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Gulf Islands National Seashore (GUIS)

Coastal Hazards & Climate Change Asset Vulnerability Assessment Protocol
September 2015

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

Contents

This document has been developed by the National Park Service - Sustainable Operations and Climate Change Branch and Park Facility Management Division Facilities Planning Branch in partnership with Western Carolina University through a Task Agreement with the Southern Appalachian Cooperative Ecosystems Studies Unit. Contributing authors: Katie Peek (kmcdowell@wcu.edu), Blair Tormey (btormey@wcu.edu), Holli Thompson (hthompson@wcu.edu), Robert Young (ryoung@wcu.edu), Shawn Norton (shawn_norton@nps.gov), Ryan Scavo (ryan_scavo@nps.gov), Melinda Koslow (melinda_koslow@nps.gov), and Beth Binns (bbinns@gmavt.net).

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Cover Photo: Program for the Study of Developed Shorelines at Western Carolina University.

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Executive Summary

The National Park Service (NPS) Sustainable Operations and Climate Change Branch, in partnership with Western Carolina University's (WCU) Program for the Study of Developed Shorelines (PSDS), has developed a **Coastal Hazards and Climate Change Asset Vulnerability Assessment Protocol**. This protocol is meant to assess the vulnerability of infrastructure to multiple coastal hazards and climate change factors (i.e., erosion, flooding, storm surge, sea-level rise, and historical flooding), over a 35-year planning horizon (2050). Unlike natural resource vulnerability, which combines three metrics (exposure, sensitivity, and adaptive capacity), the newly developed method for assessing infrastructure includes only exposure and sensitivity to coastal hazards and climate change factors in the vulnerability score; adaptation strategies are instead examined in the context of the vulnerability results. The overall goal is to standardize the methodologies and data used, allowing managers to compare the vulnerability of coastal assets across local, regional, and national levels.

A total of 148 structures and 110 transportation assets were included in the vulnerability assessment at Gulf Islands National Seashore (GUIS). Over three-quarters of the assets analyzed at GUIS are either moderate or high exposure (42% and 39%, respectively). Most high exposure assets are in the low-lying barrier island districts of the park. Over half of the assets at GUIS have a high sensitivity, primarily due to widespread historical flooding and high flood potential (most structures at GUIS are not elevated). The flood potential sensitivity metric was verified by precise threshold elevation data collected by NPS.

The majority of assets at GUIS are highly vulnerable (55%); most of these assets are structures, as 59% of structures fall into this category. A smaller number of assets have low vulnerability (5%), but a significant percentage (15%) of assets have minimal vulnerability (in the minimal exposure zone). While only 48% of transportation assets have high vulnerability, many of these assets provide access to critical resources and infrastructure. For example, the Fort Pickens Road provides the only vehicle access to over 50 assets, including several that are either historically or administratively significant to the park.

Finally, GUIS staff were polled on the feasibility of potential adaptive strategies: elevation, relocation, and protection by engineering. For structures, the option with the greatest potential was relocation (68%), followed by elevation (40%). However, relocation was deemed "easy" for only 9% of structures. For transportation assets, 34% could potentially be relocated, but only 1% could be relocated easily. This presents GUIS with some challenging decisions over the coming decade, including abandoning and removing structures, as well as developing alternate modes of transportation to key assets (i.e. ferry to Fort Pickens).

Vulnerability Assessment Products & Deliverables:

1) Excel datasheets. All results, as well as asset specific scoring, are provided in tabular form. The exposure, sensitivity, and vulnerability scores are reported alongside the FMSS data for each asset, as well as the scores for each step of the analysis. GUIS excel data can be downloaded here (username and password is needed, contact WCU): AGOL GUIS.
2) GIS Maps and Layers. All GIS data, including the exposure layers, exposure results, and final vulnerability results will be sent to the park as a separate file. The GIS data will also be available to view online at the AGOL website.
3) Park Specific Vulnerability Results Summary Document. This document, which explains the deliverables, results, adaptation strategies, and methodology can be downloaded here: AGOL GUIS

Introduction & Project Description

The National Park Service (NPS) Sustainable Operations and Climate Change Branch, in partnership with Western Carolina University's (WCU) Program for the Study of Developed Shorelines (PSDS), has developed a **Coastal Hazards and Climate Change Asset Vulnerability Assessment Protocol**. This protocol establishes a standard methodology and set of best practices for conducting vulnerability assessments in the built environment. Standardizing the methodologies and data utilized in these assessments allows managers to compare the vulnerability of coastal park assets across local, regional, and national levels.

A proposed standardized approach to assessing climate change vulnerability was described in a multiple agency (NOAA, NPS, USGS, DOD, NWF, and USFS) document titled "Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment (Glick et al., 2011)." This document defines the vulnerability of natural resources to climate change as: the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change impacts. Vulnerability under this approach is comprised of three equally weighted metrics or components: exposure, sensitivity, and adaptive capacity:

Vulnerability = Exposure + Sensitivity + Adaptive Capacity

- ✓ **Exposure** refers to whether a resource or system is located in an area experiencing direct impacts of climate change, such as temperature and precipitation changes, or indirect impacts, such as sea-level rise.
- ✓ **Sensitivity** refers to how a resource or system fares when exposed to an impact.
- ✓ **Adaptive Capacity** refers to a resource's or system's ability to adjust or cope with existing climate variability or future climate impacts.

While this formula has been successfully applied to natural systems, some aspects are less appropriate for application in the built environment (i.e., buildings, roads, etc.). For example, structures cannot inherently adapt to climate change or other hazards, while natural resources often can (a salt marsh can adapt to changes in sea level by migrating upland, whereas a building cannot). Therefore, NPS and WCU have modified the methodology and formula for conducting vulnerability assessments of assets within national parks. The new modified formula for the vulnerability of the built environment (assets, infrastructure, buildings, transportation, etc.) is as follows:

Vulnerability = Exposure + Sensitivity

For this methodology, adaptive capacity of an asset is evaluated separately and is not included in the vulnerability score. This does not mean that understanding the adaptive capacity of an asset is not important. The range of adaptation strategies or options available for key vulnerable assets within a national park is the final and perhaps most important step in the overall analysis, as any adaptation actions taken for an asset will help reduce its exposure or sensitivity, which reduces vulnerability.

One goal of this protocol is to standardize methods for evaluating the exposure of NPS assets to coastal hazards and climate change. This includes the standardization of data inputs (i.e. widely available, established data) that will allow the application of a consistent methodology among units. Another goal is to create a more complete and effective set of indicators for assessing the sensitivity of assets to coastal hazards. The focus for this protocol is on structures and transportation assets in the NPS asset database (Facilities Management Software System; FMSS), but it could be adapted to other resources.

GUIS Results Summary & Discussion

A total of **148 structures** (buildings, shelters, forts, batteries, amphitheaters, and towers) and **110 transportation assets** (roads, road segments, parking lots, docks, marinas, seawalls, and waterfronts) were included in the vulnerability assessment at GUIS. The term "asset" will be used in this document to represent any structure or transportation infrastructure listed in FMSS, regardless of ownership. Also, the results for this vulnerability assessment represent a time frame of approximately 35 years (2050).

For this assessment, each asset's exposure and sensitivity was analyzed and scored, then the exposure and sensitivity scores were combined into an overall vulnerability for each asset. More specific methodology for this analysis is described in the final sections of this document. This document provides a general summary of the results for exposure, sensitivity, and vulnerability of structures and transportation assets at GUIS. Specific exposure, sensitivity, and vulnerability scores are reported (alongside FMSS data) for each individual asset in the supplied excel datasheets; exposure and final vulnerability results are also provided as Geographic Information Systems (GIS) maps and layers.

