Implementation of ASCE 7-22, 500-Year Flood Standard Revisions in Rhode Island
January 2024

Important note: Although in the "Scope of the Work" and "Schedule Sections" of FEMA GO, the details of the project have been explained, this document provides some additional scientific and technical information. This document, which is attached to Project Scope of Work, helps better understand the need of the project and scientific methods that will be implemented.

PROJECT TEAM

PI: Dr. Chris Baxter, Professor, Ocean/Civil/Environmental Engineering, University of Rhode Island (fragility and risk assessment of buildings and civil infrastructure).
Co-PI: Dr. Annette Grilli, Research Professor, Ocean Engineering, University of Rhode Island (development of base flood elevation maps including sea level rise).
Senior Adviser: Dr. Malcolm Spaulding, Emeritus Professor, Ocean Engineering, University of Rhode Island (led STORMTOOLS initiative).
GIS Specialist: Chris Damon, Environmental Data Center, University of Rhode Island, (expert GIS and flood mapping systems).

BACKGROUND

Notice of Funding Opportunity: This project proposal concerns the Department of Homeland Security (DHS) Notice of Funding Opportunity (NOFO) in Fiscal Year 2023 for Building Resilient Infrastructure and Communities (BRIC). The NOFO is in "***recognition of the growing hazards associated with climate change, and of the need for natural hazard risk mitigation activities that promote climate adaptation and resilience with respect to those hazards***"[1] including extreme weather and chronic stressors. According to NOFO, FEMA supports three categories of activities including (1) Capacity and Capacity Building, (2) Hazard Mitigation Projects, and (3) Management Costs. Also, BRIC supports partnership activities as it indicates that "***community resilience cannot be achieved without leveraging a broad network of partners to include all levels of government, the private sector, non-profits, and educational institutions, among others".***

The scope of this project is within Capability- and Capacity-Building (C&CB) Category with a subcategory of "**Project Scoping Activities**". According to the BRIC Funding Opportunity Guideline, "**Project scoping activities are designed to develop mitigation strategies and obtain data to prioritize, select, and develop, in a timely manner, complete applications that result in either an improvement in the capability to identify appropriate mitigation projects or in the development of an application-ready mitigation project for BRIC or another funding opportunity**." Further, BRIC recognizes "the growing hazards associated with climate change, and the need for natural hazard risk mitigation activities that promote climate adaptation and resilience". One of the goals of the BRIC program is strengthening preparedness/resilience by supporting awareness initiatives that encourage public action.

[1] https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

The University of RI(URI), in partnership with state and federal agencies, has a strong track record in capacity building to help communities and municipalities understand, predict, prepare, and plan for flood risk in coastal and inland waters and has led the development and implementation of STORMTOOLS. This project focusses on developing base flood elevation (BFE) maps for the coastal areas of the state that explicitly address sea level rise (SLR) and the change in ASCE/SEI 7-22 design standards for residential structures from 100 to 500 yr flooding.

The American Society of Civil Engineers (ASCE) introduced new guidance on the design of structures from flooding, in a recently revised Supplement 2 to the ASCE/SEI 7-22 minimum design standards (2023) [1,2]. The prior design standard was 100 yr return period (or Mean Recurrence Interval, MRI) flooding for residential structures (Risk Class II), while the new standard increases the guidance to 500 yr. return period. (For Risk Class I structures the guidance remains at 100 yr., while for Classes III and IV it increases to 750 and 1000 yr., respectively). (ASCE Structure Risk Classification: I – warehouses; II – residential structures; III – high occupancy structures; and IV – critical infrastructure (hospitals, power plants, etc.)). If the MRI (500 yr) is available for the area, ASCE recommends using that value. If not, they recommend adjusting the 100 yr MRI for the desired MRI and the structure risk category. They also recommend adjusting the 500 yr. values to include provisions for sea level rise (SLR). The ASCE design standards are currently embedded in the RI state building code (specifically, Chapter 5- Flood Loads) and by extension to all building standards in the municipalities of the state.

