National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Golden Gate National Recreation Area, Presidio of San Francisco, and Fort Point National Historic Site

Summary of Results

NPS 641/197620, NPS 400/197620, May 2025

PROGRAM FOR THE STUDY OF DEVELOPED SHORELINES

Western Carolina University

ON THE COVER
View of Bonita Cove and Golden Gate Bridge
Photo credit: Program for the Study of Developed Shorelines

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Program for the Study of Developed Shorelines
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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 Golden Gate National Recreation Area (GOGA), Presidio of San Francisco (PRSF), and Fort Point National Historic Site (FOPO) in 2025. 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, approximately to the year 2050 (for full methodology, see Peek et al. 2022).

We assessed 681 buildings (including batteries, fortifications, magazines, fire control stations, lighthouses, sheds, quarters, comfort stations, vault toilets, greenhouses, monuments, towers, visitor centers, and offices) and 433 transportation assets (including roads, road segments, trails, trail segments, parking lots, bridges, trail bridges, docks, piers, and tunnels) at GOGA, PRSF, and FOPO. Most of the evaluated assets in this VA are listed as part of GOGA; we evaluated only 85 assets at PRSF (39 buildings and 46 transportation), and 18 assets at FOPO (five buildings and 13 transportation).

Less than one-fifth (18%) of assets analyzed at GOGA, PRSF, and FOPO have high or moderate vulnerability to the evaluated coastal hazards, while 12% have low vulnerability. The majority (70%) of assets have minimal vulnerability (not in any of the evaluated hazard zones). The significant number of minimal vulnerability assets is a factor of the high elevations across the region. The statistics for the combined results are primarily controlled by GOGA results, as 91% of assets evaluated are in this unit.

The vulnerability results for GOGA are similar to the combined results, as only 15% of the assets evaluated have high or moderate vulnerability, 11% low, and 73% minimal. Almost half (49%) of assets at PRSF have high or moderate vulnerability, 21% low, and 31% minimal. Seven assets at FOPO have high or moderate vulnerability, two have low, and nine have minimal vulnerability.

The assets at GOGA, PRSF, and FOPO are distributed over more than 80,000 acres, at elevations up to 2,500 feet above sea level. Due to this wide geographic and topographic range, the majority of the higher vulnerability assets are situated in a handful of areas near the coast. Over half of the high and moderate vulnerability assets are in the Stinson Beach, Crissy Field, Fort Baker-Lower, Fort Cronkhite, Fort Mason, and Point Bonita areas. Scoring details and results for all assets evaluated are reported in the provided Excel sheets.

[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."

Exposure Results

Exposure is a measure of the character, magnitude, and rate of changes a target may experience (e.g., from the impacts of natural hazards or 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 at GOGA, PRSF, and FOPO.

Exposure Indicator (Description)	Data (Citation)
Flooding potential (1% annual-chance)	Effective VE & A zones (FEMA 2017ab; 2021) USGS CoSMoS 25 cm SLR + 100-year flood zone (Limber et al. 2018) 12 inches SLR + 100-year flood inundation (ART 2020) Stinson Beach CoSMoS Data (ESA 2023; Marin County 2023)
Shoreline change (erosion, cliff retreat, coastal proximity)	USGS California Shoreline Change data (Barnard et al. 2020) USGS CoSMoS coastal cliff retreat due to SLR (Limber et al. 2018) 30-m shoreline proximity buffer (Peek et al. 2022)
SLR inundation (2050 proxy) *	NPS 2100 4.5 RCP SLR model,0.42 m rise (Caffrey et al. 2018) 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)

*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. Low exposure assets could still be seriously impacted by this hazard. Assets with minimal exposure are not in any exposure indicator hazard zone. Minimal exposure does not mean that the asset has no exposure to coastal hazards, but it is not within the mapped exposure hazard zones used in this study.

Combined Exposure Results

Sixty assets (5%) analyzed at GOGA, PRSF, and FOPO have high exposure to the evaluated coastal hazards (Table 2). Ninety-eight assets (9%) have moderate exposure, and 178 (16%) have low exposure. The assets at GOGA, PRSF, and FOPO are spread over a wide geographic and topographic range, and therefore the majority (70%) have minimal exposure using this VA protocol (Figure 1). It should be noted that GOGA assets comprise 91% of these combined results.

Table 2. GOGA, PRSF, and FOPO combined exposure results. Sum of percentages may not equal 100 due to rounding.

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	30	4%	40	6%	114	17%	497	73%	681
Transportation	30	7%	58	13%	64	15%	281	65%	433
All Assets	60	5%	98	9%	178	16%	778	70%	1,114

GOGA Exposure Results

Thirty-seven assets (4%) analyzed at GOGA have high exposure to the evaluated coastal hazards (Table 3, and Figures 2-6). The majority of the high exposure assets are in the Stinson Beach (Figure 2A), Fort Baker (Figure 3B), and Fort Mason (Figure 5A) areas of the park. Eighteen assets are within all evaluated hazard zones, including the piers and pier sheds at Fort Mason, eight waterfront assets at Fort Baker (e.g., breakwaters, seawall, and docks), and the Alcatraz waterfront.

Eighty assets (8%) at GOGA have moderate exposure and 151 (15%) have low exposure. While these assets are not ranked as high exposure within this VA protocol (we evaluate multiple coastal hazards), a significant number are within the coastal cliff retreat hazard zone. Coastal cliff erosion and retreat is a major concern for many areas of GOGA, and this hazard alone can cause irreversible damage to infrastructure (e.g., the previous collapse of Battery Bluff Panama Mounts in the Fort Funston area, Figure 6B). Many vital transportation corridors at GOGA are exposed to cliff retreat, including Conzelman Road: Segment 2 (near Battery Rathbone-McIndoe), which is one of the primary routes to park resources in the Point Bonita, Fort Barry, and Battery Mendell areas (Figure 3A). Almost three-quarters (73%) of assets at GOGA have minimal exposure (Figure 1), a result of the higher elevations in many park areas, leading to lower exposure overall to coastal flooding and SLR.

Table 3. GOGA exposure results. Sum of percentages may not equal 100 due to rounding.

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	21	3%	34	5%	99	16%	483	76%	637
Transportation	16	4%	46	12%	52	14%	260	70%	374
All Assets	37	4%	80	8%	151	15%	743	73%	1,011

