Technical Articles

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ENGINEERING WITH NATURE FOR SUSTAINABLE WATER RESOURCES INFRASTRUCTURE

'ENGINEERING WITH NATURE', INITIATIVE POUR DES INFRASTRUCTURES HYDRAULIQUES DURABLES

by

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1.Introduction

The U.S. Army Corps of Engineers (USACE) Engineering With Nature (EWN) initiative supports sustainable development of infrastructure by advancing technical practices and communication in order to align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes [1]. The tools and projects that have been developed through EWN support planning, engineering and operational practices that beneficially integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects as shown in Figure 1. The EWN initiative's focus on developing practical methods provides an achievable path toward an ecosystem approach to infrastructure development and operations that is applicable across USACE missions and business lines. By combining sound science and engineering with advanced communication practices, the EWN initiative is providing a robust foundation for effective collaboration with our partners and stakeholders.

Figure 1 (Source: [1]): EWN promotes triple-win outcomes. This initiative provides the practical means for systematically integrating social, environmental and economic considerations into decision making throughout project development. This figure shows how overlapping benefits are achieved resulting in sustainable projects.

Tool development and demonstration projects within the EWN initiative illustrate the use of:

- Science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits
- Natural processes to maximum benefit, thereby reducing demands on limited resources, minimising the environmental footprint of projects, and enhancing the quality of project benefits
- Approaches that will broaden and extend the base of benefits provided by projects to include substantiated economic, social and environmental benefits
- Science-based collaborative processes to organise and focus interests, stakeholders and partners to reduce social friction, resistance and project delays while producing more broadly acceptable projects

Engineering With Nature is being pursued through innovative research, field demonstrations, communicating lessons learnt and active engagement with field practitioners and USACE partners and stakeholders. The objectives of EWN are similar to those communicated in the Working with Nature philosophy of the World Association for Waterborne Transport Infrastructure (PIANC) [2] and the goals of EcoShape's Building with Nature programme in The Netherlands.

The capabilities and practices being developed through the EWN initiative provide direct support to the USACE Civil Works Strategic Plan (Sustainable Solutions to America's Water Resources Needs: Civil Works Strategic Plan 2011-2015), the USACE Campaign Plan (e.g. Objectives 1c, 2c, 2d, 4b) [3], as well as the recently 'reinvigorated' USACE Environmental Operating Principles [4]. Developing sustainable and resilient infrastructure systems for military installations and Civil Works will require USACE to evolve its approaches to planning, engineering and operating infrastructure. Advancing our practices will involve identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects.

2. EWN in Practice

The EWN initiative is developing and demonstrating, through multiple projects, the capabilities that are needed to achieve sustainable, triple-win project outcomes. The following project summaries are provided to illustrate the range of supporting projects that are completed or underway.

2.1 Sustainable Sediment Management through Strategic Placement and Innovative Beneficial Use Practices

In the Civil Works Navigation Programme, sediment management is a costly and challenging endeavour. Designated placement sites are limited in space and environmental restrictions limit where sediment can be placed and how it can be used. The EWN initiative, in collaboration with the Regional Sediment Management (RSM) Programme, is focusing technology development and field demonstrations to highlight opportunities for innovative sediment management practices that can reduce operational costs while also providing for an expanded range of environmental benefits. Members of the EWN team have been collaborating with Philadelphia, Jacksonville and Mobile Districts of USACE (in addition to others) on a range of navigation projects where EWN approaches can provide more sustainable solutions for sediment management. EWN principles and practices are being used by Philadelphia District to plan and design post-Sandy dredging projects that will create new environmental habitats along the coast of New Jersey. In-bay, thin-layer placement of sediment is currently being pursued and demonstrated by Mobile District as an alternative to using the ocean dredged material disposal site, as shown in Figure 2. The in-bay alternatives would provide substantial cost savings, reduce fuel usage associated with as much as a 30 mile transit distance, while providing for several beneficial uses of sediment. The EWN team members partnered with the RSM Programme to provide technical and scientific support in identifying and monitoring placement sites in Mobile Bay. Sediment placement within Mobile Bay will help to retain sediments within the system, provide opportunities for wetlands and marsh creation and provide hundreds of acres of critical habitat.

