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Ohio Creek Urban Coastal Storm Risk Management Project: An Application of Engineering With Nature® Principles in Practice

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PURPOSE: The Engineering With Nature® (EWN®) program within the US Army Corps of Engineers (USACE) funds research projects occurring in a myriad of environments, including in marine coasts, freshwater coasts, and fluvial (riverine) systems. Yet there have been fewer projects documented where EWN principles have been applied in urban landscapes, particularly to manage flood risk, a main civil works mission of the USACE. Natural hazards including increased flashiness associated with intense rainfall events have prompted the need for more sustainable infrastructure solutions that reduce flood risks in urban areas, especially when such solutions desired by stakeholders are nature-based solutions. This technical note documents a flood risk management project in Norfolk, Virginia, that incorporates EWN principles in a tidal estuary environment that not only reduces flood risk, but also provides numerous other environmental, social, and economic benefits.

BACKGROUND: The City of Norfolk developed the Coastal Adaptation and Community Transformation Plan to substantially improve conditions at several locations along the Eastern Branch of the Elizabeth River, Virginia (Figure 1). The project includes substantial modifications within the Ohio Creek watershed. Within this watershed are two thriving neighborhoods, the historic Chesterfield Heights neighborhood, and the public housing community Grandy Village, both of which have a cohesive community personality. The total population for the project area is approximately 2,200 with over 400 single family homes and 360 public housing units. Thus, the water management measures deployed in these neighborhoods must be integrated into the existing landscape while maintaining the character of place and the location of existing road networks.

A primary focus of the Ohio Creek Watershed project was to protect residential housing from nuisance flooding and future coastal inundation. During Hurricane Irene (landfall August 2011), coastal storm surge pushed up the Elizabeth River and into the few remaining low-lying areas that were the original Ohio Creek, and from there, the water inundated the neighborhoods. During hurricanes, nor'easters, and even during high tides, water from the Elizabeth River also moved backward up the stormwater drainage system and consequently prevented rainfall from draining out of the neighborhoods. During especially high surges, the water from the river backed up the system far enough to flow out onto streets and sidewalks. Even when the river was experiencing normal tide conditions, the outdated stormwater system was insufficient to convey runoff to the river during many rainfall events. Consequently, neighborhood streets and sidewalks flooded

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frequently during a typical summer thunderstorm and minor tidal flooding events. There are only two roadways from which residents can enter and leave the neighborhoods—one of which was submerged during nuisance flood events. When this roadway was flooded, the residents were cut off from the rest of the city.

Figure 1. Components of the Ohio Creek project that contributed to flood risk reduction, coastal protection, and recreation measures implemented. Image courtesy of the City of Norfolk.

To remedy the ongoing flooding, three water management measures were implemented (Figure 1). First, the shoreline was protected so that high-water levels in the river no longer enter the neighborhoods or the stormwater system. Second, rainfall across the watershed was captured to slow its flow into the stormwater system, thus providing additional storage for rainwater so that it no longer ponds in the streets. Third, a living shoreline feature was designed and constructed to minimize erosion and increase ecological benefits. The constructed project also allows the City of Norfolk to use these water management measures as opportunities to improve the social benefits available to the neighborhoods by increasing neighborhood connectivity, restoring and enhancing ecological habitat, and increasing community resilience to future flooding events.

The design and implementation of the Ohio Creek project by the City of Norfolk is a notable example of applying EWN in practice. EWN is a USACE program that supports more sustainable practices and outcomes by working to intentionally align natural and engineering processes to deliver economic, environmental, and social benefits efficiently and sustainably through collaborative processes (Bridges et al. 2018, 2021; King et al. 2020). In part, the EWN program seeks completed projects that implement holistic approaches to infrastructure design. In this case, the Ohio Creek project is applicable across USACE flood risk management (FRM) and ecosystem restoration missions. When successfully implemented, such projects that apply EWN principles

can demonstrate how science and engineering can maximize natural processes that achieve engineering, economic, social, and environmental benefits while meeting the underlying FRM objectives (Bridges et al. 2014, 2022). When implemented using a collaborative and science-based process, EWN can effectively organize and focus interests, stakeholders, and partners, and yield more broadly acceptable projects (EWN, n.d.).

The following sections present information about how a local community benefited from the design and implementation of multiple measures to reduce flood risk as accomplished through science-based collaboration set in an urban environment. This was accomplished by incorporating EWN concepts in a FRM project along a major tributary of the Elizabeth River in the Chesapeake Bay watershed.

OHIO CREEK CASE STUDY: The City of Norfolk, working with local and regional stakeholder groups, identified the values that they prioritized for the Ohio Creek project. These included replicability (the ability to apply these solutions in other parts of the city), social connectivity (including kinship, social cohesion, harmony, and pride), economic vitality (growth, destination, property value, and physical connectivity), and ecological vitality (amenities, ecology, and education).

The overall objectives of the Ohio Creek coastal storm risk management project were three-fold: coastal protection, stormwater management, and community resilience. Elements of coastal protection included an earthen berm, a flood wall, realigning Kimball Terrace, raising roads, and installing a tidal gate and living shoreline. Stormwater management components of the project included installing two pump stations, multiple parcel-level barrels and gardens, street-level bioswales, tree plantings, pipe upgrades, and pervious street pavers. Resilience elements benefiting the local community included basketball courts, walking paths, and a fishing pier (see Figure 1).

