FRM

Flood Risk Management Newsletter

National Flood Risk Management Program — Preparation, Response, Recovery, Mitigation — Driving Down Risk

Quantifying Dune Coastal Protection and Recovery

Flood Risk Management Spotlight

Cedar Rapids Flood Risk Management: A Case Study in Flood Disaster Recovery

April 2018 • vol 11 no 1

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2017 was a significant flood year across the Walla Walla District. Record spring flows challenged communities throughout the Snake River Basin in 2017 with the Boise River and Big Wood Rivers being hit particularly hard.

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USACE Assistance in Puerto Rico

After Hurricane Maria struck the island of Puerto Rico, the landscape and hydrology were significantly changed. Rivers flowed out of bank, new channels were cut, watersheds lost significant vegetation, which exacerbated flash flooding, channels were clogged with debris and hundreds of bridges collapsed, which caused water to backup.

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On the Cover

Port Arthur and Vicinity Hurricane Flood Protection Project: Failing Port Arthur HFPP I-Wall

A section of the Port Arthur and Vicinity Hurricane Flood Protection Project (HFPP or Project) is in danger of an imminent failure upon landfall of a tropical storm. This section protects several petrochemical refineries and residential areas located within Port Arthur.

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Updated National Flood Risk Management Program Guidance Coming Soon!

By Mark Roupas, Deputy Chief, Office of Homeland Security

Happy Spring! In this article I will provide a brief overview of updated guidance for the National Flood Risk Management Program (NFRMP) that will be coming soon. Hopefully by the time this Newsletter edition is published the updated guidance will already be issued.

The original guidance that established the NFRMP was issued in 2009. Since then, there have been numerous changes in our understanding of flood risk and flood risk management techniques, changes to the most significant issues in flood risk management being faced by the nation, and changes in terminology. Updated program guidance has been developed to address these changes as well as to ensure that there remains a clear understanding across USACE regarding expectations for implementation of this collaborative program. An interdisciplinary team that crosses USACE Civil Works programs and activities has been working since 2015 to develop this updated guidance. Beyond aligning guidance with current practice and understanding, there is additional information on roles and responsibilities of the USACE Flood Risk Managers and Silver Jackets Coordinators particularly related to internal and external coordination and partnership efforts needed at all levels for this collaborative program to be successful.

Changes to the vision, mission, and goals of the program are implemented through this updated guidance. The program vision and mission have been built on the concepts of resiliency, multi-objective approaches, non-stationarity, risk, and uncertainty. Importantly, the goals denote a continuum of improvement over time. We should always be striving to improve the way we deliver for the public. The vision of the program is "Our economy, our society, and our natural landscapes are well-positioned to withstand, recover, and adapt to ever changing flood risks." The mission is to "Increase capabilities across all aspects of USACE to improve decisions made internally and externally that affect the nation's flood risk." The program will also work toward three multi-year goals: 1) Improve how we manage flood risk; 2) Improve how we support others who are managing flood risk; and 3) Improve linkages between flood risk management and other water resources challenges and opportunities.

As has been the case since the NFRMP was established, each District and Division is expected to designate and support a Flood Risk Manager and Silver Jackets Coordinator (District-level) or Silver Jackets Program Manager (Division-level). The updated guidance contains more detail about the expected roles and responsibilities of the people serving in these functions than was provided in the original guidance. Additionally, all representatives of the NFRMP are expected to develop strong internal and external relationships with others who have roles to play in addressing flood risk management challenges and opportunities. These partnerships are necessary because USACE has extensive authorities and responsibilities for flood risk management which are spread across the agency. Beyond that, there are other federal agencies, states, tribes, and local governments that have responsibility for flood risk management activities or who take actions which impact our nation's exposure to flooding. The updated guidance provides additional detail about the most common partnerships. One purpose of this update is to ensure we are working to grow new valuable partnerships and enhance existing partnerships as we pursue NFRMP program goals.

The forthcoming updated guidance for the NFRMP is just the first step in ensuring that the program continues to be effective and successful into the future. The next step after the issuance of the updated guidance will be to issue an updated Program Management Plan that gives more implementation details. Additional documents, including a communications strategy and a best practices guide are also planned for future development. In closing, I would like to extend my sincere thanks to everyone who has been involved in the development of the updated program guidance. I know many people have taken time to review and provide comments and suggestions on various drafts of the document, and I know that those suggestions have helped us to develop a better document. I look forward to continuing to be involved with the NFRMP as the program moves forward in implementing this updated guidance.

2017 Floods Lead to Greater Flood Risk Management Program Role

By Tracy Schwarz, P.E., PMP, NWW

Big Wood River flooding near Ketchum, ID

2017 Was a Significant Flood Year Across the Walla Walla District.

Record spring flows challenged communities throughout the Snake River Basin in 2017 with the Boise River and Big Wood Rivers being hit particularly hard. Managing Boise River flows with upstream flood risk management reservoirs was a challenge last year because the snow runoff from January through July was the second highest in the past one hundred and seventeen years. Big Wood River is across the ridge from the Boise River and followed a similar pattern with the second largest peak flood in over 100 years of recorded history. Unfortunately in the Big Wood Basin there are no flood risk management reservoirs.

Other parts of Idaho, Oregon, and Washington also had record or near record snow packs. Arctic temperatures caused multiple rivers to freeze, causing minor floodng from ice jams. Both riverine and sheet flooding occurred across southeast Oregon and southern Idaho in January and February. The upper Snake River had high flows for several months past the normal snowmelt season. The wet winter and spring conditions caused multiple avalanches, landslides, debris jams, and other events that exacerbated flooding conditions.

For the Walla Walla District Water Management, one of the most challenging areas was the Boise River Basin in Idaho, due to the significant amount of development encroaching in the floodplains. Precipitation, in the form of rain and snowpack, and at times up to 325-percent of normal, poured into the reservoirs at Lucky Peak, Arrowrock and Anderson Ranch dams. Walla Walla District water managers worked closely with the Bureau of Reclamation and irrigators to safely manage Boise River reservoir system flows for more than 100 days. Dynamic changes in conditions on the Boise River were effectively addressed while still managing record flooding in other reservoir systems throughout the greater-Snake River Basin.

Thirty-five of Idaho's 44 counties were part of state or local disaster declarations. Twenty Idaho counties were included under two separate Presidential Disaster Declarations. The District was in flood operations from January to June 2017. During that time the EOC coordinated delivery of 400,000 sandbags and deployed 8 technical assistance missions and one direct assistance mission to help a number of communities across the District. The most notable missions included field teams at Oakley Dam with risk of releases exceeding downstream channel capacity, ice jam consultation on the Snake River, response to major channel changes in Blaine County where the Big Wood River meandered through numerous neighborhoods in the Communities of Ketchum, Hailey, Bellevue, Gimlet, and other unincorporated areas in Blaine County. The Flood Control and Coastal Emergencies (FCCE) and Water Management programs obtained aerial imagery of the peak flooding of the Payette River, Boise River, Big Wood River, and Big Lost River. The single most notable mission was the construction of an emergency levee near the City of Eagle.

Corps Constructs Temporary Levee Near Eagle Idaho

The Boise River overflowed its banks in early spring, and for more than one hundred days, emergency managers engaged in a flood fight. One of the hardest hit was Eagle Island near Boise.

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Walla Walla District's EOC responded to Ada County, Idaho, requests for help by sending a direct-assistance team to construct a 4-foot-tall levee built from HESCO barriers, stabilizing 4,300 feet of the south riverbank across from Eagle Island. This prevented pit-capture of an adjacent gravel-mining operation and reduced flood risk to the City of Boise's wastewater treatment facilities, and nearby communities and businesses.

As the Corps worked with the Bureau of Reclamation to create space in the Lucky Peak, Arrow Rock, and Anderson Ranch reservoirs, they managed flows through daily, and sometimes hourly contacts. Brandon Hobbs, Walla Walla District's liaison to the Ada and Canyon County EOCs, explained "As flooding began on the Boise River we engaged with the Ada county emergency operations center to support Ada County and its cities. We patrolled with them and looked for weak spots on the river. One of the first spots that popped up was at the Sunroc gravel pit near the head of Eagle Island. We started to see erosion and sinkholes forming which indicated a fair amount of weakness in the pit itself. As the river continued to rise it became clear the remaining natural ground surrounding the pit wasn't going to be enough, so we started exploring other ways to protect this pit from a potential pit capture". To prevent bank failure, the Corps helped build a temporary levee that was three-quarters of a mile long. Securing this area east of Eagle was essential in this operation, because flowing water would have put a large number of homes and critical infrastructure, including a highway and a wastewater treatment plant at risk.

Temporary levee near Eagle Idaho

District Flood Risk Managers Are Increasing Coordination

Once the flood waters receded in July, the District 2017 post-flood After Action Review (AAR) identified the need for more frequent internal coordination between the flood risk programs and offices in the periods where there was no Emergency Operations Center (EOC) stood up.

"This fell right in my Flood Risk Management area of responsibility", said Tracy Schwarz, District Flood Risk Manager. "Our past Flood Risk Management meetings largely focused on projects and activities such as Continuing Authorities Program (CAP), Floodplain Management Services (FPMS), and Planning Assistance to States (PAS) studies, Rehabs, Inspections, Flood Exercises, ect. The real time flood coordination part of our Flood Risk Management Program was ad-hoc meetings, occurring for a specific need rather than for routine real time coordination."

The 2017 flood taught us that the period prior to standing up an EOC and between periods where there is an EOC are critical, and a lot of high water problems occur even when there is no established EOC. In 2012 the Flood Risk Management (FRM) Program coordinated writing a document to guide communications between Water Management and Readiness during the periods that we have high water but before we have an EOC. However, a communication document is not enough, and we've learned more people needed to be involved than Readiness and Water Management, particularly in basins where there is no Water Management reservoir.

The District needed a routine way to communicate both internally and externally on current flood risk and associated activities during the flood season. The FRM Program is going to help fill this need by meeting on a more frequent basis to share and discuss information that relates to real time flood activities internal to the District as well as coordinate on external inquires and associated unified messages to stakeholders and the public, in addition to the other coordination topics we've covered in the past. We also have added Public Affairs Office to our FRM meetings due to their critical role in external communications.

For now we are trying meetings twice per month. As the year goes on we'll adjust and revise as needed. If an EOC is stood up, the real time component of these meetings will be omitted so that the EOC can serve as a central communication hub.

Modeling, Mapping, and Consequences (MMC) Production Center, Flood Inundation Mapping (FIM) Cadre Supporting the 2017 Hurricane Events

MMC Production Center member contribution to this article: **Cory Winders,** P.E.; **Russ Wyckoff,** P.E.; **Matt Fischer,** P.E.; **Ryan Hoben,** P.E.; **Michelle Carey,** GISP; HEC contributors: **Gary Brunner,** P.E.

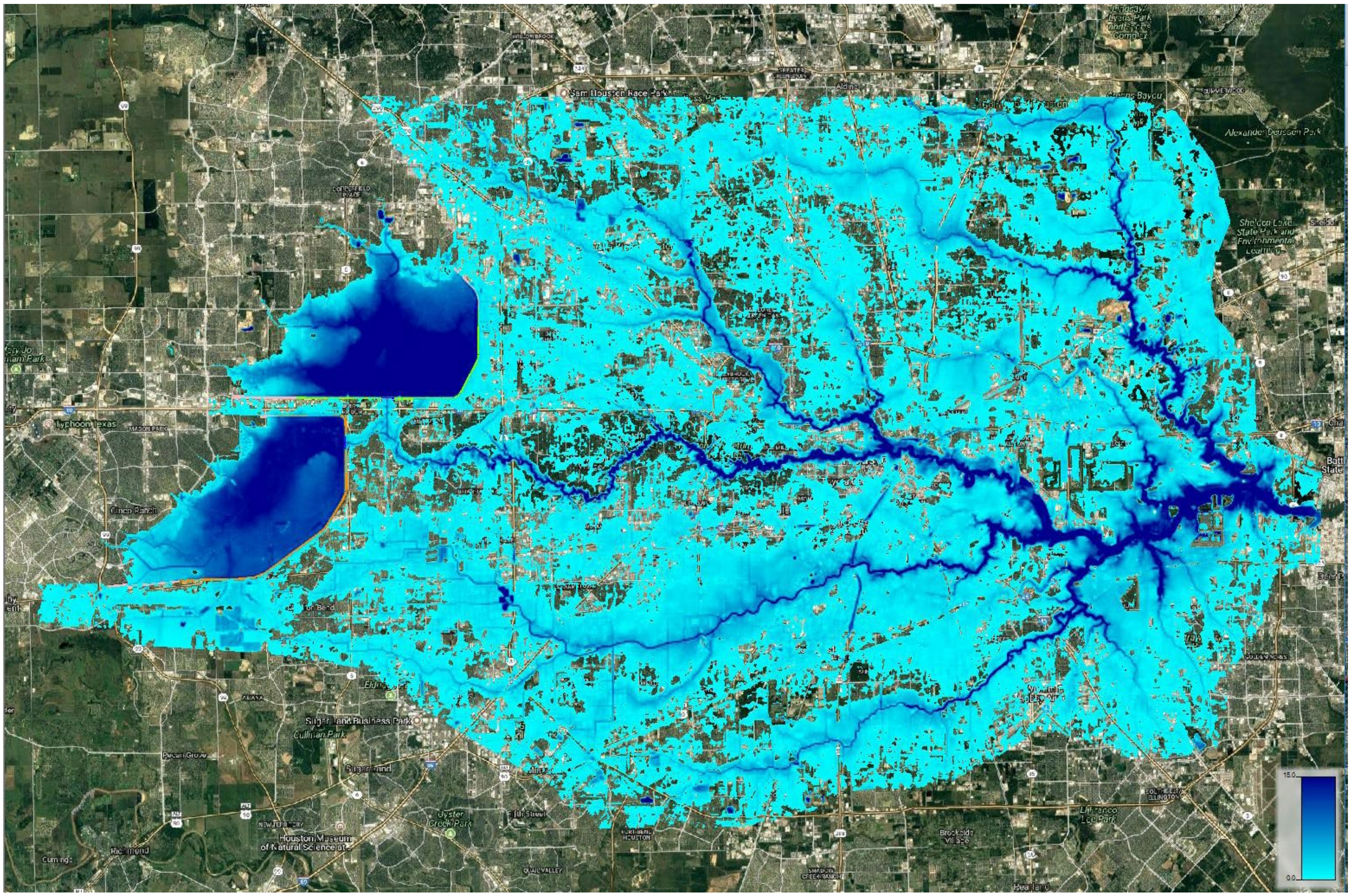

Figure 1: Maximum depth of rainfall in Buffalo Bayou

The U.S. Army Corps of Engineers (USACE) learned a valuable lesson after the 2011 Mississippi and Missouri River floods. When local resources are limited, a team of experts are needed to assist division and district offices, produce hydrologic and hydraulic modeling, consequence estimates, and inundation mapping during major flood events. The Modeling, Mapping, and Consequences Production Center Mandatory Center of Expertise (MMC MCX) responded and established the Flood Inundation Mapping (FIM) Cadre.

