source: Bing Maps, ForeSite Associates

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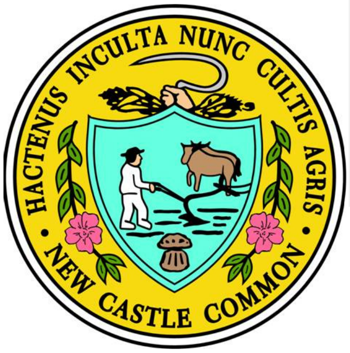
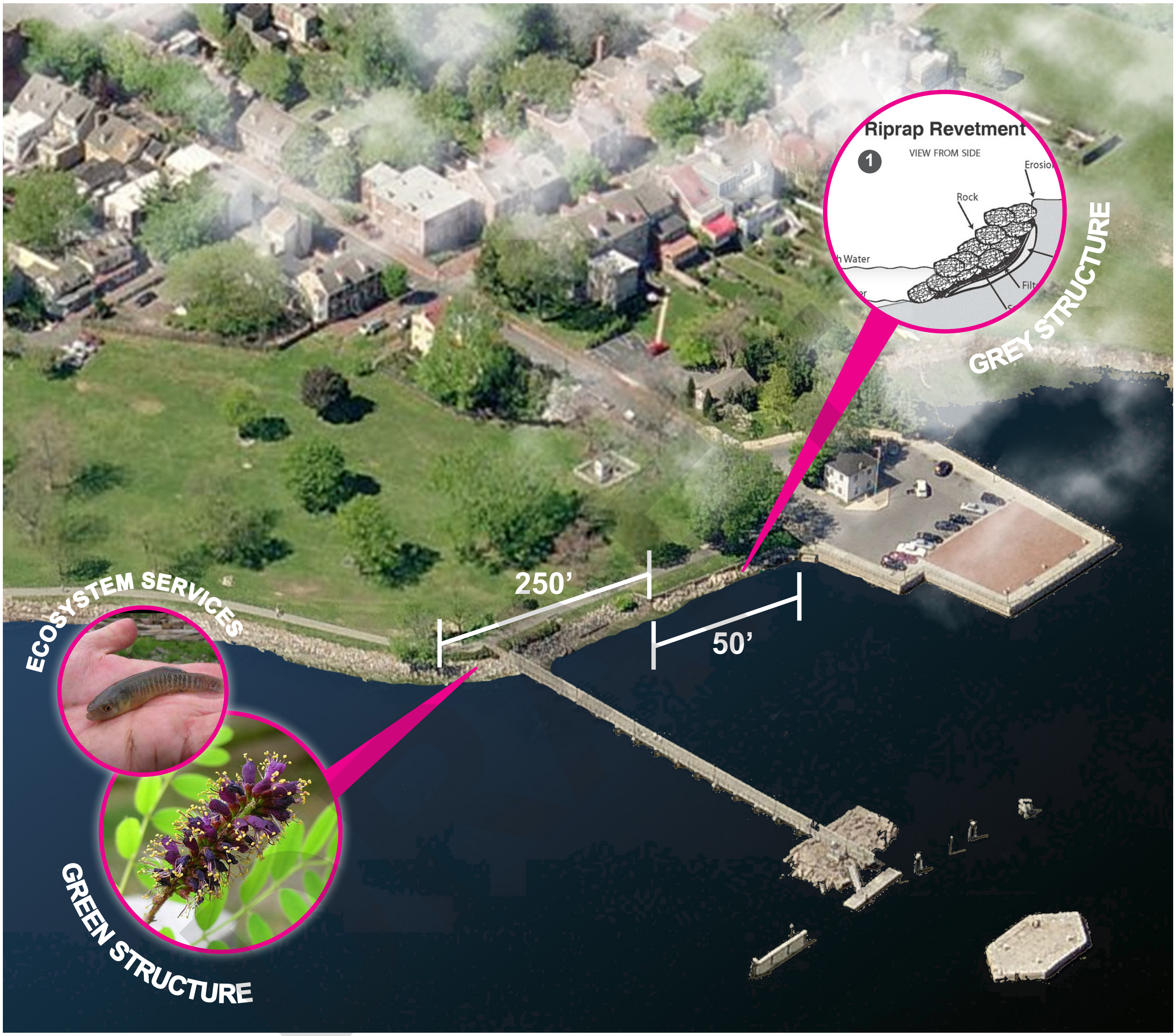