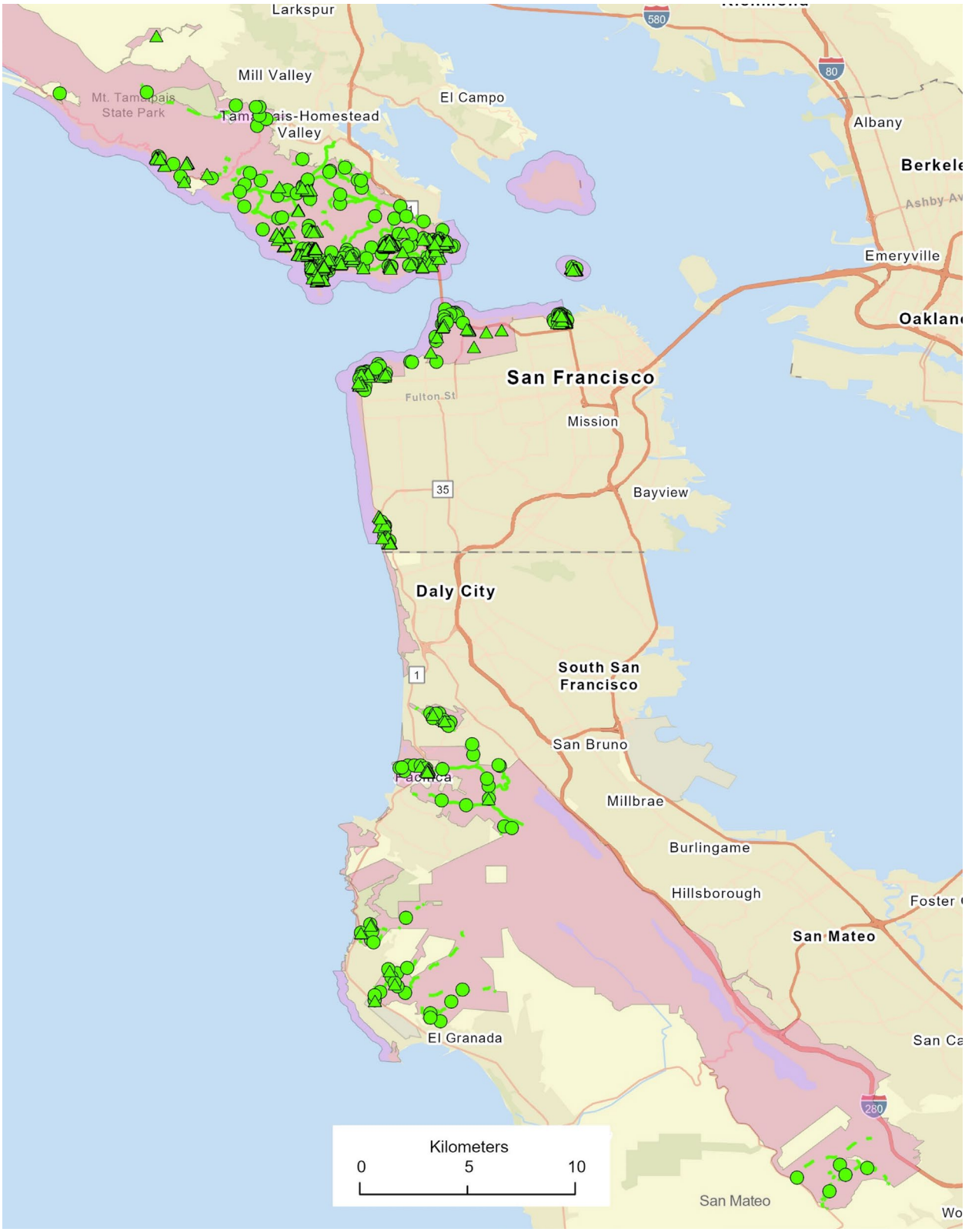

Figure 1. Distribution of almost 800 minimal exposure assets at GOGA, PRSF, and FOPO (green dots). The shaded pink area represents the GOGA park boundary. Background is ESRI World Street Map.

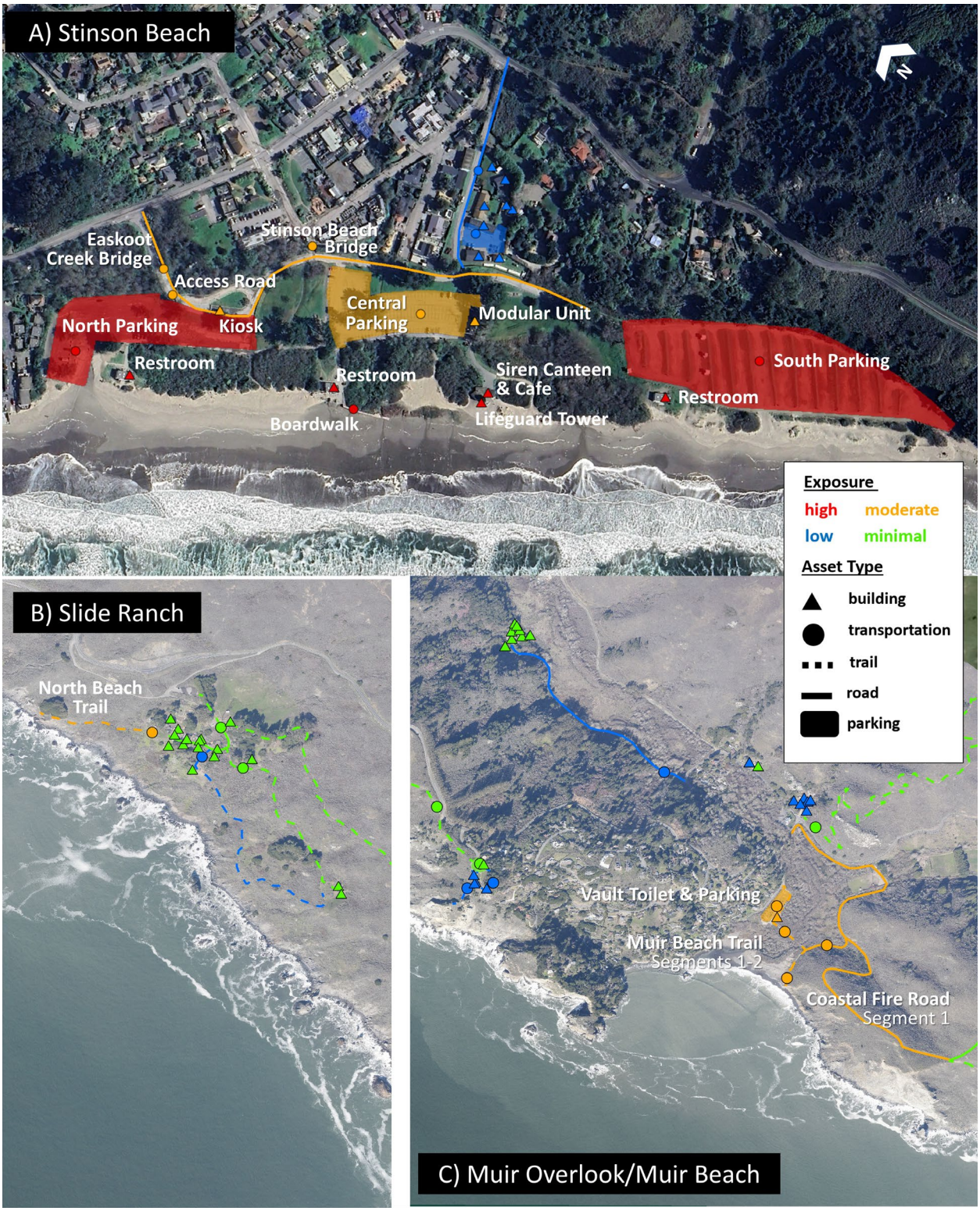

Figure 2. GOGA exposure results summary for the A) Stinson Beach, B) Slide Ranch, and C) Muir Overlook/Muir Beach areas. Only high and moderate exposure assets are labeled. Background is A) Google Earth Imagery (note direction of north) and B-C) NOAA NGS 2023 imagery (NGS 2025b).

Figure 3. GOGA exposure results summary for the A) Fort Cronkhite/Fort Barry/Point Bonita, and B) Fort Baker areas. Select assets are labeled. Background is 2022 ESRI Streaming World Imagery.

Figure 4. GOGA exposure results summary for the A) Battery Kirby, B) Lime Point, and C) Alcatraz areas. Only high and moderate exposure assets are labeled. Background is 2022 ESRI Streaming World Imagery.

Figure 5. GOGA exposure results summary for the A) Fort Mason and B) Lands End/Sutro areas. Only high and moderate exposure assets are labeled. Background is 2022 ESRI Streaming World Imagery.

