Engineering With Nature®

Proving Grounds Innovation Handbook



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Proving Grounds Innovation Handbook

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Dredge Research Collaborative

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See the varying species of grasses and plants found in project locations, ranging from beaches to grasslands. *From left to right:* beach grass (*Ammophila*), narrowleaf silkgrass (*Pityopsis graminifolia*), dune slack rush (*Juncus krausii*), sea oats (*Uniola paniculata*), butterfly bush (*Petalostylis labicheoides*), and saw palmetto (*Serenoa repens*). (Image courtesy of the EWN-LA Design Research Initiative)



See the varying species of vegetation found in project locations, ranging from beach ridges to marshlands. *From left to right:* grassleaf rush (*Juncus marginatus*), slash pine (*Pinus elliottii*), saw palmetto (*Serenoa repens*), southern watergrass (*Luziola fluitans*), spikerush (*Eleocharis geniculata*), plant pappus, southern watergrass close up, and saltmeadow cordgrass (*Sporobolus pumilus*). (Image courtesy of the EWN-LA Design Research Initiative)

Foreword

From Innovation to Common Practice

In 2023, I was honored to take the helm of the Engineering With Nature® (EWN®) program at the U.S. Army Corps of Engineers (USACE). This initiative started as a small movement to incorporate nature-based solutions into mission-critical projects and has grown into a large-scale collaboration with enterprise-wide influence. I am honored to have the EWN program support projects in Alaska, Hawaii, and on all four coasts of the continental United States and on many of the waterways in between, as noted in the *Engineering With Nature: An Atlas* series.

As human growth and development continue to influence societal dialogues, natural and nature-based solutions will continue to grow in importance and necessity. The EWN initiative strives to expand on the processes and relationships used in the past and push the limits of what will be feasible in the future to encourage creative and innovative solutions to the complex problems of today. The goal is to make incorporating EWN common practice during project development to ensure natural influences are considered throughout the lifespan of a project.

I am pleased to introduce this compendium of innovative EWN project ideas and concepts—drawn from each of the four coasts of the continental United States—that present exciting possibilities for the future. The strategies and concepts discussed in this handbook are intended to influence conversations about how EWN can be integrated into all phases of projects to support USACE missions, all in close collaboration with our partners. These concepts range from regional sediment management strategies for the beneficial use of dredged material to enhancements for flood protection and coastal resilience. This document is designed to encourage open dialogue and discussion about EWN as a valuable addition to the tools already available. As you explore each section, I urge you to consider what it will take to implement EWN until it becomes part of human nature across the enterprise.

Dr. Jeffrey K. King, PE
National Lead and Program Manager, Engineering With Nature®
U.S. Army Engineer Research and Development Center



Learn more about the beach ridge topography displayed and solutions to combat erosion in Mobile District (project details on page 74). (Photo courtesy of the EWN-LA Design Research Initiative)

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Discover more about the Gallinas Creek watershed (shown here) and other Marin County creeks within the San Francisco District (project details on page 30). (Photo courtesy of the Engineering With Nature® Landscape Architecture [EWN-LA] Design Research Initiative

Introduction



A coastal roadside in Humboldt Bay where an assortment of beneficial use methods was used to address the loss of beach and habitat areas (project details on page 22). (Photo courtesy of the EWN-LA Design Research Initiative)

Background

Throughout time, people have settled along coasts, rivers, and lakes. Water is basic for survival and critical for navigation, economic development, healthy ecosystems, and energy and food production. Maritime trade, fishing, tourism, recreation, and other industries continue to draw people to coastal areas. As a result, dynamic coastal environments have been developed and “hardened” with structures and infrastructure, leading to less resilient environments and communities.

In addition to reducing environmental resiliency, human activities are accelerating global natural hazards. Faced with the impacts of these natural hazards—including rising tides and more frequent and stronger storms and floods—communities are urgently looking for ways to adapt to and mitigate these major, long-term challenges.

So-called “hard” or “gray” structures—dams, levees, and breakwaters, for example—traditionally used to mitigate flooding, wave damage, and erosion, can also alter floodplains and interrupt natural sediment transport, leading to accelerated erosion in other parts of a system. This, in turn, results in an increased need for additional hardened structures in nearby communities, further exacerbating the problems of the entire system.

Natural and nature-based features (NNBF) can help increase the resilience of communities vulnerable to inundation and erosion due to storms and increased flooding hazards. Besides mitigating erosion and inundation risks, NNBF can increase habitat functions by promoting biodiversity while offering multiple benefits to the surrounding communities. Integrating these driving components for maximum societal impact will determine the long-term success of these solutions to life-changing challenges.

Framework of Knowledge

Since its founding in 1775, the U.S. Army Corps of Engineers (USACE) has provided leadership integral to the nation's development and has maintained to this day a vision to "engineer solutions for our Nation's toughest challenges."[1] The USACE Engineer Research Development Center facilitates the Engineering With Nature® (EWN®) program, an initiative to promote the sustainable delivery of infrastructure benefits through NNBF.

EWN integrates natural design concepts and processes with traditional engineering practices to "efficiently and effectively deliver economic, ecological, and social benefits through collaboration."[2] The goal is to maximize benefits to society while providing flood risk management (FRM) to reduce future damages to people and property caused by flooding and erosion in coastal and fluvial systems.

The NNBF used may enhance current natural landscapes or be engineered to mimic natural conditions. The *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*[3] (the NNBF Guidelines) and the companion overview document provide a foundation of knowledge to support the development and integration of these techniques. The guidelines outline the fundamental NNBF principles for successful projects and provide key messages associated with a variety of natural infrastructure. The foundational components in these guidelines can be used to advance the development and implementation of projects to further demonstrate and monitor the success of NNBF solutions. Further, the *Incorporation of Nature-Based Solutions in Civil Works Projects* memo,[4] dated 22 April 2024, builds upon the NNBF Guidelines and expands on the use and implementation of natural infrastructure. This handbook conceptualizes this natural infrastructure approach in accordance with these guidelines and initiatives.



Explore further the above referenced NNBF Guidelines and memo on *Incorporation of Nature-Based Solutions in Civil Works Projects*.

Key EWN Principles

The following four foundational principles[5] are critical to the overall success of an NNBF project:



Use science and engineering to produce operational efficiencies and support sustainable delivery of project benefits.



Use natural processes to maximum benefit, thereby reducing demands on limited resources, minimizing the environmental footprint of projects, and enhancing the quality of project benefits.



Broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits.



Use science-based collaboration to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

Strategy and Concept Development

The EWN program coordinated with relevant USACE districts and divisions to establish EWN Proving Grounds on all four coasts of the continental United States to implement, document, and share knowledge for the broader integration of NNBF principles and practices. The lessons learned in these Proving Grounds will inform decisions spanning all missions of USACE. The maximum societal benefit of these projects will be achieved with funding, alignment, and coordination among all federal, state, and local stakeholders.

At chosen Proving Grounds, a team of engineers, scientists, and landscape architects collaborated with selected points of contact within the USACE districts to identify projects that address local and regional challenges. The collective team then approached these challenges with technical and process-oriented solutions to synthesize natural and cultural values and phenomena for a system-wide focus on innovative and resilient natural infrastructure.

This collaboration yielded a suite of innovative strategies and projects that range in scale, complexity, implementation phase, and project type. In some cases, NNBF were proposed to enhance existing projects and authorizations. In other cases, NNBF were proposed for entirely new projects with the aim of pushing some historically ingrained processes toward creative and innovative solutions.

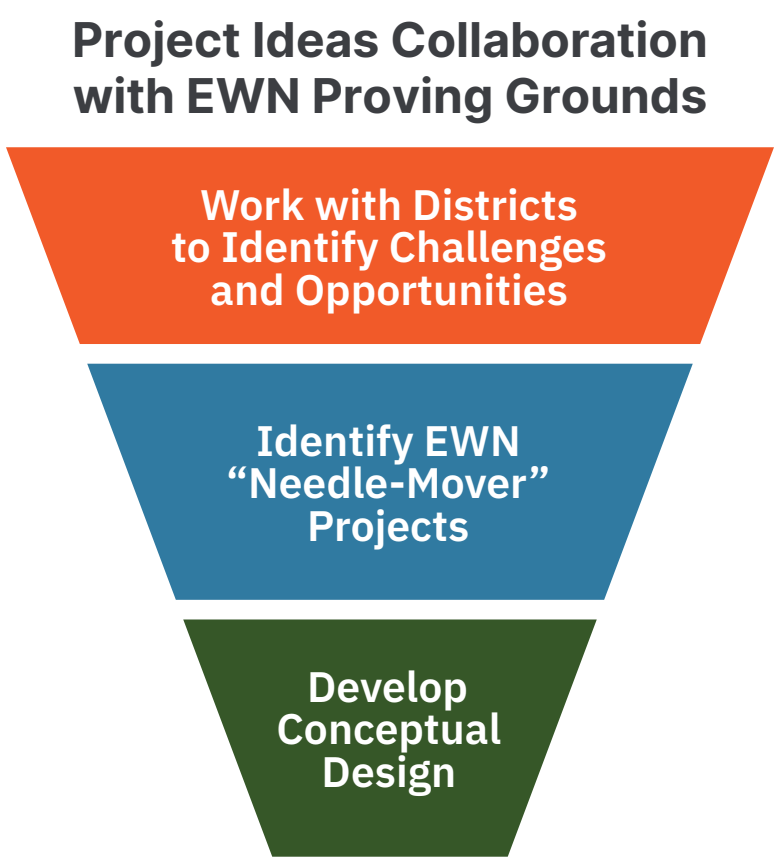


Image courtesy of Anchor QEA



Image courtesy of Anchor QEA

Each NNBF solution was pulled from the key principles and messages in the NNBF Guidelines to align with the USACE mission. This alignment is highlighted in the chapters and project features throughout this document. Icons similar to those in the NNBF Guidelines enable readers to further explore the fundamental components of these EWN concepts.

As readers examine these features and strategies along the four coasts, they are encouraged to remain receptive to the innovative solutions, to question the areas where process improvements are needed to implement these concepts for the maximum system-wide impact, and to consider ways to advocate for and advance these resilient natural infrastructures.

Introduction of Concept Elements

The introduction to each Proving Ground concept chapter lists the common core elements, highlighting relevant features. These key EWN elements are described below.



Coastal and Flood Resiliency

Includes components that attenuate or redisperse wave energy, velocity, and magnitude while increasing the resiliency of the area to future events

Habitat Creation or Restoration

Involves the creation, restoration, or enhancement of an existing or new habitat in which conditions are conducive to supporting a diverse ecosystem



Beneficial Use of Dredged Material

Is the use or alternative placement of dredged material for beneficial purposes outside permanent offshore or confined placement



Social Connectivity

Remediates previous management strategies, or lack thereof, to further protect, serve, and connect the community



Community Engagement

Includes components that encourage public interest and promote educational opportunities



Educational Opportunity

Provides sound solutions to common challenges and knowledge gaps in the field through monitoring and observation efforts



Do these icons look familiar? They link to the NNBF Guidelines. While similar, we have expanded on these icons to present common themes that incorporate the EWN concepts discussed in this document.

Organization of Chapters

Within each chapter, projects are further divided into five sections to provide the reader with a more comprehensive view on core considerations involved in the context of each project. These sections highlight the conceptual connections and collaborative communication across project teams engaging in EWN initiatives.

EWN Strategy and Concept Opportunity

Introduces the proposed strategy or feature within the context of the project area. Addresses other initiatives currently taking place and how the EWN approach would aid in collaboration.

Leveraging Opportunities

Describes conditions and challenges experienced at the project area. Includes, but is not limited to, geographic, morphological, cultural, ecological, and demographic characteristics.

Applying Natural Infrastructure

Highlights what needs to be improved and the strategy for how that improvement will take place. Offers natural infrastructure solutions that are driven with social, ecological, and environmental benefits in mind.

Recognizing Benefits

Discusses anticipated benefits from the application of NNBF. Includes anticipated effects driven by models, theory, and observations from previously implemented projects of a similar nature.

Advancing Implementation

Outlines and explains the need and necessity of next steps. Includes key design components and considerations, sponsor and stakeholder coordination, and further critical collaboration and technical efforts that need to take place.



The Elk River spit at Humboldt Bay presents the opportunity to use various beneficial use approaches (project details on page 22). (Photo courtesy of the EWN-LA Design Research Initiative)

San Francisco District

Floodplain Expansion
Pajaro River at Watsonville, California

Sediment Choreography
Humboldt Bay, California

Strategic Sediment Mobilization
Marin County Creeks, California

Strategic Sediment Placement
Eden Landing, California

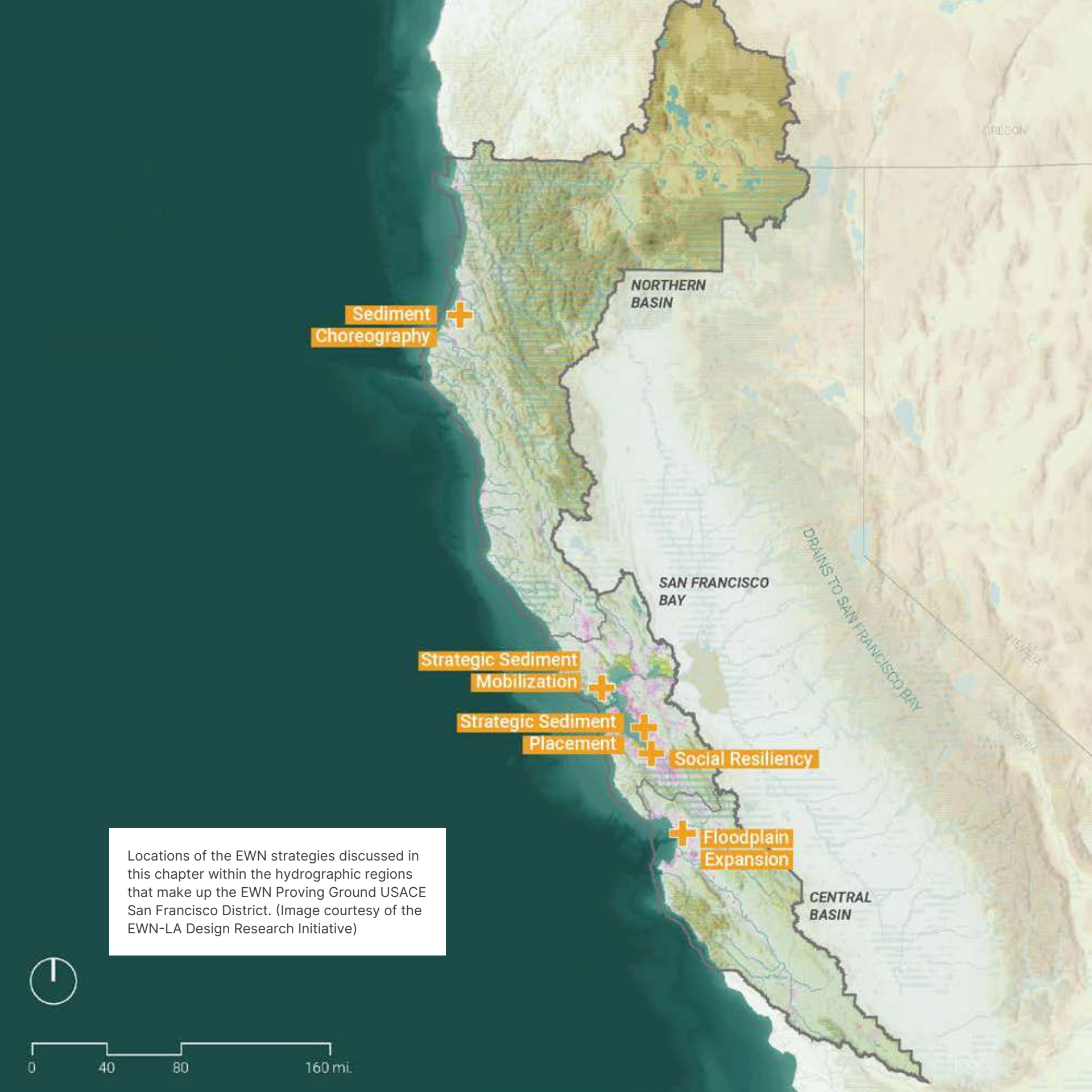
Social Resiliency
South Bay Shorelines, California

The varying terrain and ecosystems of the USACE San Francisco District present opportunities to explore floodplain expansion and the enchantment of fluvial systems; the beneficial use of dredged material, including innovative strategies for the movement, management, and placement of sediment; and the integration of social resiliency strategies with existing and proposed infrastructure.

The USACE San Francisco District was established in 1866 and runs more than 900 miles along California's Pacific coast. The district originally extended across the entire United States Pacific coast from west of the Rocky Mountains to the Hawaiian Islands. Because of that broad reach, the district had a hand in the development of almost every major port and harbor at strategic points in the region and, consequently, was integral to societal development around these locations.

Today, the USACE San Francisco District covers an area along the California coast from near Big Sur to just south of the border between California and Oregon. In this region are three distinct hydrographic areas: the Northern Coastal Basins, the San Francisco Bay Area, and the Central Coastal Basins. The Northern Coastal Basins region consists of mountains and hills extending to the ocean and contains multiple fluvial systems. The San Francisco Bay Area encompasses 6,100 square miles and includes four subembayments—Suisun, San Pablo, Central San Francisco Bay, and South San Francisco Bay—and many of the largest ports in the country. The Central Coastal Basin consists of mountainous and rugged terrain that extends to the edge of the ocean and encompasses approximately 11,450 square miles. The USACE San Francisco District maintains almost half of the waterborne commerce of the entire state of California, supports a $68 billion maritime industry, and serves more than 6.7 million people.

Because of this region's lengthy, well-populated coastline, a comprehensive regional and long-term approach is necessary to adapt to and mitigate impacts of natural hazards there. Fortunately, the USACE San Francisco District has an extensive history of commitment to incorporating natural infrastructure and is well positioned as an EWN Proving Ground to explore innovative solutions and approaches.



Locations of the EWN strategies discussed in this chapter within the hydrographic regions that make up the EWN Proving Ground USACE San Francisco District. (Image courtesy of the EWN-LA Design Research Initiative)

Floodplain Expansion

Pajaro River at Watsonville Flood Risk Management

CONCEPT HIGHLIGHTS

Exploring strategies, such as levee setbacks and floodplain lowering

Increasing floodplain connectivity, groundwater recharge, and habitat creation

Increasing access to walking trails for Watsonville and the Town of Pajaro

KEY EWN ELEMENTS



Coastal and Flood Resiliency

Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



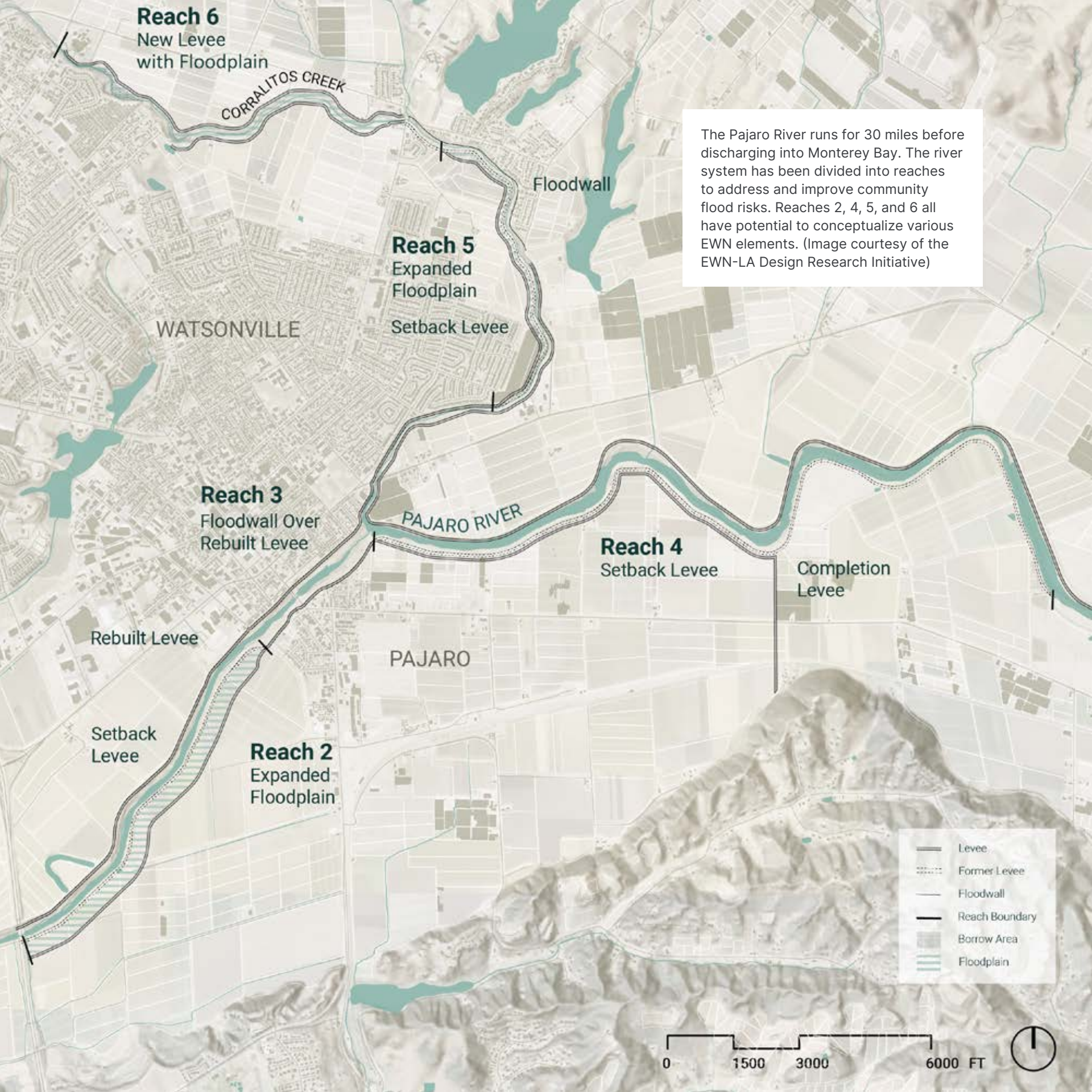
Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



The Pajaro River runs for 30 miles before discharging into Monterey Bay. The river system has been divided into reaches to address and improve community flood risks. Reaches 2, 4, 5, and 6 all have potential to conceptualize various EWN elements. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

The 30-mile-long Pajaro River in the Central Coast region of California forms the border between Santa Cruz and Monterey counties and has the most extensive levee system in the entire USACE San Francisco District. The river discharges into Monterey Bay, just west of unincorporated Pajaro and the farming city of Watsonville, whose economically vulnerable population has long been affected by floods, weakening the community's ability to respond and recover from natural hazard events.[6] Watsonville and the surrounding areas have experienced multiple large-scale floods, with major events in 1955, 1958, 1995, and 1998. As recently as winter 2023, sections of the riverbanks were breached and overtopped by intense storms.

South of Watsonville, the river runs through an incised channel that is disconnected from the surrounding floodplain and poses a continued risk to the community upstream. USACE intends to increase protection of the community by improving the levee systems and building new setback levees in places that have no current flood protection (i.e., Reach 6). The river has been divided into reaches that are currently in various stages of planning, design, and implementation. The levee setbacks provide an opportunity to explore strategies, such as complementary NNBF, to facilitate channel migration, improve FRM, and increase connectivity between the lower river and floodplain. Encouraging the river to activate its floodplain and increase inundation duration and timing in this expanded floodplain during major storms will increase ecological value, encourage groundwater recharge, and facilitate river channel migration. Excavation of borrow material from within the expanded floodplain minimizes costs, keeps sediment and soil in the area, and provides more opportunities to support native habitat and vegetation.

Leveraging Opportunities

The degradation of the riverbanks over time plus the increased frequency and intensity of storms means they no longer fully mitigate the flood risk posed by the river and, consequently, need new water control strategies where they did not previously exist or repair or replacement of the existing levees. Even common storms can pose flood risk for the community, but there are opportunities to improve the floodplain using NNBF. Although the floodplain area is limited in complexity, when the levees are set back and the floodplain is expanded, a natural infrastructure approach with low maintenance costs is conceptualized for the redesigned floodplain to keep long-term costs manageable and to promote natural processes while increasing the river's storage capacity.

Applying Natural Infrastructure

Although built structures like dikes and levees are designed to contain the more intense flows from larger storms, NNBF can help manage more common flows and the maintenance of the channel system as the natural river patterns establish. This approach may prove to be more self-sustaining over the long term while providing year-round benefits. Storms of varying intensity will change the landscape of the floodplain, and the system should be permitted to change as needed within the confines of the levees. Designs for FRM features need to consider the variability and dynamic conditions of the floodplain. Initial and periodic intentional establishment of deep pools and connected river channels has the potential to increase the floodplain storage for large storms and to improve the long-term groundwater recharge of the site.

Recognizing Benefits

The conceptualized EWN features, levee setbacks, and changes in river geometry will increase flow conveyance to mitigate the higher water-surface elevations associated with intense storms while maintaining a more natural system. Reconstructing the levees will provide the FRM required for the region, while sourcing material from borrow areas within the system will minimize cost, provide additional features within the channel geometry and floodplain, and keep sediment and soil within the area to support native flora and fauna. Setting back the levees to connect the river to its floodplains and implementing NNBF will stabilize the riverine system for lesser storms and increase the riparian habitat along the channel. A strategy that combines built systems and natural infrastructure will transform the region by detaining water and increasing geomorphic function; groundwater can be recharged, and the lost heterogeneity of the riparian zone can be reestablished. And continued maintenance of the floodplain may be less necessary as more intense storms flush the system and allow the cyclic reestablishment of the dynamic riverine system.

Next page image series. The project team conceptualized EWN features complementary to FRM and levee improvement projects. (Images courtesy of the EWN-LA Design Research Initiative)

CURRENT

Current built levee conditions



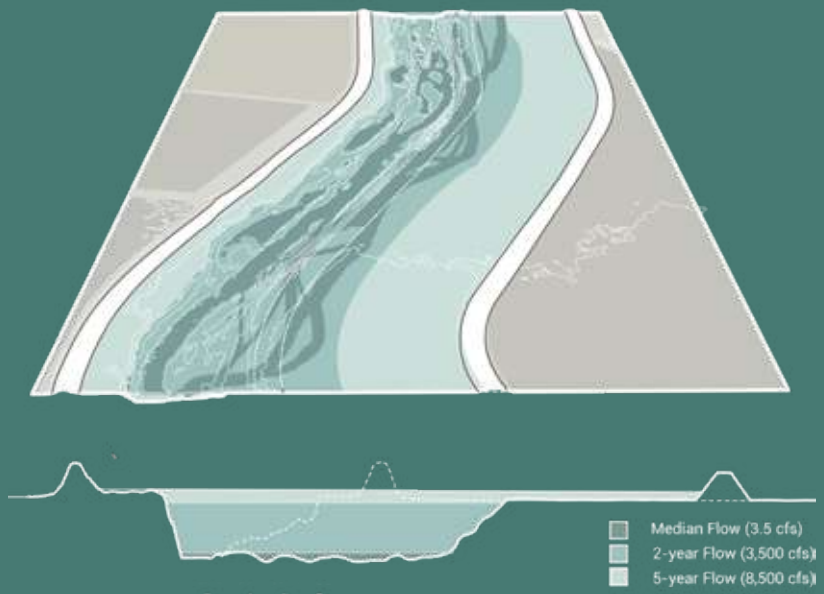
LEVEE SETBACK

Conditions after removal of the current levee and construction of 400-foot levee setback



ANASTOMOSING RIVER

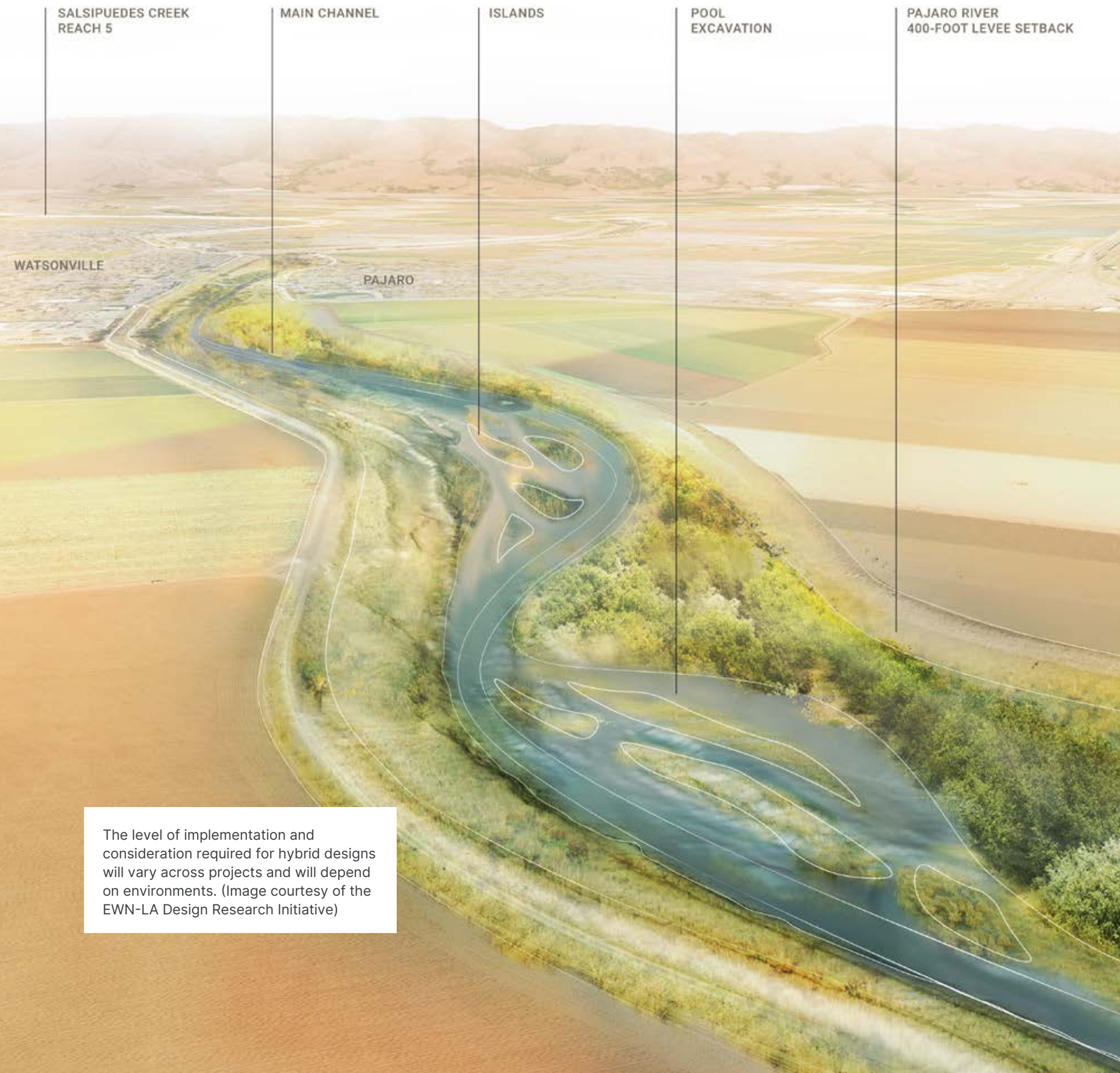
Alteration of floodplain to allow for the river to anastomose under medium flow



FLOODPLAIN CODESIGN

Alteration of floodplain to allow for floodplain activation under 2-year flow conditions





The level of implementation and consideration required for hybrid designs will vary across projects and will depend on environments. (Image courtesy of the EWN-LA Design Research Initiative)

Advancing Implementation

Ongoing initiatives to address the flood risk posed by the Pajaro River provide unique opportunities not only to implement natural infrastructure but also to consider and conceptualize the design and implementation of a natural infrastructure approach within the current technical and regulatory framework. Designed floodplain reconnection features—such as terraces and side channels—using material from within the channel to construct the levee setbacks, save the project money while providing diversity to the floodplain. This approach uses a hybrid design, or the pairing of designed features with existing natural processes, to achieve an end result and maximize overall benefits (e.g., cost savings and ecological diversity).

