

Resilient Coastal Tourist Communities



Dr. Rob Young
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Robert S. Young is the Director of the Program for the Study of Developed Shorelines, a joint Duke University / Western Carolina University venture. He is also a Professor of Geosciences at Western Carolina University and a licensed professional geologist in Florida, North Carolina and South Carolina. PSDS is a research and policy outreach center serving the global coastal community. The primary mission of PSDS is to conduct scientific research into coastal processes, storm impacts, hazard vulnerability and sea level rise and to translate that science into management and policy recommendations through a variety of professional and public outreach mechanisms. Dr. Young received a Bachelor of Science degree in Geology from the College of William & Mary, and Master of Science degree in Quaternary Studies from the University of Maine, and a PhD in Geology from Duke University where he was a James B. Duke Distinguished Doctoral Fellow.

COASTAL HAZARDS & SEA-LEVEL RISE ASSET VULNERABILITY ASSESSMENT PROTOCOL

FIIS RESULTS: NOVEMBER 2017



Program for the Study of Developed Shorelines, Western Carolina University

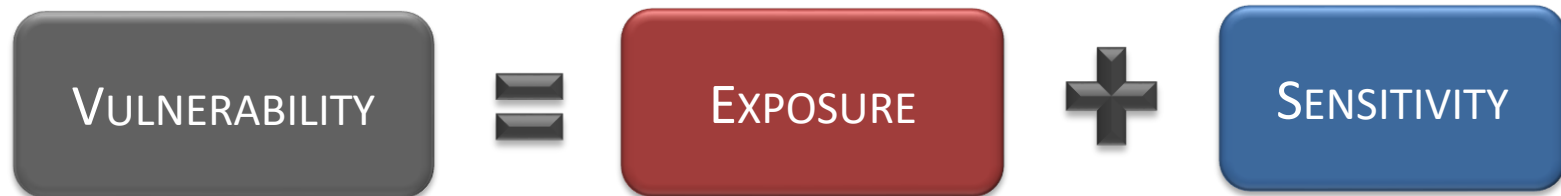
- NPS – Park Facility Management Division - Sustainable Operations Branch
- NPS – Park Facility Management Division - Facilities Planning Branch
- NPS – Climate Change Response Program



CONCEPTUAL DESIGN



METRICS OF VULNERABILITY: INFRASTRUCTURE



Adaptive
Capacity

- ✓ Still significant, but addressed separately
- ✓ Not part of vulnerability formula/score
- ✓ **Adaptation actions taken for assets help reduce exposure and/or sensitivity**



CONCEPTUAL DESIGN



EXPOSURE

if a resource is located in an area experiencing climate change & coastal hazards

Coastal hazard =
storm surge

Building 2

lower exposure
to storm surge

Building 1

high exposure
to storm surge

Exposure = location, location, location!



CONCEPTUAL DESIGN



SENSITIVITY

how an asset or system fares
when exposed to an impact

Coastal hazard =
storm surge

Building 2: at grade



higher sensitivity

Building 1: elevated



lower sensitivity

Sensitivity = independent of location

*Note: not actual building locations
or images of buildings at FOMA*



COASTAL HAZARD & SLR **EXPOSURE** INDICATORS



INDICATORS: FACTORS/DATA TO CONSIDER WHEN ANALYZING EXPOSURE OF AN ASSET

INDICATOR	DATA SOURCES
FLOODING POTENTIAL 1% ANNUAL FLOOD CHANCE \pm VELOCITY/WAVES	<ul style="list-style-type: none">FEMA Flood Zones (VE or AE); LiDAR DEM or other elevation model
EXTREME EVENT FLOODING STORM SURGE, TSUNAMI, EXTREME HIGH WATER	<ul style="list-style-type: none">NPS-specific SLOSH model; tsunami models; tide gage recorded extreme high water data
SEA-LEVEL RISE INUNDATION 2050 PROJECTION	<ul style="list-style-type: none">NPS-specific SLR modeling; LiDAR DEM or other elevation model
SHORELINE CHANGE EROSION, COASTAL PROXIMITY, CLIFF RETREAT	<ul style="list-style-type: none">State or USGS erosion rate buffers; cliff retreat rate buffers; shoreline proximity buffers
REPORTED COASTAL HAZARDS HISTORIC FLOODING, VISIBLE SLOPE INSTABILITY	<ul style="list-style-type: none">Park surveys/questionnaire results; storm imagery & reconnaissance

