NJ Living Shorelines
Engineering Guidelines Project

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2015 Living Shorelines and Coastal Restoration Summit
Bordentown, NJ - February 27, 2015

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Literature Review & Gap Analysis

• Designed to summarize what else is out there and what info it contains
• Layout
  – Summarize NJ work
    • White paper, GP, DELSI, Engineering Guidelines
  – What other states are doing
  – Current Initiatives
    • COPRI, NACCS, NNBF, Sage, NYC Research Plan, TNC
  – Gaps
    • Case studies, monitoring, valuation, ice, wakes, specific types of LS
State Reports and Guidelines

- Alabama (AL)
- Delaware (DE)
- Georgia (GA)
- Maryland (MD)
- Massachusetts (MA)
- Michigan (MI)
- New York (NY)
- North Carolina (NC)
- Rhode Island (RI)
- Texas (TX)
- Vermont (VT)
- Virginia (VA)
- Washington (WA)
Engineering Guidelines

- Primary Objectives
  - Provide guidance to engineers and regulators on the engineering components of living shorelines design
  - *Provide a common starting place to ensure consistency with GP 29 (N.J.A.C. 7:7-7.29) – “Living Shorelines GP”*
  - Reduce the number of potential failures due to poor design/construction
Usage

• Engineer knows they’re expected to follow guidelines
• NJDEP knows what engineer is expected to consider
• Meant to be “complete”, but impossible to include everything
• Not intended to be prescriptive, but rather encourage the innovation that living shorelines projects require
• Designed to be a living document
  – Deficiencies will be brought to light as the guidelines are used
  – Measuring and monitoring will be essential to refining guidance
  – Perhaps combine/integrate with ecological guidelines (?)
Approach

1. Identify factors relevant to living shoreline design
   – Mix of traditional, traditional evaluated non-traditionally, and non-traditional
   – Categorize as system, hydrodynamic, terrestrial, ecological, additional considerations
   – Provide guidance for selecting between alternatives

2. Describe approaches for determining required parameters
   – Consider different levels of rigor for different parameters and projects

3. Provide example of how these parameters influence design
   – Sills*, breakwaters*, joint planted revetment, reef balls*, living reef*

* Marsh creation assumed behind the structures
Parameter List

**System Parameters**
- Erosion History
- Sea Level Rise
- Tidal Range

**Ecological Parameters**
- Water Quality
- Soil Type
- Sunlight Exposure

**Hydrodynamic Parameters**
- Wind Waves
- Wakes
- Currents
- Ice
- Storm Surge

**Terrestrial Parameters**
- Upland Slope
- Shoreline Slope
- Width
- Nearshore Slope
- Offshore Depth
- Soil Bearing Capacity

**Additional Considerations**
- Permits/Regulatory
- End Effects
- Constructability
- Native/Invasive Species
- Debris Impact
- Project Monitoring
Suggested Design Approach

Living Shorelines Project

Level 1 Analysis

System

Hydrodynamic

Terrestrial

Ecological

Additional

Alternative Selection

Conceptual Design

Level 2/3 Analysis

Select System

Select Hydro

Select Terrestrial

Select Ecological

Select Additional

Final Design
Example: Wind Waves

• Along with wakes, typically the dominant cause of erosion
• Both the maximum and the average wave may be of concern
• Basis for most of the critical structural design parameters
Wind Waves

• **Level 1 Analysis**
  – Fetch Analysis (average and max)
  – Based on work of Hardaway (1984, 1999)

<table>
<thead>
<tr>
<th>Energy</th>
<th>Fetch (mi)</th>
<th>Weight (lb)</th>
<th>Diameter (ft)</th>
<th>Sill/Marsh BW/Beach</th>
<th>Width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>&lt;0.5</td>
<td>300-900</td>
<td>1.4-2.0</td>
<td>Sill/Marsh</td>
<td>-</td>
</tr>
<tr>
<td>Low</td>
<td>0.5 - 1.0</td>
<td>300-900</td>
<td>1.4-2.0</td>
<td>Sill/Marsh</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>1.0 – 5.0</td>
<td>400-1,200</td>
<td>1.5-2.1</td>
<td>Sill/Marsh</td>
<td>40-70</td>
</tr>
<tr>
<td>Medium</td>
<td>1.0-5.0</td>
<td>800-2,000</td>
<td>2.0-2.6</td>
<td>BW/Beach</td>
<td>35-45</td>
</tr>
<tr>
<td>High</td>
<td>5.0 - 15.0</td>
<td>2,000-5,000</td>
<td>2.6-3.5</td>
<td>BW/Beach</td>
<td>45-65</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt;15.0</td>
<td>2,000-5,000</td>
<td>2.6-3.5</td>
<td>BW/Beach</td>
<td>45-65</td>
</tr>
</tbody>
</table>
Wind Waves