How is the FIM Cadre activated during a flood event? After a formal request for assistance from the division or district and funding is received, the FIM Cadre immediately begins coordinating and developing hydrologic and hydraulic models. After model completion and district review, the model scenario inundation file is disseminated to other FIM interdisciplinary members, economists and geospatial specialists. The teams create up-to-date consequence estimates, mapping products, Google Earth keyhole markup language (KML) data layers, and animation or videos for the current and potential flood event. The products and visualization tools help the division and/or districts make risk-informed decisions, and critical information is provided upward to the Headquarters (HQ) USACE Operations Center (UOC) leadership.

The MMC developed a FIM standard operating procedures (SOP) technical manual to outline how team members will produce quality and consistent

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products, how the FIM cadre will support the organization in need, and how the team will communicate and collaborate internally and externally. The FIM cadre is presently training division and district personnel on how to develop models and mapping during emergency events.

Hurricane Harvey - Buffalo Bayou

Hurricane Harvey, Buffalo Bayou Reports of a major hurricane developing in the Gulf of Mexico caught the attention of Mr. Robert Simrall, MMC Director. The FIM Cadre leadership proactively coordinated with cadre members and determined resource availability in the event affected division and districts needed assistance. On August 24, 2017, prior to landfall of Hurricane Harvey, the Fort Worth District contacted the MMC to request assistance. The district and the MMC agreed there was an immediate need to model the Addicks and Barker reservoirs, the immediate downstream communities, Houston, Texas, and six major rivers in the State of Texas. In addition, the Mississippi Valley Division requested the FIM Cadre to assist in developing models for three rivers in southwest Louisiana nearly the same day.

The FIM Cadre developed initial hydrologic and hydraulic models with input from both districts' hydrologic, hydraulic, and coastal (HH&C) branch members. The FIM Cadre lead modeler coordinated review of the draft products with the division and district prior to upward reporting to the UOC. The models helped the districts visualize potential flood areas, and jump started important conversations.

Emphasis was placed on the Buffalo Bayou Basin where the MMC FIM Cadre team would provide modeling and mapping support for Galveston District, Southwestern Division, and Texas Department of Emergency Management (TDEM). The Addicks and Barker Dams are Corps-owned projects within the Buffalo Bayou Basin. Previously they were rated as very high consequence projects and were in the initial stages of construction to repair existing maintenance issues. Rainfall within the 102 square miles of the watershed drains to the primary waterway, Buffalo Bayou. The Buffalo Bayou carries flow downstream through heavily wooded residential areas to downtown Houston, Texas. The area downstream of Addicks and Barker Dams are some of the most densely populated areas in Houston with an estimated population of over 400,000 people. See Figure 1 Maximum Depth of rainfall in Buffalo Bayou.

The FIM modelers realized Hurricane Harvey flood impacts would not be based solely on releases from the lakes, but rather on the accumulation and distribution of the rainfall throughout the basin and the inflow accumulation at the reservoirs. The primary modeling application used was the Hydrologic Engineering Center's River Analysis Systems (HEC-RAS) software or HEC-RAS (version 5.0.3) which includes two-dimensional (2D) flow computation in conjunction with gridded rainfall accumulation. These two components of HEC-RAS made it the best tool to use for the Hurricane Harvey flood scenario modeling effort. Topography from previous Addicks and Barker models was used as the base digital elevation model (DEM). The DEM was the best available terrain data as the local survey data was included for the affected areas. Additional pertinent data included 2D grid size, inflow points, boundary conditions, rainfall data, dam outlets, roughness estimates, calibration, and bridge and inline structures. The models were continuously updated with real-time data from field personnel, river gages, and rainfall forecasting. FIM Cadre members produced inundation mapping, trafficabililty maps (for communities in the vicinity of the Corps dams and Houston), and video animation to share risk information with leadership and the public. The HEC-RAS animation feature was used for developing time-series model animations and static map products. Camtasia was used to compile model animations with project details and flood condition information to create risk-informed videos. The FIM Cadre economist took the inundation depth grid from HEC-RAS and utilized the Hydrologic Engineering Center's Flood Impact Analysis (HEC-FIA) software to calculate consequences-based estimates. The depth grid was placed over a tax parcel based structure inventory to determine number of structures impacted and value of damages for the flood event. The model computation and product development occurred August 24 to September 20, 2017. This timeline covered a day prior to the hurricane landfall, rainfall accumulation, floodwaters rising and receding. Model result comparisons were conducted against real-time field reports and the computations were found to be consistent with the floodwater conditions.

Hurricane Irma – Lake Okeechobee

While the FIM Cadre provided on-going support for Hurricane Harvey, on September 4, 2017, one week before the floodwaters of Hurricane Harvey fell below minor flood stage levels, the MMC received a request for assistance from the South Atlantic Division (SAD) office. The SAD leadership were tracking Hurricane Irma in the Caribbean and they requested the FIM Cadre to produce products for the states of Florida, Alabama, and the East Coast of the United States. SAD H&H leadership identified Corps Water Management System (CWMS) models (e.g. watershed models) within the requested geographic areas, utilized the select watershed models, and produced "what if" flood scenarios. The flood scenario results covered seven river systems located in Alabama, Georgia, South Carolina, North Carolina, and Virginia.

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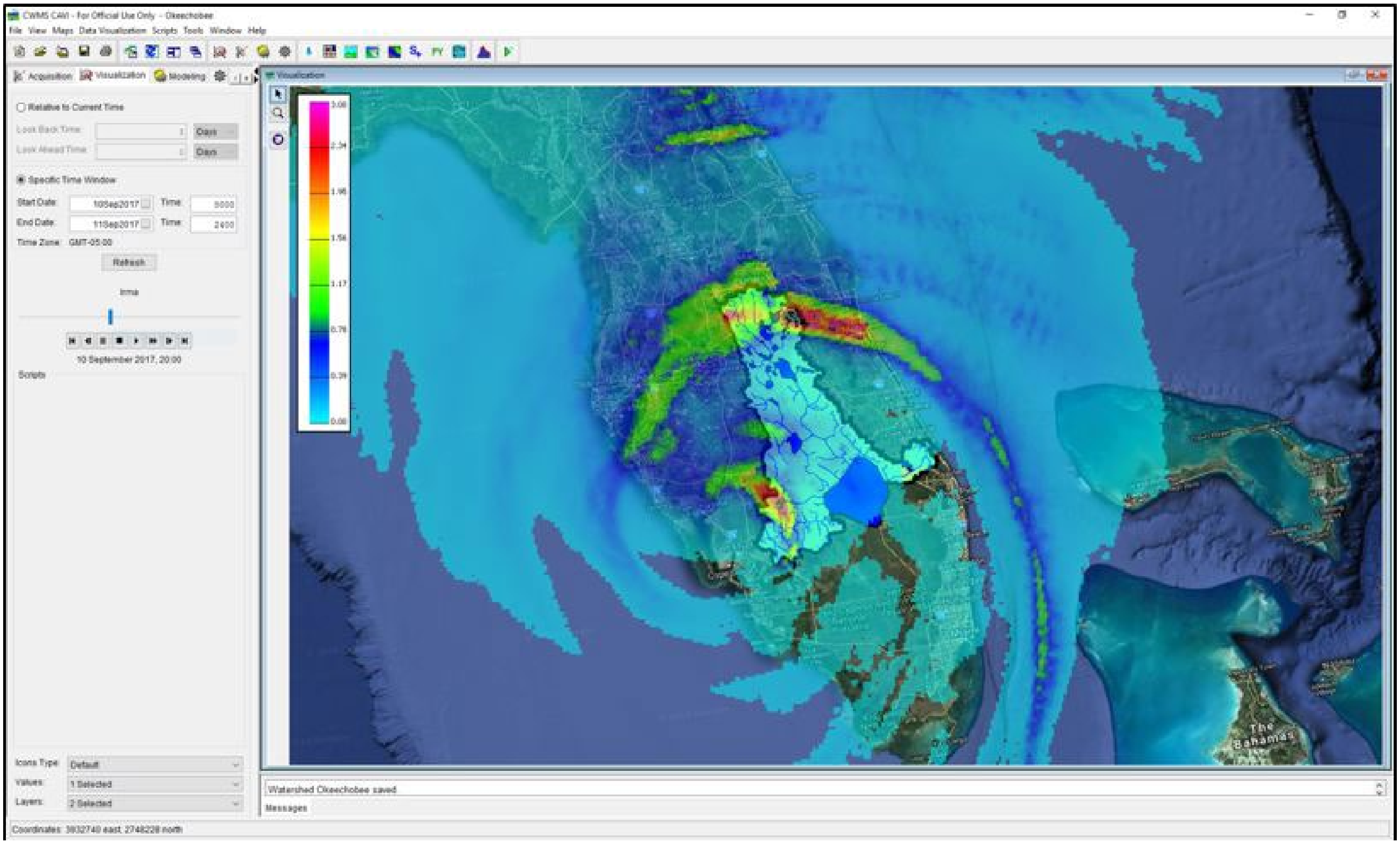

Figure 2: Hurricane Irma on Lake Okeechobee watershed

As Hurricane Irma approached Florida, the Jacksonville District began using the Lake Okeechobee CWMS watershed model to begin estimating the Lake Okeechobee inflows and stages. The 730 square mile Lake Okeechobee area is operated, at high stages, for flood control to reduce risks to the Herbert Hoover Dike project. Herbert Hoover Dike is an earthen embankment surrounding Lake Okeechobee. Historically, rain events tend to significantly increase lake stages due to the ratio of the large inflow volume from the 5,500 square mile watershed versus the small lake outlet capacity.

Jacksonville personnel simulated Hurricane Irma conditions using the Lake Okeechobee CWMS model from September 1 to October 31, 2017. The simulation estimated Lake Okeechobee inflows and stages for existing and future rainfall scenarios. The scenarios included increasing and decreasing structure releases from Lake Okeechobee based on lake regulations. Meteorological data input used within the scenarios included National Weather Service (NWS) Region 7 Quantitative Precipitation Forecasts (QPF) and varying rainfall scenarios based on no rainfall, normal late-September, and tropical storm rainfall; see Figure 2 Hurricane Irma on Lake Okeechobee watershed.

In the end, the models accurately predicted that Lake Okeechobee stages would continue to rise over a period of four weeks and peak in mid-October as a result of Hurricane Irma rainfall. The watershed model showed stages in the lake receded slowly due to both the large inflow volume from the watershed and Lake Okeechobee's small outflow capacity. Post model analysis correctly showed reduction in releases from Lake Okeechobee, in conjunction with any future rainfall beyond the NWS 7-day QPF, would increase recession times and stages within the reservoir. The model provided Jacksonville District leadership with valuable information by answering "what if" questions concerning potential future rainfall, operations, inflows, and stages at Lake Okeechobee.

Finally, the FIM Cadre and MMC were requested to develop Lake Okeechobee animation and informational images utilizing models and rainfall forecast results and also how to determine the predicted rainfall would affect the cofferdams under construction. The MMC collaborated with the Engineering Research and Development Center (ERDC) team requesting ERDC to develop the cofferdam over wash animation scenario. The MMC used Camtasia and Google Earth to create the Hurricane Irma flyover graphics and the final video for the Jacksonville District and SAD leadership to share risk-informed details with the UOC.

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Hurricane Maria – Puerto Rico

On September 14, 2017, the South Atlantic Division office contacted the FIM Cadre to start production on dam failure models for Guajataca and Toa Vaca Dams. To be able to build the 2D dam failure models, the MMC obtained the National Elevation Data (NED) from the U.S. Geological Survey (USGS) within a few hours of the request for assistance. In close coordination with personnel in Puerto Rico, the Jacksonville District and SAD personnel were able to send reservoir pool elevations, stage boundary of tidal elevations at the mouth of the river downstream of the dam, and the storage (with volume curves) of the reservoir to the MMC. The MMC developed the breach width and timing data using regression equations and projected precipitation (409 millimeters or 16 inches) which resulted in a potential dam failure, see Figure 3.

The Guajataca Dam experienced a six to 12-inch flow over the spillway a few days after hurricane landfall, which was observed by site personnel. The uncontrolled flow and a road immediately upstream of the spillway were concerns to local emergency personnel. Additional modeling was conducted to develop a spillway rating curve for Guajataca Dam which provided flow estimates based on increasing lake stages. The maximum inundation extent maps, various inundation maps, and Google Earth files based on the model output were provided to the SAD office. These products were invaluable to leadership in making decisions for emergency response and evacuation efforts.

In closing, the MMC FIM Cadre members are a dedicated group of professionals ready to support Corps organizations lacking the resources needed to produce hydrologic and hydraulic modeling, consequence estimations, inundation mapping, and risk-informed products (e.g. information

Figure 3

images and animation) during a flood event. For additional information on the FIM Cadre team, please email Cory Winders at robert.c.winders@usace.army.mil.

