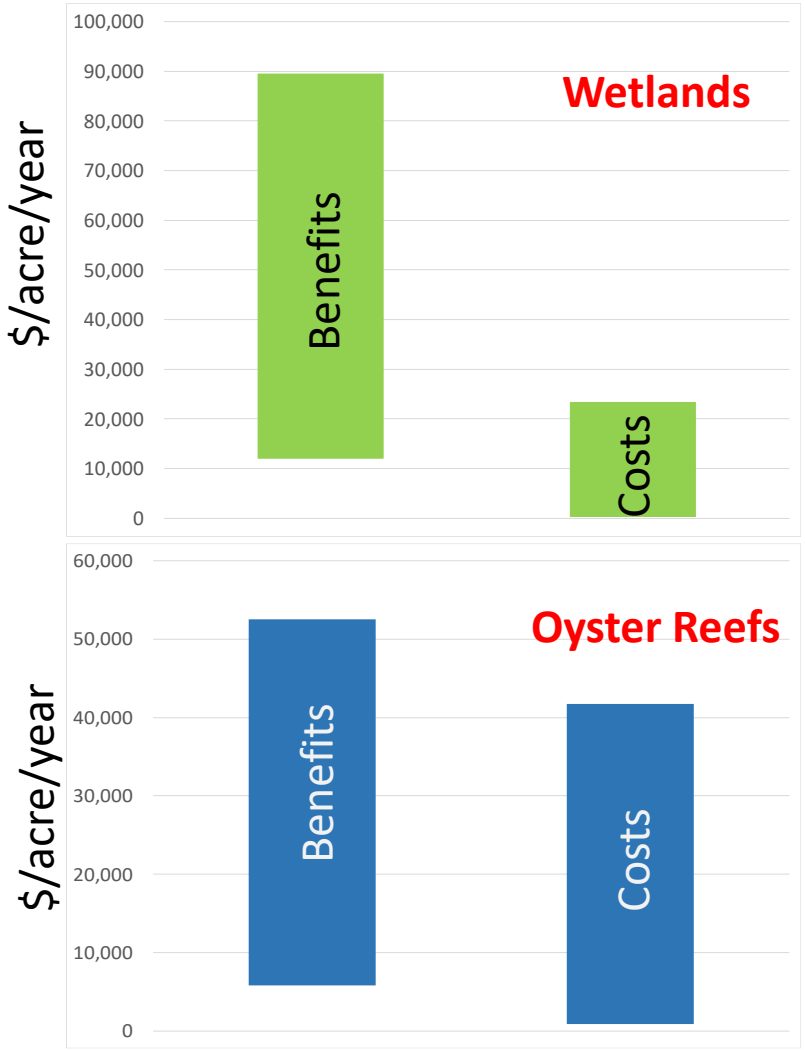
http://springhillnow.com/wp-content/uploads/2017/03/Screen-Shot-2017-03-29-at-9.37.16-AM.png

Economic Analysis

Cost-Benefit Analysis of a coastal green infrastructure project:

B > C ? or B/C > 1 ?





Case Studies

Benefit and Cost of Green Solution for Coastal Protection

Location	Gray solution cost	Green solution cost	Difference	Ecosystem benefits	B-C ratio
Greenway	5.42	7.14	1.72	4.85	**2.82**
Constitution Beach	7.81	12.92	5.11	5.91	**1.16**
Suffolk Downs	7.97	23.74	15.77	95.02	**6.02**

Costs and benefits are discounted sums over 25 years at 3% discount rate in 2017 $millions.

