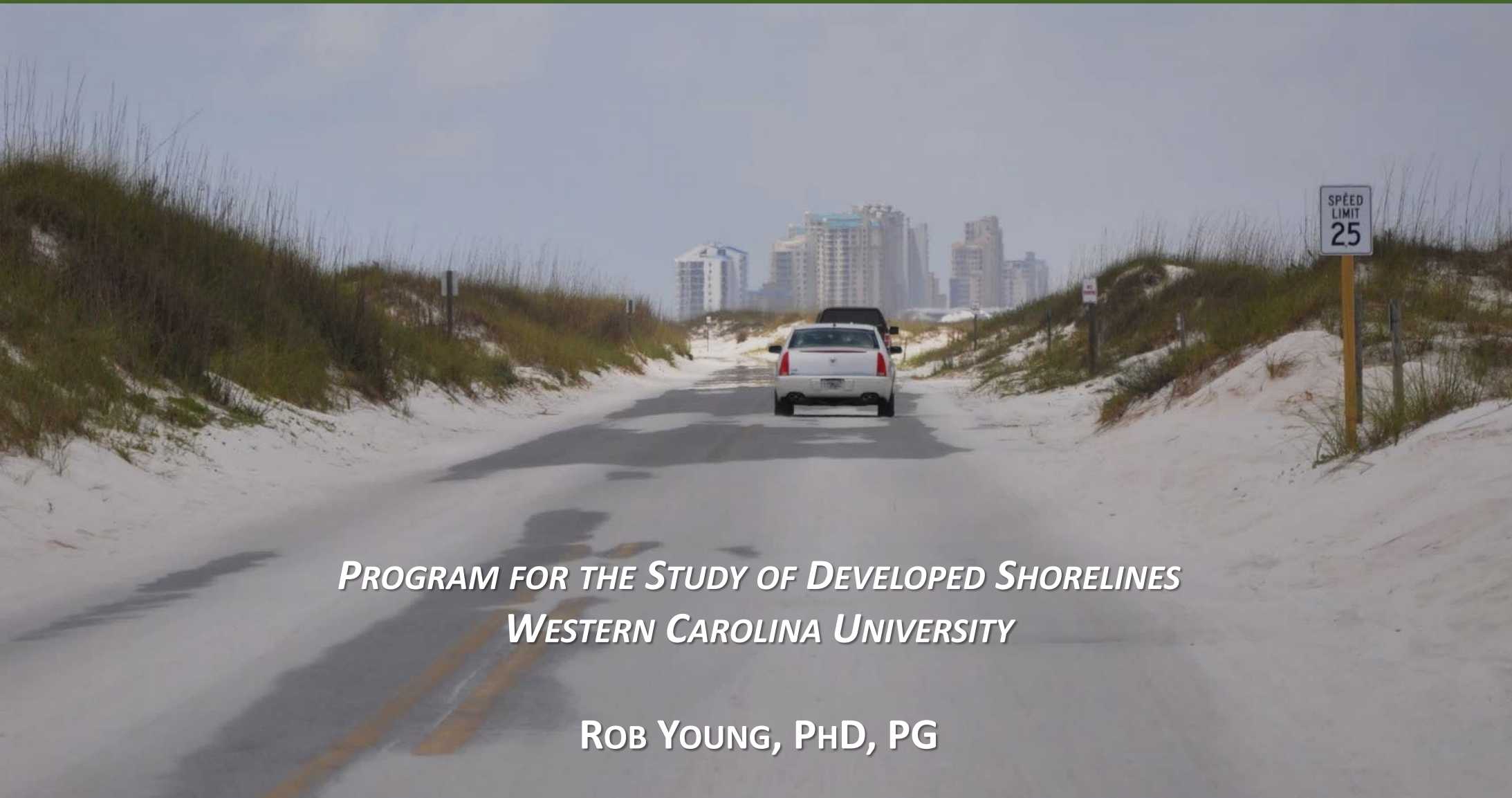


ASSESSING INFRASTRUCTURE VULNERABILITY IN NATIONAL PARKS: WCU PROTOCOLS & PAST PROJECTS



*PROGRAM FOR THE STUDY OF DEVELOPED SHORELINES
WESTERN CAROLINA UNIVERSITY*

ROB YOUNG, PHD, PG





PROGRAM FOR
THE STUDY OF
DEVELOPED
SHORELINES

WCU PSDS: Who we are



- Formed at Duke University in 1985; joint venture with WCU in 2006
- Communicate science & policy to decision-makers at all levels
- Focuses: coastal processes, natural hazards, climate change, restoration, vulnerability
- Examines the scientific basis for managing developed shorelines



Mission

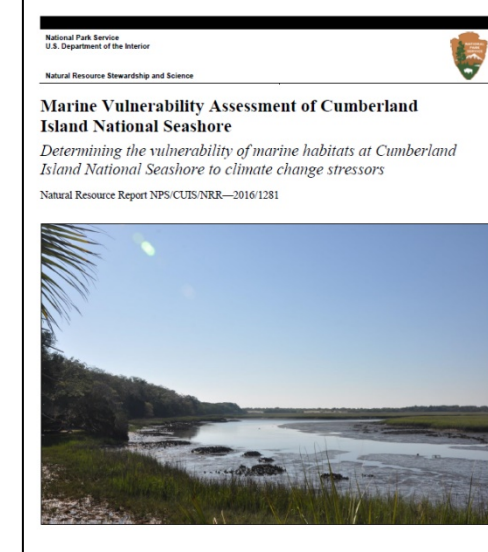
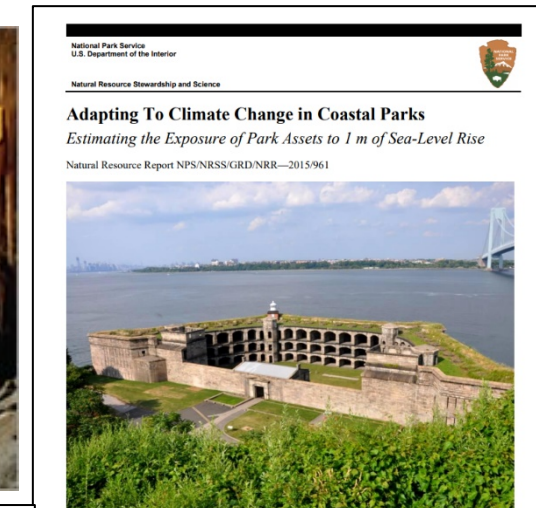
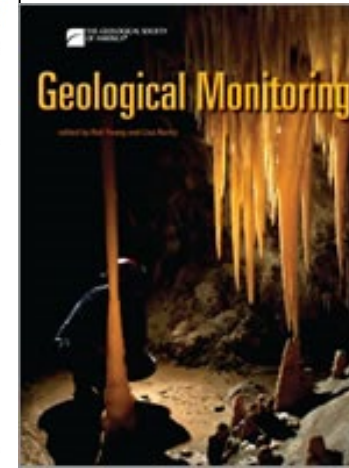
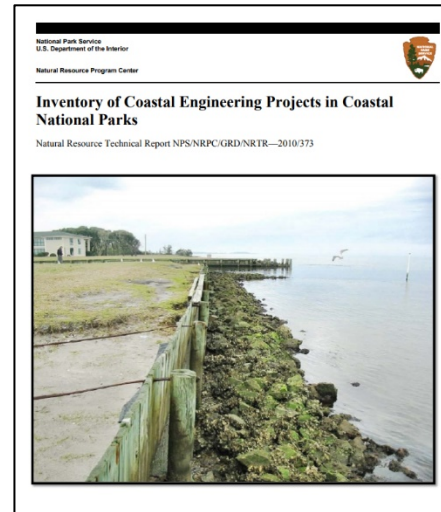
- PSDS serves as a nexus between coastal science and policy. PSDS seeks grant funding to apply innovative approaches to studying and understanding coastal processes, as well as translating new coastal science into sensible, science-based management recommendations. The center also seeks to communicate this science to the general public through traditional and non-traditional outlets.