To maximize the benefits on the Pajaro River, restore social connectivity to vulnerable communities such as Watsonville, and serve as an educational opportunity for future riverine projects to combine built and natural infrastructure, nature will need to be allowed to further sculpt the riverine system after the initial interventions and within the levees. Designers will need to consider how to minimize risks associated with the levees while allowing for the flexibility and developmental complexity of the river and associated floodplain. Extensive coordination among project stakeholders is ongoing to determine the appropriate metrics of success and to assure regulators that planning and design have considered the impacts associated with the dynamic system. The costs of construction will be incurred over a relatively short period, but the costs of adaptively managing and maintaining a dynamic system may need to be shared by stakeholders over a longer time.

Sediment Choreography

Humboldt Bay

CONCEPT HIGHLIGHTS

Reconsidering current strategies to place up to 1 million cubic yards of sediment to capitalize on possible ecological benefits and opportunities

Combining beneficial use methods to combat wetland and beach loss due to rising sea levels

Employing feeder berms, thin-layer placement, and direct placement to boost regional benefits

KEY EWN FEATURES



Coastal and Flood Resiliency

Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



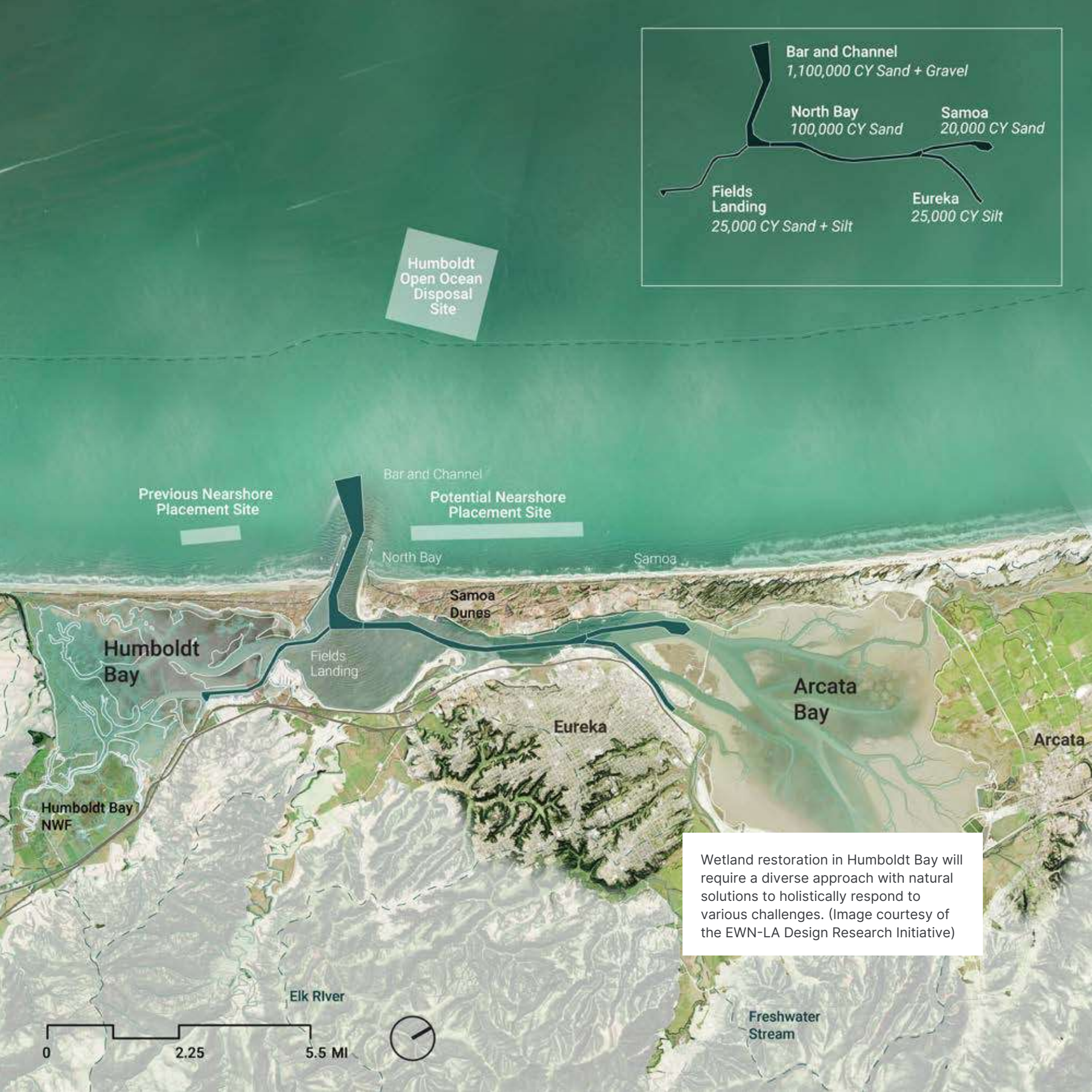
Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



Wetland restoration in Humboldt Bay will require a diverse approach with natural solutions to holistically respond to various challenges. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Humboldt Bay is near Arcata, approximately 80 miles south of the California–Oregon border. The region has lost several types of habitat and coastal infrastructure. Wind and wave erosion along the north bar of the bay drives shoreline erosion. Although wetland loss in the bay has reduced habitat for aquatic and terrestrial species, portions of the wetland are used for innovative wastewater treatment. A highway and rail system that run adjacent to the bay are highly vulnerable to relative flooding hazards. Vast freshwater wetlands in the South Bay are surrounded by berms, which are susceptible to breaching that would not only cause a transition from freshwater wetlands to saltmarsh but also likely submerge the wetlands as a result of relative flooding hazards.

Approximately 1 million cubic yards of material in this region are dredged annually and typically placed offshore in the Humboldt Open Ocean Disposal Site (HOODS), removing the material from the coastal system and providing limited ecological benefit. Although there are plans to place some of that material in an existing nearshore berm to nourish the north bar beaches,[7] capacity at the bar is limited. The availability of dredged material along with the loss of habitat and threats to coastal infrastructure provide a lot of opportunity for multibenefit efforts, such as increasing beneficial use of dredged material for marsh and mudflat resilience. Planning the placement of sediment within the context of the regional sediment sources and sinks can maximize its benefits not just at its initial placement site but also at areas farther downshore. This concept, referred to as “sediment choreography,” involves strategically placing sediment by using a combination of the methods described in the “Applying Natural Infrastructure” section with the intention of allowing natural processes—such as currents, wave action, and littoral drift dynamics—to distribute it to adjacent areas. By aligning placement with regional processes, sediment can effectively nourish and sustain shorelines, wetlands, and habitats over time, enhancing resilience and combating the current loss of habitat and threats to coastal infrastructure.

Leveraging Opportunities

Maintenance dredging in the area provides an opportunity to use innovative strategies to maximize the beneficial use of that dredged material. Because the material varies in composition, which depends on where it was dredged, proposed solutions need to consider the source material's characteristics and proximity to the beneficial use location. Dredged material must be placed intentionally and strategically, particularly given the shallow nature of the bay, to ensure the proper material reaches the critical areas that need it. Carefully choreographed placement of beneficially used sediment can help overcome the challenges posed by the scale of operations in the bay while addressing issues due to rapidly rising sea levels.

Applying Natural Infrastructure

A combination of beneficial use methods is needed to ensure the effective balance of this sediment choreography for maximum regional benefits:

Feeder Berms. They use natural wind–wave action and currents to transport dredged material from a nearshore berm to the shoreline, allowing more sand to reach the beach than is present in the original nearshore berm.

Thin-Layer Placement. Applying dredged material with this method nourishes existing marsh; provides an opportunity to balance marsh subsidence and inundation by using various technologies, such as high-velocity nozzles, sediment distribution pipelines, spreader barges, and baffle plates; and minimizes impacts to existing marsh so native vegetation can recover and regenerate.

Direct Placement. Using direct placement of hydraulically dredged material behind dikes constructed of sand from maintenance dredging or placed along the shoreline can support marsh restoration. Dredged material would be placed behind small containment berms to contain and trap fine-grained material similar in composition to the existing marshes; the dikes would be breached later to allow tidal exchange.



Consider features that address multiple facets of improvement—like adding recreational value and improving ecological habitats in addition to morphological benefits. (Photo courtesy of the EWN-LA Design Research Initiative)



Recognizing Benefits

Several benefits are to be gained by using NNBF in this region:

Feeder Berms. They allow a wider range of grain sizes to be placed and then separated naturally as the material erodes from the berm toward the shoreline. This technique also increases recreational value by protecting the shoreline while providing more habitat for species that use the beach for nesting and feeding.

Thin-Layer Placement. This approach allows the restoration and construction of additional wetland acreage and higher wetland elevations to combat relative flooding hazards while minimizing the impacts of placement on the existing marsh.

Direct Placement. It provides immediate recreational and habitat benefits for beaches and protects more erodible shorelines until vegetation is established sufficiently to be self-sustaining.

Above. Material placed in HOODS is removed from the littoral system, while material placed closer to shore in the Nearshore Sand Placement Site, particularly as feeder berms, allows the sediment to replenish the shoreline. (Image courtesy of the EWN-LA Design Research Initiative)



Advancing Implementation

The Humboldt Bay region dredged material management plan[8] needs to be updated to consider environmental and social effects; to require prioritization of beneficial use of dredged material prior to placement in HOODS as the primary placement option; and to identify, design, and permit a suite of beneficial use projects to prepare these locations to receive material as the maintenance dredging cycle permits. Emphasis on the reuse of dredged material and its associated benefits in the dredged material management plan may serve as an educational example to other regions undergoing frequent dredging cycles. Advanced maintenance dredging of smaller, more frequent projects may also benefit from this sediment choreography. The process to estimate the costs of these types of projects may need to be reconsidered to balance the cost of navigation dredging with the benefits of protecting shorelines, adjacent infrastructure and communities from erosion, flood risks, and saltwater intrusion (i.e., the benefit/cost of risk avoidance in the future that may otherwise have to be borne by the government). Coordination with local stakeholders, regulators, infrastructure entities, and community members may be required to ensure the proper balance and sharing of the construction and operational costs for the most impactful regional benefits.

Strategic Sediment Mobilization

Marin County Creeks

CONCEPT HIGHLIGHTS

Using strategic sediment mobilization, or pulse dredging, to enhance the natural sedimentation process downstream and provide increased coastal protection through a more robust sediment budget

Using natural sediment processes and behaviors in the area, such as sediment paths and high flows, to feed adjacent marshes

KEY EWN FEATURES



Coastal and Flood Resiliency

Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



It is necessary to understand local sediment sources and sinks to identify locations where strategic sediment mobilization benefits surrounding areas. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Strategic sediment mobilization is a natural-infrastructure technique that uses high flows to transport sediment downstream. Benefits of this approach can be seen in small tidal channels where sediment has silted in, limiting the capacity in these channels and reducing their function as flood control channels for nearby communities. The creeks in Marin County, in the northwestern portion of the San Francisco Bay Area, for example, carry sediment from their shallow reaches upstream and deposit it in the bay, where it forms fringe marsh habitat. But this process also results in increased sedimentation during low flows that inhibits navigation. Using a technique like pulse dredging to resuspend this sediment into the water column when creek flows are high would move the sediment from where it is a problem to areas where it adds value, such as existing marshes, nearshore habitat, and farther into the bay.

Leveraging Opportunities

Several large creeks, including Gallinas, Corte Madera, and Coyote Creeks, convey stormwater from their watersheds to San Francisco Bay. The sediment they carry during and after typical storms comes from their eroded banks and shallower upstream portions. Once deposited in the bay, this material needs to be managed or dredged and transported to a placement area where it will not impede navigation. High flows driven by precipitation have the potential to rapidly flush large quantities of water down the creeks. They also create ideal conditions for carrying sediment farther into the bay and for pushing sediment farther into marsh platforms than is feasible during low flows, particularly if the settled sediment can be resuspended into the water column.

Applying Natural Infrastructure

Strategic sediment mobilization, also referred to as pulse dredging, relies on natural forces to agitate sediment at specific upstream locations ahead of or during high flows and flush it downstream. The sediment is then resuspended into the water column by a water injection nozzle or hydraulic dredge—or by some other innovative technique—and allowed to flow through the system. By reanimating the sediment into the water column at upstream locations, this technique distributes the sediment more evenly away from recreation and navigation areas. Although traditional dredging requires multiple steps to dredge, transport, and place sediment, strategic sediment mobilization relies on timing and natural forces to transport and deposit material in a more desirable location. This has the potential to positively impact the sediment budget of the receiving water, in this case San Francisco Bay, reduce the need for maintenance dredging of small tidal channels, and feed the downstream marshes and mudflats with much-needed sediment so they can keep pace with rising sea levels.

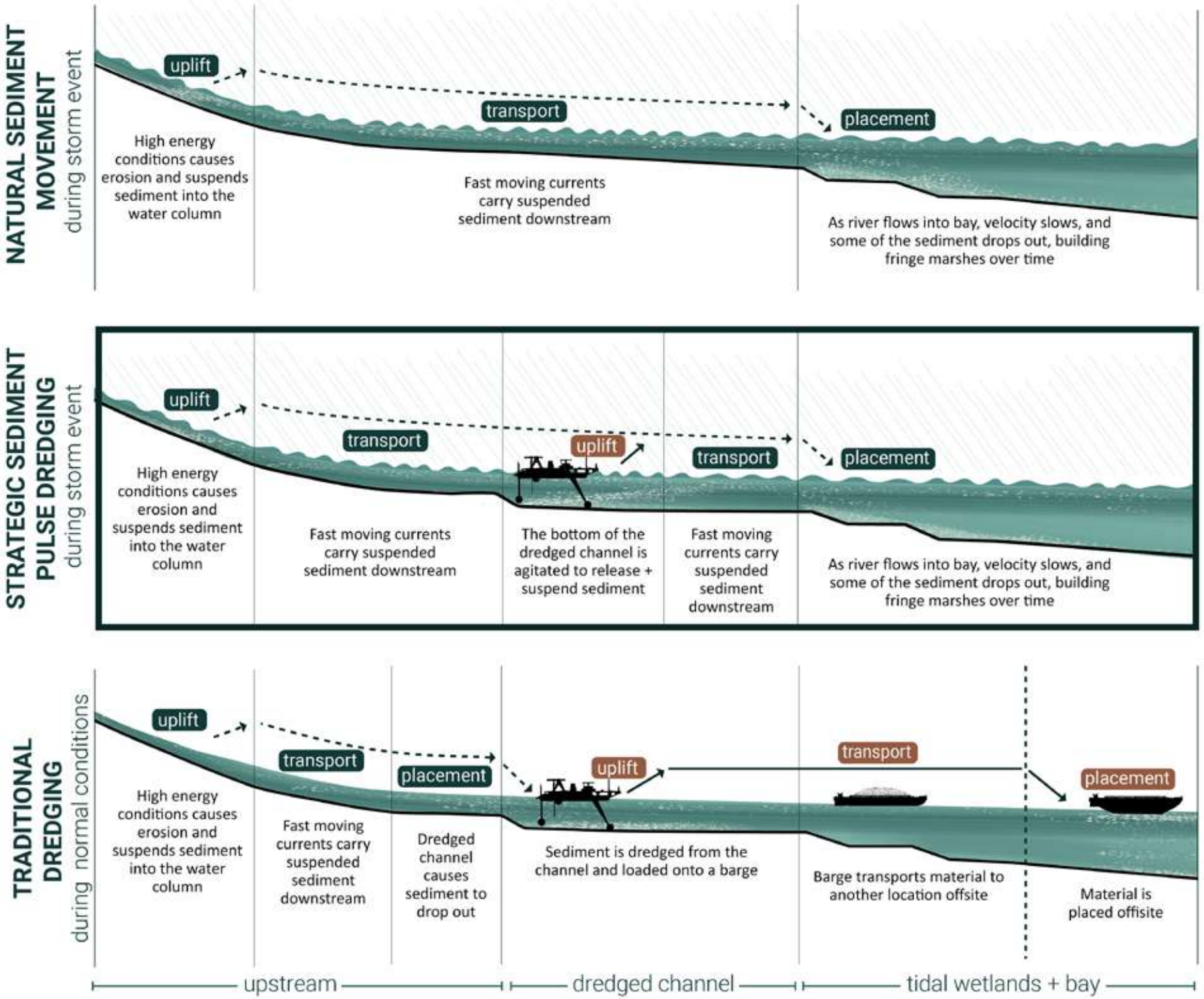


Image courtesy of the EWN-LA Design Research Initiative

1 *High-energy conditions cause erosion and suspend sediment into the water column.*

2 *Fast currents carry suspended sediment downstream.*

3 *The bottom of the dredged channel is agitated to release and resuspend sediment.*

4 *As a river flows into the bay, velocity slows and some of the sediment drops out, building fringe marshes over time.*

Sonoma Creek

Novato Creek

Gallinas Creek

San Pablo Bay

San Rafael Creek

Corte Madera Creek

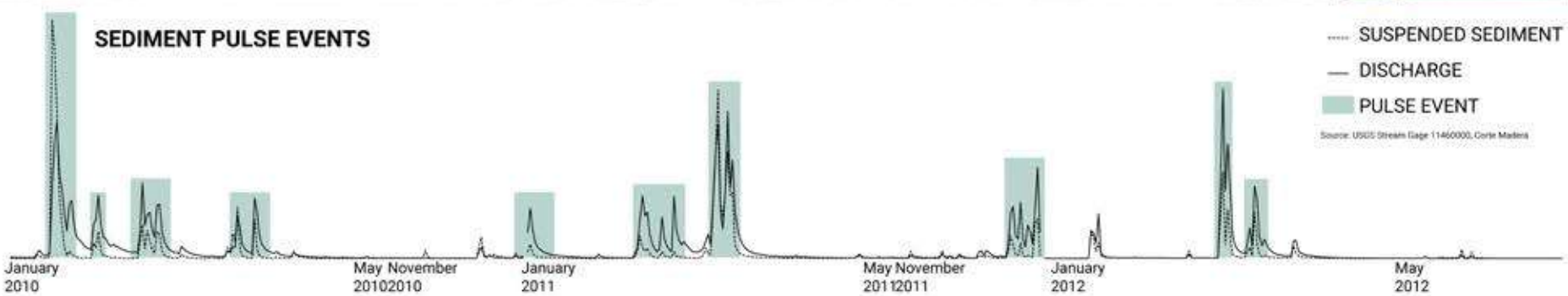
Tidal Marsh

Mudflats

Nearshore

Maintained Channel

Image courtesy of the EWN-LA Design Research Initiative



Recognizing Benefits

Strategic sediment mobilization offers several cost and ecological-restoration benefits. By taking advantage of natural sediment-transport mechanisms, this EWN technique can reduce the need for costly traditional dredging and placement operations from the mouth of the creeks. The strategic placement of sediment can also help increase the area of high-value fringe marsh habitat that is critical to the coastal ecosystem. With the bay starved for sediment, the EWN method employed by this project has the potential to significantly increase the sediment budget, further enhancing the ecological resilience and long-term health of San Francisco Bay. Overall, this approach can provide a more cost-effective and environmentally sustainable means of maintaining and restoring coastal ecosystems.

Advancing Implementation

The primary impediments to strategic sediment mobilization are timing, current regulations, and safety. Rather than occurring according to contractual timelines or workforce availability, strategic sediment mobilization occurs according to specific weather events. Given the limited predictability of these events, timing the introduction of equipment to mobilize the sediment may be challenging. And storms that create high flow velocities also often create turbidity and challenging working conditions. Innovative methods to animate the sediment may require unique technologies or pose logistical considerations related to the timing and intensity of the storms that will transport sediment as desired while still allowing for safe working conditions. Further assessment and pilot studies may be necessary to refine these parameters and assure regulators that permitting constraints can be achieved during turbulent weather.

Strategic Sediment Placement

Eden Landing

CONCEPT HIGHLIGHTS

Investigating strategic placement of fine material for tidal marsh nourishment

Increasing the sediment accretion rate to compensate for natural hazards and their impacts through the beneficial placement of dredged material

KEY EWN FEATURES

- **Coastal and Flood Resiliency**
- **Habitat Creation or Restoration**
- **Beneficial Use of Dredged Material**
- Social Connectivity
- Community Engagement
- Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



Image courtesy of the EWN-LA Design Research Initiative

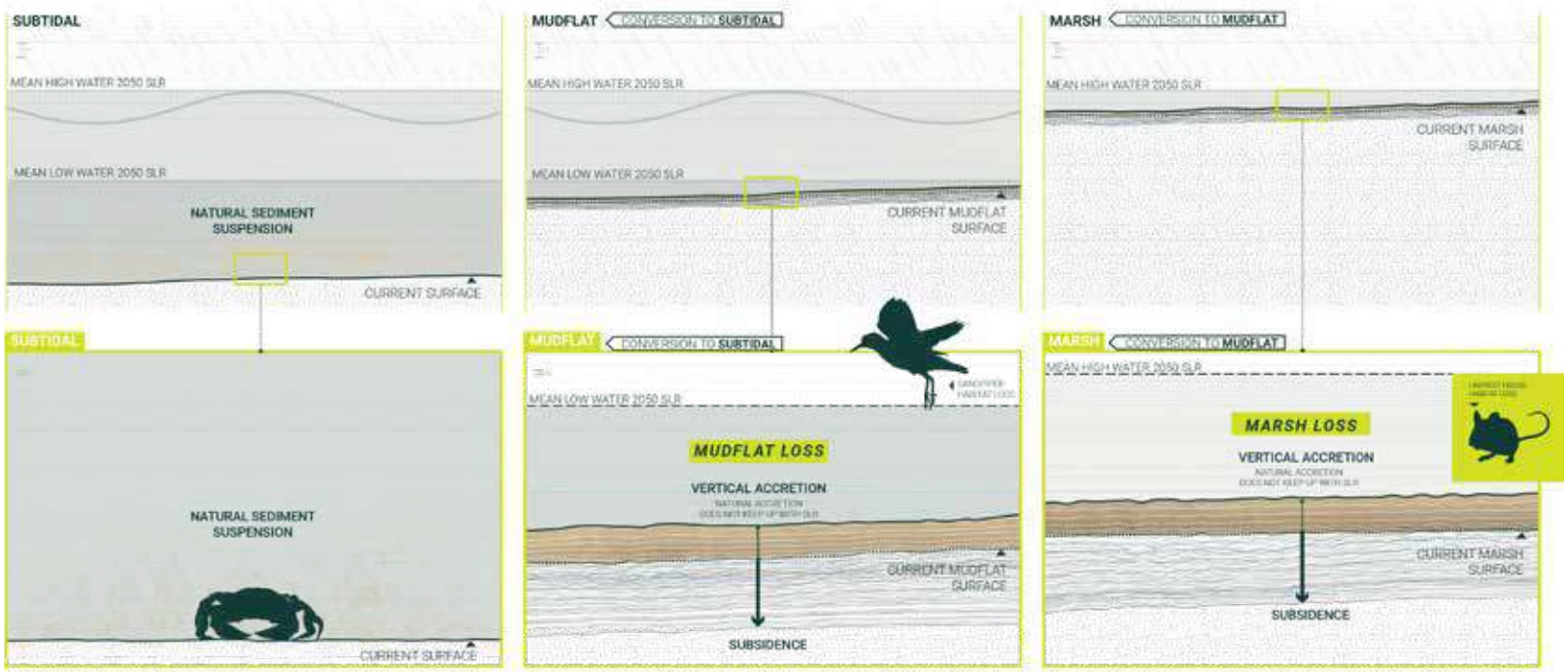
EWN Strategy and Concept Opportunity

Eden Landing is in the city of Hayward on the southern portion of San Francisco Bay. The site contains a mosaic of bermed wetlands susceptible to breaching and wetland submergence due to relative flooding hazards. Dike construction and shoreline hardening have reduced the sediment available in the water column to naturally feed existing ecosystems and are amplifying marsh loss and mudflat subsidence.

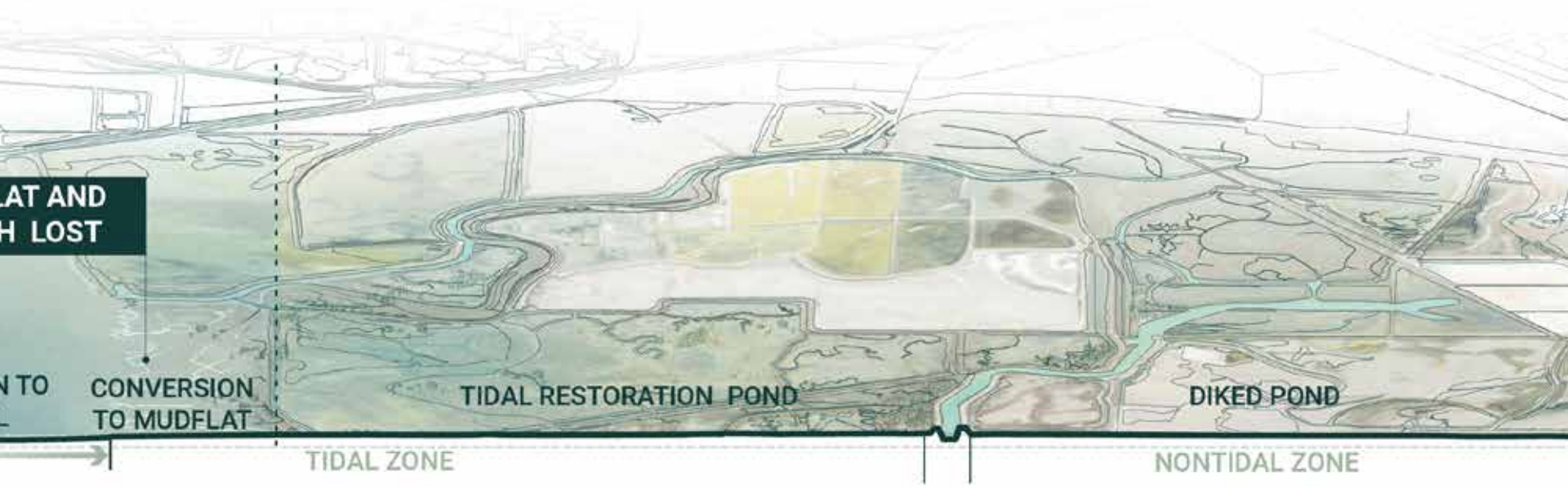
The San Francisco Bay Long-Term Management Strategy has set a target for beneficial use of 40% of the material dredged from San Francisco Bay to maintain navigable waterways, ports, and marinas,[9] aligning with USACE Chief LTG Scott A. Spellmon's goal to expand the beneficial use of dredged material to 70% by 2030[10] and complementing efforts by the Dredged Material Management Office (a joint program of the San Francisco Bay Conservation and Development Commission, the San Francisco Bay Regional Water Quality Control Board, the State Lands Commission, the USACE San Francisco District, and the U.S. Environmental Protection Agency). This policy provides an ideal opportunity to tap into a valuable resource and strategically place dredged material to raise and nourish tidal ecosystems.