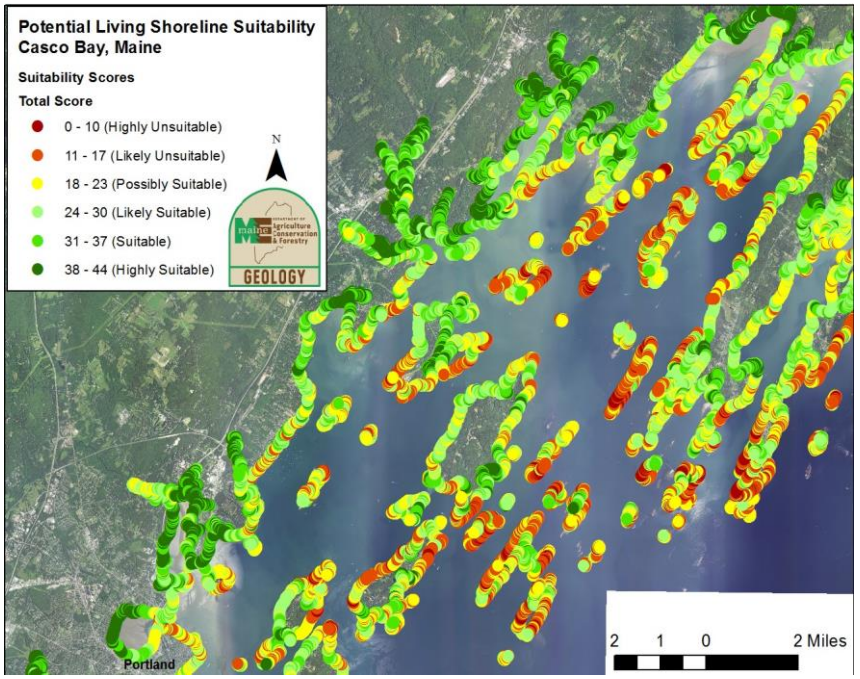
Research in collaboration with UMass Boston and Woods Hole Group

Study Sites in East Boston

A: Greenway

B: Constitution Beach

C: Suffolk Downs



https://coast.noaa.gov/digitalcoast/stories/casco.html

Low to moderate energy environment is suitable for living shoreline.