- **Goal:** consistent data sources across parks (when possible)
- **Exposure time frame:** 2050



FLOODING POTENTIAL INDICATOR DATA

Data:
**FEMA High Risk
Flood Zones
(VE and A Zones)**

Lighthouse

Ferry

Maintenance

HQ

Data Source: FEMA

VE (Highest Hazard): Areas subject to inundation by the **1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action**. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

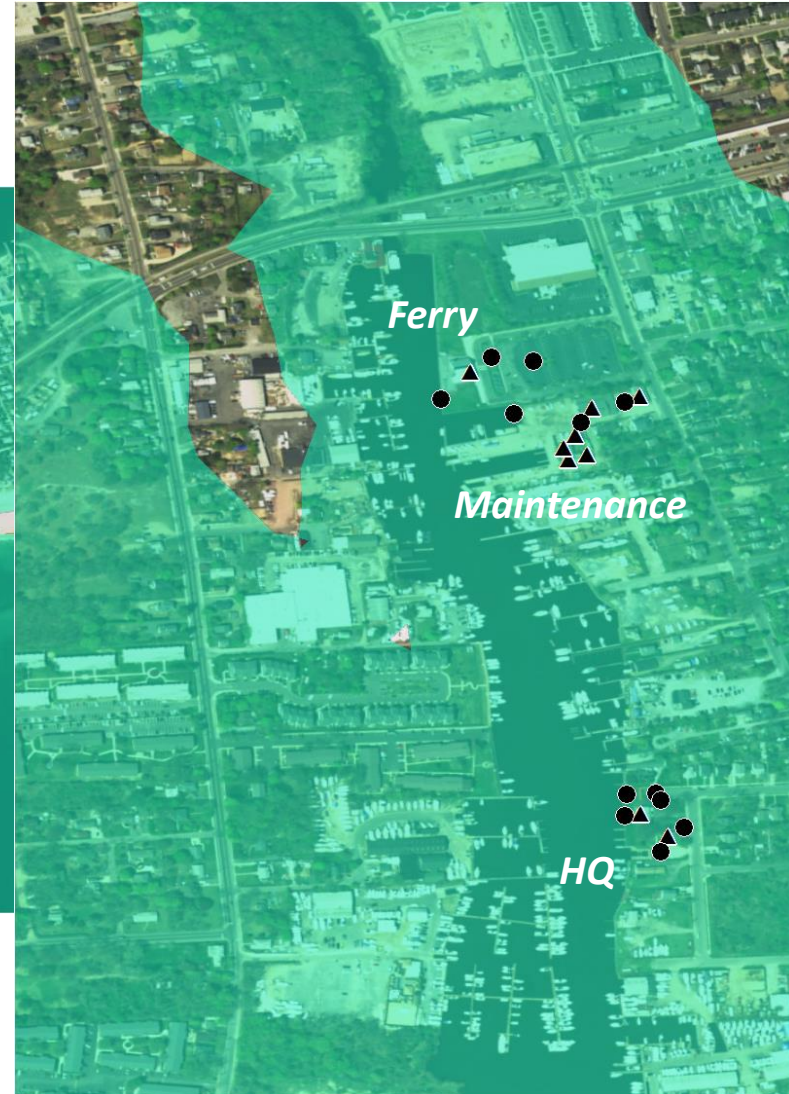
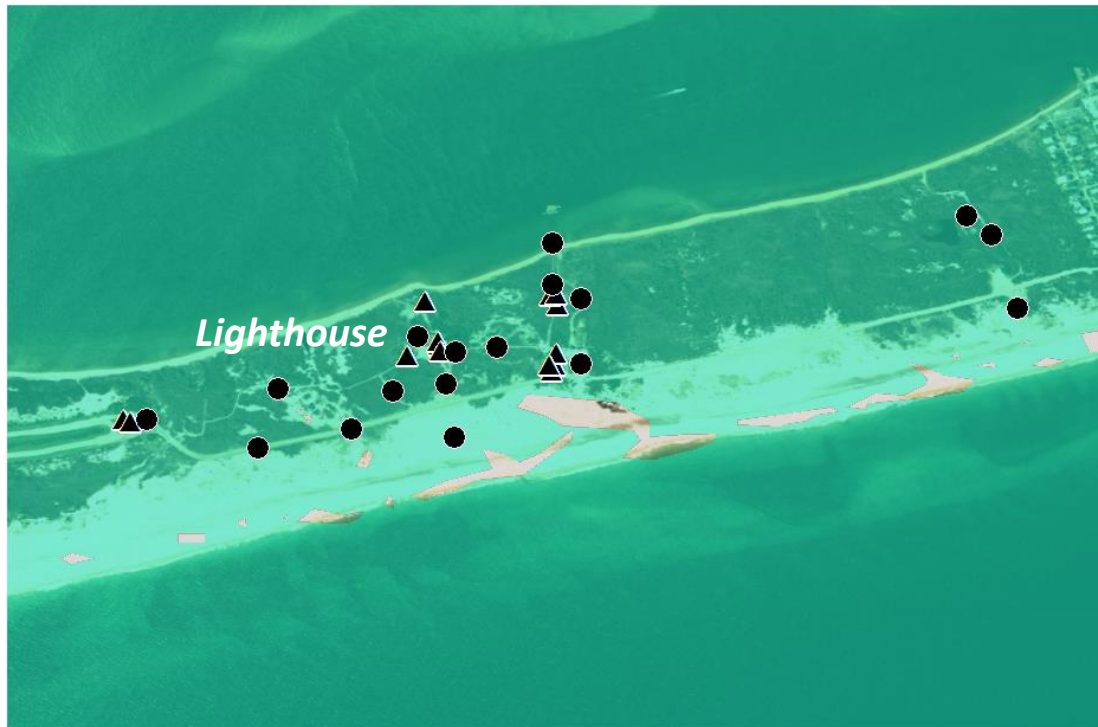
AE (or other A): Areas subject to inundation by the **1-percent-annual-chance flood event** determined by detailed methods. Base Flood Elevations (BFEs) are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.



