



Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Redwood National Park

Summary of Results

NPS 167/196687, January 2025



PROGRAM FOR
THE STUDY OF
DEVELOPED
SHORELINES

Western
Carolina
UNIVERSITY

ON THE COVER

View from Klamath River Overlook at Redwood National Park

Photo credit: NPS

Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Redwood National Park

Summary of Results

NPS 167/196687, January 2025

Program for the Study of Developed Shorelines
Western Carolina University
Cullowhee, North Carolina 28723

This document has been developed by the NPS Climate Change Response Program and Park Facilities Management Division in partnership with Western Carolina University through a Task Agreement with the Southern Appalachian Cooperative Ecosystems Studies Unit.

Please cite this publication as:

Peek, K.M., H.L. Thompson, B.R. Tormey, and R.S. Young. 2025. Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Redwood National Park: Summary of Results. NPS 167/196687. Program for the Study of Developed Shorelines, Western Carolina University, Cullowhee, N.C.

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 Redwood National Park (REDW) in 2024. In this VA, we evaluate the vulnerability (as a combination of exposure and sensitivity) of NPS buildings and transportation assets¹ to identified coastal hazards and climate change factors, approximately to the year 2050 (for full methodology, see Peek et al. 2022).

We assessed 109 buildings (including visitor centers, maintenance facilities, comfort stations, cabins, barns, and residences), and 212 transportation assets (roads, road segments, trails, parking lots, bridges, and trail bridges) at REDW. Less than one-fifth (12%) of assets analyzed have high or moderate vulnerability to the evaluated coastal hazards and SLR. The majority (83%) have minimal vulnerability (are not in any of the evaluated hazard zones). Scoring details and results for all assets evaluated 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)	REDW Data (Citation)
Flooding potential (1% annual-chance)	Effective FEMA VE & A zones (FEMA 2016; 2017)
Shoreline change (erosion, cliff retreat, coastal proximity)	USGS short term shoreline change rates (Hapke et al. 2006) 30-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050)	NPS 2050 8.5 RCP SLR model, 0.19 m rise (Caffrey et al. 2018) NOAA 1-foot SLR zone (NOAA 2022)
Extreme event flooding (tsunami)	California Tsunami Hazard Areas (Graehl et al. 2022)
Reported coastal hazards (historic flooding/active cliff retreat)	Questionnaire results & discussions (Peek et al. 2022)

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. Low exposure assets 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.

Ten assets (3%) analyzed at REDW have high exposure to the evaluated coastal hazards (Table 2), including the Brush Dance Area (Cultural Landscape) and three sections of Highway 101 (Figures 1-2). The Coastal Trail - Klamath Section (near Lagoon Creek, segment 1) is within all evaluated exposure zones (Figure 1D). Twenty-eight assets (9%) have moderate exposure, and 18 (6%) have low exposure. Over three-quarters (83%) of assets have minimal exposure, a result of the park's higher elevation leading to lower exposure overall to coastal flooding and SLR.

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

Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
	#	%	#	%	#	%	#	%	#
Buildings	1	1%	7	6%	2	2%	99	91%	109
Transportation	9	4%	21	10%	16	8%	166	78%	212
All Assets	10	3%	28	9%	18	6%	265	83%	321



Figure 1. REDW exposure results summary for the A) Crescent City, B) Crescent Beach, C) Requa North-Last Chance Grade, and D) Requa North-Lagoon Creek areas. Only high and moderate exposure assets are labeled. Background is 2022 ESRI world imagery.