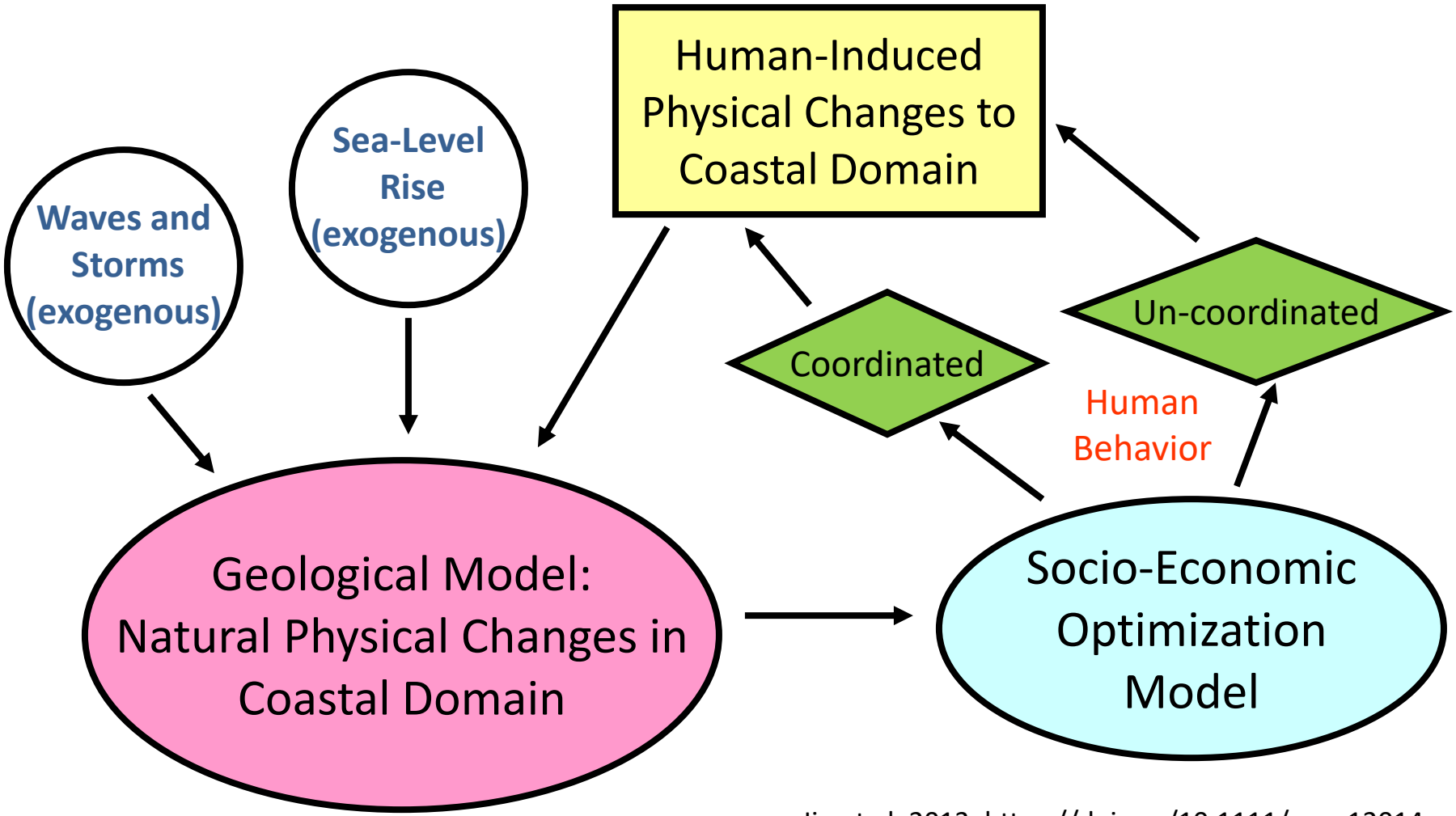
Summary: Green Infrastructure

- Green options are economically justifiable in many public projects
- Location: must consider living shoreline suitability (low to moderate energy environment)
- Hybrid system offers both ecological and economic benefits (moderately high energy environment).
- Must consider coastal population and assets (damage avoided)
- Cost-benefit results affected by the resilience of green options under sea level rise (oyster reefs grow with SLR)

- Private benefits associated with green options typically < public benefits

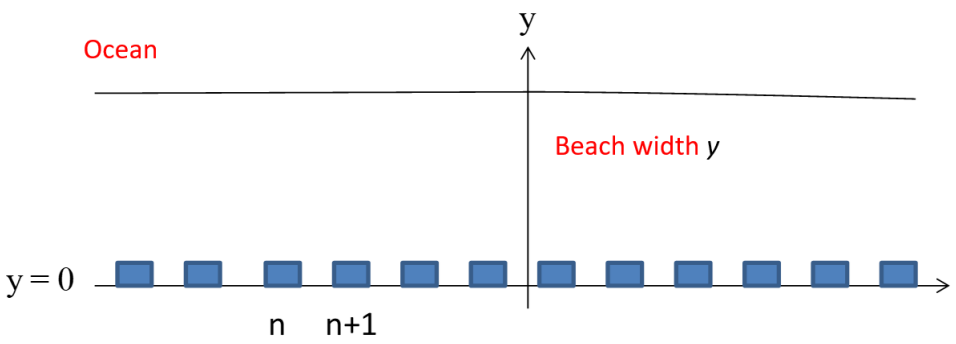
https://www.sacredheart.edu/academics/colleges--schools/college-of-arts--sciences/departments/biology/living-shorelines-in-connecticut/

Geoeconomic Analysis



Jin et al. 2013. https://doi.org/10.1111/nrm.12014

Choices of managed beach widths under environmental uncertainty



Erosion $\gamma = f(x)$

$\Pi(y,s) = B(y) - C(s)$

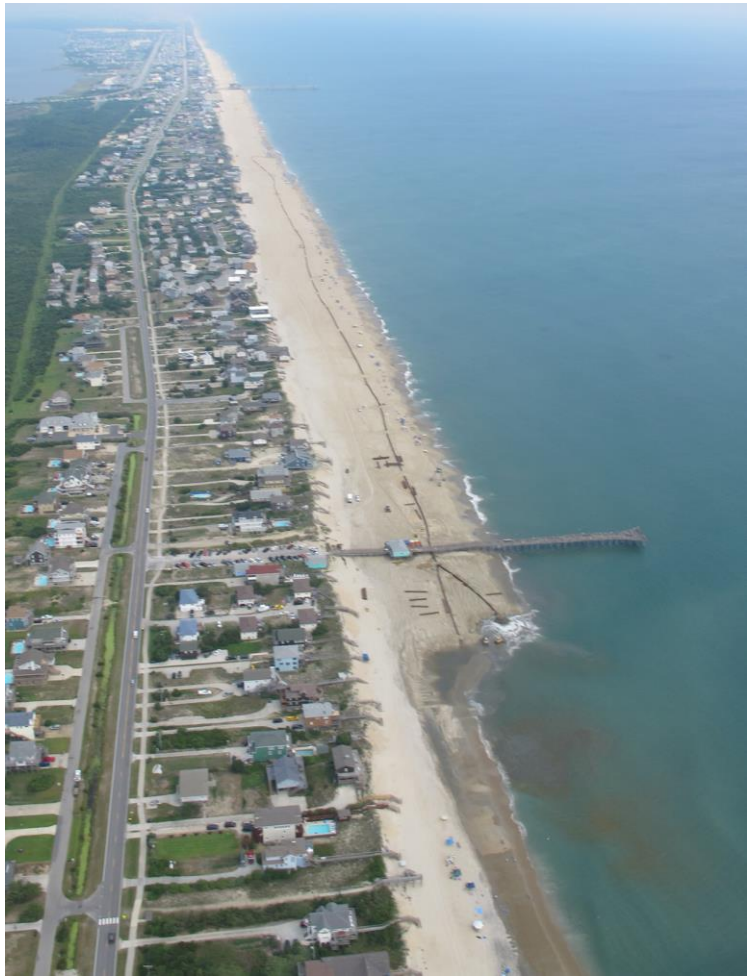
Value function $V(y) = \max_s E_t \int_t^\infty \Pi(y,s) e^{-\delta(\tau - t)} d\tau$