FUTURE WITHOUT PROJECT





Above. Without intervention, depending on subsidence, sediment deposition, and potential enhancement, habitat and ecological values change overtime, resulting in habitat loss and degradation. Given that these are very fine sediments, the energy required to move them is not anticipated to have that impact on biological resuspension as well. Note, biological features identified in this and subsequent images are used for contextual purposes only. (Images courtesy of the EWN-LA Design Research Initiative)



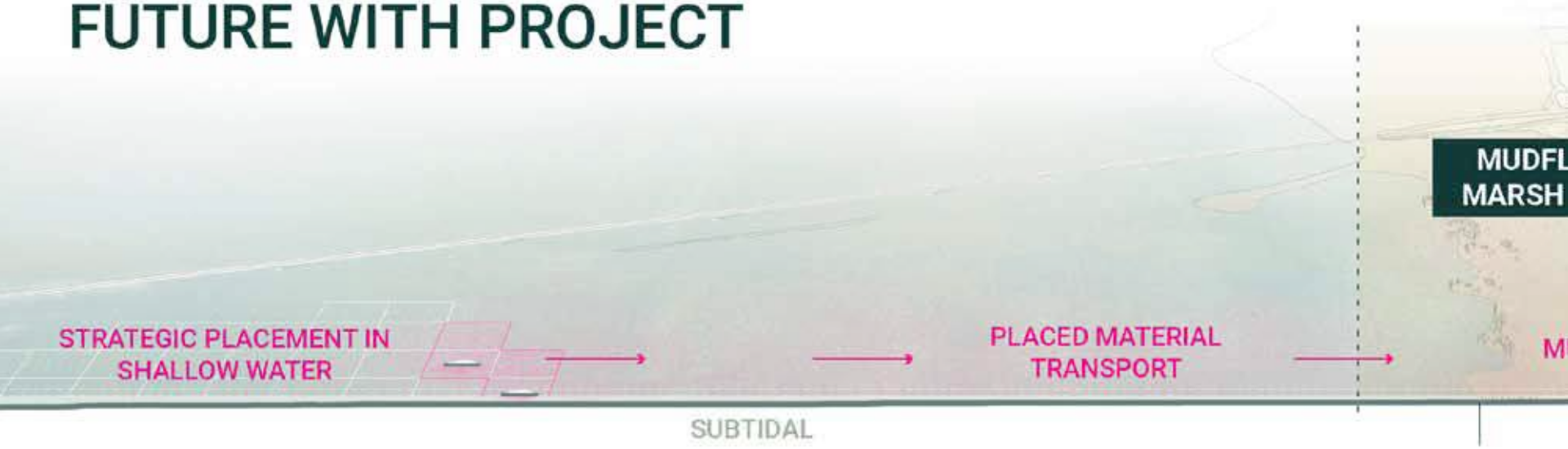
Leveraging Opportunities

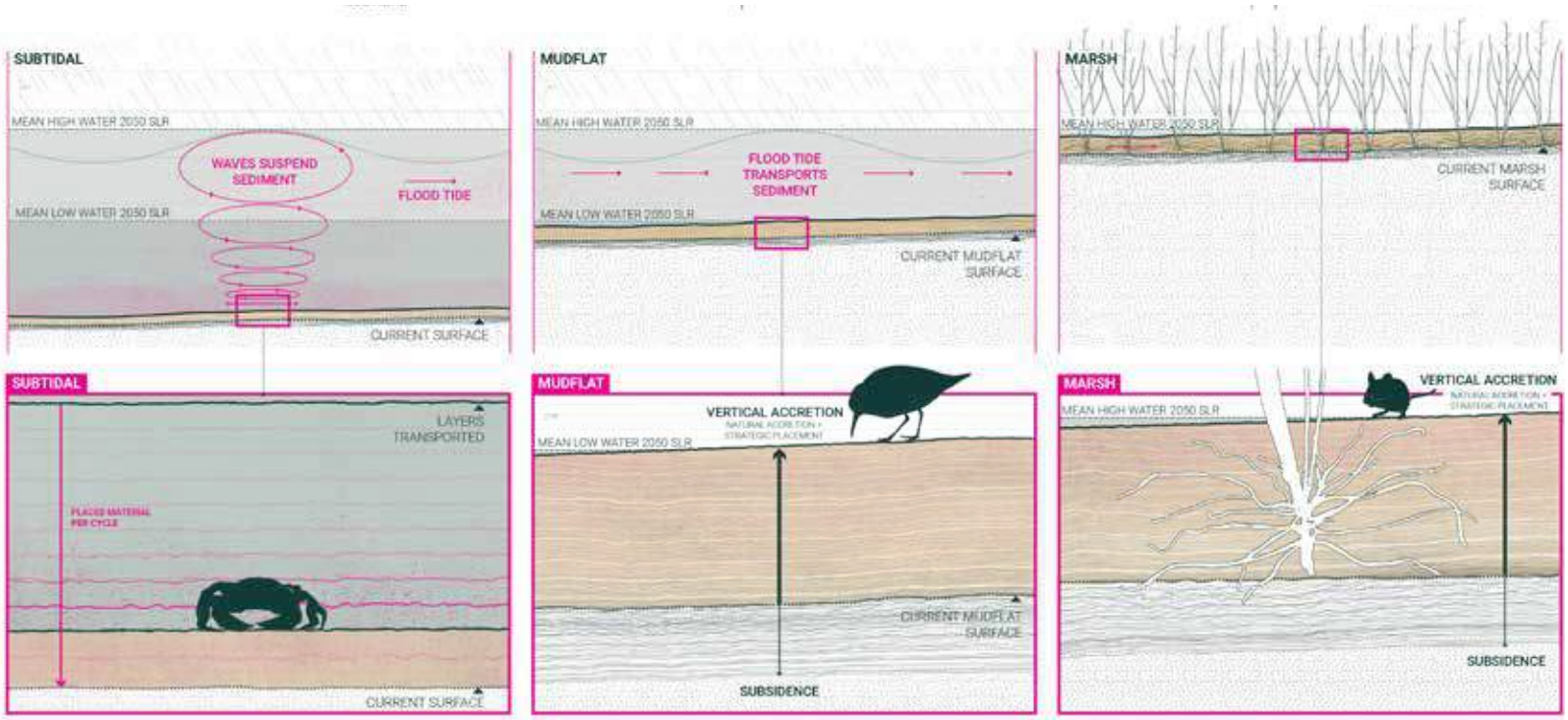
The beneficial use target and the volume of material dredged from the bay make the region ideal for EWN projects—particularly those beneficially using dredged material to enhance marshes that are eroding or drowning as a result of relative flooding hazards. The Eden Landing site is a depositional environment; fine-grained material dredged from adjacent navigation channels and strategically placed there has the potential to naturally migrate and deposit within a wetland ecosystem that would particularly benefit from it to keep pace with rising tides in a way that mimics natural processes of sediment deposition. The Water Resources Development Act of 2016 offered an opportunity to pilot the strategic placement of sediment in nearshore environments and to monitor its progression and impacts on the surrounding areas and adjacent shorelines.

Applying Natural Infrastructure

The Eden Landing placement site was selected for this pilot project after a lengthy site criteria development effort, and hydrodynamic modeling indicated there was sufficient wave action to resuspend sediment placed in the nearshore environment and adequate tidal exchange to feed the area where the marsh system is subsiding and drowning. Although the water in the region is not deep enough for traditional dredging equipment, light-loaded and extra-small scows and timing of the tides strategies were used to access the area and place the sediment. However, the placement and resuspension of this material by tidal action may result in turbid conditions that historically have been considered a challenge.

FUTURE WITH PROJECT





Above. With intervention, through the strategic placement of sediment, the existing habitat and ecological footprints are maintained. (Images courtesy of the EWN-LA Design Research Initiative)



Recognizing Benefits

The EWN methods used in this approach have the potential to reduce navigation dredging costs by allowing nature's energy to distribute the placed material in a way that benefits the surrounding shorelines, ecosystems, and communities. In an area deprived of sediment, it is ideal to have as many potential sources and methods of placing material in targeted locations as possible. The accretion associated with the migration of sediment placed in the nearshore environments will increase the extent of the existing marsh and mudflats by allowing them to migrate, which enhances the resilience of the entire ecosystem. Monitoring of the implemented project will help guide the future placement and management of sediment in the region to balance the material necessary to offset relative flooding hazards.

Advancing Implementation

Strategic sediment placement is an unconventional method of material management for the San Francisco Bay Area given the unconfined placement of material and its natural tendency to migrate. Monitoring of pilot projects and significant stakeholder coordination are required to observe, document, and communicate the relationship of the sediment, the placement location, and the adjacent shoreline. There is great potential to retain sediment as a valuable resource in the coastal environment to combat significant—and increasingly complex—extreme weather challenges.

Social Resiliency

South Bay Shorelines

CONCEPT HIGHLIGHTS

Restoring approximately 2,900 acres of habitat

Using a conceptual trail system to integrate important cultural, social, and ecological history with constructed systems

Incorporating horizontal or ecotone levees, levee setbacks, and strategic breaching

KEY EWN FEATURES

- **Coastal and Flood Resiliency**
- **Habitat Creation or Restoration**
- **Beneficial Use of Dredged Material**
- **Social Connectivity**
- **Community Engagement**
- **Educational Opportunity**



Image courtesy of the EWN-LA Design Research Initiative

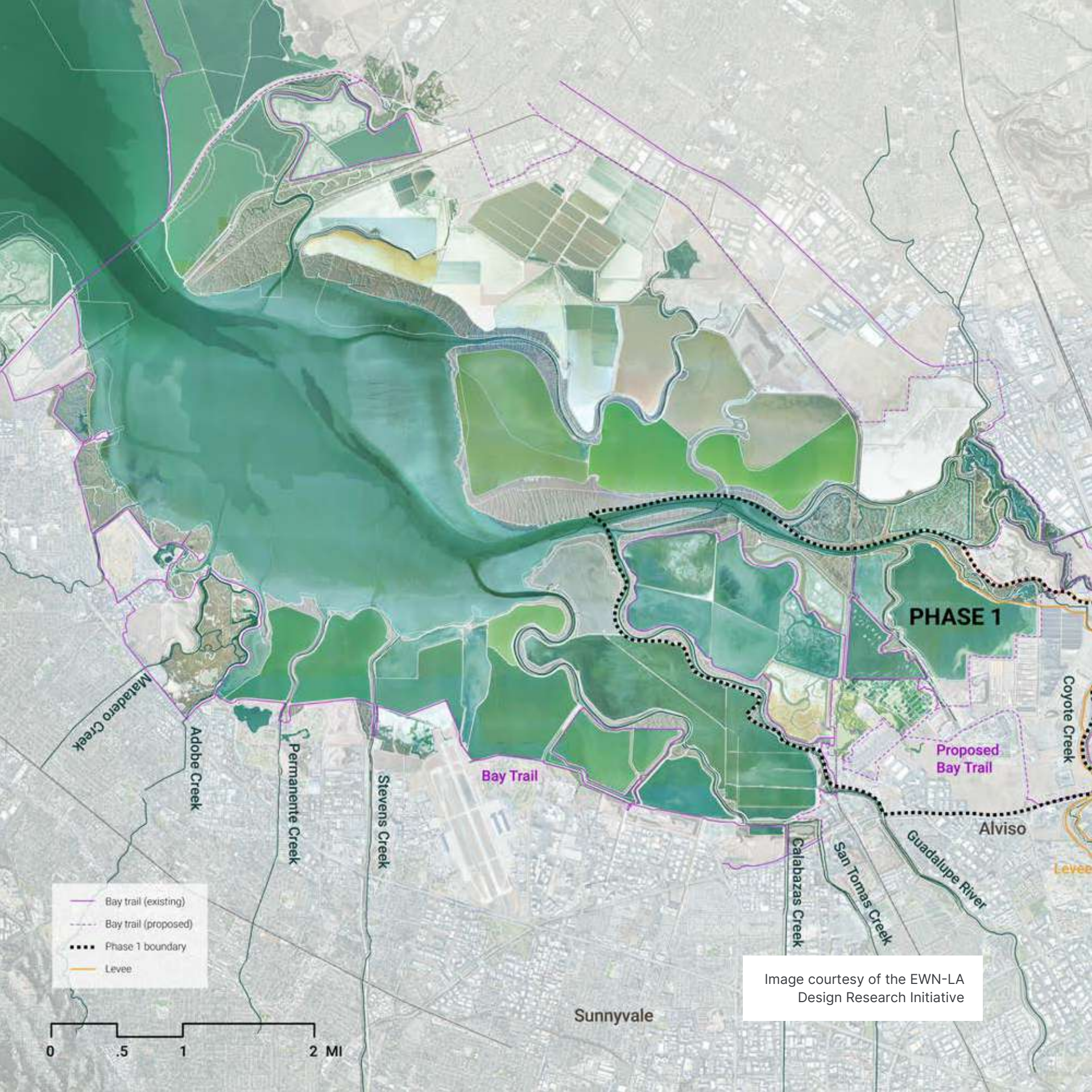


Image courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

The South Bay Salt Ponds are on the southeastern tip of San Francisco Bay directly adjacent to the Alviso district of San Jose. The shoreline consists of a mosaic of diked salt ponds with a low levee between the ponds and the upland communities. Projected relative flooding hazards suggest that the low levee is expected to be close to overtopping at mean lower low water by 2067. This relative flooding hazard would place Alviso in the 100-year flood zone, vulnerable to significant damage from storms. The South San Francisco Bay Shoreline project will build a large ecotone levee between the salt ponds and systematically breach areas of the existing salt ponds to hydraulically connect them with the bay and convert them to salt marsh habitat. The current trail system will also be affected, but key connections to the San Francisco Bay Trail will be established. Considering the salt pond system as a whole with the surrounding community in combination with ongoing projects will provide additional opportunities to connect the community with this critical ecosystem as it is restored for educational and recreational purposes.



Leveraging Opportunities

Phase 1 of the shoreline project, a multipurpose FRM, ecosystem restoration, and recreation project in San Jose, is underway as a multiagency partnership between USACE, the U.S. Fish and Wildlife Service, Valley Water, and the State Coastal Conservancy. The project manages risk for 5,500 residents and 1,100 structures, restores 2,900 acres of tidal wetlands, and improves recreation by providing key connections to the iconic San Francisco Bay Trail.[11] NNBF principles emphasize the interconnectivity of systems and the engagement of multidisciplinary teams, communities, and stakeholders for maximum benefits. Levees have been deemed necessary to protect the surrounding low-lying and vulnerable communities from rising tides.

Furthermore, connecting the trail system that runs near the salt ponds during and after construction presents an opportunity to educate and inform the community while the ponds are being restored to tidal marsh, reconnected to the bay ecosystem, and opened to tidal exchange.

Above. This panoramic view overlooks the South Bay Salt Ponds and tidal wetlands, where recreational trails offer scenic views to the public. (Photo courtesy of EWN-LA Design Research Initiative)



Applying Natural Infrastructure

Construction of this project will take many years. The first construction elements will involve constructing the levees and closure structures, constructing ecotone transitional habitat from the levees into the adjacent salt ponds, and preparing the first ponds for breaching and restoration. Connecting the existing trail system will enhance community engagement and social connectivity while increasing awareness of the need for multifaceted approaches to complex challenges.

Later years of the project will consist of breaching the first ponds and preparing the others. After the first ponds are breached, monitoring and adaptive management will take place to aid in the production of targeted high-value tidal marsh habitat. The lessons learned during this initial monitoring and adaptive management will be used to increase the efficiency of restoring other salt ponds.



Image courtesy of the EWN-LA Design Research Initiative

Recognizing Benefits

This project combines critical protection for coastal communities with the creation of high-value habitat to improve the ecosystem while connecting the local community to these habitats. The new levee system will significantly improve coastal FRM for Alviso and surrounding areas. With the levee system in place, the pond dikes will be selectively breached, allowing them to be restored to high-value tidal marsh habitat. Another benefit will be an improved trail system to increase educational and recreational opportunities for the local community to explore the new tidal marsh habitat. Additionally, the current pond dikes will be turned into an extensive trail system to increase educational and recreational opportunities for the local community to explore the new salt marsh habitat. This comprehensive and collaborative approach is a great example of using EWN to protect coastal communities, improve public access to natural resources, and allow nature to transform an environment with limited ecological value to high-value marsh habitat.

Advancing Implementation

While critical infrastructure and jurisdictional authorization is an important part of other projects along the San Francisco Bay Shoreline, a comprehensive, regional approach will need to be prioritized and maintained. This includes emphasis on ecosystem restoration as well as community engagement and education in order to balance the protection of the community and preservation of cultural heritage.



Beneficial use of dredged material is showcased at the Deer Island site to restore the once degraded 4.5-mile-long barrier island off the coast of the Mississippi Sound. (Photo courtesy of Anchor QEA)

Mobile District

Beneficial Use of Dredged Material
Dredged Material Containment Facility, Blakeley Island, Alabama

River Diversion and Reconnection
Escatawpa River, Alabama

Strategic Sediment Placement Strategy
Mobile Bay

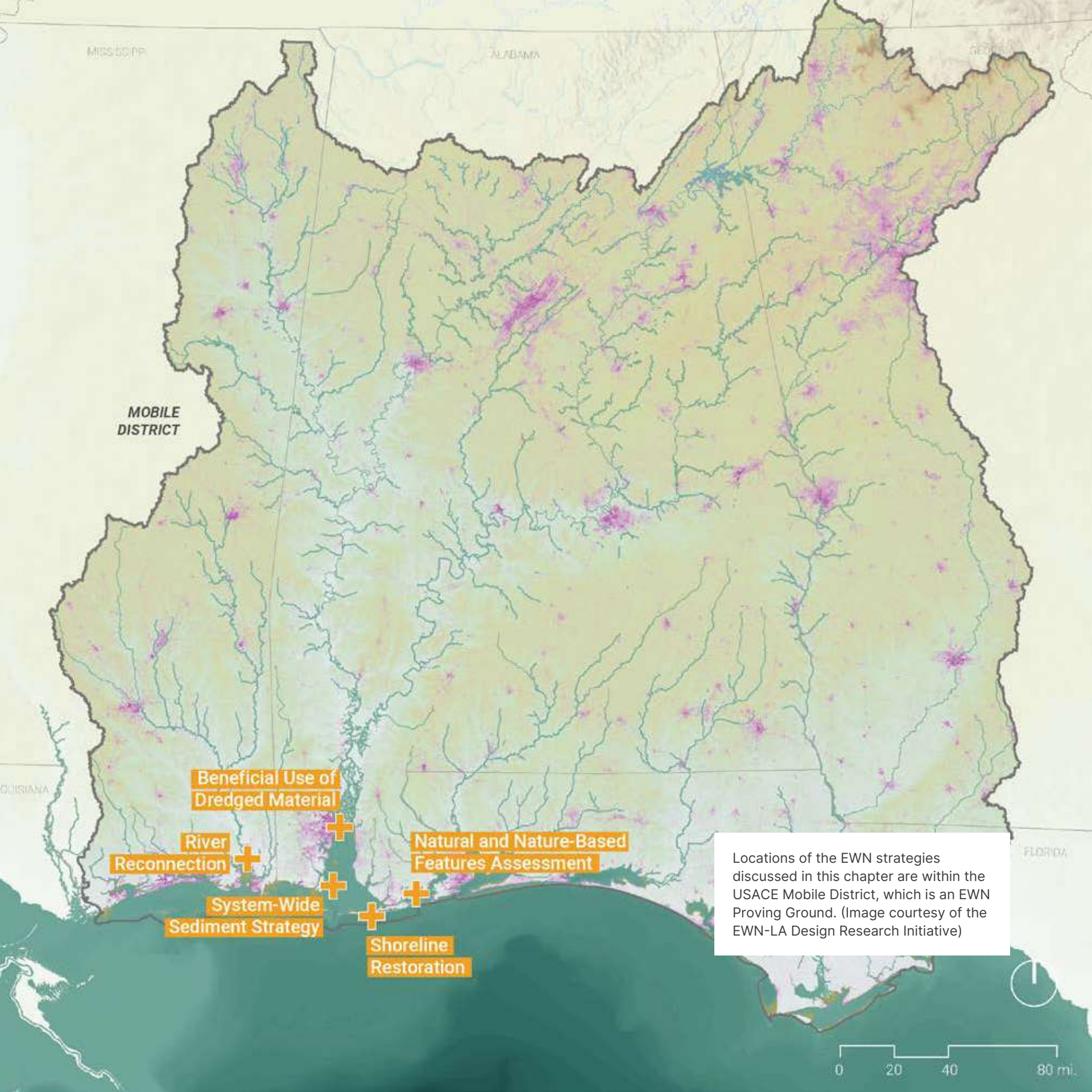
Shoreline Restoration
Fort Morgan Peninsula, Alabama

Natural and Nature-Based Features Assessment
Perdido Bay, Florida

Infrastructure and development have in many ways interrupted the natural flow of water in the Gulf Coast region and affected the movement of sediment. The complex and varied coastal environments in the USACE Mobile District provide opportunities to explore various EWN solutions to this interruption while maintaining maritime navigation, including shoreline restoration, river reconnection to the coast, beneficial use of dredged material for ecological restoration, and sediment choreography strategies.

Headquartered in Mobile, Alabama, the USACE Mobile District operates and maintains 2,200 miles of navigation channels along the Mississippi, Alabama, and Florida Panhandle coastlines, supporting numerous deep- and shallow-water ports. The district includes 6 primary watersheds, 27 lakes, and 464 recreation areas visited by more than 34 million people each year. It also includes Mobile Bay and the Port of Mobile, one of the largest ports on the Gulf Coast and Alabama's only saltwater port.

Increased human population and development along the coast, the impacts of relative flooding hazards, vulnerability to tropical storms, and upstream sediment loss all contribute to habitat loss in the region and increased risks to infrastructure and regional economies. Integrating EWN solutions is critical to maintaining this valuable ecosystem and protecting communities and infrastructure.



Locations of the EWN strategies discussed in this chapter are within the USACE Mobile District, which is an EWN Proving Ground. (Image courtesy of the EWN-LA Design Research Initiative)

Beneficial Use of Dredged Material

Dredged Material Containment Facility, Blakeley Island

CONCEPT HIGHLIGHTS

Identifying prospective beneficial use sites to extend the lifespan of the existing dredged material containment facility while providing habitat restoration and increasing ecological value of the region

Employing multiple beneficial use strategies, such as marsh placement and construction, thin-layer placement of dredged material, and strategic placement

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Dredged material containment facilities, like the one shown here, provide the material and opportunity to address coastal sediment deficiencies in a practice called *beneficial reuse*. (Photo courtesy of the EWN-LA Design Research Initiative)

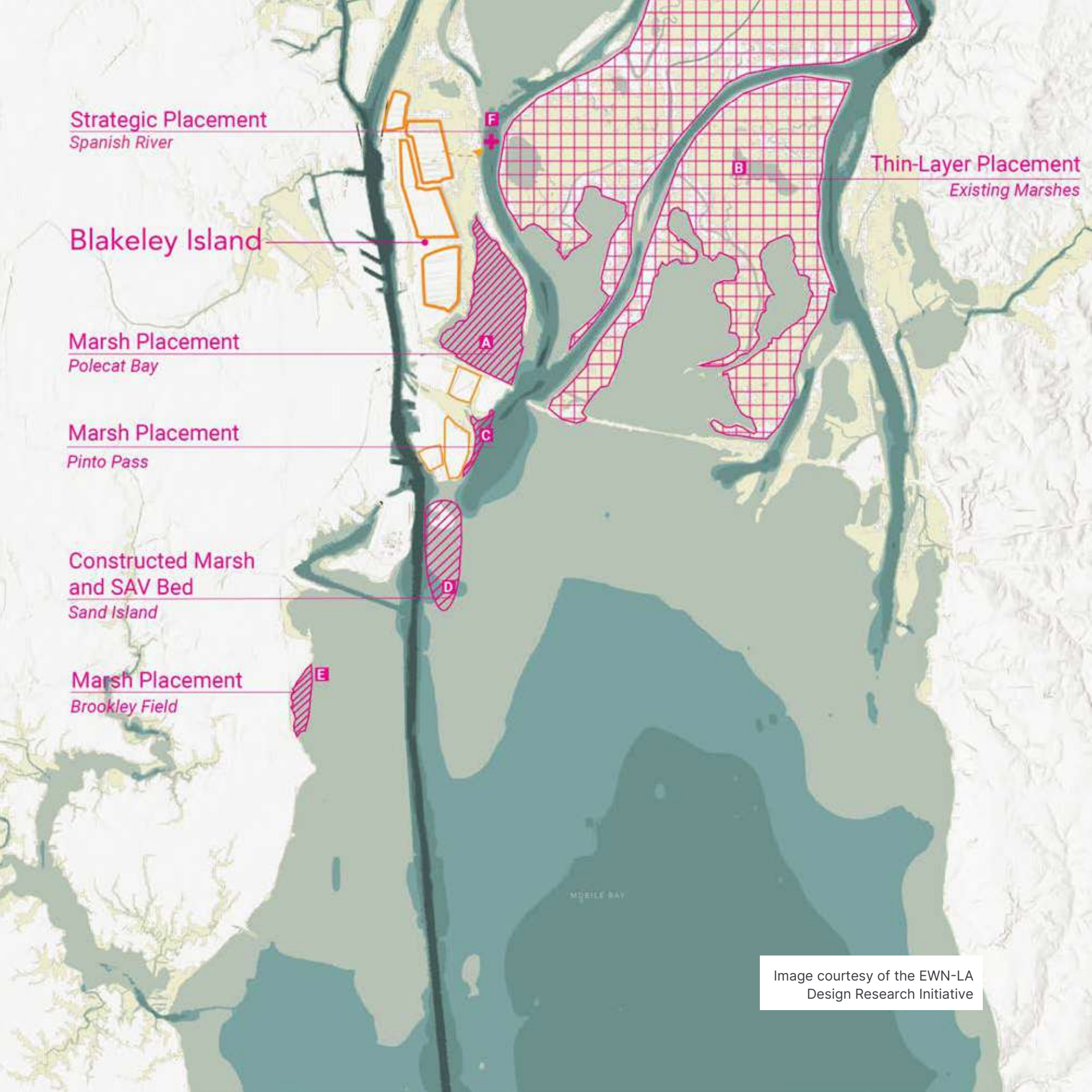


Image courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

Blakeley Island, on the east side of the Port of Mobile, is used as an upland placement facility for significant volumes of material dredged from nearby navigation channels. The confined placement of this material removes it from the natural sediment-transport regime required to sustain the region's marsh ecosystem.

The facility's capacity is limited unless dredged material can be dewatered, removed, and beneficially used. EWN strategies provide an opportunity to reclaim facility capacity for future dredging events while using this valuable resource for ecological restoration.

Leveraging Opportunities

Blakeley Island has been an industrial hot spot and an important location for dredged material management in recent years. The USACE Mobile District's Blakeley Island dredged material containment facility (DMCF) is at or near capacity, which poses a challenge for the region's dredged material management strategy because large quantities of material are dredged from the channels and docks west of the island each year. In addition, area marshes are degrading and drowning because of development and rising tides. An EWN solution that uses dredged material would free additional capacity for the DMCF while augmenting the valuable ecological features in Mobile Bay.



As a reference in terminology, the term *confined disposal facility* was used by USACE to denote federally authorized or constructed facilities prior to 1996. Thereafter, the terminology *dredged material disposal facility* was adopted. Although these terms are interchangeable, *dredged material disposal facility* is used consistently throughout this document.

Applying Natural Infrastructure

Several strategies to reuse dredged material could be used, depending on the material's composition and most impactful use.

Marsh Placement and Construction. Marshes in the region protect and provide ecological value to infrastructure along the shoreline. Logically, material dredged from the Mobile Bay sediment system could likely be used to enhance existing marshes or expand marsh areas in various locations. Introducing submerged aquatic vegetation (SAV) beds provides additional stability and offers a foundation for rich ecological diversity in new marshland. Studies have shown that "animal abundance [in SAVs] is 10–100 times more than over nearby sandy seafloor," with a single acre of seagrass supporting approximately 40,000 fish and 1,000 times as many small invertebrates.[12] These natural protection systems provide resiliency to the region while increasing the ecological habitat value.

Thin-Layer Placement. Various marshes in the region would also benefit from thin layers of dredged material to nourish them and allow them to naturally adapt to changing water conditions. Thin-layer placement of fines could support natural accretion in the areas most beneficial to the marsh.

Strategic Placement. Rather than dispose material in a DMCF, material from the facility could be reclaimed and pumped back into the river when the river is flowing rapidly. This approach uses natural processes to redistribute the returned sediment in the system and extend the life of the facility to maintain the navigation channels.



The Blakeley Island Disposal Area receives material from the Mobile Ship Channel and is a popular spot for Alabama birders to see shorebirds and waterfowl. (Photo courtesy of the EWN-LA Design Research Initiative)



As DMCF capacity decreases, the opportunity to beneficially use dredged material to enhance nearby marsh systems and add ecological value and shoreline protection becomes increasingly important. (Photo courtesy of Anchor QEA)

Recognizing Benefits

Implementing beneficial use creates opportunities to free space in placement facilities and use the material to advance favorable projects. Sufficient use could extend the life of a containment facility for years of dredging, depending on the volume and composition of material reclaimed. Augmenting current ecological features will provide wildlife habitat, increase flood resiliency as climatological events increase in intensity and sea levels rise, and provide recreational opportunities in the bay and along the shore.

Advancing Implementation

Effective beneficial use of dredged material requires an alignment of the planning, permitting, and design of ecological enhancement projects. Developing a suite of beneficial use options would provide chances for material reclamation activities to be sequenced with operational logistics and funding opportunities. Working with local stakeholders and property owners would also be key to obtaining community buy-in for these EWN solutions and could identify additional opportunities for the beneficial use of dredged material.

River Diversion and Reconnection

Escatawpa River

CONCEPT HIGHLIGHTS

Investigating river diversion and restoration of the wet pine savanna habitat

Harnessing natural infrastructure approaches such as, channel and sheet flow diversions, marsh restoration, and thin-layer placement of dredged material

Incorporating feeder berms and strategic placement of dredged material

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



Image courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

Many modifications between the Escatawpa River and Grand Bay are due to anthropogenic activities like excavating canals to channel water flows and building embankments to elevate transportation infrastructure. Communities situated along the Mississippi Sound are threatened by hurricanes and are vulnerable to inland flooding caused by intensifying tropical storms and their associated heavy rainfall, rising water levels, erosion, and subsidence. These threats also reduce natural buffers such as wet pine savannas, leaving human and ecological communities and industrial infrastructure vulnerable to wave action and storms.

EWN presents an opportunity to integrate multiple projects, including the reconnection of the Escatawpa River to its historical floodplain and the restoration of an ecosystem along Franklin Creek, to help restore a more natural symbiosis of the water, sediment, and ecosystem with the developed infrastructure and to further serve and connect adjacent communities.



The Escatawpa River, a tributary of the Pascagoula River, is a 129-mile river that runs through southwest Alabama and southeast Mississippi and drains into the Gulf of America (formerly the Gulf of Mexico) at Pascagoula Bay.

Leveraging Opportunities

Hurricanes and other natural hazards are a persistent threat in the Gulf of America; with natural hazards and extreme weather, intensifying summer storms bring increasingly heavy rainfall. Rising tides, erosion, and subsidence all contribute to habitat loss that threatens ecological communities; these challenges reduce the natural buffers available to protect the region's human communities and important industrial infrastructure. Flooding in the region is exacerbated by built infrastructure that interrupts drainage patterns and traps flood waters. Extensive infrastructure modifications in the areas between the Escatawpa River and Grand Bay have resulted in increased flooding, natural water and sediment sources disconnected from existing ecosystems, and degraded habitats. Erosion and subsidence of tidal marshes and wet pine savannas have also caused the loss of valuable ecological systems and decreased protection from coastal storms. Various initiatives, including those led by partner organizations (indicated in yellow on the image on the next page), are underway to address these challenges. If these efforts consider natural processes, they can align for maximum holistic benefits. These initiatives offer an educational opportunity to encourage future projects to maintain connectivity to surrounding systems.

Applying Natural Infrastructure

Channel Diversion. From east to west and into the wet pine savannas and tidal marshes, channel diversion would enable freshwater, sediment, and nutrients from the Escatawpa River to be diverted toward areas where they are currently absent, restoring some hydrological qualities of overland sheet flow to the region. To reduce interception of flow and to possibly reuse excavated material, filling the paper mill ditch that runs parallel to the Escatawpa River would be a component of this alternative, along with prescribed burns in the wet pine savannas.

Sheet Flow Diversion. Similar to channel diversion, this approach would include filling the papermill ditch and conducting prescribed burns in the wet pine savannas. It would also require elevating the current infrastructure to restore historical overland sheet flow from the Escatawpa River south to Grand Bay during floods.