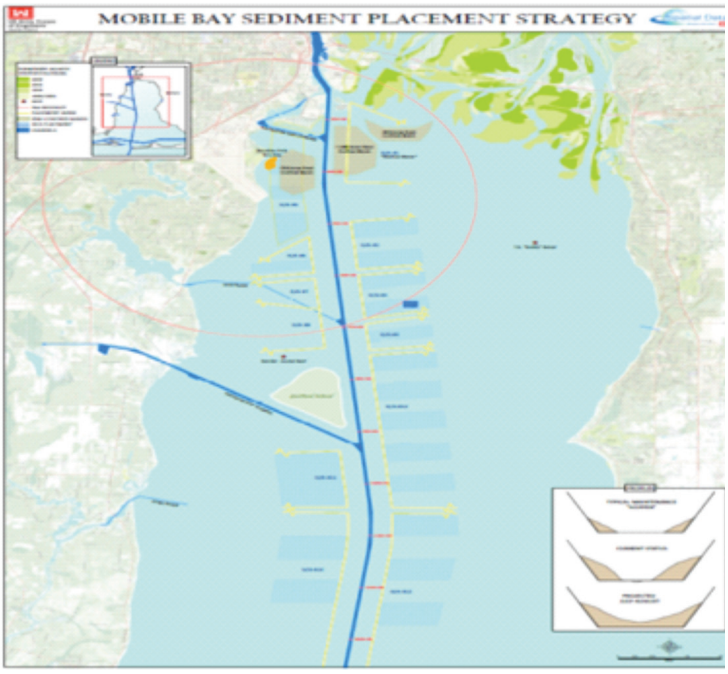

Figure 2 (Source: Courtesy of Mobile District): In-bay placement sites in Mobile Bay, AL are shown. This project demonstrates EWN by utilising sediment beneficially. This encourages the concept that dredged material is a resource.

2.2 Science that Informs How Biology Makes Use of Engineering

Threatened and Endangered Species significantly affect many USACE mission areas (e.g. flood risk management, navigation, hydropower generation, water supply). Populations of the Interior Least Tern (ILT), as shown in Figure 3, are generally associated with sandbar habitats on large rivers of the central United States, and as such, have caused considerable conflict in several USACE mission areas, leading to increased expenditures. The USACE Navigation Programme, through the Dredging Operations Technical Support and the Dredging Operations Environmental Research Programmes, has formed an EWN collaboration with the American Bird Conservancy and the U.S. Fish and Wildlife Service (USFWS) to develop a range-wide meta-population model for ITL (www.leasttern.org). In addition to providing the scientific, ecological basis for evaluating cost-efficient project designs and management scenarios, the model is also being used to provide evidence for delisting ITL from the endangered species list, which would dramatically reduce USACE project costs.

Figure 3 (Source: Courtesy of Dr. Richard Fischer, ERDC): This figure shows an ILT nesting on a sandbar. The ILT is a federally endangered species. Evidence is being currently provided to encourage delisting the ILT.

An Engineer Research and Development Centre (ERDC) led project sponsored by Department of Defense (DoD) Strategic Environmental Research and Development Programme has developed an approach for evaluating alternative management scenarios to address environmental effects on Threatened and Endangered coastal birds that will be caused by sea level rise at military installations. The project integrated climate, land use and ecosystem information into a tool set that assesses vulnerabilities related to Threatened and Endangered bird species at Eglin Air Force Base. The presence of these coastal birds currently poses restrictions on land used for training. The project team developed a series of modelling and assessment tools to evaluate alternative, long-term investments strategies that would minimise the compounding influence of sea level rise and bird habitat effects on installation land use and training.

2.3 Building Habitat into Breakwaters

An ERDC-led project sponsored by the Great Lakes Restoration Initiative is being used to demonstrate opportunities to expand the range of benefits that can be provided by infrastructure projects. As shown in Figure 4, during routine maintenance of breakwaters in Cleveland Harbour in 2012 and 2013, design modifications were made to the submerged toe blocks of the structure to provide features that will create habitat opportunities for Great Lakes fish and invertebrates. Existing breakwaters constructed in the Great Lakes provide limited habitat for fish and invertebrates, mostly in the form of small refuge spaces between concrete or rock sections, while the rest of the structure is relatively inhospitable for most organisms due to the featureless nature of the blocks. The Cleveland Harbour Green Breakwaters Project is examining the opportunities to create substantially more habitat surface on the breakwater by modifying the shape and surface texture of the constructed blocks using textured liners or modified walls in the concrete block forms.