PSDS work with NPS



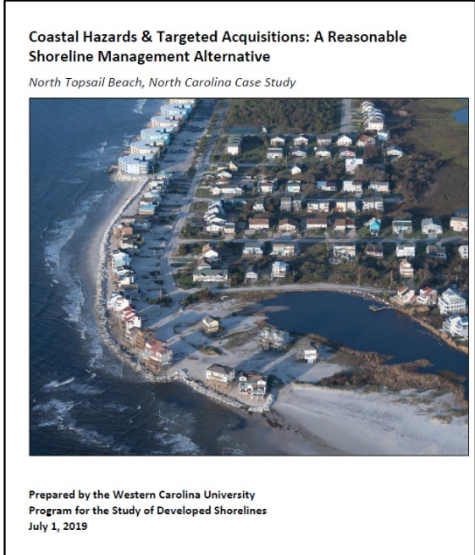
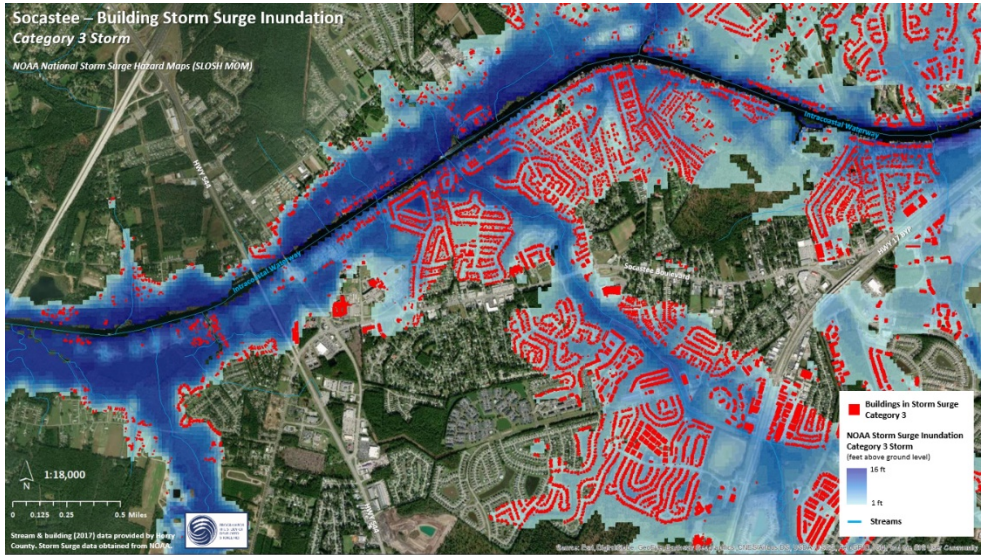
- Wetland location & evolution in GRSM (2002-2004)
- Climate history from bogs in BR Parkway (2004-2006)
- Geologic Monitoring Manual (2009)
- Channel Island N.P. wetland restoration (2006)
- Elwha River restoration project at OLYM (2011-2015)
- Mapping coastal engineering structures (2010)
- GPR survey of FOSU grounds (2012)
- CUIS marine resources VA (2016)
- NPS assets exposed to 1m SLR (2015-2020)
- GPR survey of African American cemeteries in GRSM (2021)
- YELL natural hazard VA prototype (2018-2020)
- Coastal Hazards & SLR Asset VA protocol development (2014-2015)
- **Coastal VAs - almost 40 units complete, all SER/SAG (2015-present)**





PSDS VAs Outside NPS

- Coastal hazards infrastructure VA: Town of Duck, NC
- Flood hazard exposure mapping: Horry County, SC
- Exposure & beach shoreline management study: NTB, NC
- Desalinization plant exposure analysis: Huntington Beach, CA
- VA of Dominion Energy coal waste disposal sites: Chesapeake, VA
- SELC exposure analysis: Virginia Beach, VA
- Exposure analysis for marsh migration study: Martha's Vineyard, MA



Coastal Hazards Infrastructure Vulnerability Assessment
Duck, North Carolina

February 2020



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



Coastal Hazard and Sea-level Rise Vulnerability Assessment
Chesapeake Energy Center coal ash disposal site, Chesapeake, VA

Robert S. Young, PhD, P.G., Director
 Blair R. Tormey, P.G., Coastal Research Scientist
 Katie M. Peek, P.G., Coastal Research Scientist
 Program for the Study of Developed Shorelines
 Western Carolina University - January 2017 (Updated January 2019)



VA Result Uses for NPS

- Integrated Park Improvement: BISC, JELA, & PAIS
- Infrastructure VA data to URI (COLO, FIIS, FOPU, TIMU-FOCA, GEWA)
- NCSU + USGS Opti-Pres model for decision-making of historic buildings: CALO & GUIS
- CALO campground site exposure & selection
- Collaboration with Quinn Evans Architects: LINC, CAHA, EVER
- Alaska LRTP risk assessment workshop
- VA of Discovery Bay & Port Royal Marine Labs, Jamaica
- Stabilization project evaluation for Kalaloch, OLYM

Facilities Planning Branch
Integrated Park Improvement Program Fact Sheet

National Park Service
U.S. Department of the Interior
Park Facility Management Division

Biscayne National Park Integrated Park Improvement

The coastal setting of Biscayne National Park (Biscayne) exposes park facilities and resources to harsh conditions and rapid degradation, especially to the effects of climate change (e.g., sea level rise, erosion and increasing storm surge). The park needed an investment plan that addressed those challenges while balancing competing facility and resource needs with a limited budget. So, in 2015 Biscayne developed its Integrated Park Improvement (IPI) plan, a comprehensive strategy for sustaining vital park physical and natural infrastructure, including its water-based assets. Through IPI, the park simultaneously assessed and prioritized projects at four distinct sites and this strategy now forms a consensus roadmap for park investment over the next 10 years.

Overview

Elliot Key Sunrise
Biscayne National Park

Located south of Miami, Biscayne provides recreation for boaters, beach goers, campers, wildlife enthusiasts, snorkelers and many other types of visitors. It protects rare barrier island and coral reef habitat. With much of its infrastructure pressed for repair or enhancement, the park needed to quickly develop and implement a robust plan to ensure sustainability of priority infrastructure. Accordingly, the Biscayne superintendent asked the Park Facility Management Division (PFMD) Facilities Planning Branch (FPB) to help develop an IPI strategy. The IPI process combines functional planning techniques with financial investment strategies to address a park's greatest infrastructure and resource needs. To be most effective, IPI requires broad, multi-discipline stakeholder engagement. It yields a set of thorough, multi-disciplinary, park-developed, region-approved, mission-oriented projects that optimize resource use and minimize risk.

IPI GOALS

Biscayne park management identified three broad goals for its IPI project. These same three goals could apply to any IPI project:

- To create a park-specific, results-oriented asset management development and implementation strategy
- To position the park to compete well across multiple fund sources and leverage potential partnerships
- To provide interactive tools and databases that assist the park staff with prioritizing, planning, executing and tracking projects

"This IPI effort produced a useful set of management strategies and a suite"

U.S. DEPARTMENT OF THE INTERIOR
INTERNATIONAL TECHNICAL ASSISTANCE PROGRAM

Port Royal Marine Lab, UWI, Jamaica
Coastal Hazards & Climate Change Asset Vulnerability Assessment
September 2015

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

Western Carolina University

PROGRAM FOR THE STUDY OF DEVELOPED SHORELINES

Kalaloch Shoreline Stabilization: A brief review and discussion of options

Robert S. Young, PhD, PG
Katie Peek, PG
Blair Tormey, PG
Program for the Study of Developed Shorelines

May 2021

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Integrated Coastal Climate Change Vulnerability Assessment

Colonial National Historical Park

Natural Resource Report NPS/COLO/NRR—2019/1945

CALO CG Site Selection

Assessing Historical Significance and Use Potential of Buildings within Historic Districts: An Overview of a Measurement Framework Developed for Climate Adaptation Planning

NC STATE EXTENSION

Great Island Campground

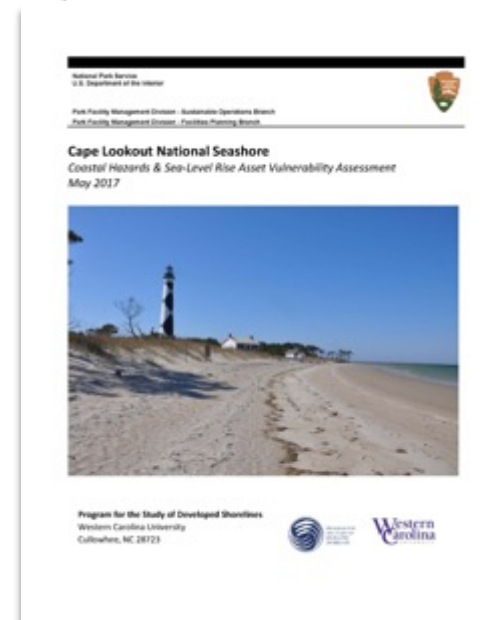
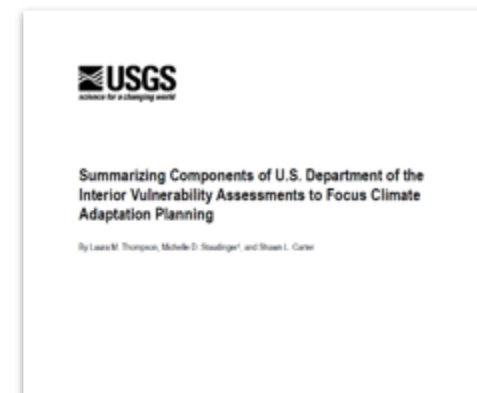
Atlantic Ocean



PRIMARY GOALS



- Asset level protocol: Create methodology for assessing vulnerability of NPS assets to coastal hazards & SLR (structures + transportation assets)
- Standardize methodology to allow comparison across regions
- Use consistent data sources: established & reliable data, universal & georeferenced, likely to be updated & maintained
- Provide actionable information!!! Decision-makers don't need a bunch of additional hazard maps to look through.
- Integrate the VA scoring into all park planning, short- and long-term





WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

➤ Vulnerability is best calculated for infrastructure as a combination of exposure & sensitivity.



Exposure - whether an asset is located in an area that experiences the hazard or impacts of climate change.