Exposure Analysis:

The most notable result of the exposure analysis at GUIS is that only a few (4%) assets (structures and transportation) have low exposure (Table 1). In fact, the majority of assets are either highly or moderately exposed (39% or 42%, respectively). Most of the high exposure assets are situated on the barrier islands at GUIS, particularly on West Ship and Santa Rosa Islands. A significant number of assets (15%) have minimal exposure, which means that the assets are not within **any** of the exposure hazard zones. Most assets with minimal exposure are located in the Fort Barrancas, Naval Live Oaks, and Davis Bayou areas of the park, where elevations are higher. For the most part, structures and transportation assets have similar exposure rankings, with the largest difference in the minimal exposure category; a much larger percentage of structures are minimally exposed compared to transportation assets (22% and 5%).

Table 1. GUIS Exposure Results Summary. Due to rounding, sum of percentages may not equal 100

Assets	High Exposure		Moderate Exposure		Low Exposure		Minimal Exposure		Total #
	#	%	#	%	#	%	#	%	
Structures	49	33%	65	44%	2	1%	32	22%	148
Transportation	51	46%	44	40%	9	8%	6	5%	110
All GUIS Assets	**100**	**39%**	**109**	**42%**	**11**	**4%**	**38**	**15%**	**258**

The wide range of exposure rankings (high to minimal) for assets at GUIS is primarily due to the widespread geographic nature of the park. The park stretches from east to west over 150 miles, encompassing a variety of elevations and environments (barrier island, upland, marsh, bayou, etc.), resulting in variable exposure.

Sensitivity Analysis:

Overall, the assets at GUIS are split between high sensitivity (52%) and moderate sensitivity (47%), with less than 1% low sensitivity (Table 2). Due to minimal exposure rankings, 38 assets were excluded from the sensitivity analysis (if an asset has minimal exposure, it has minimal vulnerability, regardless of sensitivity). When separated into structures and transportation, the sensitivity scores of GUIS assets are noticeably different. The majority of structures (69%) at GUIS have high sensitivity, whereas the majority of transportation assets (62%) have moderate sensitivity (Table 2).

Table 2. GUIS Sensitivity Results Summary. Due to rounding, sum of percentages may not equal 100.

Assets	High Sensitivity		Moderate Sensitivity		Low Sensitivity		Total # Analyzed	Excluded* (min. exposure)
	#	%	#	%	#	%		
Structures	80	69%	35	30%	1	1%	116	32
Transportation	35	32%	68	62%	1	1%	104	6
All GUIS Assets	**115**	**52%**	**103**	**47%**	**2**	**1%**	**220**	38

*Assets with minimal exposure (in no hazard zone) were excluded from the sensitivity analysis. Total # analyzed is different for sensitivity compared to exposure and vulnerability.

The vast majority of assets at GUIS have either moderate or high sensitivity. The greater sensitivity of assets at GUIS can largely be attributed to high flood damage potential and widespread historical damage. A number of assets at GUIS are built at ground level, making them susceptible to floods, as evidenced by the large number of assets that suffered damage during recent storms (i.e., Katrina, Ivan).

The Government Boat Dock Parking Lot at Davis Bayou is the only transportation asset with low sensitivity. The main factors contributing to this include its storm-resistant construction, good condition, lack of historical damage, and protection by an engineered structure. The Paint Building at Fort Pickens is the only structure at GUIS that has a low sensitivity. Assets that were in no exposure hazard zone (minimal exposure) were not evaluated for sensitivity (Table 1, Table 2).

Threshold Elevation Data Collection at GUIS

Threshold elevation data collected by the NPS Resource Information Services Division (RISD) were also included in the sensitivity analysis. Ideally, elevation of an asset would be compared to the Federal Emergency Management Agency's (FEMA) Base Flood Elevation (BFE), and the precise threshold elevations acquired by RISD make this comparison possible. This aided in the determination of more reliable elevation indicators for assets at GUIS.

The precise threshold elevation verifies the first metric (flood damage potential) within the sensitivity analysis. This elevation was compared to local BFE for each asset to determine if the asset's primary threshold was above or below BFE (Figure 1). In general, if an asset is above BFE and also elevated by design, it received a favorable score for the flood damage potential

Location	Flood Damage Potential (Elevated) (Q1)	Threshold Elevation (m, NAVD88)	BFE (m, NAVD88)	Above/Below BFE
FP Paint Building (FL10) (LCS 07472)	1	3.284	3.026	Above
0F4 FP Captains House (FL04) (LCS 07460)	1	3.468	3.026	Above
FP Cultural Office Building (FL03) (LCS 07461)	1	3.096	3.026	Above
00000KC4 DB Katrina Cottage #4	1	6.067	4.890	Above
PK Picnic Shelter West (FL 73)	1	4.802	3.334	Above
PK Picnic Shelter East (FL77)	1	4.771	3.334	Above
PK Star Pavilion (FL 70)	4	3.749	3.334	Above
PK Entrance Station (FL69)	4	4.003	3.334	Above
PK Lifeguard Building Cluster (FL72 & 74)	4	3.818	3.334	Above
PK Maintenance Building (FL71)	4	3.344	3.029	Above
PK Ranger Station Cluster (FL76 & 78)	4	3.953	3.334	Above
FP Mine Loading Room/Welding Shop (FL15) (LCS 07469)	4	1.433	3.026	Below
FP Mine Storeroom/Warehouse (FL16) (LCS 07470)	4	1.081	3.026	Below
FP Mining Casements/Restroom (FL09) (LCS 07473)	4	1.788	3.026	Below
SR Portable Lifeguard Station Tower	1	2.301	3.933	Below
Fort Pickens Fort (LCS 07459)	4	1.609	3.026	Below
DB Gov't Boat Dock Office (MS 19)	4	1.802	5.499	Below
DB Hazardous Material Storage #2	4	1.897	5.804	Below
DB Hazardous Material Storage #1	4	1.897	5.804	Below
5FP Battery Trueman (LCS 05417)	4	2.041	3.026	Below
FP Battery Cullum/Sevier (LCS 05420)	4	1.366	3.026	Below
FP Battery Payne (LCS 05416)	4	1.185	3.026	Below
FP Battery Pensacola (LCS 05411)	4	1.790	3.026	Below
FP Battery Van Swearingen (LCS 05420)	4	1.245	3.026	Below
SR Maintenance/ Ranger Station (FL67)	1	2.204	3.323	Below
0F2 FP Officers Quarters/Housing (FL02) (LCS 07462)	4	2.745	3.026	Below
5FP Visitor Center (FL38)	4	1.924	3.026	Below
F1A FP Cottage (FL01A&B) (LCS 07465)	4	2.877	3.026	Below
F7A & F7B FP Quarters/Housing (FL07 A&B) (LCS 0746)	4	2.873	3.026	Below
F8A & F8B FP Quarters/Housing (FL08 A&B) (LCS 074)	4	2.772	3.026	Below
FP Battery Van Swearingen RR (FL18) (LCS 07474)	4	2.311	3.026	Below
FP Campground Restroom A (FL24)	4	2.150	3.331	Below
FP Campground Restroom C (FL23)	4	2.751	3.026	Below
FP Campground Restroom E (FL22)	4	2.289	3.026	Below
FP Chlorinator/Well #1 Head Building (FL13)	4	1.820	3.026	Below
FP Curatorial/Warehouse (FL17) (LCS 07468)	4	1.537	3.026	Below
FP District Office (FL05) (LCS 07466)	4	2.772	3.026	Below
FP Firehouse Concession/Restroom (FL06) (LCS 07467)	4	2.226	3.026	Below
FP Jetties Restroom (FL37)	4	2.335	3.026	Below
FP Pump Plant/Field Office (FL11) LCS 07471)	4	1.900	3.026	Below
FP Well #2 Building (FL14)	4	2.905	3.026	Below
DB Gov't Boat Dock Shelter (MS20)	4	1.201	5.499	Below
DB Marina Restroom (MS 25)	4	1.607	5.499	Below

Figure 1. Snapshot of sensitivity results for GUIS, including the flood damage potential metric and threshold elevation analysis.

sensitivity metric. More specific methodology for verifying and using these data can be found in the methods section of this document.