Monitoring will be conducted throughout 2013 to document how the modified toe blocks perform in terms of providing environmental habitat and benefits in comparison to unmodified toe blocks. In order to evaluate the approach more broadly, Ashtabula Harbour, which is along the southern shore of Lake Erie at the mouth of the Ashtabula River, has been identified as a second project site. The Ashtabula project will incorporate tern nesting blocks on top of the breakwater.

Figure 4 (Source: Courtesy of Buffalo District): This figure shows a habitat-enhanced toe block being installed as a part of breakwater repair operations. The face of the toe block has been modified with horizontal lines. The project is located on a Cleveland Harbour breakwater.

2.4 Monitored Natural Recovery Guidance for Contaminated Sediment Site Remediation

In 2009, ERDC team members collaborated with the U.S. Navy and the private sector in developing

and publishing a DoD technical guide on the use of Monitored Natural Recovery for contaminated sediment sites (http://www.serdp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-200622). Development of the guidance was sponsored by DoD's Environmental Security Technology Certification Programme to support clean-up activities within the Department. The U.S. Navy estimates that its sediment clean-up liabilities include US$ 1 billion in future remediation costs. The guidance document provides a science and engineering framework for utilising naturally occurring physical, chemical and biological processes to accomplish risk reduction at contaminated sediment sites. The guidance illustrates opportunities for applying EWN for sediment clean-up at substantially lower costs – both in economic and environmental terms – compared to conventional methods that predominantly rely upon sediment removal.

2.5 EWN GIS Mapper Tool for Communicating Best Practice

The Engineering With Nature Project Mapper (EWN ProMap) is a geography-based data viewer for communicating information about projects that illustrate EWN opportunities. The EWN ProMap, shown in Figure 5, provides project information on water resources projects that illustrate key attributes of the EWN approach: 1) science and engineering is used to produce operational efficiencies, 2) making maximum use of natural processes, 3) broadening the range of benefits provided by the project, 4) using science-based collaborative processes. The overall aim of EWN ProMap is to provide a communication tool that allows users to explore and share information relevant to developing projects that implement EWN principles and practices. Projects can be viewed based upon infrastructure type (e.g. dredging project, breakwater, lock and dam) or by their environmental or social benefits. Many current and past USACE (and partner) projects have incorporated EWN principles and practices. Broadly communicating this portfolio of projects within and external to USACE will provide opportunities for expanding on these successes.

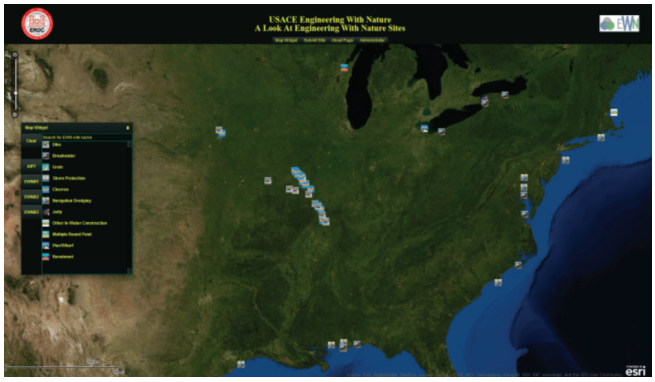

Figure 5 (Source: Courtesy of Mr. Austin Davis, ERDC): The EWN ProMap shows icons that represent project locations and type. Projects that exemplify EWN can be entered into the mapper. It is maintained by ERDC.

Examples of projects included in the EWN ProMap include Mobile District's Deer Island Restoration Project, St. Louis District's use of river chevrons, and Wilmington District's coastal reef constructed of rock dredged from the Cape Fear River, North Carolina. The Deer Island project aims to re-establish marsh along the Mississippi coast. The complete restoration is shown in Figure 6. This project represents an EWN opportunity by demonstrating the use of strategic placement of sediment for beneficial use of dredged material. The project approach maintains sand in the littoral coastal system and contributes to sustainable fisheries by providing essential habitat for juvenile fish, crabs, and shrimp. Multiple benefits, including recreation, shoreline and storm protection, marsh restoration and habitat creation are achieved as a result of this project.

