US Army Corps of Engineers®
Engineer Research and Development Center

Quantification of Integrated Watershed System Resilience: A Tiered Method

Description

Many organizations are working towards managing challenges created by the dynamics between long-term environmental change and the natural and built system. One approach is to design and manage for resilient system performance; i.e., to prepare for episodic disturbances, resist losses, recover quickly in the case of loss, and evolve to adapt in the face of long-term environmental forcing and system constraints. The concept of resilience has broad appeal, but the meaning in application is often ambiguous; thus, there are many different approaches and varying applications of the concept. The US Army Corps of Engineer's (USACE's) Engineer Research and Development Center (ERDC) has been conducting research, studies in support of District and agency partners, and demonstration studies to refine and advance a three-tiered approach to quantify coastal resilience. The three tiers are intended to provide USACE decision makers guidance and resilient alternatives for USACE planning, feasibility studies, O&M, and engineering design.

Figure 1: Integrated watershed systems like Mobile Bay rely on Community, Ecological, and Engineered Water Resources infrastructure.

Issue Addressed

The USACE's civil works water-related missions have expanded greatly in the past century to include a broad breadth of responsibilities within an environment that includes aging infrastructure and expanding populations, along with increasing environmental concerns. In 2010, over 50% of the US population lived in coastal areas; if the coastal regions were combined as a nation they would rank 3rd in global GDP ranking, behind the U.S. and China (Rosati et al. 2015; Hoskins and Keylon 2015). Preparing for episodic disturbances and long-term climate change with these challenging conditions will be necessary for future generations of engineers, planners, and decision makers. ERDC has developed a 3-tiered method to quantify resilience based upon the concepts of the resilience cycle (prepare, resist, recover, and adapt) that can be applied to various levels of decision making depending on need, time, and available funding.

Products

The Tier 1 pilot was tested in Jamaica Bay, NY, and Mobile Bay, AL, and is intended to be applicable for SMART planning-level studies. It is a systems-based approach that utilizes community expert knowledge to identify critical functions and vulnerabilities in the system (Fox-Lent et al. 2015). Tier 2 was developed as a community self-assessment tool as part of the North Atlantic Coast Comprehensive Study (NACCS; Bridges et al. 2015), and subsequently tested in a pilot conducted for Mobile Bay. Tier 2 uses data, models, and community valuation to identify site-specific critical needs and create a systems-scale resilience assessment that could apply to feasibility studies. Outcomes from the Tier 2 analysis are intended to provide information with which to evaluate, rank, and tentatively select a project plan (Rosati et al. 2015). Tier 3 has been tested at Norfolk Naval Base, VA (Burks-Copes et al. 2014) and Jamaica Bay. It develops an interconnected representation of a system through use of a Bayesian network, and utilizes numerical modeling results, historical knowledge, expert valuation and probabilistic analyses (Schultz et al. 2012). Tier 3 is data intensive and is appropriate for feasibility studies, operations, and engineering design.

Products (continued)

Future activities will conduct a wide range of research and demonstration studies to further test and refine tools, develop guidance, collaborate with partner federal and non-federal organizations, and transfer technology. Outreach, feedback, and partnerships from outside agencies and non-governmental organizations will be necessary to ensure that USACE does not duplicate but instead builds upon and contributes to previous and ongoing resilience work. Anticipated products include :

1. A database of coastal and inland infrastructure [built (USACE and community); natural; hybrid], resilient performance (damage, recovery, and adaptation relationships) for historical and future forcing.

2. A digital library of fragility, damage, and recovery functions.

3. Integrated Coastal Resilience Performance Indices for systems.

4. Documentation of both validation of guidance through a series of partnered demonstration studies, documentation including validation of and guidance for application of methods and assessment of likely future performance for demo sites.

5. Guidance for adaptation measures for coastal systems, including

   A. Validated, peer-reviewed systems approach for estimating coastal and inland resilience in application to Navigation, Flood Risk Management, and Environmental missions; and