While the FEMA Flood Insurance Rate Maps (FIRM) for the state show the 500 yr flood levels, they unfortunately do not include either the wave effects or adjustments for sea level rise. The FEMA 500 yr values also show a lack of consistency in Narragansett Bay. As an example, the FEMA 100 yr flooding maps show an approximate linear increase in surge levels from the mouth to the head of bay, from 10.3 to 13 ft or an amplification of 1.26. This is consistent with observations of storm impacts in the bay at the Newport and Providence, RI water level gauges. The 500 yr values show the opposite, a decrease from 19.82 to 18.81 ft or a de-amplification of 0.95. Intermediate locations in the bay show values that are lower than either at the head or the mouth of the bay. The scaling between the FEMA 500 yr. and 100 yr. values varies from 1.5 to 1.89. The ASCE guidance suggests an amplification of 1.0 for Class I structures (100 yr), 1.25 for residential structures (Class II) (500 yr.), 1.35 for Class III (750 yr.), and 1.4 for Class IV (1000 yr), all significantly smaller than the FEMA scaling values (1.5 to 1.89). The FEMA values are also inconsistent with a recent in-depth study on scaling of surge heights for the bay from extratropical storms [3].

STORMTOOLS design elevation maps (SDE) have been developed for coastal areas of the state and are based on 100 yr return period and explicitly include SLR [4]. The SDE maps use the same underlying surge data from the US Army Corp of Engineers, North Atlantic Coastal Comprehensive Study (NACCS) as the ASCE 7-22 scaling method [1,2]. The SDE maps are currently embedded in the RI Coastal Resources Management Council (RI CRMC), Coastal Hazard app [5] and routinely used in support of permitting of structures in the coastal zone of the state. The maps are publicly available via the STORMTOOLS Arc GIS hub [6]. Maps for 500 yr flooding levels are not, however, available. STORMTOOLS SDE maps are currently being extended to inland waters of the state to address the impact of climate change, due to enhanced precipitation, on flooding via a FEMA BRIC 2022 project [7]. This will result in a seamless SDE

maps for both inland and coastal waters considering the impacts of climate change (sea level rise and enhanced precipitation). This effort will explicitly consider the change in ASCE design standards from 100 to 500 yr.

OBJECTIVE

The objective of the present study is to develop SDE maps for the coastal areas of the state, including the impact of SLR (0 to 7ft) for 500 yr return periods that are consistent with the current 100 yr SDE maps and the ASCE 7-22 guidance and can serve as the basis for design of residential structures in the state.

TASKS

Simplified scaling method

As a first step in the process, there is a senior capstone design class (2023-2024) at University of RI, Ocean and Civil Engineering looking at how we might be able to scale the 100 yr STORMTOOLS maps to obtain 500 yr maps with SLR [8]. The method follows the ASCE guidance, scaling the 100 yr surge levels by 1.25 to determine the 500 yr surge levels. Scaling of the waves is based on the ratio of the wave crest height to the local water inundation depth at the location of interest, for varying SLR values from 0 to 10 ft. In their initial work they selected 10 locations along the southern RI coastline and from the mouth to the head of Narragansett Bay, all in the coastal flood zone (Figure 1, left side). Their initial work suggests that this is potentially possible, with 100 yr, 3 ft SLR being equivalent to 500 yr no SLR (Figure 1, right side). The correlation coefficient is reasonably high (R = 0.9891, R^2 = 0.9785) and the RMSE relatively low at 0.8240 ft.

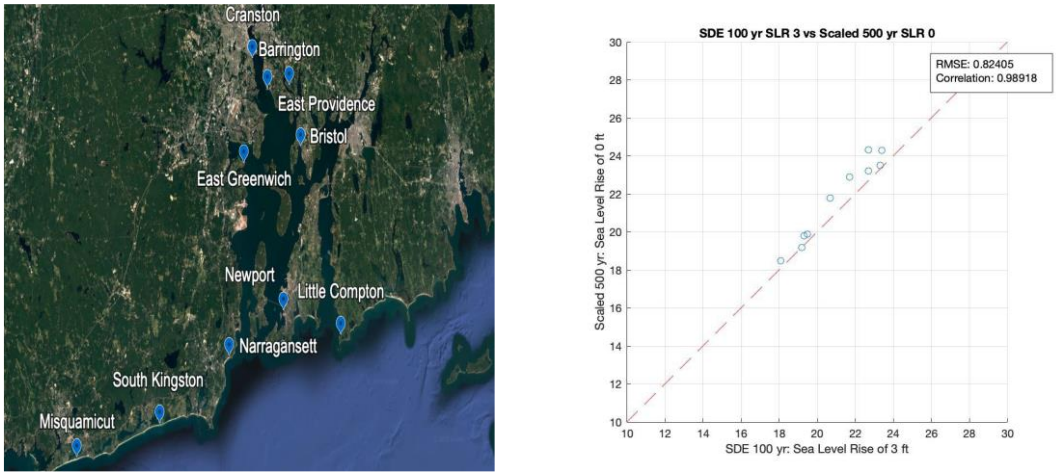


Figure 1 Map of locations of points selected (left) and 500 yr. 0 SLR vs 100 yr. 3 ft SLR regression (right).