This comparative analysis led to revised elevation metrics for several assets, including the Paint Building at Fort Pickens, mentioned earlier as the only low sensitivity structure. Because this building has a threshold that is elevated above the ground, it has a high enough elevation to be above FEMA's BFE. Therefore, the score for the Paint Building was revised based on these results. Other assets that were revised based on the elevation data include the Captains House and Cultural Office Building at Fort Pickens (Figure 1).

Vulnerability Analysis:

A majority (55%) of assets at GUIS have high vulnerability (Table 3). This is not surprising, as sandy, low-lying barrier islands are regularly subjected to multiple coastal hazards, and by nature shift and change through time. Building infrastructure within this type of environment will inherently lead to higher exposure and, therefore, higher vulnerability. In fact, most of the barrier island assets (e.g., Fort Pickens, Santa Rosa, Okaloosa, Perdido Key, West Ship Island, Horn Island, and Cat Island) are highly vulnerable, and the remaining assets from these areas are moderately vulnerable.

Table 3. GUIS Vulnerability Results Summary. Due to rounding, sum of percentages may not equal 100

Assets	High Vulnerability		Moderate Vulnerability		Low Vulnerability		Minimal Vulnerability		Total #
	#	%	#	%	#	%	#	%	
Structures	88	59%	25	17%	3	2%	32	22%	148
Transportation	53	48%	42	38%	9	8%	6	5%	110
All GUIS Assets	**141**	**55%**	**67**	**26%**	**12**	**5%**	**38**	**15%**	**258**

Almost two-thirds of the structures at GUIS are highly vulnerable. In fact, the only area of the park that does not have any highly vulnerable structures is Fort Barrancas. Many of the high vulnerability structures at GUIS are historic, located in high exposure areas, and have high sensitivity due to construction/engineering (e.g. Fort Pickens, Davis Bayou structures). However, it should be noted that most structures within the barrier island areas of Okaloosa, Santa Rosa, Perdido Key, West Ship, Horn Island, and Cat Island are of modern construction, but are also highly vulnerable. While options for reducing the vulnerability of historic structures are often limited, the vulnerability of modern structures can be reduced by addressing exposure and sensitivity during planning and construction.

Although a smaller percentage of transportation assets are vulnerable compared to structures (Table 3), many high vulnerability roads also have a high priority, as they provide critical access to numerous NPS resources. For example, many segments of the Fort Pickens Road have a high exposure and vulnerability; this road provides the only vehicle access to over 50 assets and resources (and the entire west end of the island), including many that are historically or administratively important (Figure 2). Therefore, any asset along this road is at risk of becoming inaccessible, particularly following major storm and erosional events. Even if a structure in the Fort Pickens district has low or moderate vulnerability, it may be inaccessible due to the high vulnerability road. These accessibility issues give more weight, in many cases, to the vulnerability of transportation assets at GUIS. Figure 3 shows examples of the vulnerability results from GUIS.

Figure 2. Asset vulnerability near Fort Pickens. Fort Pickens Road (lines) is the sole vehicle access to the structures at the west end of the island (pins). Red is high vulnerability, orange is moderate.

Over half of the assets at GUIS have high vulnerability using this methodology (Table 3, Figure 3). However, there are several important caveats to the assessment and results at GUIS:

1) This methodology is meant to assess the vulnerability of a park to multiple coastal hazards and climate change factors combined (i.e., erosion, flooding, storm surge, sea-level rise, and historical flooding; see indicator list in methodology section). Therefore, a park or section of park (like the barrier islands of GUIS) that has maximum exposure to one or more of these factors (i.e., surge) will inherently have a higher overall vulnerability.

2) This protocol was also developed as a means to compare vulnerability among all coastal parks, which are often environmentally distinct from one another. As previously discussed, GUIS stretches for more than 150 miles (from east to west) across multiple coastal environments, and thus has a wide variety of exposure levels within the park. Also, GUIS has several small barrier islands (like West Ship Island) that are miles offshore that already have an extremely high exposure to coastal hazards. Any assets with this amount of exposure will definitely have a high vulnerability over the next 35 years.

3) A major goal of this protocol is to create a standard protocol for vulnerability assessments, regardless of the data utilized. Therefore, as higher quality data become available for the metrics of vulnerability (exposure and sensitivity), the final rankings for these assets may change. In these cases, the same protocol will be used, but new more precise data can be utilized, increasing the reliability of the vulnerability results (see Update to Sea-Level Rise Data, p.14).

4) Access to several GUIS assets is also dependent on transportation corridors that are not owned or managed by NPS (e.g., Gulf Breeze Parkway, Pensacola Beach Road, and the Pensacola Bridge). Some low or moderate vulnerability assets could be safe from flooding (and sea-level rise), but completely inaccessible by road. Other coastal parks have similar issues that relate to ownership or jurisdiction of the transportation leading to NPS-owned assets and resources, necessitating coordination (i.e., additional collaborative vulnerability studies) with regional stakeholders, land owners, and partners.

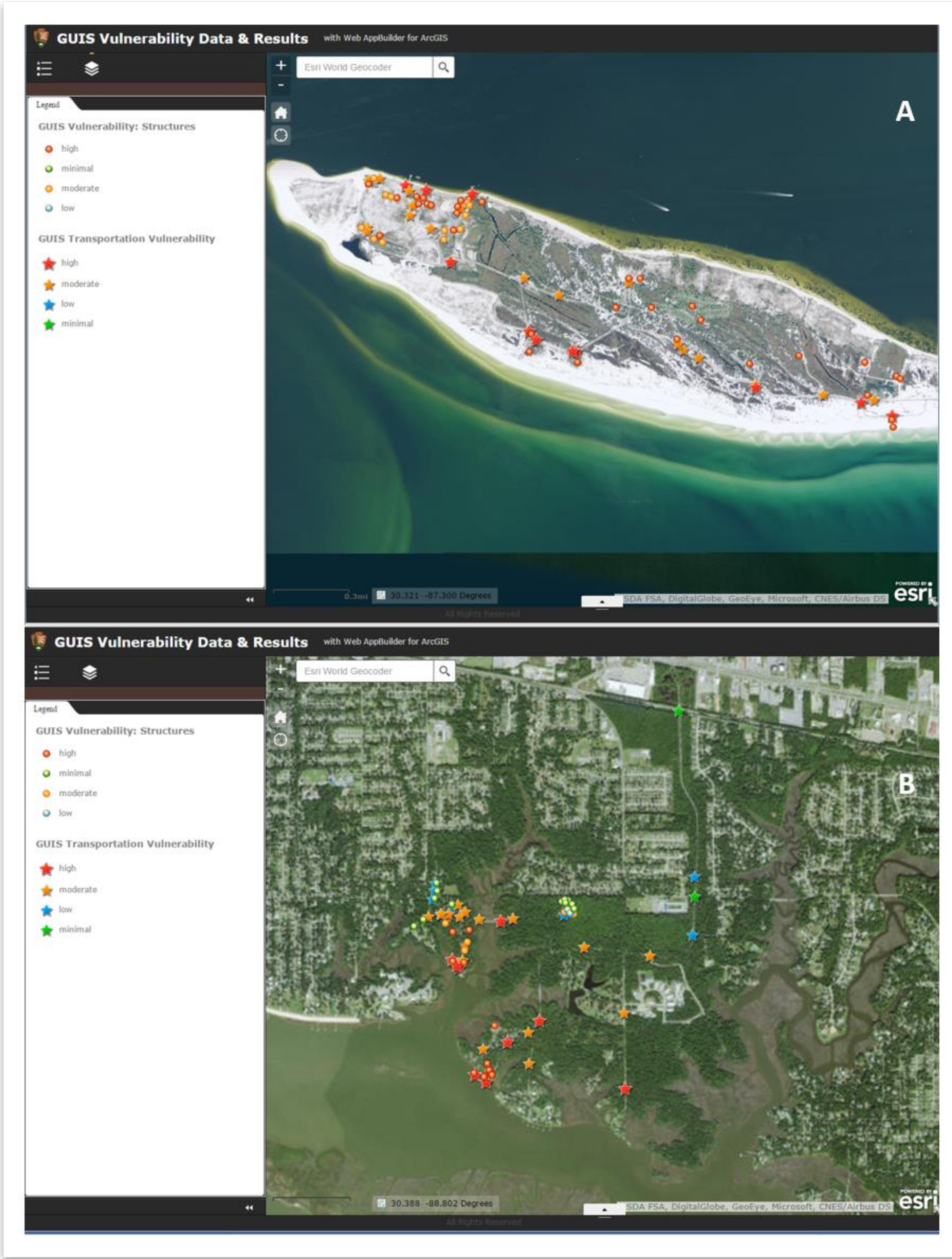

Figure 3. Example of mapped vulnerability results for GUIS assets. A) Fort Pickens District in Florida, and B) Davis Bayou District in Mississippi.