- Alternative Level 1 Analysis
  - SMB Type
    - Multiple flavors
    - Depth limited equations
    - Shallow water curves

\[ H_w = 0.283 \tanh \left[ 0.530 \left( \frac{gd}{U^2} \right)^{0.75} \right] \tanh \left[ \frac{0.0125 \left( \frac{gF}{U^2} \right)^{0.42}}{\tanh \left[ 0.530 \left( \frac{gd}{U^2} \right)^{0.75} \right]} \right] \frac{U^2}{g} \]
Suggested Design Approach

Living Shorelines Project

Level 1 Analysis

<table>
<thead>
<tr>
<th>System</th>
<th>Hydrodynamic</th>
<th>Terrestrial</th>
<th>Ecological</th>
<th>Additional</th>
</tr>
</thead>
</table>

Alternative Selection

Conceptual Design

Level 2/3 Analysis

<table>
<thead>
<tr>
<th>Select System</th>
<th>Select Hydro</th>
<th>Select Terrestrial</th>
<th>Select Ecological</th>
<th>Select Additional</th>
</tr>
</thead>
</table>

Final Design
## Selection Criteria

<table>
<thead>
<tr>
<th></th>
<th>Marsh Sill</th>
<th>Breakwater</th>
<th>Revetment</th>
<th>Living Reef</th>
<th>Reef Balls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Sea Level</td>
<td>Low-Mod</td>
<td>Low-High</td>
<td>Low-High</td>
<td>Low-Mod</td>
<td>Low-Mod</td>
</tr>
<tr>
<td>Tidal Range</td>
<td>Low-Mod</td>
<td>Low-High</td>
<td>Low-High</td>
<td>Low-Med</td>
<td>Low-Med</td>
</tr>
<tr>
<td><strong>Hydrodynamic Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Waves</td>
<td>Low-Mod</td>
<td>High</td>
<td>Mod-High</td>
<td>Low-Med</td>
<td>Low-Med</td>
</tr>
<tr>
<td>Wakes</td>
<td>Low-Mod</td>
<td>High</td>
<td>Mod-High</td>
<td>Low-Mod</td>
<td>Low-Med</td>
</tr>
<tr>
<td>Currents</td>
<td>Low-Mod</td>
<td>Mod-High</td>
<td>Mod-High</td>
<td>Low-Mod</td>
<td>Low-Mod</td>
</tr>
<tr>
<td>Ice</td>
<td>Low</td>
<td>Low-Med</td>
<td>Low-High</td>
<td>Low</td>
<td>Low-Mod</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>Low-High</td>
<td>Low-High</td>
<td>Low-High</td>
<td>Low-High</td>
<td>Low-High</td>
</tr>
</tbody>
</table>