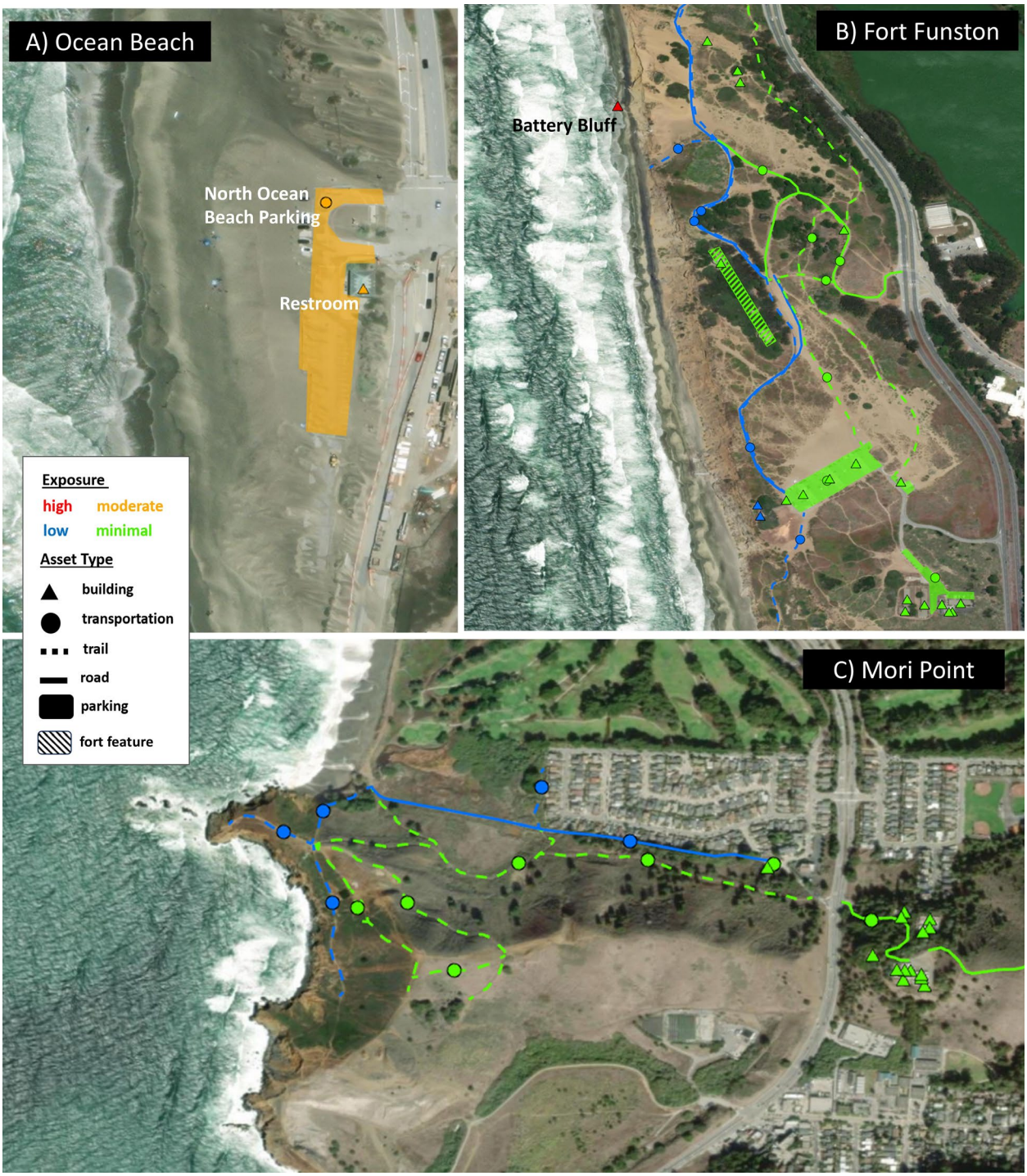

Figure 6. GOGA exposure results summary for the A) Ocean Beach, B) Fort Funston, and C) Mori Point areas. Only high and moderate exposure assets are labeled. Background is 2022 ESRI Streaming World Imagery.

PRSF Exposure Results

Seventeen assets (20%) analyzed at PRSF have high exposure to the evaluated coastal hazards (Table 4, and Figures 7-8). The majority of the high exposure assets are in the Crissy Field area of the park (Figure 8). Five assets are within all evaluated hazard zones: Building #1 on NOAA Pier, Building #2 on NOAA Pier, Crissy Field Channel Bridge, Torpedo Wharf at Fort Point, and Presidio Area A District Waterfront. Seventeen assets (20%) at PRSF have moderate exposure, 25 (29%) have low exposure, and 26 (31%) have minimal exposure (Table 4).

Table 4. PRSF exposure results. Sum of percentages may not equal 100 due to rounding.

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	7	18%	6	15%	13	33%	13	33%	39
Transportation	10	22%	11	24%	12	26%	13	28%	46
All Assets	17	20%	17	20%	25	29%	26	31%	85

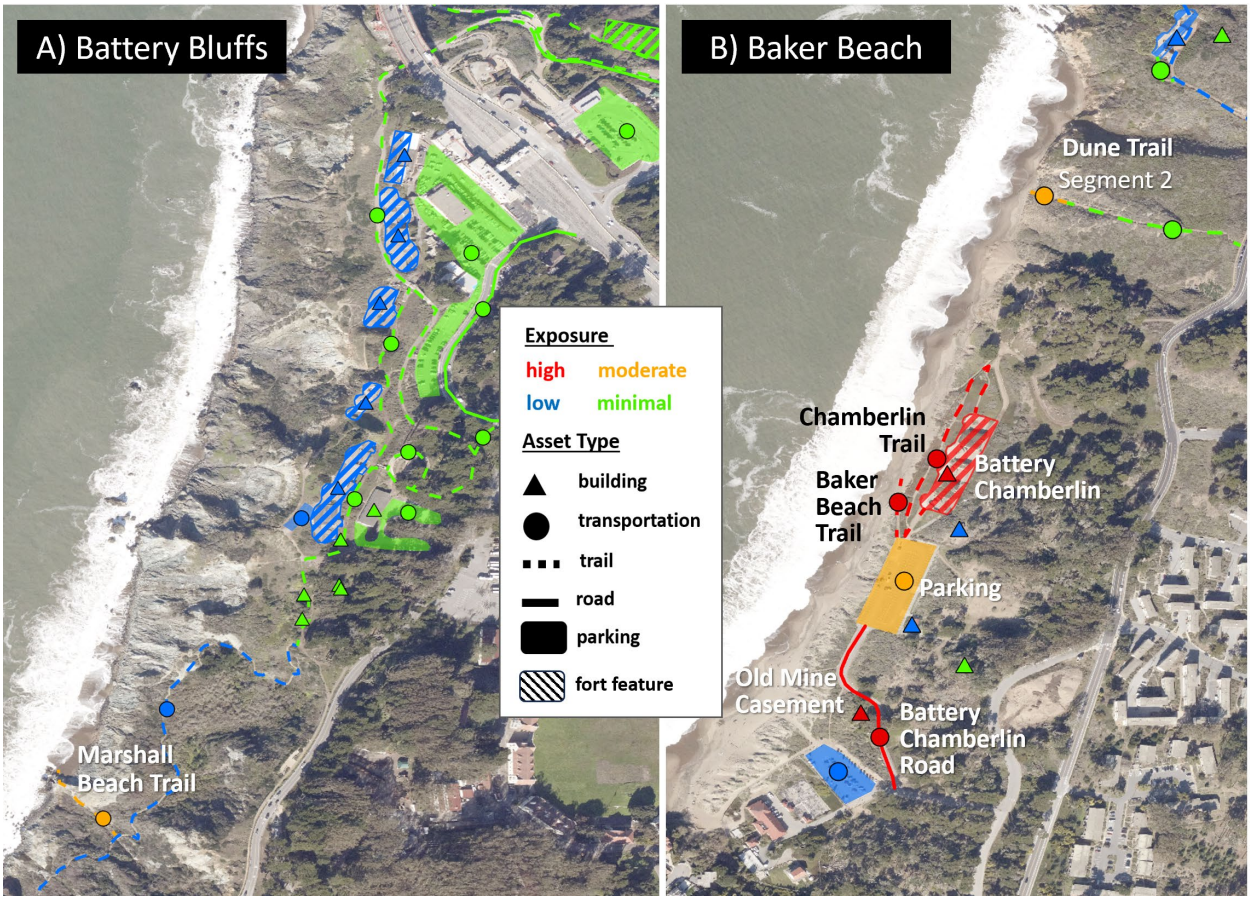

Figure 7. PRSF exposure results summary for the A) Battery Bluffs and B) Baker Beach areas. Only high and moderate exposure assets are labeled. Background is NOAA NGS 2023 imagery (NGS 2025b).