EXTREME EVENT FLOODING INDICATOR DATA



Data:
Storm Surge Cat 3 SLOSH Model



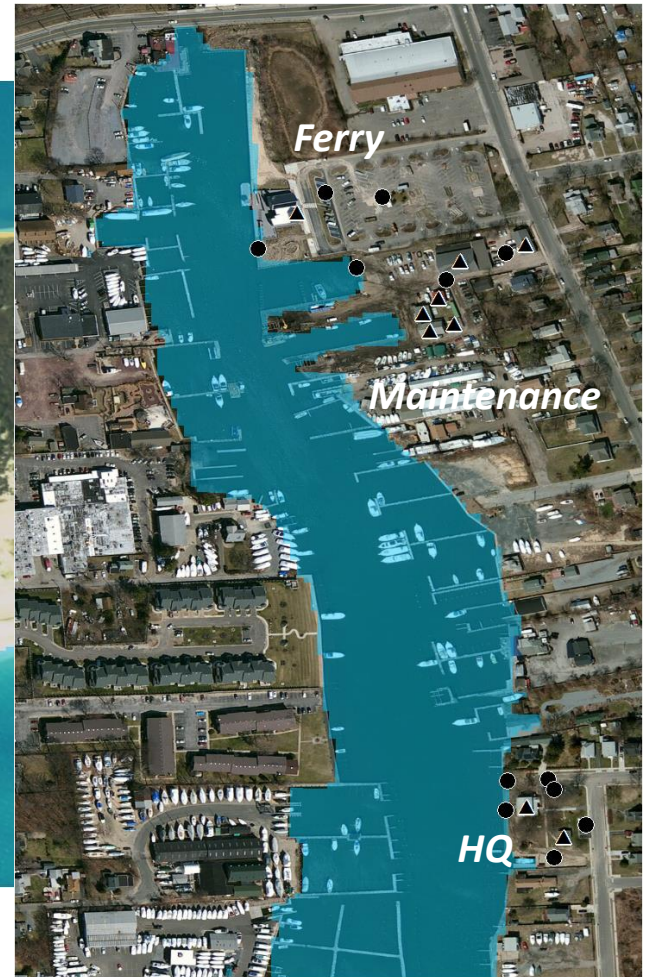
Data Source: NPS CCRP



SLR INUNDATION INDICATOR DATA



Data:
Sea-level rise (SLR)