Figure 6 (Source: Courtesy of Mobile District): This figure shows an aerial view of Deer Island post restoration. Deer Island has survived multiple storm events. It continues to be a habitat source for a number of bird species and sea turtle eggs have been documented on the island as well.

The St. Louis District has led the way for river engineering with its use of chevrons that direct flows to maintain the location of the navigation channel while preserving the function of secondary channels for habitat along the Mississippi River, as shown in Figure 7. These structures are sustainable in that they create and/or improve habitat for fish, macro-invertebrates and other species in the river. In addition, these structures utilise the river's energy to maintain navigable depths in the main channel, improve current sets through the navigation spans of several bridges and deposit sediment downstream of the chevrons for increased environmental diversity in the reach which ultimately reduces dredging. The St. Louis Districts projects embody the EWN concept by demonstrating how cost-effective engineering practices can enhance the habitat value of navigation infrastructure.

Figure 7 (Source: Courtesy of St. Louis District): This figure shows an aerial photo of chevrons at Bolter's Bar on the Mississippi River. River training structures, such as chevrons, address problems associated with dynamic rivers. They have proven to not only have provided navigation benefits, but considerable environmental benefits as well.

In the late 1990s, as a part of a capital dredging project on the Cape Fear River in Wilmington, NC, an offshore hard-bottom reef was constructed using rock dredged from the river. Standard practice would have been to dispose of the rock in the designated disposal site. However, members of the project team in the Wilmington District recognised the opportunity to create a regionally rare form of coastal habitat in the South-East Coast of the United States. The project team collaborated with engineers and biologists to design the offshore reef called the Wilmington Offshore Fisheries Enhancement Structure (WOFES). The reef's longest arm, known as Leg 'A', is approximately one nautical mile in length and Leg 'B' is 2,000 feet long which is shown in Figure 8. Fisheries surveys performed after construction of the structure have documented the environmental benefits associated with the project, which has served as the location of multiple fishing tournaments since its construction.

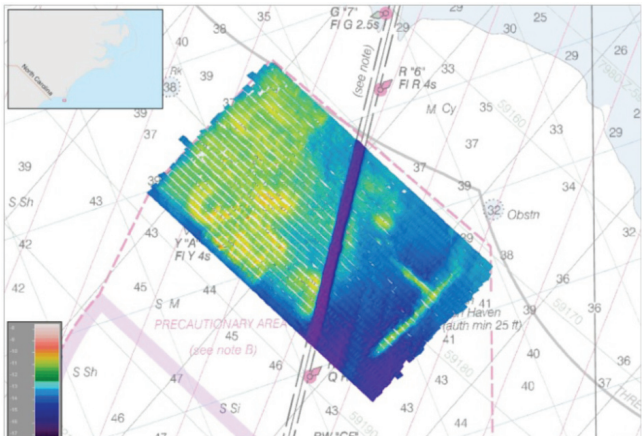

Figure 8 (Source: Courtesy of Wilmington District): The L-shaped structure is one of the largest constructed reefs in the United States. This project demonstrates dredged material can be purposefully used to make essential fish habitat. The WOFES is very popular recreational site for fishermen.

2.6 Engineering With Nature for Coastal Resilience

Engineering With Nature research scientists created a research partnership in 2012 that seeks to accomplish three goals: 1) advance the efficiency of engineering and operational practices involving dredging and dredged material management, 2) expand and extend environmental benefits produced through sediment management and 3) improve the resilience and sustainability of coastal systems facing short- and long-term uncertainties related to climate change and other drivers. The collaboration draws together scientists and engineers from ERDC, USFWS, U.S. Geological Survey and other organisations to develop capabilities to characterise and manage coastal wetlands in response to sediment and nutrient flux, climate change and sea level rise and beneficial use of dredged sediments. The project is applying advanced technologies for measuring, predicting and promoting mineralogical sediment processes in coastal wetland environments in order to sustain these features into the future. Figure 9 shows multiple plantings intended for wetland creation. The tools and technologies developed through this collaboration support planning, engineering and operations in coastal systems. This joint effort represents a research partnership that spans the Navigation, Ecosystem Restoration and Flood Risk Management business lines.

