FORENSIC ANALYSIS: COXSACKIE BOAT LAUNCH, NY

PROJECT BACKGROUND

The Coxsackie Boat Launch is one of six locations included in a study called *What Made Shorelines Resilient: A Forensic Analysis of Shoreline Structures on the Hudson River Following Three Historic Storms*. The sites had either traditional or non-traditional nature-based shoreline stabilization techniques and were impacted by Tropical Storms Irene and Lee in 2011 and Post-Tropical Storm Sandy in 2012. Separate case studies describing each site and the impact of the three storms have been prepared. Two additional reports describe the methodology used and the common project performance factors. All eight documents can be found at [http://www.hrnerr.org/shorelinesforensicanalysis](http://www.hrnerr.org/shorelinesforensicanalysis). Each Forensic Analysis included the review of historic photographs and design drawings, interviews with project managers and designers, field data collection, and modeling of the hydrodynamic conditions during each of the three storms. Collectively, this information was used to create a holistic picture of each site, from which the critical project performance factors could be determined. Impacts from debris, undersized stones, improper slopes, as well as monitoring and maintenance protocols, adaptive management, and maturity of vegetation were all considered. Overall, the boat launch at Coxsackie fared well during the major storm events due to the natural shore slopes created by the terraced design that were inundated during the storms, and the presence of mature vegetation.

SITE BACKGROUND

The waterfront in the Village of Coxsackie, New York, has historically been utilized for a variety of industrial purposes including: a factory site, a ferry terminal, and a municipal solid waste storage area. The Coxsackie waterfront, like many others along the Hudson River Valley, became a convenient location for the disposal of dredge material from numerous local navigation projects. This dredge material currently serves as the foundation for a significant portion of the peninsula on which the Coxsackie Boat Launch is located. New York State Office of Parks restored the park located on the site in 2004.
with added amenities including a new parking lot, playground, gazebo and walkway along the boat launch bulkhead. A historic shipwreck (The Storm King) sits just offshore of the northern tip of the project site helping to stabilize the shoreline immediately landward. However, an erosional hot spot developed between the shipwreck-protected area of coastline and an adjacent stabilized area. Beginning in 2011, local and state officials sought solutions to mitigate erosion, while maintaining human access to the shoreline. The selected design included regrading the shore with clean fill and a shallow slope, creating three terraces of medium-sized stone for native re-vegetation, and the placement of boulders in the shore zone to act as a wave break and limit the impact of ice. The project was constructed in the spring of 2012 and is highlighted as a Demonstration Project in the Hudson River Sustainable Shorelines Project (https://www.hrnerr.org/hudson-river-sustainable-shorelines/).

**SHORELINE STABILIZATION HISTORY**

To create a history of the shoreline evolution at the Coxsackie Boat Launch, we used Google Earth for aerial photographs and www.historicaerials.com for both aerial photographs and topographic maps. A time-lapse video of the changes was created and is archived at https://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/. The eroding section of the Coxsackie coastline exists between an intentionally stabilized section of the shoreline and an unintentionally stabilized section. Immediately to the west of the project site, the shoreline is protected by a rock revetment with stone ranging in size between one to two feet in diameter. Immediately to the east of the project site the shoreline is protected by a partially submerged shipwreck. Aerial photographs of the site (Figure 2) suggest the erosional hot spot has been in existence for some time but only recently reached a critical point where it was threatening the parking lot. The left image is an aerial photograph of the eroded segment of shoreline in 2010 prior to the design and construction of the new park, with the frame of the ship being clearly visible during low tide. The center photograph reveals the extent of the dramatically eroded area that was located to the north of the park. The right image is an aerial photograph from Google Earth, showing the park in September 2013 after surviving all three of the extreme weather events.

![Figure 2 – Close-ups of the Coxsackie site showing from left to right the pre-construction (2010) aerial view, pre-construction (2010) ground view, and post-construction (2013) aerial view.](image)

**DESIGN AND ECOLOGICAL ALTERATIONS**

The original shoreline stabilization plan called for a traditional solution, extending the existing rock revetment and tying it into the bulkhead, creating a uniform line of defense. The Sustainable Shorelines Project Team worked with the owners of the site to encourage the implementation of important ecological principles, such as
shoreline curvature, complexity and reduced slope, to both protect the shoreline and promote the development of a resilient and diverse habitat in the shore zone. Ultimately, the final design called for re-grading the shore zone to a shallow slope with clean fill, creating three terraces using medium sized stones, and the planting of appropriate vegetation (Figure 3). Medium-sized stone was also used to stabilize a nearby outfall to reduce or eliminate erosion due to outflow. Larger boulders were placed in the shore zone to help dissipate waves and act as an ice break. The design called for stones approximately two feet in diameter, but with additional consulting from Stevens Institute of Technology, smaller stones were chosen. The terraces were planted with two species of bulrush, pickerelweed, dogwood and buttonbush. Sycamore trees were planted further upland near the parking lot. Figure 4 shows the engineering design for the property.