Quantifying Dune Coastal Protection and Recovery through Decadal Time-scales along NC's Outer Banks

Lead PI: **Katherine Brodie,** Ph.D., ERDC-CHL Co-PIs: Margaret Palmsten, Ph.D, Naval Research Lab; **Nicholas Spore,** M.S., ERDC-CHL; **Ian Conery,** Ph.D. Candidate, East Carolina University, ERDC-CHL Pathways Intern

Coastal foredunes are sandy features that form the landward boundary of many of the Nation's beaches and result from the dynamic balance between littoral, Aeolian, ecological, and in some-cases, anthropogenic (human) processes. During severe storms, when waves and water levels are elevated, sand can be removed from the dune when waves collide with the dune face, leading to dune erosion. Dunes thus offer protection to the ecosystems and coastal communities behind them by acting as a sacrificial buffer to large storm surge and waves. In contrast, during dry, high-wind events, sand is transported from the sub-aerial beach and deposited in the dune, leading to dune growth or landward migration, depending on the geometry of the system. In this way, dunes add resilience to coastlines by naturally recovering. First order control on the morphological response of the dune to wind and hydrodynamics is function of the magnitude and duration of the primary driving force – wind speeds and fetch distance for Aeolian processes and wave and water level heights for the hydrodynamic processes – relative to the sediment characteristics and geomorphology of the beach-dune system.

Because foredunes act as a natural barrier between the ocean and coastal development, USACE is particularly interested in how dunes can be utilized to increase coastal resiliency over long time-scales, as well as offer coastal protection during storms. To accurately quantify the amount of resilience and/or protection that dunes may provide a coastal system, research is needed to (1) quantify dune volume change rates (both growth and erosion) relative to environmental forcing parameters and (2) evaluate tools and numerical models that can be used to simulate these processes. USACE is also interested in improving tools for beach project design (e.g. Beach-fx) to identify optimal distribution of sediment between the dune, sub-aerial beach, or nearshore and to properly plan for renourishment intervals.

Some of ERDC's recent dune research has focused on using the Outer Banks of North Carolina as a natural laboratory to observe the evolution of natural and developed dunes on timescales ranging from storms to decades. In addition to this field-based research, ERDC has also initiated laboratory investigations on the role of plant roots in stabilizing dunes during storms, and the development of coupled vegetation and morphological evolution models. This write-up summarizes the analysis of the field investigations, as well as initial testing and

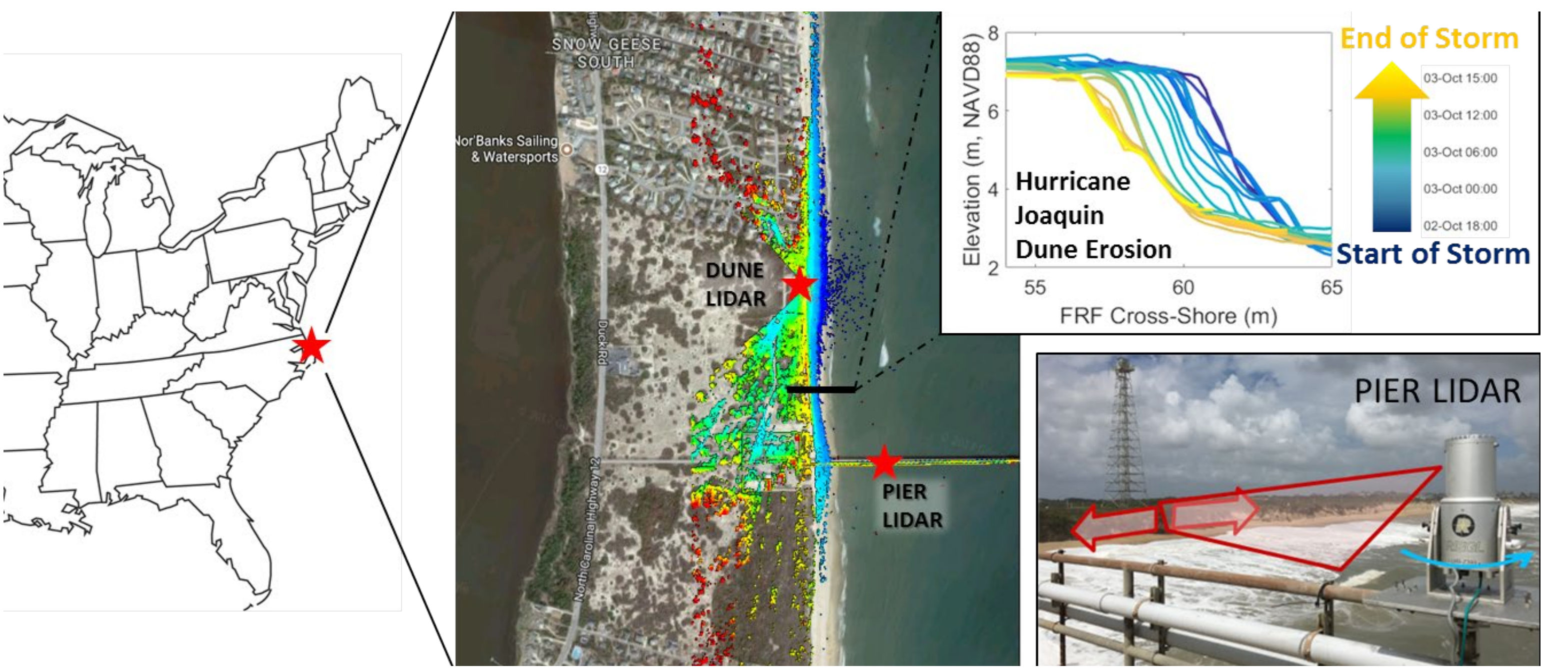

Figure 1 – Lidar data (rainbow colors represent elevation) collected at the Field Research Facility (FRF) in Duck, NC by the continuously operating dune lidar (not shown) and pier lidar scanner (bottom right). These state-of-the-art instruments observe detailed dune erosion during storm events (example transect shown in upper right) to collect critical data to improve USACE's understanding of the coastal protection from surge and waves offered by dunes.

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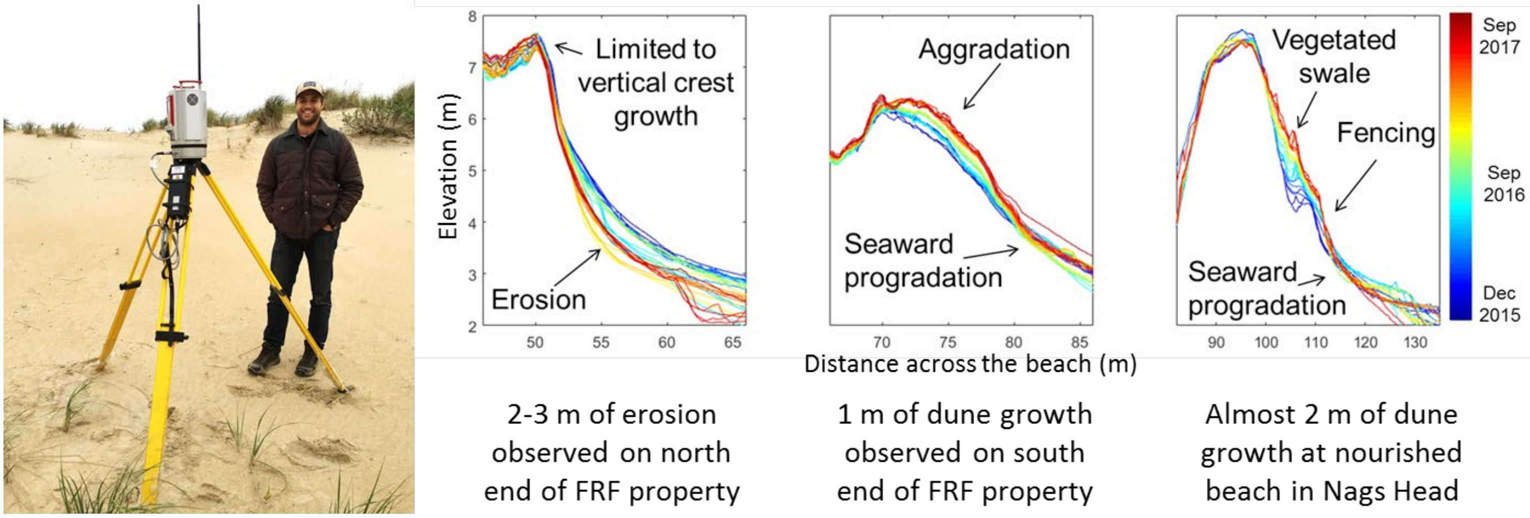

Figure 2 - ERDC-CHL Pathways Intern and East Carolina University Ph.D. Candidate, Ian Conery, uses terrestrial lidar (left image) to scan three dune systems along NC's outer banks. Significantly different responses have been observed between the three sites (compare transect evolution through time between the three images) which can be related to alongshore variability in beach width and sediment grain sizes.

evaluation of new tools ERDC can utilize to simulate the observed morphological evolution, but does not discuss results from the other efforts. This research was motivated partly by the 2016 "Dune Management Challenges on Developed Coastlines" Workshop , which indicated a need to "expand observations of beach-dune morphodynamics and sediment budgets over greater spatial and temporal scales" and to "improve numerical models of dune formation, growth, and erosion to cross spatial and temporal scales". To address these needs, ERDC focused on utilizing the Field Research Facility (FRF) in Duck, NC to execute a series of field campaigns designed to answer the following three research questions:

1. How fast do dunes erode during collision regime (waves hitting, but not over-topping the dune) storms? Can we simulate the observed erosion using available tools/models from the literature?
2. How fast do dunes grow? Do those rates vary between natural (FRF field site) and developed/managed systems (Nags Head, NC field site)? Can we simulate the observed growth using available tools/models from the literature?
3. How do dunes on an open, collision-regime coast evolve over long time-scales? Are the same processes important at long (years to decades) and short (days to years) time-scales? Can we develop tools to simulate the observed dune evolution over 30 years at the FRF?

Question 1's focus is on improving quantitative morphodynamic observations of dune evolution during collision regime storms —processes that occur rapidly on the time-scale of minutes to days. To accomplish this, ERDC utilized data from two continuously operating terrestrial lidar scanners on the FRF property (Figure 1), which provide hourly observations of high-resolution (100s of points per square meter) three-dimensional beach topographic evolution. In addition, one of these lidar scanners collects thirty-minute time-series of water levels at the shoreline simultaneously with topographic data, capturing the wave-by-wave evolution of the beach and dune.

ERDC is using these data to evaluate common swash and dune erosion parameterizations, as well as process-based numerical models (e.g. CShore, XBeach). Early results suggest the parametric dune erosion model may be a useful tool for districts both as a quick estimate of the protective lifetime of a dune in advance of an approaching storm (i.e. expected retreat distance given wave and water level forecasts) and also as a simple tool to evaluate proposed dune designs prior to running a full Beach-fx simulation. The continued testing and development of this model is also a focus of one of the USCRP research initiatives (USACE, NRL & USGS collaboration). In addition, these data will help improve the uncertainty estimates in using CShore to simulate dune erosion inside of Beach-fx, USACE's planning-certified model for Federal Beach Projects.

Question 2 is focused on improving quantitative morphodynamic observations of dune growth using monthly terrestrial lidar scans of three sites – two natural dune systems along the FRF property, and one developed dune system at a recently nourished beach in Nags Head, NC (Figure 2).

These data are one of the most spatially and temporally dense datasets of dune evolution ever collected, particularly on a managed dune system. In the spirit of the Dune Management Challenge Workshop's academic research goals, this research is being co-led by a local Ph.D. graduate student at East Carolina University (also a pathways intern at ERDC-CHL), who is also working

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closely with the town of Nags Head to improve the management of their beach-dune system. Results show that accretion can be as episodic as erosion (with significant growth during some Hurricanes and Nor'easters, Figure 3) and that significant variability can exist in a dune's response to similar forcing conditions, with spatial variability in hydrodynamics and beach morphology at 10s to 100s of m playing a critical role in dune evolution on the timescale of months. Early results show observed dune growth is well-correlated with Aeolian transport models , when sediment supply is not limited; and future work will evaluate how to incorporate these findings into USACE tools like Beach-fx.

Question 3 has utilized the FRF's 35+ year record of morphology, waves, and wind data to investigate the processes controlling dune evolution on decadal time-scales. Significant differences in the response of the north and south ends of the FRF's dune system were observed that could not be explained by variability in the wind or wave forcings. In fact, the only significant correlations found were between dune volume, shoreline position, and surf-zone volume. Analysis of historical regional shorelines suggests that alongshore processes and regional sediment dynamics may be affecting sediment supply within the system and therefore influencing long-term dune morphological evolution. These findings suggest future tools that USACE utilizes for management of coupled dune, beach, and surf-zone systems at project-relevant timescales (storms through decades) must account for both long-term inter-annual variations in sediment supply as well as short-term intra-annual variability in Aeolian and hydrodynamic processes (Figure 4).

While the above research questions are focused largely around basic research, their findings and results will directly improve USACE's dune design guidance, ability to quantify dune-related coastal resiliency, understanding of management challenges, and ultimately lead to improved management of our coastlines. These research efforts benefited from complimentary ongoing work supported by the USCRP and future work will focus on integrating relevant academic dune advancements into ERDC research and USACE tools, with a specific emphasis on testing predictive capabilities for USACE project-specific needs. ERDC will also be sure to communicate any new findings to the USACE Coastal Working Group, as well as the broader coastal science community.