Sensitivity - how an asset will fare when exposed to a natural hazard or climate change stressor (amount of damage).

Adaptive Capacity

- ✓ Not part of vulnerability formula/score
- ✓ **Adaptive actions taken for assets help reduce exposure and/or sensitivity**



WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

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

Sensitivity Indicator	Data Sources
Flood Damage Potential	Site visits, threshold elevation data, questionnaire & discussions with park staff
Storm Resistance & Condition	Questionnaire & discussions with park staff; FMSS
Historical Damage	Questionnaire & discussions with park staff, park documents/report, imagery
Protective Engineering	Questionnaire & discussions with park staff, site visits, aerial imagery

Exposure

+

Sensitivity

=

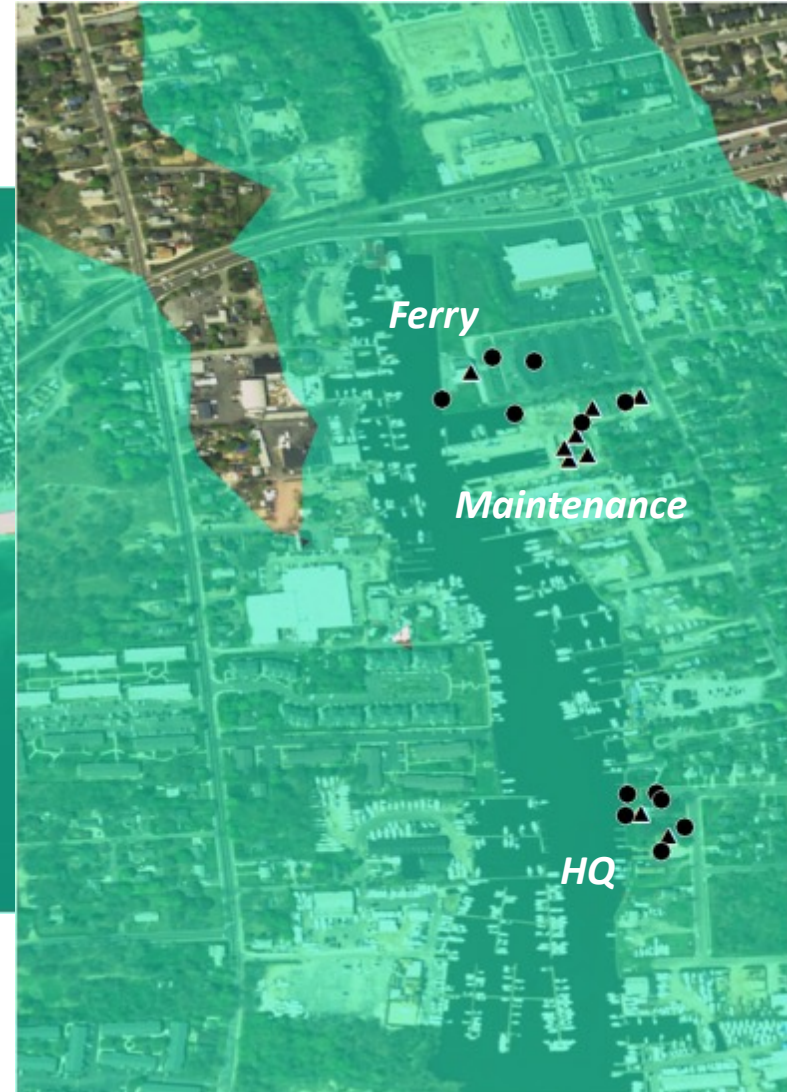
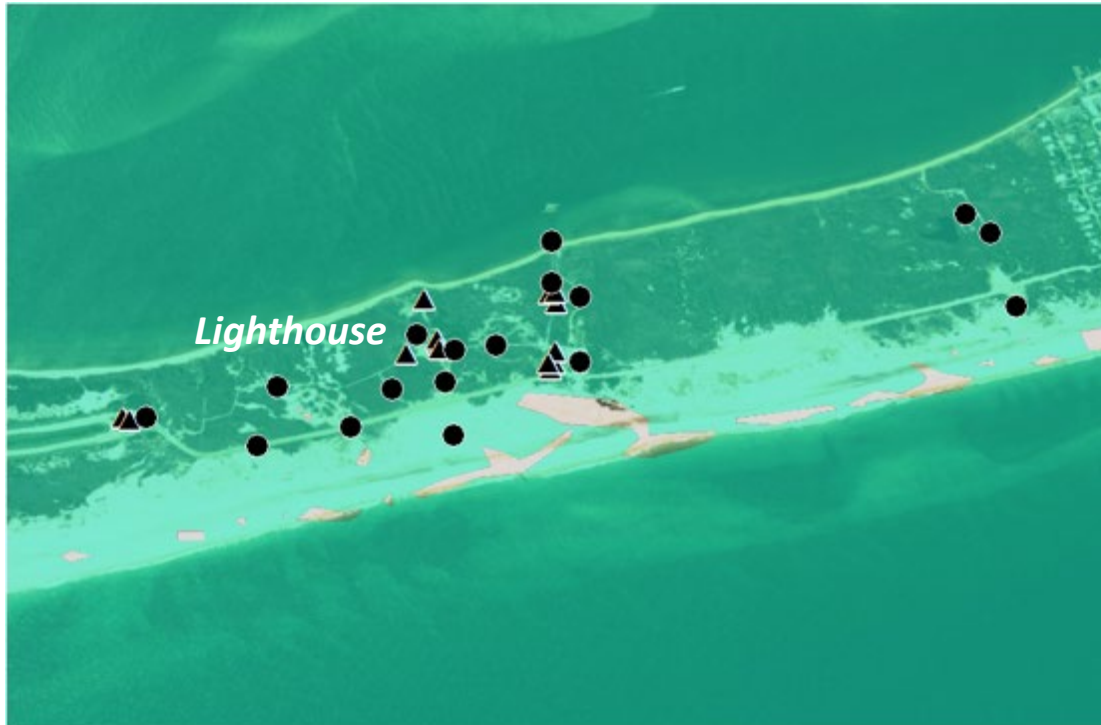
Vulnerability



EXTREME EVENT FLOODING INDICATOR DATA



Data:
Storm Surge Cat 3 SLOSH Model



Data Source: NPS CCRP



SENSITIVITY INFORMATION – PARK 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

FMSS Asset Information		Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)
------------------------	--	------------------------	--

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). Do not consider the LOCATION of the asset in your response, but instead focus completely on construction.

FMSS Asset Information		Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)
------------------------	--	------------------------	--

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.

FMSS Asset Information		Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)
------------------------	--	------------------------	--

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 to an asset from an event (the prior flooding question is about the LAND near the asset being inundated)

FMSS Asset Information		Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)
------------------------	--	------------------------	--

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)?

FMSS Asset Information				Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)	
#	Asset Code	Year Built	FMSS Code	Asset Description	Yes	
42	4100	1964	15935	Q-00000154-HO-TA-154 Ocean Qtrs		Click here to add any comments
7	4100	1950	18216	BU-HQ-76 Park Headquarters		Click here to add any comments



WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

EVER – Example Exposure Results



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Exposure Analysis Data Results

[Definitions of WCU Columns on Next Sheet \(Click Here to View\)](#)