Battery Park Bulkhead Replacement
Conceptual Design & Permitting

ForeSite Associates



source: Bing Maps, ForeSite Associates

Much of the shoreline along Battery Park in Old New Castle DE has been armored or bulkheaded over time. There is one, approximately 50 foot, section of a wooden bulkhead, near the Delaware St. wharf parking lot, that is well beyond its service life and is in need of repair / replacement. The City of New Castle (City) enlisted the assistance of the professional design firm, ForeSite Associates Inc. (FA), to re-think the replacement and incorporate more green technologies. It was determined a living shoreline would be an appropriate treatment for the site. The City was awarded a Delaware Coastal Management Assistance Grant to aide in funding this feasibility study to better determine best practices to integrate a living shoreline in the area of bulkhead replacement, for a length of 50ft, and extend along the shoreline an additional 250ft to increase ecosystem services and shoreline resilience.

When completed this shoreline will be one of the most northern installations of living shorelines in the state of Delaware and the Park an excellent platform to inform the general public of the benefits of these adaptive systems.

Living shorelines are not a “one size fits all” technology. To be successful, the installation needs to respond to the energy of the adjacent water body. For example, Delaware’s inland bays and creeks are protected from the ocean tides tend to be low energy wind and wave systems, where as the shorelines that interact directly with ocean currents moving across the Atlantic, are high energy systems; with river systems varying in-between energy regimes, depending on watershed contribution and channel morphology. Prior to settlement many portions of the upper and lower Delaware River Estuary shorelines that were exposed to high wind and wave energy had vast areas of tidal marsh, natural spaces of thick vegetation that aide in dissipating wave energy as it nears the shoreline. Most of the tidal marsh areas along our coastlines and river bodies have been filled in for various reasons, with most relating to direct / more convenient water access. To restore these tidal marshes to what they were prior to settlement is usually not practical as the space needed, at a scale to sufficiently dissipate the wave energy, no longer exists.

To enhance the seasonally brackish tidal marsh within the proposed work area along Battery Park, the design team implemented a grey to green system of approach. While not a new idea to the design team and most likely not the professional community, the design theory has been very well outlined for a broader audience by SageCoast.org, a consortium of the USACE, NOAA, and FEMA, along with other project partners. The graphic below is an excerpt from their brochures and illustrates the continuum of shoreline strategies from only green technologies, to only grey technologies, and

2 source: http://sagecoast.org/

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a range of intermediate hybrid strategies. It is this design theory of hybrid strategies that forms the foundation of the proposed concept plan, the inclusion of grey technologies to respond to the hydrodynamic energy at the site and the inclusion of green technologies for the system to increase ecosystem services, increase habitat value, and adapt better to storm surges and sea level change.

LITERATURE REVIEW

1

US Army Corps of Engineers (2015). North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk. *Engineer Research and Development Center* ERDC SR-15-1

This document is the main report prepared by the US Army Corps of Engineers in response to the Disaster Relief Appropriations Act, of 2013 (Public Law 113-2). Specifically the document responds to the Act's mandate that "the Secretary shall conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps". One of the nine key findings outlined in the documents preface notes "Communities should adopt combinations of solutions, including nonstructural, structural, natural and nature-based, and programmatic measures to manage risk, where avoidance is not possible." The document expands beyond traditional structural risk reduction measures to include more emphasis on nonstructural, natural, and nature-based features (NNBF). It is this inclusion of NNBF that the design team feels strongly supports the integration of hybrid systems into the conceptual plan for the replacement of the bulkhead.

