FRM
Flood Risk Management Newsletter

Building a Foundation for Resiliency

Levee Resilience or "Getting the Grass to Grow"

Existing Levee Infrastructure: Risk-Informed Challenges and Opportunities

When the Sky Isn't the Limit – Evaluating UAS Support to Flood Risk Management

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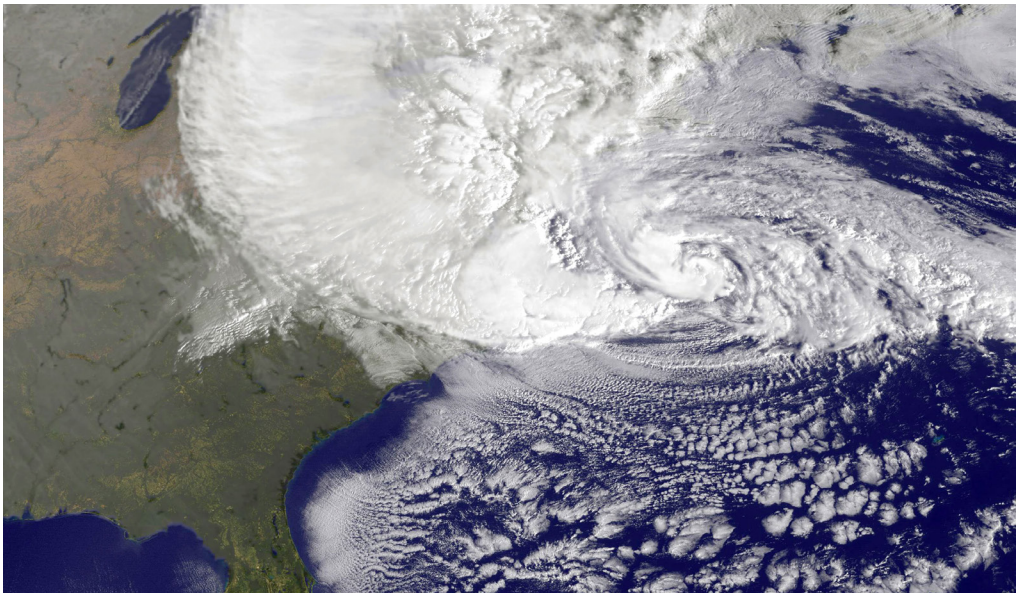
Reflecting on Hurricane Sandy Five Years Later

By Mark Roupas, Deputy Chief, Office of Homeland Security



Hurricane Sandy, pictured at 1240 UTC, churns off the east coast on Oct. 29, 2012, in the Atlantic Ocean.

Best wishes for an extended fall season. I know many of us within USACE, as well as many of our external partners, remain heavily engaged in response and recovery missions in Texas in the aftermath of Hurricane Harvey and in Florida, Puerto Rico and the Virgin Islands in the aftermath of Hurricanes Irma and Maria. However, I am reminded during our current efforts of the fact that we are approaching the five-year anniversary of Hurricane Sandy. As you may remember, Hurricane Sandy originated in the Caribbean on October 22nd, 2012. On October 29th, 2012 Hurricane Sandy made landfall near Brigantine, NJ as a post-tropical cyclone. Although Hurricane Sandy came ashore in the mid-Atlantic region, essentially the entire East Coast and parts of the Great Lakes were impacted to some degree, with effects extending from Florida to Maine. The most significant damage occurred in New Jersey, New York, and Connecticut, with extensive devastation around the NY-NJ Harbor region.

Hurricane Sandy led to the deaths of at least 117 people in the United States, according to the Centers for Disease Control and Prevention, and resulted in more than $65 billion in damages. On January 29th, 2013 Congress signed into law Public Law (PL) 113-2, the Disaster Relief Appropriations Act of 2013, which provided just under $50 billion to help with the recovery effort. USACE received approximately $5.1 billion of that funding, primarily for infrastructure recovery. I've asked a number of USACE subject matter experts to provide me with some of their brief thoughts on the experience of Hurricane Sandy, including the things that went well, some things that did not go as well as expected, and some items that we have learned from and improved upon. My thanks to USACE members Joe Vietri, Roselle Stern, Donald Cresitello, Joe Forcina, Lin Miller, and Edward Loomis from the North Atlantic Division (NAD), Anthony Ciorra and Lynn Bocamazo from the New York District, and Amy Guise and Dave Robbins from the Baltimore District, for their insights, suggestions, and recollections on Hurricane Sandy.

Of the $5.1 billion that USACE received from PL 113-2, $4.6 billion went to NAD to fund a total of 159 studies and projects. The funding was split among the Flood Control and Coastal Emergencies Program (FCCE), the Operations and Maintenance Program (O&M), the Authorized but Unconstructed Program (ABU), the Continuing Authorities Program (CAP), and the Ongoing Studies Program (OGS). Funds for FCCE were used to complete emergency repair to 25 coastal storm risk management (primarily beachfill) projects, while O&M funds were used to dredge navigation channels, and repair piers and hurricane barriers. Prior to Hurricane Sandy, 19 coastal storm risk management projects had been approved but had not yet begun construction. Approximately $2.8 billion was allocated to fund these projects. Of these 19 projects, six are complete, four are currently under construction, eight will begin construction pending coordination with state and local officials, and one determined to be no longer economically justified was terminated. A total of 12 small coastal storm risk management projects are in the planning/design phase under the CAP, execution of which does not require additional congressional authorization.

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Additionally, 16 coastal storm risk management studies underway when Hurricane Sandy hit are in various stages of completion in the OGS Program.

In addition to the Hurricane Sandy Recovery Program projects and studies outlined previously, PL 113-2 directed the North Atlantic Coast Comprehensive Study (NAACS), a $19-million collaborative effort between the Corps and federal, state, regional and local government agencies, and non-Government organizations, tribal officials, and academia. Released to Congress on January 28th, 2015, the NACCS examined risk-reduction measures along the 31,000 miles of coastline impacted by Hurricane Sandy, and included the Coastal Storm Risk Management Framework, a customizable, common methodology that public and private interests can utilize together, applying technical products and planning tools, to assess risk and identify solutions.

Resulting from the NAACS, nine new Focus Area Studies will target specific high risk communities and consider various unique area concerns from subsidence and sea-level rise to back-bay inundation, while still maintaining a systems approach to the development of alternative plans and courses of action. The Corps has, in place, signed agreements with states and localities to begin analyzing New York-New Jersey Harbor and Tributaries, New Jersey Back Bays, Nassau County Back Bays in New York, the City of Norfolk in Virginia, and Washington D.C. The Delaware Back Bays and Bay Coast, the Rhode Island Coastline, the Connecticut Coastline, and the City of Baltimore, MD, are additional areas recommended for evaluation.

While Hurricane Sandy was a significant event that caused extensive impact and damage, it is important to recognize that there were also successes in the midst of managing the event. In particular, NAD leadership decided early on to establish a separate arm to manage their post-Hurricane Sandy work, and enlisted personnel with the appropriate expertise from across the agency to staff the temporary Hurricane Sandy Coastal Management Division. Very close coordination at all levels of the organization, with the Office of the Assistant Secretary of the Army for Civil Works, and with external regional stakeholders, the Office of Management and Budget, and Congress enabled much more efficient and effective execution, and could possibly serve as a management model for future events of this magnitude.

The NACCS revealed the substantial benefit that came from the existing coastal storm risk management projects as well as the importance of good risk communication. This effort further emphasized the importance of working off of good science and data, as well as the crucial importance of collaborating with diverse partners in order to obtain the best possible information. The collaboration, at all levels of government and with non-governmental organizations and private entities before, during, and after the storm was also a success worthy of highlighting. By developing a collective process, built on solid science and policy, we were able to create a comprehensive pre-storm process for resilience planning. And

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The U.S. Army Corps of Engineers works aggressively Nov. 6, 2012 to repair a levee breach caused by Hurricane Sandy in Montoloking, NJ. (Photo Credit: Mary Markos, USACE Public Affairs)

even better, this process is transferrable to other regions, nations, and natural disasters; it's not just limited to the East Coast and coastal storm risk. Hurricane Sandy also demonstrated the importance of aspects of coastal flooding previously not in the forefront, such as the impacts to back-bay and inland areas. Because of the wide-spread inundation within the coastal floodplain, Hurricane Sandy impacted many areas previously considered to be at low risk due to their location. This has made us much more aware of the storm impacts to things like evacuation routes, utilities, critical infrastructure, and community functioning.

From an infrastructure perspective, Hurricane Sandy demonstrated the tremendous benefit of coastal storm risk management projects. A study to examine project performance revealed large differences in the level of damage in areas with projects in place, compared to those without projects within the same county. Those areas with projects experienced far less damage and demonstrated a higher level of resilience, with communities able to return to normal much sooner than those areas without the benefit of Corps projects. The level of risk reduction offered by the projects in place was extremely impressive, especially when considering that the projects in New York and New Jersey, in particular, were subjected to unprecedented tide surges, and water levels substantially higher than their design conditions. This clearly demonstrated the enormous importance and benefit of a healthy berm and dune.

Hurricane Sandy also provided numerous lessons learned and identified areas of continued improvement, to use in the future. For instance, to the Corps could improve methods of ensuring that existing project data is current. This would allow improved estimation of rehabilitation requirements following an event. Enhanced communication of vulnerability and the need for proactive preparedness with external partners and stakeholders would also be beneficial. This communication should include, as well, consideration of the full array of coastal storm risk management measures. And a deeper examination of the continuum of nonstructural, structural, natural and nature based features and policy and programmatic approaches will help lead to even more comprehensive and sustainable coastal storm risk management solutions.

