Shoreline Resilience and Inlet Management

Paige Hovenga, Steve Elgar, Britt Raubenheimer, Levi Gorrell
Coastal Ponds

- Saltwater or brackish ponds typically separated from the ocean by a narrow, barrier beach
- Cape Cod, Martha’s Vineyard, Nantucket, and mainland Massachusetts shorelines
- Provide many ecosystem services including habitat, recreation, support of local economy
Background

- Flood mitigation – neighboring properties
  - Due to rainfall, groundwater levels, overwash surges, snowmelt

- Environmental – improve water quality
  - Tidal flushing of the pond to increase salinity and reduce nitrogen
  - E.g., shellfish populations

- Facilitate migration of marine species
  - Diadromous fish
  - E.g., herring to spawn

Tisbury Great Pond

Sesachacha Pond
1) Understand the physical processes that result in beach recovery after machine-made or natural breaching

2) Determine breaching strategies that optimize exchange between coastal ponds and the ocean
   • inlet cut geometries and environmental conditions
Tisbury Great Pond (TGP) on Martha’s Vineyard

Pond size: 735 acres
Avg. Depth: 1.6-2.5 m (5.4-8.2 ft)

Martha’s Vineyard Coastal Observatory
(tide, wave, and wind data)
Tisbury Great Pond (TGP) on Martha’s Vineyard

- First recorded opening in the early 1700’s
- Barrier beach is intentionally opened ~4 times a year when pond is around 1m above sea level

08/2003: Complex flood shoal
05/2010: More definitive channel
12/2010: Same opening
05/2015: Cut further west
04/2017: Subaerial shoals
10/2021: Subaerial shoals
Observations at Tisbury Great Pond, MV (2018)

Breached Mar 23

Mar 29

Apr 23

May 1

Pond

Beach

Ocean

Breach

West

East

North

West

East

Tisbury Great Pond

Ocean

Breach
Observations at Tisbury Great Pond, MV (2018)

Breached Mar 23
- Waves from east, spit grows to west
- Beach

Mar 29
- Waves from west, spit grows to east
- East

Apr 23
- Shore normal waves, sand moves onshore, breach closes
- West

May 1
- East

Direction (deg)
- West
- East

Mar 23
- Beach
- West
- East

Mar 29
- Beach
- West
- East

Apr 23
- Beach
- West

May 1
- Beach
Water Levels in Tisbury Great Pond (2018)

- Pond is breached
- Storms, wind?
- Tidal fluctuations
- Pond closes

Meters Below Average High Pond

Date
Oct 29, Nov 05, Nov 12, Nov 19, Nov 26, 2018

South
North
XBeach (Roelvink et al., 2019)

• Numerical model that simulates hydrodynamic and morphodynamic processes

• Develop an XBeach model to test a variety of....
  • Environmental conditions (water levels, tides, waves)
  • Inlet cut geometries (cut width, depth, angle relative to the shoreline)
Tisbury Great Pond Bathymetry

Merged Topo-bathymetry

Onshore

Offshore

Barrier Beach
Max elevation ~2m

Pond

Ocean

Zoomed in near inlet

Cross-shore Profile

Elevation, m (NAVD88)

0
0.5
1 km

0
0.1
0.2 km

Barrier Beach
Inlet
Barrier Beach
Schematized XBeach Model Domain

- **Barrier Beach**
- **Pond**
- **Ocean**
- **Machine-made inlet**
- **Channel through the flood shoal**
- **Flood shoal region**

Cross-shore Profile:
- **Pond**
- **Channel through flood shoal**
- **Machine-made inlet**
Environmental Conditions for XBeach Modeling

Water Levels
• Measured tides (start at low tide)

Waves
• Wave height = 1 meter (~3 foot)
• Wave period = 6 seconds
• Wave direction = 135 deg (oblique waves from the southeast)

Simulation Run Time = 72 hours
Look for closure of the inlet....
Water Level Fluctuations Near the Inlet

Intermittent wetting and drying due to tidal fluctuations

Waves from the southeast

Pond

Ocean

Inlet Closed

Wave Height = 1 m
Wave Period = 6 sec
Wave Direction = 135 deg
Modeled Bed Elevation Change

**Cross-shore Coordinate (m)**

<table>
<thead>
<tr>
<th>Bed Elevation (m)</th>
<th>Bed Elevation Change (m)</th>
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</thead>
<tbody>
<tr>
<td>-6</td>
<td>-1</td>
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<tr>
<td>-5</td>
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<tr>
<td>-4</td>
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<td>-2</td>
<td>3</td>
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<tr>
<td>-1</td>
<td>4</td>
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**Alongshore Coordinate (m)**

- Sediment deposited into the pond
- Erosion of the channel through the flood shoal
- Sediment deposited

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16
Sediment Erosion and Deposition in the Inlet

- Erosion of the walls of the inlet
- Sediment deposition in the inlet

Elevation, m (NAVD88)
- t=72 hrs
- t=0 hrs
## Preliminary Results

- Moderate waves lead to faster closure
  - Wave Heights = 0.3, 1, and 3 m
- Channel infilling is sensitive to the channel length and curvature
  - Presence of the flood shoal
- Ongoing work to test a range of...

<table>
<thead>
<tr>
<th>Environmental conditions</th>
<th>Wave height, period, direction</th>
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<tbody>
<tr>
<td></td>
<td>Tide range (spring or neap)</td>
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<td></td>
<td>Starting tide level (rising or falling)</td>
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<tr>
<td></td>
<td>Water levels</td>
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<td>Wind speed and direction</td>
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<table>
<thead>
<tr>
<th>Inlet cut geometries</th>
<th>Cut width, depth, and angle</th>
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</thead>
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<table>
<thead>
<tr>
<th>Morphologies</th>
<th>Pond length, width, contour depth</th>
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<tbody>
<tr>
<td></td>
<td>Offshore bathymetry</td>
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<tr>
<td></td>
<td>Features (flood and ebb shoals, sand bars)</td>
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</tbody>
</table>

Contact information: paige.hovenga@whoi.edu
08/2003 | Complex flood shoal
12/2004
07/2008
05/2010
12/2010
05/2015
05/2016
04/2017 | More definitive channel
10/2021

Tisbury Great Pond

Cut further west

Same opening

Cut further west
Sesachacha Pond

03/1995

08/2003

05/2004

05/2007

Less of a flood shoal

07/2007

Same opening

05/2010

Cut is longer than TGP

06/2014

04/2017

10/2021
Test 109; $H=0.3$ m and Tides=measured

More drying when $H=1$ m compared to $H=0.3$

More sediment is pushed onshore with $H=1$ m, which fills the inlet faster

Instantaneous Water Levels at Different Timesteps

Test 107; $H=1$ m and Tides=measured

Flooding in the surrounding areas outside the shoal inlet. This occurs during all the high tides, especially hour 30

There are a few areas where the dune is being breached. But this large, flooded area has spilled over from the channel at the bend and then dries out.

Test 108; $H=3$ m and Tides=measured
Schematized XBeach Model Domain

Pond length = 1500 m
Pond width = 1000 m
Contour depths

Extracted Offshore Bathymetry
Parallel Contours

Bathymetry Extracted up to Dune Crest

Contour depths

Depth, m (NAVD88)
Observations at Tisbury Great Pond, MV (2018)
Water Level Fluctuations Near the Inlet

Intermittent wetting and drying due to tidal fluctuations

Inlet Closed