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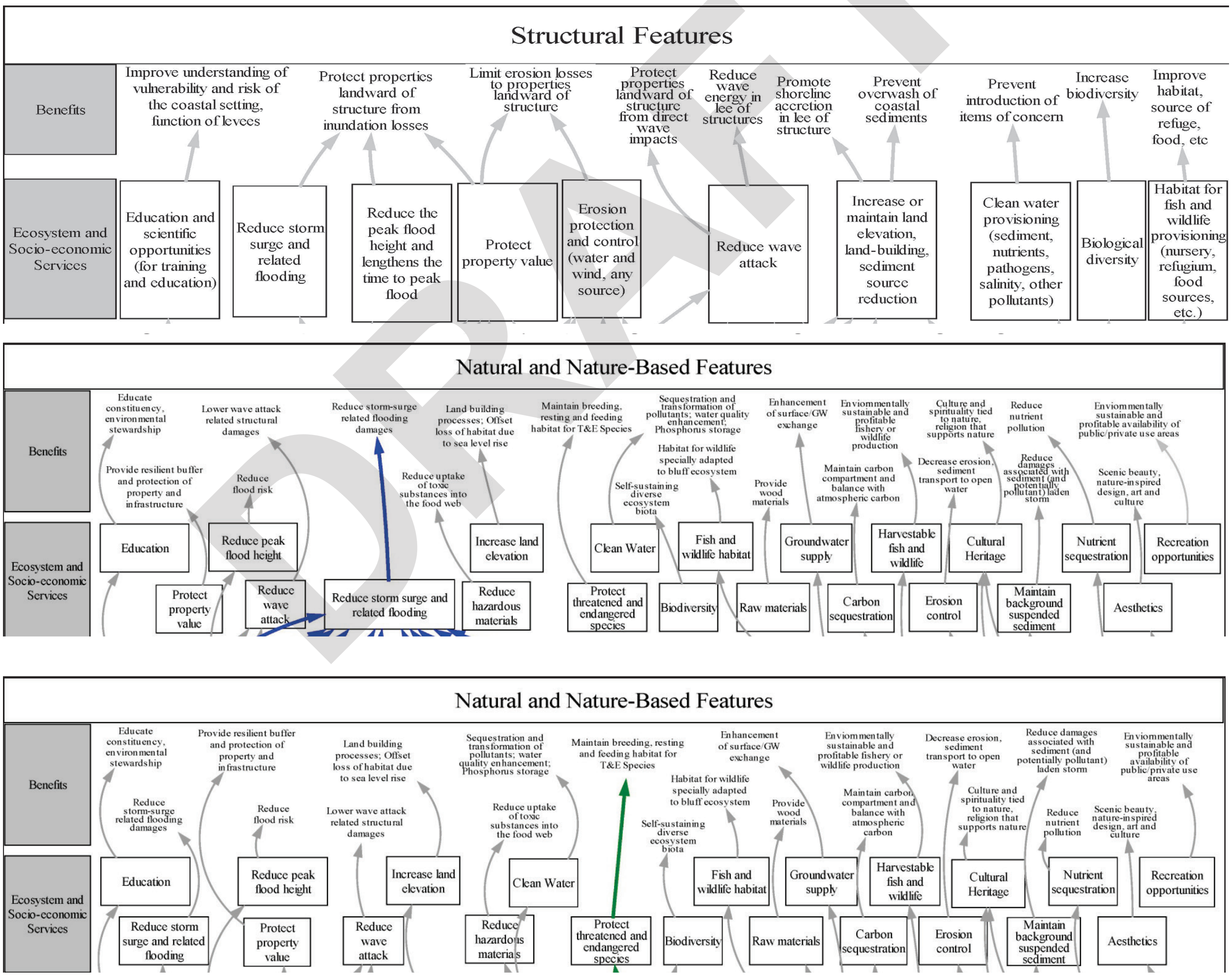
Identify Possible Solutions 	NNBF Report and Brochures	Advances the science on NNBF strategic placement, how these features can be applied, and the benefits they provide. Includes the technical report, Use of Natural and Nature-Based Features for Coastal Resilience (Bridges et al. 2015), as well as user-friendly consolidated brochures.
	Conceptual Regional Sediment Budget	Identifies the sources and sinks for sediment. Also identifies opportunities for the strategic placement of dredged material for NNBF.
	State and District of Columbia Analyses Appendix	Provides State by State chapters that discuss each State and District's post Hurricane Sandy landscape, sea level change considerations, and vulnerability assessment.
	Vulnerability Decision Tree	Provides a question tree that guides local users through the exposure and vulnerability assessment criteria and weightings.