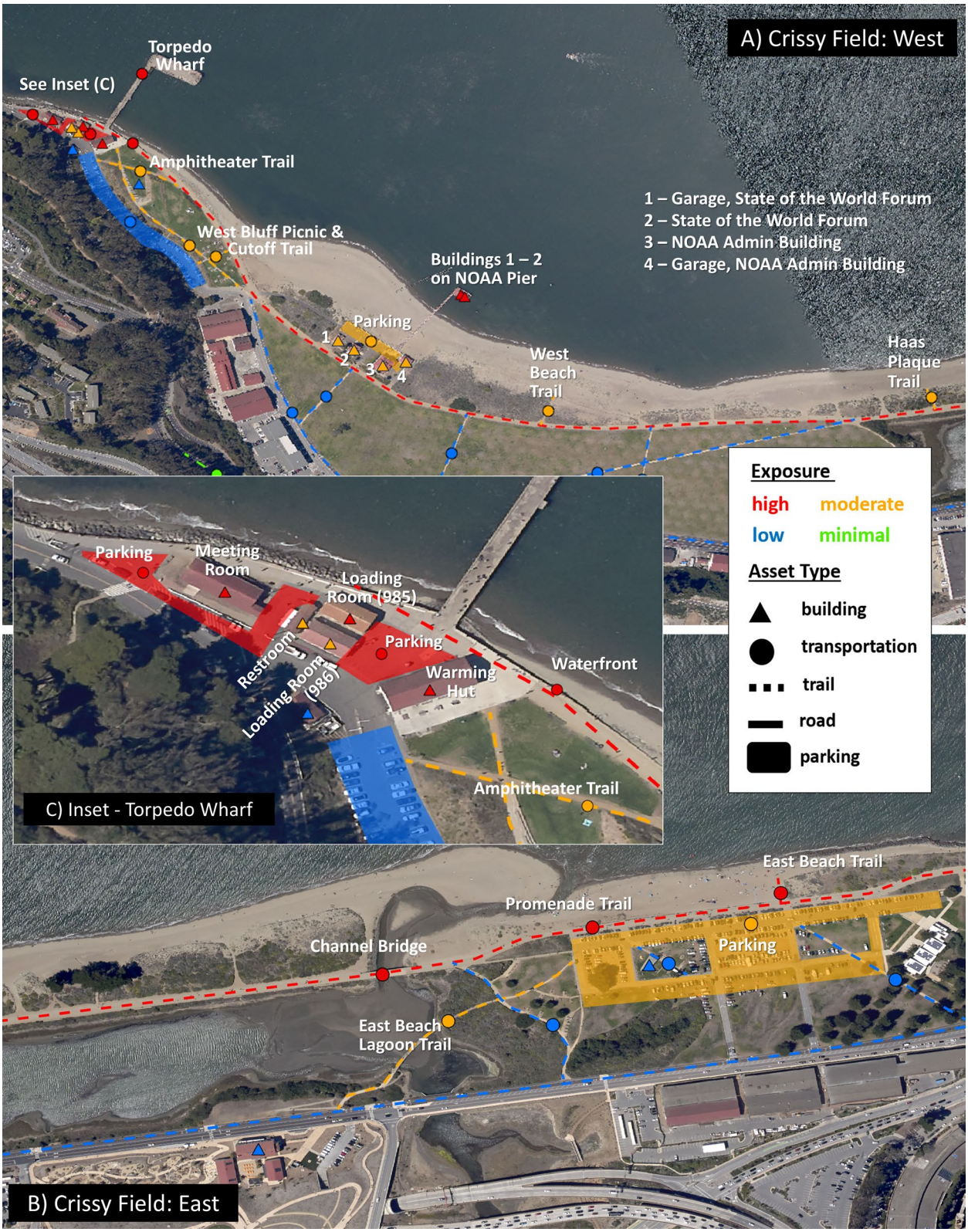

Figure 8. PRSF exposure results summary for the A) Crissy Field: West, B) Crissy Field: East and C) Inset - Torpedo Wharf areas. Only high and moderate exposure assets are labeled. Background is NOAA NGS 2022 imagery (NGS 2025a).

FOPO Exposure Results

Six assets analyzed at FOPO have high exposure to the evaluated coastal hazards (Table 5, and Figure 9): Fort Point, Seawall - Derussys and Elliots, Marine Drive, Marine Drive Parking Lot, Fort Point Parking Lot, and Bay Trail. Only one asset (the seawall) is within all evaluated hazard zones. One asset at FOPO has moderate exposure, two have low exposure, and nine have minimal exposure.

Table 5. FOPO exposure results. Sum of percentages may not equal 100 due to rounding.

	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	2	40%	0	0%	2	40%	1	20%	5
Transportation	4	31%	1	8%	0	0%	8	62%	13
All Assets	6	33%	1	6%	2	11%	9	50%	18

Figure 9. FOPO exposure results summary. Only high and moderate exposure assets are labeled. Background is 2022 ESRI Streaming 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 three or four of these indicators, moderate sensitivity assets have unfavorable determinations for two indicators, and low sensitivity assets have unfavorable determinations for zero or one indicator. Assets with minimal exposure are not analyzed for sensitivity (this is the case for 778 assets at GOGA, PRSF, and FOPO).

Combined Sensitivity Results

One hundred and sixteen assets (35%) analyzed at GOGA, PRSF, and FOPO have high sensitivity to the evaluated coastal hazards. The majority (63%) of assets have moderate sensitivity, and eight assets have low sensitivity (Table 6). It should be noted that GOGA assets comprise 80% of these combined sensitivity results.

Table 6. GOGA, PRSF, and FOPO combined sensitivity results. Sum of percentages may not equal 100 due to rounding.

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	56	30%	121	66%	7	4%	184	497
Transportation	60	39%	91	60%	1	1%	152	281
All Assets	116	35%	212	63%	8	2%	336	778

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

GOGA Sensitivity Results

Ninety assets (34%) analyzed at GOGA have high sensitivity to the evaluated coastal hazards. The majority (64%) of assets have moderate sensitivity, and seven (3%) assets have low sensitivity (Table 7). Few assets at GOGA are significantly elevated above local ground level, storm resistant, or protected by effective engineering. Almost half of the assets evaluated (44%) were reported as being in poor condition. However, most evaluated assets have not been damaged by flooding or erosion in the past. Fifteen assets received an unfavorable rating for all sensitivity indicators, including the North Restroom, South Restroom, and Lifeguard Tower at Stinson Beach (Figure 10); Model Industries Building and Cliffside Road at Alcatraz; Conzelman Road: Segment 2 (near Battery Rathbone-McIndoe); Lower Fort Mason Trail; and the North Ocean Beach Parking Lot.

Table 7. GOGA sensitivity results. Sum of percentages may not equal 100 due to rounding.

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	43	28%	105	68%	6	4%	154	483
Transportation	47	41%	66	58%	1	1%	114	260
All Assets	90	34%	171	64%	7	3%	268	743

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

Figure 10. Stinson Beach area, looking north. Note the high water on the beach, dune breaches, and flooding in the South Parking Lot and near the South Restroom. All three of the assets shown (Lifeguard Tower, South Restroom, and South Parking) were reported to be in poor condition and have high sensitivity using this VA protocol. Photo by NPS.

PRSF Sensitivity Results

Twenty-six (44%) assets analyzed at PRSF have high sensitivity to the evaluated coastal hazards. The majority (56%) of assets have moderate sensitivity, and no assets have low sensitivity (Table 8). Few assets at PRSF are significantly elevated above local ground level, storm resistant, or protected by effective engineering. Over half of the assets evaluated (55%) were reported as being in poor condition. However, most evaluated assets have not been damaged by flooding or erosion in the past. Five assets received an unfavorable rating for all sensitivity indicators: Baker Beach Trail (Boardwalk), Batteries to Bluffs Trail (CT), Marshalls Beach Trail, Presidio Area A District Waterfront, and Crissy Field Channel Bridge.