GUIS Adaptation Strategies & Planning

Adaptation Strategies:

Due to the timing of the GUIS Climate Friendly Park (CFP) workshop and questionnaire completion, a limited number of adaptive strategies were examined (compared to those listed in Table 8, methodology section). These include: whether an asset could potentially be elevated (structures only), relocated, relocated easily, or protected by engineering. Below is a brief description of the questions asked of the GUIS staff for each adaptive strategy.

- **Potential to Elevate**: Could the asset be elevated (without considering monetary restrictions)?
- **Potential to Relocate**: Could this asset never be relocated due to reasons such as: 1) the asset is of such an extreme size it would never be feasible to physically relocate, 2) the asset must be in its exact location due to historical or cultural restrictions, or 3) there is no available NPS-owned space to relocate the asset?
  - **Easy to Relocate**: Is the asset designed/constructed in a manner that would allow simple relocation? This is a follow up to the potential to relocate question.
- **Potential to Engineer**: Are any of the following assets likely to be protected by a seawall (or other engineered structure/landscape modification) if damaged or threatened by coastal hazards? *Consider criticality, historical significance, visitor experience, natural/cultural resource protection, and park mission.

Potential to Elevate:

Due to high flood potential and a significant history of flooding within the park, elevating structures at GUIS could potentially reduce the vulnerability of many key structures. Over one-third of structures were reported as having the potential to be elevated (40%, Table 4), and many of these assets have high priority and substantial day-to-day administrative use. For example, the Fort Pickens area District Office, Lifesaving Station, and Captains House, the Perdido Key Ranger Station Cluster, and the West Ship Island Administration Office/Public Restroom all have high Asset Priority Index (API) values (≥ 70), and were indicated as having the potential to be elevated (Table 5).

Table 4. Summary Statistics for Potential Adaptive Strategies. Results from questionnaire.

Asset Type	Potential to Elevate	Potential to Relocate	Easy to Relocate	Potential to Engineer
Structures	40%	68%	9%	35%
Transportation	n/a	34%	1%	13%

Potential to Relocate:

Results from the GUIS questionnaire also show that over two-thirds of structures have the potential to be relocated (Table 4). Primarily, structures designated as “easy to relocate” were those that were designed to be mobile, such as the Katrina Cottages at Davis Bayou (on wheels) and the Portable Lifeguard Station Towers. For transportation, only 34% were designated as having the potential to be relocated, and only 1% as easy to relocate (one boat ramp). Relocating most of these assets would likely be difficult, due to numerous factors, including logistical, engineering, fiscal, political, historical/cultural, or natural resource concerns.

Although many restrooms and picnic shelters at GUIS were listed as difficult to relocate (Table 5), there was discussion at the CFP workshop about the likelihood of replacing these assets after a storm. For example, the Picnic Shelters at Santa Rosa (large, heavy duty concrete structures) will not likely be replaced in the same manner when destroyed or damaged. The park noted that although many of these assets have strong construction, they are threatened by erosion and have been undermined in the past. A plan to abandon/remove or significantly redesign these structures once they are eventually damaged might be the most prudent course of action for the park.

Many of the structures reported to have no relocation potential are historical or culturally significant. For example, the Fort Pickens area Captains House, District Office, Lifesaving Station, and the Range Finding Tower, as well as the CCC Cabins at Davis Bayou and Fort Massachusetts, were all listed as assets that could never be relocated (Table 5); all of these are historic and are part of the NPS List of Classified Structures (LCS) (inventory of all historic and prehistoric structures that have historical, architectural, and/or engineering significance within parks).

The primary road (Fort Pickens Road) accessing the Fort Pickens district has high vulnerability and priority, and many sections of this road were reported as having no relocation potential. This may (in part) be due to a lack of suitable land for relocation, as the barrier island is narrow and the road sits adjacent to sensitive beach and dune environments. As coastal hazards increase and sea level rises, it may no longer be feasible to use this road to access this area of the park. This, in combination with the impracticality of relocating Fort Pickens (and related assets), may eventually lead to a need for an alternative mode of transportation for reaching this area (i.e., a ferry system). In fact, several other NPS-owned roads at GUIS are similarly positioned, including J Earle Bowden Road at Santa Rosa and Johnson Beach Road at Perdido Key. Both roads have highly exposed segments (at least 50% of their length) and provide significant access to resources and visitor sites within the park. While an alternative mode of transportation may not be imminent, major adaptation actions will likely be necessary in the next decade. Therefore, it would be beneficial to have plans in place for these changes, as the Fort Pickens area is a popular destination for visitors to GUIS.

Table 5. Example of Adaptation Strategies for Structures/Buildings: Results from questionnaire.

	Assets		Potential Adaptation Actions				
	Name	Vuln.	Elevate	Relocate	Relocate Easily	Engineer	API/OB
Florida	SR Picnic Shelters (all)	H	Y	Y	N	N	39/3
	SR Restrooms (all)	H	Y	Y	N	N	50/3
	FP Captains House	M	Y	N	N	Y	85/1
	FP District Office	H	Y	N	N	Y	100/1
	FP Lifesaving St.	H	Y	N	N	N	100/1
	FP Range Finding Tower	H	Y	N	N	N	85/1
	PK Ranger Station Cluster	H	Y	Y	N	N	70/1
	PK Star Pavilion	H	Y	Y	N	N	39/3
	NLO HQ/VC	H	N	Y	N	N	80/1
	NLO Group Camping Rest.	M	Y	Y	N	N	41/3
Mississippi	WSI Fort Mass.	H	N	N	N	Y	85/1
	WSI Admin/Public Rest.	H	Y	Y	N	N	73/1
	DB Katrina Cottages (all)	M	Y	Y	Y	N	30/4
	DB CCC Cabins (both)	H	N	N	N	N	36/5
	DB Marina Restroom	H	N	Y	N	N	63/2
	DB VC/HQ	H	N	Y	N	N	81/1
	HI Generator Building	H	Y	Y	N	N	42/4

Potential to Engineer:
More than one-third of GUIS structures were listed as likely to be protected by engineering in the future. Many of these assets may be protected by engineered structures, such as the Fort Pickens seawall, while others might employ “soft” engineering, like the beach nourishment and dune stabilization at Fort Massachusetts (Table 5). Only 13% of the transportation assets analyzed were deemed likely to be protected by engineering in the future.

<u>Adaptation Planning</u>
GUIS has begun the process of reflecting on ways to integrate the results of the vulnerability assessments into park planning. Below is a list of key questions from the workshop, along with the park responses and suggestions.

<u>1. Was this type of climate change/hazard information used in the past?</u>

A. General Management Plan (GMP): Brand new GMP was released this winter, did take into account a small amount of climate change information, but not this extensive.

B. Design Advisory Board (DAB): There is currently a protocol (related to hazards and climate change) for projects that go through DAB (projects > $500,000). However, what about projects that do not meet that $500,000 threshold? Potentially use this type of product for projects that are not part of the DAB.