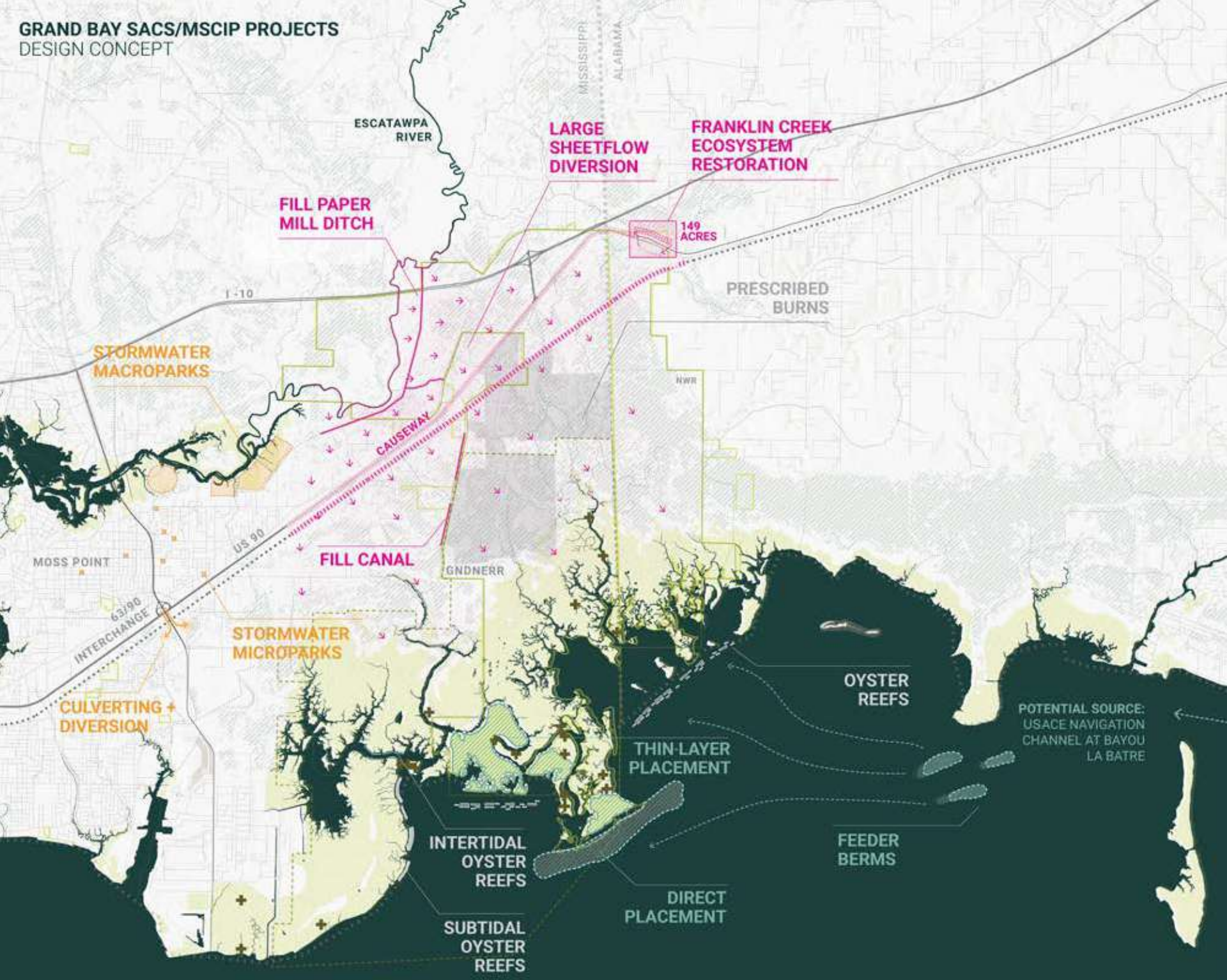


Image courtesy of EWN-LA Design Research Initiative



In areas between the Escatawpa River and Grand Bay, natural infrastructure can reconnect historical floodplains and enhance existing ecosystems to attenuate the impacts of storms and flooding on built infrastructure. (Photo courtesy of the EWN-LA Design Research Initiative)

Marsh Restoration and Thin-Layer Placement. For the degrading marsh along the nature preserve and coastal environment, marsh restoration and thin-layer placement of dredged material could be used to nourish and enhance. Thin-layer placement of fines could enhance the natural capacity of those marshes to accrete and gain elevation as they adapt to rising tides.

Feeder Berms and Strategic Placement. These solutions using dredged material near the shoreline could encourage the distribution of the sediment into the marsh system. Strategic placement of dredged material could be designed so that longshore transport will convey sediment westward along the historical alignment of the shoreline, potentially nourishing shoals, island systems, and the eroding marshes.

Recognizing Benefits

The preferred alternative chosen by the USACE Mobile District is the sheet flow diversion. Restoring more natural flow regimes will relieve storm-induced floods for the community and provide the ecosystem with the disturbance cycles, water, and sediment that historically balanced the region. Sheet flow diversion may be preferred over channel diversion to minimize impacts to the area for maximum benefit. This approach combines filling of the paper mill ditch, prescribed burns, marsh restoration, and strategic placement of dredged material to support the multiple-layers-of-defense approach.

When implemented intentionally and collaboratively, EWN strategies for responding to the linked issues of flooding and habitat degradation between the Escatawpa River and Grand Bay have the potential to transform the lives of the citizens of local communities and support the long-term ecological health of the region. This will require extensive collaboration and coordination between agencies, partners, funding sources, and communities—an effort that is both necessary for the future of the region and a tremendous opportunity.

Advancing Implementation

A concerted effort to identify, align, and implement individual projects for the largest regional impact will be necessary to realize the most benefits. This effort may require significant investments not only for infrastructure accommodations and land acquisition but also for sharing the costs of project design and implementation and for long-term maintenance and monitoring. Collaboration will be required between agencies, entities, and the community.

Strategic Sediment Placement Strategy

Mobile Bay

CONCEPT HIGHLIGHTS

Encouraging natural accumulation of sediment

Creating feeder berms and strategic placement of dredged material

Developing oyster reefs, tidal marsh, and seagrass

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative



This map highlights completed and ongoing restoration projects. Opportunities for proposed restoration should complement the existing or ongoing projects in the area. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Mobile Bay is the receiving body for more than two-thirds of Alabama's waterways. Its primarily shallow estuarine habitat provides for a wide variety of wildlife, but the bay faces several ecological challenges, including shoreline erosion and habitat loss. The approximately 7 million cubic yards of material dredged annually from the navigation channels could be a valuable resource for combating ecological challenges in the region if managed effectively.

Various EWN strategies could provide significant improvements and increased resilience for the Mobile Bay region. They include the installing feeder berms, beneficially using dredged material, and using natural infrastructure to improve sediment management, address erosion, and curb or abate habitat loss.



Mobile Bay, one of the largest estuarine systems in the United States, is composed of tidal marshes, cypress swamps, bottomland hardwoods, oyster reefs, and barrier islands. Because of its environmental diversity, it is ecologically rich, supporting numerous mammal, reptile, amphibian, bird, and fish (both fresh and saltwater) species. The region is economically dependent on the Port of Mobile and ecologically dependent on the extensive marsh system.

Leveraging Opportunities

The Bay Channel bisects Mobile Bay from north to south, while the predominant sediment-transport patterns run from east to west in accordance with the prevailing winds, currents, and tidal forces that the sediment encounters after entering the bay from the delta system to the north. Traditional maintenance of the navigation channels removes this sediment from the natural system. Shoreline erosion has been addressed primarily by hardening the shoreline, which in the long term disrupts critical habitat and reduces resilience and adaptability. Solutions that encourage the natural attenuation of material and the planting of vegetation that can adapt to changing conditions would greatly benefit long-term erosion management. The large volume of material dredged annually presents an opportunity to expand the beneficial use of this valuable resource, keeping it in the natural system while maintaining the navigation channels.

Applying Natural Infrastructure

Several EWN solutions that use dredged material have been proposed to address key ecological needs in Mobile Bay. Two of these include creating feeder berms and placing material to create new ecological features or enhance existing ones.

Feeder Berms. These dispersive placement areas use the natural power of the bay to place and distribute material. This strategy relies on natural hydrological cycles to distribute the material after it is placed in key locations throughout the bay and allows the water to place the sediment, accelerating the natural attenuation of material. Feeder berms would reduce the cost and time required for material placement and may even provide better results than mechanical placement because the location and timing of the attenuation would mimic the natural changes of bay forces.

Strategic Placement. The development and enhancement of oyster reefs, tidal marshes, and seagrass beds, whose long decline is due to anthropogenic factors, are key components in the ecological restoration of the bay. These projects could use a mix of mechanical placements in the bay, allowing for natural processes to distribute the material.

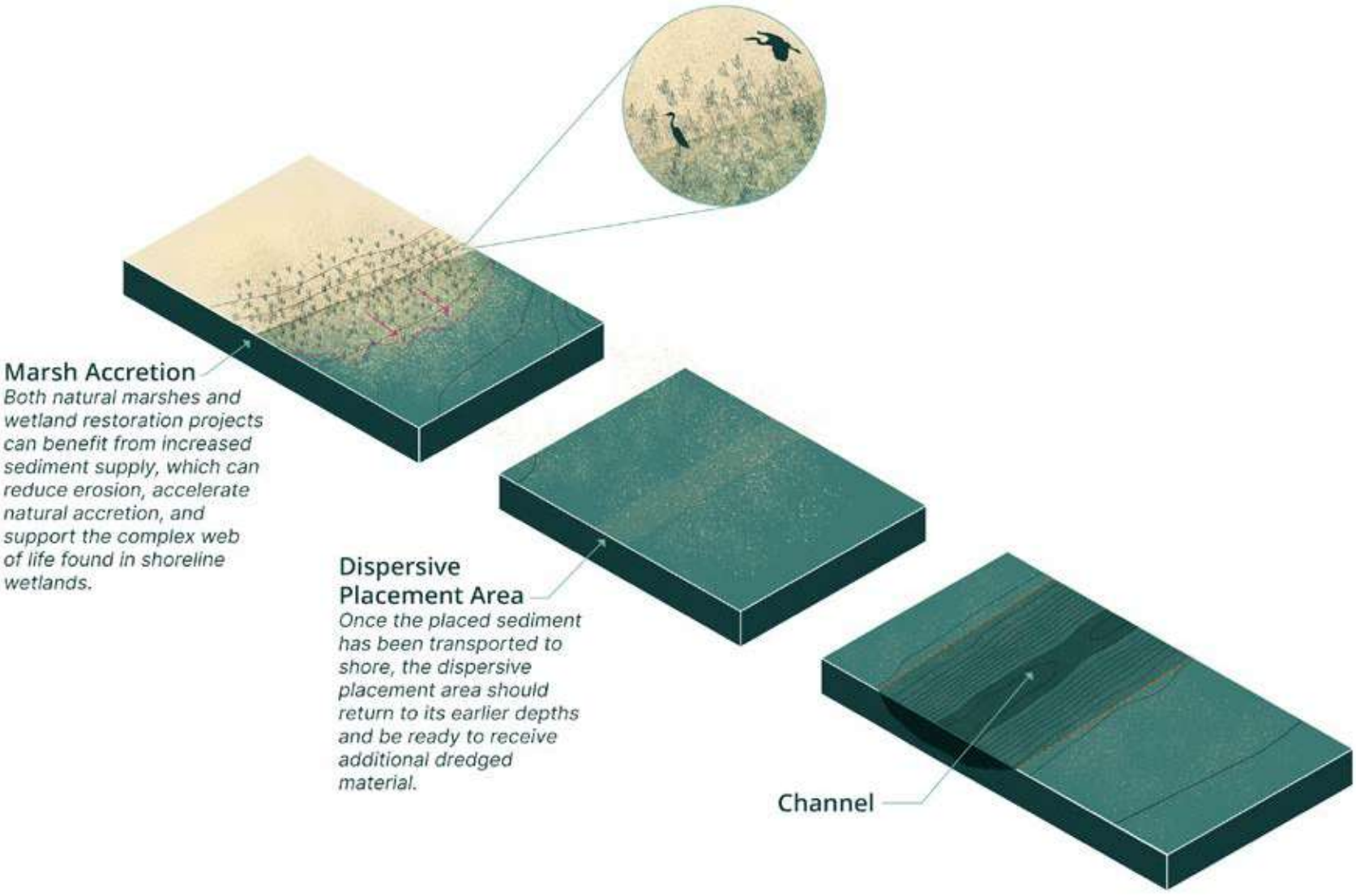


Image courtesy of the EWN-LA Design Research Initiative



Photo courtesy of the EWN-LA Design Research Initiative

Recognizing Benefits

Placing dredged material for ecological restoration retains the material in the natural system and may ultimately reduce the transport distance for placement while enhancing the local ecosystem. This also alleviates the dependence on DMCFs and placement areas by reducing the capacity demand. Furthermore, such ecosystem restoration projects provide critical habitat while increasing coastal communities' ecological and anthropogenic resilience against shoreline erosion and other natural hazards.

Advancing Implementation

Several ongoing initiatives and directives in the area align with EWN strategies, such as USACE's directive to increase beneficial use and the ongoing restoration efforts of the USACE Mobile District, the Mobile Bay National Estuary Program, and The Nature Conservancy in Alabama. Working with such entities, while increasing the involvement of additional stakeholders, including neighbors, property owners, and local governments, will provide a path toward long-term success of EWN in Mobile Bay.



USACE Mobile District maintains approximately 6 million cubic yards annually of dredged material from Mobile Harbor, with 4 million cubic yards explicitly coming from the Bay Channel. This dredged material has to be placed in an upland facility or beneficially used.[13]

Shoreline Restoration
Fort Morgan Peninsula

CONCEPT HIGHLIGHTS

Layering habitat types across constructed elevation changes to provide stability and increased wave dissipation

Assessing the use of erodible berms, beach ridges, and subtidal oyster reefs

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Infrastructure found between coastlines and wetland regions are at increased flood risk and can benefit from natural solutions, specifically habitat restoration, to increase future inundation. (Photo courtesy of the EWN-LA Design Research Initiative)



Areas of low elevations combined with the effects of rising tides threaten beach ridges like Fort Morgan Peninsula, seen here. (Photo courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Fort Morgan Peninsula, at the mouth of Mobile Bay, is exposed to inundation during coastal storms. The peninsula is a mix of residential areas and protected wildlife refuge with shorelines that are either hardened in developed areas or characterized by tidal marshes with sand beach margins and the intricate ridge-and-valley topography of relic beach ridges. Like most other shorelines around Mobile Bay, these shorelines face substantial erosion that will likely increase as flood risks accelerate in the coming decades. Advancing water levels also presents significant challenges to habitat management because the area is marked by very low elevations that could transition to subtidal habitat with even relatively low rising water levels. A great deal of biodiversity and ecological productivity are at risk, and the loss of these habitats would increase the exposure of the peninsula's inhabitants to storms and flooding. Strategic placement of dredged material could provide additional resilience and erosion resistance for this invaluable location.

Leveraging Opportunities

Fort Morgan Peninsula experiences significant erosion along its shorelines. This erosion is exacerbated by the presence of hardened shorelines, which protect a small portion of shoreline in the short term but reduce adaptability, remove habitat, and cause adjacent shorelines to erode more severely. EWN approaches could be used in several ways to protect the area from further erosion.

Applying Natural Infrastructure

Several EWN solutions have been proposed to reduce erosion and provide habitat for wildlife: erodible berms, constructed beach ridges, and subtidal oyster reefs.

Erodible Berms. These structures constructed near the shore and farther offshore would disperse erosive wave energy and encourage the deposition and accretion of sediment. Nearshore berms would build up the current beach, while offshore berms would create an area of low wave energy to encourage deposition. This new area of accretion could then be leveraged for marsh plantings to increase the stability of the sediment.

Beach Ridges. They are constructed of coarse-grained material and fine dredged material would be placed, allowing nature's energy to transport the material within the system to mimic the old ridges that have eroded. This would include layering different habitat types, such as beach, marsh, and forest, across constructed elevation changes to provide stability and wave dissipation.[14]

Subtidal Oyster Reefs. These reefs provide multiple benefits, including a natural habitat for increased biodiversity, protection from incoming wave energy, and a reduction in sediment lost to deeper basins from shoreline erosion. Subtidal oyster reef systems can be oriented to naturally retain sediment behind or among the reefs, thereby supporting seagrass and marsh habitats and protecting the resident wildlife.

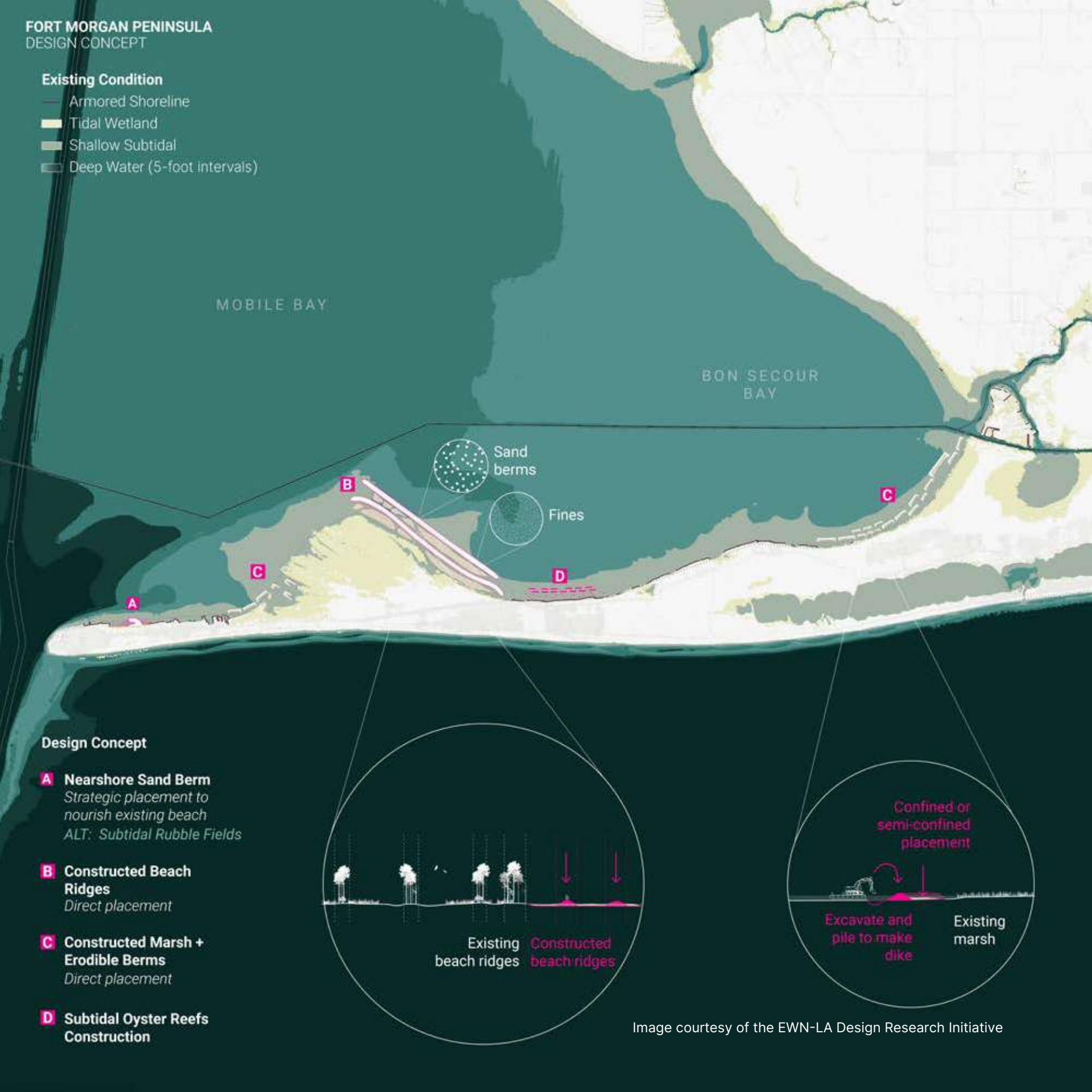


Image courtesy of the EWN-LA Design Research Initiative



Image courtesy of the EWN-LA
Design Research Initiative

Recognizing Benefits

The beach ridges and erodible berm are designed to be altered by natural processes to produce over time a landscape that is increasingly linked to the natural system both functionally and aesthetically. The EWN concepts proposed could significantly reduce near-term erosion and would likely encourage deposition and accretion that would help protect human and animal residents of Fort Morgan Peninsula from rising water levels.

Advancing Implementation

Early assessment of these EWN solutions indicate they would be viable. Further assessment, modeling, and stakeholder outreach will be essential for selecting and designing NNBF. Coordinating with landowners on the peninsula, including the U.S. Fish and Wildlife Service, which manages the Bon Secour National Wildlife Refuge, will be instrumental in successfully implementing the solutions. EWN in this location, in conjunction with the strategies outlined for the entire USACE Mobile District, could be leveraged to create a holistic plan for maximum impact on the region.

Natural and Nature-Based Features Assessment

Perdido Bay

CONCEPT HIGHLIGHTS

Proposing NNBF to combat erosion and improve resiliency to storms and rising tides

Offering EWN solutions, such as seagrass habitats and augmentation, oyster reefs, and marsh creation

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative

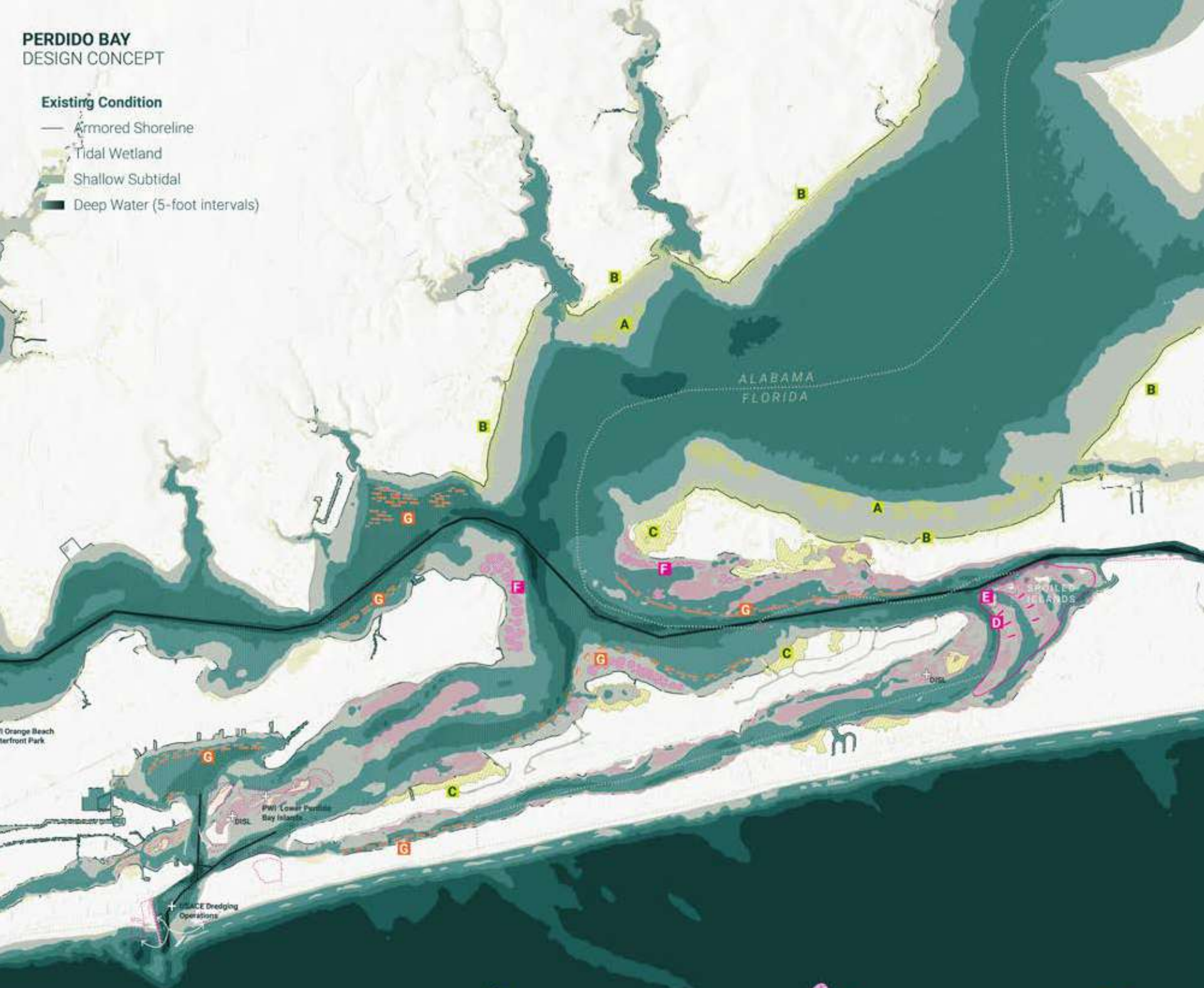


Image courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

Perdido Bay is a relatively small bay at the mouth of the Perdido River on the border of Alabama and Florida. The main economy in this region is recreation and tourism. USACE's *South Atlantic Coastal Study* of the region's flood and storm risk showed the bay is particularly vulnerable to the effects of natural hazards, such as rising tides and increased storm intensity, because a high percentage of its shoreline is hardened.[15] Using EWN concepts to promote ecological restoration can combat the effects of coastal erosion while increasing resilience to natural hazard impacts.

Leveraging Opportunities

A large portion of the Perdido Bay shoreline has been armored or hardened, which has removed critical habitat and reduced long-term resiliency, leaving it vulnerable to storms and increased flooding hazards while increasing the erosion of adjacent nonarmored shoreline areas. Seagrass beds in the bay have been significantly reduced in size and number, leading to concerns that water quality may degrade in the future if deepening of the seagrass beds prevents sufficient light from reaching the plants. But substantial effort has already been undertaken to ameliorate the bay's water quality by reducing point-source pollution. This has produced a significant rebound of seagrass in the bay. Additionally, EWN has contributed to providing a more resilient and adaptable solution to offset these impacts by using the surplus of dredged material in the region.

Applying Natural Infrastructure

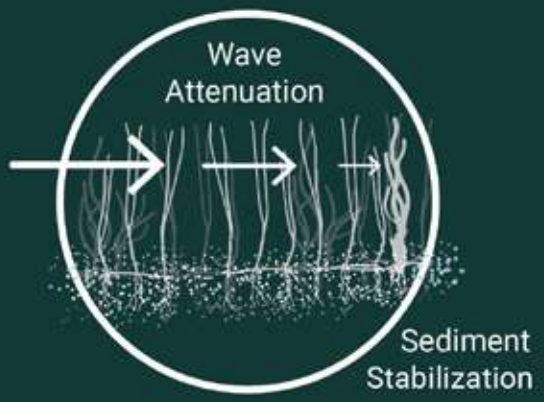
The several EWN solutions proposed for Perdido Bay include seagrass bed augmentation, oyster reefs, and marsh creation.

Seagrass Augmentation. This approach would require a multipronged strategy, including constructing subtidal berms, placing material to augment elevation, and planting seagrass. Subtidal berms, which could beneficially reuse dredged material, would be built where the elevation is sufficient but the wave energy is too great for plants to take root. Dredged material could also be used to raise the elevation of areas where current elevation and natural accretion are insufficient for seagrass to root.

Oyster Reefs. They could be installed where bay water is sufficiently salty and waterways are too narrow to support more horizontally extensive features or where reefs at the outer edges of shoals could reduce erosion and encourage sediment deposition.

Marsh Creation. It is feasible in some unvegetated shallows where dredged material can be placed directly to construct relatively large marsh islands. In other cases, thin-layer placement of dredged fines could accelerate in situ marsh accretion and facilitate adaptation to flood risks.

