Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for San Juan National Historic Site

Summary of Results

NPS 393/189898, August 2023

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Executive Summary

This document presents the results of the **Coastal Hazards & Sea-Level Rise (SLR) Asset Vulnerability Assessment (VA)** completed by Western Carolina University at San Juan National Historic Site (SAJU) in 2021. In this VA, we evaluate the vulnerability (as a combination of exposure and sensitivity) of NPS buildings and transportation assets[1] to identified coastal hazards and climate change factors, approximately to the year 2050 (for full methodology, see Peek et al. 2022).

We assessed 35 buildings/structures (including fortifications, bastions and walls, batteries, guard houses, bunkers, a monument, a lighthouse, a visitor center, administrative buildings, and lift stations) and 14 transportation assets (including roads, parking lots, trails and sidewalks, and a waterfront system) at SAJU. Twelve percent of assets analyzed have high vulnerability to the evaluated coastal hazards and SLR, while over two-thirds (67%) have minimal vulnerability (are not in any of the evaluated hazard zones). Scoring details and results for all assets evaluated at SAJU are reported in the provided Excel sheets.

Exposure Results

Exposure is a measure of the character, magnitude, and rate of changes a target may experience (e.g., from the impacts of climate change or a natural hazard influenced by climate change; NPS 2021). In this VA, we evaluate the exposure of each asset to the following coastal hazard indicators: flooding potential, shoreline change, SLR inundation, extreme event flooding, and reported coastal hazards (Table 1).

Table 1. Exposure indicators and hazard data sources used.

Exposure Indicator (Description)	SAJU Data (Citation)
Flooding potential (1% annual-chance)	Preliminary FEMA VE & A zones (FEMA 2009)
Shoreline change (coastal proximity)	35-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050)	NPS 8.5 RCP SLR model, 0.22 m rise (Caffrey et al. 2018)
Extreme event flooding (category 3 surge & tsunami inundation)	NOAA national storm surge hazard maps (Zachry et al. 2015), PREMA Tsunami Evacuation Zone A (PREMA 2018), NOAA 10 ft SLR (NOAA 2022)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

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[1] The NPS Facility Management Software System (FMSS) database defines assets as "…a physical structure or grouping of structures, land features, or other tangible property that has a specific service or function, such as a farm, cemetery, campground, marina, or sewage treatment plant. The term 'asset' shall also be applied to movable items, such as vehicles and equipment."

Assets with high exposure are within at least four exposure indicator hazard zones. Assets with moderate exposure are within two or three exposure indicator hazard zones. Assets with low exposure are within only one exposure indicator hazard zone. The asset could still be seriously impacted by this hazard. Assets with minimal exposure are not in any exposure indicator hazard zone. This does not mean that the asset has no exposure to coastal hazards, but it is not within the exposure hazard data used in this study.

Less than one-quarter (24%) of assets analyzed at SAJU have either high or moderate exposure to coastal hazards and SLR (Table 2, and Figure 1). One-fifth (20%) of the assets have high exposure, 4% have moderate, and 8% have low. The majority (67%) of assets analyzed have minimal exposure. These results are largely a factor of the higher elevations of most assets above the steep coastline of SAJU. Most high exposure assets at SAJU are near the coast (< 35 meters). Four assets (two buildings and two transportation) at SAJU are within all evaluated exposure zones, including the El Canuelo Fort, Devil's Sentry Box, Paseo Del Morro (Jeep Trail), and El Morro Waterfront System.

Table 2. SAJU exposure results. Sum of percentages may not equal 100 due to rounding.