<u>2. How could this vulnerability assessment be integrated into planning?</u>

A. Upcoming projects: Potentially could be used for upcoming projects. One interesting note about the exposure data for roads is that when plotted at 0.1 mile points (presented during meeting), the red areas (high exposure) are the exactly location where the road realignment is focused.

B. Storm Response: This assessment could potentially help make decisions post-storm. For example when an asset is destroyed/damaged by a storm, should GUIS replace-in-kind, replace with something different, or do not replace at all? Each project can be evaluated based on the checklist.

C. Future Projects: Raw exposure map layers could be used for future projects, by reviewing if the location is in any of these hazard layers.

D. Other Existing GUIS Planning Documents: Potentially could also be used in incident response plan (5 year plan) and natural resources management plan. Perhaps development plans? Foundation document: call it something like climate change and adaptive strategies to help justify what they are doing.

Unique Factors & Considerations for GUIS

Geomorphologic & Geographic Challenges:

GUIS has a unique set of geographic and geomorphic challenges for conducting a vulnerability assessment. The park has assets in two non-contiguous states (Alabama separates the Florida and Mississippi assets), and the distance between the assets from east to west is over 150 miles. Also, a significant portion of assets are located along rapidly changing barrier island shorelines (Fort Pickens, Santa Rosa and Mississippi island areas). Both the sea-level rise and storm surge models utilize data that represent a snapshot in time for shoreline position and elevation within the park. The models use the National Elevation Dataset, which should be "updated continually to integrate newly available, improved elevation source data." Due to the widespread nature of the assets at GUIS, the sources within this dataset are variable across the park (e.g., year acquired, raw data vendor, and methods). In some locations, the data sources may be several years old, and can quickly become outdated as the barrier island migrates and changes. This is especially true if the area experiences a major erosion or storm event, as these events can completely reconfigure a barrier island's shoreline and topography.

Storm Surge Data:

The SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model that is utilized for the storm surge indicator uses a composite of several thousand model runs with differing storm conditions each time to predict surge. There are two products of this: the Maximum Envelope of Water (MEOW), which is a set of worst case scenarios for certain characteristics like storm category, speed, trajectory, and tide level; and the Maximum of the Maximum Envelope of Water (MOM), which is the worst of all potential scenarios modeled. Therefore, the surge data included in the exposure analysis (the SLOSH MOM) represents the maximum *potential* surge conditions of a Category 3 storm at GUIS.

However, in a few cases, the surge layer did not show inundation for extremely problematic areas of the park (e.g., areas with high rates of erosion, flooding, and overwash). For example, only a few assets were included in the raw surge data layer at Opal Beach near Santa Rosa (Figure 4). This area is located on a narrow portion of the barrier island (< 0.25 miles wide) that has had multiple episodes of flooding, overwash, and erosion in recent years (Figure 5). Therefore, adjustments were made to the scores based on additional factors, such as park geomorphology and discussions with NPS. In the case of Opal Beach area, all assets were adjusted to a **high exposure** score.

Figure 4. Opal Beach recreation area of GUIS, with the SLOSH model data for a category 3 storm (purple shaded). Notice a significant portion of assets are not included in this modeled zone.

Sea-Level Rise Data:

The NPS-specific sea-level rise layer used for the exposure analysis in this study is a "bathtub" inundation model that projects sea-level rise in the park to the year 2050 (intermediate projection). It is largely derived from the seamless National Elevation Dataset for the park and doesn't take into account engineered protective structures (e.g. seawalls), which could change the effects of sea-level rise. Also, for some areas, this sea-level rise model (over the short-term) showed little to no change when compared to the most recent aerial imagery. This is likely a factor of the age of the elevation data, as well as the rapid shifts in shoreline position in many areas (Figure 5). A newer and more complex model is in the final stages of development by the NPS Climate Change Response Program (CCRP). This new improved dataset could potentially alter the exposure of assets at GUIS to sea-level rise.

Update to Sea-Level Rise Data, September 2015:

Preliminary results from a new sea-level rise model provided by the CCRP have been incorporated into the GUIS exposure and vulnerability results as of September 2015. These data have been compared to the previous sea-level rise data, and changes to the results have been completed. The sea-level rise exposure metric results were altered for five assets based on the new model.

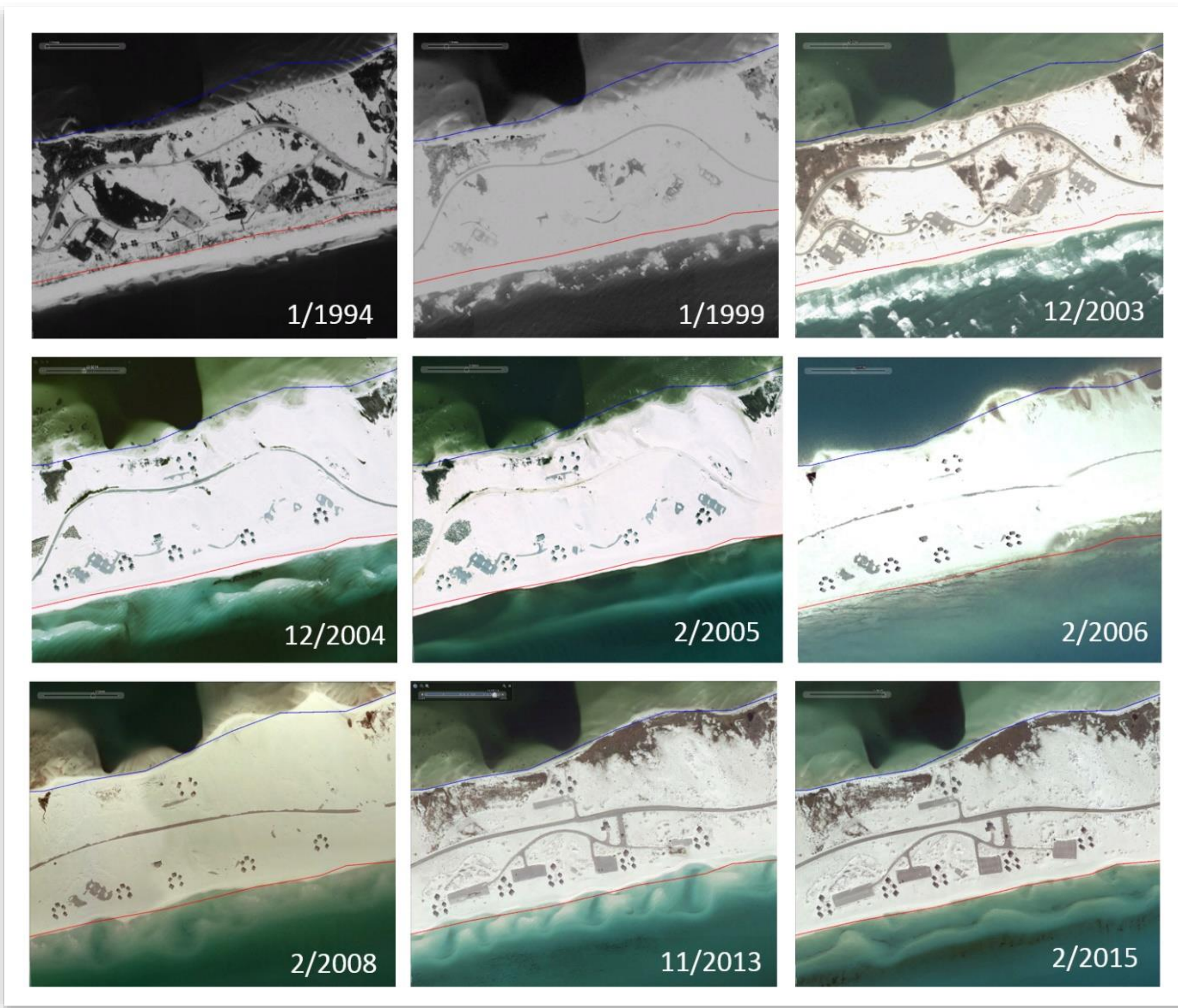

Figure 5. Changes at Opal Beach recreation area of GUIS over time. The red and blue lines represent the ocean front and estuarine shorelines from the 2015 aerial imagery.