excerpt from cited document

2

Bridges, T. S., Wagner, P. W., Burks-Copes, K. A., Bates, M. E., Collier, Z., Fischenich, C. J., Gailani, J. Z., Leuck, L. D., Piercy, C. D., Rosati, J. D., Russo, E. J., Shafer, D. J., Suedel, B. C., Vuxton, E. A., and Wamsley, T. V. 2014. Use of Natural and Nature-based Features (NNBF) for Coastal Resilience. ERDC TR-X-XX. Vicksburg, MS: U.S. Army Engineer and Research Development Center.

This document is the technical report on Natural and Nature Based Features (NNBF) prepared as a supporting document to the above referenced Comprehensive plan. The document provides an overall through analysis of NNBF, including living shorelines, and their contributions to sea level change adaptation, storm surge, and overall shoreline resiliency. The document synthesized some of the big picture findings into three Casual Maps. Each map identifies key points related to system benefits, ecosystem and socio-economic services, processes and functions, influential structure and components, and feature types. Portions of these maps are included on the next page that illustrate the comparison of the benefits and ecosystem and socio-economic services as they relate to structural features, NNBF, and NNBF as they relate to threatened, endangered and sensitive species (TES). Due to the size reduction to be included in this brief literature review some of the text may not be legible, the entire maps can be viewed in the appendices section. Important to note though in this comparison is even if text is difficult to distinguish the quantity of arrows and boxes clearly illustrate the use of NNBF systems doubles the ecosystem and socio-economic services (indicated by the two rows shown for each chart) when compared to only using structural features. Similar to the Comprehensive plan, the design team feels this document and its comparisons, strongly supports the feasibility of integrating a hybrid systems into the conceptual plan for the replacement of the bulkhead and illustrates the greater degree of functional features offered by NNBFs.



excerpts from cited document; see appendices for full causal maps

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3

Gittman, R. K., Popowich, A. M., Bruno, J. F., & Peterson, C. H. (2014). Marshes with and without sills protect estuarine shorelines from erosion better than bulkheads during a Category 1 hurricane. Ocean & Coastal Management, 102, 94-102.

Excerpt from Abstract:
In this study, the performances of alternative shoreline protection approaches during Hurricane Irene (Category 1 storm) were compared by 1) classifying resultant damage to shorelines with different types of shoreline protection in three NC coastal regions after Irene; and 2) quantifying shoreline erosion at marshes with and without sills in one NC region by using repeated measurements of marsh surface elevation and marsh vegetation stem density before and after Irene. In the central Outer Banks, NC, where the strongest sustained winds blew across the longest fetch; Irene damaged 76% of bulkheads surveyed, while no damage to other shoreline protection options was detected. Across marsh sites within 25 km of its landfall, Hurricane Irene had no effect on marsh surface elevations behind sills or along marsh shorelines without sills. Although Irene temporarily reduced marsh vegetation density at sites with and without sills, vegetation recovered to pre-hurricane levels within a year. Storm responses suggest that marshes with and without sills are more durable and may protect shorelines from erosion better than the bulkheads in a Category 1 storm. This study is the first to provide data on the shoreline protection capabilities of marshes with and without sills relative to bulkheads during a substantial storm event, and to articulate a research framework to assist in the development of comprehensive policies for climate change adaptation and sustainable management of estuarine shorelines and resources in U.S. and globally.

This research article was an exciting find by the design team. We feel it really speaks to the power of an adaptable system and hope research such as this can continue in more northern states. The project site is an excellent location to contribute to the knowledge base of shoreline resilience in studying the historic patterns in the area and future responses after the shoreline has been constructed.