An analysis shows that when the 500 yr 2 ft SLR is scaled from the 100 yr 5 ft, it gives an R^2= 0.95, RMSE = 1.28 ft; for the 500 yr SLR 5 ft scaled from the 100 yr 7ft SLR gives R^2 = 0.77, RMSE- 1.85 ft; and 500 yr 7 ft SLR scaled from the 100 yr 10 ft SLR gives R^2= 0.69, RMSE = 2.47 ft. The analysis clearly shows that the performance of the method decreases with increasing SLR value. The students will look at more case examples and improve the scaling methods to account for variations more accurately in wave crest heights. If the performance improvements are sufficient the current SDE maps will be relabeled to provide BFE for 500 yr., with SLR varying from 0 to 7 ft. This will likely serve as an interim step in generating 500 yr. flooding maps.

SDE Maps Based on Application of STWAVE and XBeach to RI Coastal Areas

This task is focused on using the same methodologies used in the original development of the SDE maps documented in Spaulding et al [4] to generate SDE maps for 500 yr with 0, 2, 3, 5 and 7 ft of SLR. Note that in the most recent (2022) NOAA update to SLR projections for RI, the NOAA High value, which is embedded in the RI CRMC permitting standards, is 6.44 ft for 2100, thus the peak value in this effort is 7 ft.

The US Army Corp of Engineers steady state wave model, **STWAVE**, [9] will be applied to Narragansett Bay using the grid area shown in Figure 2 to predict steady state wave conditions in the study area. Forcing at the open boundary for waves and at the surface for winds will be provided from USACE North Atlantic Coastal Comprehensive study (NACCS) [11]. The surge levels will be determined using the ASCE 7-22 scaling method, based on the current SDE 100 yr maps with 0 SLR. The results of the simulation will be estimates of the significant wave heights in the study area. The analysis will be performed for 500 yr., SLR 0, 2, 3, 5, and 7 ft. These results will then be sacled to estimate wave crest heights.

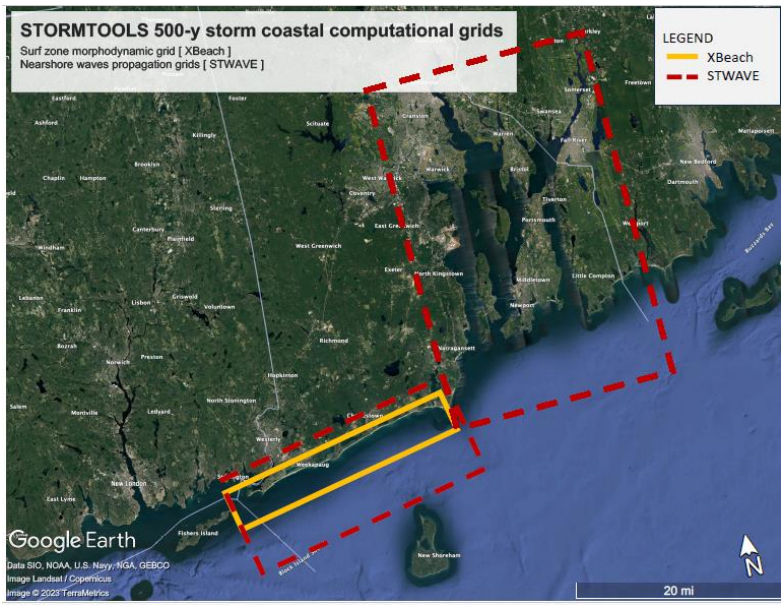


Figure 2 Locations for application of **STWAVE** (red dashed line) and **XBeach** (yellow solid lines)

For the southern coast of RI, the shoreline will erode with changes in surge level and waves [4]. To estimate these changes, **XBeach**, a geomorphological model [10,12], will be applied to

predict the shoreline erosion/accretion for 500 yr surge levels and varying sea levels rise values (see yellow solid lines in Figure 2). Model output will show the change in topography (erosion/accretion) of the coastal zone. **STWAVE** model will then be applied to the modified shoreline topography. Simulations will be repeated for SLR cases from 0 to 7 ft. These results will then be used to estimate wave crest heights.

The results from the bay and southern RI shoreline will be used to generate SDE maps (surge with SLR, plus associated wave crest heights) for 500 yr flooding. These maps will be accessible via the STORMTOOLS Hub [6], SDE 500 yr. flooding maps (Figure 3).