COASTAL PROTECTION



Seagrasses prevent erosion and protect from storm surge

SPAWNING + NURSERY HABITAT

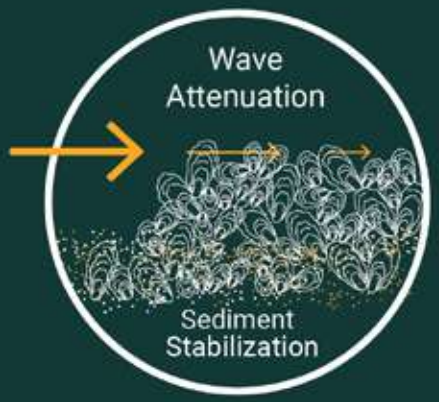


Juvenile fish feed and seek shelter in seagrasses

FOOD WEB SUPPORT

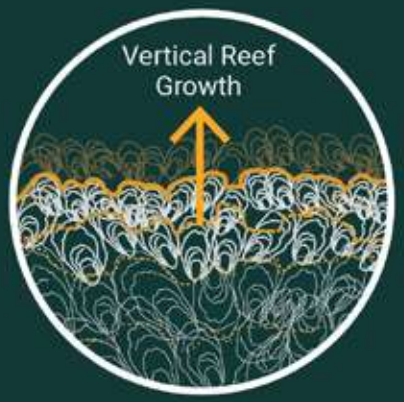
Aquatic fauna and fisheries production rely on seagrasses

COASTAL PROTECTION



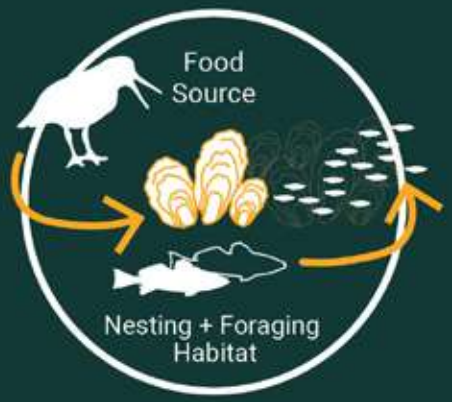
Oyster reefs can reduce erosion and serve as barriers to storms and tides

CLIMATE RESILIENCE



Oyster reefs are self-perpetuating and can potentially keep pace with sea level rise

HABITAT CREATION

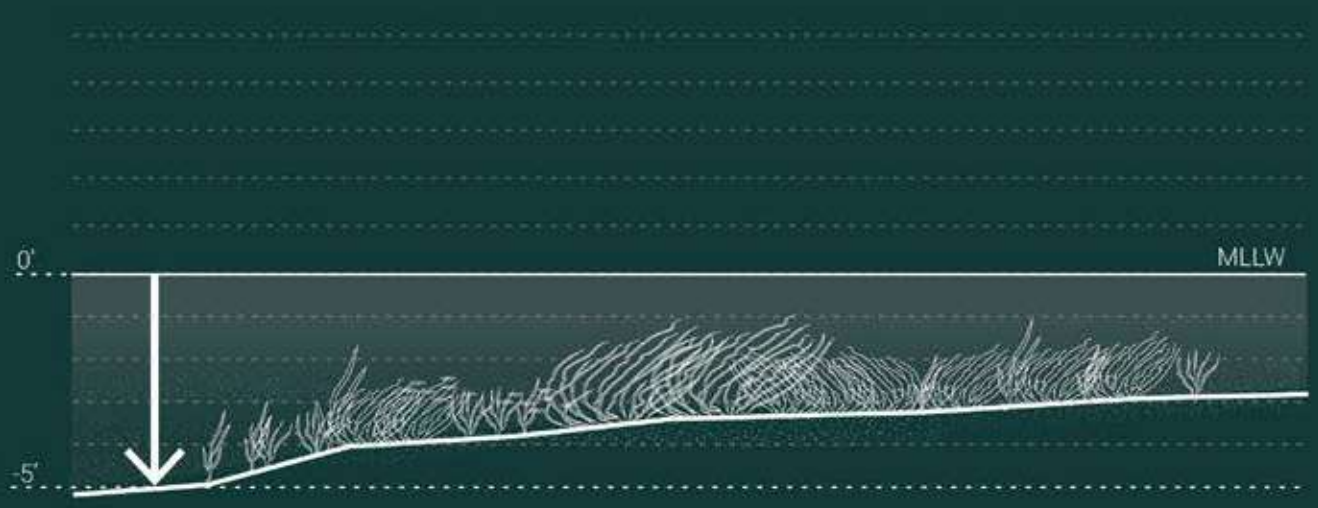


Oyster reefs are essential fish habitat and serve as prey for other animals

Image courtesy of the EWN-LA Design Research Initiative

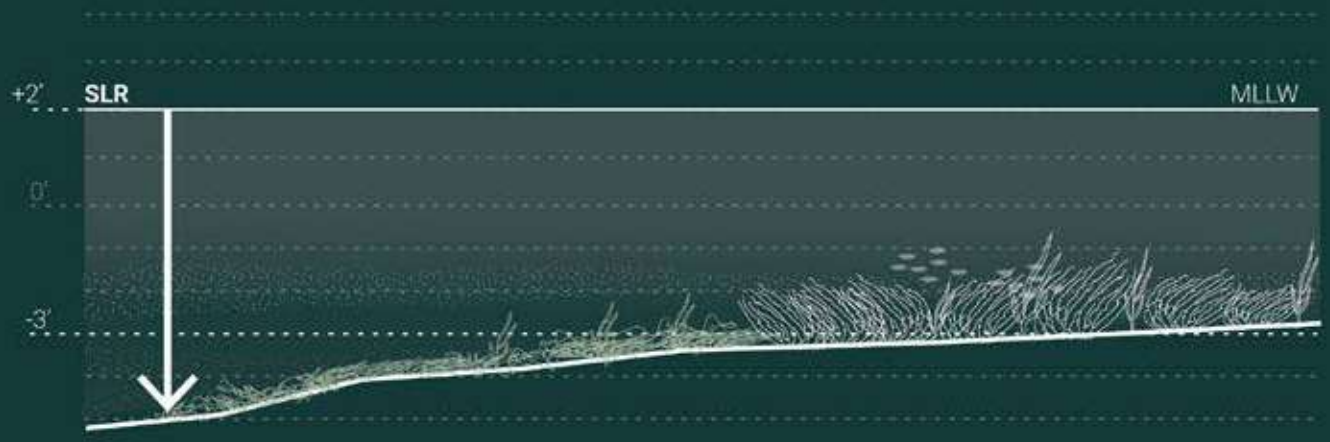
PRESENT DAY

Seagrasses succeed in calm, clear, shallow waters with enough sunlight



FUTURE WITHOUT PROJECT

With rising tides, the amount of light reaching seagrasses is reduced and the habitat risks drowning



FUTURE WITH PROJECT

Beneficial use of material can accelerate seagrass acretion rate and help the elevation keep pace with rising tides

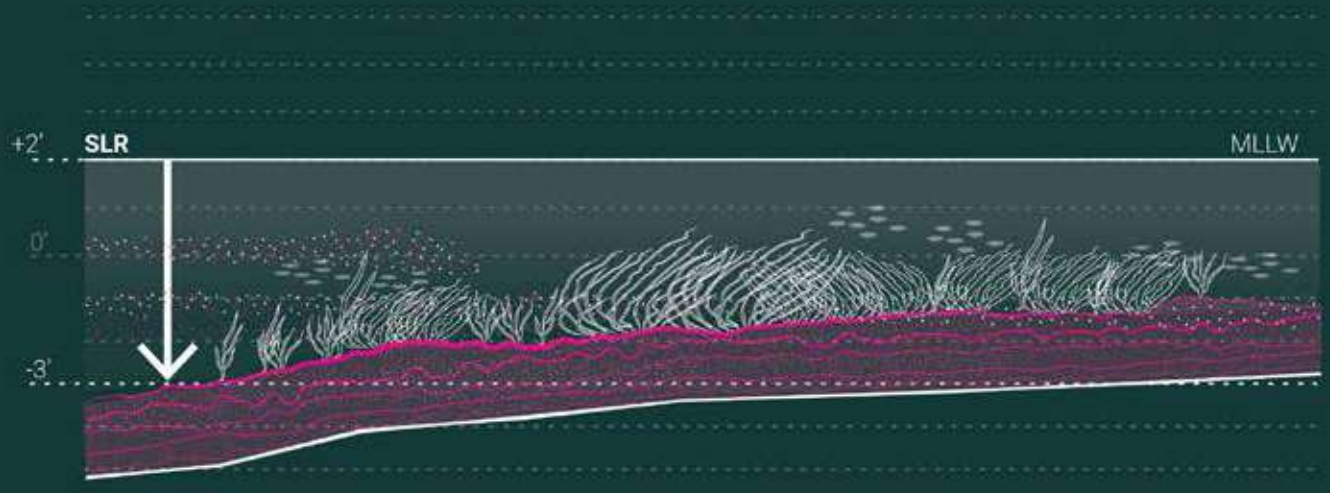


Image courtesy of the EWN-LA Design Research Initiative

Recognizing Benefits

EWN provides increased resilience and adaptability in the face of climatological changes. Unlike shoreline armoring, EWN can provide habitat for displaced wildlife and, in turn, increase biodiversity in surrounding areas in addition to providing multiple layers of defense against changes in sea level. Oyster reefs can be built in heavily trafficked areas where larger projects would be impractical. They would reduce erosion and encourage deposition in these areas, which could then become valuable for marshes and seagrass beds.

Advancing Implementation

Many stakeholder organizations are already deeply engaged in ecological work in the area, and coordinating and pooling resources with them will be important to achieving success in Perdido Bay. A low percentage of dredged material is currently beneficially used, creating an opportunity to increase the beneficial use of this natural resource. Obtaining additional funding to procure enough sediment to construct NNBF and new beneficial use options will be the biggest challenge and is key to advancing implementation. Appropriate governmental partnerships and grants may prove to be a valuable source of capital funds.



Image courtesy of the EWN-LA Design Research Initiative

Philadelphia District

Ecosystem Management
New Jersey Back Bays

Dunes and Nearshore Maintenance
Atlantic Coast, New Jersey and Delaware

Beneficial Use of Dredged Material
Cape May, New Jersey, Dredged Material Containment Facilities

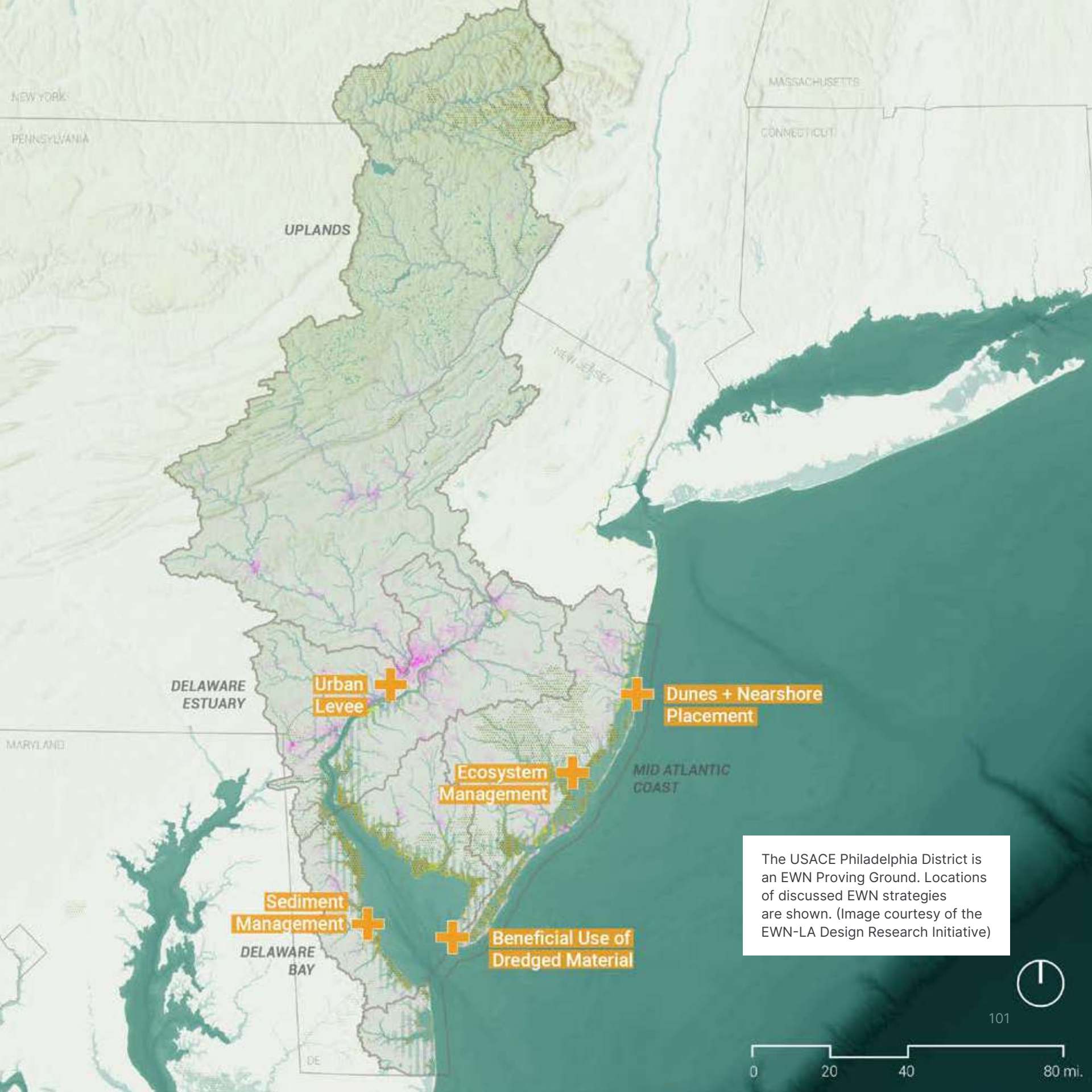
Urban Levee
Eastwick, Pennsylvania

Sediment Management
Murderkill River, Delaware

Maintaining more than 550 miles of navigable waterways in systems ranging from inland bays to coastal plains and from rural to densely populated urban areas, the USACE Philadelphia District presents unique opportunities for natural infrastructure. These include ecosystem restoration for FRM, beneficial use of dredged material for shoreline restoration and sustainability promotion, strategic management of coastal dunes for storm risk mitigation, urban levee construction for fluvial FRM, and overall sustainable sediment management.

Located in USACE's North Atlantic Division, the USACE Philadelphia District was established in 1866 and originally covered the Delaware River Watershed to the adjacent Atlantic Coastal Plain. With 150 miles of coastline and 1.1 million acres of wetlands, the district currently supports more than 9 million people in portions of New York, Pennsylvania, New Jersey, Delaware, and Maryland. The district comprises five physiographic regions: the Appalachian Plateau, Ridge Valley, New England, Piedmont, and the Atlantic Coastal Plain.[16]

A major theme running through the history of the district is "responsiveness to change, to the Army, to Congress, and to its customers' needs."[17] The district has supported projects at the state and local levels and has worked with the U.S. Environmental Protection Agency (USEPA), the U.S. Coast Guard, the Federal Emergency Management Agency, the Federal Aviation Administration, and the City of Philadelphia. In addition to maintaining navigable waterways and protecting communities from coastal storm and flood threats, the USACE Philadelphia District has expanded its environmental services beyond regulatory permitting to support the USEPA Superfund program and to include components of ecosystem restoration in its civil works program.[18] Natural infrastructure can be integrated into these various programs, where policy and regulations allows, or can provide complementary benefits for support projects.



The USACE Philadelphia District is an EWN Proving Ground. Locations of discussed EWN strategies are shown. (Image courtesy of the EWN-LA Design Research Initiative)

Ecosystem Management
New Jersey Back Bays

CONCEPT HIGHLIGHTS

Modeling storm surge reduction in the presence of structures incorporating NNBF

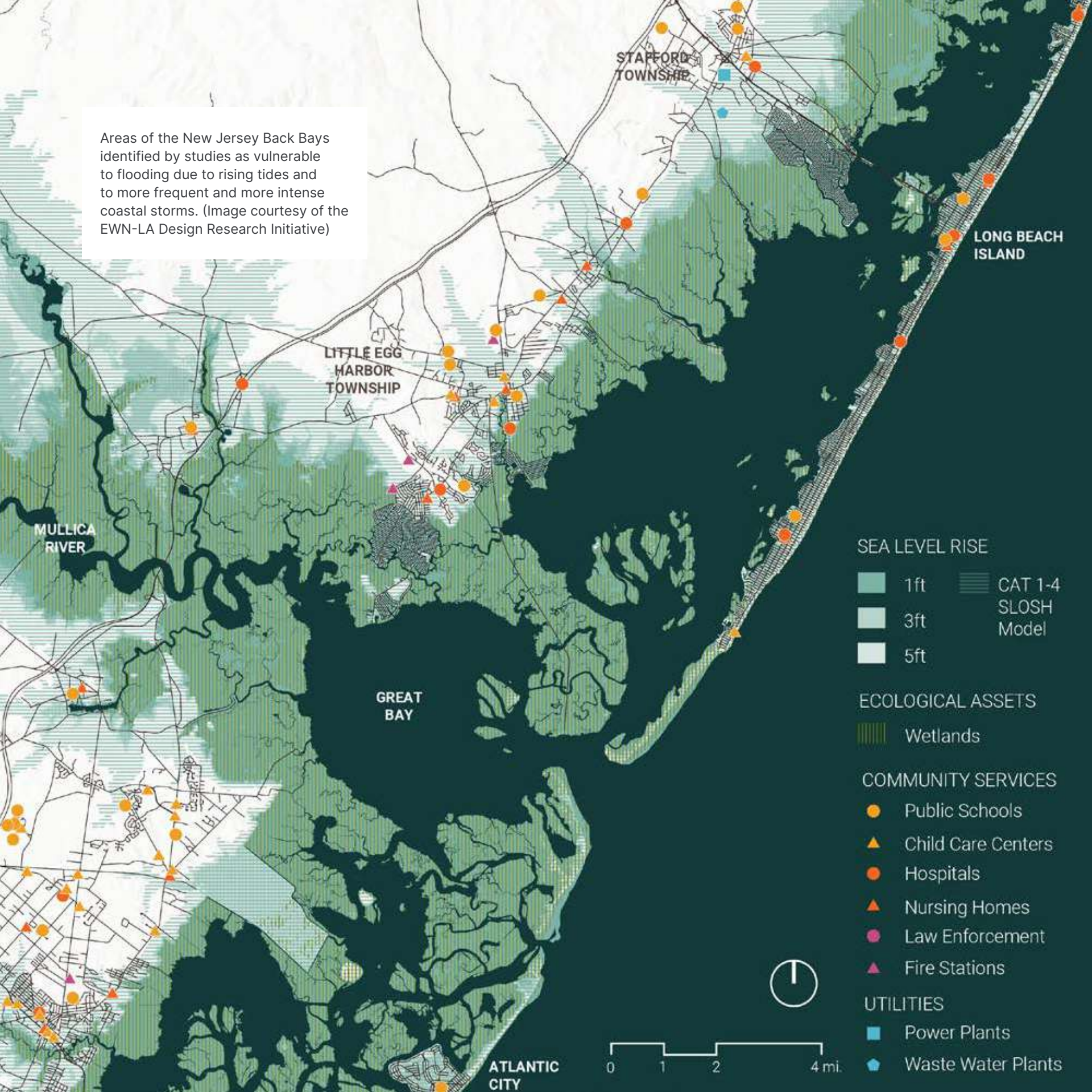
Using intentional wetland sloping, chevron cluster structures, and storm surge dissipation

KEY EWN FEATURES

- **Coastal and Flood Resiliency**
- **Habitat Creation or Restoration**
- **Beneficial Use of Dredged Material**
- Social Connectivity
- **Community Engagement**
- **Educational Opportunity**



The proximity of this project to recreational areas and urban infrastructure provides a general educational opportunity for the public and requires extensive community engagement. (Image courtesy of the EWN-LA Design Research Initiative)



Areas of the New Jersey Back Bays identified by studies as vulnerable to flooding due to rising tides and to more frequent and more intense coastal storms. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

The New Jersey Back Bays, an area of marsh and wetland estuarine ecosystems, are located along the eastern shore of New Jersey and behind the New Jersey barrier islands of Monmouth, Ocean, Atlantic, Burlington, and Cape May counties. This region has been historically susceptible to flooding from events like Hurricane Sandy in 2012, where storm surge flowed through coastal inlets into the back bay region, impacting neighborhoods up and down the coast. These coastal storms continue to increase in frequency and intensity as a result of natural hazards and rising tides, necessitating coastal storm risk management and resilience planning in the area.[19] Solutions using NNBF have the potential to improve FRM strategies for multiple lines of defense to reduce storm surge and flood impacts from Little Egg Inlet north into Barnegat Bay. This section explores conceptual strategies that are independent of other initiatives in the region but may be used to supplement or complement them as feasible.

Leveraging Opportunities

Historical storms, including Hurricane Sandy, have significantly affected the communities in the back bays of coastal New Jersey. The area of interest, including Great Bay and Little Egg Harbor, periodically experiences high storm surge and increased flooding. Notably, storms push significant volumes of water into the back bay system, increasing water levels. Immediate impacts and associated flooding are experienced until conditions improve to allow the water to flush back out of the bay. Various initiatives at the federal, state, and local levels are exploring opportunities to improve the region's resiliency and manage the flood risk associated with storms. The existing landscape comprises the beaches and dunes in the open ocean and tidal marsh ecosystems and islands situated along the back bays. These myriad features present an opportunity to enhance these back bay systems with NNBF to better support FRM for the coastal communities. Conceptual NNBF could be implemented alongside an array of structural and nonstructural measures.

Applying Natural Infrastructure

Strategic placement of NNBF throughout the back bay system and innovative ideas to slow down storm surge should be explored and, when appropriate, could be constructed out of dredged material. The impact and benefits of NNBF should be interactively considered as part of system-wide strategies for the region and iteratively assessed to maximize benefits. Potential alternatives, such as chevron features, wetland slopes, and flow-path realignments, present opportunities to slow the surge of water into the back bays. Storm surge reduction attributable to NNBF should be iteratively investigated through a modeling approach to discern what mitigation technique would be possible.

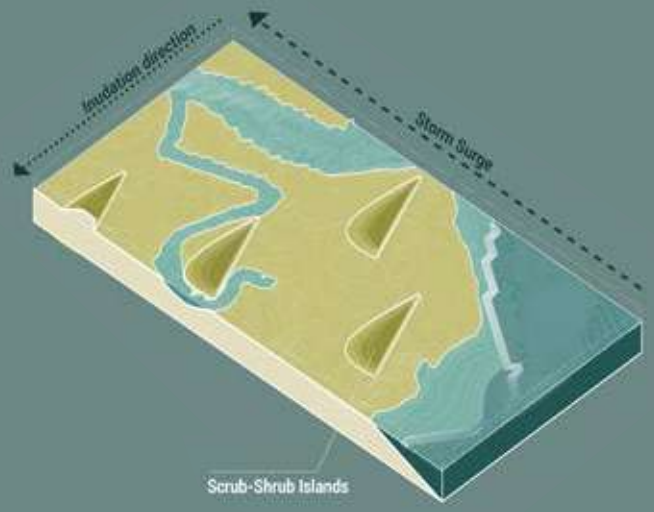
Wetland Slopes. Intentional wetland sloping would be created and encouraged with strategic substrate placement and vegetation establishment to stabilize slopes, redirect surge toward the center of the bays, and reduce inundation time across the wetland. The configuration and geometry of the desired wetlands would need to be iteratively modeled to refine the storage retention and flow redirection impacts.

Chevron Clusters. These structures capture sediment and reduce storm surge that may inundate the wetland. Orientation of the centerline of the chevron would consider the predominant storm surge angle entering the inlet as well as wind moving across the wetland. The scale, location, orientation, and complexity of the chevrons would need to be iteratively modeled to maximize impact.

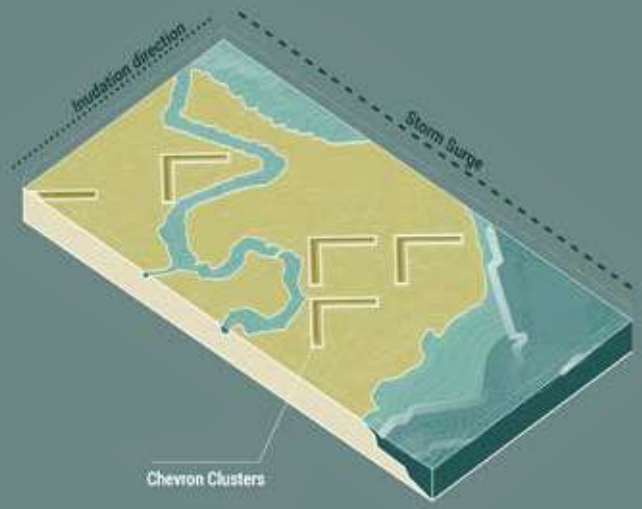
Storm Surge Dissipation. These channelization alternatives could be considered to facilitate storm surge dissipation through the bay rather than to further exacerbate the barrier bar by traveling through the primary navigation channel. Orientation efforts would include aligning the inlet of the flood relief channel toward the south and lengthening land features to further encourage westward movement.

Right. The nature-based components emphasize the use of natural material rather than hard gray infrastructure. The shape and orientation are presented to maximize beneficial outcomes that would likely take a more natural shape as natural processes interact with the system. (Image courtesy of the EWN-LA Design Research Initiative)

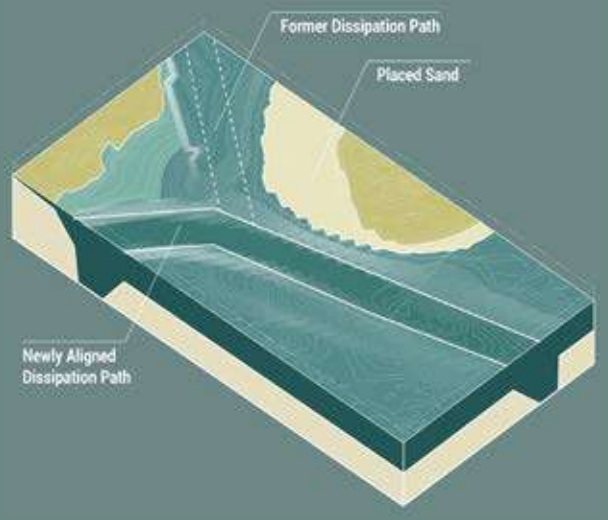
WETLAND SLOPES

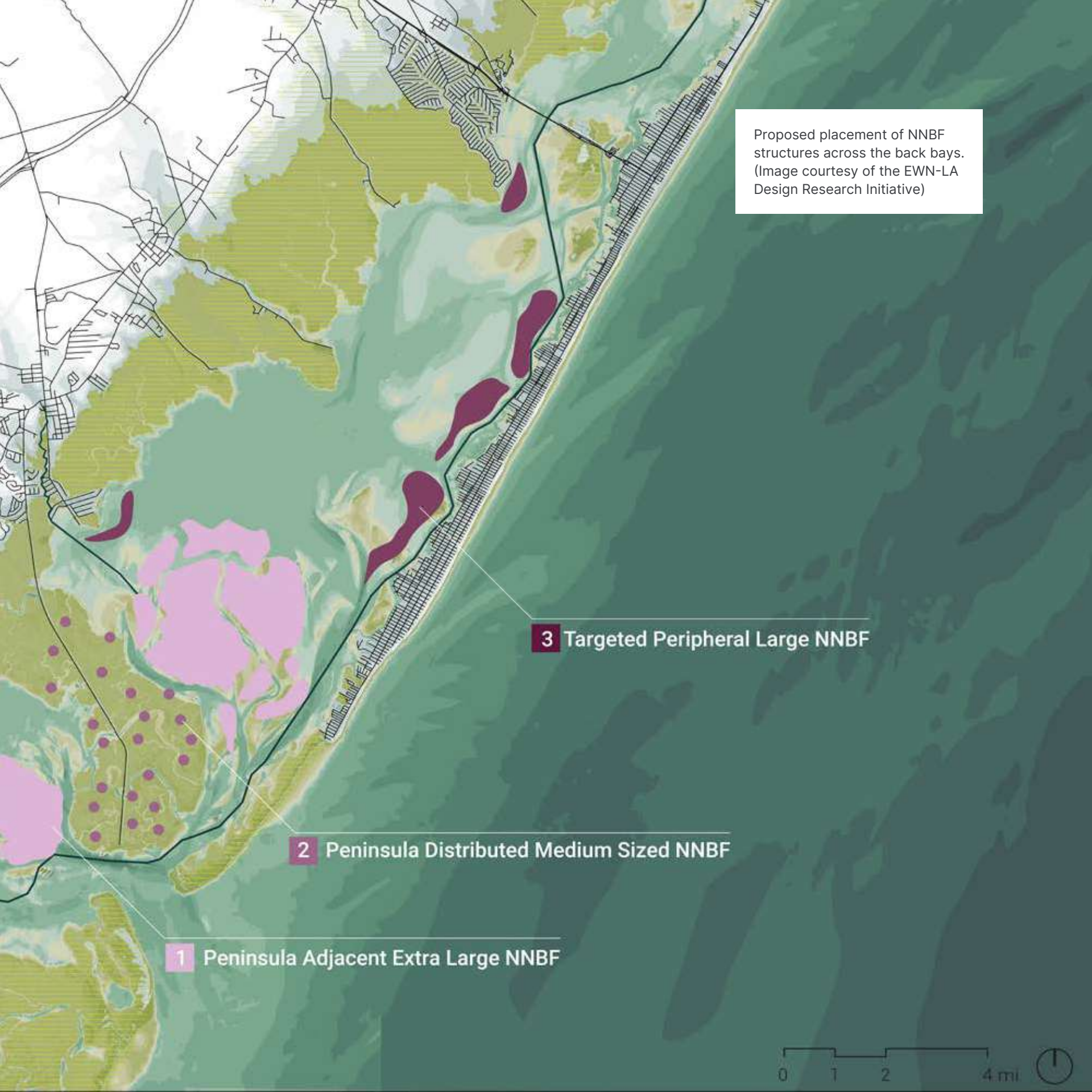


CHEVRON CLUSTERS



STORM SURGE DISSIPATION





Proposed placement of NNBF structures across the back bays. (Image courtesy of the EWN-LA Design Research Initiative)

Recognizing Benefits

The existing multiple lines of defense against coastal storms—beaches and dunes, back bays, and coastal community enhancements—along with the structural and nonstructural interventions to mitigate storm surge impacts can be further enhanced by NNBF. EWN strategies to manage the flow of water through the natural and manufactured systems and to minimize risk to adjacent communities will be necessary. The conceptual idea behind directional interventions encourages mitigation of storm surge on the storm-facing side of the coast while accommodating the passage of water on the backside.

Advancing Implementation

The scale and complexity of the solution will need to reflect the problem. In this scenario, it is likely that a structural, nonstructural, or natural infrastructure approach alone will not address the challenges posed by storms. Integration of concurrent initiatives will provide the greatest benefit to the region. When used in concert, structural, nonstructural, and natural infrastructure approaches will provide maximum protection. Integrating such a wide range of solutions will require extensive stakeholder engagement and collaboration to manage and assess their overall benefits.

Dunes and Nearshore Maintenance

Atlantic Coast

CONCEPT HIGHLIGHTS

Researching resilient dunes, focused on the benefits of vegetation diversity, placement, and integration

Researching dune stabilization techniques, including seabale cores

Implementing plant diversity, dune morphology, and innovative core construction to enhance natural dune systems

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of Georganna Collins



Dunes on the Atlantic coast benefit from vegetation, which increases stability and overall resilience. (Photo courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Dunes are nature's way of providing coastal protection against storm surge and extreme events. Regarded as one of the most economical and aesthetically pleasing coastal protection measures, dunes are largely preferred over seawalls, rock revetments, and other traditional hardened shoreline stabilization structures because of their ability to dissipate wave energy rather than reflect waves onto beaches or neighboring properties.[20] Dunes are dynamic, complex systems that are formed and shaped by the wind and the waves. Technical strategies to make dunes more robust, such as vegetation variation, core construction techniques, and dimensional design features, could be explored to use this natural coastal protection system more effectively.

Leveraging Opportunities

The USACE Philadelphia District is instrumental in maintaining the New Jersey and Delaware coastline from Manasquan Inlet south to Fenwick Isle. Projects typically involve constructing dune-and-berm systems intended to reduce the risk of storm damage. The beaches associated with these dune systems offer recreational and ecological value to the region while providing protection to the coastal communities. While maintenance to these natural systems is both recognized and encouraged, additional reinforcement may be necessary to provide greater protection and evolve with the continually changing extreme weather impacts.

Applying Natural Infrastructure

Various strategies can be considered to enhance the natural dune systems, including variation in native plant diversity, dune morphology and design template, and innovative core construction strategies.

Plant Diversity. High-density vegetation atop dunes can significantly improve dune resistance during erosional events. Greater native plant density and extensive root systems allow for higher root mass in the dune itself, leading to greater compaction, which helps reduce scarping and erosion.

Dune Morphology. The combination of a wider beach berm and wider dunes can increase the dissipation of wave energy, resulting in reduced wave heights at the dune toe. This allows dunes to endure longer attacks from storm waves, as any sediment lost to dune recession increases the width of the beach berm, prolonging dune life under given conditions when compared to a taller, narrower dune morphology.

Innovative Core Construction. Although planting vegetation atop dunes has become an accepted way to extend dune life, variations in the core construction of the dune can also be considered. The dynamic and adaptive nature of dune morphology should be considered and further assessed in core variation designs. Adding more-resilient cores to the dunes (such as geobags filled with sand or dredged material, rubble mound material, or *Sargassum*) to offer protection from extreme storms is being studied and offers an educational opportunity in innovative approaches for increasing dune resiliency. The idea is that such core structures will be visible only during the extreme weather events and will be covered with beach-quality sands as part of poststorm restoration.[21]

WILDLIFE BENEFITS



Seaside Goldenrod
(*Solidago sempervirens*)
is an important food source for **monarch butterflies** migrating along the Atlantic Coastal Flyway during fall.



Coastal Panicgrass
(*Panicum amarum Elliot* var. *amarulum*)
produces calorie-dense seeds that are an important food source for **songbirds, waterfowl, and small mammals** during the fall and winter.



Coastal Little Bluestem
(*Schizachyrium littorale* (Nash) Bickn.)
has a symbiotic relationship with **ghost crabs**, who collect and store little bluestem seed heads in their dune burrows.



Image courtesy of the EWN-LA Design Research Initiative





Sprawling dune systems on the Atlantic shores are crucial to the successful health and longevity of coastal communities. (Photo courtesy of the EWN-LA Design Research Initiative)

Recognizing Benefits

The natural dune system is dynamic by nature, and resilient solutions using dunes will need to consider this. Improvements to make the dunes more robust and resilient as they pertain to storm risk management will need to allow the dunes to continue to morph as needed while accounting for the effectiveness of the system, the long-term operational and maintenance needs, and the community impact. Integrating innovative approaches to this inherently natural infrastructure approach would further enhance the protective, resilient, and ecologically diverse system.