   B. Updated engineering guidance for resilient coastal infrastructure design, monitoring, operations and maintenance.

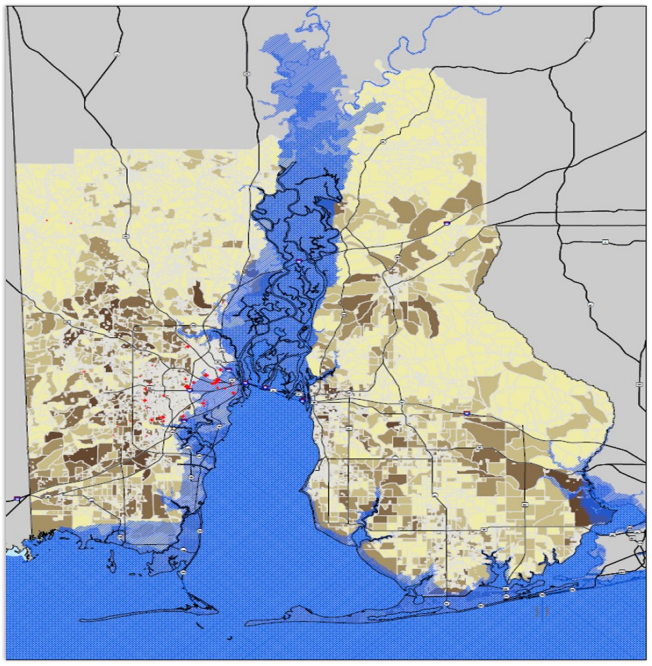

Figure 2. Mobile Bay, AL, was chosen as a pilot study site or Tiers 1 and 2. Jamaica Bay, NY, also was evaluated using Tiers 1 and 3 following Superstorm Sandy.

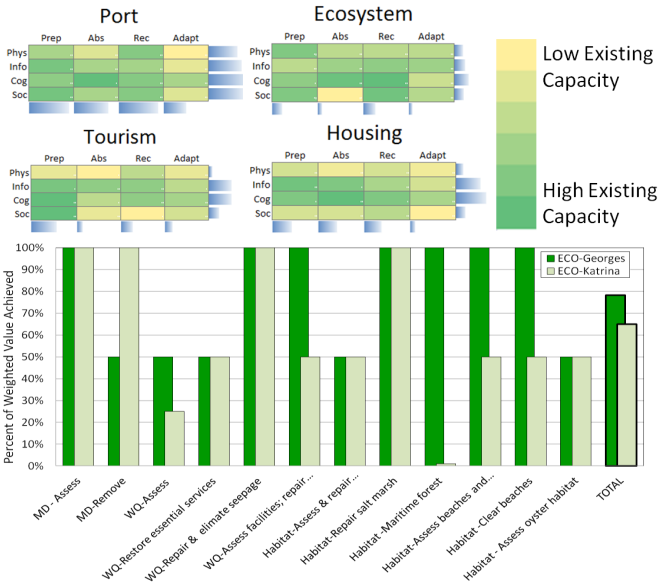

Figure 3. Example results from evaluation of resilience within Mobile Bay using Tier 1 (top) and Tier 2 (bottom). Tier 1 shows results from the 4 stages of resilience between the physical, informational, cognitive, and social domains. Tier 2 is displaying results from the evaluation of the Ecological Infrastructure system within Mobile Bay to a historical and hypothetical future storm.

Projected Benefits

Applied research and development on quantifying resilience will provide a validated, peer-reviewed approach to assessing USACE water resource infrastructure resilience within a systems approach. Results will provide a baseline assessment of resilience and guidance for planning, engineering design, monitoring, operations and maintenance within a constantly changing environment for a broad variety of hazards.

Points of Contact

Julie Dean Rosati, Research Engineer,
Julie.D.Rosati@usace.army.mil

Igor Linkov, Research Scientist,
Igor.Linkov@usace.army.mil

Katherine Touzinsky, Research Contractor,
Katherine.F.Touzinsky@usace.army.mil

Jeff Lillycrop, Technical Director,
Jeff.Lillycrop@usace.army.mil

Cate Fox-Lent, Research Engineer,
Catherine.Fox-Lent@usace.army.mil,

Additional References and Resources

Bridges, T., et al. 2015. Use of Natural and Nature-Based Features for Coastal Resilience. ERDC-SR-15-1, US Army Corps of Engineers Engineer Research and Development Center, pp. 480.

Burks-Copes, K., et al. 2014. Risk Quantification for Sustaining Coastal Military Installation Asset and Mission Capabilities. Submitted to: The Strategic Environmental Research and Development Program (SERDP), Report RC-1701, pp. 364.

ERDC Climate Change website, https://climatechange.erdc.dren.mil/projects.html#

Hoskins, K. D., and R. A. Keylon. 2015. Impact Assessment: Federal Coastal Habitat Investments Support People, Fish, and Wildlife. Restore America's Estuaries, Washington D.C. pp. 1-64.

Fox-Lent, C., M. Bates, I. Linkov. 2015. A Matrix Approach to Community Resilience Assessment: An Illustrative Case at Rockaway Peninsula. Environment Systems and Decisions. Vol. 35 pp. 209-218.

Rosati, J.D., K.F. Touzinsky, W.J. Lillycrop. 2015. Quantifying Coastal System Resilience for the USACE. Environment Systems and Decisions, 35:196-208.

Schultz, M.T., S.K. McKay, L.Z. Hales. 2012. The Quantification and Evolution of Resilience in Integrated Coastal Systems. ERDC TR-12-7, US Army Corps of Engineers Engineer Research and Development Center.