Harvey Cedars, N.J., July 31, 2013 -- The Army Corps of Engineers oversee progress on beach and dune nourishment for Long Beach Island and Atlantic City. The coastal restoration is part of mitigation efforts, funded by the Sandy Relief Act, to reduce risks of property and infrastructure damage from coastal storms like Superstorm Sandy. Rosanna Arias/FEMA Photo by Rosanna Arias - Jul 30, 2013 - Location: Harvey Cedars, NJ

From a technical perspective, developing further improvements in our understanding of coastal floodplains and coastal storms, gained from our experience with Hurricane Sandy, will also benefit our preparation for future coastal storm events. For example, low-probability high-magnitude events are not frequently mapped, and communication of risk in areas that would be inundated by these events is not typically carried out. Additionally, in recent years, we have seen shifts in storm tracks away from the historical norms. For future coastal storm events, we need to consider larger storms, higher magnitude storms, and anomalous storm tracks in order to more fully anticipate all possible scenarios. Addressing these technical shortcomings, brought to light by Hurricanes Sandy, Harvey, Irma, Jose, and Maria, and many storms in between, will help to better prepare and position the agency for the next coastal storm. Expect to see an article on potential improvements in this area in our next newsletter.

As we continue to work through recovery efforts following recent hurricanes, we will continue to identify lessons learned and areas for future improvement. We will add them to those lessons that Hurricane Sandy taught to us, and continue endeavors to improve upon our processes and abilities as best we can, as we prepare for the next storm event. My thanks, again, to the North Atlantic Division, for all of their insight in shaping this article and for all of their hard work before, during, and after Hurricane Sandy.

Levee Resilience or "Getting the Grass to Grow"

By Steve Larson, Ph.D, Engineer Research and Development Center - Environmental Laboratory

Figure 1. Addition of hydromulch, grass seed, and biopolymer to soil of Kaufman Levee.

The Mississippi River reaches flood stage at least once a year along its entire length. Since 1927, USACE engineers have been controlling these floods with levees and people living along the Mississippi have come to expect this protection. USACE and other agencies have long required a grass cover for the levees. Grasses have been shown to provide armoring against wave wash, current, overtopping and rainfall. Unfortunately, "getting the grass to grow" is an often heard complaint from levee safety and maintenance personnel.

In FY10, funding was provided by the US Army for research into ways to maintain dirt roads and berms on training installations. A common soil bacterium, Rhizobium tropici develops in a symbiotic association with the roots of leguminous plants, like beans. R. tropici also produces an extracellular polysaccharide (EPS) biopolymer outside the bacterial cell wall. This EPS, did, indeed, improve properties of soil aggregation thus decreasing soil erosion from wind and rainfall on slopes and roadbeds. The biopolymer was successfully field tested at the Iowa Army Ammunition Plant over a period of three years.

This biopolymer was transitioned to the USACE Civil Works Program in FY14 and was supported for field testing on new levee construction at Kaufman Levee No. 1 (Fort Worth District). Bermuda grass is the preferred grass for levees in the Southeastern United States. It is a long-lived, warm season perennial that spreads by rhizomes, stolons and seeds. The leaves are flat and spreading. Once established, it forms a dense sod that can withstand sedimentation and long periods of inundation. It can grow over a wide pH range and will even tolerate saline soil. Working with Fort Worth District, the R. tropici biopolymer was applied along with hydromulch and hydroseeding. The biopolymer was added to the hydroseed mix and didn't require either extra time for application or extra equipment (Figure 1). Three concentrations of biopolymer were tested against a control (with no biopolymer) in order to establish the most cost-effective use of the material. The test areas were then left to develop normally, which included a flood event of the Trinity River. Establishment of Bermuda grass on the levee was evaluated after one year. One meter squares were outlined as randomly selected plots within each test area. Digital images were obtained of each plot as well as on-site plant growth and diversity evaluations. Individual plants were sampled from each plot for laboratory examination of differences in root architecture between the treatments.

Image analysis verified the greater establishment of Bermuda grass and the decreased incidence of invasive plant species in the areas amended with the biopolymer (Figure 2). The increased above ground biomass contributes to

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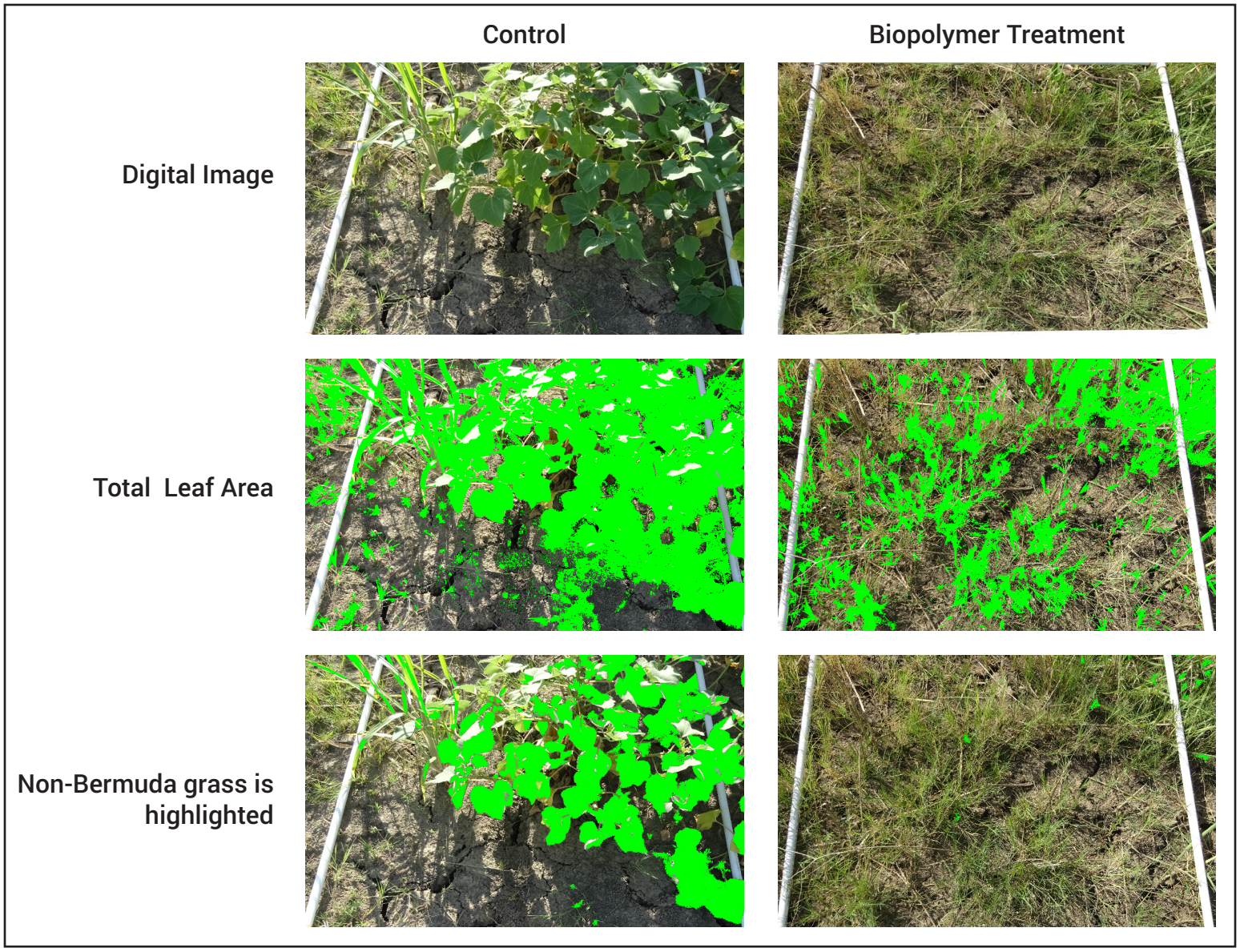

Figure 2. Digital image analysis of sample plots in control (untreated) and biopolymer treated areas of the Kaufman Levee.

soft armoring of the levee during an overtopping flood event. Root analysis showed significantly greater total root area and root surface area in plants grown in biopolymer-amended soil. Root area has a direct influence on soil slope stability. The small flexible roots increase the soil fiber strength. Larger roots that intersect the shear plane of the slope act as individual anchors. Amending the soil with biopolymer increased above and below-ground biomass which contributes to greater armoring of the soil surface and decreased soil erodibility. This directly reduces costs of levee construction (fewer repeat visits to re-grass), reduces levee maintenance costs over the lifetime of the levee, and contributes to levee safety.

For more information see:

Larson, S.L., Newman, J.K., Griggs, C.S., Beverly, M. and Nestler, C.C. 2012. *Biopolymers as an Alternative to Petroleum-Based Polymers for Soil Modification: Treatability Studies.* ERDC TR-12-8, USACE Engineer Research and Development Center, Vicksburg, MS.

Larson, S.L., G. Nijak, Jr., M. Corcoran, E. Lord and C. Nestler. 2016. *Evaluation of Rhizobium tropici-derived biopolymer for erosion control of protective berms. Field study: Iowa Army Ammunition Plant.* ERDC TR-16-5, USACE Engineer Research and Development Center, Vicksburg, MS.

Larson, S.L., M.K. Corcoran, D.B. Gent, A. D. Butler and C. Nestler. 2017 (in press). *Improved levee resilience through soil application of a natural organic polymer.* USACE Engineer Research and Development Center, Vicksburg, MS.