**Bold denotes critical parameters requiring level 2/3 analysis**
Quantitative Interpretation

- Based on guidance where established criteria
  - Only available for a limited number of parameters
  - Should be revisited on the basis of monitoring data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low/Mild</th>
<th>Moderate</th>
<th>High/Steep</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion History</td>
<td>&lt;2 ft/yr</td>
<td>2 ft/yr to 4 ft/yr</td>
<td>&gt;4 ft/yr</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>&lt;0.2 in/yr</td>
<td>0.2 in/yr to 0.4 in/yr</td>
<td>&gt;0.4 in/yr</td>
</tr>
<tr>
<td>Tidal Range</td>
<td>&lt; 1.5 ft</td>
<td>1.5 ft to 4 ft</td>
<td>&gt; 4 ft</td>
</tr>
<tr>
<td><strong>Hydrodynamic Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waves</td>
<td>&lt; 1 ft</td>
<td>1 ft to 3 ft</td>
<td>&gt; 3 ft</td>
</tr>
<tr>
<td>Wakes</td>
<td>&lt; 1 ft</td>
<td>1 ft to 3 ft</td>
<td>&gt; 3 ft</td>
</tr>
<tr>
<td>Currents</td>
<td>&lt; 1.25 kts</td>
<td>1.25 kts to 4.75 kts</td>
<td>&gt;4.75 kts</td>
</tr>
<tr>
<td>Ice</td>
<td>&lt; 2 in</td>
<td>2 in to 6 in</td>
<td>&gt; 6 in</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>&lt; 1 ft</td>
<td>1 ft to 3 ft</td>
<td>&gt; 3 ft</td>
</tr>
</tbody>
</table>
Suggested Design Approach

Living Shorelines Project

Level 1 Analysis

| System | Hydrodynamic | Terrestrial | Ecological | Additional |

Alternative Selection

Conceptual Design

Level 2/3 Analysis

| Select System | Select Hydro | Select Terrestrial | Select Ecological | Select Additional |

Final Design
Conceptual Design

- Plan and profile
Suggested Design Approach

Living Shorelines Project

Level 1 Analysis

| System | Hydrodynamic | Terrestrial | Ecological | Additional |

Alternative Selection

Conceptual Design

Level 2/3 Analysis

| Select System | Select Hydro | Select Terrestrial | Select Ecological | Select Additional |

Final Design
Example: Wind Waves

• Level 2 Analysis
  – Collect measurements
    • Provides real data at the site, but...
    • Consider factors like seasonality, etc.
    • Instrumentation
      – Pressure gauge
      – Accelerometer buoy
      – Acoustic wave gauge
      – Ultrasonic range measurement
      – Wave wire
      – Lidar/radar
      – Visual
Example: Wind Waves

• Level 3 Analysis
  – Modeling
  – Can capture important bathymetric induced modifications to the wave field
Suggested Design Approach

Living Shorelines Project

Level 1 Analysis

| System | Hydrodynamic | Terrestrial | Ecological | Additional |

Alternative Selection

Conceptual Design

Level 2/3 Analysis

| Select System | Select Hydro | Select Terrestrial | Select Ecological | Select Additional |

Final Design
Final Design

- Plan, profile, detailed specifications
Approach Specific Guidance

- Sill
- Revetment
- Breakwater
- Living Reef
- Reef Balls

Marsh Sill

Description
Sills are low elevation typically stone structures that are constructed in the water parallel to the existing shoreline. Sills are often used as armoring for fringe marshes or wetlands that require a higher degree of protection. Sills dissipate wave energy and reduce bank erosion, causing waves to break on the offshore structure, rather than upon the natural, more fragile shore. Additionally, the tamed area of water lying behind the sill allows sand and sediment to accumulate between the structure and the shoreline. With time this process can eventually raise the elevation of the bottom and create a perched beach. This unique effect not only serves to further stabilize the shoreline or marsh behind the sill, but replaces lost and eroded land. Often the area between the sill and the shoreline is filled during construction to accelerate the development of the perched beach and planted with marsh plantings for stabilization.

Figure 7: Typical Sill
Each Parameter Discussed

Hydrodynamic Parameters

Wind Waves

Approaches for designing marsh sills for wave heights range from the simple fetch based approaches presented in the main body of these guidelines, to more traditional engineering approaches based on a design wave height. Traditional engineering approaches for the design of rubble mound structures are discussed in the Coastal Engineering Manual (US Army Corps of Engineers, 2002) and The Rock Manual (CIRIA; CUR; CETMF, 2012). Relevant considerations include the geometry of the structure, the size of the armor units, the amount of energy dissipation, spacing (for segmented sills), and scour potential. The two most frequently used approaches to select the appropriate armor stone based on the structure geometry and the incident wave conditions are the (Hudson, 1959) and (Van der Meer, 1988) formulas.
Parting Thoughts...

• Interest is staggering
• Need to find out what works for NJ
  – Unique urban environments
  – Ice?
  – Need to get projects on the ground
  – Monitoring will be critical
• Guidelines will need to be updated
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