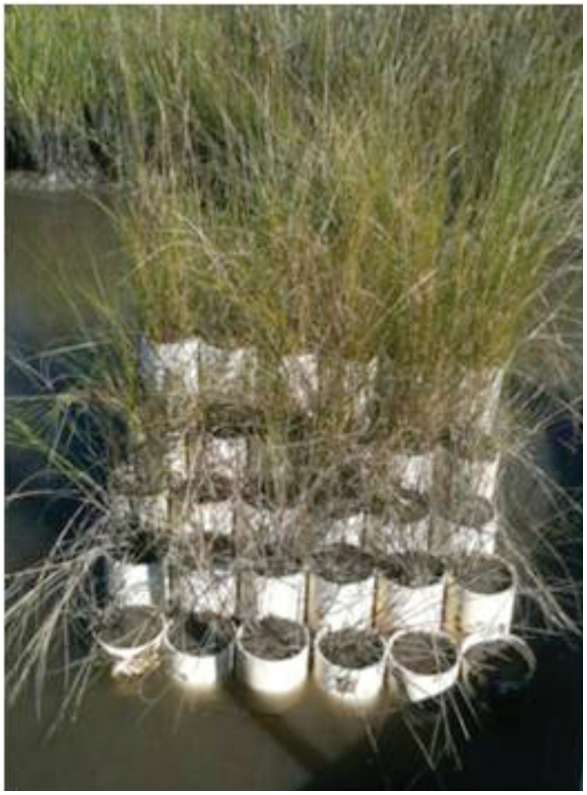

Figure 9 (Source: Courtesy of Dr. Craig Fischenich, ERDC): This figure shows multiple plantings arranged for wetland creation on the Louisiana coast. Coastal systems are a critical component of our nation's infrastructure. The USACE recognises the need to encourage and sustain the resilience of our coasts.

3. Conclusion

Solutions that beneficially integrate engineering and natural systems can greatly support sustainable development of water resources, coastal and port infrastructure. Engineering With Nature enables more sustainable delivery of economic, social and environmental benefits associated with infrastructure while directly supporting USACE's Civil Works strategic planning goals and other directives. Such directives encourage creating synergies between sustainability and the execution of projects and programmes. There are a multitude of existing and developing projects in the U.S. that exemplify aspects of the EWN approach that 1) makes use of science and engineering to generate operational efficiencies, 2) maximises the productive use of natural process, 3) expands the range of benefits provided by projects and 4) applies science-based collaborative approaches. A wide variety of projects in marine coastal, riverine and large freshwater lake environments are already in place and there are major opportunities for the USACE to expand EWN in the near future. The projects provided above are good models for how EWN can be applied in the future in that the capabilities developed and demonstrated through EWN are broadly applicable and relevant across the USACE mission and business lines. Advancing the use of EWN within current and future practice will continue to be pursued through innovative demonstrations, communicating about lessons learned, focused research and development, and active engagement and collaboration with our partners and stakeholders. As the USACE 'does more with less', EWN will help expand the range of benefits provided through our water resources, coastal and port infrastructure, which will ultimately lead to more sustainable projects.

4. References

[1] U.S. Army Corps of Engineers (USACE) (2012): "Engineering With Nature Fact Sheet", http://el.erdc.usace.army.mil/ewn/, accessed July 7, 2012.

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[4] U.S. Army Corps of Engineers (USACE) (2012a): "USACE "reinvigorates" Environmental Operating Principles", http://www.usace.army.mil/Media/NewsArchive/tabid/204/Article/3592/usacereinvigorates-environmental-operating-principles.aspx (accessed September 13, 2012).

SUMMARY

Pursuing the objective of sustainable development of water resources, coastal and port infrastructure poses both challenges and opportunities for U.S. Army Corps of Engineers (USACE). The USACE Civil Works Strategic Plan establishes the need for evolving our approach to engineering and operating infrastructure. Advancing our practices will involve identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects. 'Engineering With Nature' (EWN) is a USACE Civil Work's initiative that supports more sustainable practices, projects and outcomes by working to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.