Construction of the Ohio Creek project began in mid-January 2020. After 3.5 years of construction with a budget of over $100M, the project was completed and celebrated with a ribbon cutting ceremony in June 2023. How those project objectives were implemented consistent with EWN principles is presented below.

Producing Efficiencies. The challenge that was met during the Ohio Creek project was to deliver the flood risk reduction measures in a dynamic coastal environment while successfully incorporating the social and cultural values articulated by multiple stakeholders. The commitment to use EWN principles for the project's design required the understanding, coordination, and knowledge of multiple engineering and scientific fields, landscape architects, and community members, as well as contractors to achieve project efficiencies. The integration and collaboration across disciplines resulted in a design that increased infrastructure and community resilience while decreasing project costs. As such, several features were included in the final design that produced project efficiencies while strengthening the community's resilience. Infrastructure features such as an earthen berm was designed to serve as a multipurpose structure along much of its length. One section of the berm was topped with a multipurpose trail, which allowed access to the fishing pier and living shoreline beyond (Figure 2). In another section, the berm was seeded with native wildflowers to enhance the habitat value of the structure (Figure 3). In addition, a former

channelized creek was daylighted, so it now functions as an urban stormwater conveyance system with the features of a natural Atlantic coastal stream habitat, greatly improving ecosystem benefits. Daylighting reopens creeks previously covered by pavement or diverted into pipes. The previous hard infrastructure was not able to accommodate floodwaters, and thus contributed to flooding of the neighborhood.

Figure 2. Aerial view of a section of the completed Ohio Creek flood risk management project. Notable project features shown include the fishing pier (*middle left*), restored wetland (immediately to the *right* of the pier), pump station (*lower right*), and living shoreline (*middle center* and *right*) along the right descending bank of the Elizabeth River. Image courtesy of the City of Norfolk.

Figure 3. Neighborhood bioswales were installed and planted with native species as a localized flood risk reduction measure while also providing groundwater infiltration and habitat uplift benefits (*left*). The earthen berm constructed to reduce flood risk was planted with native wildflower species to enhance the habitat value associated with the structure (*right*). Images courtesy of the City of Norfolk.

Using Natural Resources. The as-constructed Ohio Creek project includes native plant species that were used as part of the flood risk reduction measures. Plant species were chosen that fit within the coastal Virginia habitat type that is expected to thrive under prevailing conditions. Low-growing native grasses and other vegetation were planted in the bioswales constructed at street level as well as on the 1 mile-long (1.6 km)* earthen berm constructed along the river (Figures 3 and 4). The daylighting of the local creek restores this habitat and flood conveyance feature to serve as habitat for local species (Figure 5). Wetlands (greater than 3 acres; 1.2 ha) were created as part of the living shoreline (1,500 ft; 457 m), as the most landward feature of this measure as well as other locations within the community.

Plant species selection was based on several criteria, including species that are native and adapted to the region, can provide wildlife habitat and food production, can uptake stormwater pollutants, and have historic and cultural significance. Other selection criteria that were more measure-specific included size (small herbaceous species), aesthetic appearance (seasonal color, foliage, and flowers), wildlife value (enhance biodiversity and provide shade), and engineering considerations (reduce runoff and encourage groundwater infiltration). Overall, the use of natural resources, especially the daylighting of the local creek, enhance the overall engineering and environmental benefits of the project.

Figure 4. Aerial photo of the coastal measures used to reduce flood risk and shoreline erosion, including an earthen berm (armored riverside), living shoreline, and oyster beds. Image courtesy of the City of Norfolk.

* For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Figure 5. Aerial view of the completed community infrastructure at Resilience Park. The park includes features such as a shared-use path, basketball courts, athletic field with underdrains, playground, and plaza. A local creek was daylighted as both a flood reduction and an enhanced habitat feature. Image courtesy of the City of Norfolk.

Broadening Benefits. Multiple benefits are being realized as the result of the project's implementation. Further, sustainability was an undercurrent during project planning and construction, so the completed project offers both present and future value consistent with stakeholder objectives. The following provides details of how the project provided engineering, social, environmental, and socioeconomic benefits.

Engineering Benefits. Native plants were used in the design to function as soil engineers reducing erosion, reducing the project's carbon footprint, and providing an improved substrate for native plant growth. The bottom substrate of the daylighted creek and pervious pavers placed on one street were designed to provide biofiltration of stormwater and encourage increased infiltration of stormwater enabling groundwater recharge (Figures 5 and 6). Daylighting the creek serves as an additional flood conveyance feature (Figure 5).

Figure 6. Aerial view of the pervious pavers (red colored) being placed on Marlboro Avenue in the Chesterfield Heights neighborhood. Image courtesy of the City of Norfolk.