Table 8. PRSF sensitivity results. Sum of percentages may not equal 100 due to rounding.

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	13	50%	13	50%	0	0%	26	13
Transportation	13	39%	20	61%	0	0%	33	13
All Assets	26	44%	33	56%	0	0%	59	26

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

FOPO Sensitivity Results

No assets analyzed at FOPO have high sensitivity to the evaluated coastal hazards. Eight assets have moderate sensitivity, and one has low sensitivity (Table 9). Only one asset (Bay Trail) was reported to have been damaged by flooding and/or erosion in the past, while most were reported as having effective protective engineering.

Table 9. FOPO sensitivity results. Sum of percentages may not equal 100 due to rounding.

	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total Analyzed	Excluded*
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**#**
Buildings	0	0%	3	75%	1	25%	4	1
Transportation	0	0%	5	100%	0	0%	5	8
All Assets	0	0%	8	89%	1	11%	9	9

*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).

Combined Vulnerability Results

Ninety-seven assets (9%) analyzed at GOGA, PRSF, and FOPO have high vulnerability to the evaluated coastal hazards, 105 (9%) have moderate vulnerability, and 134 (12%) have low vulnerability (Table 10). The majority (70%) of assets have minimal vulnerability (Figure 1). It should be noted that GOGA assets comprise 91% of these combined results.

Table 10. GOGA, PRSF, and FOPO combined vulnerability results. Sum of percentages may not equal 100 due to rounding.

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	43	6%	50	7%	91	13%	497	73%	681
Transportation	54	12%	55	13%	43	10%	281	65%	433
All Assets	97	9%	105	9%	134	12%	778	70%	1,114

GOGA Vulnerability Results

Sixty-five assets (6%) analyzed at GOGA have high vulnerability to the evaluated coastal hazards, 89 (9%) have moderate vulnerability, and 114 (11%) have low vulnerability (Table 11, and Figures 11-16). The majority (73%) of assets evaluated at GOGA have minimal vulnerability. The considerable number of low and minimal vulnerability assets is a factor of the high elevations in many areas of the park.

Table 11. GOGA vulnerability results. Sum of percentages may not equal 100 due to rounding.

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	28	4%	47	7%	79	12%	483	76%	637
Transportation	37	10%	42	11%	35	9%	260	70%	374
All Assets	65	6%	89	9%	114	11%	743	73%	1,011

Twenty-eight assets at GOGA have both high exposure and high sensitivity, including the USCG Shed, Mine Wharf, and Seawall at Fort Baker; Pier 1, Pier 1 Shed, Pier 3, and Pier 4 at Fort Mason; and the South Restroom, South Parking Lot, North Restroom, North Parking Lot, Lifeguard Tower,

Siren Canteen and Café, and the Beach Boardwalk (not currently in FMSS) at Stinson Beach. Thirteen assets have high vulnerability and a high asset priority index (API ≥ 70, as reported in FMSS; Table 12). Most of these assets are also listed within the Historic Structures in the Cultural Resources Inventory System (HS-CRIS). The Alcatraz Waterfront is the only GOGA asset with high vulnerability and the highest possible priority (API=100; Table 12). Severe damage or loss of this asset would severely hinder park operations and visitor access, as this waterfront provides the only access to the island.

Table 12. GOGA assets with high vulnerability and a high priority (API ≥ 70), sorted by area.

Asset Name	GOGA Area	API	Historic*
Alcatraz Waterfront	Alcatraz	100	Yes
Road from Wharf to NW end of Island (AL-227)	Alcatraz	79	Yes
Model Industries Building (AL-082)	Alcatraz	70	Yes
Pier 2 (FM318)	Fort Mason	92	Yes
Pier 3 (FM320)	Fort Mason	92	Yes
Pier 2 Shed, Lower Fort Mason (FM-319) FMC	Fort Mason	92	Yes
Pier 3 Shed, Lower Fort Mason (FM-321) FMC	Fort Mason	92	Yes
Lime Point Fog Signal Station	Lime Point	72	Yes
Point Bonita Suspension Bridge	Point Bonita	80	Yes
Point Bonita Truss Bridge #2	Point Bonita	70	
Point Bonita Tunnel Entrance Bridge	Point Bonita	70	
Point Bonita Truss Bridge # 1	Point Bonita	70	
Lighthouse, Point Bonita (PB001)	Point Bonita	70	Yes

* Included in the Historic Structures in the Cultural Resources Inventory System (HS-CRIS)

High Vulnerability Areas

Most of the high vulnerability assets at GOGA are in the Fort Baker, Fort Mason, Point Bonita, and Stinson Beach areas. The vulnerability at Fort Baker and Fort Mason is largely a function of exposure, as the high vulnerability assets are located directly on (or within) Horseshoe and San Francisco bays. At Point Bonita, vulnerability is largely controlled by sensitivity, as this narrow high-elevation ridge is only exposed to cliff retreat (not flood-related hazards).

At Stinson Beach, both exposure and sensitivity play a key role in the number of high vulnerability assets. Two-thirds of the assets in the Stinson Beach area of GOGA have a moderate or high vulnerability to the evaluated coastal hazards (Figure 11A). This is a significantly higher percentage than the GOGA park-wide results, where only 12% are moderate or high exposure. Most assets in the Stinson Beach area are within the California Tsunami Hazard zone, and many are highly exposed to flooding from the Pacific Ocean and/or Easkoot Creek. Recent storms have caused significant overwash and dune erosion, further exposing nearby assets to coastal flooding and potential damage from erosion (Figure 10). Park staff reported that numerous buildings and transportation assets have been previously flooded, and many areas are experiencing active shoreline erosion. All assets at Stinson Beach have moderate or high sensitivity, as none were elevated, storm resistant, or have protective engineering. High sensitivity assets were either in poor condition or damaged by past flooding (or both).