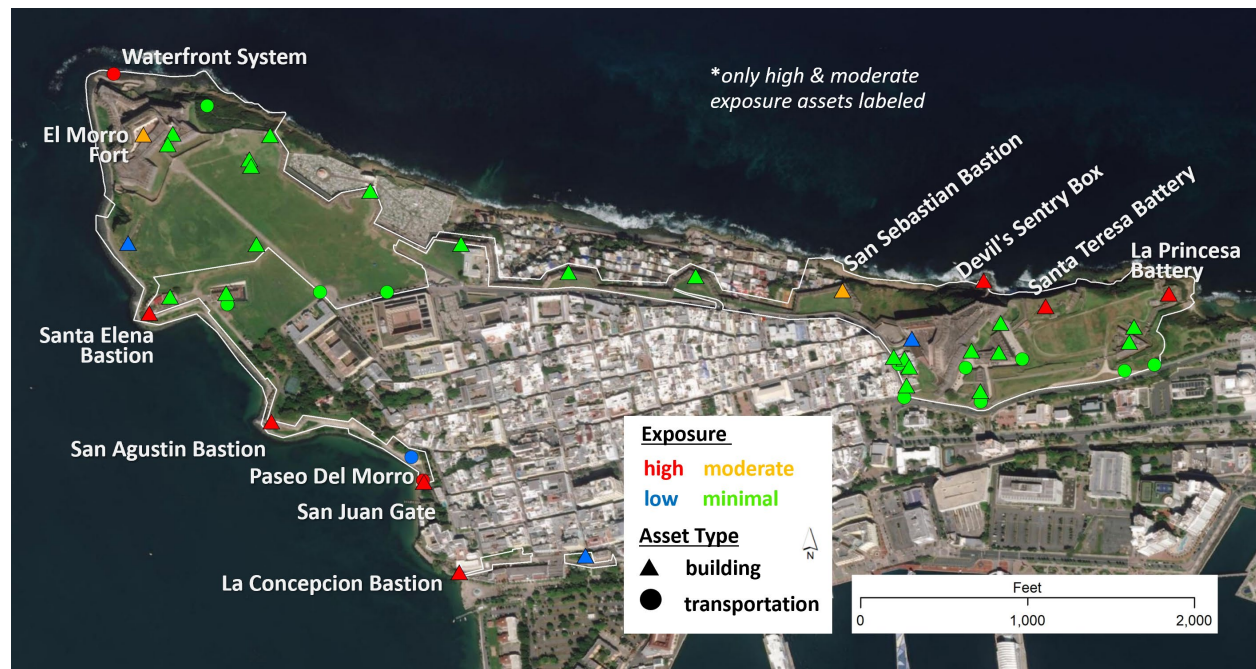| Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
	#	%	#	%	#	%	#	%	#
Buildings	8	23%	2	6%	3	9%	22	63%	35
Transportation	2	14%	0	0%	1	7%	11	79%	14
All Assets	10	20%	2	4%	4	8%	33	67%	49

Figure 1. SAJU exposure results summary. Only high and moderate assets are labeled. Background map is ESRI streaming imagery.

Sensitivity Results

Sensitivity reflects the degree to which a resource is affected by exposure (NPS 2021). In this VA, we assess the following sensitivity indicators: flood damage potential/elevated, storm resistance and condition, historic damage, and protective engineering. In general, assets with high sensitivity have unfavorable determinations for 3 or 4 of these indicators, moderate-sensitivity assets have unfavorable determinations for 2 indicators, and low-sensitivity assets have unfavorable determinations for 0 or 1 indicator. Assets with minimal exposure are not analyzed for sensitivity (this is the case for 33 assets at SAJU).

Eight assets analyzed at SAJU have high or moderate sensitivity to coastal hazards and SLR (Table 3). The two assets with high sensitivity (El Canuelo Fort and La Princesa Battery) are not elevated, have been significantly damaged by coastal flooding in the past, and lack protective engineering. All assets analyzed at SAJU are storm resistant (e.g., fortifications), and most are in relatively good condition and protected by engineering.

Table 3. SAJU sensitivity results. Sum of percentages may not equal 100 due to rounding.

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
	#	%	#	%	#	%	#	#
Buildings	2	15%	6	46%	5	38%	13	22
Transportation	0	0%	0	0%	3	100%	3	11
All Assets	2	13%	6	38%	8	50%	16	33

*Minimal exposure assets were excluded from the sensitivity analysis; total number analyzed is different for sensitivity.

Vulnerability Results

Vulnerability is a measure of the degree to which park resources and assets are "susceptible to harm from direct and indirect effects of climate change, including variability and extremes" (NPS 2021). In this VA, we evaluate the vulnerability of infrastructure assets as a simple combination of exposure and sensitivity ratings. It should be noted that the vulnerability of any asset can change with time (e.g., due to adaptation actions or the result of geomorphic change).

Nearly one-quarter (22%) of assets evaluated at SAJU have high or moderate vulnerability to coastal hazards and SLR, and only a few (10%) have low vulnerability (Table 4, and Figure 2). Over two-thirds (67%) of assets have minimal vulnerability. It is important to emphasize that many assets at SAJU have large areal extents (e.g., fortifications, batteries, wall sections, bastions), but are scored as single assets. For example, the El Morro Fort has a moderate vulnerability, although only one corner of the fort is within the extreme event flooding and erosion zones (the rest of the asset is outside all exposure hazard zones).

Table 4. SAJU vulnerability results. Sum of percentages may not equal 100 due to rounding.

Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
	#	%	#	%	#	%	#	%	#
Buildings	6	17%	3	9%	4	11%	22	63%	35
Transportation	0	0%	2	14%	1	7%	11	79%	14
All Assets	6	12%	5	10%	5	10%	33	67%	49

Six assets at SAJU have high vulnerability and a high asset priority index (API ≥ 70, as reported in FMSS). This includes the El Canuelo Fort, Devil's Sentry Box, La Princesa Battery, Santa Teresa Battery, Santa Elena Bastion, and San Agustin Bastion. Two assets (El Canuelo Fort and La Princesa Battery) have both high exposure and high sensitivity.

Figure 2. SAJU vulnerability results summary. Only high and moderate assets are labeled. Background is ESRI streaming imagery.

SAJU Unique Considerations

Non-FMSS assets: At the request of park staff, we evaluated the exposure of four landscape-scale assets not listed in FMSS (our protocol does not evaluate the sensitivity of landscapes). These assets include the Cementerio Santa María Magdalena de Pazzi, Lomento de los Vientos, Sector San Miguel of La Perla, and the La Perla Community (Figure 3). The Sector San Miguel of La Perla and

La Perla Community have high exposure, the Cementerio Santa María Magdalena de Pazzi has moderate exposure, and the Lomento de los Vientos has low exposure to the evaluated hazards. Scores for these assets are included in the exposure section of the results spreadsheet.

Figure 3. Exposure results for non-FMSS assets at SAJU. Background is ESRI streaming imagery.

Shoreline change: United States Geological Survey or other shoreline erosion rate data are not available for the coastlines within SAJU. As a result, we used a simple coastal proximity buffer of 35 meters, which accommodates an erosion rate up to 1m/year and assumes that infrastructure near the coast is likely to experience multiple coastal hazards within the 35-year (2050) timeframe of this analysis (Peek et al. 2022).

SLR data: We used the 2050 8.5 Representative Concentration Pathway (RCP) SLR projection (0.22 m rise) and inundation model (Caffrey et al. 2018) developed specifically for NPS units to score exposure for this indicator. However, we also provided alternate scores using the 2100 4.5 RCP SLR projection (0.49 m rise) for comparison (see Peek et al. 2022).

Extreme event flooding data: In most cases, we use storm surge models produced by NPS (Caffrey et al. 2018) within this protocol; however, these data are not available for SAJU. To evaluate exposure to extreme event flooding (including tsunami and storm surge), we used the Puerto Rico Emergency Management Agency (PREMA) Tsunami Evacuation Zone A (PREMA 2018), National Oceanic and Atmospheric Administration (NOAA) SLOSH Category 3 high tide inundation model (National Storm Surge Hazard Maps - Version 2; Zachry et al. 2015), and NOAA SLR 10 ft inundation zone (NOAA 2022).

Linear assets: NPS-owned roads and trails at SAJU were not segmented, as they are relatively short features (< 0.75 miles in length). Therefore, each road or trail has only one score for exposure,

sensitivity, and vulnerability. Any statistics or estimates of value represent the entire road, even if only a small portion has high exposure or vulnerability.

References

Caffrey, M., R.L. Beavers, and C. Hawkins Hoffman. 2018. Sea level rise and storm surge projections for the National Park Service. Natural Resource Report. NPS/NRSS/NRR—2018/1648. National Park Service. Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2253283.

Federal Emergency Management Agency (FEMA). 2009. National Flood Hazard Layer. https://www.fema.gov/flood-maps/national-flood-hazard-layer. Accessed September 2021.

National Park Service (NPS). 2021. Coming to terms with climate change: Working definitions. National Park Service Climate Change Response Program, Fort Collins, Colorado.

Puerto Rico Emergency Management Agency (PREMA). 2018. Tsunami Evacuation Zone of Puerto Rico. Hurricane Evacuation Study (HES) Vulnerability Analysis funded by the National Hurricane Program. https://services.arcgis.com/XG15cJAlne2vxtgt/arcgis/rest/services/PR_EvacuationZones_20180615/FeatureServer. Accessed September 2021.

National Oceanic and Atmospheric Administration (NOAA). 2022. Sea Level Rise Viewer. Available at: https://coast.noaa.gov/slr/#/layer/slr. Accessed September 2021.

Peek, K.M., B.R. Tormey, H.L. Thompson, and R.S. Young. 2022. Coastal hazards & sea-level rise asset vulnerability assessment protocol: Updated project description & methodology. Natural Resource Report. NPS/NRSS/CCRP/NRR—2022/2427. National Park Service. Fort Collins, Colorado. Available at: https://doi.org/10.36967/2293653.

Zachry, B.C., W.J. Booth, J.R. Rhome, and T.M. Sharon. 2015. A National View of Storm Surge Risk and Inundation. Weather, Climate, and Society, 7(2), 109–117. DOI: Available at: https://doi.org/10.1175/WCAS-D-14-00049.1.

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U.S. Department of the Interior