Data Info: NPS-specific SLR models 2050
Intermediate Projection (obtained from
NPS Climate Change Response Program)



SHORELINE CHANGE INDICATOR DATA



Data: 35-year erosion buffer zones & coastal proximity buffers

Data Source: USGS Erosion Rates





REPORTED COASTAL HAZARDS DATA



Data Sources:
Historical Flooding
Reports (Questionnaire) &
Storm Imagery



Historical Flooding Data

<https://arcg.is/1Gq0yy>

Has the SITE or LAND AREA near any of the following assets been flooded in previous storm events?

* This question is referring to the site or land 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. Please note in the comments if the flooding is non-coastal (e.g., heavy rainfall, ponding, or drainage issues).

FMSS Asset Information					Record Answers (add x)	Comments (clarifications, unsure, unfamiliar with asset, etc.)
#	Asset Code	Year Built	FMSS Code	Asset Description	Yes	
1	4100	1964	111677	BU-BB-Sun Shelter		Click here to add any comments
2	4100	1964	105369	BU-BB-Snack Bar		Click here to add any comments
3	4100	1964	105370	BU-BB-Restrooms/Utility Room		Click here to add any comments



EXPOSURE SCORING & DRAFT RESULTS



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Exposure Analysis Data Results

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

Step 1: Score for Exposure Indicator Zones

Step 2

Step 3

Step 4

Step 5

Step 6

Step 7

ID	Location	Area	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	Binned Score Raw	VE Zone Auto High Score	Exposure Score Unmod	WCU Flagged Asset	Exposure Score	Exposure Rank
1	Q-00000154-HO-TA-154 Ocean Qtrs	TA	4		1	1	4	1	11	3	4	4		4	high
2	BU-HQ-76 Park Headquarters	HQ		4	4	1	4	4	17	4		4		4	high
3	BU-HQ-72 Headquarters Annex	HQ		4	4	1	4	4	17	4		4		4	high
4	Q-00000103-HO-SH-103 Sailors Haven Housing Unit	SH	4	4	1	1	4	1	11	3		3		3	moderate
5	BU-HQ-73 Patchogue Boat House	HQ		4	4	1	4	4	17	4		4		4	high
6	BU-HQ-77 PMF Maintenance Facility	HQ		1	1	1	4	1	8	2		2		2	low
7	BU-HQ-78 Vehicle Vessel Shop	HQ		4	4	1	4	4	17	4		4		4	high
8	Q-00000006-HO-WH-06 Qtrs #6	WH		4	1	1	4	1	11	3		3		3	moderate
9	Q-00000002-HO-WH-02 Qtrs #2	WH		4	1	1	4	1	11	3		3		3	moderate
10	BU-HQ-79 PMF Warehouse	HQ		4	1	1	4	4	14	3		3		3	moderate
11	Q-00000003-HO-WH-03 Qtrs #3	WH		4	1	1	4	1	11	3		3		3	moderate
12	Q-00000004-HO-WH-04 Qtrs #4	WH		4	1	1	4	1	11	3		3		3	moderate
13	Q-00000005-HO-WH-05 Qtrs #5	WH		4	1	1	4	1	11	3		3		3	moderate
14	Q-00000007-HO-WH-07 Qtrs #7	WH		4	1	1	4	1	11	3		3		3	moderate
15	BU-HQ-81 River Room (Conference)	HQ		4	1	1	4	4	14	3		3		3	moderate
16	Q-00000008-HO-WH-08 Qtrs #8	WH		4	1	1	4	1	11	3		3		3	moderate
17	Q-00000009-HO-WH-09 Qtrs #9	WH		4	1	1	4	1	11	3		3		3	moderate
18	Q-00000010-HO-WH-10 Qtrs #10	WH		4	1	1	4	1	11	3		3		3	moderate
19	Q-00000011-HO-WH-11 Qtrs #11	WH		4	1	1	4	1	11	3		3		3	moderate
20	Q-00000012-HO-WH-12 Qtrs #12	WH		4	1	1	4	1	11	3		3		3	moderate
21	Q-00000001-HO-WH-01 Qtrs#1	WH		4	1	1	4	1	11	3		3		3	moderate
22	BU-WF-224 Curatorial Storage	WF		1	1	1	4	1	8	2		2		2	low
23	BU-LS-219 Single Story Connector Bldg	LS		4	1	1	4	1	11	3		3		3	moderate
24	Q-00000151-HO-CA-151 Carrington House	CA	4		1	1	4	1	11	3	4	4		4	high
25	BU-LS-93a Comfort Station	LS		4	1	1	4	1	11	3		3		3	moderate
26	Q-00000152-HO-CA-152 Carrington Cottage	CA		4	1	1	4	1	11	3		3		3	moderate
27	Q-00000104-HO-SH-102 Qtrs#102	SH		4	1	1	4	1	11	3		3		3	moderate
28	BU-SH-107 Comfort Station	SH		4	1	1	4	1	11	3		3		3	moderate
29	BU-SH-104 Visitor Center	SH		4	4	1	4	1	14	3		3		3	moderate
30	BU-OP-51 Wilderness Visitor Center	OP	4		1	1	4	1	11	3	4	4		4	high
31	BU-TA-156 Maintenance Shop	TA		4	1	1	4	1	11	3		3		3	moderate
32	BU-TA-157 Comfort Station	TA		4	4	1	4	1	14	3		3		3	moderate
33	BU-TA-158 Pump House	TA	4		1	1	4	1	11	3	4	4		4	high