Army Corps Builds Foundation for Resiliency

By JoAnne Castagna, Ed.D, New York District

Nestled in the Sandy Hook Bay, the community of Port Monmouth, New Jersey has experienced flooding, blizzards, and major storms that have swept through the area throughout the years. It's Atlantic hurricane season once again, and life-long Port Monmouth resident Charles Rogers reminisces about past storms that have battered the area and his experiences.

"My father placed me on his shoulders and walked through four feet of water to take me to my grandmother's house during the hurricane of 1944," said Rogers. The "1944 Great Atlantic hurricane" was a destructive and powerful tropical cyclone that swept across a large portion of the East Coast in September of that year. During Hurricane Donna in 1960, the area was evacuated, and Rogers and his entire family were transported by the U.S. Coast Guard via an amphibious vehicle to the firehouse to safety.

"In 2012, Hurricane Sandy placed almost four feet of water in my house and six feet in my cellar and we lost our heating, electric, food and personal items," said Rogers. The outlook on future storms is much brighter for Rogers due to the Port Monmouth Flood Risk Management Project being performed by the U.S. Army Corps of Engineers, New York District. "It's an important project to protect Port Monmouth residents," said Rogers.

The Corps in partnership with the New Jersey Department of Environmental Protection Bureau of Coastal Engineering, is working on this project that will make the community more resilient during future storm flooding and surge. To help with this resiliency, the Corps decided to include an environmentally friendly soil stabilization process that has never been used by the Corps before on a flood risk management project. The process makes the project stronger, improves the community's quality of life, and saves tax-dollars.

A concrete floodwall is being constructed to help reduce flooding as part of the Port Monmouth Flood Risk Management Project in Port Monmouth, New Jersey. Credit: JoAnne Castagna, Public Affairs.

The project area is made up of low lying salt and freshwater marsh and there are many residential and commercial structures sitting right on or near this marshland. Erosion over the years has removed much of the natural beachfront and dune complexes that provided coastal protection to the community from storm surge. Hurricane Sandy further exacerbated the problem by causing millions of dollars in damages, destroying 750 homes and businesses in Port Monmouth alone.

The project includes two phases of work that together will reduce the risk of flooding throughout the entire community. The first phase was completed in 2015 and provides storm risk reduction from the Sandy Hook Bay. This work included building up and widening the shoreline, constructing a 15-foot high protective dune – spanning a mile and half long, and constructing a new stone groin perpendicular to the shoreline. A groin structure extends out from the shore into the water and interrupts water flow and limits the movement of sand, to prevent beach erosion and increase resiliency. In addition, a fishing pier was extended 195 feet and walking paths were built to provide the public access to the beach area.

The second phase is in progress and will provide a line of defense surrounding Port Monmouth. The work includes constructing a concrete floodwall - the length of almost 22 football fields - to reduce flooding from the Pews Creek to the west and the Compton Creek to the east. Additionally, pump stations, road closure gates and a tide gate at Pews Creek will be constructed.

In addition, a system of levees will be constructed. The levees that are being constructed need a strong foundation. The land is made up of low lying salt and freshwater marsh that is not strong and very saturated, so this soil needs to be removed and replaced with better soil to construct upon.

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Marshy soil is being mixed with concrete and water to create a strong foundation for a levee as part of the Port Monmouth Flood Risk Management Project in Port Monmouth, New Jersey. Credit: JoAnne Castagna, Public Affairs.

"Typically, it's cost effective to remove and replace the unsuitable soil, but in the New York and New Jersey region it's a different story," said David Gentile, project manager, New York District, U.S. Army Corps of Engineers. "In urban areas it's hard to find disposal sites, so the soil would have to be picked up by trucks and transported to a location that can accept it and new more suitable soil trucked in, which is expensive, especially since we are moving a mountain of material," said Gentile.

Gentile decided to move forward with a cost effective solution for the soil that has never been accomplished before by the Corps on a flood risk management project. This solution is a process called In Situ Soil Stabilization. Instead of removing and replacing the marsh soil, this process allows engineers to leave the soil where it is. A material, such as common Portland cement and water is mixed with the existing soil to strengthen the porous marsh soil, creating an impermeable foundation for a levee.

There are numerous benefits to this process, but the biggest benefactor is the surrounding community that sits just a few hundred feet from the project area. This process eliminates the need for over 1,750 tri-axle truck trips, carrying wet, mucky, and odorous material, through residential streets. Rogers an active member of the Port Monmouth community agrees, "When this process was put on the table it sounded good then. Anytime you can use what is there and not have large truck loads of materials running up and down the roads you save money. It's a big plus for the project, the residents, and the environment."

Ken Johnson, engineer with the Corps' New York District, added, "Less trucks means the local roads and bridges are spared from possible damage, there is less air pollution, noise complaints are greatly reduced, and there is an overall savings of landfill space along with financial savings."

Gentile added, "The public is very supportive of the project and tax-payers will save an estimated $700 thousand." This project is expected to be completed by 2020 and designed to provide flood protection that can withstand another Hurricane Sandy.

Dr. JoAnne Castagna is a Public Affairs Specialist and Writer for the U.S. Army Corps of Engineers, New York District. She can be reached at joanne.castagna@usace.army.mil.

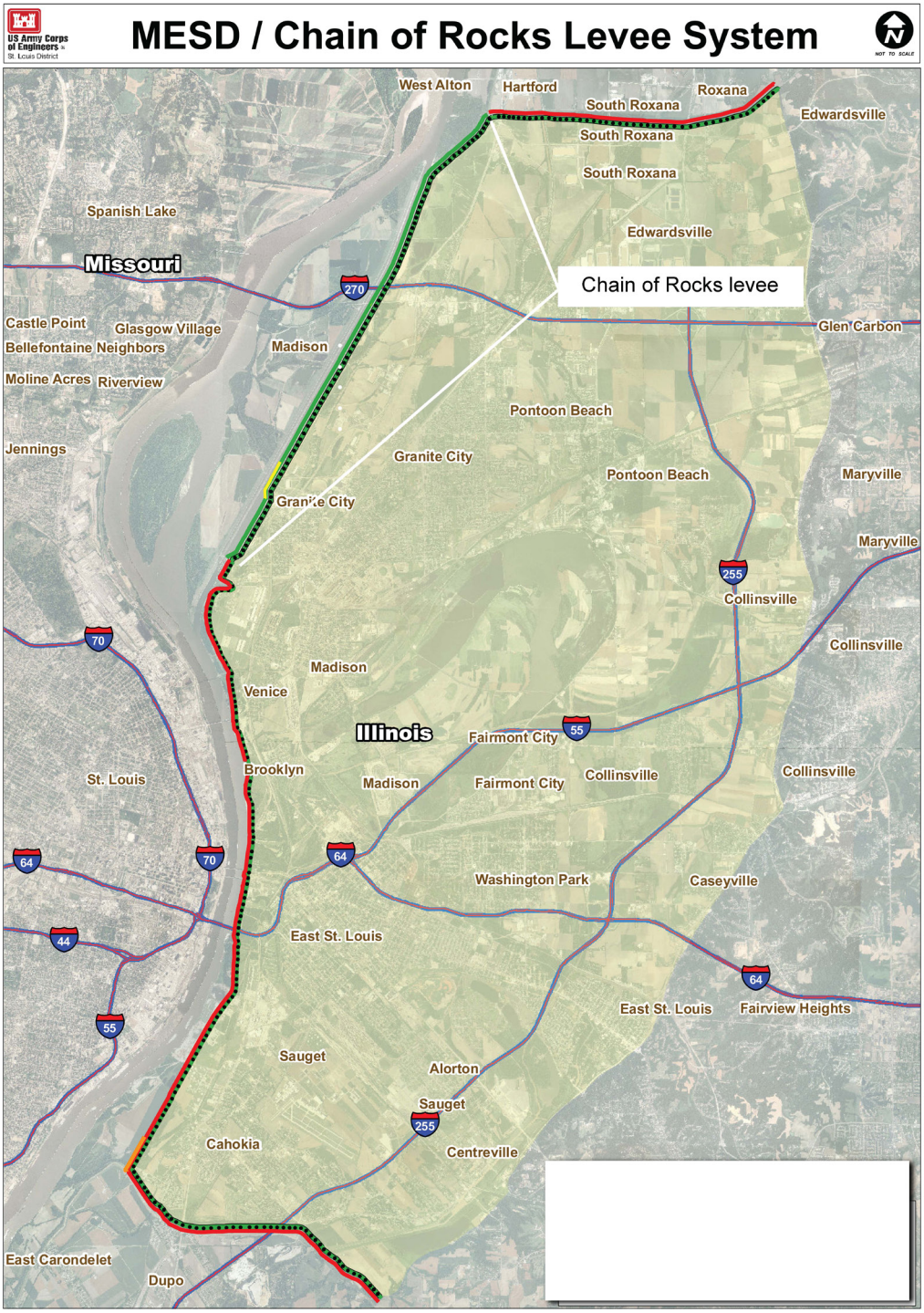
The Port Monmouth, New Jersey shoreline was built up and widened and a fishing pier extended as part of the Port Monmouth Flood Risk Management Project in Port Monmouth, New Jersey. Credit: JoAnne Castagna, Public Affairs.

Existing Levee Infrastructure: Risk-Informed Challenges and Opportunities

By Jose Lopez, St. Louis District

In June of 2017, the USACE Director of Civil Works, Mr. James Dalton, asked USACE to "Embrace and Operationalize Risk-Informed Decision Making". Upon first read many might think this directive to be benign or at the very least restatement of our mission since USACE has been a risk management Agency for centuries. Hurricane Katrina was a defining moment in the evolution of risk informed decision making when it made landfall on August 29th, 2005 in southeast Louisiana. The challenges of embracing and more explicitly operationalizing risk informed decision making for existing USACE built infrastructure quickly became salient and noticeable to most, if not all, within the Agency. So the directive to "embrace" and more importantly "operationalize" risk informed decision making is a call to arms to continue the shift from an Agency of certainty to an Agency that understands, quantifies and seeks to embrace and make decisions under levels of uncertainty.