Figure 3 – Cross-section presenting engineering design for shore zone (NYS OPRHP and HRSSP).

Figure 4 – Overview of Coxsackie Boat Launch shore design (NYS OPRHP and HRSSP).

The planting of the native species took place in early May during the spring growing season, in order to maximize the potential for stability and growth. By retaining the shallow slope of the shoreline, many of its natural ecological features were retained and easy public access to the river was preserved. The three photographs below (Figure 5) show the development of the shore zone along the once eroding northern shoreline. The left photo-
graph clearly displays the terraces during construction. The center photograph shows the shoreline one month after the plantings had been placed. The right photograph was taken three months after the initial planting, showing substantial growth within a considerably short amount of time.

Figure 5 – Development of the shore zone, from left to right: during construction (Feb. 2012), after planting (June 2012), and three months later (July 2012).

COLLECTION OF ENGINEERING DATA

Multiple sources of data were collected and analyzed to understand the behavior of the shoreline at Coxsackie. The conclusions of the Forensic Analysis at Coxsackie were based on the following sources/types of information:

- Historic Aerial Photographs
- Topographic Maps
- Photographs (construction, pre- and post-storm photographs of the site)
- Initial Site Visit
- Discussions with Developer
- Engineering Plans
- Correspondence with Permit Staff
- Final Site Visit (including topographic/bathymetric survey)
- Hindcast of Storm Conditions (Wave and Water Level Climatology)

CHARACTERIZATION OF SITE CONDITIONS

The Coxsackie boat ramp is located in a special flood hazard area (AE zone) with a base flood elevation (BFE) of 14 feet NAVD 88 as established by FEMA (panel 36039c0281f, effective May 16, 2008). The BFE represents the water elevation expected during the 1% annual chance of occurrence or 100-yr storm event. The BFE is a useful baseline with which to compare both the typical and storm conditions at the site. The Sustainable Shorelines physical forces climatology dataset (http://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/physical-forces-statistics/) was used to characterize the conditions during a typical year. The climatology is based on a one-year numerical simulation of conditions within the Hudson and was generated using an ultra-high resolution version of the NYHOPS numerical model. The climatology was developed based on the conditions in 2010 and included one significant Nor’easter. A maximum water level ($W_{max}$) of 6.06 ft above NAVD88 was simulated during 2010 along with a maximum wind wave

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Climatology</th>
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<tr>
<td>$W_{max}$ (ft NAVD 88)</td>
<td>6.06</td>
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<tr>
<td>$H_{max}$ (ft)</td>
<td>0.91</td>
</tr>
<tr>
<td>$H_{med}$ (ft)</td>
<td>0.09</td>
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<tr>
<td>Ice $t_{med}$ (in)</td>
<td>4.7</td>
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<tr>
<td>Ice $t_{90%}$ (in)</td>
<td>9.1</td>
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<tr>
<td>$H_{wake}$ (in)</td>
<td>3.5-8.5</td>
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height ($H_{\text{max}}$) of 0.91 ft and a median wind wave height ($H_{\text{med}}$) of 0.09 ft. An analysis of the fetches at the site confirms that the site is low energy with respect to wind waves. The relevant fetches are shown in Figure 6, where the average and maximum fetches were found to be 3,640 ft (0.7 mi) and 5,530 ft (1.0 mi), respectively. Ice information collected by the U.S. Coast Guard and compiled as a part of the climatology (http://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/ice-conditions/) indicate that the site is subjected to significant icing. The median ice thickness (Ice $t_{\text{med}}$) observed during the ice season (December-March) was 4.7”, with thicknesses up to 9.1” occurring 10% of the time (Ice $t_{90\%}$). Wake observations recorded over a two-day period during the summer of 2012 and 2013 by summer students contained maximum recorded wakes ($H_{\text{wake}}$) between 3.5” and 8.5”.

Figure 6 – Coxsackie fetch analysis.  
Figure 7 – Bathymetric and topographic data for Coxsackie.

