Shoreline Stabilization along the Delaware River Using Wave Attenuation Devices

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Presentation Overview

- What are Wave Attenuation Devices (WADs)?
- How do they work?
- Project Setting and Need
- Alternative Analysis
- Project Implementation
  - Design
  - Permitting/Agency Coordination
  - Construction
- Monitoring
What is a WAD?

> WAD stands for Wave Attenuation Device
  - Attenuation by definition is the loss in intensity (energy) passing through a medium or object.

> WADs is a registered trade mark of Living Shoreline Solutions, LLC (LSS)

> WAD technology evolved from artificial reef structures

> WADs come in different sizes & shapes depending on project needs/goals

> A WAD is a precast concrete structure
  - hollow, three-sided, pyramid-shaped with triangular baffles on each facet.
How Are They Made

> WADs are site-specifically engineered and designed based on site specific data and Project Objectives

> Complex steel form systems are then engineered and manufactured to produce the desired concrete WADs and shipped to project site for product manufacturing using local labor and materials, contributing to the areas economic stability.

> WADs are produced with a minimum, 5,000 psi marine grade concrete that is dosed with 3 pounds of 650 fibermesh, per cubic yard of concrete. Testing after 7 days curing shows wall strength of over 7,000 psi.
How Do They Work

- When waves hit a solid object, the wave experiences defraction and deflects around and off the object—causing a shadow zone directly behind the object and erosional zone next to it—the cup pattern

- Wave Attenuation—allows the energy to enter the array greatly reducing the reflection of energy—instead, the energy is spread in multiple directions causing energy to dissipate as it passes between or through the baffles
WADs as Shoreline Protection

Step 1 (the wave brunt) Attenuation

Step 2 (lower energy) Attenuation

Step 3 (severe storm) Attenuation

Created Dune, Slope or other Supratidal Feature

Enhanced and Stabilized Resilient Shoreline Zone

Existing Beach

Passive Accretion and/or Optional Nourishment (may be beach and/or marsh)

Existing Bottom

Orange arrows represent wave energy

Example of Spacing (ft)

0  25  50  75  100  125  150  175  200  225  250  275

MHW

MLW
Delaware City Refinery Shoreline Stabilization Project
The Issue

> The shoreline along the Delaware River behind the Delaware City Refinery docks was being eroded.

> Storm-driven wave actions was the predominant cause.

> Delaware City Refining Company (DCRC) recognized that if nothing was done to mitigate this that within a few years facility infrastructure would be threatened or compromised.
Why is it Eroding Here?

North approaching wind wave with 2% occurrence frequency, with a significant wave height of 0.57 m and peak period of 2.7s.
How Much has Eroded

- To quantify the amount and rate of erosion occurring - A comparison was done between the shoreline in 2007 and 2013.

- 9,500 Square feet or 1.7ft/yr of shoreline was estimated to be lost during the 6 year period.
What The Erosion Looks Like

Panoramic Photo Coverage

Aerial Imagery from February 2012

Panorama 2

Storm Surge Rack Line

MHHW

MHW
Evaluation Process

Examples of Options Evaluated
- Dredge/Beach Replenishment
- Shoreline Riprap
- Sills/Breakwater
- Wave Attenuation

Alternative Analysis – Comparison of potential solutions effectiveness, costs and risks/impacts
- Level 1 (Preliminary)
  ○ Fatal Flaws, Purpose and Need Criteria, Significant Environmental Impacts, Practicality, Etc.
- Level 2 (Qualitative)
  ○ Environmental Impacts, Cost, Implementation Issues, Safety, Etc.
- Level 3 (Quantification)
Data Collection

- Hydrographic Surveys (Bathymetry)
  - Site tidal conditions (NOAA)
- Bottom Conditions
  - Substrate
  - Geotech (Grain size, compressibility, etc)
- Wind-Wave Analysis/Modeling
- Seasonal Analysis
- Modeling Wave Attenuation
- Based on site specific conditions and model data a WAD system and layout is developed.
Why WADs Winning Option

Advantage of WADs over other Options evaluated - Sills/Breakwaters/Revetment:

> Dissipates (vs. reflects) wave energy
> Greater ecological uplift potential
> Smaller impact footprint;
> Promotes passive (natural) accretion;
> Greater long-term stability and reliability;
> Modular Design - Reduced maintenance/repair requirements;
> Maintained hydraulic connectivity behind structure; and
> Increasingly viewed by agencies as a “greener” alternative
Geotech investigation found:

- A firm sand layer underlying the Project site at a uniform elevation

- Soft unconsolidated sediment overlying sand layer varied in thickness across the project

Bathymetry data confirmed large mudflat, shallow slope profile extended to dock pilings
What Does the Modeling Say?

Significant wave energy is contacting the shoreline

Addition of WADs

WADs nearly eliminates wave energy from contacting the shoreline

Modeling results predict near 100% wave attenuation under this and lesser energy scenarios.

Note: The modeling also indicates that the WADs will not affect areas off-site.
**Design Elements**

- Wave Energy Attenuation Devices (WADs)
- Minor Nourishment and Upland Fill:
  - To Restore Pre-existing Slopes
- Improved Oil Containment Boom System:
  - Protective of the Shoreline and WADs
Authorization/Permitting

> Permitting Process Summary:
  - Timetable: over year
  - Coordination and consultation with multiple federal, state and local agencies – Meetings, site visits, etc.
  - Four public notices
  - One public hearing
  - Submission of approved Monitoring and Contingency Plans
  - One permit modification – Construction technique

> Received Permits:
  - Federal Authorization – US Army Corp of Engineers (USACE) Individual Permit
    - Authorizing Pilings, WADs and Beach Nourishment
  - State Authorization – Delaware Coastal Management Program (DCMP) – Consistency Certification
  - DNREC – Subaqueous Lands Permit & Water Quality Certification
  - State Historic Preservation Office (SHPO) – Letter of No Impact
Phase I – Construction

Project Summary

> 497 WADs to protect 1,400 linear feet of shoreline
> 22 pilings to hold new boom system
> Designed gap to allow boats access for boom deployment
> Approximately 7,400 ft$^2$ of beach nourishment
WAD Delivery and Staging
Construction – WAD Placement
Installed
Post Construction Monitoring Program

- Monitoring Parameters
  - Sediment Accretion;
    - Shoreline profiles and pre-established measuring points
  - Sedimentation Profiles;
    - Boring logs
  - Vegetation;
    - Observations and mapping of changes in vegetation
  - WAD Structural Stability
  - Wildlife Observations; and
    - Observations of wildlife within the project area
  - Major Storm Events
    - Log of major storm event
All elevations measured relative to NOAA Tidal benchmark 1762 E 2001 (+3.77' NAVD 88)

Shoreline profile surveyed by Cardno on 11/18/15, 5/26/16, and 11/21/16
Shoreline profiles surveyed by Cardno on 11/18/15, 5/12/16, and 11/21/16

All elevations measured relative to NOAA Tidal benchmark 1762 E 2001 (+3.77' NAVD 88)
Thank You

Special Thanks to Delaware City Refining Company and our Partners
Questions