Once flood risk infrastructure is built and put into service history has shown that society, generally, follows that infrastructure; and thus the risk is transformed from simply flood risk to infrastructure risk (i.e. dam risk, levee risk, etc.). That risk must be managed because in comparison to flood risk, the built infrastructure risk is an imposed risk by those who built and those who maintain the infrastructure. This can be exemplified by the three largest levee systems located on the east bank of the Mississippi River across from the City of St. Louis. The Lower Wood River levee system, the Upper Wood River levee system and the East St. Louis levee system; three systems that currently protect over 300,000 lives plus many billions of dollars in property. These systems were designed and constructed by USACE and have been operated by local sponsors since the 1950s. Since the late 2000s there have been ongoing studies with the aim of identifying what and how many features would need to be implemented to help remediate foundation issues identified during the record flood in 1993.



Alignment and leveed area of East St. Louis and Vicinity Flood Protection Project

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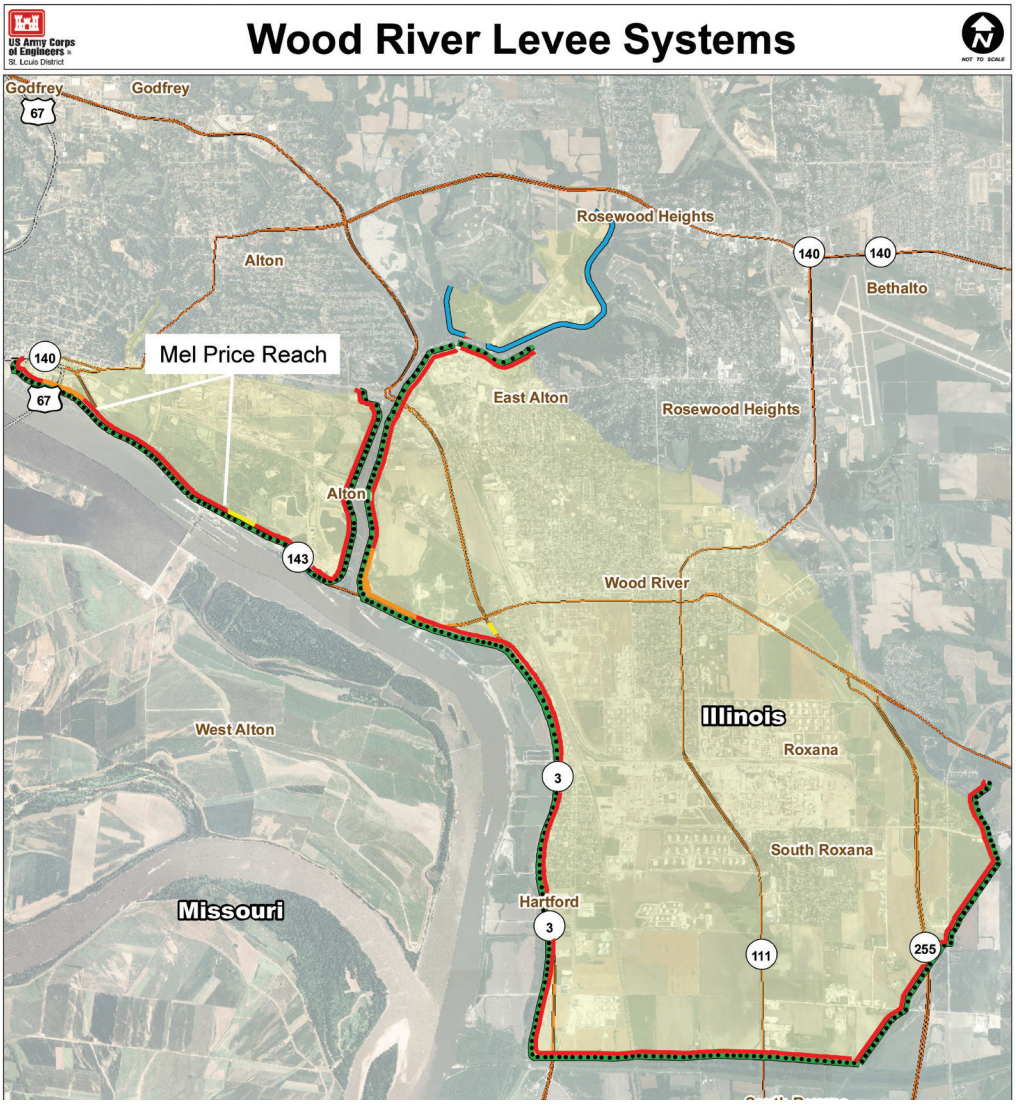

Alignment and leveed area of Wood River Flood Protection Project

"This process allowed for a more comprehensive understanding of the flooding hazard, infrastructure behavior as well as associated consequences of failure."

Since 2014, USACE, along with the non-federal sponsors, has embarked on three studies that operationalize risk informed decision making and more specifically attempt to address the challenges of determining appropriate levels of investment for built existing infrastructure and the associated risks. Beginning with the Upper Wood River levee system USACE performed a quantitative risk assessment that allowed the Agency and the non-federal sponsor to better inform selection of the remediation measures for underseepage. This process allowed for a more comprehensive understanding of the flooding hazard, infrastructure behavior as well as associated consequences of failure. These factors combined, allowed for a more cost effective selection of alternatives that was commensurate with the estimated risk while also accounting for the uncertainty associated with complex flood risk infrastructure. This study recommends a $29 million dollar remediation that is commensurate with the level of risk. In comparison, previous studies for this system had yielded remediation measure with costs upwards of $130 million. Similar risk-informed studies are under way for the Lower Wood River levee system, a much longer and more complex system with higher consequences, but that experiences similar foundation problems during high-water events. Once again, the risk-informed study will seek to inform USACE and the non-federal sponsor on the most cost-effective remediation measures. In the East St. Louis System (i.e. MESD and Chain of Rocks) a risk-informed design spearheaded by USACE and the non-federal sponsor is ongoing utilizing the existing Baseline Condition Risk Assessment (BCRA) that was performed on the system to better understand the existing risk. The previous decision document that was approved (Circa 2011) for the project was performed using deterministic standards and was only being justified on economic benefits. This risk informed design will seek to evaluate the recommended modifications that the non-federal sponsor could implement in order to evaluate whether the proposed design are commensurate with the levee system risk in an effort to justify them based on life safety considerations as well as economic and environmental.

Embracing and operationalizing risk-informed decision making is what a risk management agency should be doing. Utilizing the best available science, technology and critical thinking engineers and scientists from USACE Districts along with our partners can continue to drive the change and progress towards making smart investment decision that maximize the cost-effectiveness for remediation/repair of existing infrastructure. Mr. Dalton's directive to embrace and operationalize risk-informed decision making across the Agency is resonating throughout all levels of operation, and we will be a better Agency for it.

When the Sky Isn't the Limit – Evaluating UAS Support to Flood Risk Management

By Alex Renaud, Brittany Bruder, Ph.D, **and Kate Brodie,** Ph.D
Engineer Research & Development Center, Coastal & Hydraulics Laboratory, Field Research Facility

Clockwise from the top left, UAS imagery of the beach and surf zone; a UAS with ground surveying equipment and a nourishment project behind it; aerial views of the ground control targets over the CHL-FRF pier; and various UAS flight data collection focus zones on the CHL-FRF property.

The development of Unmanned Aerial Systems (UASs) has continued to accelerate over the past decade, with many airframes and software in use across a diverse array of commercial, military, and recreational sectors. As UAS flexibility, affordability, and operability have improved, the door has opened for a wide variety of remote sensing applications, including improving emergency management before, during, and after natural disasters. UAS platforms provide high-resolution spatial data at low altitudes and likely can fill a number of gaps between ground and high-altitude surveying practices that traditionally support flood risk management (FRM). Specifically, USACE could integrate UAS platforms to: provide time-efficient disaster preparation, response and recovery; enable expedient and efficient data acquisition, management, and dissemination to mitigate risks; and quickly assess damages to FRM infrastructure and prioritize recovery operations. UAS observation of dynamic and inaccessible FRM-relevant areas in a safe, effective, and inexpensive manner could therefore reduce existing limits to current USACE FRM practices.

Though UAS technology brings many benefits, significant differences in data quality, efficiency, and cost exist between platforms, sensors, and processing

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UAS platforms flown at the June Duck Pilot UAS for FRM Field Experiment. By column left to right: 3DR X8+, Sensefly eBee, DJI Phantom, BirdsEyeView FireFLY6 Pro, DJI Matrice 100, Multirotor G4 Skycrane, Riegl RiCopter, Sky-watch Cumulus, 3DR Solo, PrecisionHawk Lancaster

software and therefore an investment of resources is needed to identify and evaluate the most applicable technologies for USACE. To this end, ERDC researchers have initiated a multi-lab effort to identify and develop defendable and consistent UAS based methodology and data products that seamlessly integrate with numerical models to monitor coastal terrain (topography and nearshore water depths), storm-damage reduction infrastructure, and ecosystem health in support of USACE FRM actions. Over the past year, the project's principal investigators (Dr. Kate Brodie – CHL, Dr. Robert Fisher – GRL, Molly Reif – EL, Dr. Ty Hesser-CHL, and Dr. Matt Farthing – CHL) and their teams began reviewing UAS technology and adapting UAS platforms to the USACE FRM mission. Developing UAS data collection and processing approaches demands significant field deployment testing to ensure that the technology is robust enough for USACE District deployment as well as interaction and discussions with Districts as to their needs.