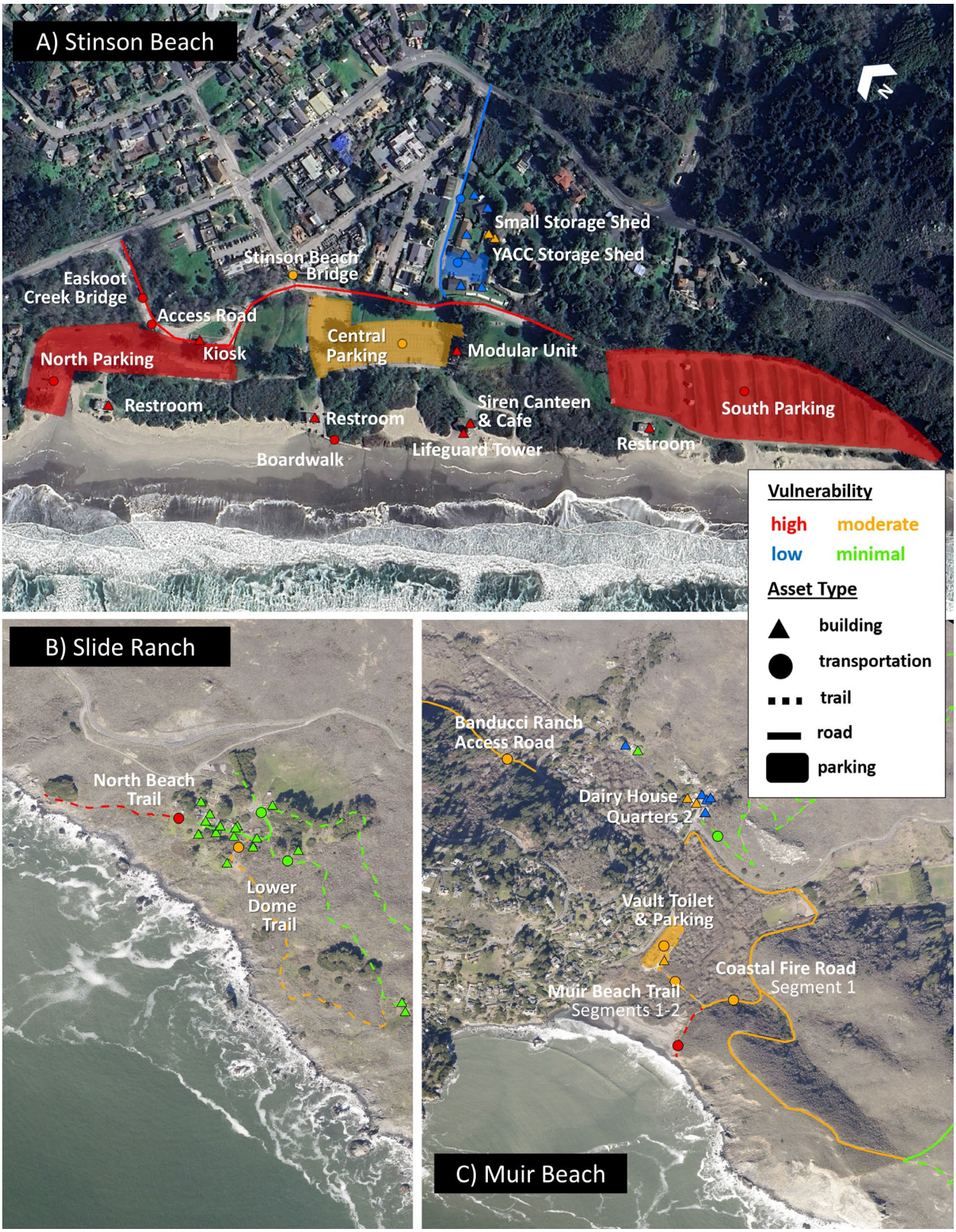

Figure 11. GOGA vulnerability results summary for the A) Stinson Beach, B) Slide Ranch, and C) Muir Beach areas. Only high and moderate vulnerability assets are labeled. Background is A) Google Earth Imagery (note direction of north) and B-C) NOAA NGS 2023 imagery (NGS 2025b).

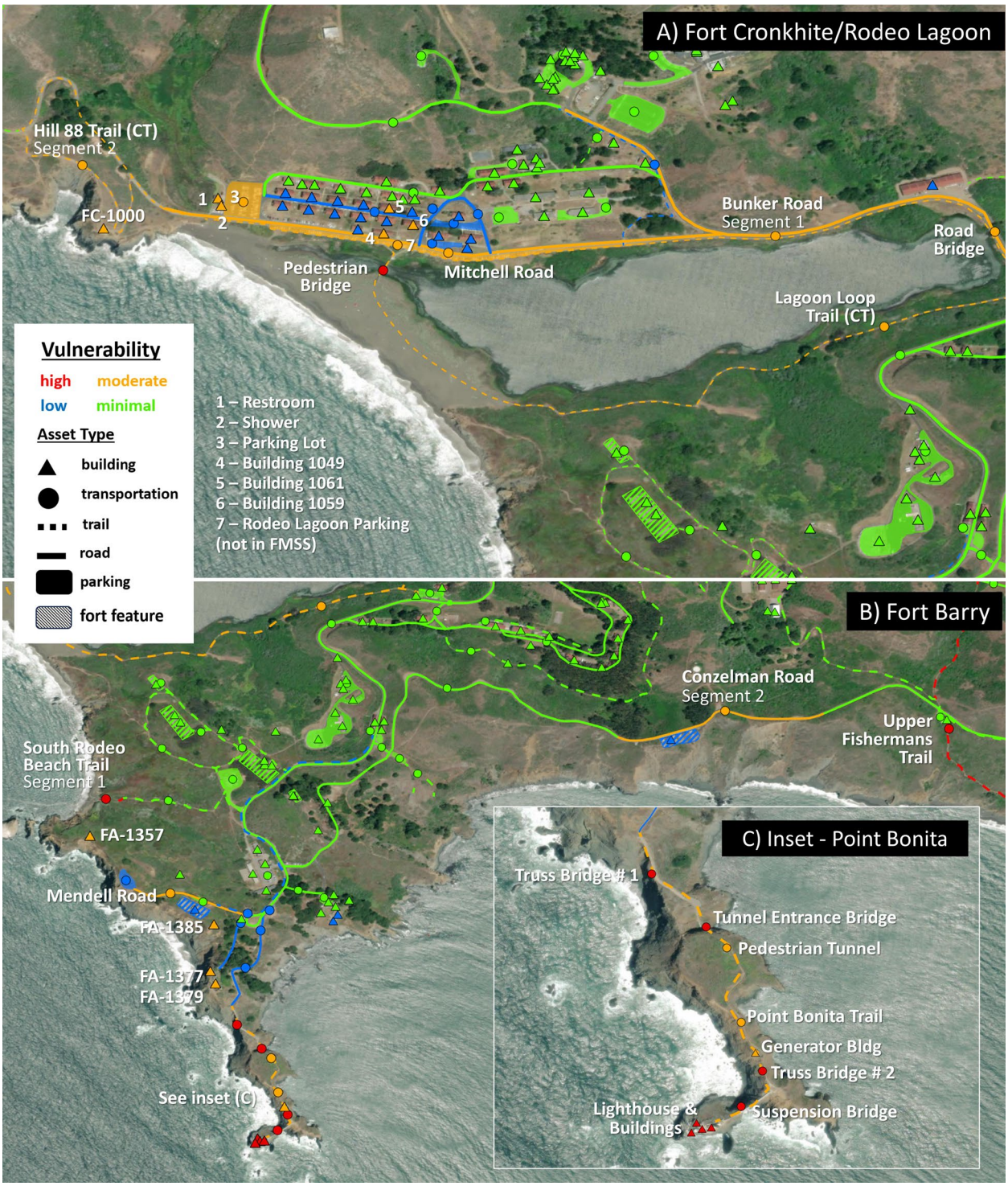

Figure 12. GOGA vulnerability results summary for the A) Fort Cronkhite/Rodeo Lagoon, B) Fort Barry, and C) Inset - Point Bonita areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