Erosion Buffers & Coastal Proximity Data:
Erosion rate data were acquired from the U.S. Geological Survey, Coastal and Marine Geology Program (http://coastal.er.usgs.gov/shoreline-change/). Where available, the short-term erosion rates (data from the 1970's to 2004) were utilized to make buffer zones for a 35-year time frame. Rates were binned into the following categories before buffering: 1m/year, 2m/year, 4m/year, 6m/year, 8m/year, etc. (continuing increments of 2m). For shorelines without erosion rate data (ocean or estuarine), a simple "coastal proximity" buffer was applied. The erosion buffers and the proximity buffers combined make up this exposure indicator zone at GUIS.

Roads at GUIS:
Due to the barrier island nature of the park, several of the roads at GUIS are long and linear in nature (e.g., Fort Pickens and SR J Earle Bowden Roads). In order to acquire sensitivity data for the roads at GUIS, roads were divided into segments. These segments were based on several factors, primarily exposure level and connectivity/access to other park assets. A total of eight roads were divided into segments; the two roads with the most segments were the Fort Pickens (8) and SR J Earle Bowden (5) roads. Portions of some road segments were both inside and outside of an exposure zone (for example, only part of a road may intersect the FEMA VE zone). In these cases, a judgment call was made using the approximate percentage of the road within the zone, as well as the location of the hazard (if the hazard is only present at the terminus of the road, or intersects in the middle of the road).

Methodology of Vulnerability Assessment

The **Coastal Hazards and Climate Change Asset Vulnerability Assessment Protocol** has four primary steps:

1) Exposure Analysis and Mapping
2) Sensitivity Analysis
3) Vulnerability Analysis
4) Adaptation Strategies Analysis

Step 1: Asset Exposure Analysis & Mapping
The first step in the protocol is to analyze the exposure of NPS assets to coastal hazards and climate change. Standard exposure indicators have been determined by WCU; these indicators represent the primary factors or hazards that should be evaluated to determine an asset's exposure (to the year 2050). The five general exposure indicators are: flooding potential, extreme event flooding, sea-level rise inundation, shoreline change, and reported coastal hazards. The goal of this methodology is to standardize the data sources for exposure analysis, using widely available and regularly updated sources (when possible). Table 6 summarizes these indicators, as well as common data sources for each.

Table 6. Exposure Indicators for Asset Coastal Hazards and Climate Change Vulnerability

	Exposure Indicator	Common Data Sources
☑	**Flooding Potential** 1% annual flood chance ± velocity/waves	FEMA Flood Zones (VE or AE); LiDAR DEM or other elevation model
☑	**Extreme Event Flooding** storm surge, tsunami, extreme high water	NPS-specific SLOSH model; tsunami models; tide gage recorded extreme high water data
☑	**Sea-Level Rise Inundation** 2050 projection	NPS-specific SLR modeling; LiDAR DEM or elevation other model
☑	**Shoreline Change** erosion, coastal proximity, cliff retreat	State or USGS erosion rate buffers; cliff retreat rate buffers; shoreline proximity buffers
☑	**Reported Coastal Hazards** historic flooding, visible slope instability	Park surveys/questionnaire results; storm imagery & reconnaissance

The exposure analysis utilizes data imported into Geographical Information Systems (GIS) format, as exposure is directly dependent on location and mapped hazard data (whether the area experiences the hazard). Digital hazard data are gathered for each of the exposure indicators, such as the online georeferenced FEMA flood map layers. The only dataset that does not come from a widely available, well established source is the reported coastal hazards layer, which is derived from storm imagery, reconnaissance, and direct communication with park personnel. Each exposure data layer thus represents an exposure indicator hazard zone for a particular park. Assets that are located within a particular zone are assigned a higher score than assets located outside of the hazard zone.
The following sections describe the specific methods, scoring, and common data sources of each exposure indicator.

Flooding Potential:
The flooding potential indicator describes hazards related to the 1% annual flood chance, including waves and water velocity. For most parks, data for this exposure indicator comes from FEMA's digital flood maps (https://msc.fema.gov/portal/search). Two primary FEMA flood zones are utilized: the VE and AE zones (and sometimes the A, AO, or AH). According to FEMA, the VE zones are areas subject to inundation by the 1-percent-annual-chance flood event, with additional hazards due to storm-induced velocity wave action, and the AE zones are areas subject to inundation by the 1-percent-annual-chance flood event (determined by detailed methods). For a further description of the FEMA flood zones, including the other A zones, see FEMA's website: http://www.fema.gov/flood-zones.

If an asset is within the AE (or other A) zone, it receives an unfavorable score (4) for the flooding indicator. Any asset within the VE zone (the highest hazard zone) receives an unfavorable score for the flooding indicator, and is also assigned an automatic high score for exposure overall. Assets in neither flood zone receive a favorable score (1) for this indicator. Within some parks the FEMA data is incomplete; in these cases, other elevation data sources (such as LiDAR DEMs) are used to supplement the FEMA data.

Extreme Event Flooding:
The extreme event flooding indicator captures flooding from major storms, tsunami, and other extreme high water events. **Storm surge** is the primary extreme event flooding that occurs within parks along the east and gulf coast of the U.S. The data source for storm surge is a NOAA surge

inundation model: Sea, Lake, and Overland Surges from Hurricanes (SLOSH; more information: http://www.nhc.noaa.gov/surge/slosh.php). The SLOSH model uses a composite of several thousand model runs with differing storm conditions each time to predict surge. There are two products of this: the Maximum Envelope of Water (MEOW), which is a set of worst case scenarios for certain characteristics like storm category, speed, trajectory, and tide level; and the Maximum of the Maximum Envelope of Water (MOM), which is the worst of all potential scenarios modeled. The surge data included in the exposure analysis (the SLOSH MOM for a category 3 storm) represents the maximum potential surge conditions. SLOSH storm surge data for this protocol was supplied by the NPS Climate Change Response Program (CCRP).

For parks that are not subject to tropical storms and surge (primarily west coast parks), an alternative extreme event flooding hazard is evaluated, commonly either modeled **extreme high water** events or modeled **tsunami** hazard zones. Data for extreme high water events were provided by CCRP; these data map historic patterns of extreme high water events based on tide gage information. The source of the tsunami hazard data is variable, but commonly comes from state agencies or universities.

If an asset falls within the mapped category 3 storm surge zone, extreme high water zone, or the tsunami hazard zone, it receives an unfavorable score (4) for the extreme event flooding indicator. If it lies outside of these zones, it receives a favorable score (1) for this indicator.

Sea-Level Rise:
The sea-level rise indicator describes the potential rise in water within parks by the year 2050. The data source for this exposure indicator is a NPS-specific sea-level rise inundation model provided by the NPS CCRP. The estimated inundation extent was achieved by utilizing a modified bathtub approach as developed by NOAA, and attempts to account for local and regional tidal variability and hydrological connectivity. Polygon extents consist of 4 model-run scenarios using sea-level change maps produced by Colorado Center for Astrodynamics Research at the University of Colorado in Boulder. The maps are based on Representative Concentration Pathways (RCP), which are four greenhouse gas concentration trajectories. Two RCPs were modeled, a moderate RCP, 4.5 and the most extreme RCP, 8.5. Each RCP was projected to the years 2050 (condition used for this protocol) and 2100. One caveat of these data is that the model does not incorporate local land level change (subsidence or uplift). For many parks this is not a problem, as this change is relatively small compared to the amount of predicted water level rise. However, the sea-level rise data in parks with high rates of subsidence (parks in southern Louisiana) or uplift (many Alaska parks) will require adjustment.