Advancing Implementation

USACE offers the most widely accepted planning and engineering guidance for the coastal design and implementation community. The ideal way to encourage innovative approaches to coastal resilience using dune and berm systems would be to advance pilot studies with the intent to update the existing USACE *Coastal Engineering Manual* EM 1110-2-1100.[22] Updates to this technical document may require further research studies as well as publication of ancillary guidance documents (e.g., technical notes and reports) that would provide regional assessment and design to account for local conditions.

State and local communities provide significant feedback to systems that serve a resilient purpose but also have recreational and social impacts. A risk and benefits analysis with significant stakeholder engagement early in the process will need to continue to be built into the planning to develop resilient systems that provide social and ecological value. Dune and berm systems should be used in combination with other features and measures to provide the necessary coastal protection while considering community needs.

Beneficial Use of Dredged Material

Cape May Dredged Material Containment Facilities

CONCEPT HIGHLIGHTS

Beneficially using dredged material reclaimed from DMCFs to enhance adjacent habitats and surrounding ecosystems

Using feeder berms, wetland elevation, and a transitional slope to increase capacity

KEY EWN FEATURES

- **Coastal and Flood Resiliency**
- **Habitat Creation or Restoration**
- **Beneficial Use of Dredged Material**
- **Social Connectivity**
- Community Engagement
- **Educational Opportunity**



Photo courtesy of the EWN-LA Design Research Initiative



Beach placement of material from neighboring DMCFs offers a nourishment alternative for vulnerable beaches around Cape May. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

The USACE Philadelphia District maintains navigation channels in the Delaware River and Delaware Bay and along the Atlantic coast. The majority of the material dredged from these channels is placed in upland facilities known as DMCFs. Many of these facilities are positioned along the Atlantic Flyway.

Cape May's beachfront is a popular destination for people and wildlife alike, and its location at the southernmost point of New Jersey leaves it vulnerable to longshore high wave energy from the Atlantic Ocean, high boat traffic from the Delaware Bay, and overall flood risks due to the effects of natural hazards. DMCFs have a finite life span, and as they continue to fill up with dredged material, they present a unique opportunity to reclaim the placed material to enhance the region's ecological value, coastal resilience, and, potentially, social resilience, all while prolonging the lifespan of these functional facilities.

Leveraging Opportunities

There are 11 federal DMCFs along the banks of the Delaware River and Delaware Bay throughout the Atlantic Flyway. Each year, hundreds of thousands of shorebirds stop to rest and feed in the area during migration season. Material from the DMCFs has the potential to be beneficially used to enhance threatened habitats that support these birds and improve nearby recreational areas. This could address threats to the facilities (such as limited operational lifetime, shoreline erosion, and overall capacity) while allowing continued maintenance of the waterways and enhancing the ecological value of the surrounding area.

Applying Natural Infrastructure

Currently, placement in the Cape May DMCF is alternated between the cells to allow adequate settling time for the material. A series of natural infrastructure approaches is recommended to increase the overall capacity of the facility and to address changing shoreline conditions that are creating steep side slopes threatening the stability of the facility. Techniques applicable to the Cape May DMCF could be considered at other facilities.

Feeder Berm. Sand from the DMCF could be used to create a feeder berm along the shoreline of the facility. This berm would provide a source of sediment for the eroding shoreline and natural separation of the sediment presents an opportunity to feed the wetland. In this scenario, the material from the DMCF is beneficially used to increase the life span of the facility while maintaining the habitat critical to the region.

Wetland Elevation. Dredged material placed in the facility naturally separates, with sand settling out and fine-grained material remaining in its water column. The operation of the facility could be modified to use its spillways to transport the finer grained material out of the facility and into the adjacent wetlands to feed that ecosystem. This technique would free space in the facility while using the marsh to improve water quality flowing through the system and sustaining the wetland system to encourage ecological diversity and habitat enhancement.

Transitional Slope. This approach pushes the boundaries of what is considered appropriate for an authorized DMCF by using a series of check dams along the outermost footprint of the facility to filter material as it migrates down the slope to the surrounding landscape and wetland. Material from the facility would be used to create a gradual system that would manage future inflows in a way that keeps the sediment within the natural system.

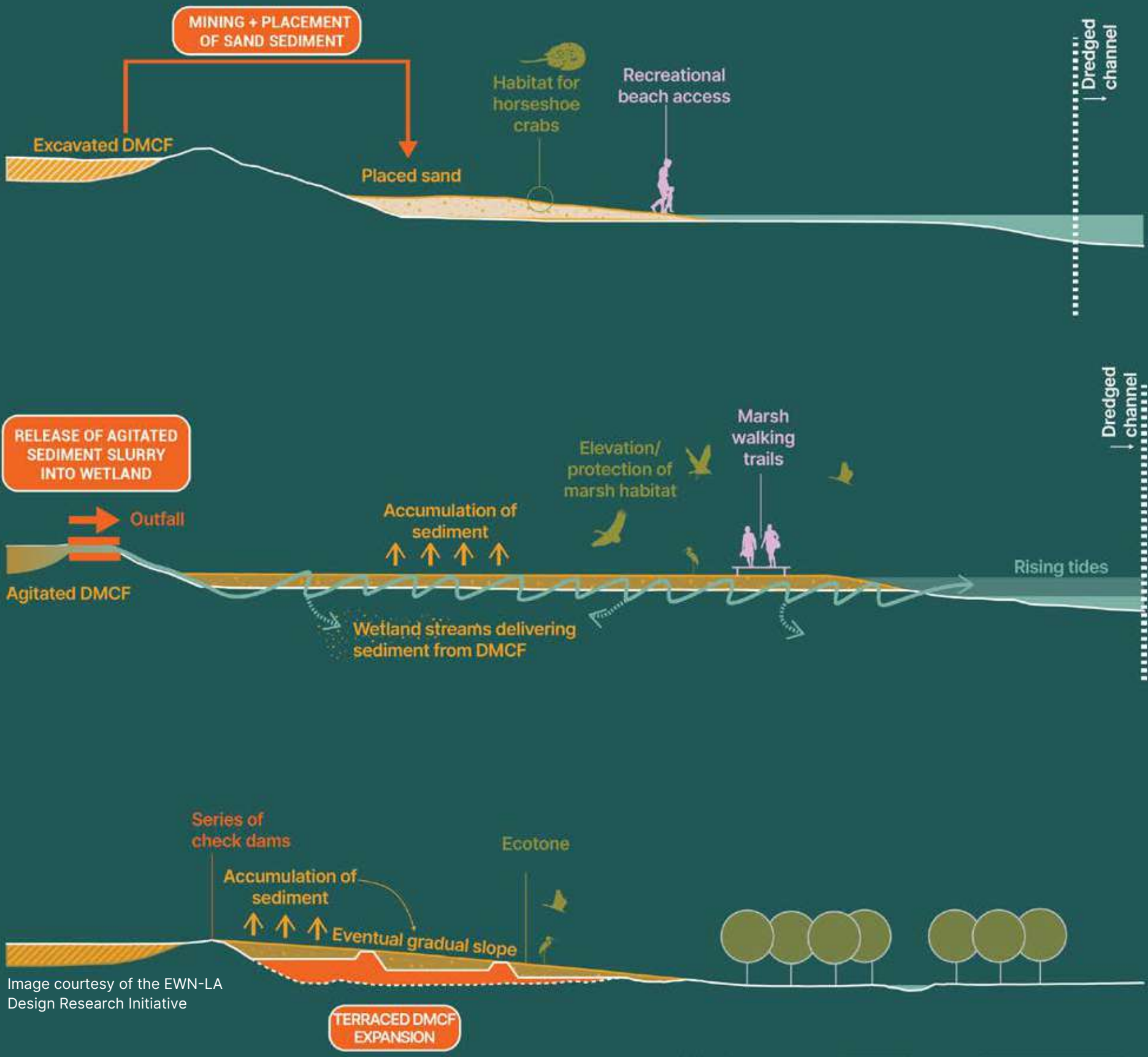
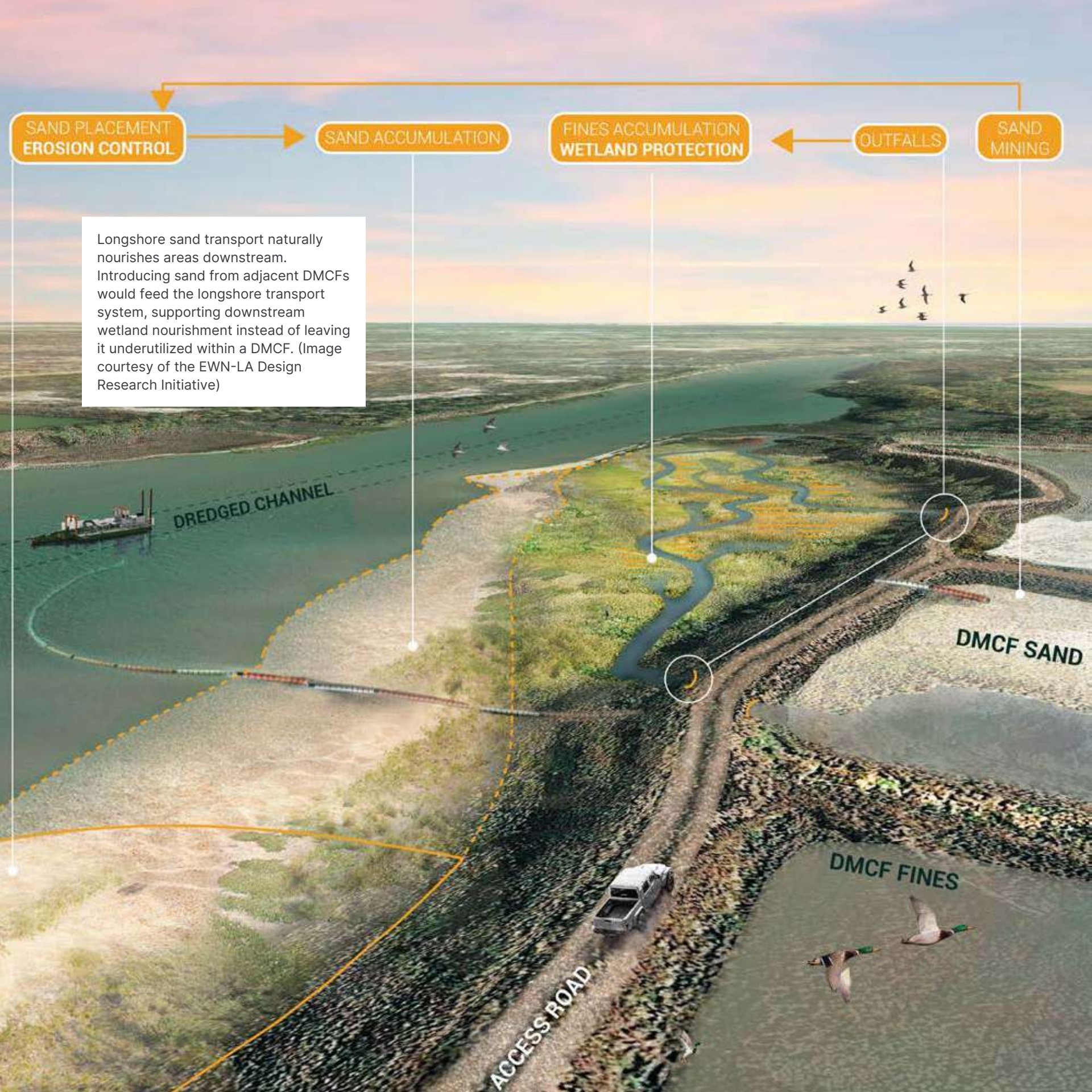


Image courtesy of the EWN-LA Design Research Initiative



Longshore sand transport naturally nourishes areas downstream. Introducing sand from adjacent DMCFs would feed the longshore transport system, supporting downstream wetland nourishment instead of leaving it underutilized within a DMCF. (Image courtesy of the EWN-LA Design Research Initiative)

Recognizing Benefits

Creation of a feeder berm to the north of the western cell will provide shoreline protection and address the ongoing erosion in that area. This berm will also protect the facility and downstream wetlands, provide a beach connection from the jetty, furnish shorebird habitat, and avoid the trapping of horseshoe crabs (*Limulus polyphemus*). Softening the dike line along the eastern cell and adding a direct discharge will allow treated sediment to feed the shoreline with reclaimed material while reintroducing this material into the sediment-transport process, enhancing the wetlands and shoreline downstream. Expected enhancements to the wetland area consist of increased material, habitat creation, and, consequently, the encouragement of more ecological diversity. The feeder berm will protect the discharge points downstream, allowing the sediment to move and stay within the system.

These natural infrastructure approaches to address concerns at the Cape May DMCF may encourage and inspire similar approaches to be implemented in the area. Addressing the unintended consequences of coastal infrastructure through a nature-based lens enhances the beneficial aspects of coastal processes and may even reduce the frequency of future operational maintenance.

Advancing Implementation

As sediment removed from the natural system sits in DMCFs for an indefinite period of time, the threat that these facilities will reach capacity increases. Rather than create new, expensive, and unsustainable DMCFs, use of dredged material reclaimed from the DMCFs could enhance the habitat and ecosystem and provide educational and recreational opportunities. Reclaiming dredged material ensures that the sediment will remain in the natural system while providing additional placement options for dredging navigable waterways.

Logistically, it will be challenging to maintain existing operational facilities and reclaim dredged material while preserving navigation channels. Advanced planning to balance the maintenance dredging cycle with the timeline for reclaiming dredged material will be required. In addition, end uses of the beneficially used material will need to be confirmed, designed, and permitted to prepare for implementation. A process-oriented, system-wide approach may be required through the planning, design, dredging, placement, monitoring, and maintenance life cycles so that the system can be adaptively managed for the largest positive regional net impact.

Urban Levee

Eastwick

CONCEPT HIGHLIGHTS

Combining traditional FRM strategies and NNBF to increase ecological, social, and aesthetic benefits

Integrating a proposed levee with existing and new trails and paths that further connect to established points of interest

Incorporating ecological enhancements, fostering social connectivity, and optimizing viewshed and aesthetic appeal

KEY EWN FEATURES

- **Coastal and Flood Resiliency**
- **Habitat Creation or Restoration**
- Beneficial Use of Dredged Material
- **Social Connectivity**
- **Community Engagement**
- **Educational Opportunity**



Photo courtesy of the EWN-LA Design Research Initiative



Image courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

Urban levees are becoming increasingly necessary as rising tides and increased impervious areas, paired with greater storm intensity and frequency, result in multiple flooding sources for urban developed communities. For example, Eastwick is one of the lowest-lying communities in Philadelphia. Built atop 6,000 acres of historical wetlands, Eastwick has been prone to flooding because of its low elevation and proximity to Darby and Cobbs Creeks and the Delaware River. Today, the densely built residential neighborhood is experiencing increases in the frequency, duration, and intensity of riverine and marsh flooding during storms. In addition to environmental threats, Eastwick residents have a complicated history with the decisions surrounding the land and community.[23]

Four major kinds of flooding endanger the Eastwick neighborhood: riverine, coastal, tidal, and stormwater.[24] Combined flooding from any or all of these sources threatens residents and infrastructure. Riverine flooding is the most acute form of flood risk threatening the Eastwick community, prompting reinforcement specifically to Cobbs Creek and associated historical overflow. After evaluating multiple FRM measures, USACE proposed constructing levees because of their cost effectiveness, reduced risk to homes, and minimal impact on community cohesion. Levees are earthen embankments used to protect land that is normally dry but may be flooded when rainfall or storm surge raises water levels in a nearby body of water. Although levees do not eliminate flooding, they do provide a physical barrier between rising water and threatened property, wildlife, and people.

Leveraging Opportunities

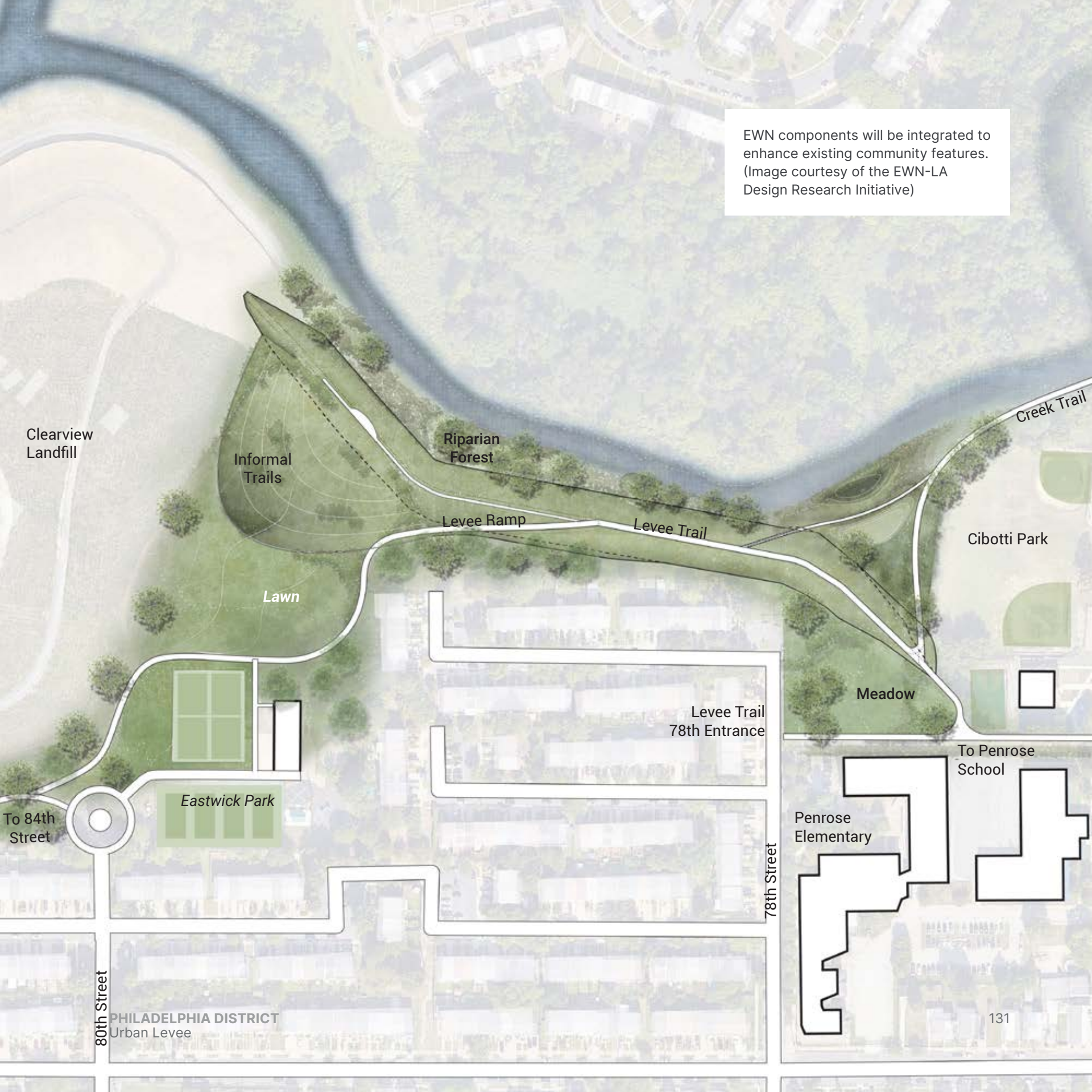
FRM projects that included nature-based components have experienced higher levels of preparedness, greater resistance, quicker recovery, and the ability to adapt to flooding. A holistic approach to traditional levee design can be invaluable to a community experiencing recurring and intensifying floods and can enhance the ecological and social value of a project. The combination of a comprehensive FRM strategy and NNBF can increase the ecological, social, and aesthetic benefits of the protection system.

Applying Natural Infrastructure

Ecological Enhancements. A levee alignment set back from the shoreline presents an opportunity to increase the ecological value of the levee by maximizing creek-adjacent wetlands and riparian buffers to improve overall river connectivity and to increase flood protection. Complementary measures with this alignment would preserve as much as feasible of the upland wetlands constructed during prior restoration efforts, minimize impacts to the existing riparian forest habitat to the north, and reduce the overall levee footprint.

Social Connectivity. The Eastwick community has historically used the area along the creeks recreationally and socially through a series of open spaces and trail systems. Complementary measures focused on maintaining this social connectivity while providing FRM (including ramps compliant with the Americans with Disabilities Act, bicycle paths, and pedestrian trails) and diversification of spaces for public use (e.g., an amphitheater, a lawn, and living classrooms) could be integrated and built around the levee system. This would encourage public access and support overall social activity, accessibility, and integration to existing trail networks.

Viewshed and Aesthetics. Levees, by function, involve an increase in elevation to protect the land behind them from rising water during storms. Levees are also traditionally uniform and monolithic, affecting the viewshed and isolating the community from the aesthetic value of the creeks and surrounding habitat. Complementary measures to the proposed levee, such as lessening of levee slopes, tree screens, floodplain benching, and overlook creation, could blend the levee into the surrounding landscape and improve the visual interest of the system.

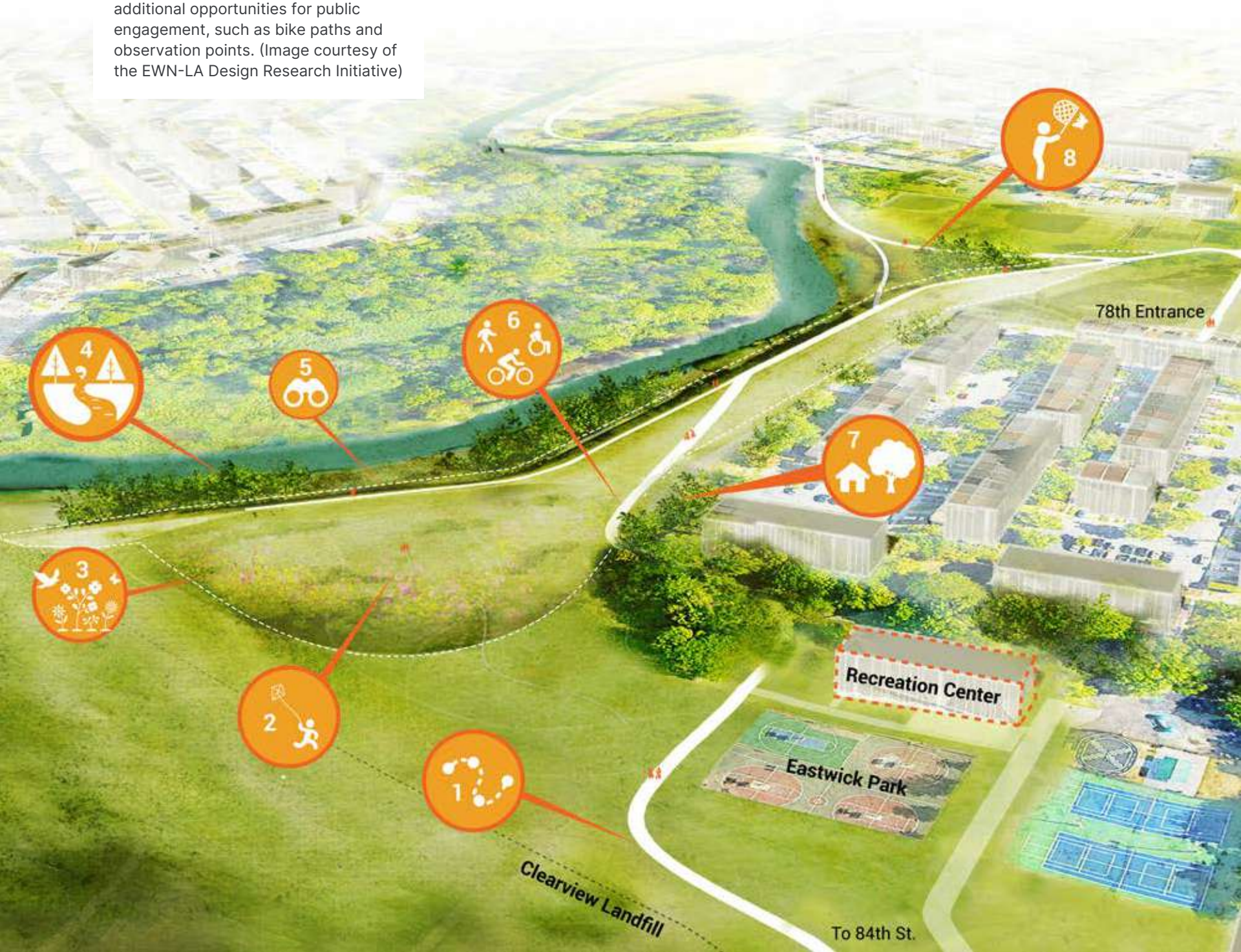


EWN components will be integrated to enhance existing community features. (Image courtesy of the EWN-LA Design Research Initiative)

PHILADELPHIA DISTRICT
Urban Levee

1. Trail Connections to Nearby Attractions
2. Graded Levee Slope
3. Bird and Pollinator Plantings
4. Managed Riparian Habitat
5. Creek Overlook
6. ADA/Bike Accessible Trail
7. Tree Screen
8. Outdoor Classroom

EWN components will provide additional opportunities for public engagement, such as bike paths and observation points. (Image courtesy of the EWN-LA Design Research Initiative)



Recognizing Benefits

Preserving existing habitats, planting various species of vegetation to support intended habitat development, and introducing strategic features to traditional FRM strategies offer a focused and intentional FRM approach with habitat diversification and improved public accessibility. Increasing the ecological value of the levee system adds a layer of defense against flood risk, improves resilience for the flood-prone community, and enhances the sustainability of a natural system in an urban environment. This design concept incorporates social connectivity with an FRM project that provides ecological and habitat value to urban areas.

Advancing Implementation

The success of this style of project will depend on coordination between agencies and entities to balance the priorities of all parties while implementing a project that provides maximum value to the community. A traditional levee approach provides FRM but may not consider features that increase the recreational, social, and habitat value of the levee system. When the levee is so close to the surrounding community, these values have to be weighed more substantially than they traditionally may be.

Sediment Management
Murderkill River

CONCEPT HIGHLIGHTS

Encouraging natural sediment accumulation

Reconnecting a marsh and riverine systems

Backfilling mosquito ditches

Increasing social connectivity

KEY EWN FEATURES



Coastal and Flood Resiliency



Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Image courtesy of the EWN-LA Design Research Initiative



Existing Conditions. Mosquito ditches disrupt the natural flow of water, significantly altering the marsh ecosystem and accelerating habitat loss. Major storms and rising sea levels further degrade the marsh, turning this area into open water. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

Methods of mosquito control and disease prevention known as “mosquito ditches” were dug by hand through salt marshes in an attempt to mitigate the extreme mosquito populations in coastal regions. These hand-dug ditches altered the natural water movement through the marsh and adjacent riverine systems, leading to habitat loss. When combined with the impacts of major storms and rising tides, these ditches transform surrounding marsh to open water. EWN solutions could be proposed to reconnect the riverine and marsh systems more naturally; for example, by using dredged material to build up certain features in the marsh and strategically cut the existing mosquito ditches, encouraging water to flow more naturally through the system and allowing sediment to accrete organically. In this low-energy system, sediment moving along the natural waterways collects in the ditches, smothering wetland habitat and wildlife. To relieve this collection and mitigate the adverse impacts on the surrounding channels, maintenance dredging to remove shoaled areas would be conducted. The opportunity to use dredged material beneficially from the channel for marsh buildup provides a natural infrastructure rehabilitation approach while addressing the sediment buildup and manufactured water flow in the mosquito ditches.

Leveraging Opportunities

Reconnecting the marsh to the riverine system through intentional material placement in the marsh will reduce shoreline erosion, support local species, and stabilize the existing marsh. Placement of dredged material to manage higher flows while supporting the existing marsh will raise the height, create fish habitat by excavating adjacent large shallow pools, and reconnect the marsh to the tidal flow of the Murderkill River. Expanding the recreational boating area in the historically ditched marshes presents an engagement opportunity for the community to connect with this system.

Applying Natural Infrastructure

As tides rise, the mosquito ditches prevent natural tidal sedimentation accumulation, which in turn can lead to a subsided marsh unable to combat rising waters. With the proposed intervention, newly excavated tidal creeks will be used to pump dredged material from the nearby channel into the mosquito ditches. The filled ditches and excavated creeks will restore a more natural tidal regime, encourage natural accumulation of sediment over time, and help mitigate the deleterious effects of rising tides.