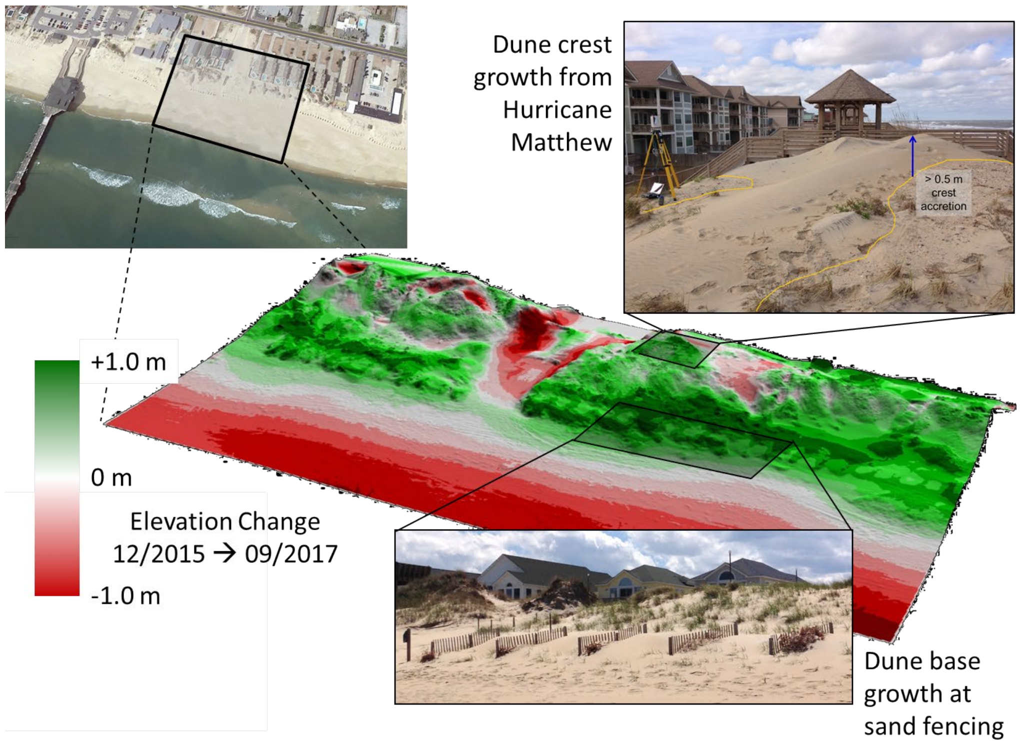


Figure 3 – Elevation change (colors) observed with terrestrial lidar at a developed dune system behind a nourished beach in Nags Head, NC. Some locations experienced over 1 m of elevation growth (dark green colors) in less than two years. Sand fencing (bottom picture) helped trapped sand at the dune base and significant dune growth was often observed during Hurricanes due to the strong winds and wide, nourished beach preventing erosion by waves.

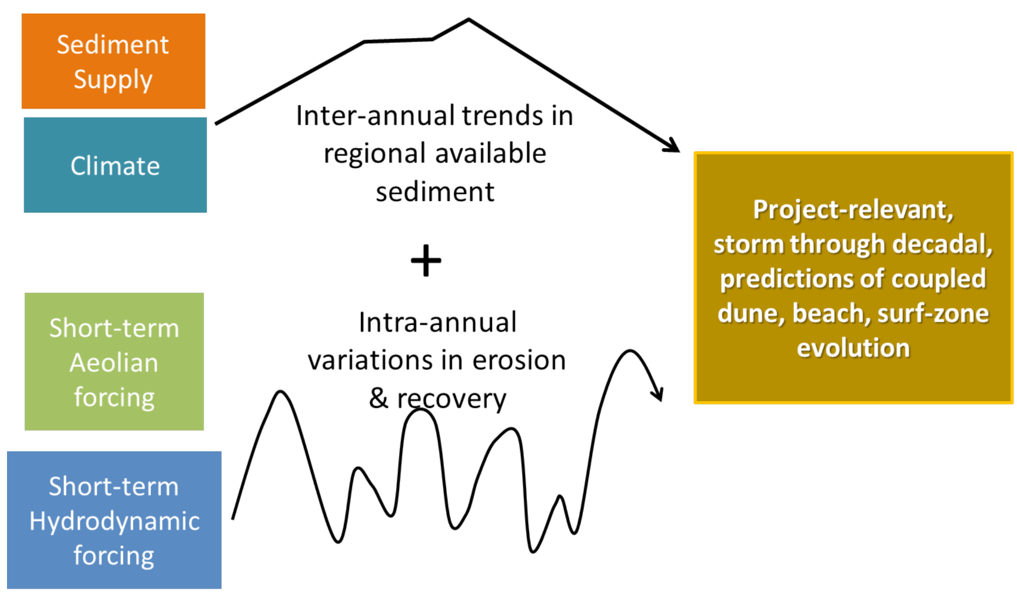
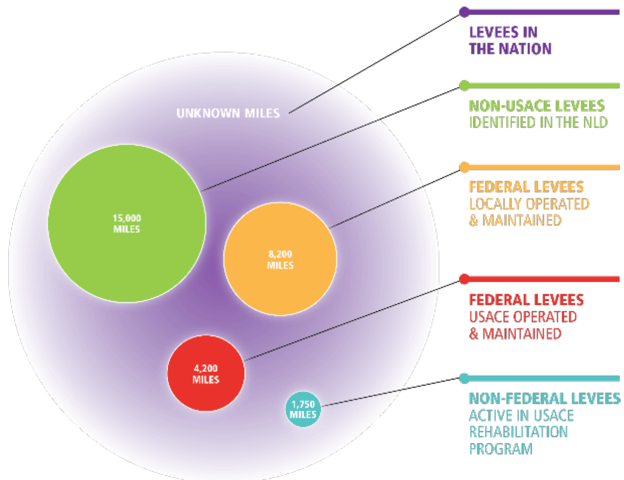


Figure 4. Conceptual model of controls on coupled dune, beach, and surf-zone evolution at storm through decadal timescales.

USACE Conducts First Analysis of Risk and Benefits of USACE Levees

By Chris Baker, SWT

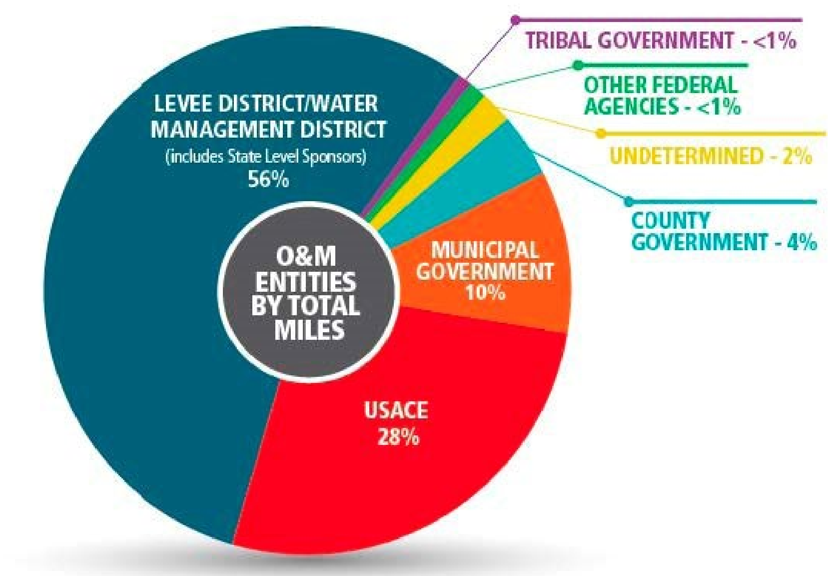
The Levee Safety Program has recently completed an analysis of the current understanding of the flood risks and benefits associated with levee systems included within USACE portfolio of levees. Utilizing the best available information gathered from risk assessments, this report provides valuable information that allows for improved management and investments at a portfolio level, including policy and technical guidance, training, and research and methods development. In addition, this report establishes a baseline that allows for future analysis of portfolio trends in inventory and risks.



USACE portfolio levees represent an unknown portion of the total levees in the United States. There are roughly an equal number of miles of levees in the National Levee Database that are within the USACE Levee Portfolio as outside.

Overview of the USACE Portfolio

The USACE levee portfolio includes about 2,220 levee systems totaling approximately 14,150 miles in length. Over 1,200 levee sponsors operate and maintain 2,000 of these levee systems, spanning roughly 70% of the length of the entire portfolio, pointing out that effective risk management is unlikely without comprehensive approaches of sponsors, communities and USACE. To complicate matters further, fifteen percent of levees include multiple segments, which usually means multiple operations and maintenance authorities. Since performance of the levee is only as good as its "weakest link," understanding and engagement of all parties within a single system is critical.



Breakdown of USACE portfolio levees by entity responsible for operations and maintenance and the percentage of miles of the total portfolio.

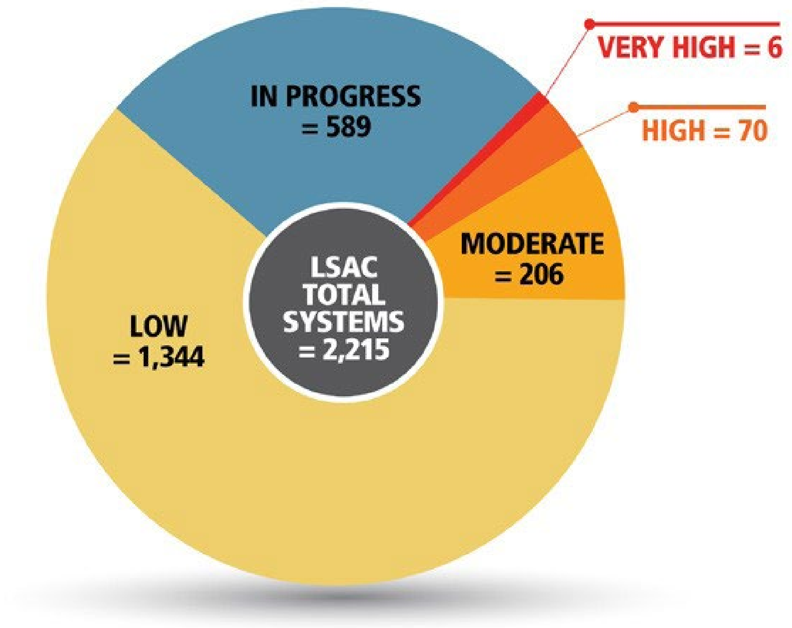
Much of What We Value is Behind USACE Levees

- 4,500 schools
- 300 Colleges and Universities
- 34 Major Sport Venues
- 25% of the National Daily Refining Capacity
- National Historic Sites (e.g., National Mall)

Continued on page 12.

Overview of Risk

Thirteen percent of the levees in the portfolio are considered moderate, high, or very high risk – levees that require interim risk reduction measures to reduce risk while longer term and more comprehensive solutions are being pursued. Although this is a relatively small number compared to the overall portfolio, people and property are concentrated behind these higher risk levees. Of the 11 million people that are behind USACE portfolio levees, 86 percent of them live behind moderate, high or very high-risk levees. Most of these levees have multiple risk drivers. Please note: this information is based on completion of risk assessments for 73 percent of the portfolio.

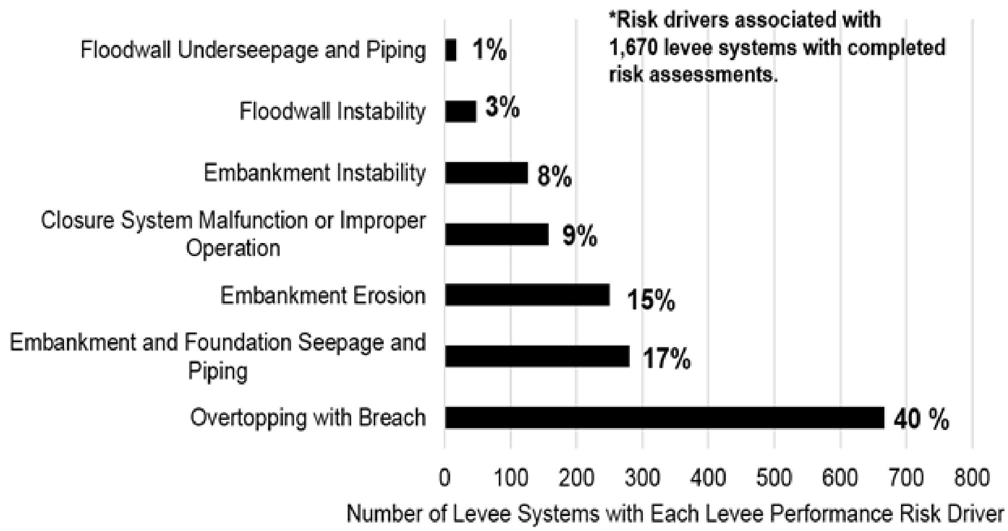


Risk assessment results to date. LSAC is an acronym that stands for Levee Safety Action Classification. These classifications have five categories (very low risk to very high risk).

Some Key Risk Drivers

The graphic below shows the top levee performance drivers.

- As you can see, overtopping followed by breach is the top risk driver for levees within the USACE portfolio. The likelihood of overtopping varies considerably across the portfolio -- from a 1-in-2 chance to a 1-in-5,000 chance of overtopping any given year, with a majority around a 1-200 annual chance. USACE continues to work to update data and refine H&H models to refine these estimates, some of which have high uncertainty.
- Seepage through or beneath the levee is the second most common performance risk driver impacting 17 percent of the portfolio. This risk driver is impacted by the presence of an estimated 16,000 degrading, undersized or unreliable pipes and conduits.
- In addition to risks associated with the levee itself, risk assessments take into consideration how vulnerable a population behind a levee is by assessing preparedness of the community to evacuate those behind a levee if needed. For example, 63 percent of communities have either incomplete or non-existent evacuation plans.



Percentage of levee systems with each levee performance risk driver. One system may have multiple drivers.

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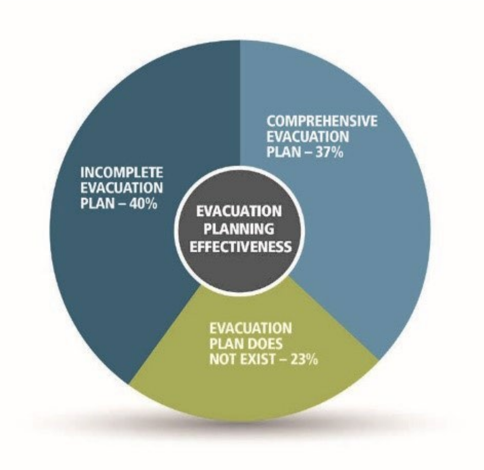

Communities behind nearly on quarter of the levees have no evacuation plan.

Cost Estimates to Reduce Risk

Initial cost estimates, which are agnostic as to who pays, range from $6.5 billion to $38 billion, with an expected cost of $21 billion. One observation from this data is that relatively modest costs ($300 million) of improving evacuation effectiveness across all levees is a smart investment. Costs are significantly lower than infrastructure improvements and directly reduces risk to loss of life by getting people out of harm's way.

The full report will be available this spring on the Levee Safety website.

USACE Levees - Only Part of the Picture

As a Nation, we know little about the condition or risks associated with levees outside the USACE portfolio. As such we do not have a true national look at the risks and benefits levees provide to the nation. The Levee Safety Program is working with Silver Jackets to coordinate with states, tribes, local communities and private levee owner-operators to conduct a one-time voluntary inspection and risk assessment for all levees in the Nation.