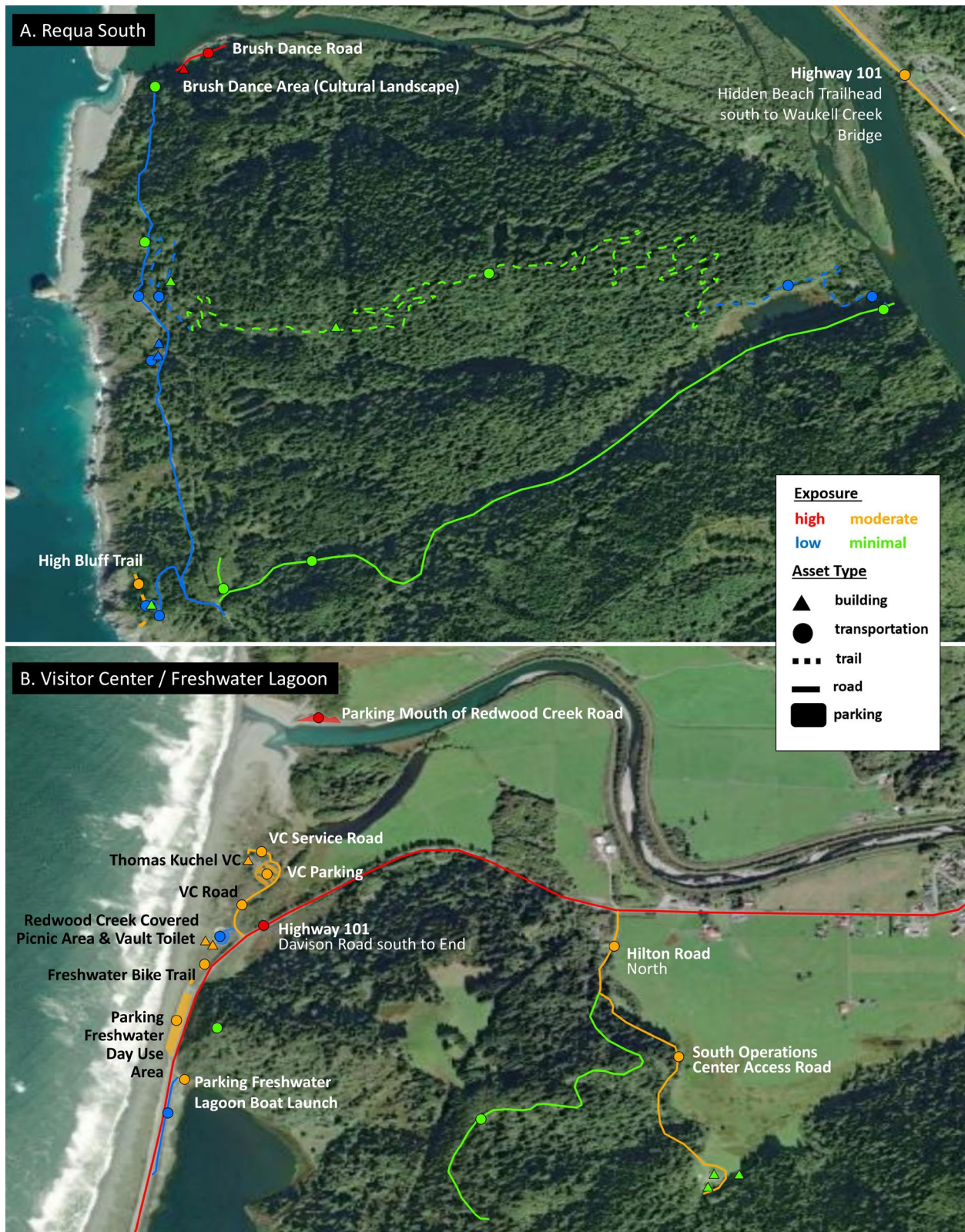


Figure 2. REDW exposure results summary for the A) Requa South and B) Visitor Center/Freshwater Lagoon areas. Only high and moderate exposure assets are labeled. Background is 2022 ESRI world imagery.

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 265 assets at REDW).

Seven assets (13%) analyzed at REDW have high sensitivity to coastal hazards and SLR, including the Pumphouse Enderts Beach, Coastal Trail - Nickel Creek/Last Chance Section, Coastal Trail - Klamath Section (near Lagoon Creek, segment 1), Coastal Drive, and Brush Dance Road. The majority (86%) of assets have moderate sensitivity, and one asset has low sensitivity (Table 3). Few assets at REDW are significantly elevated above local ground level, storm resistant, or protected by effective engineering. However, most evaluated assets are in good condition and have not been damaged by flooding or erosion in the past. Brush Dance Area (Cultural Landscape) and Highway 101 - Parking Damnation Creek Trail south to DeMartin Bridge (Last Chance Grade) received an unfavorable rating for all sensitivity indicators.