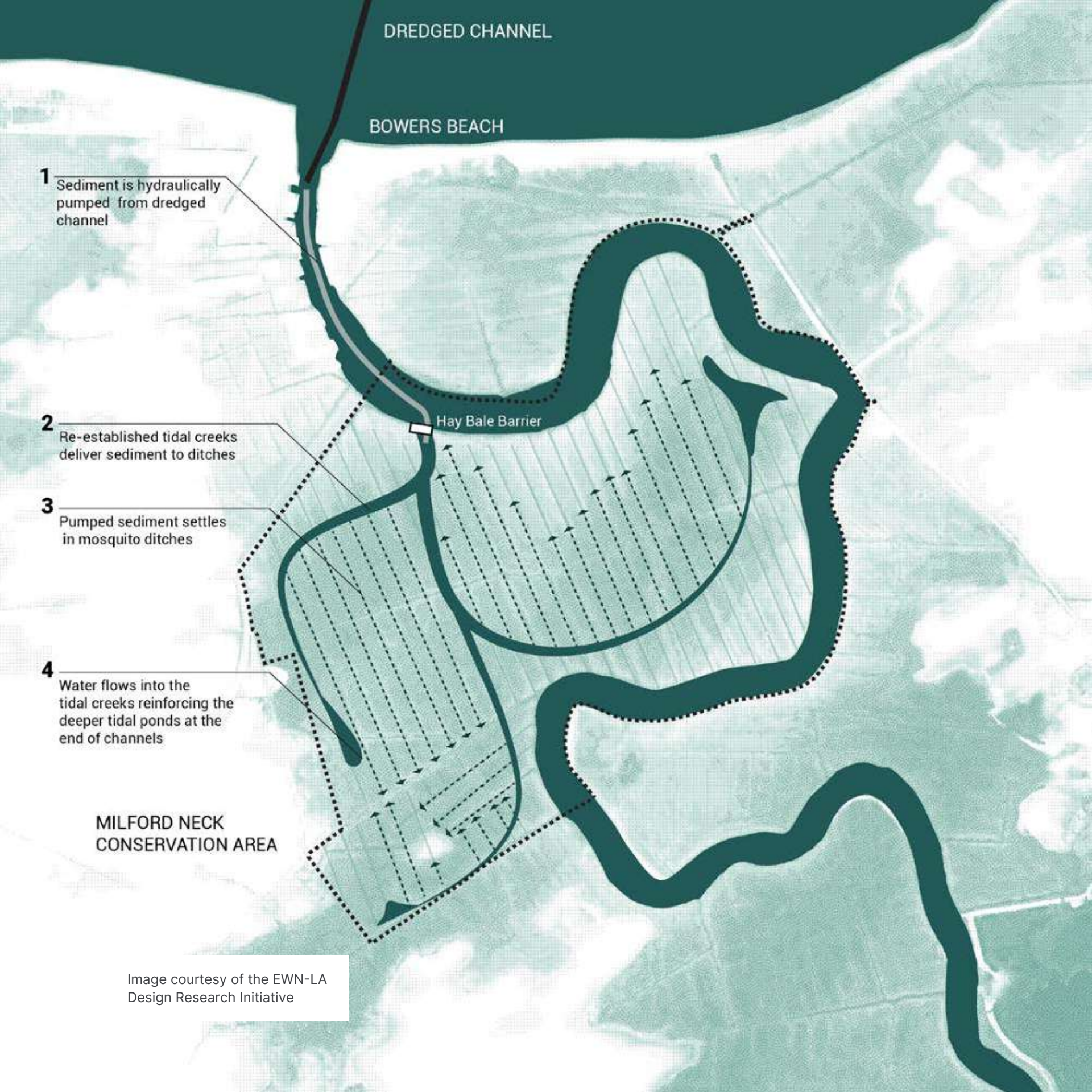
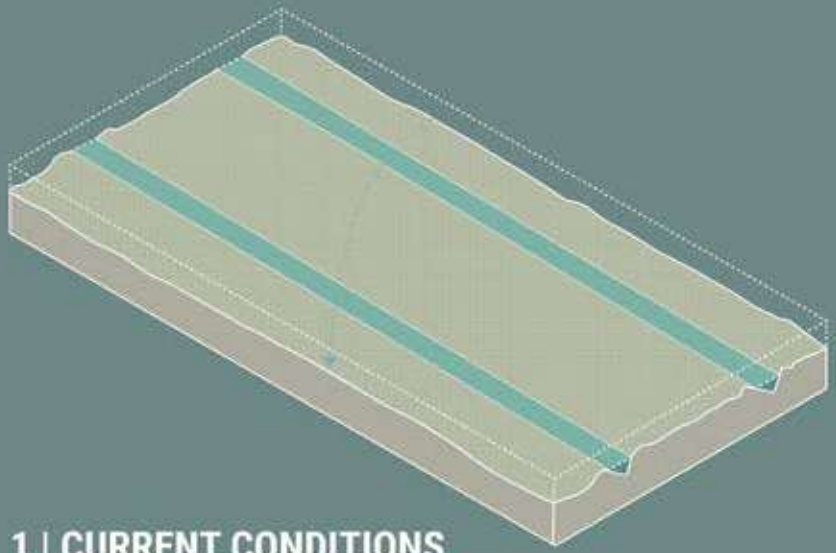
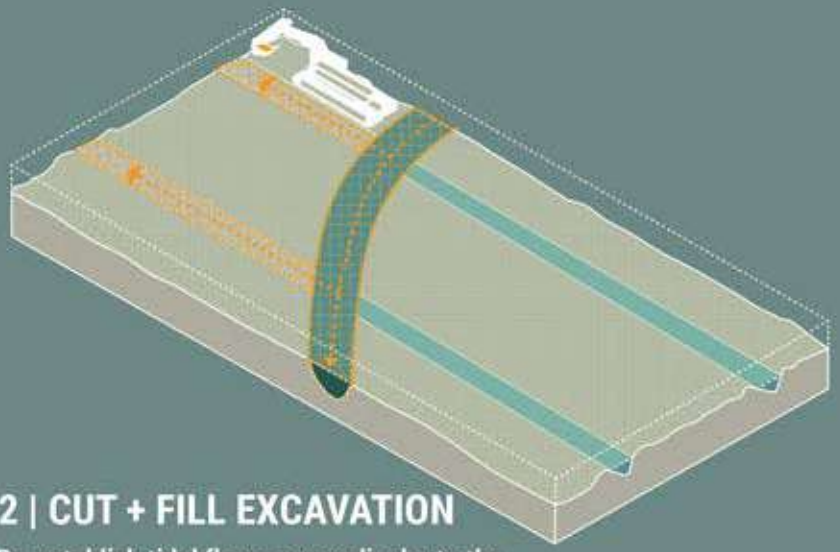


Image courtesy of the EWN-LA Design Research Initiative



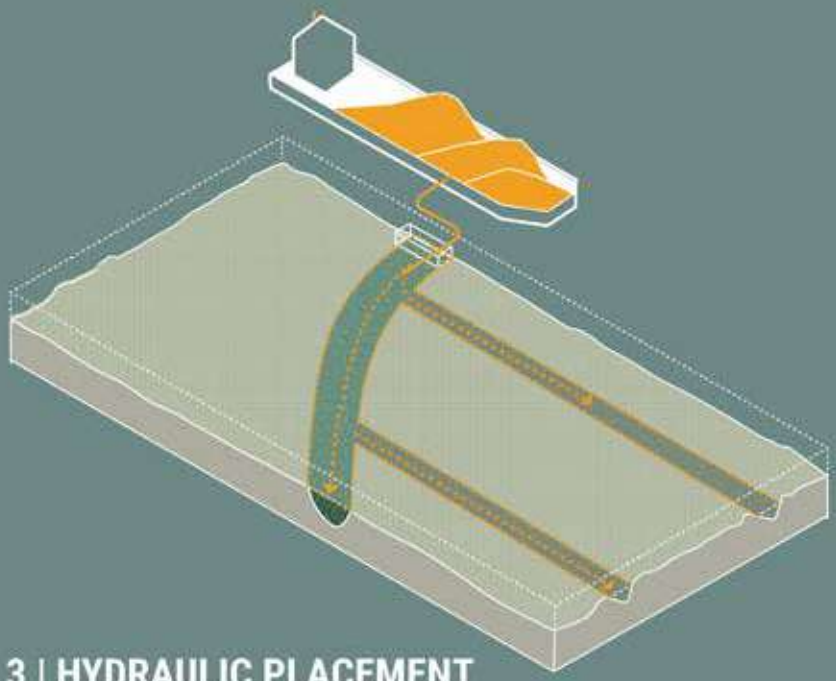
1 | CURRENT CONDITIONS

Historical mosquito ditches disrupt natural tidal flows through the marsh and alter patterns of sediment accretion, threatening marsh subsidence under rising tides.



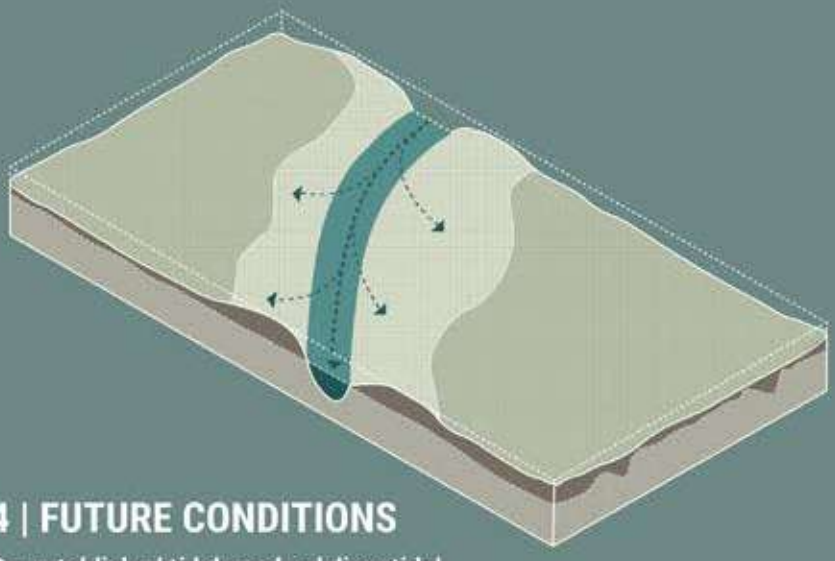
2 | CUT + FILL EXCAVATION

Re-establish tidal flows perpendicular to the mosquito ditches. Use excavation material to back fill mosquito ditches on higher ground.



3 | HYDRAULIC PLACEMENT

Pump nearby dredged material into re-established tidal channels connected to mosquito ditches, allowing sediment to settle and fill the ditches.



4 | FUTURE CONDITIONS

Re-established tidal creeks deliver tidal sediments to the marsh and mitigate the effects of rising tides on the marsh habitat.

Image courtesy of the EWN-LA Design Research Initiative

Recognizing Benefits

This EWN strategy of reclaiming dredged sediment for marsh buildup and restoring more natural flow patterns could be applied to other ditched areas experiencing similar sediment buildup, manufactured flow, and nearby erosion. This strategy to diversify and restore low and high marsh areas, with the expectation that the high marsh area will be filled manually with excavation material and the low marsh areas will be gravitationally filled with hydraulically pumped material, provides flood risk resilience while aiming to mimic a natural system. A few small, shallow tidal ponds, constructed at the end of each tidal creek to act as reservoirs, would increase habitat value by attracting birds and fish, which eventually will deter the mosquitoes that the ditches were originally intended to address.

Advancing Implementation

The greatest challenge is that these areas typically are not located in navigationally significant economic regions that require frequent dredging and, consequently, may not be prioritized. But the ecological significance of these restored areas has the potential to provide FRM benefits as regional sea level rise continues, in addition to educational and social opportunities for public engagement regarding the impact of outdated historical processes on a community's future.



Photo courtesy of the EWN-LA Design Research Initiative

Great Lakes Region

Self-Perpetuating Marsh
Chicago District—Duck Creek Delta

Coastal Erosion Mitigation Along Bluffs
Detroit District—Lake Michigan Multiple Shorelines

Open-Cell Wetland
Buffalo District—Conneaut Harbor-Presque Isle

Consisting of fresh water, driven by local winds, and considered to be nontidal, the Great Lakes exhibit characteristics unique from other coasts of the continental United States. Despite its uniqueness, the area experiences challenges similar to those faced by shorelines across the country—wetland and nearshore habitat loss, shoreline erosion, and decreased flood control. A growing effort to retain sediment in the nearshore environment coupled with a broader understanding of NNBF presents a unique opportunity to explore EWN strategies.

Established in 1933, the USACE Great Lakes and Ohio River Division includes 17 states and 355,300 square miles of land, marsh, and riverine systems and has shorelines on all five Great Lakes.[25] Its 2,582 miles of waterways transport 35% of the country's waterborne commerce, totaling an annual average of 175 million tons.[26] The Great Lakes region spans more than 10,000 miles of coastline and is the largest freshwater reserve in the world, providing a vital source of drinking water for millions of people.

Development, land use changes, and industrialization have resulted in significant coastal wetland loss, which has affected water quality, habitat, and flood control. This wetland loss has exacerbated other environmental stressors, such as harmful algal blooms and dynamic hydrologic water conditions. Although fluctuating levels and their associated environmental conditions have always been part of the Great Lakes, accelerating natural hazards have intensified them and made them more significant and extreme. The USACE Districts surrounding the Great Lakes—Buffalo, Chicago, and Detroit—have a particular opportunity to incorporate EWN and NNBF to ameliorate these basin-wide stressors.

Through sediment management, USACE Great Lakes and Ohio River Division can foster and maintain the economic and ecological resilience of the region, bridging navigational needs with habitat creation. Various initiatives are underway to provide innovative solutions for the region, including the Great Lakes Restoration Initiative,[27] focused on projects to protect and restore the Great Lakes, and the Great Lakes Coastal Resiliency Study,[28] focused on a comprehensive watershed assessment of the coastal areas to identify measures to improve coastal resiliency. The types of strategies range from passive management of sediment for wetland restoration to nourishment of the nearshore system with beneficial use of dredged material to management of the natural process of the bluff system.



Locations of discussed EWN strategies relative to the three surrounding USACE Districts—Buffalo, Chicago, and Detroit. (Image courtesy of the EWN-LA Design Research Initiative)

CHICAGO DISTRICT

Self-Perpetuating Marsh

Duck Creek Delta

CONCEPT HIGHLIGHTS

Creating self-perpetuating marsh at the creek delta while considering barrier islands for protection and maintenance of sediment in the system

Beneficially using dredged material

KEY EWN FEATURES


Coastal and Flood Resiliency

Habitat Creation or Restoration


Beneficial Use of Dredged Material


Social Connectivity


Community Engagement


Educational Opportunity



The Duck Creek Delta sits at the mouth of the Fox River and was once protected by the Cat Island Chain. (Photo courtesy of the EWN-LA Design Research Initiative)



Proposed catchment islands could be constructed out of dredged material to encourage sedimentation and to increase the habitat at the mouth of the system. (Image courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

The Duck Creek Delta is a historically significant wetland complex located in the USACE Chicago District just north of Green Bay, Wisconsin, and the mouth of the Fox River. This area was named for its abundance of waterfowl and the supporting vital habitat and breeding grounds. But the marshes there have been depleted through anthropogenic and natural processes. Nutrient-laden agricultural and development practices have contributed to harmful algal blooms and vegetation degradation. Intense storms have eroded the marshes and the adjacent shoreline. And invasive species have overwhelmed native plants, limiting biodiversity.

The Cat Island Chain, approximately 1 mile northeast of the delta, has become heavily eroded from extreme high-water events.[29] The loss of these islands contributed further to the degradation of the Duck Creek Delta. As of 2012, this island chain is being restored as a DMCF with beneficial use of clean navigation material, thereby offering protection from wind and wave effects, which is a step toward restoring the natural processes for this area.

A self-perpetuating marsh is a unique EWN strategy that would use natural sedimentation as well as dredged material to establish catchment areas that would then collect sediment from the fluvial system and encourage the development of a deltaic system. This approach would also capitalize on higher flow events from the creek to flush and maintain channels while strategically directing sedimentation. Proof-of-concept-level modeling supports strategic irregularity in the alignment of the catchment islands to protect the delta from additional wind and wave action while encouraging deposition of the fluvial sediment. These wetlands are anticipated to expand over time; and, with intentional seeding and planting, they have the potential to develop a robust network of emergent marsh, submergent marsh, and wet prairie.

Leveraging Opportunities

The Duck Creek Delta serves as a trading route and was heavily modified over the past two centuries to accommodate the needs of early industries, such as lumber, stone quarrying, bricks, and shingles. Consequently, the overall quality and resilience of the creek and delta have fluctuated significantly. Lake levels rise and fall, invasive species spread and overwhelm, heavy winter storms and ice shear erode the shoreline, and surrounding land use practices increase sedimentation and nutrient load. These factors make this landscape highly dynamic and prime for restoration.

The Cat Island Chain is itself a restoration project, protecting and restoring approximately 1,225 acres of shallow water and wetland habitat beneficially using dredged material. But prior to this restoration, the Duck Creek Delta was vulnerable to harsh environmental and erosional forces. Without coastal protection, the wetlands continued to degrade, and the higher flow rates carrying sediment away from the creek's banks resulted in the sediment being dispersed into Green Bay, leaving the nearshore area starved for sediment.

Applying Natural Infrastructure

Self-Perpetuating Marsh. The conceptual EWN strategy involves constructing three barrier islands at the Duck Creek Delta to capture fluvial sediment. With strategic placement and orientation, the goal is for these new islands to protect the surrounding areas during storms and seiche. In addition to the added protection, the naturally shaped islands will act as a strategic corral for sediment, slowing down the flow of Duck Creek as it enters Green Bay and allowing sediment to accumulate and expand the barrier islands. The placement of the islands will need further evaluation to ensure optimal capture, but conceptual modeling demonstrated the viability of the strategy. Consideration will also be necessary to maintain some channelization through the marsh to support flushing of the system and recreational boating. Once placed, the islands will be seeded and planted with native grasses to minimize erosion, encourage ecosystem growth, and increase overall resilience to high flow rates and sediment starvation. Monitoring and maintenance along with periodic planting events may encourage habitat establishment and diversity and combat invasive species as the marsh platform accumulates and grows.

Habitat Diversity and Material Sourcing. The area outside of the proposed wetland has been scoured by waves and lacks habitat diversity. Excavating borrow pits in this area will provide habitat diversity, while the excavated material can be used to reinforce the catchment islands.

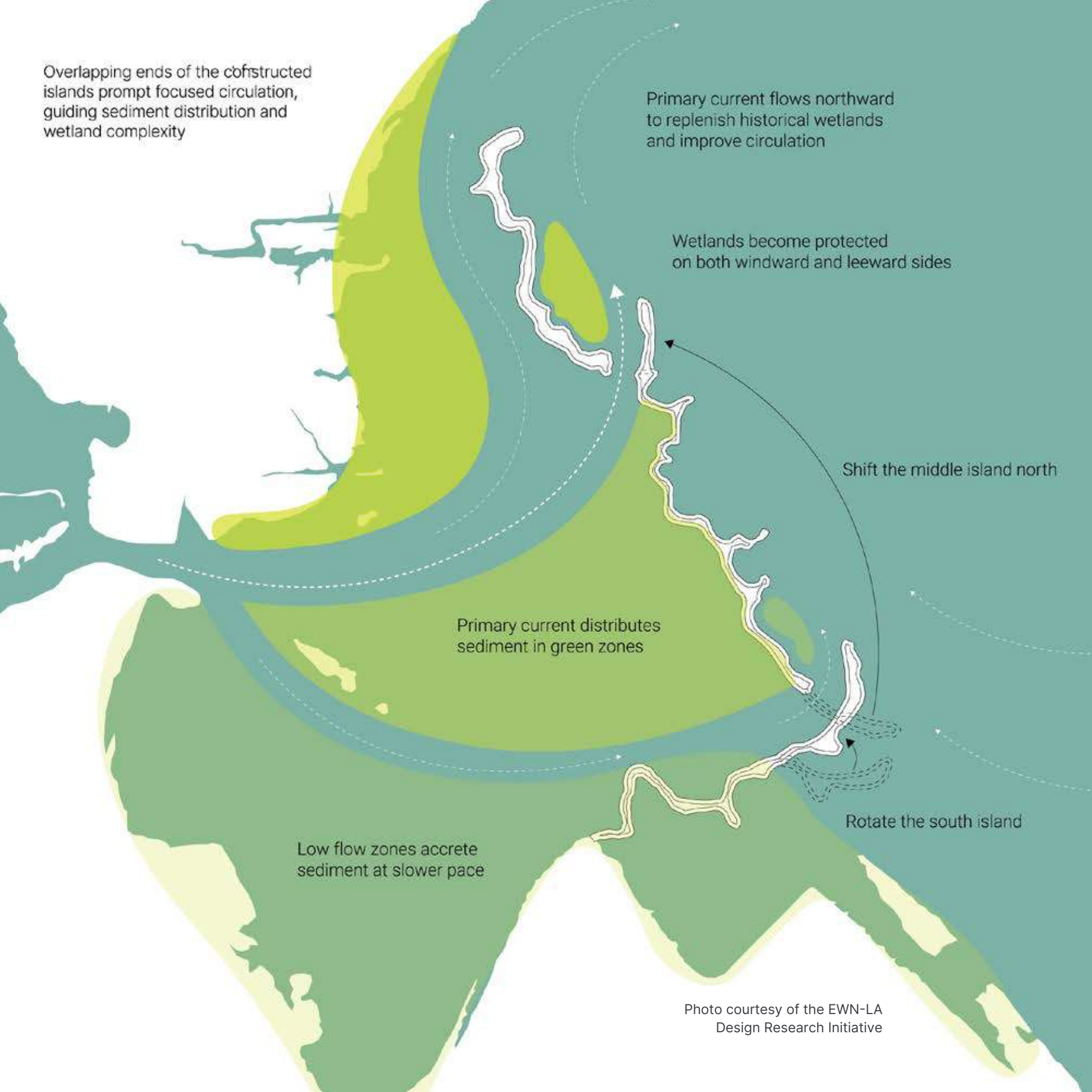
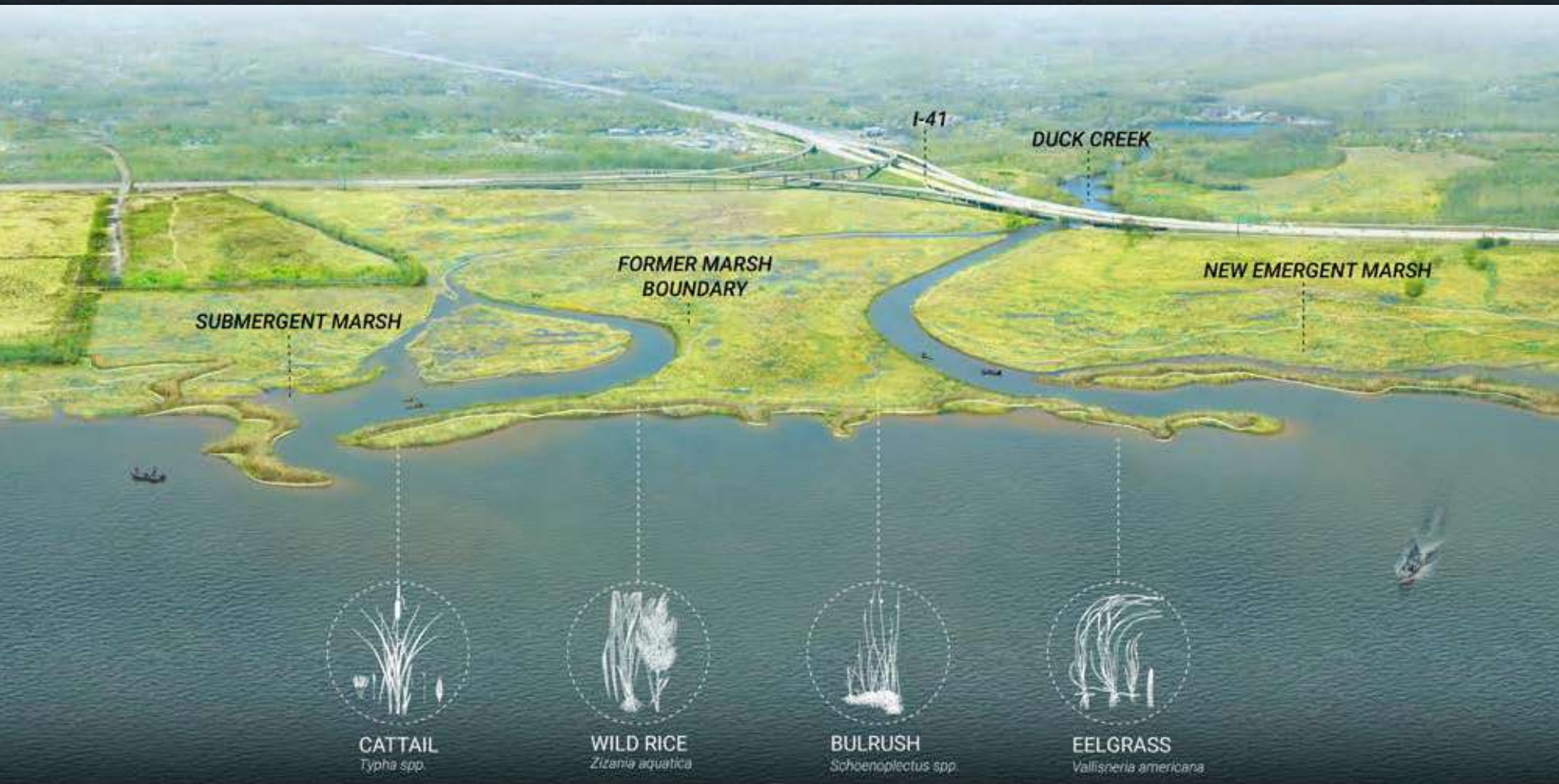


Photo courtesy of the EWN-LA Design Research Initiative



The borrow pits from initial construction used to create the catchment islands along with the self-perpetuating marsh strategy increase biodiversity and habitat complexity. (Images courtesy of the EWN-LA Design Research Initiative)



Recognizing Benefits

Increasing the network of wetlands can improve the area's ability to serve as a natural filter for contaminants, a carbon sequester, and a coastal buffer. Morphologically, the islands will provide protection for microhabitats to form, encouraging a higher diversity of native plant communities. Creating catchment islands protected by the Cat Island Chain means these structures can be designed with minimal hardened surfaces; however, design will need to consider seiches and impacts from ice. With successful implementation, the reestablished wetlands will provide critical habitats for larger wildlife, such as fish and birds. In addition to coastal protection, strategically placing dredged material aligns with the USACE Chief LTG Scott A. Spellmon's 2030 beneficial use vision, thereby offering another success story in the reuse of dredged material.

Advancing Implementation

Successful implementation of this project will require further design and assessment to understand how the fluvial system will evolve, depositing sediment around the catchment islands and expanding toward the Cat Island Chain. Further, carefully considering the conceptual features and alignments is crucial to encourage flushing and functionality of the system at various water levels.

The catchment islands themselves will need to range from submerged marsh to emergent marsh or wet mesic shrub prairie to remain robust enough to withstand varying water levels and higher flows from the creek. Coordinating with various agencies will be important to integrate the knowledge necessary to create the desired habitat while performing the targeted engineering function.

This type of project also requires significant local stakeholder involvement for long-term success. Defining the responsible parties and their roles will for the long-term monitoring and maintenance of the wetland will be important while it fully establishes as a self-sustaining system. Additionally, invasive and monoculture vegetation will need to be controlled until native vegetation has established the root network and species diversity necessary to naturally combat these species.

DETROIT DISTRICT

Coastal Erosion Mitigation Along Bluffs

Lake Michigan Multiple Shorelines

CONCEPT HIGHLIGHTS

Exploring coastal erosion techniques that balance bluff erosion and natural nourishment of nearby beaches

Incorporating sediment rundown along with boulder field and littoral sediment placement to reduce bluff erosion and replenish beaches

KEY EWN FEATURES



Coastal and Flood Resiliency

Habitat Creation or Restoration



Beneficial Use of Dredged Material



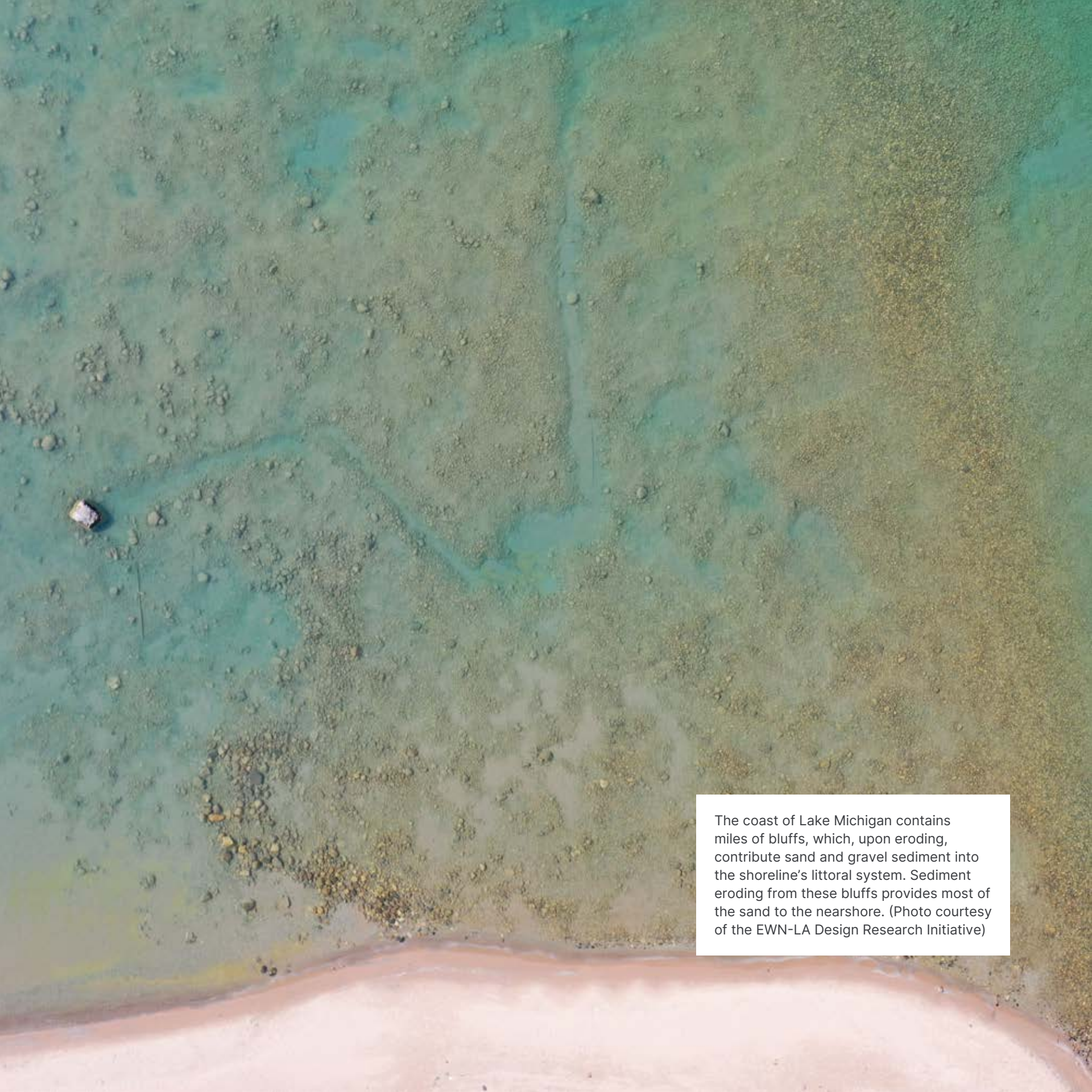
Social Connectivity



Community Engagement



Educational Opportunity



The coast of Lake Michigan contains miles of bluffs, which, upon eroding, contribute sand and gravel sediment into the shoreline's littoral system. Sediment eroding from these bluffs provides most of the sand to the nearshore. (Photo courtesy of the EWN-LA Design Research Initiative)



The bluff-and-beach system along Lake Michigan provides shoreline stability while nourishing beaches downshore when erosion occurs. (Photo courtesy of the EWN-LA Design Research Initiative)

EWN Strategy and Concept Opportunity

The bluff-and-beach system of eastern Lake Michigan sits along vast dune fields that are timbered or mined for sand and gravel. Towns and harbors rely on these industries and on tourism (especially along the local beaches), which are supported by maintenance of the navigation channels and beaches. The shorelines along this system have been privatized in some locations and protected through national seashore and state park designations in others. Although beneficial from a littoral sediment-transport perspective (i.e., by introducing sediment for downshore beach nourishment and habitats), the natural processes that erode the bluffs and nurture the adjacent beaches and shore are often undesirable from the point of view of the property owners who live along the shorelines of the eroding areas and the municipalities that rely on that tax base. This paradox—erosion is naturally occurring but undesirable—is common throughout many coastal communities, and strategies to balance this juxtaposition may be beneficial from a long-term planning perspective.