Dynamics of beach width

$$dy = [s - f(x)]dt + \sigma y dz$$

$z(t)$ is a Wiener process $dz = \kappa_t \sqrt{dt}$

The variance of the change in a Wiener process grows linearly with time (t)



www.nagsheadnc.gov

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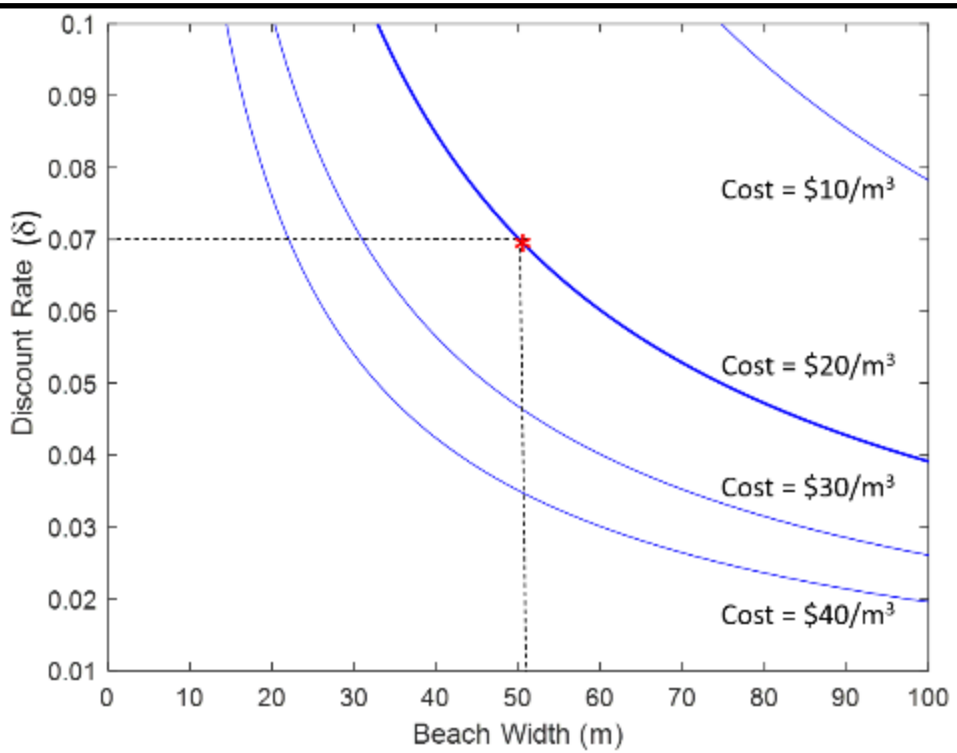
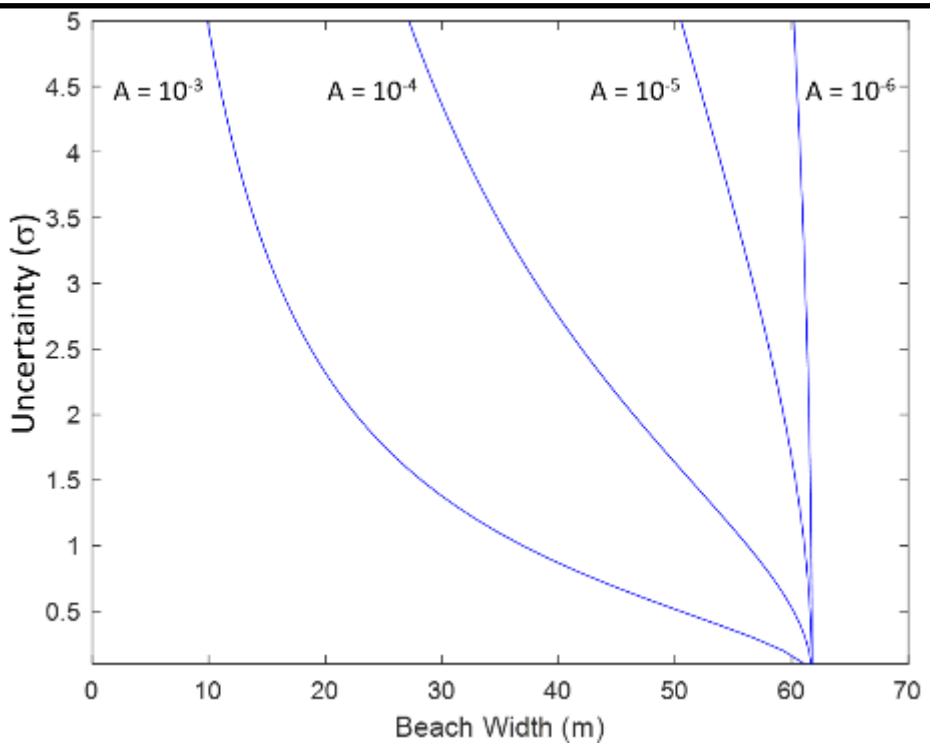