"UAS platforms ranged from small quadcopters with traditional high-resolution cameras to large fixed-wing airframes with lidar scanners."

Much of the UAS Support for FRM initiative revolved around a three-week collaborative field experiment in June 2017 designed to assess the capabilities and limits of various UAS sensors, platforms, and data collection and processing methodologies. The experiment was hosted at the Coastal and Hydraulics Laboratory's Field Research Facility (CHL-FRF) in Duck, NC, a town on the northern portion of the Outer Banks. The experiment brought together nine UAS flight teams and two traditional manned platforms from ERDC labs (CHL, CRREL, EL, and GRL), federal government agencies, private industry, and academia.

The teams flew their 12 different airframes across the CHL-FRF property more than 180 times, combining for well over 2700 minutes of airtime. UAS platforms ranged from small quadcopters with traditional high-resolution cameras to large fixed-wing airframes with lidar scanners. One platform combined both flight mechanisms, vertically taking off before switching to traditional-fixed wing flight (aka Vertical Take-Off and Landing, or VTOL). Platform sensor packages measured spectra in and outside the visible band (IR, multispectral, and thermal) as well as produced Lidar point clouds of the terrain, bathymetry, and ocean surface. Short of surviving some periods of high wind and rain, there was rarely a moment where a UAS platform wasn't up in the air.

The CHL-FRF property allowed for testing UAS-based sensors over surf-zone, beach, dunes, barrier island, marsh, and estuarine environments. CHL-FRF constructed a mock jetty to assess UAS approaches to identify movement

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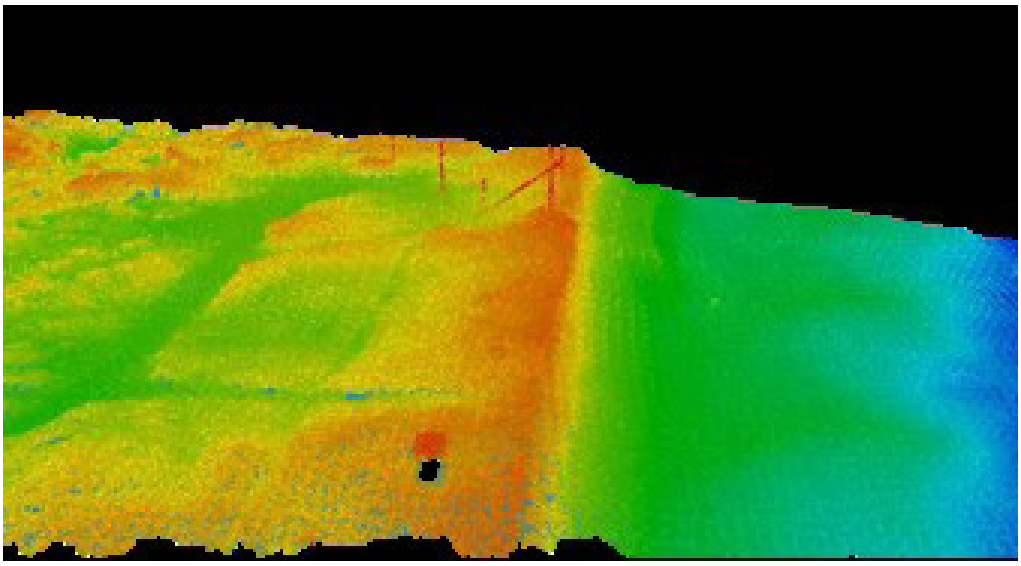
and deterioration of coastal structures. Ground control points (GCPs) were also constructed to geo-reference imagery and assess data accuracy. Targets of various size, shape, color, and spectral signatures were borrowed from the National Geodetic Survey (NGS) and National Geospatial-Intelligence Agency (NGA) to evaluate UAS feature detection. CHL-FRF personnel also conducted bathymetry surveys with their amphibious vessel and 3D terrestrial lidar surveys as additional control data sets.

"The experiment data have allowed ERDC to evaluate how well different platforms and sensors are able to quantify terrain, surf-zone bathymetry and hydrodynamics, infrastructure condition, as well as environmental parameters."

The only price of admission for experiment participation was the teams' agreement to provide their data to other participants. In return, CHL-FRF provided everyone with the ground control and survey data that allowed the UAS data to be assessed against traditional non-UAS data collection methods as well as inter-comparisons between UAS approaches. By inviting a large number of teams to collect data at the same location and same time period, the UAS Support to FRM initiative was able to generate a unique, comprehensive dataset of various UAS platforms and sensors. The diverse array of platforms provided a wide array of flight patterns and collection methodologies and allowed assessment of a range of platforms and sensors without USACE having to purchase and train using all the systems. The experiment data have allowed ERDC to evaluate how well different platforms and sensors are able to quantify terrain, surf-zone bathymetry and hydrodynamics, infrastructure condition, as well as environmental parameters. Specifically, ERDC has used the experiment data to investigate the quality (accuracy & resolution) of topographic and bathymetric digital elevation models (DEMs), the accuracy of surf-zone surface current and wave runup observations, and the ability to detect edges and disruption in coastal infrastructure. These observational capabilities may be used for districts to rapidly estimate pre- and post-storm changes in sand volume or levee conditions. From the environmental perspective, the experiment supported efforts to classify vegetation species, distribution, and associated landscape metrics that help characterize the ecological health involved with FRM.



UAS mounted Velodyne Lidar scan of CHL-FRF dune line and surrounding area/vegetation. Onshore to offshore reads left to right, colors show elevation from low (blue) to high (red).

Future efforts will also develop approaches to integrate the UAS data with numerical models to improve risk analysis with a defensible, probabilistic approach. For example, in the case of hurricane flood risk, a data assimilation framework would couple historical and offshore bathymetry, pre-storm UAS-based observations, hurricane forecasts, and CHL's existing flood risk numerical prediction models to better forecast storm impacts and necessary post-storm assessment and recovery actions.

As they pour over the data from the June CHL-FRF experiment, the UAS Support for FRM team members are already looking forward towards directly applying these UAS platforms at USACE Districts. UAS teams will be deploying UAS platforms for mapping and assessment tasks across a number of different environments. This year's active tropical cyclone season has strongly reminded us how USACE continues to serve critical FRM roles in identifying hazards; developing an interdisciplinary understanding of physical, chemical, and biological recovery processes that occur; and providing easily accessible, timely datasets to support flood modeling and forecasting. As nature continues to intensify its limits on our country's coastal and riverine development, UAS advancement will enhance USACE's own observational and decision-making capabilities in these areas.

Baltimore District Develops Innovative Watershed Modeling Techniques

By Becca Nappi, Baltimore District

In order to complete USRB watershed screenings, flood risk areas in Binghamton are depicted on a map along with critical structures points and the flood events that could affect it.

Since 1936, communities in New York's Upper Susquehanna River Basin have experienced severe flooding, causing massive property damages and loss of life. In 2016, the U.S. Army Corps of Engineers, Baltimore District, began a feasibility study to explore current and potential flood damage reduction measures in this area and provide a comprehensive watershed assessment.

Baltimore District's Upper Susquehanna River Basin (USRB) Comprehensive Flood Damage Reduction Feasibility Study, sponsored by the New York Department of Environmental Conservation, will identify flood risk management strategies and measures to reduce flood risk in flood-prone communities in New York's portion of the USRB.

"Flood risk management is a shared responsibility, and we are eager to conduct this study to advance potential implementation measures by various entities and demonstrate shared results in an area that has been so devastated by flooding in the past," said Amy Guise, Baltimore District chief of Planning Division.

Delivering a successful study plan that accurately maps areas with relatively high flood risk in the USRB is no small undertaking. Just within the state of New York, the USRB drains approximately 4,520 square miles and reaches more than 12 counties.

The feasibility study team will assess the current risk of flooding in New York's USRB; propose ways to minimize the impacts from flooding; determine cursory environmental and economic impacts from flooding; and suggest structural and nonstructural alternatives to reduce risks to life and property. "The products from the study will not only adhere to USACE requirements and processes, but will provide very meaningful data and tools for the State of New York and its communities," said Guise.

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Baltimore District, in partnership with the NYS Department of Environmental Conservation, hosted public meetings within Owego, Chenango and Sidney, New York in November 2016. These meetings allowed those living in the area an opportunity to give feedback and testimonials regarding the recent local flooding events.

Performing under the Corps' 3x3x3 study process, the study team has managed to find innovative methods for watershed modeling. This format states that a planning study shall be no more than $3 million, take no more than three years, and have three concurrent levels of review.

"This team has made a great contribution to the Planning Community and our 3x3x3 study process," said Guise. "They used technological advancements and developed a process for estimating damages and project costs to create preliminary benefit-to-cost ratios."

Baltimore District strayed from the traditional flood risk management study method of depending on the iteration of new data for watershed modeling. Within such large modeling areas, this process is typically lengthy and requires extensive amounts of input from preliminary risk assessments and economic estimations.

Instead, Baltimore District relied on existing readily-available data to include flood damage estimations for preliminary rapid assessment through geographic information system (GIS) based methodologies.