Flood Risk Management Spotlight

Shirley with her award from the Federal Executive Board, Innovation Connection

Shirley Johnson has been producing top quality work in the Rock Island District, Hydrologic Engineering Section, for many years. Shirley is a Licensed Professional Hydrologist and has established a vast network of interagency contacts and the know-how to find both historic and current floodplain management information.

Shirley has served as lead or support role on numerous Iowa and Illinois Silver Jacket interagency efforts since their inception. Shirley has developed and fostered trust and collaboration with local, state, academic, and federal partners, in a way that has led to innovative and ground-breaking work, especially in Iowa.

For example, Shirley assisted the Iowa Flood Center and Iowa Department of Natural Resources by providing models and floodplain information for creation of an inundation map library for flood-prone communities, and the development of the FEMA-compliant statewide floodplain mapping program. This effort received a 3rd place award from the Federal Executive Board, innovation connection in the fall of 2017.

In addition, Shirley served as pilot lead for two phases of a pilot project to develop and evaluate methods to establish rating curves for water surface sensors mounted on the bottom of bridges. This work combined the strengths of the USGS technical experience and network coupled with the low cost of the Iowa Flood Center bridge sensor network to strengthen flood forecasting capability in streams and support hazard response and mitigation planning. Several communities have benefitted from the pilot project and are using local funds to establish sensors and rating curves in their community.

Shirley is currently leading the Iowa Flood Risk Data Inventory interagency effort where she worked with state and Federal partners to identify and catalogue all of the hydraulic models developed by state/federal agencies and display the metadata about these models on a web-based geospatial inventory. For each model, the inventory includes information on stream name, site description, study extent, type of model, model software, agency name, point-of-contact, date of model data, and model development notes. This work delivers on partners request to have a single point to view information for hazard response and mitigation planning.

Shirley has served as a mentor to numerous junior (and senior) level staff, which has built capacity for recent and future Silver Jacket interagency efforts. In addition, she enjoys a good craft beer, is funny, and is a down-right nice person to be around.

USACE Assistance in Puerto Rico **By Logan Wilkinson**, P.E., SAJ

PL 84-99 provides the U.S. Army Corps of Engineers the authority to prepare for, respond to and recover from severe natural disasters, such as Hurricanes Irma and Maria, which cause flooding or coastal damages, under the Flood Control and Coastal Emergency (FCCE) appropriation. After Hurricane Maria struck the island of Puerto Rico, the landscape and hydrology were significantly changed. Rivers flowed out of bank, new channels were cut, watersheds lost significant vegetation, which exacerbated flash flooding, channels were clogged with debris and hundreds of bridges collapsed, which caused water to backup. This caused a significant threat to life safety, improved property, and critical roadways.

Air drop of supersacks as part of the Guajataca Dam stabilization efforts.

Upon arriving in Puerto Rico, I set up an Interagency Flood Fight Task Force with participation from myself (USACE PL 84-99 SME), the USACE Local Government Liaison Team Leader, the Puerto Rico Department of Natural and Environmental Resources, Department of Agriculture, Department of Transportation and Public Works, and the Puerto Rico Emergency Management Agency. The purpose of this task force was to identify sites and provide Technical Assistance from USACE to Puerto Rico officials, or Direct Assistance providing material and/or emergency contracting. Upon the request of the Government of Puerto Rico, the Jacksonville District (SAJ) launched a team of engineers to conduct Technical Assistance via emergency inspections of critical flood sites and provide recommendations to local entities for emergency and long term remediation. In total, SAJ engineers inspected 177 sites. SAJ also awarded an emergency contract for $1.68 M to construct a temporary levee to keep the Yauco River within its normal channel and alleviate flooding to the town of Yauco and critical transportation routes in the area. The project was completed in late January of 2018. Additionally, SAJ worked under PL 84-99 authority and a FEMA Mission Assignment to conduct emergency drawdown and stabilization efforts at the Guajataca Dam.

Under the PL 84-99 Rehabilitation Program, the district sent engineers to do inspections of 17 federally constructed Levees and Flood Control works which have been turned over to the Department of Natural and Environmental Resources (DNER) in Puerto Rico for Operations and Maintenance. The district found that two projects were eligible for federal rehabilitation assistance, Rio Grande de Manati and Rio Puerto Nuevo. The Rio Grande de Manati levee provides flood damage reduction measures

Continued on page 15.

Left: USACE SMEs demonstrate how to properly set up HESCO barriers at Toa Baja. Right: USACE SMEs demonstrate how to place sandbags.

to a population of around 4,000 residents with estimated property values around $15 million. The levee system sustained severe embankment damages for about 5,000 linear feet and the contract, awarded in December 2017, will restore the levee to the pre-storm conditions. For the Rio Puerto Nuevo project, which reduces risk to approximately 70,000, the main project impacts were sediments deposited on the lower channels as the result of Hurricane Maria. Approximately 200,000 cubic yards of sediment deposited on the lower channels reduced the current channel capacity by 75% in some areas. A contract for rehabilitation has not been awarded yet, but is in process.

The Government of Puerto Rico also requested flood fight materials, which USACE provided to the Puerto Rico Emergency Management Agency (PREMA). These materials included 450,000 sandbags, 5,100 feet of HESCO barriers, 1,000 supersack sandbags, 500 wire rope slings with shackles for air operations using the supersacks, and 75 rolls of poly sheeting. On 11 November 2017, USACE held a flood fight training for various Puerto Rican agencies, with 60 personnel in attendance, on how to properly implement HESCOs, sandbags, and poly sheeting for flood fighting. The flood fight training took place in Toa Baja on the beach where sand is readily available and at one of the sites inspected for severe flooding to the community of Levittown. Levittown was flooded during the storm events due to clogged stormwater drains that were unable to properly discharge, making it an ideal location for a flood fight training session.

USACE personnel who conducted the training included Logan Wilkinson - SAJ Natural Disaster Program Manager, Brenda Calvente - SAJ Project Manager Forward for Puerto Rico, Matthew Collins - MVS Flood Fight Technical Expert, and John Osterhage - MVS Flood Fight Technical Expert. Participating agencies included PR Highway Authority, Department of Transportation and Public Works, Department of Natural and Environmental Resources, PR Emergency Management Agency, PR National Guard Firefighters, PR State Agency for Emergency and Disaster Management, and PR Search and Rescue.

Port Arthur and Vicinity Hurricane Flood Protection Project: Failing Port Arthur HFPP I-Wall

By Mike DeMasi, SWD, and **Alicia Rea**, SWG

1. Executive Summary

The Port Arthur and Vicinity Hurricane Flood Protection Project (HFPP or Project), authorized by the Flood Control Act of 23 October 1962, PL 87-874, in accordance with House Document No. 505, 87th Congress, 2nd Session, is in danger of an imminent failure in the sections shown in Figure 2 upon landfall of a tropical storm. This section protects several petrochemical refineries and residential areas located within Port Arthur. Failure of this section of the HFPP will allow any storm surge access to the protected area resulting in excessive costs to industry and adverse impacts upon the state's economy ranging from \$100M to \$1B. This structural failure, which had occurred near the peak of the 2017 Tropical storm season, created an urgent need for interim repairs to be made to the failed section. This section is composed of a 600 foot length of both braced and unbraced I-walls. Failure occurred along a 200-foot section of the wall which compromised the remaining portion of its length.

Figure 1 (left): Satellite map showing area of concern; Figure 2 (right): Failed and compromised sections

Continued on page 17.

2. Project Description

The Port Arthur and Vicinity Hurricane Flood Protection Project includes 34.4 miles of protective works consisting of earthen levees, concrete and steel sheet pile floodwalls and twelve pumping stations. The system has numerous appurtenant structures including vehicular and railroad closure structures, street and highway ramps and gated gravity drainage structures.

3. Extent of Damages

On 1 August 2017 a local fisherman in the navigation channel noticed the damage section of I-wall and posted a picture on Facebook. Within hours of the fisherman's post, people who knew what this wall protected were calling the local sponsor. Galveston District's (SWG) levee safety team was notified later the same day and proceeded to the site to meet the local sponsor. The section of I-wall in complete failure is shown in Figures 4 and 5, below. The engineer team requested a complete hydrographic survey on both sides of the wall. Hydrographic survey team from SWG's Port Arthur Office arrived the next day to provide a detailed survey of the channel side. Also SWG's GIS team used a Z-Boat (remote controlled vessel) to survey behind the wall due to the shallow depths and safety concerns with a total slope failure. The surveys showed very little foundational support remained for the wall pilings, rendering this section of the structure essentially ineffective in combatting storm surge-related flooding. Figure 5 and 6 below shows the channel survey results.

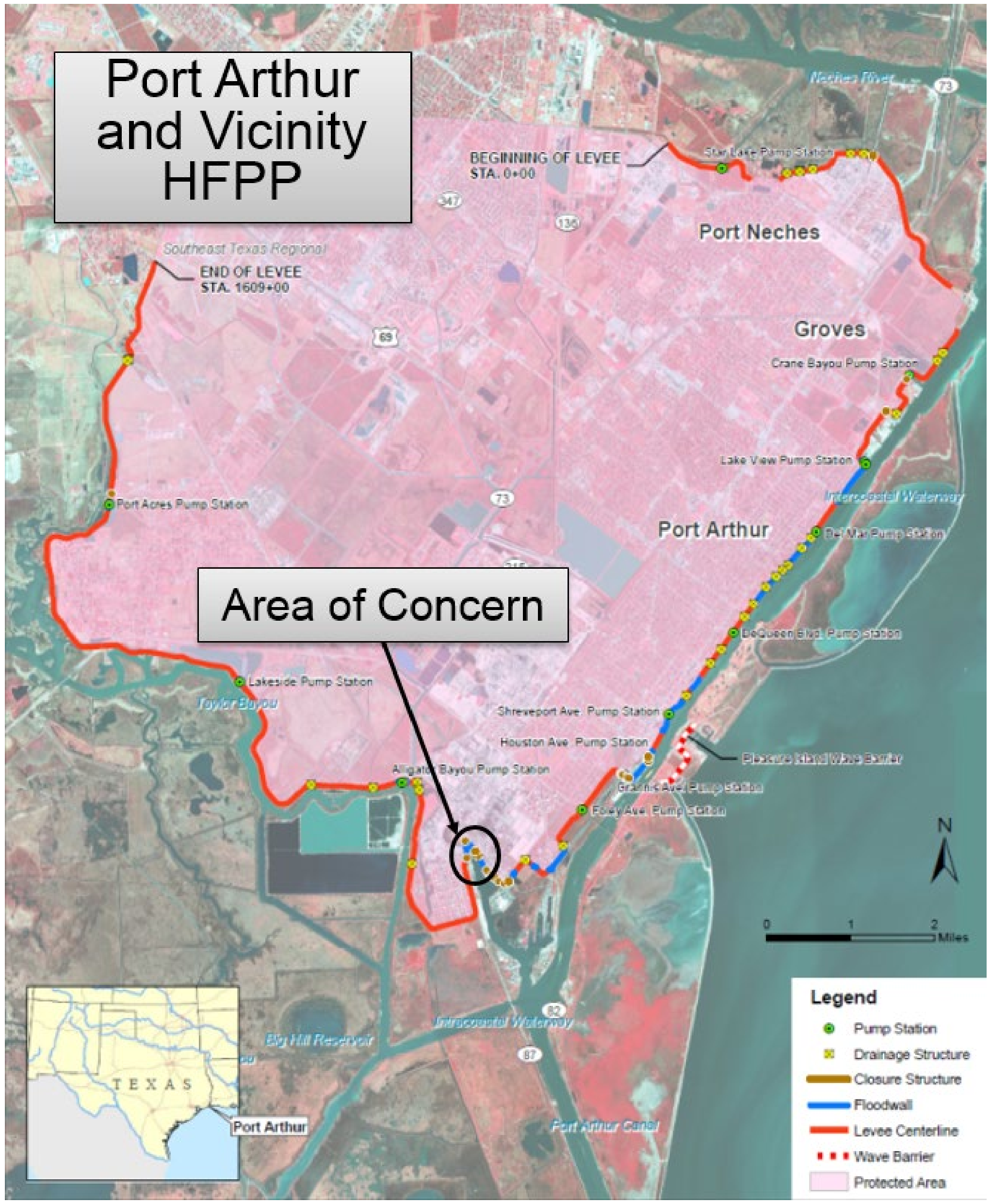

Figure 3: Port Arthur and Vicinity HFPP

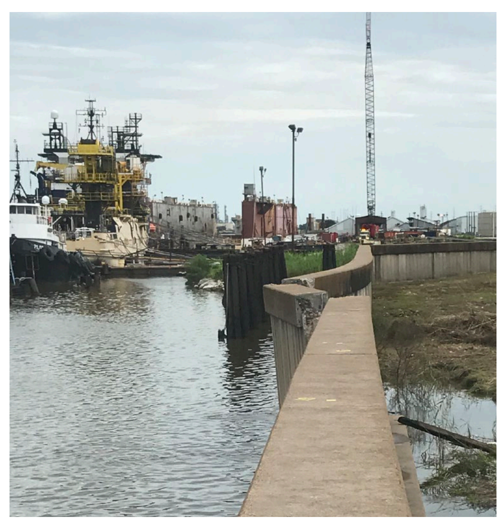

Figure 4 (left): Failed section viewed from South, facing North; Figure 5 (right): Failed section viewed from North, facing South

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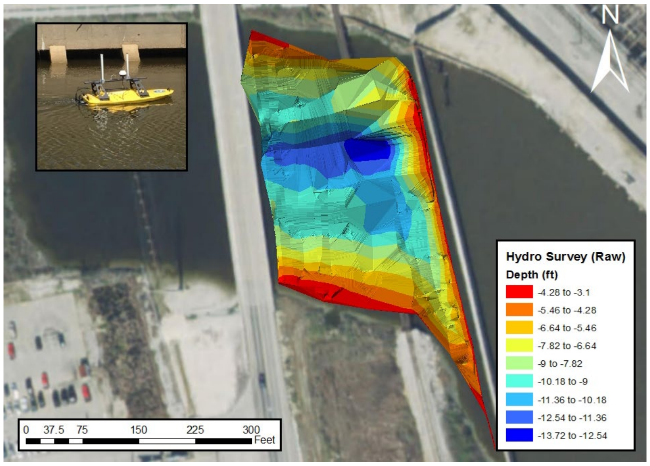