Eastern Lake Michigan presents an intriguing confluence of factors that indicate EWN approaches may balance the competing needs of protecting shorelines and maintaining longshore littoral processes. Ongoing dredging in the region provides good quality material to direct toward productive nearshore uses to support beaches and tourism. Access to good-quality beaches is also a public health and environmental parity issue. This relationship between geomorphology, hydrology, ecology, and human uses results in challenging problems without simple solutions. These problems demand innovative, sensitive approaches that work with, not against, natural processes and cultural values.

Leveraging Opportunities

Sediment from bluff erosion is an important factor in the sediment budgets along Lake Michigan shorelines. But sporadic privatization of the shorelines has resulted in irregular bluff failure and sediment starvation. Bluffs that fail act as "feeders" to the natural littoral transport, nourishing adjacent nearshore environments; but bluffs with longer-term stabilization measures do not contribute to the nearshore hydrodynamic system.[30] Without a continuous source of feeder sediment from the bluffs, the nearshore lakebed erodes, and "when erosion of nearshore lakebed takes place . . . it cannot be restored as sandy shores can. The fine sediments are lost to circulate in the lake and settle out in deep water basins."[31] An ideal approach to solve this problem will reintroduce sediment where needed in the system to continue to feed the nearshore environment.

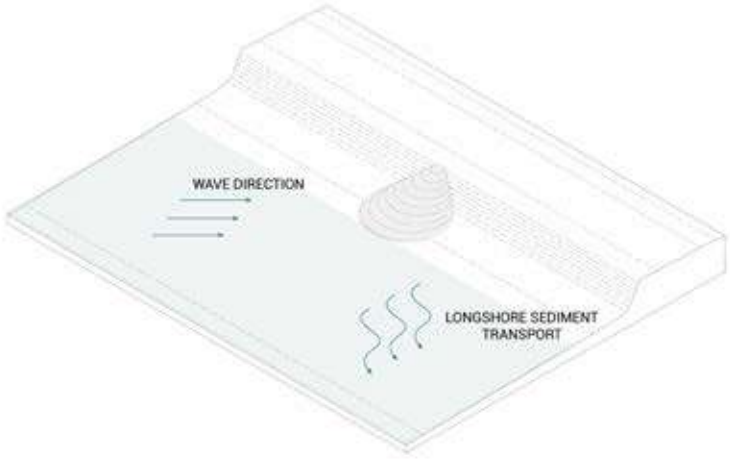
Applying Natural Infrastructure

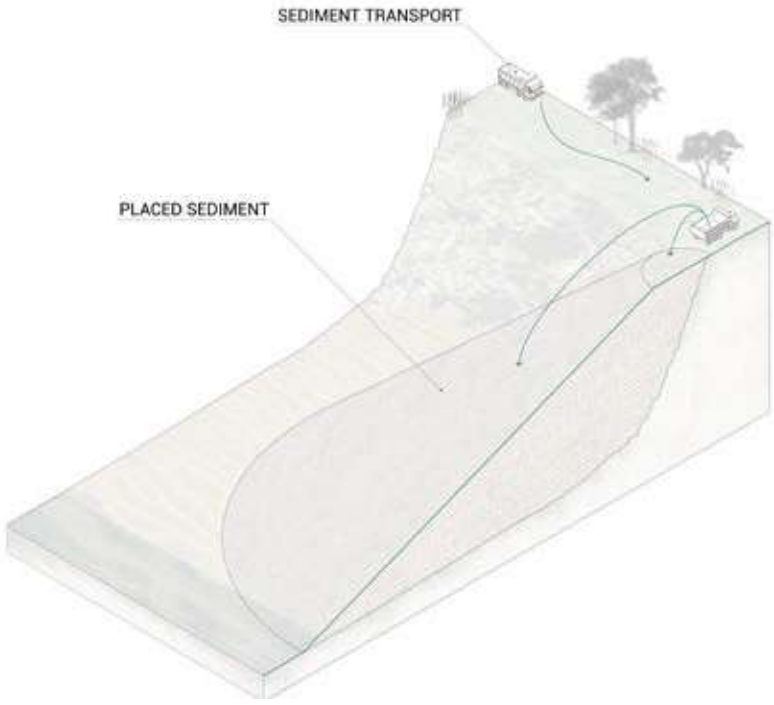
Because bluff erosion is not isolated to a single location, different types of approaches may be necessary to balance site constraints and desired outcomes. Two concepts developed with this in mind lean on natural processes and sediment sources local to the area of concern. These concepts—boulder field and littoral placement and sediment rundown—seek to minimize bluff recession and nourish nearby beaches through periodic sediment placement. Both concepts may serve as sources of inspiration and provide educational opportunities for addressing shoreline bluff erosion.

Boulder Field and Littoral Sediment Placement. This strategy places boulders the nearshore environment (similar to existing glacial deposits) either on a bed of cobbles or a cohesive nearshore foundation where feasible. The intent is to position the boulders to discourage long-term trapping of sand and sediment and to avoid tombolos. Instead, the boulders attenuate wave energy and provide a demarcated placement area for dredged sediment. Fines from this sediment dredged during nearby harbor maintenance are winnowed out, and the sand remains to disperse gradually and feed the natural beach system.

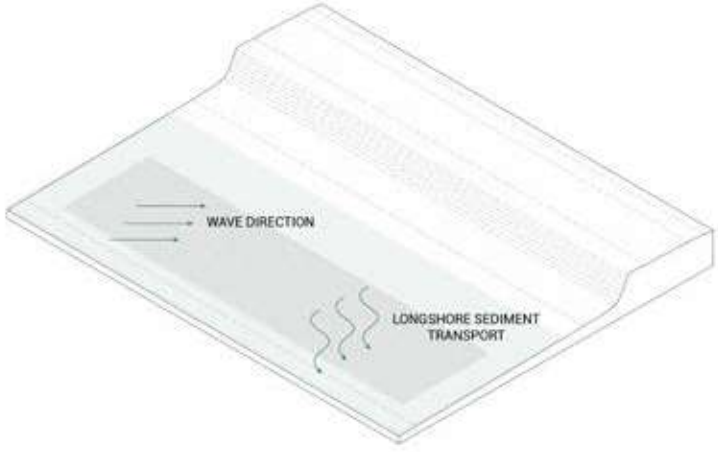
Sediment Rundown. This technique introduces sediment into sediment-starved portions of the natural system by allowing sand and gravel mined from upland locations to cascade down the receding bluff to mimic talus landforms. Wave action at the toe of the bluff will scour away the talus over time, moving the sediment downshore and improving resilience of any bluffs along the way. The winnowing processes that occur in the nearshore environment sift through the well-graded material to maintain strand formation and nourish beaches.

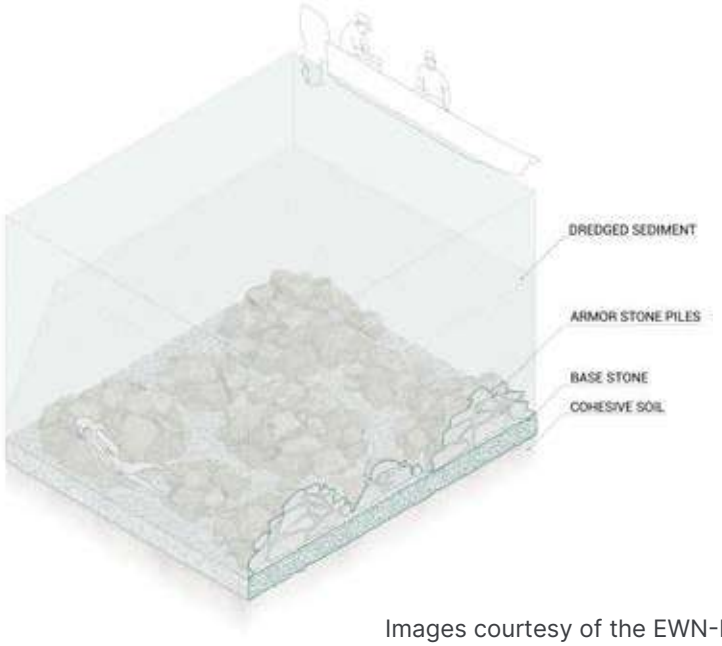
Boulder Field and Littoral Sediment Placement





Sediment Rundown





Images courtesy of the EWN-LA Design Research Initiative



Option 1. Sands disperse gradually to feed the natural beach system from placed dredged sediment. (Image courtesy of the EWN-LA Design Research Initiative)



Option 2. Mimicking talus landforms, sand will cascade down receding bluffs and eventually move down shore where it can nourish beaches. (Image courtesy of the EWN-LA Design Research Initiative)

Recognizing Benefits

Boulder field and littoral placement involves strategic placement of boulders offshore to attenuate wave energy and provide an alternative placement location for dredged sediment from nearby harbor maintenance. The boulders would be placed far enough offshore to avoid impacts from ice formation but shallow enough to reduce the erosion potential of wind and waves and to prevent tombolo formation and long-term trapping of sand nearshore. Strategic placement of dredged material in the adjacent nearshore area will encourage the gradual dispersion of sand, nourishing downshore beaches.

The sediment rundown strategy presents an opportunity to address the sporadic bluff erosion as needed while informing the public about the natural littoral processes by cyclically creating talus and letting it erode. This approach does not require a significant capital investment and could be implemented within a sensitive adaptive management paradigm.

Evaluating each project area individually allows a more concentrated approach that accounts for the unique challenges and demands of each region. A combined EWN approach of bluff management to slow the retreat of the bluff itself while allowing some erosional events to continue feeding the nearshore sediment system could provide a balance between existing land uses and natural processes.

Advancing Implementation

The greatest challenge in this region will be balancing anthropologic needs with the erosive nature of the natural system. A dynamic bluff-and-beach system adjacent to stagnant land use practices will require a strategic intervention of various potentially unconventional management techniques. EWN may prove effective in preserving land reaches to feed private shorelines. Significant stakeholder coordination, public education, and long-term implementation strategies will be necessary to maintain the viability of these strategies.

EWN should be considered and assessed as part of a holistic approach for the region. NNBF could be integrated into ongoing initiatives such as Great Lakes Coastal Resiliency Study and Great Lakes Restoration Initiative as part of a suite of projects to help manage restoration and remediation and to provide coastal resilience.

BUFFALO DISTRICT

Open-Cell Wetland

Conneaut Harbor-Presque Isle

CONCEPT HIGHLIGHTS

Implementing open-cell wetlands that hold and disperse sediment to nearby shorelines

Using dynamic shoaling to replenish sediment and minimize bluff erosion

KEY EWN FEATURES



Coastal and Flood Resiliency

Habitat Creation or Restoration



Beneficial Use of Dredged Material



Social Connectivity



Community Engagement



Educational Opportunity



Photo courtesy of the EWN-LA Design Research Initiative

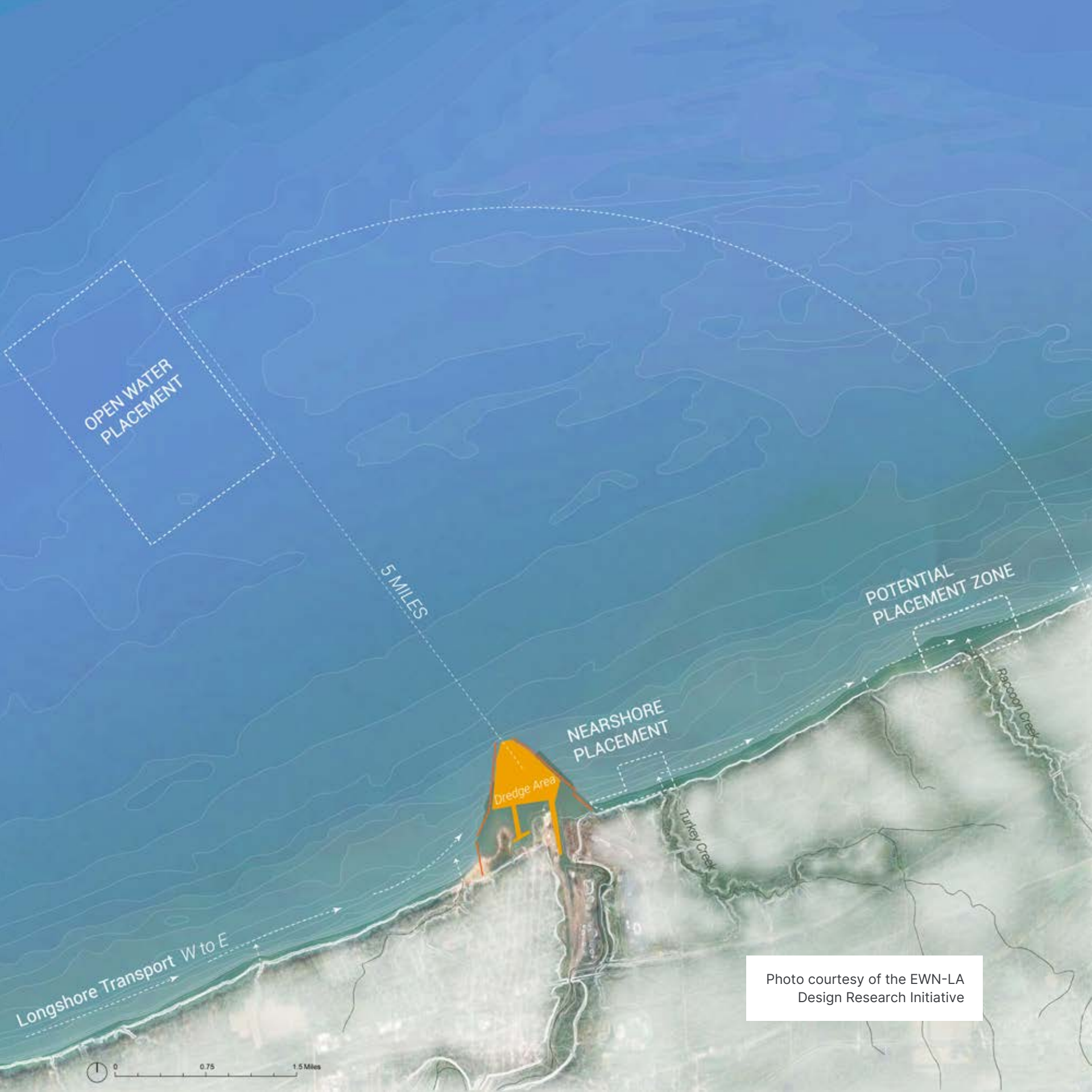


Photo courtesy of the EWN-LA Design Research Initiative

EWN Strategy and Concept Opportunity

The Conneaut Harbor area experiences sediment loss and starvation events downshore due to the presence of the Conneaut Harbor breakwaters. These breakwaters have disrupted the natural sediment movement, specifically the east to west littoral transport toward Presque Isle. Dredging is required to maintain the harbor and integrity of the breakwaters; consequently, placement alternatives are required for the material. A number of rivers flow into this stretch of shoreline, carrying dispersive tendencies and contributing to the aquatic habitats in this region of Lake Erie, which supports a number of significant Great Lakes fish species.

This suite of characteristics aligns for EWN to improve and restore habitat through nearshore placement of dredged material, with conceptual implementation of an open-cell wetland and dynamic shoaling. This approach would reintroduce the dredged material from the harbor into the local littoral system to balance wave protection, sediment placement needs, coastal wetland connectivity, habitat development, and longshore drift. Conceptually, this structure would effectively hold an equivalent dredging cycle's worth of material to gradually disperse dredged sediment to renourish the nearshore and improve habitat value.

Leveraging Opportunities

Dredging Conneaut Harbor presents an opportunity to replenish sediment in the littoral system while enhancing habitat value in the region. Rather than store it in the open-water placement site approximately 4 miles into the lake, the material could be placed within a similar radius at the mouth of creeks to encouraging winnowing and dispersion of the sediment.

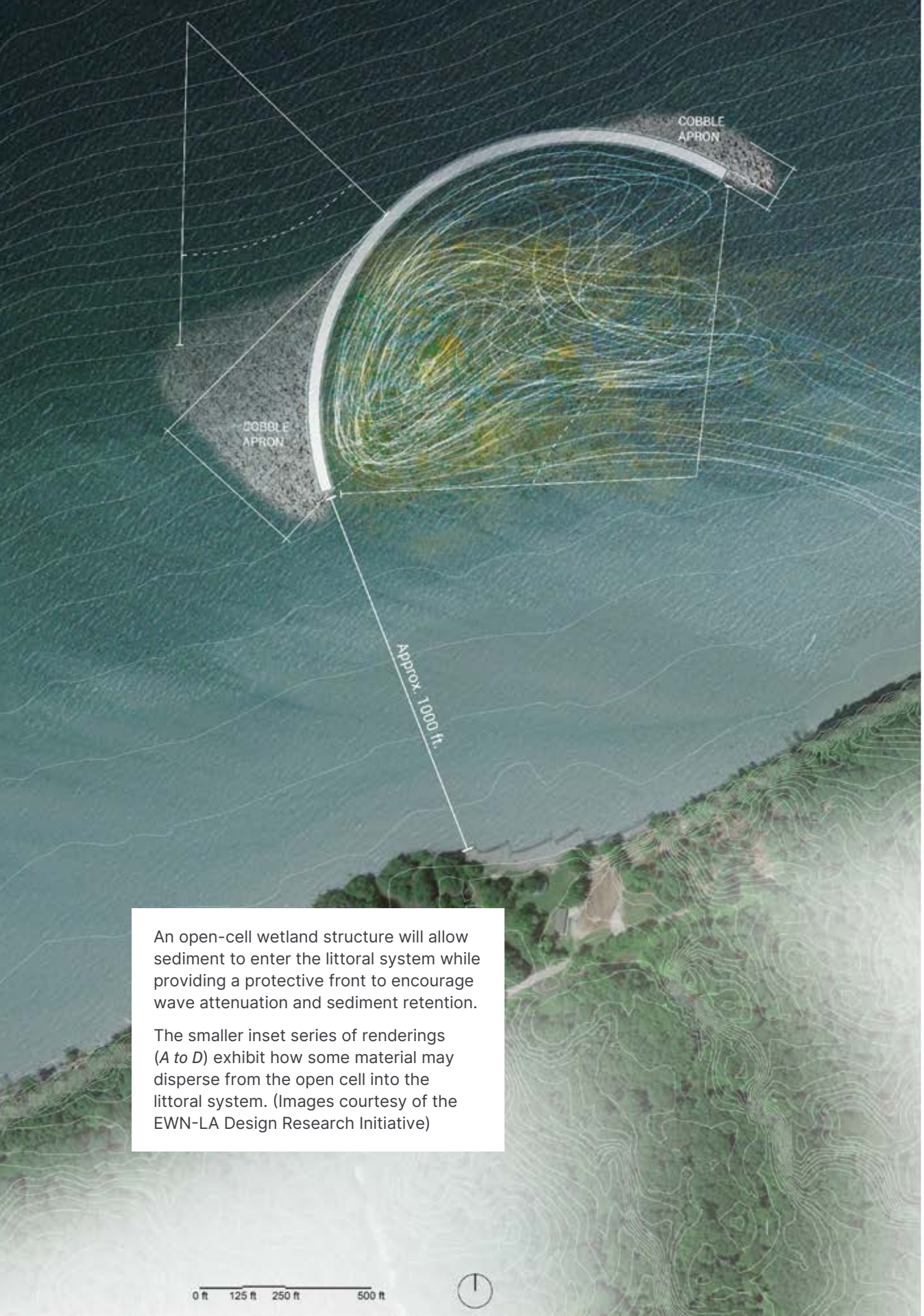
The habitat of the three main fish of interest—smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), and lake trout (*Salvelinus namaycush*)—will be considered in the design and placement strategy of the structures. They prefer, respectively, shallow waters near shorelines or islands, cool water characterized by moderate currents and substrates of rocks or gravel, and rocky or gravelly substrates in deeper, well-oxygenated water. All three have similar food webs and spawning seasons.

Applying Natural Infrastructure

Beneficial use of dredged material and dynamic shoaling structures are alternatives to the open-water placement of dredged material. These structures are designed to hold one dredging cycle's worth of material.

Open-Cell Wetland. This placement will consist of an open back and protective structural front. The open back will allow sediment to settle in the immediate vicinity and then be dispersed back into the local littoral system, while the protective front will promote wave attenuation and allow increased sediment retention during daily events. The reduced wave environment will create conditions conducive for establishment of submerged wetland vegetation.

Dynamic Shoaling. This approach uses boulder ridges to define a wedge, with cobble fields at both ends of the wedge. Additional cobble ridges are placed beyond the primary placement area. Dredged material placed in the system is initially contained by the wedge. The material then migrates over the cobble ridges, which slow the movement of the sediment and retain it in the littoral system long enough to replenish the nearshore sediment and reduce bluff erosion.

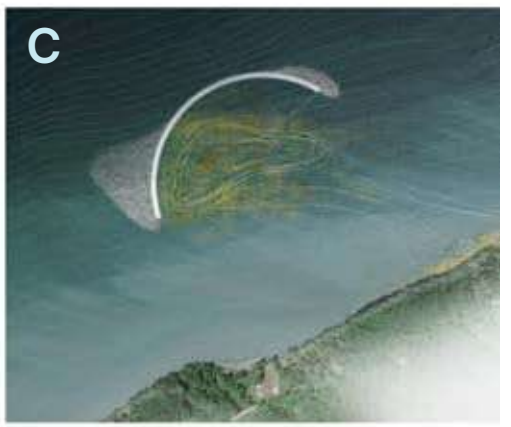


An open-cell wetland structure will allow sediment to enter the littoral system while providing a protective front to encourage wave attenuation and sediment retention.

The smaller inset series of renderings (*A to D*) exhibit how some material may disperse from the open cell into the littoral system. (Images courtesy of the EWN-LA Design Research Initiative)



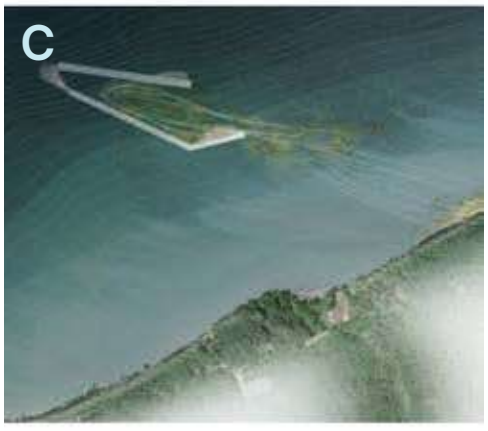


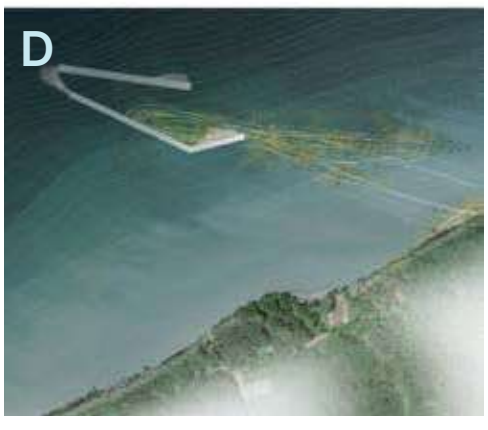












COBBLE APRON

COBBLE APRON

COBBLE APRON

Approx. 1200 ft.

0 ft 125 ft 250 ft 500 ft

A dynamic shoaling structure has a wedge orientation that encourages dredged material to slowly move over cobble ridges and replenish nearshore sediment.

The smaller inset series of renderings (*A to D*) visualize the dispersion of that material. (Images courtesy of the EWN-LA Design Research Initiative)

Recognizing Benefits

Not only do these dynamic shoaling structures offer an alternative to open-water placement for one dredging cycle's worth of material, but also its protective front promotes wave attenuation and allows for increased sediment retention. The dispersive nature of the structures enables them to contain the initial placement of material and allow it to migrate back into the local littoral system, nourishing the nearshore environment.

Along with offering erosion-control measures and an alternative to offshore placement of sediment, nearshore structures will enhance the Great Lakes ecosystem. Designed with functionality for fish habitats, the structures offer shelter, breeding grounds, and feeding areas for various fish species. The dynamic and dispersive nature of the structures enables the system to adjust to water events and provides flexibility in the habitat types created. Placement of dredged material at the mouth of creeks also provides currents to further move the sediment and improve water oxygenation necessary to enhance the breeding and nursery habitats for the diverse fish population.

Advancing Implementation

Successful implementation will require proper design to initially contain sediment and allow prolonged dispersion, given the varying water levels and seiche events. The system will need to withstand storm and ice events while creating the conditions required for sediment transport and habitat development.

The habitat replenishment goal is equally important to this type of project; therefore, coordinating with resource agencies will be critical. This placement approach will be an active operational area and a habitat creation area, and the priorities of both will need to be balanced.

The site location and ultimate sediment transport will also likely cross jurisdictional lines, thereby involving unique regulatory requirements and authorizations. Coordination will be required to ensure the regulations support this type of project while encouraging similar innovative approaches.



Photo courtesy of the EWN-LA
Design Research Initiative

The Way Forward

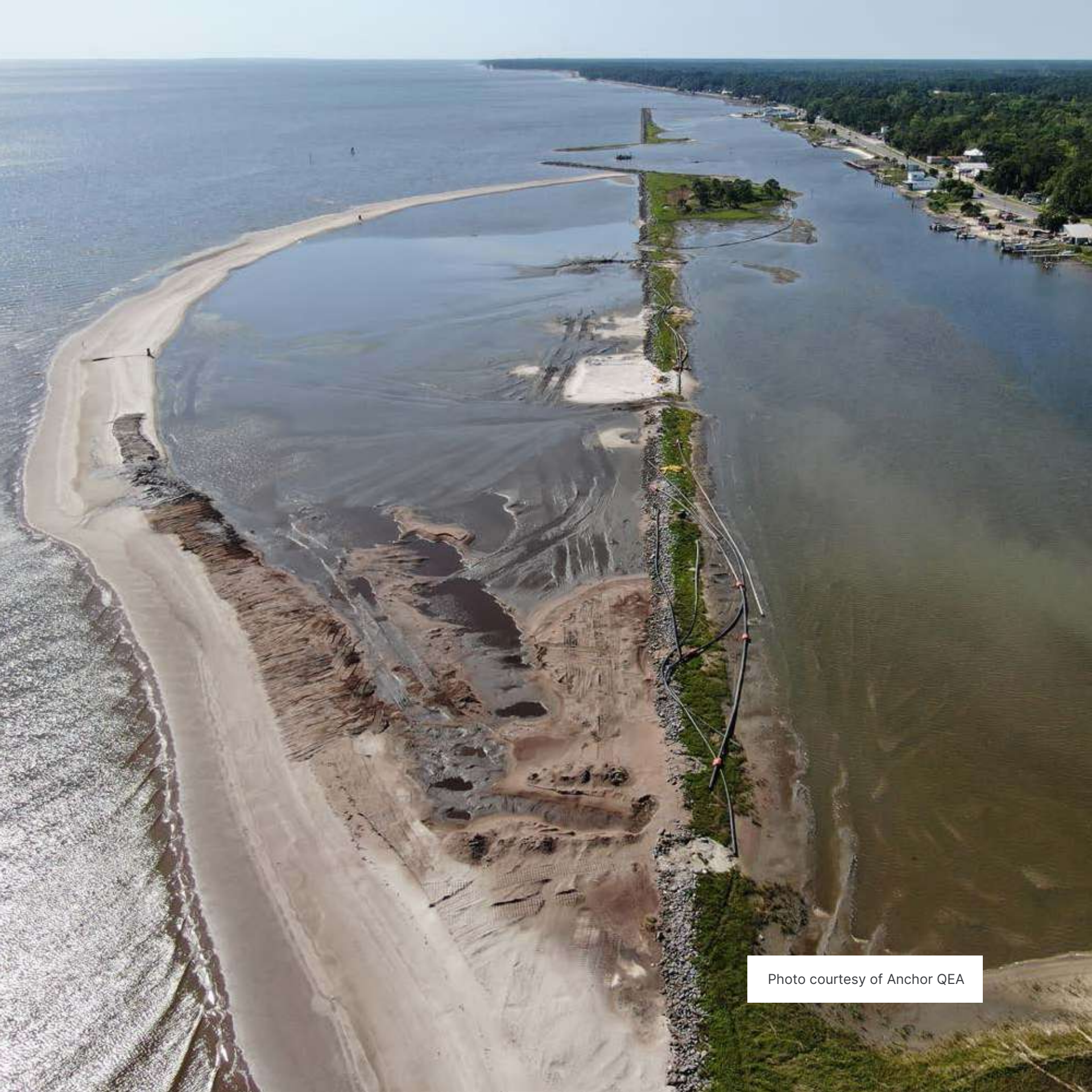


Photo courtesy of Anchor QEA

This handbook provides nationwide examples of EWN strategies implemented on key coasts and waterways in the United States. These strategies, centered around features, such as adaptability, habitat enhancement, and long-term risk mitigation, prioritize ecosystem longevity and infrastructure using resiliency methods under projected conditions rather than short-term mitigation approaches.

Action to advance EWN design strategies, update policy, and authorize funding to implement projects is necessary. Ongoing data collection and adaptive management will be required to continually learn and improve how to use these approaches. The responsibility for long-term adaptive management may require some creative partnering agreements, as it will likely need to be shared between the government and nonfederal sponsors for maximum community impact.

Threats from hazards to coastlines will not subside but rather will increase in frequency and complexity, driving the need for innovative strategies to work within these dynamic ecosystems for a sustainable and resilient future. Integration of solutions incorporating EWN and NNBF in traditional USACE mission areas supplies threatened coastal communities with multiple layers of defense against current and future natural hazards such as rising tides and increased frequency and magnitude of storms and floods. Continuing to consider and implement EWN strategies, along with policy updates, technical guidance, and ongoing knowledge sharing at a large scale, will shift these solutions from innovative ideas to common practices in the industry.

As coastal communities remain a focal point of societal expansion, establishing EWN approaches as common practice through vulnerability awareness and intentional action becomes imperative for the health, safety, and success of future generations.



Photo courtesy of the EWN-LA
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Photo courtesy of the EWN-LA Design Research Initiative

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14. ABSTRACT

The *Engineering With Nature® Proving Grounds Innovation Handbook* provides a comprehensive framework for integrating innovative natural and nature-based features and sediment management strategies to address climate-driven hazards and increase resilience in coastal and fluvial environments. Developed through collaboration between engineers, scientist, landscape architects, and U.S. Army Corps of Engineers districts and divisions, the EWN Handbook showcases a diverse collection of projects within the four coasts of the United States and offers the wide range of approaches available to achieve multiple benefits (economic, ecological, and social) through the application of traditional engineering with natural infrastructure solutions. The document aims to offer practitioners ideas on how to incorporate EWN concepts and strategies in all phases to build more resilient, multifunctional projects that protect communities and ecosystems against future natural hazards.

15. SUBJECT TERMS

Beneficial use; Beneficial use of dredged material; Coastal and flood resiliency; Community engagement; Educational opportunities; Engineering With Nature®; Environmental engineering; Flood Risk Management; Habitat creation; Habitat restoration; Natural and nature-based features; Natural infrastructure; Proving Grounds; Sediment management strategies

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