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

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
	#	%	#	%	#	%	#	#
Buildings	2	20%	7	70%	1	10%	10	99
Transportation	5	11%	41	89%	0	0%	46	166
All Assets	7	13%	48	86%	1	2%	56	265

*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).

Thirteen assets (4%) analyzed at REDW have high vulnerability to the evaluated coastal hazards, 25 (8%) have moderate vulnerability, and 18 (6%) have low vulnerability (Table 4, and Figures 3-4). The majority (83%) of assets have minimal vulnerability. Brush Dance Area (Cultural Landscape), Brush Dance Road, and Coastal Trail - Klamath Section (near Lagoon Creek, segment 1) have both high exposure and high sensitivity. Four segments of Highway 101 (a primary route through and into the park) have high vulnerability: North End to Crescent City Vista, Parking Damnation Creek Trail south to DeMartin Bridge (Last Chance Grade), DeMartin Bridge south to Hidden Beach Trailhead, and Davison Road south to End. While no assets have both high vulnerability and a high asset priority index ($API \geq 70$, as reported in FMSS), four assets have moderate vulnerability and a high API: the Thomas Kuchel Visitor Center, Coastal Drive, and both segments of Enderts Road.

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

Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
	#	%	#	%	#	%	#	%	#
Buildings	2	2%	5	5%	3	3%	99	91%	109
Transportation	11	5%	20	9%	15	7%	166	78%	212
All Assets	13	4%	25	8%	18	6%	265	83%	321



Figure 3. REDW vulnerability results summary for the A) Crescent City, B) Crescent Beach, C) Requa North - Last Chance Grade, and D) Requa North - Lagoon Creek areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI world imagery.