ID	Location	Area	Step 1: Score for Exposure Indicator Zones						Step 2	Step 7		Geospatial Data		Location Code	Asset Code	Facility Type	Optimizer	API	CRV	DM	CSDM
			1a. FEMA VE Zone Score	1b. FEMA A Zone Score	1c. Erosion Proximity Score	1d. SLR Score	1e. Surge Cat 3 Score	1f. Historic Flooding Score		Raw Score from Step 1	Exposure Score	Exposure Rank	Latitude								
1	FLBC Lane Bay Chickee	FLBC		4	4	4	4	4	20	4	high	25.283245	-80.892031	67320	6300	6310	3	81	\$169,293	\$0	\$0
2	FLBC Hellis Bay Chickee	FLBC		4	4	4	4	1	17	4	high	25.253331	-80.878623	67327	6300	6310	3	81	\$169,293	\$96,950	\$0
3	FLBC Pearl Bay Chickee	FLBC		4	4	4	4	1	17	4	high	25.259499	-80.856291	67328	6300	6310	3	81	\$163,038	\$0	\$0
4	FLBC Roberts River Chickee	FLBC		4	4	4	4	1	17	4	high	25.316145	-80.908147	67331	6300	6310	3	81	\$163,038	\$0	\$0
5	FLBC North River Chickee	FLBC		4	4	4	4	1	17	4	high	25.331790	-80.937325	67332	6300	6310	3	81	\$163,038	\$0	\$0
6	FLBC Watson River Chickee	FLBC	4		4	4	4	4	20	4	high	25.332583	-80.980660	67352	6300	6310	3	81	\$163,038	\$86,670	\$0
7	FLBC Shark River Chickee	FLBC		4	4	4	4	4	20	4	high	25.368720	-81.045115	67356	6300	6310	3	81	\$163,038	\$11,076	\$0
8	FLBC Harney River Chickee	FLBC		4	4	4	4	4	20	4	high	25.432656	-81.091054	67364	6300	6310	3	81	\$11,375	\$0	\$0
9	FLBC Oyster Bay Chickee	FLBC	4		4	4	4	4	17	4	high	25.323396	-81.066354	67369	6300	6310	3	81	\$163,038	\$0	\$0
10	FLBC Joe River Chickee	FLBC		4	4	4	4	1	17	4	high	25.279724	-81.065669	67370	6300	6310	3	81	\$163,038	\$0	\$0
11	FLBC South Joe River Chickee	FLBC	4		4	4	4	1	17	4	high	25.220772	-81.018842	67375	6300	6310	3	81	\$163,038	\$0	\$0
12	FLCG 401 Walk-in Comfort Station	FLCG	4		1	1	4	4	14	4	high	25.137101	-80.936835	66835	4100	4124	2	58	\$348,755	\$545	\$545
13	FLCG 402 A-Loop Comfort Station	FLCG	4		1	1	4	4	14	4	high	25.136684	-80.940103	66836	4100	4124	2	58	\$367,686	\$567	\$567
14	FLCG 403 A-Loop Comfort Station	FLCG	4		1	1	4	4	14	4	high	25.136386	-80.941398	66838	4100	4124	2	58	\$585,659	\$676	\$676
15	FLCG 404 B-Loop Comfort Station	FLCG		4	1	1	4	4	14	3	moderate	25.136495	-80.944269	66839	4100	4124	3	58	\$359,543	\$506	\$506
16	FLCG 405 B-Loop Comfort Station	FLCG		4	1	1	4	4	14	3	moderate	25.136163	-80.945302	66846	4100	4124	3	58	\$417,532	\$486	\$905
17	FLCG 407 T-Loop Comfort Station	FLCG		4	1	1	4	1	11	3	moderate	25.138547	-80.941270	66852	4100	4124	2	58	\$347,936	\$495	\$495
18	FLCG 408 T-Loop Comfort Station	FLCG		4	1	1	4	1	11	3	moderate	25.138848	-80.942315	66854	4100	4124	2	58	\$481,913	\$567	\$567
19	FLCG 430 Flamingo Amphitheater	FLCG	4		4	4	4	4	20	4	high	25.137078	-80.932329	70993	7900	7910	3	50	\$291,957	\$0	\$0
20	FLCG 411 Walk-in Comfort Station	FLCG	4		1	4	4	4	17	4	high	25.137109	-80.933323	79271	4100	4124	2	58	\$530,105	\$580	\$580
21	FLCG 409 Flamingo Fee Station	FLCG	4		1	1	4	4	14	4	high	25.137123	-80.938908	226603	4100	4129	2	55	\$75,834	\$373	\$373
22	FLCG Flamingo Eco Tent # 1	FLCG	4		1	1	4	4	14	4	high	25.136647	-80.936939	251490	4100	4129	2	67	\$51,878	\$0	\$0
23	FLCG Flamingo Eco Tent # 2	FLCG	4		1	1	4	4	14	4	high	25.136645	-80.937038	251499	4100	4129	2	67	\$51,878	\$0	\$0
24	FLCG Flamingo Eco Tent # 3	FLCG	4		1	1	4	4	14	4	high	25.136805	-80.937076	251500	4100	4129	2	67	\$51,878	\$0	\$0
25	FLCG Flamingo Eco Tent # 4	FLCG	4		1	1	4	4	14	4	high	25.136803	-80.937179	251501	4100	4129	2	67	\$51,878	\$0	\$0
26	FLCG Flamingo Eco Tent # 5	FLCG	4		4	1	4	4	17	4	high	25.136541	-80.937211	251502	4100	4129	2	67	\$51,878	\$0	\$0
27	FLCG Flamingo Eco Tent # 6	FLCG	4		4	1	4	4	17	4	high	25.136529	-80.937312	251503	4100	4129	2	67	\$51,878	\$0	\$0
28	FLCG Flamingo Eco Tent # 7	FLCG	4		4	1	4	4	17	4	high	25.136580	-80.937593	251504	4100	4129	2	67	\$51,878	\$0	\$0
29	FLCG Flamingo Eco Tent # 8	FLCG	4		4	1	4	4	17	4	high	25.136557	-80.937694	251505	4100	4129	2	67	\$51,878	\$0	\$0
30	FLCG Flamingo Eco Tent # 9	FLCG	4		1	1	4	4	14	4	high	25.136719	-80.937420	251506	4100	4129	2	67	\$51,878	\$0	\$0
31	FLCG Flamingo Eco Tent #10	FLCG	4		1	1	4	4	14	4	high	25.136717	-80.937522	251507	4100	4129	2	67	\$51,878	\$0	\$0
32	FLCG Flamingo Eco Tent # 11	FLCG	4		1	1	4	4	14	4	high	25.136770	-80.937661	251508	4100	4129	2	67	\$51,878	\$0	\$0
33	FLCG Flamingo Eco Tent # 12	FLCG	4		1	1	4	4	14	4	high	25.136821	-80.937744	251509	4100	4129	2	67	\$51,878	\$0	\$0
34	FLCG Flamingo Eco Tent # 13	FLCG	4		1	1	4	4	14	4	high	25.136691	-80.937875	251510	4100	4129	2	67	\$51,878	\$0	\$0



WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

OBX – Example Sensitivity Results + FFE



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ID	Location	Area	Flood Damage Potential (Elevated)	Effective BFE (ft. NAVD88)	First Floor Elevation (ft. NAVD88)	Threshold Above or Below BFE	Storm Resistance	Condition	Historical Damage	Protective Engineering	Step 3	Step 4		Geospatial Data		Location Code	Asset Code	Facility Type	State	Optimizer
											Total Raw Score (sum step 1)	Sensitivity Score	Sensitivity Rank	Latitude	Longitude					
1	BI HS Coast Guard Station (Hilton)	BI Coquina	4	10	8.51	Below	4	1	1	4	11.5	3	moderate	35.829186	-75.558928	28912	4100	4110	NC	2
2	BI HS Lifesaving Station (Ranger Station)	BI Coquina	4	10	7.18	Below	4	1	1	4	11.5	3	moderate	35.828745	-75.558724	28913	4100	4110	NC	2
3	BI BD Coquina Comfort Station	BI Coquina	1	11	12.12	Above*	4	1	1	4	8.5	3	moderate	35.832067	-75.558654	28918	4100	4124	NC	3
4	BI WW Coquina Day Use - Showers	BI Coquina	1	11	12.86	Above*	4	1	4	4	11.5	3	moderate	35.832093	-75.558723	95948	5200	5210	NC	3
5	BI HS Lifesaving Station Boathouse - Building 100A	BI Coquina	4	10	7.29	Below	4	1	1	4	11.5	3	moderate	35.828883	-75.558735	113449	4100	4160	NC	2
6	BI HS Bodie Island Lighthouse	BI Lighthouse	4	10	5.20	Below	4	1	1	4	11.5	3	moderate	35.818538	-75.563339	28923	4100	4173	NC	1
7	BI HS Double Keepers Quarters (Visitor Center)	BI Lighthouse	4	10	6.55	Below	4	1	4	4	14.5	4	high	35.818271	-75.563997	28924	4100	4110	NC	1
8	BI HS LH Store House	BI Lighthouse	4	10	5.82	Below	4	1	1	4	11.5	3	moderate	35.818546	-75.564167	28926	4100	4180	NC	1
9	BI HS LH Cistern	BI Lighthouse	4	10			4	1	1	4	11.5	3	moderate	35.818360	-75.564010	28927	5100	5110	NC	2
10	BI BD LH Comfort Station	BI Lighthouse	4	10	5.57	Below	4	1	1	4	11.5	3	moderate	35.818889	-75.564413	28928	4100	4124	NC	3
11	BI BD Boneyard Storage Building	BI Lighthouse	4	10	6.01	Below	4	1	1	4	11.5	3	moderate	35.823303	-75.568932	28929	4100	4141	NC	4
12	BI HS Bodie Island Lighthouse Oil House	BI Lighthouse	4	10	5.20	Below	4	1	1	4	11.5	3	moderate	35.818526	-75.563344	229422	4100	4180	NC	1
13	BI BD Carpenter Shop	BI Maintenance	4	10	8.34	Below	4	4	4	4	16.0	4	high	35.845534	-75.545375	28887	4100	4160	NC	3
14	BI BD Maintenance Shop	BI Maintenance	4	10	8.07	Below	4	4	4	4	16.0	4	high	35.845793	-75.563994	28888	4100	4160	NC	3
15	BI BD Lumber Shed	BI Maintenance	4	10	6.38	Below	4	1	4	4	14.5	4	high	35.846178	-75.564388	28890	4100	4180	NC	4
16	BI BD Traffic Cone Shed	BI Maintenance	4	10	6.53	Below	4	1	4	4	14.5	4	high	35.846039	-75.564272	28891	4100	4180	NC	4
17	BI BD Recycling Storage	BI Maintenance	4	10			4	1	4	4	14.5	4	high	35.846063	-75.564560	28892	4100		NC	4
18	BI BD Gas Shed	BI Maintenance	4	10	6.81	Below	4	1	4	4	14.5	4	high	35.845811	-75.564416	28893	4100	4160	NC	4
19	BI BD Haz-Mat Building	BI Maintenance	4	10	7.02	Below	4	1	1	4	11.5	3	moderate	35.846001	-75.564541	28909	4100	4141	NC	3
20	BI BD Ranger Generator Building	BI Maintenance	1	10	11.19	Above*	4	1	1	4	8.5	3	moderate	35.834951	-75.572561	28961	4100	4180	NC	3
21	BI BD Range Observation Building	BI Maintenance	1	10	10.17	Above*	4	1	1	4	8.5	3	moderate	35.835060	-75.572634	28962	4100	4141	NC	3
22	BI WP Range Above Ground Storage Tank	BI Maintenance	4	10	9.15	Below	4	1	1	4	11.5	3	moderate	35.836439	-75.574460	28963	5100	5110	NC	5
23	BI BD Oregon Inlet CG Kiosk	BI Oregon Inlet	4	8	7.73	Below	4	1	1	4	11.5	3	moderate	35.800077	-75.545375	28935	4100	4129	NC	3
24	BI BD Oregon Inlet CG Loop A Shower Building	BI Oregon Inlet	1	8			4	1	1	4	8.5	3	moderate	35.800673	-75.545011	28939	4100	4124	NC	3
25	BI BD Oregon Inlet CG Loop A Comfort Station	BI Oregon Inlet	1	8	10.02	Above	4	1	1	4	8.5	3	moderate	35.800604	-75.545061	28940	4100	4124	NC	3
26	BI BD Oregon Inlet CG Loop B Shower Building	BI Oregon Inlet	1	8			4	1	1	4	8.5	3	moderate	35.798881	-75.544803	28941	4100	4124	NC	3
27	BI BD Oregon Inlet CG Loop B Comfort Station	BI Oregon Inlet	1	8	12.36	Above	4	1	1	4	8.5	3	moderate	35.798954	-75.544677	28942	4100	4124	NC	3
28	BI BD Oregon Inlet CG Loop C Shower Building	BI Oregon Inlet	1	8			4	1	1	4	8.5	3	moderate	35.797727	-75.544996	28943	4100	4124	NC	3
29	BI BD Oregon Inlet CG Loop C Comfort Station	BI Oregon Inlet	1	8	11.61	Above	4	1	1	4	8.5	3	moderate	35.797805	-75.545073	28944	4100	4124	NC	3
30	BI BD Oregon Inlet Fishing Center Comfort Station	BI Oregon Inlet	4	8	6.52	Below	4	1	1	4	11.5	3	moderate	35.797096	-75.548073	28948	4100	4124	NC	3
31	BI BD Oregon Inlet Fishing Center Lift Station Building	BI Oregon Inlet	4	8			4	1	1	4	11.5	3	moderate	35.796525	-75.546786	28949	4100	4150	NC	3
32	BI BD Oregon Inlet Fishing Center	BI Oregon Inlet	1	8	9.34	Above*	4	1	4	4	11.5	3	moderate	35.796748	-75.548164	80998	4100	4110	NC	3
33	BI BD Oregon Inlet Fishing Center Storage Building	BI Oregon Inlet	4	8	5.51	Below	4	1	4	4	14.5	4	high	35.796976	-75.548180	110388	4100	4141	NC	4
34	BI BD Oregon Inlet Fishing Center Exhibit Building	BI Oregon Inlet	4	8	6.61	Below	4	1	4	4	14.5	4	high	35.797058	-75.547803	110389	4100	4123	NC	3
35	BI QT Q117	BI QT	1	11	16.09	Above*	4	1	4	4	11.5	3	moderate	35.844774	-75.563141	28898	4100	4130	NC	4
36	BI QT Q118	BI QT	1	11	16.22	Above*	4	1	4	4	11.5	3	moderate	35.844554	-75.562899	28900	4100	4130	NC	4
37	BI QT Q119	BI QT	1	11	18.72	Above*	4	1	4	4	11.5	3	moderate	35.844041	-75.563116	28901	4100	4130	NC	4
38	BI QT Q120	BI QT	1	11	18.78	Above*	4	1	4	4	11.5	3	moderate	35.844256	-75.563364	28903	4100	4130	NC	4
39	BI BD RM Necropsy Building	BI QT	4	11			4	1	1	4	11.5	3	moderate	35.841390	-75.562480	241897	4100	4129	NC	0



WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

CALO – Example Vulnerability Results



Next

Vulnerability Assessment Data Results						
Definitions of WCU Columns on Next Sheet (Click Here to View)						
Metrics of Vulnerability		Vulnerability				
Exposure	Sensitivity	Raw Score	Final Score	Final Rank		