4

Schile, L. M., Callaway, J. C., Morris, J. T., Stralberg, D., Parker, V. T., & Kelly, M. (2014). Modeling tidal marsh distribution with sea-level rise: Evaluating the role of vegetation, sediment, and upland habitat in marsh resiliency. PloS one, 9(2), e88760.

Excerpt from Abstract:
We examined marsh resiliency using the Marsh Equilibrium Model, a mechanistic, elevation-based soil cohort model, using a rich data set of plant productivity and physical properties from sites across the estuarine salinity gradient. Four tidal marshes were chosen along this gradient: two islands and two with adjacent uplands. Varying century sea-level rise (52, 100, 165, 180 cm) and suspended sediment concentrations (100%, 50%, and 25% of current concentrations), we simulated marsh accretion across vegetated elevations for 100 years, applying the results to high spatial resolution digital elevation models to quantify potential changes in marsh distributions. At low rates of sea-level rise and mid-high sediment concentrations, all marshes maintained vegetated elevations indicative of mid/high marsh habitat. With century sea-level rise at 100 and 165 cm, marshes shifted to low marsh elevations; mid/high marsh elevations were found only in former uplands. At the highest century sea-level rise and lowest sediment concentrations, the island marshes became dominated by mudflat elevations. Under the same sediment concentrations, low salinity brackish marshes containing highly productive vegetation had slower elevation loss compared to more saline sites with lower productivity. A similar trend was documented when comparing against a marsh accretion model that did not

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model vegetation feedbacks. Elevation predictions using the Marsh Equilibrium Model highlight the importance of including vegetation responses to sea-level rise. These results also emphasize the importance of adjacent uplands for long-term marsh survival and incorporating such areas in conservation planning efforts.

The use of models in research provides varying information. They are helpful to obtain data that might otherwise not be plausible to collect. However, models often include assumptions or averages to produce the data. Either way the use of models only increases the knowledge base on living shorelines and potentially provides researches a platform to begin more site specific data gathering. The concept plan prepared for this site does include varying areas of vegetation elevation in the hopes that migration can occur should sea level change effect the area.

5

Davis, J. L., Currin, C. A., O'Brien, C., Raffenburg, C., & Davis, A. (2015). Living Shorelines: Coastal Resilience with a Blue Carbon Benefit. PloS one, 10(11), e0142595.

Excerpt from Abstract:
Because they provide the ecosystem services associated with natural coastal wetlands while also increasing shoreline resilience, living shorelines are part of the natural and hybrid infrastructure approach to coastal resiliency. Mashes created as living shorelines are typically narrow(< 30 m) fringing marshes with sandy substrates that are well flushed by tides. These characteristics distinguish living shorelines from the larger meadow marshes in which most of the current knowledge about created marshes was developed. The value of living shorelines for providing both erosion control and habitat for estuarine organisms has been documented but their capacity for carbon sequestration has not. We measured carbon sequestration rates in living shorelines and sandy transplanted Spartina alterniflora marshes in the Newport River Estuary, North Carolina. The marshes sampled here range in age from 12 to 38 years and represent a continuum of soil development. Carbon sequestration rates ranged from 58 to 283 g C m-2 y~1 and decreased with marsh age. The pattern of lower sequestration rates in older marshes is hypothesized to be the result of a relative enrichment of labile organic matter in younger sites and illustrates the importance of choosing mature marshes for determination of long-term carbon sequestration potential. The data presented here are within the range of published carbon sequestration rates for S. alterniflora marshes and suggest that wide-scale use of the living shoreline approach to shoreline management may come with a substantial carbon benefit.

As a very knew area of study the additional benefits of carbon sequestration in tidal marsh systems expands the repertoire of ecosystem services green systems can contribute. The vegetation primarily studied in this report is typical of a more saline marsh environment. This species can be utilized at the project site but the conceptual design suggests increasing this palette to include more forb species as noted in the vegetation surveys. Additional research would be needed to determine if the different vegetation morphology would effect sequestration rates.

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