Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Fort Monroe National Monument

Summary of Results

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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 Fort Monroe National Monument (FOMR) in 2022. 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 14 buildings/structures (including quarters, restrooms, batteries, a seawall, and a pumphouse) and 14 transportation assets (roads/road segments and parking) at FOMR. The majority (61%) of assets analyzed have moderate vulnerability to the evaluated coastal hazards; all other assets (39%) have high vulnerability. No assets have low or minimal vulnerability. Scoring details and results for all assets evaluated at FOMR 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)	FOMR Data (Citation)
Flooding potential (1% annual-chance)	Effective FEMA VE & A zones (FEMA 2016)
Shoreline change (coastal proximity)	30-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050 proxy) *	NPS 2100 4.5 RCP SLR model, 0.64 m rise (Caffrey et al. 2018)
Extreme event flooding (category 3 surge)	NPS storm surge inundation model (Caffrey et al. 2018)
Reported coastal hazards (historic flooding)	Questionnaire results & discussions (Peek et al. 2022)

 *See Unique Considerations

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

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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."

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.

All assets analyzed at FOMR have high (34%) or moderate (66%) exposure to the evaluated coastal hazards (Table 2, and Figure 1-2). These results are a factor of the park's high exposure to coastal flooding, as indicated by the widespread Federal Emergency Management Agency (FEMA) AE zone (1% annual chance flood) and the modeled category 3 storm surge inundation extent across the park. In addition, all assets have been flooded by past coastal storms (primarily Hurricane Isabel). Four assets are within all evaluated exposure zones, including the Waterfront Protection – Rip Rap & Seawall, Fuller Lane, Fuller Lane Dump Station Parking, and Walker Airfield Runway Road. No assets have low or minimal exposure.

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

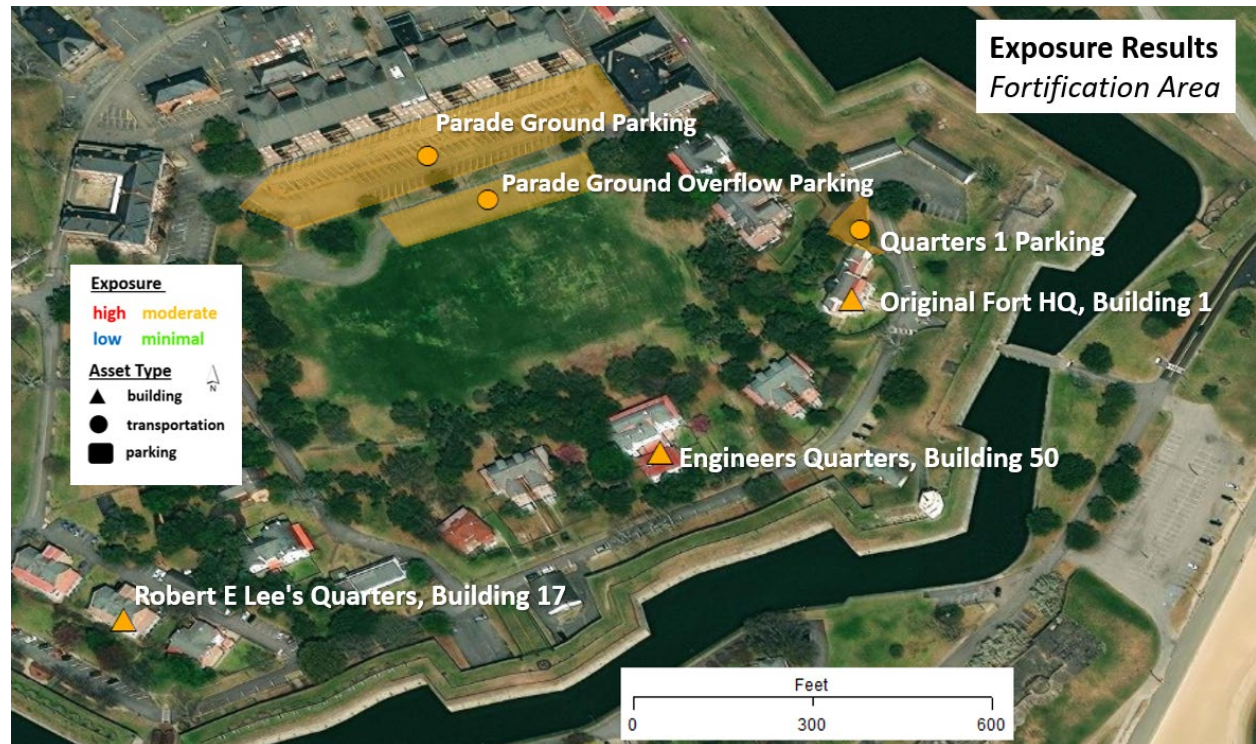| Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
	#	%	#	%	#	%	#	%	#
Buildings	2	14%	12	86%	0	0%	0	0%	14
Transportation	12	44%	15	56%	0	0%	0	0%	27
All Assets	14	34%	27	66%	0	0%	0	0%	41

Figure 1. FOMR exposure results for the fortification area. Background map is ESRI streaming imagery.

Figure 2. FOMR exposure results for the Fenwick Road area. Only high exposure assets and areas 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.

Only three assets analyzed at FOMR have high sensitivity to coastal hazards and SLR: Building 211, Officer's Club – Restroom Building, and Building 247. The majority (90%) of assets have moderate sensitivity, and only 2% have low sensitivity (Table 3). All assets that are high sensitivity are not elevated, storm resistant, or protected by engineering. Only a few assets are in poor condition or have sustained significant damage during coastal flooding.