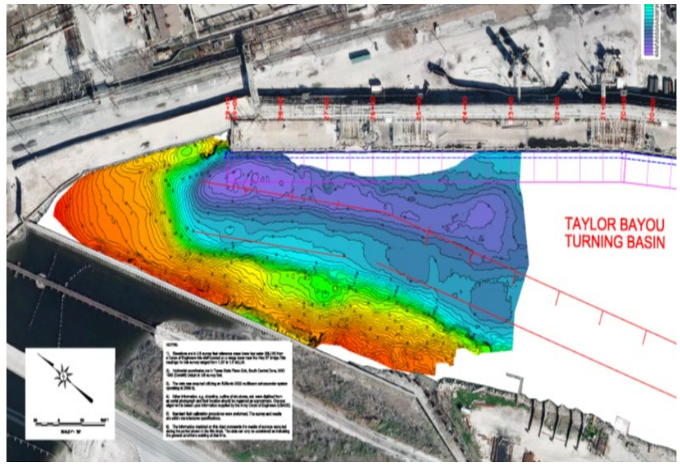

Figure 6 (left): Z-Boat survey results; Figure 7 (right): Navigation channel survey results

4. Description of Safety Concerns

The results from a Semi-Quantitative Risk Assessment (SQRA) for the HFPP were presented to the Levee Senior Oversight Group (LSOG) on 25 October 2016 in Baltimore, MD. The risk associated with the Potential Failure Mode (PFM) for overtopping with breach is high and is the controlling PFM for the entire levee system. The likelihood of overtopping with breach was estimated to be 0.1% to 1% with associated loss-of-life estimated to be 1 to 10 residents and economic loss of $100M to $1B. There is high confidence in the overtopping frequency and the life loss estimates; however, there is a moderate to high level of uncertainties in the economic damage estimates. These uncertainties are related to the secondary economic impact of industrial facilities, as well as of the local and/or national impacts if the refinery plants were to be inundated. The potential environmental impacts were also considered in the risk assessment, and were judged qualitatively to be substantial if the facilities were inundated. A constructed soil berm in the Sabine-Neches Waterway, called Pleasure Island, is a contributor of overtopping risk. The island functions as a wave barrier and was incorporated into the original design of the levee system. Hurricane loading, including Hurricane Ike, has led to erosion and degradation of this island over time. This feature no longer provides the same level of wave protection as was assumed in the design; making the levee susceptible to higher surge.

When the SQRA was conducted, considering a breach prior to overtopping, the risk was determined to be moderate with the primary PFMs related to I-wall stability. However, as a length of the I-wall is already in failure and has compromised the strength of the wall's remaining length, the risk associated with a breach prior to overtopping could reasonably be considered extremely high, if not a certainty.

Consequences related to this failure are driven by the population of the City of Port Arthur and the existence of several fuel refining complexes. Estimated population at risk (PAR) due to levee breach ranges from 370 to 35,600 depending on the scenario and storm magnitude. The population in the leveed area also has a social vulnerability with a local poverty rate exceeding 30 percent. The local economy has diversified sources of income, but is predominantly dependent on the petroleum refining industry. The principle sources of income are derived from processing petroleum and petroleum by-products. Port Arthur is a nationally important petroleum processing center and deep water port (ranked #18 among U.S. ports in 2013 tonnage). It is home to the Motiva refinery, the largest in the country, with a production capacity of 603,000 barrels per day. The Motiva refinery also represents 60% of national jet fuel production. Other large refineries include Valero, Chevron, and Total. Together the large refineries comprise 15-20% of the land area within the levee boundary. Incremental direct damages are estimated to be $100M to $1B. In addition to direct damage to physical property, flooding adversely effects commercial and industrial properties by shutting down operations during the flood event itself and the recovery period afterwards. Suppliers and customers linked to these businesses are also impacted. These indirect business losses may be regional in scope or, as in the case for the large petroleum refiners, the national economy can be adversely effected.

Continued on page 19.

5. Technical Interim Solution

The repair plan included two phases. First phase was to fill the scour hole on the flood and protected sides with sand to stabilize the existing wall. The sand fill was armored with 1,700 large sand bags. The fill and sand bags were placed alternately on both sides to maintain equal pressure distribution to avoid further destabilizing the existing structure. SWG provided the sandbags to the local sponsor as part of flood fight operations. Also as part of this phase HESCOs were moved to the site from the National Flood Fight Materiel Center (NFFMC). This phase of the interim solution was completed on 21 August which closed the hole in the I-wall as seen in Figure 8.

HESCO baskets from the USACE NFFMC were shipped to the site as a backup to serve as an additional line of protection if needed. They were stockpiled on site in Port Arthur. In the event of a storm that may risk failure of the interim system, the HESCO baskets will be placed within two to three days before an expected storm landfall. The HESCO alignment will follow the land bridge further behind the area shown in Figure 10. The HESCOs would only be necessary if the phase 1 repairs could not be constructed before the potential impact of a tropical storm or hurricane.

Figure 8: Sand placement to stabilize wall

Phase two began on 22 August with driving the first set of 50 foot sheet piles but was quickly put on hold when Hurricane Harvey developed in the Gulf of Mexico. Hurricane Harvey caused about a 6 foot storm surge and dumped more than 60 inches of rain within the Port Arthur area. The phase 1 repairs held during Hurricane Harvey.
Phase 2 included a sheet pile wall constructed behind the failed I-Wall to create a secondary line of protection. The sheet pile tied into the existing wall 100 – 200 feet beyond the failure. This resulted in a total of about 1,000 LF of sheet pile wall. Figure 10 shows the approximate location of the sheet pile wall. SWG and MVN levee experts reviewed the sponsors 60% design documents and allowed construction to start before final design documents were completed. USACE Mapping and Modeling

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Center also developed inundation mapping. This modeling was used during town hall presentations to the general public to increase awareness of the risks associated with I-wall failure and repairs. Phase 2 repairs were completed on 3 October.

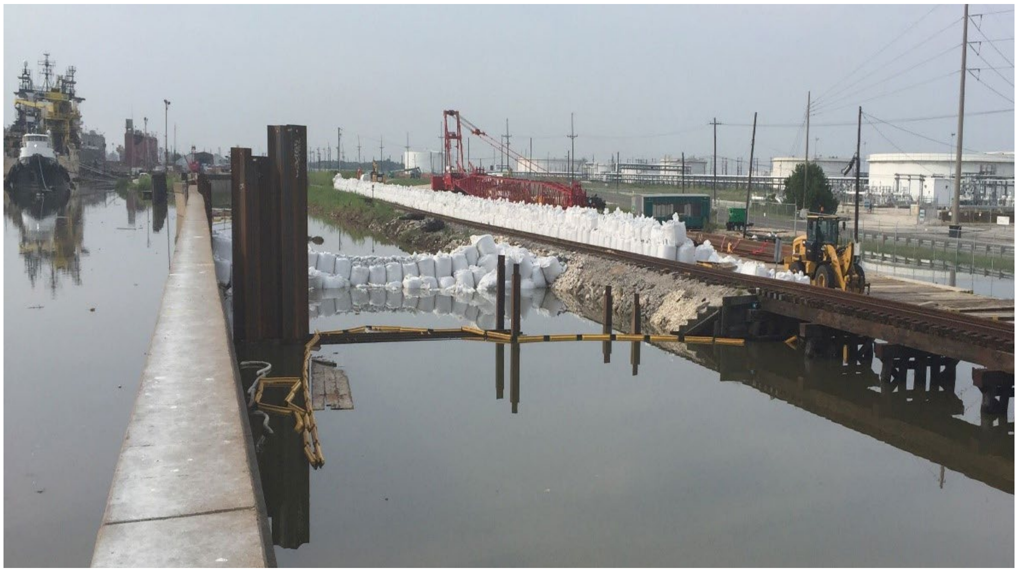

Figure 9 (bottom): Start of Phase 2 Sheet Pile Wall

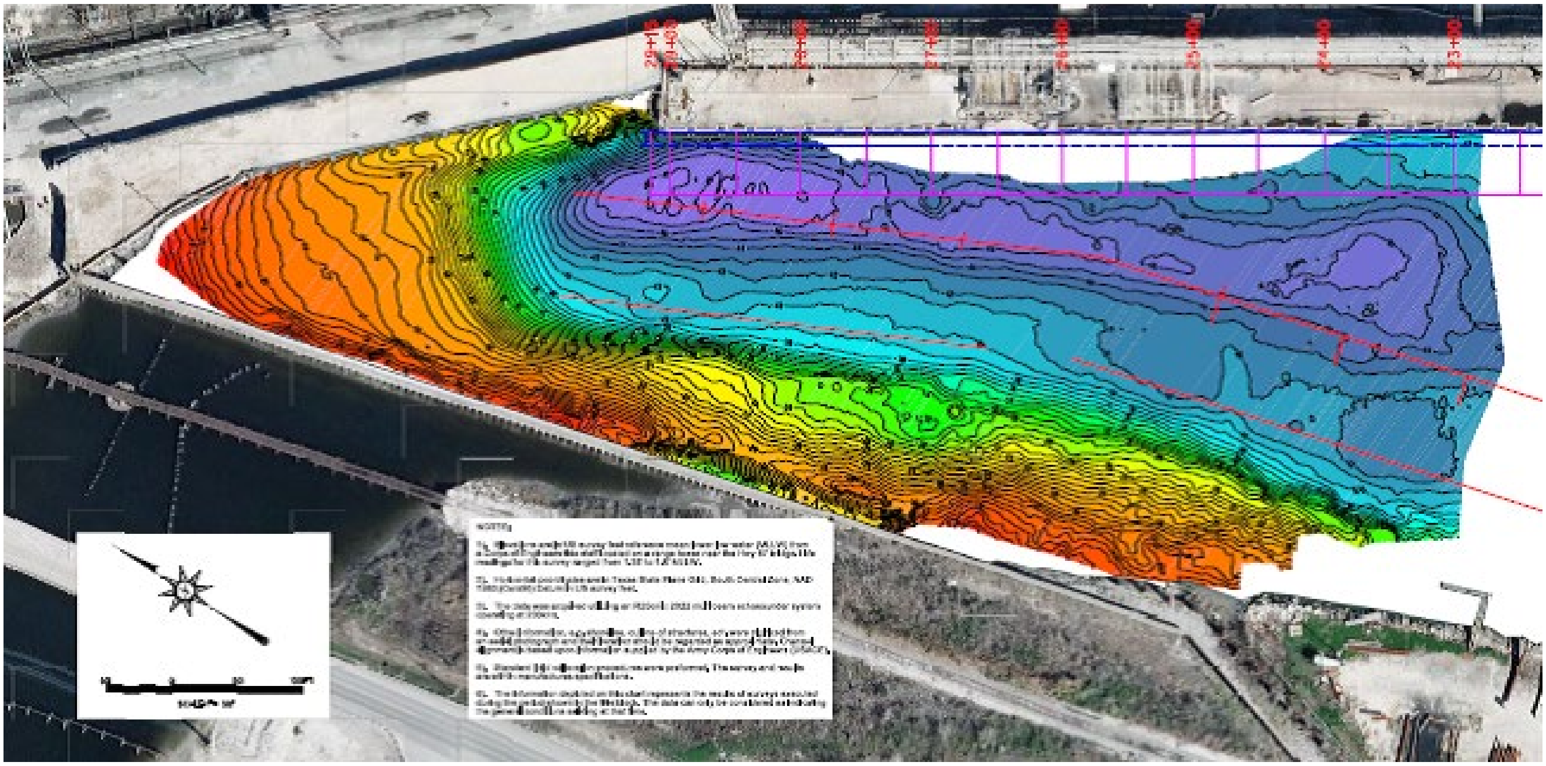

Figure 10. Approximate location of the sheet pile wall, fill, and sandbags.

6. Remediation Authority

The primary responsibility for repair and maintenance costs is with the local sponsor. The Port Arthur HFPP local sponsor has historically maintained the system to USACE standards. The sponsor was very responsive to the I-wall failure and completed extensive repairs to ensure the citizens and industry were protected by the HFPP. USACE provided technical assistance and coordination through PL84-99 authority. Also flood fight materials as mentioned above were provided under the same authority. USACE remains in close coordination with not only the local sponsor but also the Jefferson County Emergency Management and State of Texas Department of Emergency Management. The permanent fix for the I-wall at this HFPP as well as similar I-walls at Texas City HFPP and Freeport HFPP are all wrapped into the Texas Coastal Study which is scheduled to be complete within the next two years. USACE will continue to work with the local sponsor through the 2018 Hurricane season on risk messaging to the public.

Flood & Coastal Systems Research & Development Program Releases "FY17 Accomplishments and Infusion of Products into Practice" Booklet

By Mary Cialone, U.S. Army Corps of Engineers, Engineer Research & Development Center, Coastal & Hydraulics Laboratory

Overview

The Flood & Coastal Systems (F&C) Research & Development (R&D) Program recently released a booklet summarizing FY17 accomplishments from the five F&C focus areas and the infusion of the research products into practice (Figure 1). The five focus areas include: resilient coastal systems, watershed management, resilient infrastructure, emergency management, and risk and uncertainty analysis. The booklet highlights statistics for the number of products (models, tools, publications) completed in FY17 (195) and the number of collaborations (144) with a broad-reaching audience including other USACE laboratories, USACE Districts, national and international federal agencies, non-government organizations, and universities.