Baltimore District's Civil Engineering section developed a methodology that analyzes flood grids for four kinds of floods to estimate the risk associated with:

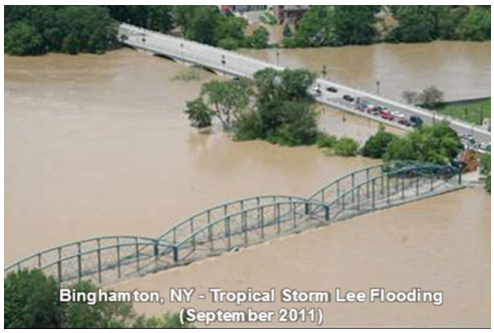
- Structure inventory based on New York's property rolls, and
- Critical infrastructure inventory developed using Homeland Security's Infrastructure Program Database

Economic flood risk was estimated by intersecting flood hazard areas based off of the hydrologic and hydraulic models with both of these property inventories. This produced an estimate of flood damage costs and the likelihood of major flooding.

These estimated damages were used to create "hot spots" throughout the USRB watershed that show areas where both high flood risk and high economic losses are probable as a result of riverine flooding.

"These preliminary benefit-to-cost ratios are a great way to assess federal interest in a project, and focus on the best opportunities throughout the 4,500-square-mile watershed," said Guise.

This new methodology allowed the Corps to more efficiently map the watershed and focus on areas in most need of structural and nonstructural alternatives that could help minimize flood damage.
This study is expected to be complete by 2019.



In September 2011, Tropical Storm Lee hit Binghamton, New York and the USRB area. The storm caused massive flooding and damages throughout the river basin area.

Watershed Analysis Tool (HEC-WAT), Version 1.0

By Lea Adams, Chief, Water Resource Systems Division, Hydrologic Engineering Center (CEIWR-HEC)

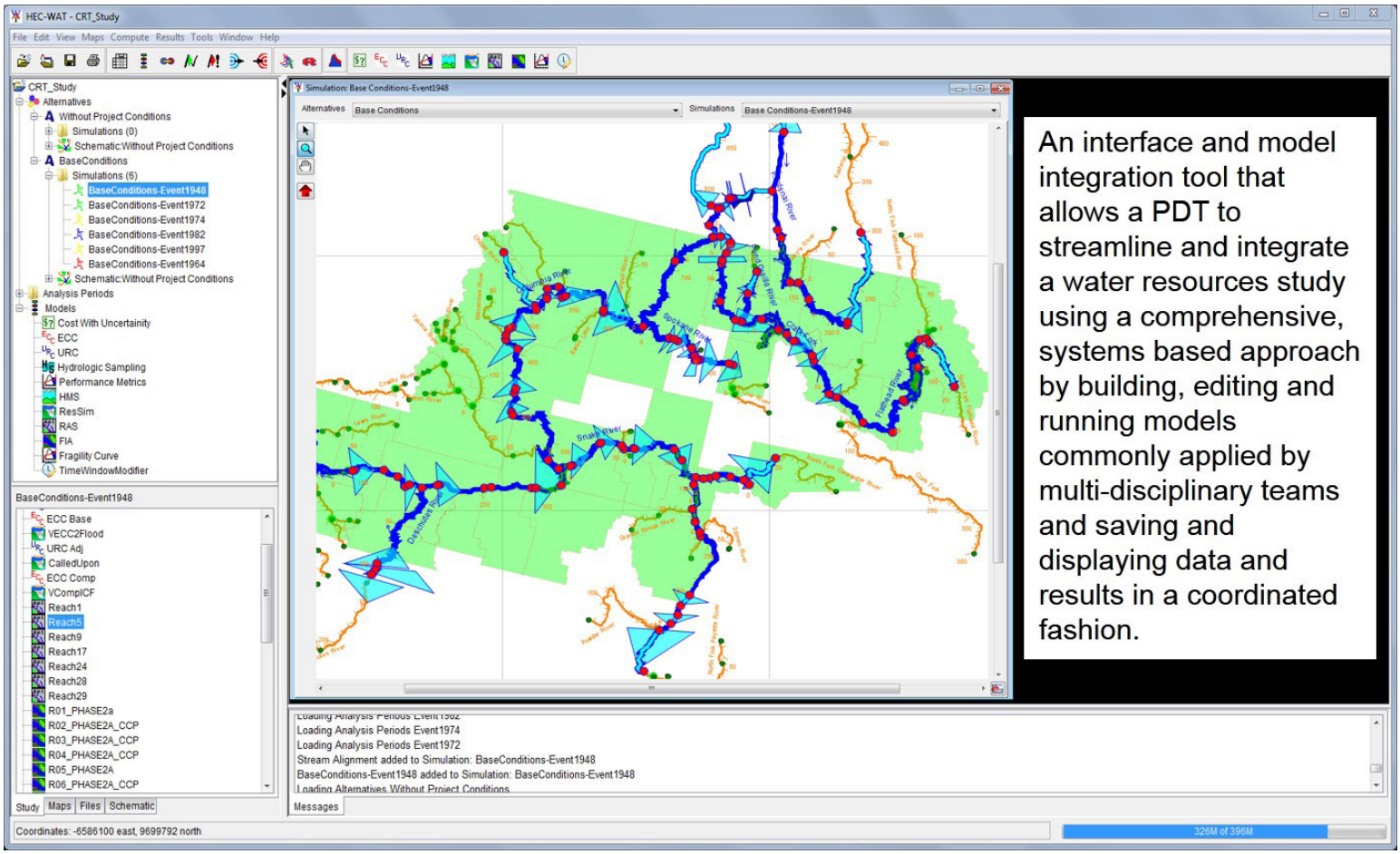


Figure 1. HEC-WAT Framework

United States Army Corps of Engineers (USACE) policy states that USACE will analyze water resources projects, including flood risk management projects, using a risk framework that incorporates watershed, systems and life-cycle approaches. USACE's CEIWR-HEC developed the Watershed Analysis Tool (HEC-WAT) to provide software to the field that supports these requirements, and the first official release of HEC-WAT (Version 1.0) is now available on the CEIWR-HEC website.

HEC-WAT is a model integration tool that orchestrates analyses across multiple pieces of water resources software to streamline study efforts for multi-disciplinary teams (Figure 1). Many pieces of software within the CEIWR-HEC suite of tools are implemented within HEC-WAT, thus allowing a study team to perform many of the necessary hydrologic, hydraulic, and planning/consequence analyses from a single interface. The HEC software currently incorporated in HEC-WAT includes HEC-HMS (hydrology), HEC-ResSim (reservoir operations), HEC-RAS (hydraulics), and HEC-FIA (flood consequences).

Model integration is achieved through the concept of a "plug-in". Each plug-in serves as a communication bridge between HEC-WAT and an individual piece of software. HEC-WAT provides the integration framework, while all analysis functionality is maintained in the primary software packages (e.g. HEC-HMS, HEC-RAS, etc.). The individual pieces of software provide the editors, reports, and computational analyses.

The HEC-WAT framework was designed to meet the following objectives: organize and develop alternatives; access software applications directly; view and compare alternative results; support plan formulation; and perform system analyses (Figure 2).

HEC-WAT is intended to help study teams perform alternative analysis in an intuitive and collaborative manner by involving technical staff across all disciplines early in the study process. Integrating multiple water resource software packages into a common framework helps eliminate data handling issues that might arise when one modeler provides model output for others to use. HEC-WAT supports risk-based analyses and risk-informed decision-making via

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Figure 2. Columbia River Basin

application of the Flood Risk Analysis (FRA) compute type. FRA uses event-based Monte Carlo-style uncertainty sampling to evaluate the full range of possible conditions across a watershed or within a system, which in turn provides a more complete picture of flood risk in a watershed. Sampling of input hydrology (precipitation or flows) and fragility data occurs within HEC-WAT, while sampling of other model parameters and initial conditions occurs within the individual applications.

With the FRA compute option, HEC-WAT advances USACE's ability to perform risk analyses, and can be used to support levee certification, dam and levee safety assessments, and planning and design studies.

HEC-WAT has been used on a number of studies to help address a range of challenging issues. These include the Columbia River Treaty Review; Russian River Forecast Informed Reservoir Operations (FIRO) study (Figure 3); Red River of the North climate study; and dam safety studies (Bluestone and Success Dams).

Future HEC-WAT development includes full implementation of life cycle modeling to address rehabilitation, repair and flood recovery; calculation of expected annual costs; adding several new compute types;