Many current and past USACE projects provide positive examples of what can be achieved through the application of these concepts and practices: river training structures that enhance fisheries habitat in the Mississippi River, a coastal reef constructed of rock dredged from the Cape Fear River, North Carolina and use of sediment from a navigation project to construct a near-shore berm that nourishes a beach in Ft. Myers, Florida. These and other project examples illustrate opportunities to produce more sustainable systems through the use of:

- Strategic placement of sediments, in combination with hydrodynamics and natural transport processes, to build near-shore habitats
- Engineering features to focus natural processes to minimise navigation channel infilling and to transport and focus sediments for positive benefits
- Cost-efficient engineering practices for enhancing the habitat value of infrastructure
- Natural systems, such as wetlands and other features, to reduce the effects of storm processes and sea level rise on shorelines and coasts
- Science-based communications processes to improve stakeholder engagement and collaboration

RÉSUMÉ

Le développement durable en matière de d'infrastructures portuaires et côtières et de ressources hydrauliques constitue, pour le corps des Ingénieurs de l'Armée américaine (US Army Corps of Engineers, USACE), à la fois un défi et une opportunité. Le Plan Stratégique de Travaux de Génie Civil de l'USACE souligne la nécessité de faire évoluer les approches adoptées en ingéniérie pour ce type d'infrastructures. Il est possible d'améliorer nos pratiques en identifiant tout ce qui permet de mieux intégrer les milieux naturels dans la conception technique afin de proposer des projets plus acceptables sur le plan social, économiquement rentables et durables d'un point de vue environnemental. Composer avec la Nature (Engineering with Nature) est une initiative de l'USACE visant à promouvoir, dans le domaine du génie civil, des pratiques et des projets plus durables soucieux de concilier les aspects techniques et environnementaux afin de générer, au travers de processus interactifs, des avantages en termes économiques, sociaux et de développement durable optimisés en termes d'ingéniérie et de sauvegrade de l'environnement.

De nombreux projets déjà réalisés ou en cours sont autant d'exemples des bénéfices qu'on est en droit d'attendre de la mise en application de ces concepts et démarches, qu'il s'agisse des aménagements fluviaux favorables au développement piscicole réalisés dans le Mississipi, de récifs artificiels construits à partir d'enrochements extraits au Cap de Fear River en Caroline du Nord ou de rechargements de plage à Fort Myers en Floride à partir de sédiments fluviaux dragués dans le cadre d'un projet de navigation. Ces exemples de projet illustrent, comme tant d'autres, toutes les possibilités d'aménagements plus durables, rendues possibles par le recours :

- A des mises en place judicieuses de sédiments en fonction des conditions hydrodynamiques et des mouvements sédimentologiques du site afin de favoriser le développement d'habitat naturel côtier
- A la mise en oeuvre de structures spécifiquement conçues pour limiter l'accrétion dans les chenaux de navigation et favoriser les dépôts dans les zones souhaitées
- A des techniques économiques permettant de valoriser les infrastructures au bénéfice de l'habitat naturel
- Aux étendues naturelles telles que les marais ou autres zones humides susceptibles de réduire les effets des ondes de tempête ou de la remontée du niveau des eaux le long des côtes
- A des efforts de communication scientifique permettant d'augmenter le niveau de mobilisation et d'engagement des décideurs

ZUSAMMENFASSUNG

Die Verfolgung des Ziels einer nachhaltigen Entwicklung von Wasserressourcen und Küsten- und Hafeninfrastruktur stellt für das U.S. Army Corps of Engineers (USACE) sowohl eine Herausforderung als auch eine Gelegenheit dar. Der ingenieurtechnische Strategieplan von USACE zeigt den Bedarf, unseren Ansatz für den Bau und Betrieb von Infrastruktureinrichtungen weiterzuverfolgen. Die Weiterentwicklung unserer Methoden wird die Identifizierung umsetzbarer Handlungen beinhalten, die ergriffen werden können, um technische Entwicklung und natürliche Systeme besser zusammenzuführen und zu integrieren, um gesellschaftlich besser akzeptierte, wirtschaftlich tragbare und ökologisch nachhaltige Projekte zu entwickeln. Bauen mit der Natur ('Engineering with Nature' (EWN)) ist eine Bau-Initiative von USACE, die nachhaltigere Baupraktiken, Projekte und Ergebnisse unterstützt, indem so gearbeitet wird, dass bewusst natürliche und bautechnische Prozesse zusammengeführt werden, damit effiziente und nachhaltige ökonomische, umweltfreundliche und soziale Leistungen durch gemeinsame Prozesse erbracht werden.