Topographic and bathymetric surveys of the site were conducted to obtain detailed information about upland elevations, nearshore slopes, and offshore depths. The survey data (Figure 7) indicate that the elevation to the east of the project site slopes rapidly between depths of -5 ft (NAVD 88) and -10 ft. Further offshore, the elevation rises again to -5 ft before rapidly sloping off to a depth of -30 ft. The area immediately north and offshore of the project site is very flat, ranging in elevation between 0 ft and -5 ft.

**Hindcast Storm Conditions**

Conditions during the three historic storms were hindcast using the NYHOPS numerical model. The water levels during both Irene and Sandy significantly exceeded the 95th percentile based on the 2010 climatology. When compared to the surrounding land elevations, which are on the order of + 5 ft NAVD 88, the hindcasts indicate...
that the site was submerged during the peak of the storms. The hindcast water level during Sandy matches a nearby high-water mark observation collected by the USGS, which registered 9.2 ft NAVD88 (Figure 8). The wave heights hindcast during both Irene and Sandy significantly exceeded both the 95th percentile and maximum wave heights from the 2010 climatology (Figure 9). While these results indicate the relative significance of these storms, in an absolute sense the wave heights are not indicative of high-energy conditions. This suggests that other factors such as wakes (for which the available data is extremely limited), ice, or debris may be playing a more significant role in the shoreline erosion at the Coxsackie site.

**Figure 8** – Modeled water levels (ft NAVD 88) at Coxsackie during Irene, Lee, and Sandy.

**Figure 9** – Modeled wave heights at Coxsackie during Irene, Lee, and Sandy.

**DOCUMENTED PERFORMANCE**

Monitoring through July 2012 indicated that the gradual slope, terraced rock, and vegetative plantings had at least temporarily stabilized the eroding shoreline (Figure 10). Very few plantings died off in the immediate months following the restoration project and the pickerelweed and bulrush showed significant growth. Less than a year after the completion of construction, the Coxsackie Boat Launch was impacted by Irene and Lee, and then a
year later by Sandy, but the site only suffered minimal damage during the storms. Although not the focus of this analysis, the most recent site visit completed in March of 2014 suggests that significant ice accumulation over the winter may have caused more damage to the project than any of the three storms. From an ecological and recreational perspective, the project has been a success in retaining and enhancing the natural appeal of the Coxsackie shoreline, increasing the diversity of the nearshore habitats, and preserving human access to the shore zone. From an engineering perspective, the project has been largely successful in reducing the amount of erosion along the Coxsackie shoreline, even during intense storms. It should be noted that the project did little to impede floodwaters from inundating upland areas, but as an erosion control approach, the project has been successful.

![Figure 10 - Left to right: vegetation established (2013), ice during winter (2013-14), and additional photograph (2013).](image)

**FINDINGS**

Overall, the Coxsackie site performed well immediately after construction. However, evidence recently collected during the preliminary site visit suggests that a lack of maintenance and heavy icing during the winter of 2014 and 2015 may have damaged the project. During the three historic storms, there are several factors that likely contributed to the minimal damage experienced at the site. The first is the contribution of a fully developed root system to the stability of the vegetation and the overall erosional resistance of the shoreline. The fact that the site was able to withstand larger storms including Irene, Lee, and Sandy once the vegetation was fully established highlights the importance of providing temporary protection for shoreline projects in which the vegetation provides a significant part of the structural integrity of the shoreline. Secondly, the location and orientation of the Coxsackie Boat Launch shoreline likely protects it from severe impacts during coastal storms. As a north-facing coastline located in the upper portion of the Hudson, Coxsackie is not subjected to the same intense wave action during storms as sites located further downriver. For shorelines oriented similarly to Coxsackie, there is a potential secondary storm threat related to enhanced flow and debris associated with extreme runoff during large rain events. It is believed that the flat slopes and terraces utilized at the site helped to limit damage due to floating debris. Previous studies have shown that many living shorelines projects are able to survive major storms because during the storm they are submerged, allowing the waves to pass over the top of the structures without causing significant erosion. Even when not submerged, the flat slope between terraces allows debris to be pushed up the slope rather than scouring the slope. The recent damage observed due to ice highlights an important factor that differentiates ecologically enhanced shoreline design in the northeast from traditional living shorelines design in the Gulf Coast and Mid-Atlantic regions. While many of the factors are similar, there are expected to be important differences, such as ice, that will require a refinement of the established design guidelines for this region.