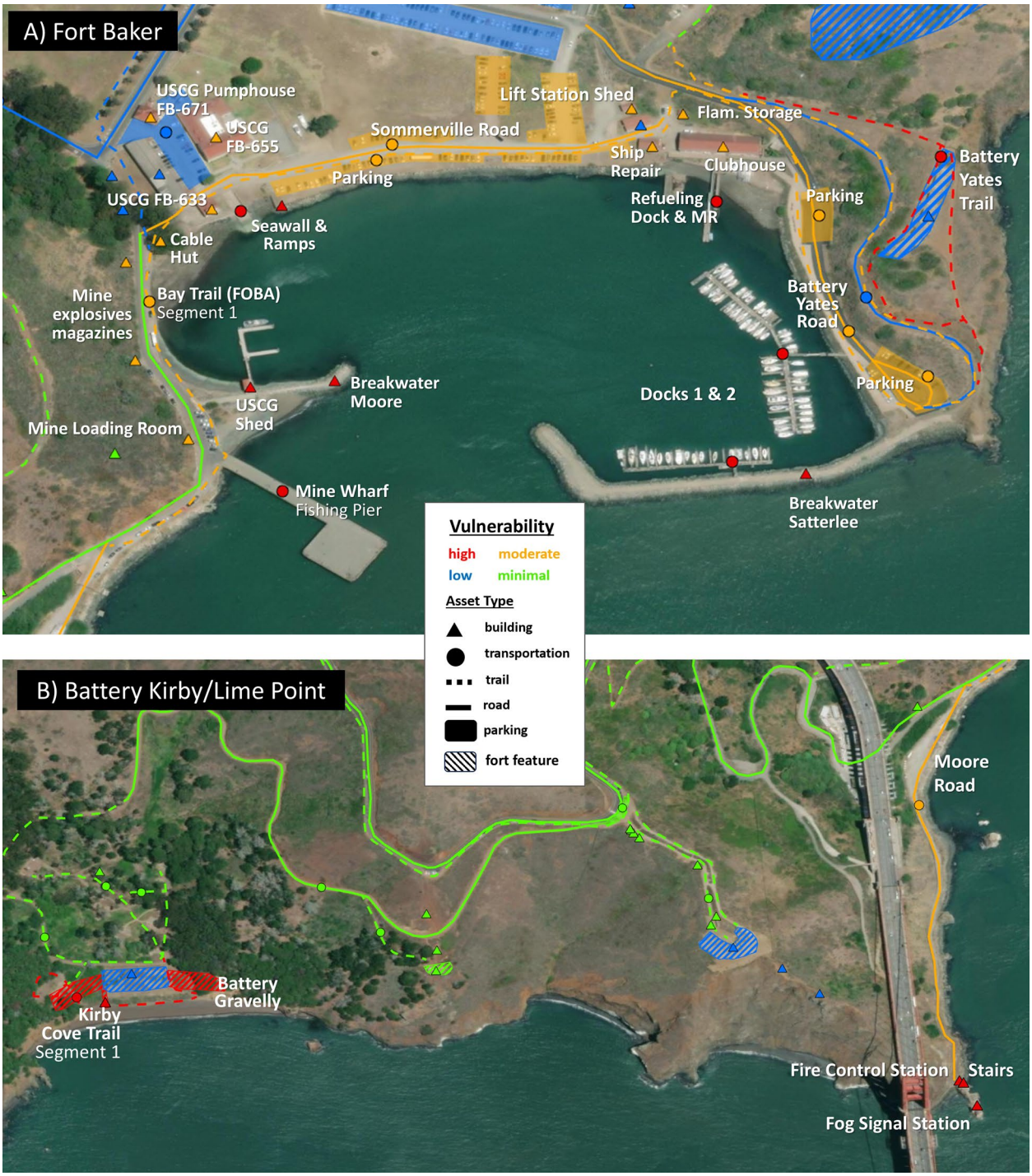

Figure 13. GOGA vulnerability results summary for the A) Fort Baker and B) Battery Kirby/Lime Point areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

Figure 14. GOGA vulnerability results summary for the A) Alcatraz and B) Fort Mason areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

Figure 15. GOGA vulnerability results summary for the A) Lands End/Sutro, and B) Fort Funston areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

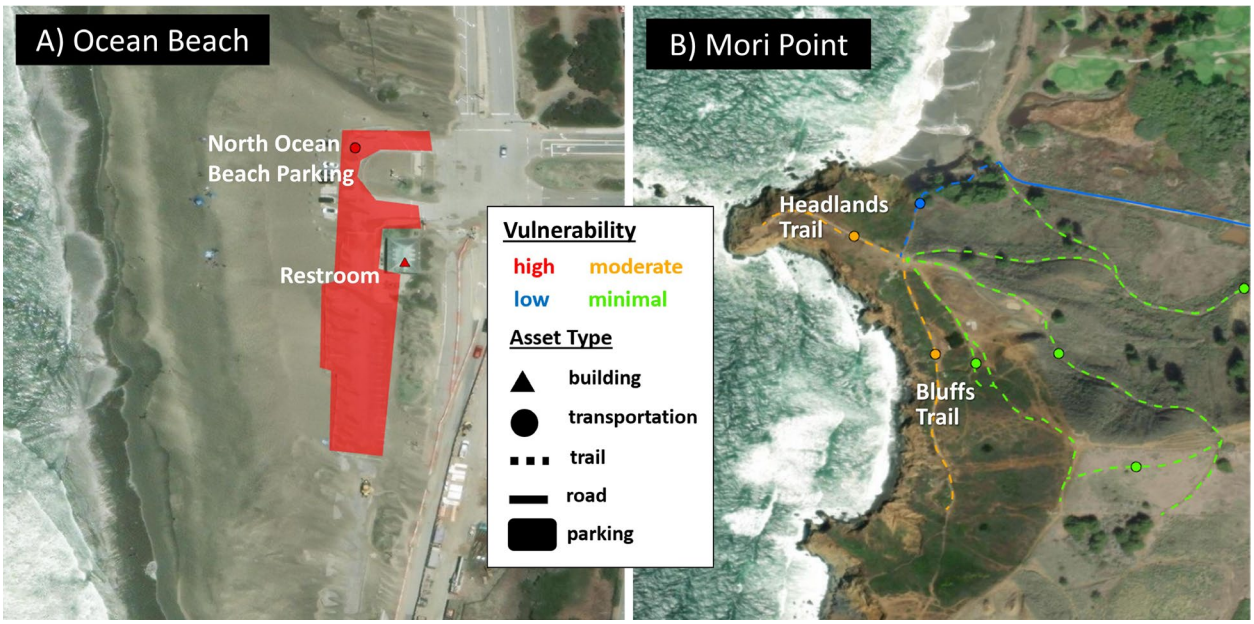

Figure 16. GOGA vulnerability results summary for the A) Ocean Beach and B) Mori Point areas. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

PRSF Vulnerability Results

Twenty-six assets (31%) evaluated at PRSF have high vulnerability to the evaluated coastal hazards, fifteen (18%) have moderate vulnerability, and eighteen (21%) have low vulnerability (Table 13, and Figures 17-18). Almost one-third (31%) of assets at PRSF have minimal vulnerability.

Table 13. PRSF vulnerability results. Sum of percentages may not equal 100 due to rounding.

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	13	33%	3	8%	10	26%	13	33%	39
Transportation	13	28%	12	26%	8	17%	13	28%	46
All Assets	26	31%	15	18%	18	21%	26	31%	85

Ten assets at PRSF have both high exposure and high sensitivity, including Battery Chamberlin Road and Chamberlin Trail at Baker Beach (Figure 17B); and the Meeting Room, Warming Hut, and Building #2 on the NOAA Pier at Crissy Field (Figure 18). Only one asset has moderate vulnerability and a high priority (API ≥ 70, as reported in FMSS): the Torpedo Wharf at Fort Point. No assets have high vulnerability and a high priority. Eight high vulnerability assets are also listed in HS-CRIS. The majority of the high vulnerability assets are in the Crissy Field area, where there is significant exposure to flood hazards and associated wave activity.