If an asset falls within the mapped 2050 SLR zone, it receives an unfavorable score (4) for the sea-level rise indicator. If it lies outside of the mapped SLR zone, it receives a favorable score (1).

Shoreline Change:
For most parks, particularly those along the U.S. East and Gulf coasts, shoreline **erosion** buffers are created using known erosion rate data. These data are commonly acquired from the U.S. Geological Survey, Coastal and Marine Geology Program (http://coastal.er.usgs.gov/shoreline-change/) or from state coastal management programs. Short-term erosion rates (usually data ranging from the 1970's to 2004) are utilized to make buffer zones for a 35-year time frame. Rates are binned into the following categories before buffering: 1m/year, 2m/year, 4m/year, 6m/year, 8m/year, etc. (continuing increments of 2 meters).

Many national parks along the west coast of the U.S. contain steep cliff shorelines. In some cases, these shorelines are retreating significantly due to cliff erosion; this is particularly true of areas comprised of unconsolidated materials (sands and gravels) or loosely consolidated bedrock (commonly sedimentary rock). In these cases, cliff retreat data will be utilized in place of erosion rate data (when available). Like erosion rates, the cliff retreat rates are utilized to make **cliff retreat** buffer zones for a 35-year time frame (2050). Below 1 meter, retreat rates are binned into detailed increments, with categories of: 0.25m/year, 0.5m/year, 0.75m/year, and 1m/year, and the same categories as shoreline erosion for rates above 1 meter: 1m/year, 2m/year, 4m/year, 6m/year, 8m/year, etc. (increments of 2 meters).

For shorelines without erosion or cliff retreat rate data (ocean, estuarine, or developed areas), a simple **coastal proximity** buffer is applied. The coastal proximity buffer distance used is 35 meters, which can accommodate an erosion rate up to 1m/year, and can account for the fact that infrastructure close to the shoreline is highly likely to experience a range of coastal hazards within the 35 year (2050) timeframe of this analysis.

If an asset falls within the erosion, cliff retreat, or coastal proximity buffer zone, it receives an unfavorable score (4) for this indicator. If it lies outside of these zones, it receives a favorable score (1).

Reported Coastal Hazards:
All of the other exposure indicators represent the *potential* area that could be affected by coastal hazards; the zones do not represent data from actual past events. Therefore, it is essential to have one indicator that includes actual reported coastal hazards. Understanding what has happened in the past in an area is essential to predicting what may happen in the future.

Historical flooding information for each park is commonly obtained from a questionnaire that is completed by park staff. Historical flooding information is also derived from storm imagery, reconnaissance visits, and direct communication with park personnel. For this indicator, the following question is posed to park personnel as part of the questionnaire:

"Have any of the following assets (or lands around the asset) been FLOODED in previous storm events? * This question is referring to the lands or area around an asset. Even if the asset was not built during a particular storm, we would like to know if that location has been flooded in the past."

For high elevation parks with cliff retreat and no flooding hazards, a similar question is asked for this indicator, and is related to **visible slope instability**. For cliff retreat, it is important to know if the landscape around an asset is currently showing signs that further retreat and erosion is imminent.

After scores are given for each exposure indicator (either 1 or 4), they are summed and binned to get a total exposure score for each asset. Final binned exposure scores fall into one of four ranking categories (based on the number of exposure zones): minimal exposure (asset does not lie within any mapped hazard zone), low exposure (1 zone only), moderate exposure (2-3 zones), and high exposure (4-5 zones). Specific scoring ranges can be found within the Excel results sheets. Any assets that obtain an exposure ranking of minimal are not further analyzed for sensitivity. Finally, all asset types (transportation and structures) are analyzed for exposure using the same general methodology.

Step 2: Asset Sensitivity Analysis
The second step in the protocol is to analyze the sensitivity of NPS assets to coastal hazards and climate change. Similar to exposure, a set of indicators was determined for asset sensitivity. Unlike exposure, however, sensitivity is evaluated independent of location (only exposure is location-dependent). Sensitivity refers to how that asset would fare when exposed to the hazard, which is a function of the inherent properties or characteristics of the asset. While the sensitivity indicators for structures and transportation assets are generally the same (Table 7), how sensitivity is addressed during design and construction is very different.

Because digital sensitivity data are not generally available, the primary data source for much of the sensitivity analysis is an asset-specific questionnaire. This questionnaire contains detailed questions related to the various sensitivity indicators (e.g., is the structure elevated above base flood elevation). It is distributed to appropriate personnel within each unit— typically individuals that possess long institutional memory and familiarity with park facilities. Where appropriate, sensitivity data is also obtained from FMSS, the National Bridge Inventory, aerial imagery, and site visits.

Bridges are considered transportation assets, but have additional factors that must be considered when analyzing sensitivity to coastal hazards and climate change. Table 7 summarizes the four general sensitivity indicators (for all assets), as well as the four additional bridge indicators. The following section describes each sensitivity indicator in detail, including data sources, methodology, and scoring.

Table 7. **Sensitivity Indicators for Asset Coastal Hazards and Climate Change Vulnerability**

Sensitivity Indicator		Data Sources
☑	**Flood Damage Potential (Elevated)**	Asset questionnaire; direct measurements of threshold elevation
☑	**Storm Resistance & Condition**	Asset questionnaire; FMSS database
☑	**Historical Damage**	Asset questionnaire; discussion with park staff
☑	**Protective Engineering**	Asset questionnaire; field & aerial imagery analysis; WCU Engineering Inventory
Additional Bridge Indicators		
☑	**Bridge Clearance**	National Bridge Inventory (item 39)
☑	**Scour Rating**	National Bridge Inventory (item 113)
☑	**Bridge Condition**	National Bridge Inventory (item 59 & 60)
☑	**Bridge Age**	National Bridge Inventory (item 27); FMSS database

Flood Damage Potential:
The flood damage potential indicator represents how likely an asset is to be inundated if the surrounding land area is flooded. For structures, this usually means whether or not the building is constructed on elevated stilts or pilings. Alternatively fill be added to the surrounding land to artificially elevate the asset above local ground height. This information is commonly obtained through the park questionnaire or visual inspection during site visits. For this indicator, the following question is posed to park personnel as part of the questionnaire:

"Are any of the following assets elevated at least 5 feet above local ground level (including critical utilities)? Examples include: 1) assets on stilts or pilings, or 2) assets built on artificial fill material above local ground level. NOTE: If elevated, but not quite 5 feet, indicate in comments."

When available, threshold elevation data collected by the NPS Resource Information Services Division (RISD) are included in the sensitivity analysis. These data, which have been collected at only a handful of parks thus far, are acquired with sub-centimeter Global Positioning System (GPS) equipment in order to record accurate threshold and asset elevations. In parks that do not have these data, the questionnaire (in combination with field work) is the primary data source used to determine whether an asset is elevated. The questionnaire generally inquires whether an asset is elevated above ground level – in the case of structures, at least 5 feet. Ideally, elevation of an asset would be compared to FEMA's Base Flood Elevation (BFE), and the precise threshold elevations acquired by RISD make this comparison possible. This can aid in the determination of highly reliable elevation indicators for structures within parks. It should be noted however, that elevation is one of several indicators used to calculate the sensitivity of an asset, and availability of precise elevation data, while preferable, is not critical in gauging overall sensitivity and vulnerability.

The precise threshold elevation verifies the first metric (flood damage potential) within the sensitivity analysis. This elevation is compared to local BFE for each asset to determine if the asset's primary threshold was above or below BFE. If an asset is elevated above BFE, it will receive a favorable score for the flood damage potential sensitivity metric (only if it is within a FEMA flood zone).

If an asset is reported to be elevated on stilts, built on elevated fill, or has a threshold above FEMA BFE, it receives a favorable score (1) for the flooding potential indicator. If it is not elevated (built at grade), it receives an unfavorable score (4) for the indicator.