The living shoreline and earthen berm were constructed to reduce coastal inundation from the Elizabeth River (see Figure 4). A roadway was elevated in place to reduce the likelihood that this evacuation route would be inundated during future flooding events so that residents could use this route to evacuate the area if flooded (see Figure 1). Two pump stations were constructed along with an upgrade to the stormwater network to improve storage capacity and conveyance by converting the old gravity-controlled system into a hydraulic pump managed stormwater system. The largest pump station was designed to fit in with the historic architectural characteristics of the neighborhood (Figure 7).

Figure 7. Aerial view of the Ballentine Pump Station designed to fit with the historic character of the neighborhood. The pump station includes features such as publicly accessible power outlets, parking, and sheltered space from the elements. The pump station is designed to handle increased amounts of rainfall today and into the future. Image courtesy of the City of Norfolk.

Social Benefits. Providing social benefits was a key aspect of the project, consistent with the values identified by community stakeholders. Many of the social benefits were included in the design and construction of Resilience Park (see Figure 5). Recreational features included a shared-use path (for walking, biking, and as a fitness trail), basketball courts, an athletic field with underdrains, playgrounds, and a plaza. A fishing pier was also constructed that extends into the Elizabeth River that is available for community use (see Figures 1 and 2). The walking path to the new fishing pier is located on top of the earthen berm, which serves as a multipurpose structure (see Figure 4).

Environmental Benefits. There were numerous features that were integrated into the design of the project that produced environmental benefits. For example, 2,000 trees were planted to increase habitat value and biodiversity, produce needed shade for people, and help reduce flooding. A living shoreline was constructed along the river that includes an oyster reef and wetland habitat features (see Figure 4). The oyster reef also serves to reduce wind and wave energy originating from the river. The earthen berm was seeded with native wildflowers to enhance the habitat value of the structure (see Figure 3). Additionally, planted trees and other plant species will greatly increase wildlife value of the project, and as plants mature, wildlife value is expected to increase. Carbon sequestration and nutrient cycling are both expected to increase as native plants are expected to grow exponentially as these project features mature. And the enhanced wildlife value is expected to attract insect pollinators, birds, and small mammals.

Socioeconomic Benefits. The project features are designed to minimize both short- and long-term maintenance of the completed project. The raised roadway reduces losses associated with future

flooding events and provides emergency services access during storm events. Oyster reefs integrated into the design of the living shoreline could serve as a future economic benefit supporting local oyster fishermen. Reducing flood risks is improving community cohesion and increasing housing/real estate values, which is also enabled by the inclusion of recreational amenities (see Figures 2 and 5) built as part of the project's design.

Promoting Collaboration. The project team meaningfully engaged community stakeholders early and often during the planning, design, and implementation phases of the project (Figure 8). Over 40 community meetings were held during this time. Community stakeholders were engaged in several ways, including via design charettes, feedback sessions, outdoor demonstrations, civic league meetings, door hangers, and quarterly newsletters. Both the quantity and quality of engagements contributed to the success in attracting community members to attend these events. Participants included Chesterfield Heights and Grandy Village residents; Norfolk Public Schools staff; Chesterfield Academy (a local elementary school) staff, parents, and students; Norfolk Redevelopment Housing Authority representatives; staff from Norfolk City departments; Old Dominion, Norfolk State, and Hampton University faculty and staff; and members of local stakeholder organizations the Elizabeth River Project, Elizabeth River Trail, and Wetlands Watch.

Figure 8. One of the many community meetings held during the planning and design phases of the project. Stakeholders were meaningfully engaged early and often and contributed to the project's success, which is consistent with community values. Image courtesy of the City of Norfolk.

Engagement with the community continues postconstruction, with activities including meetings with the Chesterfield Heights Civic League and Grandy Village Management Council through community retain-your-rain workshops and volunteer events, scheduling MyNorfolk service

request training events, meetings with Chesterfield Academy administrators, and one-on-one resident interactions. These ongoing community engagements allow for modifications to the completed design (replacing dead plants, removing nuisance trees, etc.), helping to improve the short- and long-term success of the project.

SUMMARY: The City of Norfolk worked diligently with community stakeholders to identify the values that they wanted exemplified in the completed Ohio Creek project, including replicability, social connectivity, and economic and ecological vitality. These values were integrated into the three primary objectives of the Ohio Creek coastal storm risk management project: coastal protection, stormwater management, and community resilience. Multiple structural and nonstructural elements were included in the project's design, including an earthen berm, a flood wall, raised roads, a tidal gate, and a living shoreline. Other sustainable management features embedded into the project were multiple street-level bioswales, tree plantings, stormwater pipe upgrades, and pervious street pavers. Recreational benefits included basketball courts, walking paths, and a fishing pier.

The result of the implemented project is the realization of multiple environmental, economic, and social benefits consistent with EWN principles. Sustainability was an undercurrent of the project's design, which focused on creating both current and future value consistent with stakeholder objectives. The design and implementation of the Ohio Creek project by the City of Norfolk is a notable example of applying EWN in practice, and addresses FRM and ecosystem restoration, consistent with USACE civil works missions. As implemented, the Ohio Creek project demonstrates how science and engineering can maximize natural processes that achieve engineering, economic, social, and environmental benefits while meeting the underlying flood risk management objectives, yielding a broadly acceptable project.

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