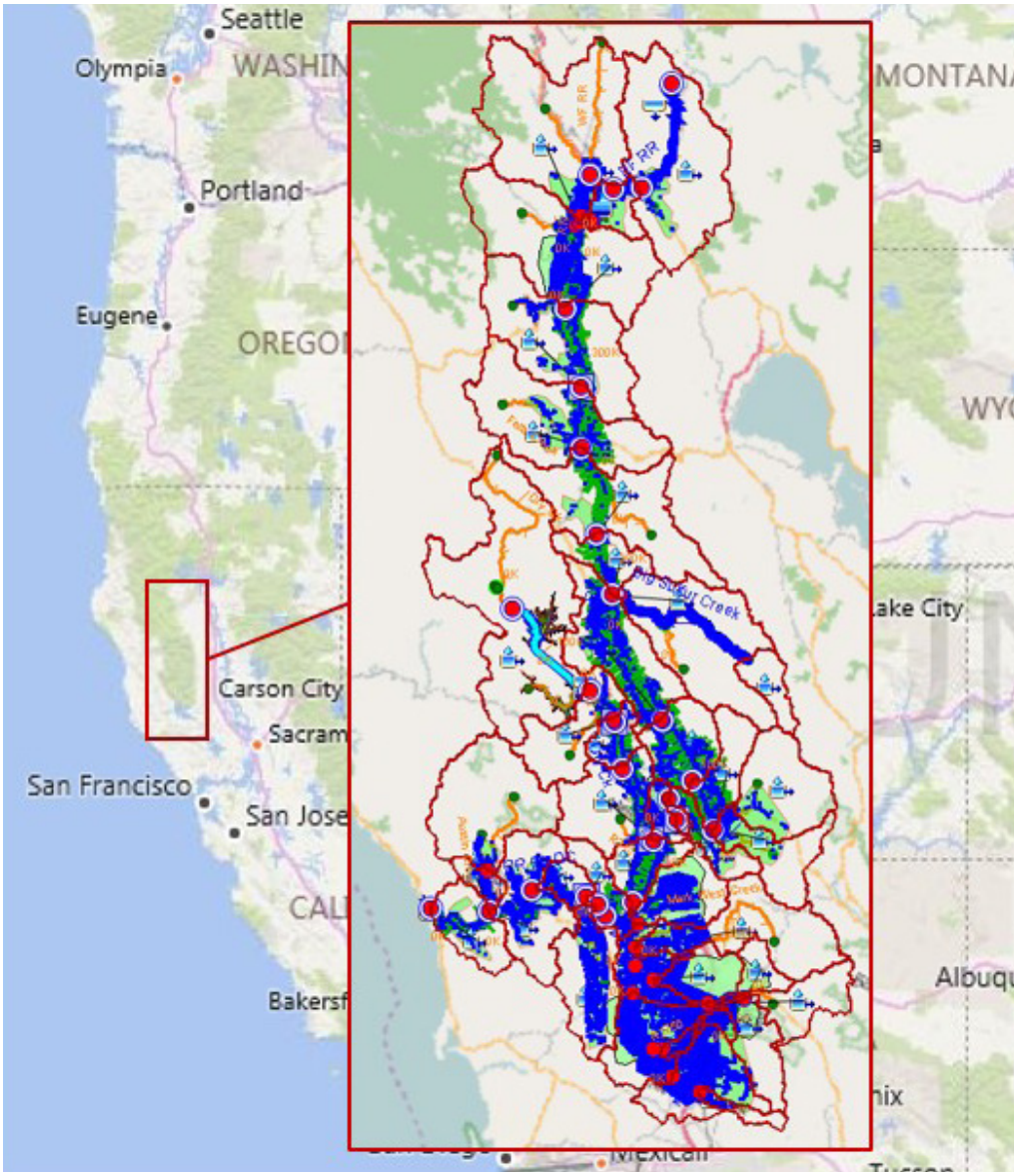


Figure 3. HEC-WAT Russian River Study

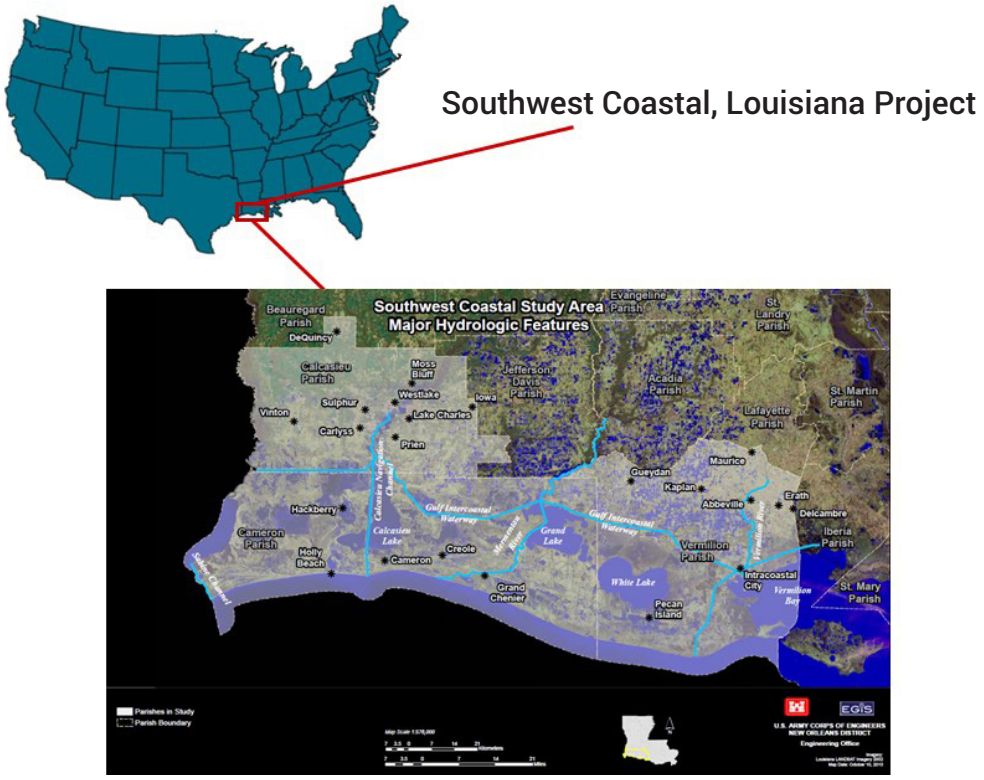
and expanding parameter sampling capabilities.

Other goals for HEC-WAT development include making the software more intuitive; enhancing compute speeds; improving graphics and reporting capabilities; and ensuring that it remains stable and robust under ever-increasing computational demands.

HEC-WAT Version 1.0 is now available from the CEIWR-HEC website http://www.hec.usace.army.mil/software/hec-wat/. Documentation includes the HEC-WAT User's Manual; HEC-WAT Quick Start Guide; and, a Hydrologic Sampling User's Manual. CEIWR-HEC requests that suggestions, comments, and reports on issues be sent to hec.wat@usace.army.mil. Comments and suggestions on the usability of HEC-WAT and recommendations for additional results reporting would be greatly welcomed. For further information regarding HEC-WAT, contact Lea Adams (lea.g.adams@usace.army.mil) at (530) 756-1104).

Nonstructural Plan Recommended for Coastal Louisiana

By the Southwest Coastal Louisiana Project Delivery Team



The Southwest Coastal Study area is shown here. Two different authorities which had overlapping study areas, but different mission areas, provided the opportunity to have a single, cooperative PDT as well as study alternatives developed with a more holistic, systems approach.

As has been documented many times, the people, economy, unique environment, and cultural heritage of southwest Louisiana are at risk due to hurricane storm surge flooding and wave impacts. The area's low elevation, proximity to the Gulf of Mexico, land subsidence, and rising sea level, are expected to exacerbate flooding from hurricane events, shoreline erosion, saltwater intrusion, and loss of wetland and chenier habitats in the future. Therefore, in two separate study authorizations for southwest Louisiana, Congress authorized the investigation of alternatives to: (1) provide risk reduction from damages deriving from hurricane storm surge, and (2) significantly restore environmental conditions.

In the combined authorizations for the Southwest Coastal study, the area encompassed over 4,700 square miles of varying terrain in Calcasieu, Cameron, and Vermilion Parishes in Louisiana. The study area contains over 52,000 structures, over 26,000 of which were estimated to be at risk either presently or for the projected future conditions. The study area also contains approximately 1,100,000 acres of estuarine, wetland, and forested habitat.

The study faced many challenges, not the least of which dealt with modifications in guidance as well as the implementation of SMART Planning into an existing legacy study. As a legacy study where SMART Planning principles and milestones were applied, this effort also helped inform the transformation of the Civil Works program in general. The study was accomplished using a risk informed decision methodology to evaluate, screen, and compare potential solutions from a multitude of sources such as State of Louisiana Master Plan, Louisiana Coastal Area (LCA) approved plans, Coastal Wetlands Planning, Protection and Restoration plans, Local/Parish Plans, Non-Governmental plans, public scoping meetings, and interagency team involvement. After sorting through approximately 300 concepts or features, approximately 100 were found to be unique and viable features. The study involved countless meetings screening features that crossed political boundaries, hydrologic basins, and which addressed a multitude of problems. Overcoming an aggressive schedule for this type of complex effort, the study was completed while additionally overcoming funding challenges early in the process. Even with the many challenges the study team did a remarkable job shaping the recommended plan, listening to stakeholders, and communicating the $3.2 Billion recommendation for Southwest Coastal Louisiana.

The recommended plan consists of a NED plan of nonstructural and localized storm surge risk reduction features to reduce hurricane storm surge damage risks in three Parishes. The NED plan reduces the risk of coastal storm damages through independent features that elevate or flood-proof structures in the 25-year floodplain predicted to occur in 2025. The NED plan includes raising 3,462 residential structures in-place above the predicted 2075 1-percent chance base flood elevation; flood-proofing 342 non-residential structures; and constructing localized storm surge risk reduction measures around 157 warehouses. The raising of residential structures, the flood-proofing of non-residential structures, and the construction of localized storm surge risk reduction measures will be implemented on a voluntary participation basis.

The recommended plan also consists of an NER plan comprised of 49 features to restore coastal habitats in three Louisiana Parishes. The NER plan will provide benefits in two estuaries by

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rebuilding tidal wetlands, preventing shoreline erosion, and replanting rare native vegetation. The NER plan includes nine marsh restoration features, five shoreline protection features, and Chenier reforestation with invasive species control at 35 locations.