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

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded
	#	%	#	%	#	%	#	#
Buildings	3	21%	11	79%	0	0%	14	0
Transportation	0	0%	26	96%	1	4%	27	0
All Assets	3	7%	37	90%	1	2%	41	0

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).

The majority (61%) of assets analyzed at FOMR have moderate vulnerability to the evaluated coastal hazards; all other assets (39%) have high vulnerability (Table 4, and Figures 3-4). No assets have low or minimal vulnerability. Two high vulnerability assets, Gullick Drive - South Section and Waterfront Protection - Rip Rap & Seawall, also have a high asset priority index (API ≥ 70, as reported in FMSS). The Original Fort Headquarters - Building 1 has moderate vulnerability and the highest possible API (100).

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

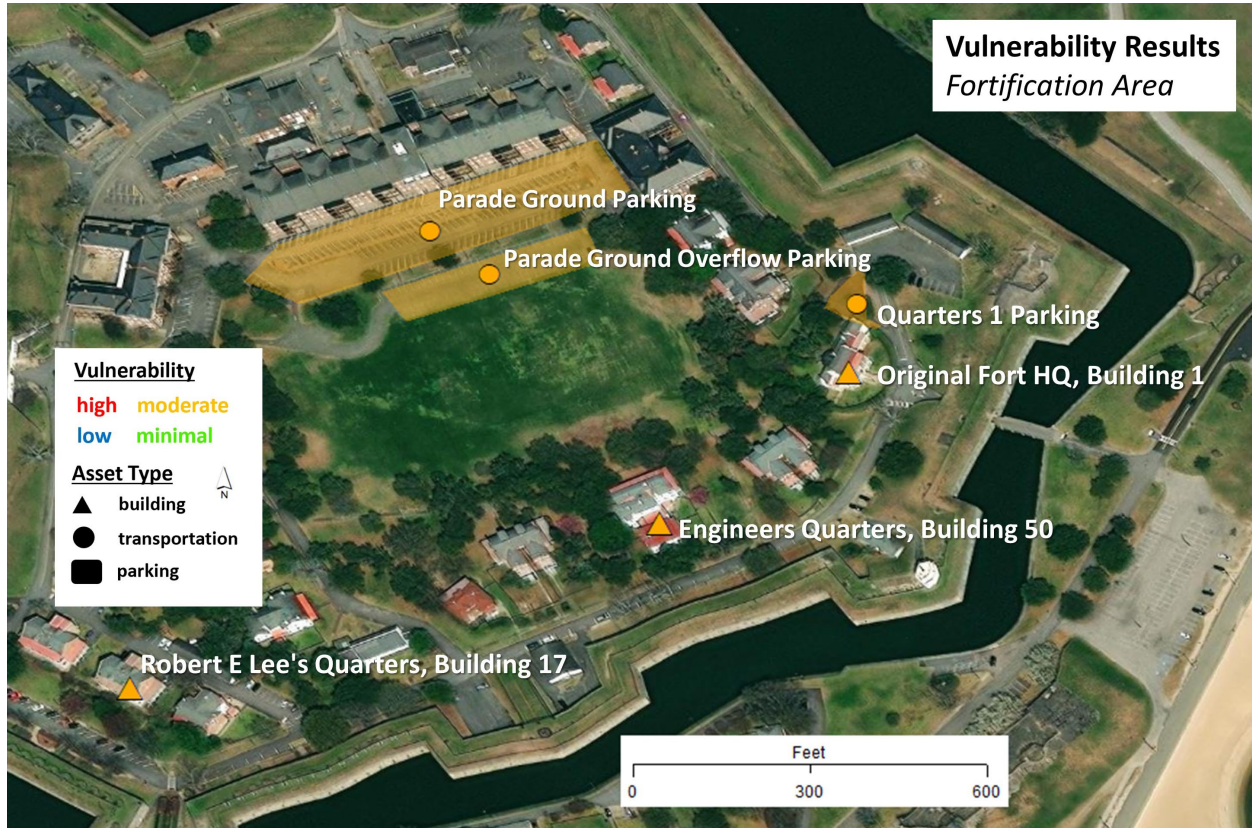| Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
	#	%	#	%	#	%	#	%	#
Buildings	5	36%	9	64%	0	0%	0	0%	14
Transportation	11	41%	16	59%	0	0%	0	0%	27
All Assets	16	39%	25	61%	0	0%	0	0%	41

Figure 3. FOMR vulnerability results for the fortification area. Background is ESRI streaming imagery.

Figure 4. FOMR vulnerability results for the Fenwick Road. Only high vulnerability assets and areas are labeled. Background is ESRI streaming imagery.

FOMR Unique Considerations

Shoreline change: United States Geological Survey (USGS) or other shoreline erosion rate data are not available for FOMR, which has non-oceanfront coastlines. As a result, we used a simple coastal proximity buffer of 30 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 30-year (approximately 2050) timeframe of this analysis (see Peek et al. 2022).

SLR data: We used the 2100 4.5 Representative Concentration Pathway (RCP) SLR projections and inundation model from Caffrey et al. (2018) developed specifically for NPS units to score exposure for this indicator (0.64 m rise for FOMR). These data are used as a proxy for 2050 SLR to accommodate higher SLR projections recently released by the National Oceanic and Atmospheric Administration (see Peek et al. 2022).

Threshold elevation: We incorporated building threshold elevation data (provided by FOMR) into the Flood Damage Potential sensitivity indicator for six assets (see Peek et al. 2022).

Linear assets: Due to the length and exposure variability of Fenwick Road and Gullick Drive, we divided each of these roads into two segments. We evaluated each segment individually for exposure, sensitivity, and vulnerability, and assigned each segment a modified location code (segments share the same FMSS attributes). All other roads were not segmented, as most are already relatively short features and/or have similar exposure. Each of these roads 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.

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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.