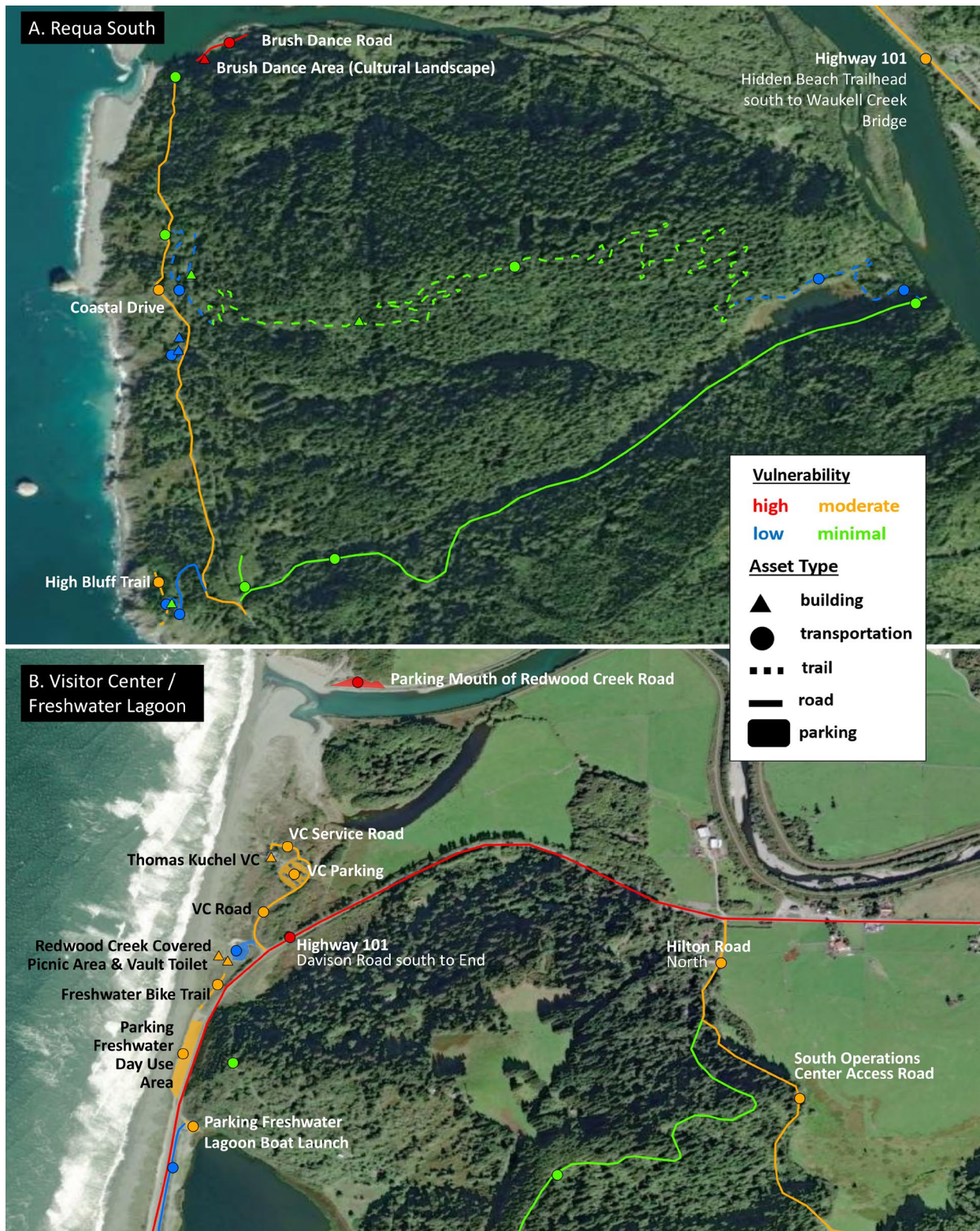


Figure 4. REDW vulnerability results summary for the A) Requa South and B) Visitor Center/Freshwater Lagoon areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI world imagery.

REDW Unique Considerations

FMSS assets: One asset was analyzed at REDW that is not listed in FMSS, Highway 101. This asset is owned by the State of California but provides primary access to park resources.

Linear assets: Due to exposure variability, we segmented three roads at REDW: Enderts Beach Road (two segments), Hilton Road (two segments), and Highway 101 (seven segments). We also segmented three trails: Coastal Trail – Crescent Beach Section (two segments), Coastal Trail – Klamath Section (two segments), and Coastal Trail – Flint Ridge Section (three 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). Any statistics or estimates of value represent the entire road, even if only a small portion has high exposure or vulnerability.

Shoreline change data: We used USGS California Shoreline Change Data, 1952-2002 (Hapke et al. 2006) to create erosion buffer zones for REDW (see Peek et al. 2022 for methodology). We also included the Central California CoSMoS v3.1 projections of coastal cliff retreat due to 21st century sea-level rise (0.25 m + cliff retreat projection; Limber et al. 2018) for comparison. For REDW shorelines that do not have erosion rate data we used a simple 30-meter proximity buffer.

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). 2016. National Flood Hazard Layer. Humboldt County, CA. <https://www.fema.gov/flood-maps/national-flood-hazard-layer>. Accessed June 2024.
- FEMA. 2017. National Flood Hazard Layer. Del Norte County, CA. <https://www.fema.gov/flood-maps/national-flood-hazard-layer>. Accessed June 2024.
- Graehl, N., J. Patton, J. Bott, R. Wilson, Y. LaDuke, and K. Miller. 2022. Tsunami Hazard Area Map. California Geological Survey and the California Governor's Office of Emergency Services. <https://www.conservation.ca.gov/cgs/tsunami/maps>. Accessed June 2024.
- Hapke, C.J., D. Reid, B.M. Richmond, P. Ruggiero, and J. List. 2006. National assessment of shoreline change: Part 3: Historical shoreline changes and associated coastal land loss along the sandy shorelines of the California coast: U.S. Geological Survey Open-file Report 2006-1219.

Limber, P.W., L.H. Erikson, A. O'Neill, A. Foxgrover, and P. Barnard. 2018. Coastal Storm Modeling System (CoSMoS) for Central California, v3.1 [Data set]. U.S. Geological Survey. <https://doi.org/10.5066/P9NUO62B>

National Oceanic and Atmospheric Administration (NOAA). 2022. Sea Level Rise Viewer. Available at: <https://coast.noaa.gov/slr/>. Accessed June 2024.

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

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>.



EXPERIENCE YOUR AMERICA™

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 167/196687, January 2025