For decades, the eastern part of the State surrounding the Mississippi River and the city of New Orleans garnered the majority of Federal attention and dollars. The Southwest Coastal feasibility study was the first comprehensive "large-scale" study to attempt to address the unique issues experienced in the western part of the State. The study team had to overcome a lack of communication, cooperation, and trust from the communities that never experienced the Corps' planning process. As the study progressed, it became clear that the traditional solution of large-scale levee alignments to reduce damages from storm surge would not meet the minimum Corps requirements for the benefits achieved to be greater than the cost to implement. Many homeowners were not happy with this outcome as the pain of flooding from recent hurricanes like Rita and Ike was still very real for many families. Interestingly, much of the public did not want levees. The Southwest portion of the State of Louisiana is very flat and in many places is at or below sea-level. Locally it was perceived that levees would hold flood waters in once an event had passed. Therefore, non-structural alternatives were extensively evaluated. Although often used as an alternative but rarely as a comprehensive approach to address 100% of the structures in a study area of this size, non-structural alternatives were quickly gaining favor as the best means for addressing coastal storm surge damages.

Due to the sheer size of the non-structural alternative, guidance for such a large scale recommendation had numerous gaps and omissions that were revealed as the non-structural alternative got further developed. This internal analysis of Corps non-structural policy led to not only a year-long study pause but also helped lay the groundwork for the issuance of Planning Bulletin 2016-01. In order to help facilitate Vertical Team understanding some of the complexities of the non-structural analysis, a national workshop was held to discuss implementation and planning issues that needed to be resolved in order for the Corps to support the non-structural recommendation. The information learned during the Southwest Coastal evaluations helped to inform the national policy on non-structural assessments. Additionally, the process utilized to develop the non-structural features and the lessons learned from the analysis have been shared with other teams throughout USACE to help improve the quality and efficiency of planning studies.

> "The Southwest Coastal feasibility study has been called the first ever feasibility effort in Louisiana to combine 'large-scale' ecosystem restoration and coastal storm damage risk reduction."

The revised non-structural guidance allowed for the continuation of the study and maintained the momentum that led to the successful delivery of a complex project that greatly enhances USACE's image and provides a high level of customer satisfaction. However, two years ago it is unlikely that the State or local parishes would have been so welcoming of the Corps recommendation.

Without a doubt, the largest accomplishment of the study was to let the planning process work and arrive at the best solution for the citizens of Louisiana. Two years ago, the vast majority of the State was opposed to the draft recommendation and the way implementation was being recommended. The original recommendation was presented during a public review period and generated over 2,600 negative comments. That forced the team to go back and work with the Mississippi Valley Division and Headquarters staff to identify options to refine the plan and its implementation to gain broader public and sponsor support. Stakeholder involvement, public review, and the non-Federal Sponsor views were used to help inform policy reviewers and decision makers, enabling a plan to be developed that was a win-win for the Federal government and citizens of Louisiana. The National Economic Development (NED) recommendation, consisting entirely of non-structural measures, totals nearly $1B.

Despite the complexities of the NED evaluation, there is also a large-scale National Ecosystem Restoration (NER) recommendation. Evaluating the ecosystem restoration alternatives across such a large study area required a diversity of measures, assessment of critical habitat and infrastructure, and consideration of an incredibly complex landscape that is home to some of the most productive estuarine habitats in the nation. Alternatives include shoreline protection, chenier (ridge) restoration, marsh restoration, as well as two longer term hydrologic studies that could not be completed under the Southwest Coastal study effort. The NER recommendation totals over $2B.

The Southwest Coastal study represents a collaborative partnership between the State of Louisiana and the New Orleans District Corps of Engineers, leveraging talent, data and research from these and other supporting agencies. The Southwest Coastal feasibility study has been called the first ever feasibility effort in Louisiana to combine "large-scale" ecosystem restoration and coastal storm damage risk reduction. Two different authorities which had overlapping study areas, in addition to differing mission areas, provided the opportunity to develop a more holistic, systems approach. The study is unique in that it recommends the

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largest non-structural plan in the Corps with nearly 4,000 structures eligible for participation and large-scale ecosystem restoration features to combat southwest coastal Louisiana's increasing land loss issues. The study effort encountered many complex issues, ranging from evaluating an enormous study area; transitioning from a legacy study to SMART Planning; shortage of study funds; reconciling public comments; evolving non-structural guidance; reducing risk to critical infrastructure, working on other Federal lands, and developing methodologies to formulate and evaluate large scale non-structural features. In addition to technical issues faced in such a large study, there was a very engaged and active public who had strong opinions that ultimately helped shape the study.

The Southwest Coastal Louisiana feasibility study is recognized as a groundbreaking effort in combining large-scale ecosystem restoration and coastal storm damage risk reduction. The study merged overlapping mission areas and their opportunities, utilizing an integrated water resources management approach, to develop a comprehensive array of alternatives that considers economic benefits, ecosystem quality, and public safety. The study culminated in a combined recommendation of a non-structural plan encompassing nearly 4,000 structures along with forty nine ecosystem restoration features to improve the resiliency of Southwest Louisiana.

Engineer Circular (EC) 1165-2-218 Levee Safety Program Policy and Procedures

By Jasmin Austin, St. Paul District

The Headquarters Dam and Levee Safety Program Branch is excited to announce that the draft Engineer Circular 1165-2-218 is completed and currently undergoing review! This EC details the policies and procedures for the implementation of the U.S. Army Corps of Engineers Levee Safety Program. The contents of the EC are applicable across multiple Communities of Practice, at all levels within USACE.

There are four guiding principles which are the fundamental values founding the Levee Safety Program: 1) Hold life safety paramount; 2) Corporately manage risk; 3) Ensure open and transparent engagement; and 4) Learn and adapt. These guiding principles are supported through program objectives which commit to maintaining an effective program governance, increasing understanding of the benefits and risks of levee systems for all stakeholders, and contributing to the management of flood risk in communities with levees. Through detailing the requirements for program governance and discussing the risk framework, the EC describes how program objectives are achieved.

The EC is organized into four sections. The first section outlines the basic programmatic requirements for Levee Safety Program governance. USACE will maintain a three-level, decentralized organization to implement the program at district, division, and HQUSACE levels. National program oversight and coordination is provided by the Levee Senior Oversight Group and the Levee Safety Steering Committee. The Levee Safety Program is further supported by USACE centers of expertise, laboratories, and Communities of Practice. Furthermore, the EC defines how the Levee Safety Program will integrate and collaborate with other programs, like Flood Risk Management and Emergency Management, and the Federal Emergency Management Agency (FEMA).

The Levee Safety Program is committed to making risk-informed decisions and utilizes the risk framework which consists of three basic activities: risk assessment, risk management, and risk communication. The framework provides an analytical way to gather, record, and evaluate information to make recommendations for decisions or actions relating to levee systems. The next three sections of the EC discuss each piece of the framework.

The EC was developed by a team of levee safety professionals representing multiple districts across USACE and just recently went through an internal review. All USACE personnel with a responsibility for planning, design, construction, operation, maintenance inspection, assessment, and rehabilitation of levee systems were encouraged to participate in the agency-wide review and provide feedback.

An external review will kick off soon to capture feedback from our Levee Safety partners and stakeholders, including non-federal levee sponsors, interested associations, other federal agencies and interested individuals. This review will last approximately 60 days and begin in winter of 2017.

Following the reviews, an analysis and summary of comments will be generated and posted to the Dam and Levee Safety SharePoint site, which will identify the key policy issues articulated, areas needing clarification and other common comments received. This will occur for the internal and external comments separately, as the responses to internal comments will largely be addressed prior to the external comment period. The team will also determine appropriate changes to the EC that will occur based on the feedback.

Rollout of the final EC 218 is expected to occur in early summer of 2018 and will be supported with internal and external webinars to discuss the review comment adjudication process, as well as provide implementation and communication guidance and materials.

Information about the reviews along with the draft EC can be accessed on the Dam and Levee Safety SharePoint site at - https://cops.usace.army.mil/sites/DLS/Shared%20Documents/Forms/AllItems.aspx.

Other Important Information

Events

This listing is for information only and is not a complete list of FRM-related meetings. These meetings are not endorsed by the Corps of Engineers unless specifically stated. If we have failed to list a conference/meeting/symposium that would be of interest to the Flood Risk Management community, please forward the conference details to us.

5-9 November 2017 – **Annual American Water Resources Association Conference** – Portland, OR – http://awra.org/index.html

7-11 January 2018 – **98th American Meteorological Society Annual Meeting** – Austin, TX – https://annual.ametsoc.org/2018/

26-29 March 2018 – **National Hurricane Conference** – Orlando, FL

17-22 June 2018 – **Association of State Floodplain Managers 42nd Annual Conference** – Phoenix, AZ – http://floods.org/index.asp?menuID=223&firstlevelmenuID=181&siteID=1

8-13 December 2016 – **9th National Summit on Coastal and Estuarine Restoration and Management** – Long Beach, CA – https://www.estuaries.org/2018-summit-general-info

Be sure to check out floods.org for the dates of state conferences and training opportunities: http://www.floods.org/n-calendar/calendar.asp?date=3/12/2016

FRM Statements of Need: Submitting "Statement of Need" is the first step in the process of a concept becoming a requirement for research and development. If USACE District personnel have problems or situations they feel should be addressed by research, the Flood Risk Management Gateway, http://operations.usace.army.mil/flood.cfm, is the place to submit these research Statements of Need (SoNs).

Past issues of this newsletter, various links, news items, and presentations, are all available on the Flood Risk Management Gateway, https://operations.erdc.dren.mil Check it out!

This newsletter is a product for and by the Flood Risk Management Community. The views and opinions expressed in this unofficial publication are not necessarily those of the U.S. Army Corps of Engineers or the Department of the Army.

*If you would like to submit an article or an idea for an article for the next edition of the newsletter, or if you have any comments or questions about articles in this edition, please email **Stephanie.N.Bray@usace.army.mil.***

FRM Flood Risk Management Newsletter

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