Viele laufende und vergangene USACE-Projekte liefern positive Beispiele dafür, was durch die Anwendung dieser Konzepte und Praktiken erreicht werden kann: Flussregelungs-maßnahmen, die den Lebensraum von Fischen im Mississippi verbessern, ein Küstenriff, welches aus Steinen erbaut wurde, die im Cape Fear River, Nord-Carolina, ausgebaggert wurden, und die Verwendung von Sediment aus einem Projekt der Seeschifffahrt zum Bau einer küstennahen Berme, die einen Strand in Fort Myers, Florida, stabilisiert. Diese und andere Projektbeispiele zeigen Möglichkeiten, um nachhaltigere Systeme durch die folgenden Anwendungen aufzubauen:

- Strategische Platzierung von Sedimenten in Kombination mit hydrodynamischen und natürlichen Transportprozessen, um küstennahe Lebensräume herzustellen
- bautechnische Eigenschaften zur Fokussierung natürlicher Prozesse, um den Eintrag in die Fahrrinne zu minimieren und abzuransportieren, und zur Verwendung des Sediments für einen positiven Nutzen
- kosten-effiziente technische Praktiken zur Verbesserung des Lebensraums an Infrastruktureinrichtungen
- natürliche Systeme, wie Feuchtgebiete oder andere Einrichtungen, um den Einfluss von Stürmen und den Anstieg des Meeresspiegels auf Küstenlinien und Küsten zu reduzieren
- wissenschaftlich basierte Kommunikationsprozesse, um das Engagement der Stakeholder und die Zusammenarbeit zu verbessern

RESÚMEN

La búsqueda del objetivo de un desarrollo sostenible de infraestructuras hidráulicas, portuarias y costeras, plantea retos y oportunidades para el Cuerpo de Ingenieros del Ejército de los Estados Unidos (USACE). El Plan de Obra Pública del USACE establece la necesidad de evolucionar en su aproximación al diseño y a la operación de sus infraestructuras. El desarrollo de este planteamiento debe permitir identificar aquellas actuaciones que permitan mejorar los diseños de los proyectos, de tal manera que éstos resulten aceptables, económicamente viables y ambientalmente sostenibles. 'Diseñando Naturalmente' (EWN) es una iniciativa del Departamento de Obras Públicas del USACE que busca una mejora de las prácticas ambientales, del diseño de los proyectos y de la ejecución de las obras, en una estrategia que integra el proceso de diseño en un planteamiento global basado en el desarrollo económico sostenible y en la búsqueda de mejoras sociales y ambientales.

Los proyectos del USACE, pasados y actuales, muestran ejemplos de los resultados que se pueden lograr aplicando esta clase de procedimientos y de conceptos: estructuras fluviales que permiten mejorar el hábitat de los peces en el río Mississippi, bermas costeras ejecutadas con materiales procedentes de dragado en el río 'Cape Fear' (Carolina del Norte), utilización de sedimentos procedentes de un proyecto de mejora de la navegación para construir la berma de contención de una playa artificial en Ft. Myers (Florida). Estos y otros ejemplos de proyectos realizados muestran oportunidades de generar sistemas sostenibles, a través del uso de:

- Disposición de sedimentos en ubicaciones estratégicas, que en combinación con procesos naturales de transporte generen hábitats en zonas costeras
- Diseños centrados en los procesos naturales que minimicen los depósitos de material en canales, o que permitan el transporte de sedimentos buscando la generación de beneficios naturales
- Prácticas ingenieriles eficientes desde un punto de vista de su análisis coste-beneficio, que mejoren los valores naturales de la infraestructura
- Sistemas naturales, como los humedales, que reduzcan los efectos de los temporales y del incremento del nivel del mar en zonas costeras
- Procesos de comunicación con los interesados que, a partir de un análisis racional, ayuden a mejorar los objetivos a obtener con un determinado proyecto