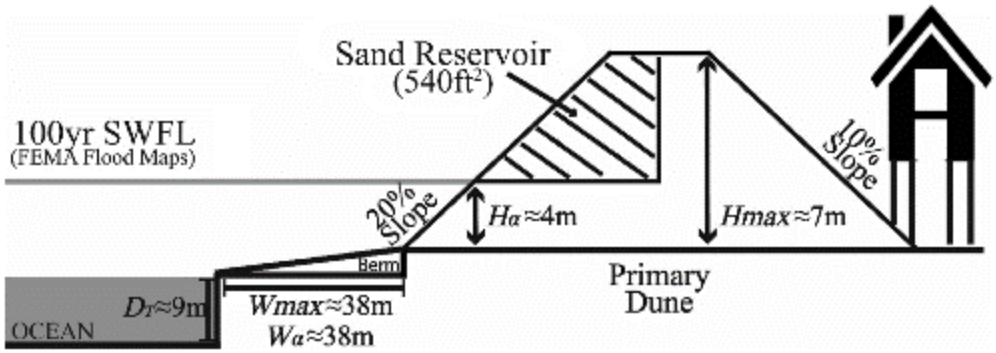


Beach width = *f*(-cost, -discount rate, -uncertainty)

Risk aversion can affect a coastal property owner's choice of beach width in contradictory ways: the expected benefits of hazard protection must be balanced against the expected costs of repeated nourishment actions.

Can coastal communities continue to hold the line?

Sea Grant
Woods Hole



https://cdnsciencepub.com/doi/10.1139/anc-2020-0024

Engineered coastal berm-dune renourishment in New Jersey (Kolodin et al. 2021)

A geoeconomic model of the natural and anthropogenic processes that shape beach and dune morphology. The model results suggest:

- Coastal communities may exhibit significant differences in their capabilities to maintain engineered dunes depending on stakeholder wealth and risk perception.
- Communities with strong preferences for ocean views are less likely to maintain large-scale berm-dune structures over the long term.

Shoreline Change Response Strategies

We should view sea-level rise adaptation from the context of sustainable hazard mitigation, to reduce the long-term risk to life and property from hazards.

- **In the near term (< 30 years): improve the resilience of coastal communities (gray and green coastal protection, disaster training and education).**
- **Over the long term: consider the overall effect of mitigation efforts on current and future generations. Managed retreat is likely to be the only course of action available in many places.**

https://thehill.com/opinion/energy-environment/489024-rapidly-rising-sea-level-and-the-future-of-our-coasts/

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