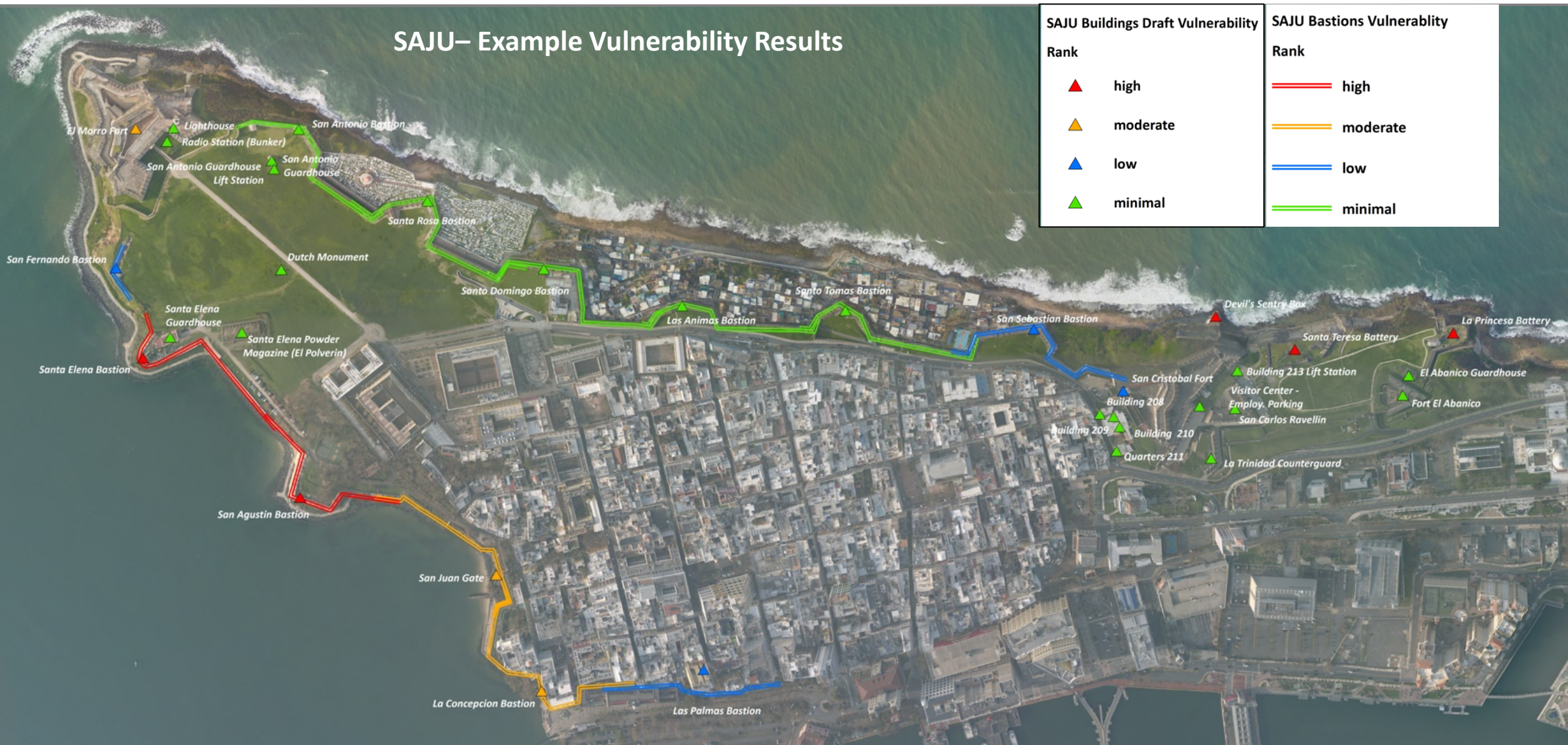


ID	Location	Area	Exposure	Sensitivity	Raw Score	Final Score	Final Rank	Location Code	Asset Code	Facility Type	State	Optimizer	API	FCI	CRV	Park Conc.	DM	CSDM	Ranking	Qty	UM	Historic	Year	LCS
1	CP BD Restroom Cape Point	CP Cape Point	3	3	6	3	moderate	43987	4100	4124	NC	4	47	0.000	\$35,716		\$0		GOOD	110	GSF	N	1993	
2	CP BD Cape Lookout Coast Guard Station	CP Coast Guard	2	3	5	2	low	44098	4100	4160	NC	2	58	0.978	\$910,805		\$890,814	\$132,303	SERIOUS	3,279	GSF	Y	1917	91769
3	CP BD Cape Lookout Coast Guard Station Equipment Building	CP Coast Guard	3	4	7	4	high	44100	4100	4141	NC	3	63	0.269	\$406,195		\$109,221	\$109,221	POOR	1,620	GSF	Y	1940	91771
4	CP BD Cape Lookout Coast Guard Station Galley/Summer Kitchen	CP Coast Guard	2	3	5	2	low	44097	4100	4123	NC	2	58	0.528	\$153,060		\$80,891	\$80,891	SERIOUS	341	GSF	Y	1917	91770
5	CP BD Incinerator Building at Cape Coast Guard Station	CP Coast Guard	3	3	6	3	moderate	114197	4100	4141	NC	5	0	0.000	\$80,236		\$0		GOOD	320	GSF	N	1943	
6	CP BD Summer Kitchen Cistern at Cape Coast Guard Station	CP Coast Guard	3	2	5	2	low	114199	4100	4141	NC	3	51	0.000	\$25,074		\$0		GOOD	100	GSF	N	1991	
7	CP BD Davis Island Gun Club	CP Davis Island	4	4	8	4	high	43997	4100	4180	NC	5	0	0.638	\$1,029,097		\$656,501	\$739,661	SERIOUS	3,800	GSF	N	1973	
8	CP BD Generator Storage Shed Les & Sally's	CP Les & Sally's	4	3	7	4	high	98245	4100	4141	NC	4	27	0.000	\$32,206		\$0		GOOD	192	GSF	N	1960	
9	CP BD Les & Sally's Main Building	CP Les & Sally's	4	3	7	4	high	44094	4100	4123	NC	3	35	0.000	\$607,556		\$0		GOOD	2,355	GSF	N	1957	
10	CP BD Les and Sally's Summer Kitchen	CP Les & Sally's	4	3	7	4	high	98239	4100	4110	NC	4	25	0.000	\$99,311		\$0		GOOD	384	GSF	N	1960	
11	CP BD Les and Sally's VRP Shed	CP Les & Sally's	4	3	7	4	high	114210	4100	4141	NC	4	17	0.000	\$20,059		\$0		GOOD	80	GSF	N	2000	
12	CP BD RM ATV Storage Shed Cape	CP Les & Sally's	4	3	7	4	high	98246	4100	4141	NC	4	29	0.000	\$64,412		\$0		GOOD	384	GSF	N	1960	
13	CP BD Sleeping Quarters # 1 Les & Sally's	CP Les & Sally's	4	3	7	4	high	98241	4100	4131	NC	4	25	0.000	\$0		\$0		GOOD	384	GSF	N	1960	
14	CP BD Sleeping Quarters # 2 Les & Sally's	CP Les & Sally's	4	3	7	4	high	98242	4100	4131	NC	4	25	0.000	\$99,590		\$0		GOOD	384	GSF	N	1960	
15	CP BD ATV Shed Cape	CP Lighthouse	3	3	6	3	moderate	44091	4100	4141	NC	4	29	0.000	\$40,258		\$0		GOOD	240	GSF	N	2003	
16	CP BD Shade Shelter #1 Beach Shuttle	CP Lighthouse	3	3	6	3	moderate	106670	4100	4129	NC	4	41	0.000	\$101,815		\$0		GOOD	512	GSF	N	2006	
17	CP BD Cape Lookout Light Station Oil House	CP Lighthouse	3	2	5	2	low	97012	4100	4180	NC	3	51	0.000	\$24,155		\$0		GOOD	144	GSF	Y	1859	91821
18	CP BD Cape Lookout Light Station Visitor Center	CP Lighthouse	4	3	7	4	high	106668	4100	4129	NC	3	58	0.226	\$638,043		\$144,000		POOR	896	GSF	N	2006	
19	CP BD Cape Lookout Lighthouse	CP Lighthouse	3	3	6	3	moderate	85982	4100	4173	NC	1	100	0.085	\$63,566,336		\$5,423,851	\$3,875,564	GOOD	963	GSF	Y	1859	18
20	CP BD Light Station Restroom Facility	CP Lighthouse	3	3	6	3	moderate	106669	4100	4124	NC	3	70	0.146	\$478,958		\$69,787		FAIR	896	GSF	N	2006	
21	CP BD Lighthouse (Oceanside) Restrooms	CP Lighthouse	4	3	7	4	high	43985	4100	4124	NC	4	47	0.000	\$47,976		\$0		GOOD	119	GSF	N	1993	
22	CP BD Lighthouse Keepers Quarters	CP Lighthouse	4	3	7	4	high	44267	4100	4129	NC	2	81	0.142	\$1,870,705		\$265,813	\$198,980	FAIR	3,246	GSF	Y	1873	
23	CP BD Lighthouse Summer Kitchen	CP Lighthouse	4	3	7	4	high	44266	4100	4160	NC	4	39	0.644	\$85,862		\$55,325	\$63,891	SERIOUS	500	GSF	N	1890	
24	CP BD Shade Shelter #2 Cape Lookout Beach	CP Lighthouse	4	3	7	4	high	43994	4100	4180	NC	4	42	0.045	\$28,508		\$1,295	\$1,459	GOOD	196	GSF	N	1999	
25	CP BD Shade Shelter at Old Cape Concession Dock	CP Lighthouse	4	3	7	4	high	91279	4100	4180	NC	4	42	0.000	\$30,254		\$0		GOOD	208	GSF	N	2004	
26	CP BD Shade Shelter Visitor Center	CP Lighthouse	3	3	6	3	moderate	44021	4100	4180	NC	4	42	0.000	\$33,163		\$0		GOOD	750	GSF	N	1999	
27	CP BW Cape Water System Building	CP Lighthouse	3	4	7	4	high	114216	4100	4150	NC	2	33	0.754	\$120,354		\$90,709		SERIOUS	480	GSF	N	2005	
28	CP BD Barden House- 4C Keepers Quarters	CP Lookout Village	4	3	7	4	high	51072	4100	4129	NC	2	51	0.792	\$506,991		\$401,772	\$376,772	SERIOUS	2,022	GSF	Y	1907	91766
29	CP BD Bryant House	CP Lookout Village	3	4	7	4	high	51084	4100	4180	NC	3	51	1.012	\$391,030		\$395,682	\$219,134	SERIOUS	1,400	GSF	Y	1928	271581
30	CP BD Coca-Cola House	CP Lookout Village	4	3	7	4	high	51073	4100	4180	NC	3	51	0.294	\$577,501		\$169,965	\$146,139	POOR	2,233	GSF	Y	1920	91837
31	CP BD Fishing Cottage #2	CP Lookout Village	4	4	8	4	high	51081	4100	4129	NC	3	64	0.462	\$261,466		\$120,803	\$124,452	POOR	1,011	GSF	N	1950	
32	CP BD Fishing Cottage #2 Generator Building	CP Lookout Village	4	4	8	4	high	114203	4100	4150	NC	4	33	0.450	\$30,089		\$13,530	\$8,217	POOR	120	GSF	N	2006	
33	CP BD G.C.Willis House	CP Lookout Village	4	4	8	4	high	51078	4100	4180	NC	3	51	0.533	\$289,397		\$154,209	\$141,891	SERIOUS	1,260	GSF	N	1950	
34	CP BD Gaskill-Guthrie House	CP Lookout Village	3	4	7	4	high	51169	4100	4180	NC	3	51	1.080	\$280,757		\$303,206	\$127,455	SERIOUS	950	GSF	Y	1915	91832
35	CP BD Generator Building at Barden House-4C Keepers Quarters	CP Lookout Village	4	3	7	4	high	114205	4100	4150	NC	5	0	0.000	\$22,316		\$0		GOOD	89	GSF	N	1907	
36	CP BD Guthrie Ogilvie House	CP Lookout Village	4	4	8	4	high	95110	4100	4130	NC	3	51	0.775	\$253,755		\$196,649	\$178,564	SERIOUS	1,350	GSF	Y	1957	91829
37	CP BD Jetty Worker #1 Equipment Storage	CP Lookout Village	4	4	8	4	high	114206	4100	4141	NC	5	0	0.000	\$150,443		\$0		GOOD	600	GSF	N	1984	
38	CP BD Jetty Worker House #1	CP Lookout Village	4	4	8	4	high	51071	4100	4180	NC	5	51	0.357	\$691,036		\$246,412	\$230,668	POOR	2,672	GSF	N	1915	



WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

SAJU– Example Vulnerability Results

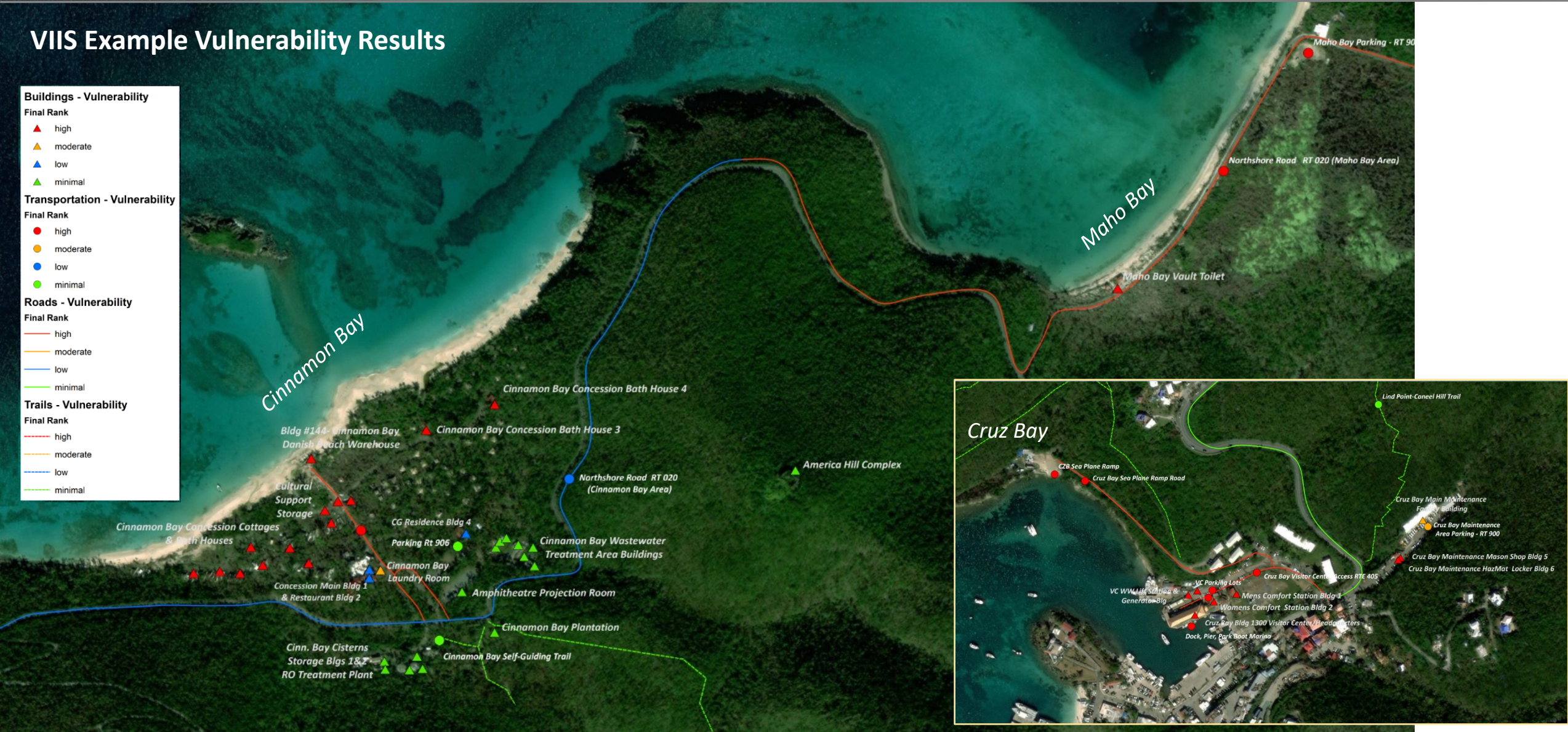




WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

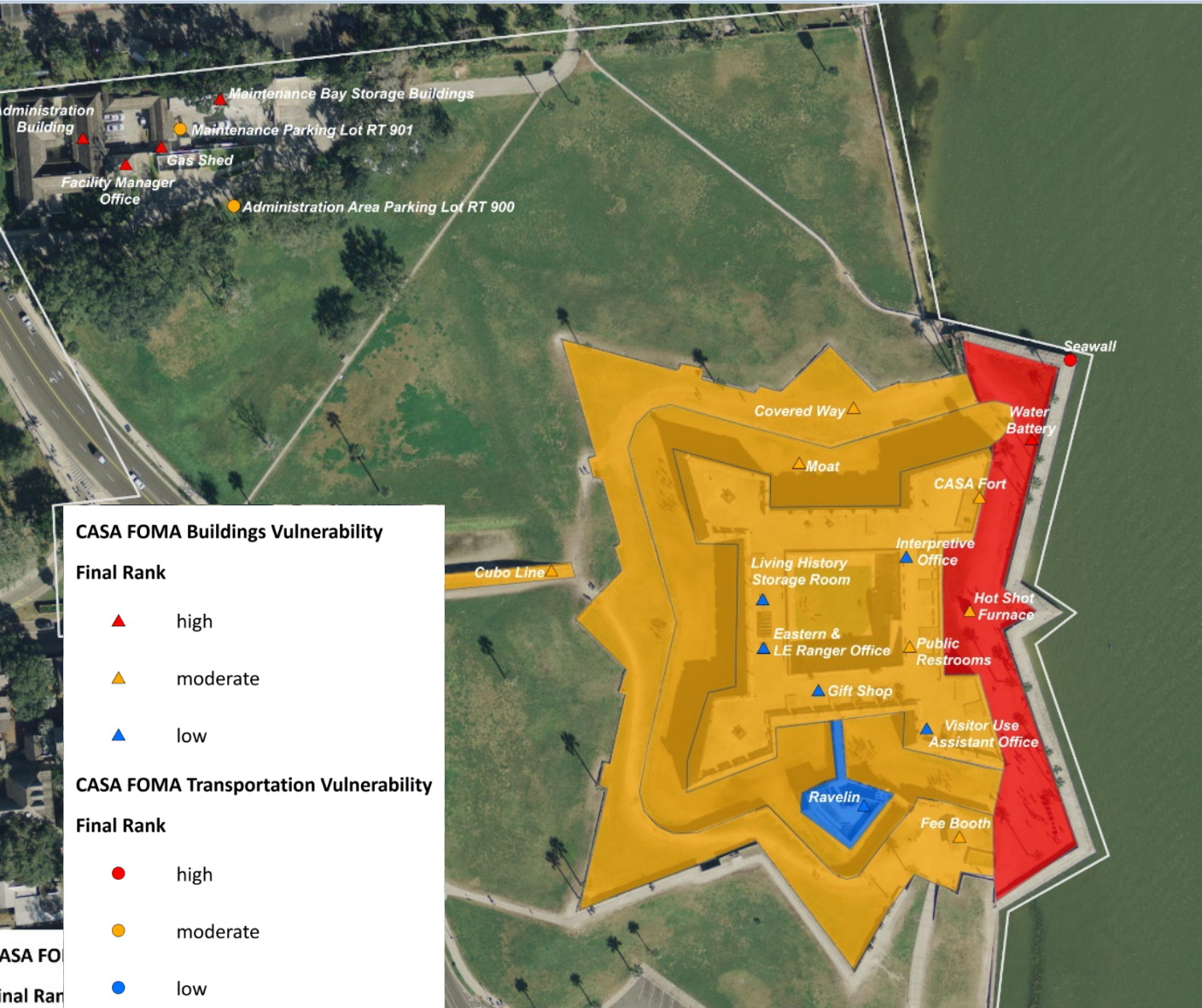
VIIS Example Vulnerability Results

- Buildings - Vulnerability**
Final Rank
- ▲ high
 - ▲ moderate
 - ▲ low
 - ▲ minimal
- Transportation - Vulnerability**
Final Rank
- high
 - moderate
 - low
 - minimal
- Roads - Vulnerability**
Final Rank
- high
 - moderate
 - low
 - minimal
- Trails - Vulnerability**
Final Rank
- high
 - moderate
 - low
 - minimal





WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

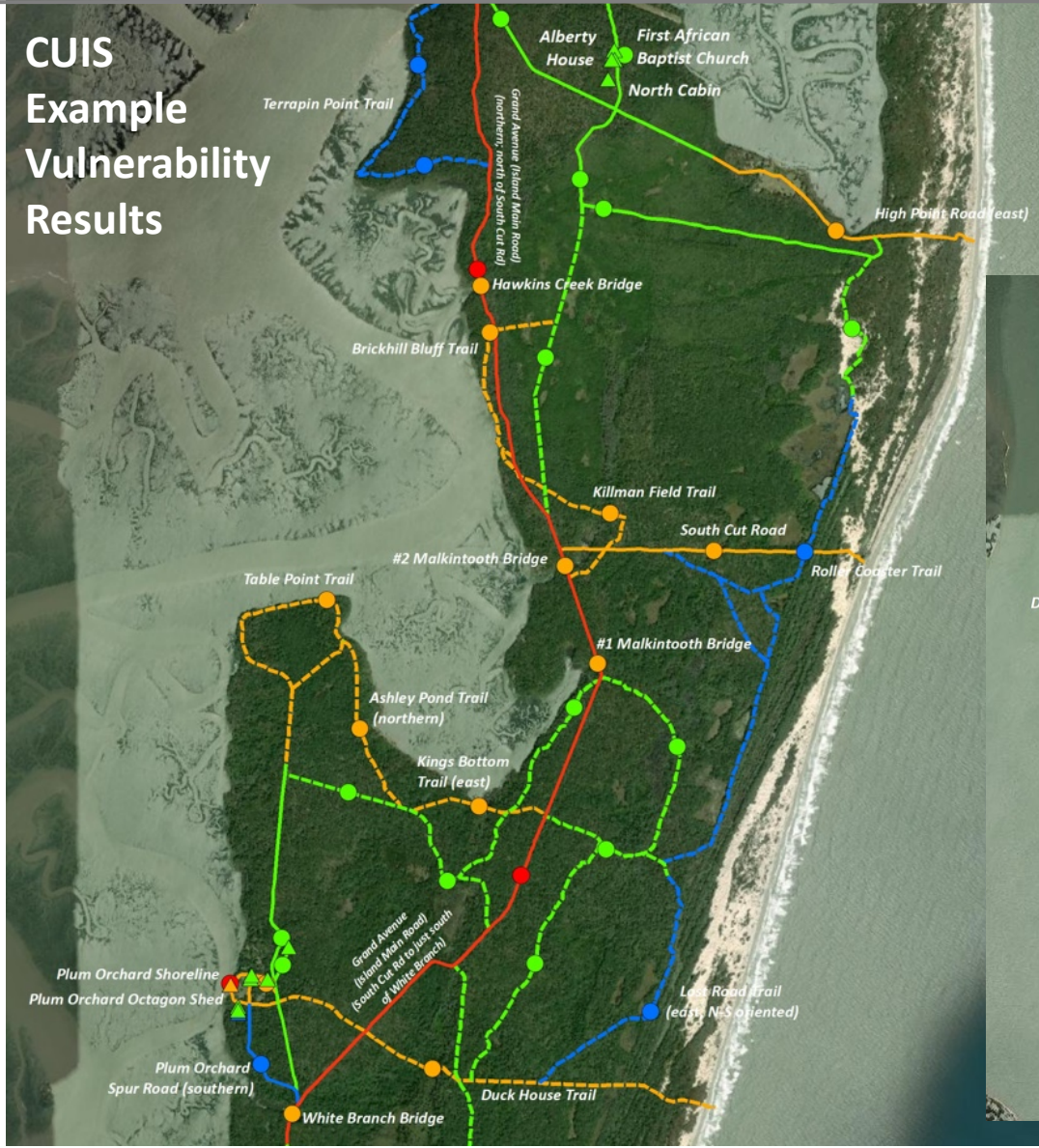
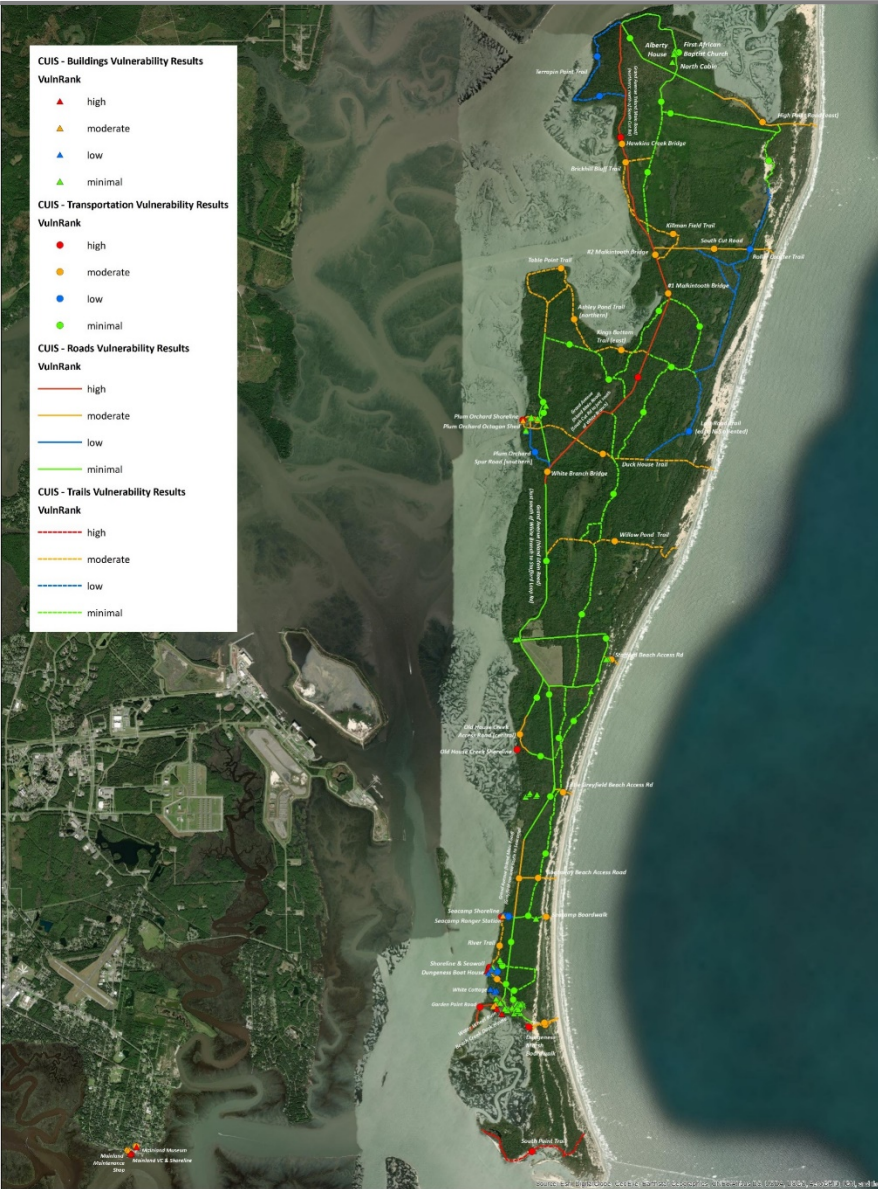


CASA-FOMA Example Vulnerability Results





WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol





WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

Google Earth Pro

File Edit View Tools Add Help

Search

ex: Tokyo, Japan

Get Directions History

Places

- HI HS CCC Cabin 323
- HI HS CCC Cabin 324
- HI BD CCC Generator Shed
- HI BD Billy Mitchell Pilot Facility
- HI BD Frisco CG Loop B Comfort St
- HI BD Frisco Campground Kiosk
- HI BD Natural Resources Storage B
- HI BD Frisco CG Loop A Comfort S
- HI BD Frisco CG Loop A Shower Bu
- HI BD Frisco CG Loop B Shower Bu
- HI BD Frisco CG Loop C Comfort S
- HI BD Frisco CG Loop C Shower Bu
- HI BD Frisco CG Loop E Comfort St
- HI BD Frisco CG Loop E Shower Bu
- HI BD Frisco Day Use Comfort Stati
- HI WP Frisco Water Treatment Plan
- HI BD Frisco Water Plant Pumppho
- HI BD Frisco Water Plant Storage B
- HI HS Hatteras Weather Station
- HI HS Hatteras Weather Station Shv
- HI HS Hatteras Weather Station Sh
- HI MT Carved & Etched Granite M
- HI MT Carved & Etched Granite M
- HI MT Carved & Etched Granite M
- HI BD Haulover SST/Shower Comp
- HI HS Lighthouse
- HI HS Lighthouse Oilhouse
- HI AS Original Lighthouse Ruins**
- HI HS DKQ (Museum of the Sea)
- HI HS PKQ (Principal Keepers Quar
- HI BD LH Comfort Station

OBX Example Vulnerability Results – Google Earth

HI AS Original Lighthouse Ruins	
FID	128
ID	129
Location	HI AS Original Lighthouse Ruins
Area	HI Lighthouse
Exposure	4
Sensitivit	3
Raw_Score	7
Final_Scor	4
Final_Rank	high
Latitude	35.254922
Longitude	-75.520701
Location_C	28660
Asset_Code	7200
Facility_T	7210
State	NC
Optimizer	4
API	20
FCI	0
CRV	76707.56
Park_Conc_	
DM	0
CSDM	0
Ranking	GOOD
Qty	300
UM	SF
Historic	N
Year	1802
LCS	0

Directions: [To here](#) - [From here](#)

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2021 TerraMetrics

Google Earth

1985

Imagery Date: 2/19/2017 lat 35.245514° lon -75.540804° elev 0 ft eye alt 43654 ft

Coastal Hazards Infrastructure Vulnerability Assessment

Duck, North Carolina

February 2020



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



Western
Carolina
UNIVERSITY





WCU Coastal Hazards & SLR Asset Vulnerability Assessment Protocol

- ✓ Taking **adaptation actions** can reduce an asset's **exposure** and/or **sensitivity**, which in turn, lowers its overall **vulnerability**

Adaptation Action	Effect on Vulnerability & Rationale
Elevate	Reduces the sensitivity of the asset; elevating an asset (pilings or artificial fill) 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 by an engineered structure (e.g., seawalls) or landscape modifications (e.g., drainage, nourishment, restoration) 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	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 give more flexibility for replacement.



Application

- It's not just where the water will be, but what happens when it gets there.
- Provides details at the asset level embedded within existing asset-management database
- These data are being used in multiple ways:
 - Short-term planning, spending, maintenance
 - Post-storm rebuilding
 - Long-term planning for cultural resources (e.g. Portsmouth Village, Cape Lookout, NS)



Benefits

- Clear, science-based guidance for the allocation of limited funding for maintenance, improvement, and rebuilding of park infrastructure.
- Data to support the funding of adaptation/resilience projects for infrastructure and historic structures that are mission critical.
- The best way to protect natural resources in coastal parks is to make very wise decisions about your infrastructure.