Storm Resistance & Condition:
This sensitivity indicator represents how well an asset will resist damage from coastal hazards based on two factors: 1) overall storm resistance and 2) condition. Assets built to storm-resistant standards, with quality construction, or in good condition are less likely to be damaged by coastal hazards. For this indicator, the following two questions are posed to park personnel:

"Are any of the following assets built to resist flood/wave storm damage? Examples include: 1) assets built to specific storm-resistant standards/engineering codes, or 2) assets particularly or inherently resistant to other forms of damage or deterioration (e.g., fortifications)."

"Are any of the assets listed below particularly vulnerable to flood/wave damage due to condition? In other words, is the asset in poor condition due to deterioration, lack of maintenance, etc.? DO NOT consider the location of the asset (even if it is near the water or commonly flooded), only consider the physical condition of the asset itself. The condition should be considered independent of the asset's location."

This sensitivity indicator is scored as a combination of storm resistance and condition. If an asset is reported to be storm resistant, it receives a favorable score (1) for half of the total score for this indicator (and vice versa). If the asset is reported to be in poor condition, it receives an unfavorable score (4) for half of the total score for this indicator (and vice versa).

Historical Damage:
The historical damage indicator represents if an asset has been damaged by coastal hazards in the past, as assets that have been previously damaged are more likely be damaged in the future. This is similar to the reported coastal hazards exposure indicator, but instead of focusing on the site or area around an asset, this indicator is focused on damage to the asset itself. For this indicator, the following question is posed to park personnel as part of the questionnaire:

Have any of the following assets been significantly DAMAGED in previous storm/flooding events (water/wave damage only)? * This question is focused on the actual damage from an event (the prior flooding question is about the LAND near the asset being inundated)

If an asset is reported to have been damaged in the past, it receives an unfavorable score (4) for this indicator. If it has not been damaged in the past it receives a favorable score (1) for the indicator.

Protective Engineering:
This indicator represents if an asset is protected by engineering including hard structures (e.g., seawalls, bulkheads) or landscape modifications (e.g., significant drainage alteration, major restored landscape). This indicator assumes that assets protected with engineering are less likely to be damaged by coastal hazards. Data sources include the questionnaire, the NPS coastal engineering inventory (http://www.nature.nps.gov/geology/coastal/monitoring.cfm), and site visits. The following question is posed to park personnel as part of the questionnaire:

Are any of the following assets currently being protected by an engineered structure (e.g., seawall, bulkhead) or other major engineering (e.g. drainage, major landscape modification, major restored landscape)? Explain if needed.

If an asset is reported to be protected by engineering, it receives a favorable score (1) for this indicator; if the asset is not protected by engineering, it receives an unfavorable score (4) for the indicator.

Bridge Indicators: Clearance, Scour Rating, Condition, and Age:
For bridges within the National Bridge Inventory (NBI) database (public bridges over 20 feet in length), additional indicators are considered; the data for these indicators comes directly from the NBI database. The bridge sensitivity additional indicators include: clearance, scour rating, condition, and age. Table 8 below describes each indicator, including the description, rationale, and scoring.

Table 8. Additional Bridge Indicators

Indicator	Description & Rationale	Scoring (NBI score = sensitivity score)
Clearance	Bridges with higher clearance above the water surface are less likely to be damaged by coastal hazards.	*Amount of clearance in feet*: > 15 = 1; 9-15 = 2; 1-8 = 3; 0= 4
Scour Rating	Bridges with scour issues are more likely to be damaged by coastal hazards.	*Rating*: n/a = 1; low & stable (5-8) = 2; stable (4) = 3; critical = 4
Condition	Bridges in poor condition are more likely to be damaged by coastal hazards.	*Condition Rating*: n/a = 1; 0-3 = 2; 4-6 = 3, 7-9 = 4
Age	Bridges closer to their lifespan are more likely to be damaged by coastal hazards.	*Age (in years):* 0-25 = 1; 26-50 = 2; 51-75 = 3; > 75 = 4

To calculate a sensitivity score, each asset is first given a score for all applicable indicators. These scores are summed to obtain a total raw score for sensitivity, then binned into three categories reflective of the number of unfavorable indicators: low sensitivity, moderate sensitivity, and high sensitivity. Specific scoring ranges can be found within the Excel results sheets.

Step 3: Asset Vulnerability Analysis

To obtain a vulnerability score for each asset, the exposure and sensitivity scores are summed, and then binned into four vulnerability ranking categories. The ranking categories are as follows: minimal vulnerability (assets with minimal exposure and not included in the sensitivity analysis), low vulnerability, moderate vulnerability, and high vulnerability. Specific scoring ranges for vulnerability can be found within the Excel results sheets. A subset of the assets from the completed vulnerability analysis will be chosen for development of adaptation strategies (step 4).

Step 4: Adaptation Strategies Analysis

After the vulnerability analysis is complete, adaptation strategies will be analyzed for key assets within each park. FMSS data such as Asset Priority Index (API) and Optimizer Band (OB) can help select the assets to analyze for adaptation strategies. Assets analyzed will likely include those with high vulnerability and high priority and/or high criticality (API/OB), as well as high vulnerability assets with low priority and/or criticality. This adaptation analysis begins with discussions with the park, or by way of a questionnaire. This portion of the analysis focuses on the options available to the park to reduce the overall vulnerability of key assets. An outline of potential adaptation strategies to reduce coastal hazards and climate change vulnerability has been compiled by WCU for both structures and transportation assets (Table 9).

Table 9. Adaptation Strategies to Reduce Vulnerability of Assets to Coastal Hazards and Climate Change

Adaptation Action	Effect on Vulnerability and Rationale
☑ **Elevate**	Reduces the **sensitivity** of the asset; elevating a structure (and critical utilities) or transportation asset (i.e., a road) reduces the risk of flood damage.
☑ **Relocate**	Reduces the **exposure** of the asset; relocating the asset to a lower risk area reduces the likelihood that it will experience impacts from coastal hazards/SLR.
☑ **Protect/Engineer**	Reduces the **exposure** and/or **sensitivity** of the asset; protecting the asset with an engineered structure or landscape modifications (i.e., drainage) can reduce the likelihood that the asset will experience, or obtain damage from, coastal hazards/SLR.
☑ **Decommission & Remove**	Eliminates the vulnerable asset.
☑ **Storm-Resistant Redesign**	Reduces the **sensitivity** of the asset; redesigning the asset to be more storm resistant can reduce the likelihood of damage from coastal hazards/SLR.
☑ **Engineering Downgrade** (transportation assets only)	Reduces the **sensitivity** of the asset; downgrading the amount of engineering (i.e., replacing paved parking lot with shell material lot) can reduce the cost of rebuilding after damage and gives more flexibility for replacement.

This protocol is designed solely to assess the vulnerability of physical infrastructure. However, there are other adaptation actions for vulnerable assets that would not reduce the vulnerability of the physical asset, but instead its function. For example, a park might consider moving the critical contents within a building to a higher floor to reduce potential flood damage. Similarly, parks may decide to shift an asset's function to a less vulnerable asset. These adaptation actions do not change the vulnerability of the original asset (i.e., exposure and sensitivity remain the same); instead these actions change the criticality of the asset, potentially making it less of a concern to the park.

Additional NPS Climate Change Resources

Additional efforts are being made by NPS to address climate change in the coastal zone, as well as other critical environments. A number of these studies aim to improve the understanding of overall trends in climate change stressors, while others have focused on recording the specific effects of those stressors on natural and cultural resources within parks. Using this research and the latest climate science, the NPS is guiding adaptation efforts at units nationwide. Below are some of the climate change related resources at NPS:

- General Climate Change at NPS: http://www.nps.gov/subjects/climatechange/index.htm
- Climate Change Adaptation for Cultural Resources: http://www.nps.gov/subjects/climatechange/adaptationforculturalresources.htm
- Coastal Adaptation: http://www.nps.gov/subjects/climatechange/coastaladaptation.htm
- NPS Climate Change Adaptation Plan: http://www.nps.gov/orgs/ccrp/upload/NPS_CCActionPlan.pdf