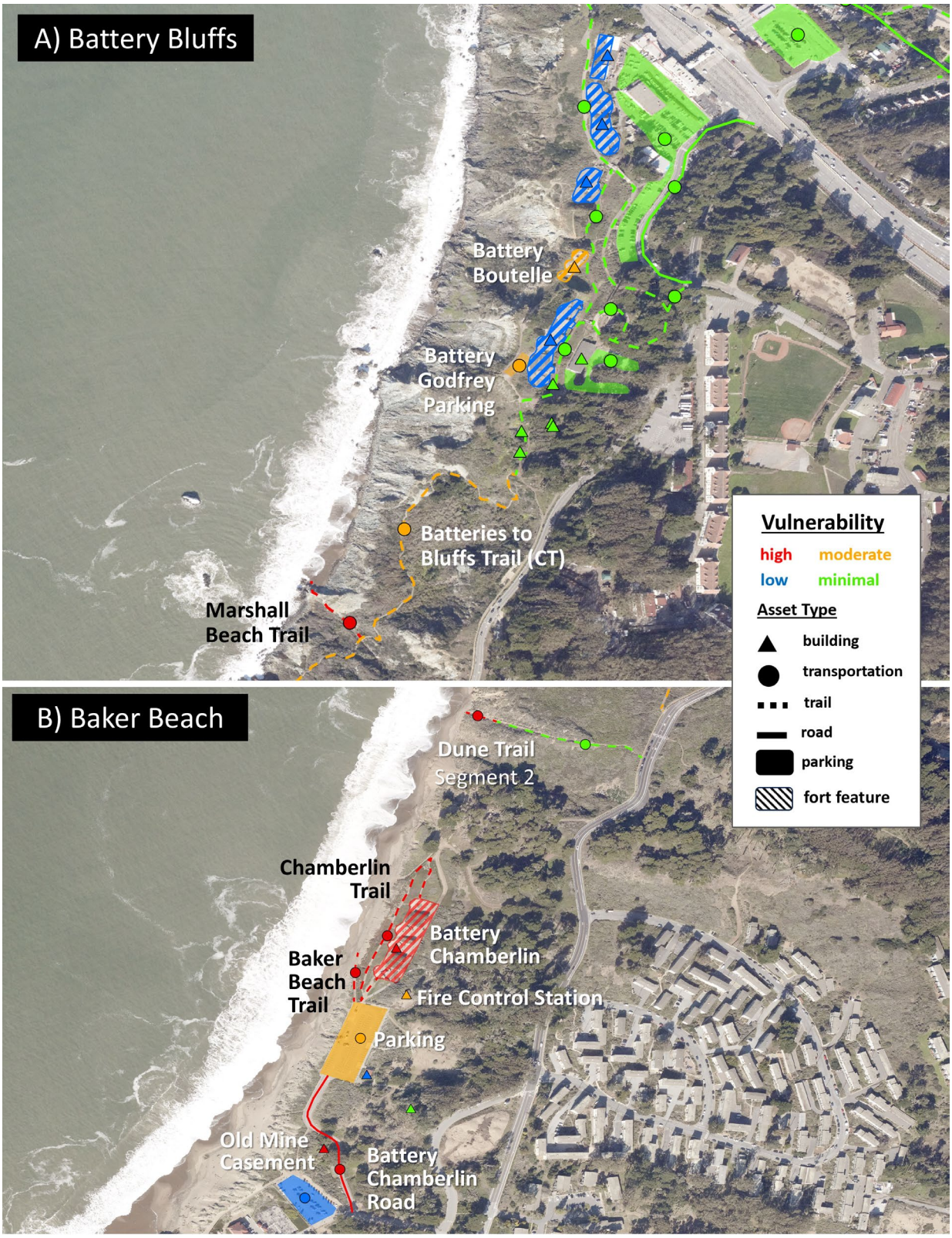

Figure 17. PRSF vulnerability results summary for the A) Battery Bluffs and B) Baker Beach areas. Only high and moderate vulnerability assets are labeled. Background is NOAA NGS 2023 imagery (NGS 2025b).

Figure 18. PRSF vulnerability results summary for the A) Crissy Field: West, B) Crissy Field: East, and C) Inset - Torpedo Wharf areas. Only high and moderate vulnerability assets are labeled. Background is NOAA NGS 2022 imagery (NGS 2025a).

FOPO Vulnerability Results

Six assets at FOPO have high vulnerability to the evaluated coastal hazards, one has moderate vulnerability, and two have low vulnerability (Table 14, and Figure 19). Nine assets at FOPO have minimal vulnerability. Three assets at FOPO have moderate or high vulnerability and the highest possible priority (API=100, as reported in FMSS): Marine Drive, Long Avenue, and Fort Point. Severe damage or loss of Marine Drive would severely hinder park operations and visitor access, as this road provides the only access to fort area.

Table 14. FOPO vulnerability results. Sum of percentages may not equal 100 due to rounding.

	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total
Assets	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**
Buildings	2	40%	0	0%	2	40%	1	20%	5
Transportation	4	31%	1	8%	0	0%	8	62%	13
All Assets	6	33%	1	6%	2	11%	9	50%	18

Figure 19. FOPO vulnerability results summary. Only high and moderate vulnerability assets are labeled. Background is 2022 ESRI Streaming World Imagery.

Vulnerability & Adaptation Efforts

Several recent studies have focused on the climate change vulnerability of natural resources in the Golden Gate region. In 2024, the National Oceanic and Atmospheric Administration (NOAA) released an addendum and update to their 2015 climate change vulnerability assessment of marine resources (habitats, species, and ecosystem services) in the north-central California region (Hutto et al. 2015; Hutto 2024). Using the same methodology, a natural resources vulnerability assessment for the Golden Gate area was completed by EcoAdapt and Golden Gate Biosphere Network (2024) in collaboration with the NPS, assessing the vulnerability and potential adaptation strategies for priority ecosystems and species. Although these studies do not focus on infrastructure directly, park resources are an interconnected system that must be managed collectively. Any adaptation projects completed for natural resources will likely impact other nearby resources, including infrastructure.

For example, GOGA is currently in the process of planning the rehabilitation of all three visitor parking lots (North, Central, South) at Stinson Beach (Figure 10; NPS 2024). A primary goal of this project is to add resiliency and adapt to the increasing intensity and frequency of storms. Project plans incorporate strategies for natural resources, infrastructure, and visitor use. Specific improvements include dune and floodplain/riparian restoration, parking lot realignment, and improved traffic circulation (via better road and parking design). These modifications have the potential to improve the overall resiliency and vulnerability of the parking lots and nearby assets.

GOGA, PRSF, & FOPO Unique Considerations

FMSS assets: We analyzed three assets at GOGA that are not currently listed in FMSS: Sommerville Road Parking, Rodeo Lagoon Parking, and Stinson Beach Boardwalk.

Linear assets: Due to exposure variability, we segmented six roads at GOGA: Fort Funston Service Road (two segments), Alcatraz Road from Wharf to NW End (two segments), Bunker Road (two segments), Conzelman Road (three segments), Tennessee Valley Upper Trail – Service Road (two segments), and Muir Beach Coastal Fire Road (two segments). We also segmented seven trails: South Rodeo Beach Trail (two segments), Kirby Cove Trail (two segments), Fort Baker Bay Trail (two segments), Lands End Trail (four segments), Muir Beach Trail (two segments), and Hill 88 Trail (two segments) at GOGA; and the Dune Trail (two segments) at PRSF.

We evaluated each road or trail 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 or trail, even if only a small portion has high exposure or vulnerability.

Flood potential data: In addition to the effective Federal Emergency Management Agency (FEMA) data for Marin (2017), San Francisco (2021), and San Mateo (2017) counties, we used the United States Geological Survey (USGS) CoSMoS 25 cm SLR plus 100-year flood zone (Limber et al. 2018); Adapting to Rising Tides (ART) 12 inches SLR plus 100-year flood inundation model (ART 2020); and Stinson Beach CoSMoS Data (ESA 2023; Marin County 2023).

Shoreline change data: We used USGS California Shoreline Change Data, 1998-2016 (Barnard et al. 2020) to create erosion buffer zones for GOGA (see Peek et al. 2022 for methodology). We also used 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 GOGA shorelines that do not have erosion rate data, as well as FOPO and PRSF, we used a simple 30-meter proximity buffer.

SLR data: We used two sources for the SLR exposure indicator: 1) National Oceanic and Atmospheric Administration (NOAA) 1-ft SLR model (2022), and 2) NPS 2100 4.5 Representative Concentration Pathway SLR projection and inundation model (Caffrey et al. 2018; 0.42 m or 1.4 ft rise for GOGA). These data are used as a proxy for 2050 SLR to accommodate higher SLR projections recently released by NOAA (see Peek et al. 2022).

Condition data: We used GOGA, PRSF, and FOPO Parametric data (provided by park staff) for the condition indicator of 107 assets.

National Bridge Inventory data: The Point Bonita Suspension Bridge, Rodeo Lagoon Bridge, Easkoot Creek Bridge, and Point Lobos Viaduct at GOGA; and the Crissy Field Channel Bridge at PRSF are in the National Bridge Inventory (NBI), which contains several attributes that were used as additional sensitivity indicators (scour rating, condition, and age). We use a different scoring system (see Peek et al. 2022) for bridges with additional NBI sensitivity indicators.

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