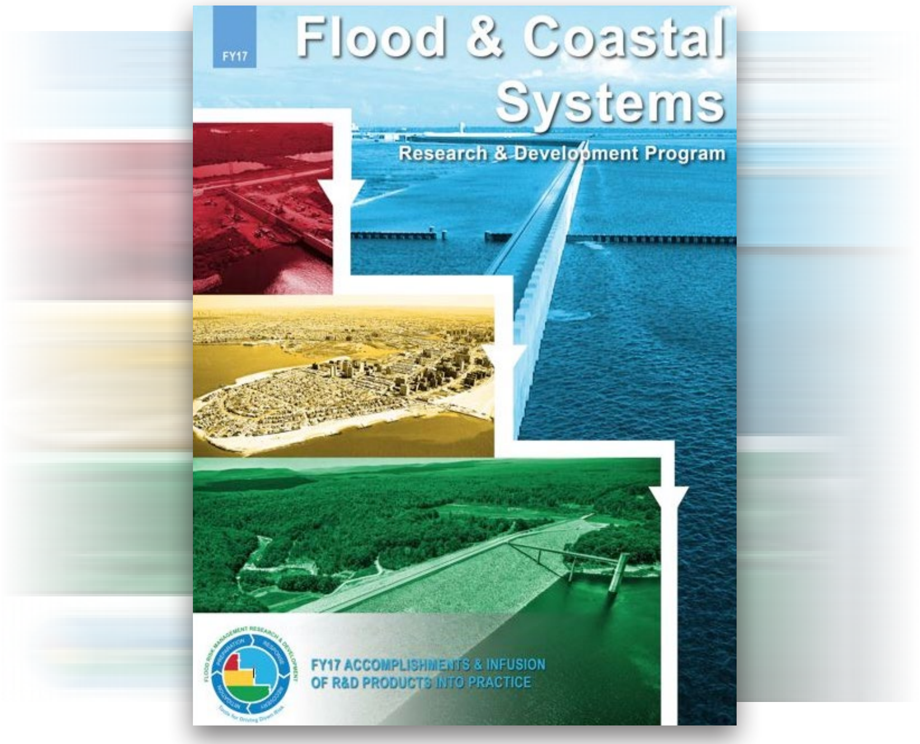

Figure 1. Cover of the Flood & Coastal Systems Research & Development FY17 Booklet

Goals and Products

The overarching goals of the F&C Systems R&D Program are to take a systems approach to reducing risk, increasing resiliency, and advancing sustainable infrastructure in collaboration with partnering agencies. The products from this program facilitate efficent and effective assessment of USACE water resources projects in terms of their risk-based capacity to function through flood and storm-induced hazards over short-term (event driven durations) to long-term time periods. Assessment of water resource projects spans the entire watershed, in all climates and settings from tropical to ice-affected, coastal and inland, involving USACE business processes including planning, designing, constructing, operating, maintaining, and rehabilitation. Capabilities to prevent loss of life, minimize property damage, and reduce the life-cycle costs of projects are critical. Products include advanced representation of physical processes and design models, economic models and decision support software, infrastructure condition and risk assessment tools, infrastructure design guidance, innovative Operation & Maintenance (O&M) technologies, flood-alert instrumentation, expedient emergency response capabilities, and the ability to take advantage of new real-time data sources (e.g., precipitation radar) to accurately forecast real-time flow and stages.

The booklet summarizes FY17 successes and accomplishments for the Flood & Coastal Systems Research and Development Program. The information shows the value, breadth, and impact that the associated research products have provided, and example applications illustrate how they are being transferred into practice. Please contact the author, Mary.A.Cialone@usace.army.mil to request a copy of the booklet.

Cedar Rapids Flood Risk Management: A Case Study in Flood Disaster Recovery

By Jeff Jacobs, IWR

In the summer of 2008, the city of Cedar Rapids, Iowa experienced several weeks of devastating flooding of the Cedar River, which flows through large portions of the community and the city's downtown area. Located in east-central Iowa (Figure 1), Cedar Rapids is Iowa's second-largest city, with a population of over 250,000 across its entire metropolitan area.

Cedar Rapids is home to many important businesses and economic activities. It is the national headquarters of Rockwell Collins, a major avionics system production company, and of the freight transport company CRST. The city has two major hospitals and the Eastern Iowa Airport lies just south of the city's metropolitan area. Cedar Rapids is perhaps best known, however, as a leading national grain processing and distribution center. Archer Daniels Midland, Cargill, General Mills, Ingredion, and the Quaker Oats Company all have commodity processing centers in Cedar Rapids. Every day, approximately 1.3 million bushels of corn and 100,000 bushels of soybeans are processed in Cedar Rapids.

Cedar Rapids' experience in recovering from this unprecedented flood disaster offer an excellent opportunity to review and document the suite of actions implemented across the community, and to reflect upon lessons the city's recovery may hold for larger, national-level trends in flood risk management. This paper from the Corps' Institute for Water Resources is based upon discussion with city officials and other local experts in Cedar Rapids during the week of May 8-12, 2017, and some of the author's observations regarding flood disaster recovery.

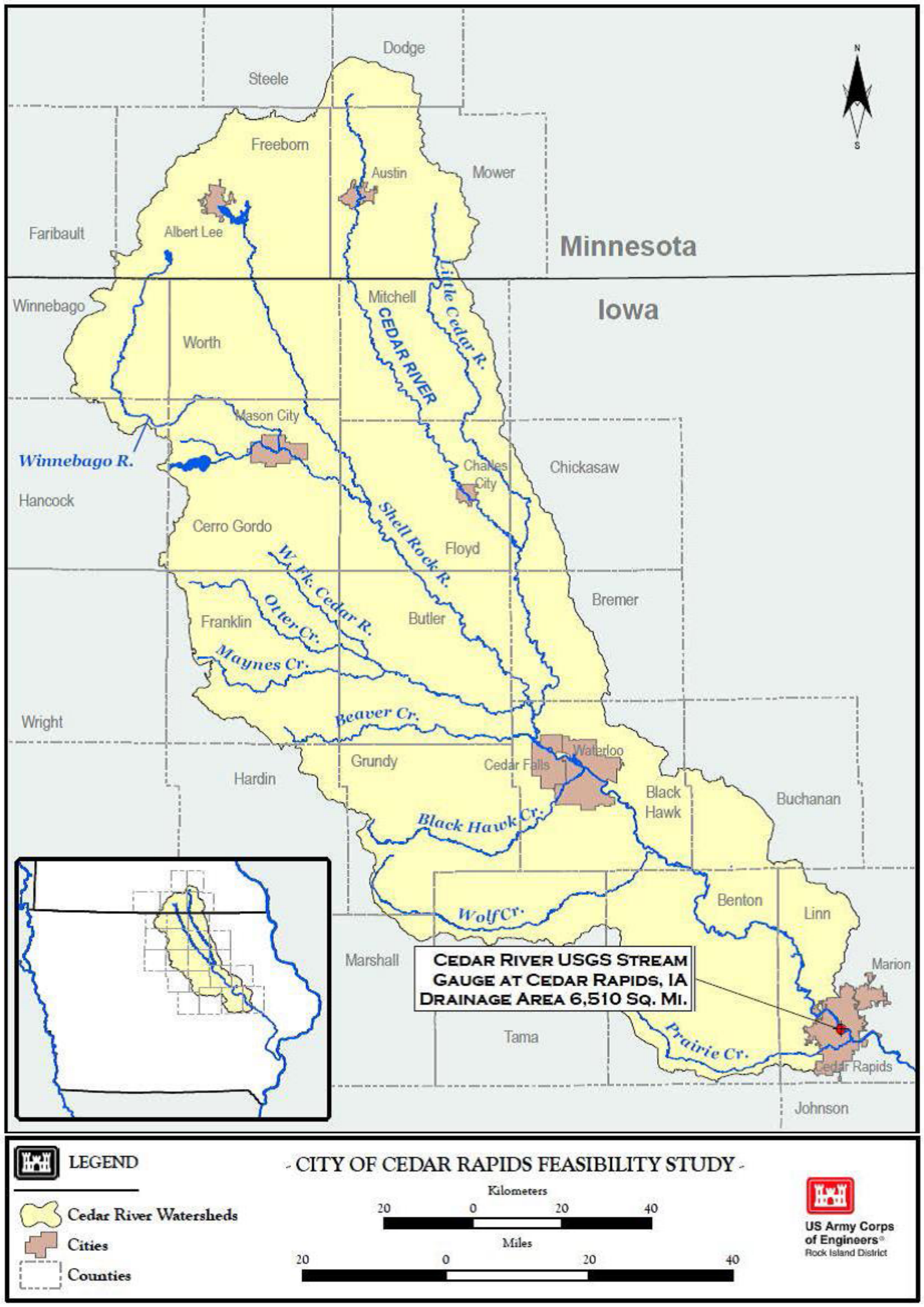

Figure 1 Cedar Rapids and the Cedar River Watershed. Source: U.S. Army Corps of Engineers, 2010.

The following represent major lessons from the Cedar Rapids flood recovery experience.

Continued on page 23.

1. The 2008 Cedar River flood was unprecedented in terms of river discharge, river stage, extent, and duration.

The 2008 flood was estimated as having a return period of well beyond 500 years (Buchmiller and Eash, 2010). Cedar River discharge on June 13, 2008 was nearly double the previous record high annual Cedar River flows (Figure 2).The flood was unprecedented in Cedar Rapids' history. At its peak on June 13, 2008, the river was nearly 20 feet above local flood stage. Understanding the extreme, unprecedented magnitude of the 2008 flood is fundamental to explanation of the extent and variety of the post-2008 flood activities.

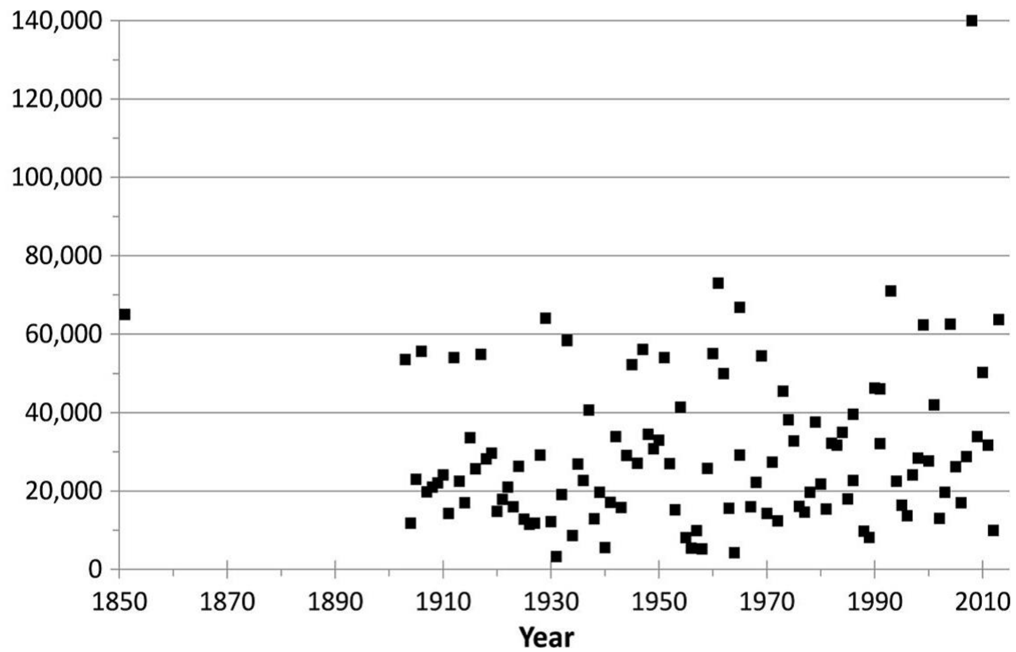

Figure 2 Cedar River peak annual discharge. Source: U.S. Army Corps of Engineers, 2010. Adapted from Buchmiller and Eash, 2010.

2. Damages in the 2008 Cedar River flood were extensive and unprecedented.

Cedar River flood waters damaged thousands of residential and business structures and affected tens of thousands of residents. Loss estimates of the 2008 flood were approximately $5.4 billion, the largest natural disaster in Iowa history (City of Cedar Rapids, undated). The losses in the 2008 flood triggered a Presidential disaster declaration under the 1988 Stafford Act.

3. The 2008 flood served as a catalyst for numerous post-flood actions and outcomes.

A smaller Cedar River flood would have had fewer impacts, and likely would not have initiated all the disaster recovery initiatives and actions taken in Cedar Rapids since 2008. Because the flood triggered a Presidential disaster declaration, however, federal emergency supplemental resources became available to Cedar Rapids through FEMA and HUD. These resources were essential for several important post-flood actions and activities, including but not limited to a new levee around the city's WPC facility, and the extensive voluntary buyout program on the east side of the Cedar River. Many of the beneficial post-2008 actions taken in Cedar Rapids could not have been implemented without a Presidential disaster declaration, and the associated (federal) resources that became available.

The 2008 flood provided a shared experience that, although tragic, forged a degree of community cohesion and a shared experience of working toward a single goal to save the city. That experience has been a strong and valuable unifying theme for the city in its post-2008 flood recovery.

4. The approach, agencies, and criteria in post-flood recovery decisions and actions are markedly different than those employed in more proactive, traditional water resources project planning.

Criteria for determining whether a community is eligible for federal emergency supplemental resources after a flood, and the appropriate amounts of those resources, are different than, for example, benefit-cost analyses employed in traditional federal water project evaluation. Post-flood, taxpayer monies awarded through FEMA and HUD for disaster recovery and reducing future risk are not subjected to the same criteria as for traditional federal water projects (e.g., levees and dams). Those emergency resources are not subject to the federal Water Resources Development Act authorization process for water projects.

This is not a complaint or criticism. Rather, it is an observation regarding differences in analytical considerations and criteria regarding federal expenditures for flood risk management initiatives, projects, and recovery.

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5. Post-2008 changes in Cedar Rapids reflect a national-level paradigm shift in flood risk management.

It is increasingly difficult to obtain federal appropriations for traditional flood risk management projects. At the same time, federal resources often can be obtained via emergency supplemental relief in the event of a major (flood) disaster. These resources can be devoted to a wide range of innovative disaster recovery actions, such as acquisition and buyout of severe repetitive loss (SRL) properties. The relative merits of expenditures of resources in a post-flood recovery context (reactive), compared to more deliberate "pre-flood" evaluation processes (proactive), is an issue of considerable national-level importance and merits further discussion and examination.

6. Despite damages and devastation that often attend extreme flood events, the post-flood recovery process may offer opportunities for communities to fundamentally change land uses in, and their relationship with, floodplain areas. These opportunities may include increasing resilience in the broadest sense, including economic development and revitalization.