Figure 3 STORMTOOLS SDE maps for 500 yr with SLR.

DELIVERABLES

1. A technical report/paper describing the methodology and results of the study.
2. Access to on-line STORMTOOLS Design Elevation (SDE), 500 yr maps (including both surge and wave crest heights) with sea level rise (SLR) (0, 2, 3, 5, and 7) for all coastal areas of the state via the STORMTOOLS Hub.
3. Training session at the conclusion of the study in access and use of maps in planning and permitting process.

SCHEDULE

The schedule for the individual tasks in the project is provided in Table 1.

Table 1 Project schedule.

Project Schedule	**18 months; Sep 1, 2024 - Apr 1, 2026**					
Year	**2024**	**2025**				**2026**
Quarter	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**
Months from start of project	1	5	7	11	15	18
1. Application of simplified method						
1.1 Prepare paper summarizing methodology						
1.2 Relabel SDE maps links STORMTOOLS Hub						
2. Application of STWAVE to Narragansett Bay						
2.1 Simulation of 500 yr, 0 SLR case						
2.2 Compare 500 yr case to 100 yr case						
2.3 Simulation of 500 yr, 2, 3, 5, and 7 SLR cases						
3. Application of STWAVE to southern RI shoreline						
3.1 Simulation of 500 yr, 0 SLR case						
3.2 Simulation of 500 yr, 2, 3, 5, and 7 SLR cases						
4. Application of XBeach Southern RI coast						
4.1 Simulation of 500 yr, 0 SLR case						
4.2 Simulation of 500 yr, 2, 3, 5, and 7 SLR cases						
5. Assemble SDE maps for all cases, access via STORMTOOLS Hub						
6. Stakeholder engagement and public outreach						
6.1 Kickoff meeting						
6.2 Training in application of SDE maps						
7. Final report and publication						

Period of Performance: 18 months starting from Sep 2024.

References

[1] American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI), (7-22). Minimum Design Loads and Associated Criteria for Buildings and Other Structures. American Society of Civil Engineers. https://www.asce.org/publications-and-news/asce-7.

[2] ASCE/SEI 7-22 Supplement 2 for Minimum Design Loads and Associated Criteria for Buildings and Other Structures. American Society of Civil Engineers. (https://ascelibrary.org/doi/10.1061/9780784415788.sup2).

[3] Kouhi, S., Hashemi, M. R., Spaulding, M., and Hara, T., 2022. Modeling the impact of sea level rise on maximum water elevation during storm surge events: a closer look at coastal embayments. Climatic Change, 171(3), 1-20.

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[5] RI Coastal Resources Management Council (RI CRMC) Coastal Hazard App http://www.crmc.ri.gov/coastalhazardapp.html.

[6] STORMTOOLS ArcGIS Hub (https://stormtools-mainpage-crc-uri.hub.arcgis.com/). SDE maps https://stormtools-design-elevation-sde-maps-crc-uri.hub.arcgis.com/.

[7] Hashemi. R., M. Amini, and M. L. Spaulding, 2022. Seamless Flood Risk Mapping Tool for Coastal and Inland Waters of RI in a Changing Climate; Extension of STORMTOOLS using FEMA maps and hydrological modeling, FEMA BRIC 2022 proposal.

[8] Rynkowski, Chase, Connor Young, Jelani Pool, Max Hirsh, Emily Linardakis, Daisy Delgado, Frederik Hoffmann, Jack Templeton, Sam Pineda, and Justin Panadero, 2023. Application of STORMTOOLS Coastal Environmental Risk Index (CERI) to Infrastructure and Extension to Wind Damage, University of RI, 2023-2024, Senior Capstone Design Course in Ocean, Civil and Environmental Engineering, Narragansett, RI.

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[10] Grilli, A.; Spaulding, M.L.; Oakley, B.A.; Damon, C. Mapping the coastal risk for the next century, including sea level rise and changes in the coastline: Application to Charlestown RI, USA. *Nat. Hazards* **2017**, *88*, 389–414.

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[12] Roelvink, D., Ad Reniers, Ap van Dongeren, Jaap van Thiel de Vries, Robert McCall, and Jamie Lescinski, 2009. Modeling storm impacts on beaches, dunes and barrier islands, Coastal Engineering, Volume 56, Issues 11–12, November–December 2009, p. 1133-1152 https://doi.org/10.1016/j.coastaleng.2009.08.006