Although not possible to foresee at the time, the June 2008 Cedar River flood opened a window of economic and community redevelopment and revitalization for Cedar Rapids. Cedar Rapids, especially its downtown area in the 500-year floodplain area, clearly is a very different community today than it was before June 2008. Extreme floods like the 2008 event thus often represent a paradox: causing tremendous damages and suffering, but providing unique opportunities to initiate fundamental changes in land use, and changes in economic development and urban settlement.

7. Cedar Rapids' post-flood actions have initiated numerous long-term processes at multiple scales, which will be ongoing for the foreseeable future.

The city and its citizens have experienced and understand the potential destructive power of the Cedar River, and the need to respect the floodplain. Part of the city's approach to wise uses of the floodplain has been a "multiple lines of defense" strategy that includes numerous, complementary actions implemented at different scales. These actions include property-level zoning considerations, protocols and lines of responsibility for city employees and contractors during rising flood waters, and flood risk outreach efforts within the community.

8. Cedar Rapids' resilience to flood disasters has increased.

Part of Cedar Rapids' increased flood resilience results from multiple, coordinated actions by numerous actors, with shared responsibilities, at a variety of scales. The city's resilience has increased by a combination of tangible, on-the-ground measures, well-coordinated administrative oversight, and logistical protocols developed and enacted since 2008.

9. Comprehensive flood risk management entails integrated water management, and watershed-scale approaches and considerations.

Many respondents noted the relevance and importance of water quality in the context of Cedar Rapids flood risk management. Initiatives such as the Middle Cedar River Partnership illustrate connections between upstream land cover and land use, and downstream hydrology. These basin-wide connections will continue to be an important part of the dialogue and process in comprehensive flood risk management for Cedar Rapids.

10. The 2016 flood—although not of 2008 proportions—illustrated the city's increased resilience, and its improved flood preparedness and response capacities.

The city may be advised to continue to use future floods as means to assess the city's flood response capabilities, as well as opportunities to learn about remaining vulnerabilities and risks and ways in which they might be reduced.

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Interagency Efforts By Lisa Bourget, IWR

Sometimes we can accomplish more together than separately.

That's the underlying premise behind a deliberate focus on interagency flood risk management efforts within the Corps of Engineers. The concept is to make funds available to Corps staff for work that it undertakes in collaboration with other flood risk management partners. Each partner brings its own particular expertise and authorities to the effort, stretching both available resources and the sphere of possible flood risk management solutions.

The concept was initially tested through 18 "pilot" studies in FY2011-FY2012 that built on the coordination successes of state-led Silver Jackets teams. Funds were later made available from the Corps' Levee Safety Program for interagency risk communication efforts associated with levee systems. In FY2016, the Corps' Flood Plain Management Services Program (FPMS) budget was increased to achieve the Administration objective of using Corps expertise to assist with the development of nonstructural approaches. A portion of the FPMS budget is now apportioned to interagency work, with submissions for FY19 funding consideration due May 22.

Interagency efforts are distinguished by the Corps working collaboratively with at least two additional governmental partners where each partner makes a substantive contribution to the effort, often via work-in-kind. Partners can include tribal, federal, state, regional, or local governments; universities, businesses, or task forces; or others that can help advance solutions to flood risk management challenges. Silver Jackets teams, which facilitate collaborative solutions to state flood risk priorities, offer an established forum for interagency coordination, and most interagency efforts are undertaken by Silver Jackets teams. Formal cost-sharing agreements are not required. On average, each dollar invested by USACE leverages another dollar in partner contributions.

The nature and type of interagency efforts vary, limited only by guidance for the program from which the funds originate (most typically FPMS.) More than 350 interagency efforts initiated since 2011 address both riverine and coastal flooding issues. Examples include technical and planning assistance associated with sea-level rise, development of a flash flood warning system plan, performing nonstructural assessments, assisting development of a flood plain management plans for a tribal entity, undertaking a post-wildfire flood risk assessment, developing flood inundation maps, and assisting in public outreach and risk communication. Two articles in this newsletter provide additional detail on a specific interagency effort: Incorporation of Green Infrastructure into Hazard Mitigation Planning, and Scottsbluff Nonstructural Mitigation Identification.

The ultimate goal of these interagency efforts is to further flood risk reduction. Outcomes achieved are documented using weighted indicators on a flood risk management continuum that progresses from "raising awareness" to "prompting action" to "reduces/ manages flood risk." Ancillary outcomes that achieve non-monetary social benefits or improve environmental function are also captured.

Incorporation of Green Infrastructure into Hazard Mitigation Planning By Megan Thompson, LRH

Green Infrastructure is the development of natural areas that can ease flooding, provide habitat, and provide cleaner air and water. Hazard Mitigation is any sustained action taken to reduce or eliminate the long-term risk to life and property from hazard events, such as flooding. It is an on-going process that occurs before, during, and after disasters and serves to break the cycle of damage and repair in hazardous areas. The combination of both Green Infrastructure and Hazard Mitigation was the topic of a recent case study in Huntington, West Virginia.

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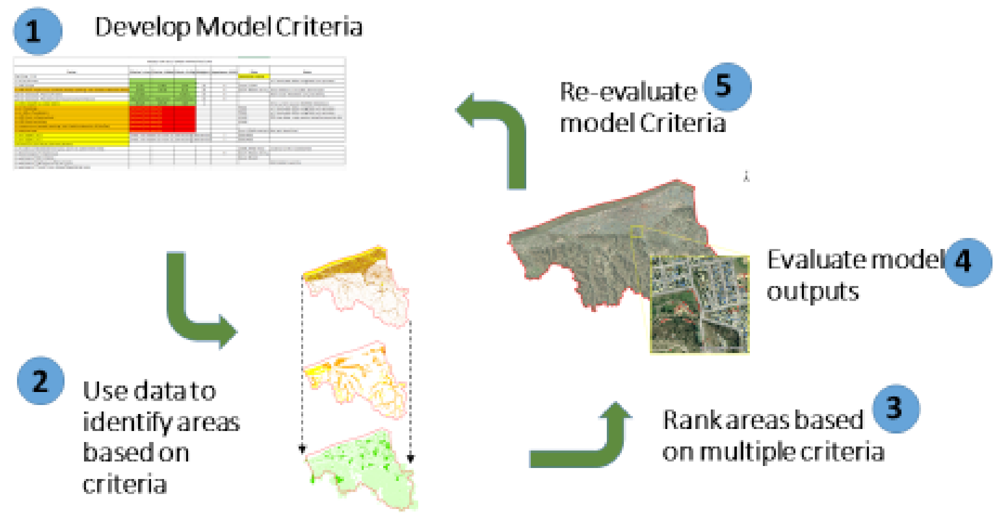
Huntington is a city with a population of just over 49,000 people located at the confluence of the Guyandotte River and the Ohio River. West Virginia has experienced significant flooding in recent history, including five separate Major Disaster Declarations in 2015 relating to flooding, and the City of Huntington has a long history of flooding issues that impact property and movement around the City after a storm.

A collaborative team looked at how and where to include Green Infrastructure as a means of mitigating flood impact. After application to the Environmental Protection Agency, Huntington was selected as one of two locations nationally for further work and was provided with grant funding. The team expanded and took on complementary development of a Geographic Information System (GIS), building on expertise available from the U.S. Army Corps of Engineers and coordinating through the West Virginia Silver Jackets team. Ultimately, team members included the Environmental Protection Agency (EPA) Region 3, Federal Emergency Management Agency (FEMA) Region III Risk Analysis Branch, the West Virginia Region II Planning and Development Council (WV REGION 2 PDC), the City of Huntington, the United States Army Corps of Engineers (USACE) Huntington District, West Virginia's Division of Homeland Security and Emergency Management, the West Virginia University GIS Technical Center, Marshall University, the six Counties in WV REGION 2 PDC, and a variety of other local stakeholders.



Graphic illustrating the steps taken for the GIS Site Suitability Model (Provided courtesy of Ken Hendrickson, USEPA)

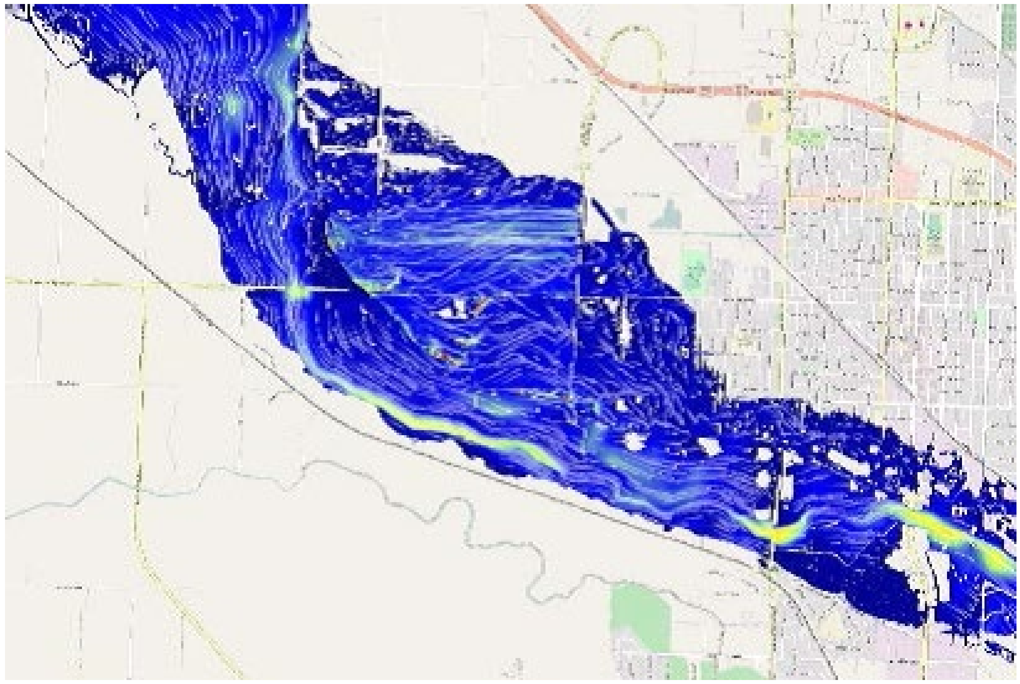
Steps for the two complementary efforts included:

- Identifying what programs needed to be integrated into the planning process.
- Developing an agreed-upon planning process for incorporating Green Infrastructure/Low Impact Development (GI/LID) in hazard mitigation plans.
- Developing recommendations for a methodology to identify GI/LID sites and practices that provide flood hazard mitigation and improved water quality.
- Providing case study examples of GI/LID practices that provide flood hazard mitigation and improved water quality.
- Creating and developing an innovative GIS model/tool for identification and prioritization of GI and LID sites. The GIS-based tool assists the City in identifying areas where green infrastructure practices may reduce storm water runoff and provide flood mitigation. This model/tool is for use at the state level, with possible eventual use at the national level.

The team held workshops with local government officials and presented results at public meetings with both government officials and residents of the City. The team drafted a final report entitled "Incorporating Green Infrastructure into Hazard Mitigation Planning in West Virginia". The GIS model/tool is currently being tested. Results will assist the City of Huntington in determining target areas for nonstructural, nature-based approaches to manage flood risk in vulnerable neighborhoods. The City plans to use the GI Plan and the GIS tool in considering future development. In addition, WVPDC Region II plans to incorporate results into local and regional Hazard Mitigation Plans. It is our hope that other communities will use the examples as they update their Hazard Mitigation Plans, leading to more systematic consideration of GI in conjunction with flood mitigation.

Scottsbluff Nonstructural Mitigation Identification

By Jamie Prochno, NWO



2D model output in the Vicinity of Scottsbluff

The City of Scottsbluff, located along the North Platte River in the Nebraska Panhandle, is a growing community, a center of tourism, and a regional economic hub. An interagency effort undertaken by the Nebraska Silver Jackets team has given the city improved information for managing its flood risks, including detailed topographic information provided by the Nebraska Department of Natural Resources (NDNR), a new streamgage installed by the U.S. Geological Survey (USGS), and detailed hydrologic and hydraulic analyses undertaken by the U.S. Army Corps of Engineers. This information will be used by the City of Scottsbluff and other communities along the North Platte River to make land use decisions.

> "The City will be able to use the depth and water surface elevation information produced from this effort to ensure that new development is less subject to flood risk."

Flood risk information for the City of Scottsbluff and the North Platte River from Lake McConaughy to the Wyoming/Nebraska state line was updated as part of this interagency effort. The flood risk data shown on the Flood Insurance Rate Map for the City of Scottsbluff dated from 1979, and available data and modeling methodologies have since improved significantly. This effort updated both the hydrologic and hydraulic data. Hydrologic data was leveraged from models developed for previous efforts by Silver Jackets teams in both Nebraska and Wyoming. The models were updated to incorporate additional recurrence intervals and the 1-percent plus discharge. Hydraulic models used LiDAR data provided by the Nebraska Department of Natural Resources (NDNR). Flood risk data on Winters Creek, a tributary of the North Platte River near Scottsbluff, was updated using a two-dimensional model in order to determine how shallow flooding dispersed through an agricultural area.

The City will be able to use the depth and water surface elevation information produced from this effort to ensure that new development is less subject to flood risk. The community can also base future flood risk mitigation activities on the data produced from this effort, including identifying how high structures should be elevated, areas of high velocity and depth that may be appropriate for structure acquisition, and structures that can be safely dry floodproofed.

The USGS partnered with the City of Scottsbluff to install a streamgage in the community (USGS 06680500) in 2015. Funding for the streamgage is shared with the City. Current river streamgages upstream and downstream of the community, managed by USGS and NDNR, are heavily impacted by irrigation diversions. Locating a gage in the City of Scottsbluff provides data pertinent to the population which can be presented with inundation mapping resulting from the hydraulics assessment. The results of the floodplain modeling have been shared with the NDNR, the USGS, and City of Scottsbluff for use in inundation mapping and land use decision-making.

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.

22-25 April 2018 – **American Water Resources Association Spring Specialty Conference: GIS and Water Resources X** – Orlando, FL - http://awra.org/meetings/Orlando2018/index.html

14-18 May 2018 – **Public Law 84-99 Basic PROSPECT Course** – Kansas City, MO

10-13 June 2018 – **National Flood Conference** – Washington, DC - http://pcievents.cvent.com/events/national-flood-conference/event-summary-35338c3b5cbe445ca576904e68a8350b.aspx

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 2018 – **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!

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

US Army Corps of Engineers