EXPOSURE MAPS



Lighthouse Area

FIIS Transportation Exposure

Rank

- high
- moderate
- low
- minimal

FIIS Structures Exposure

Rank

- ▲ high
- ▲ moderate
- ▲ low
- ▲ minimal

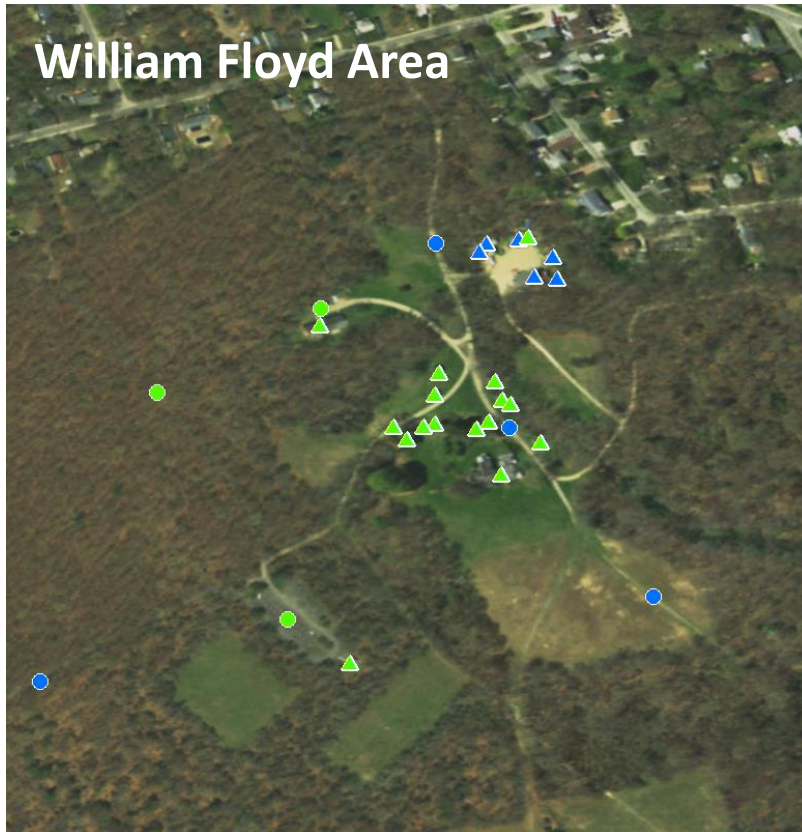




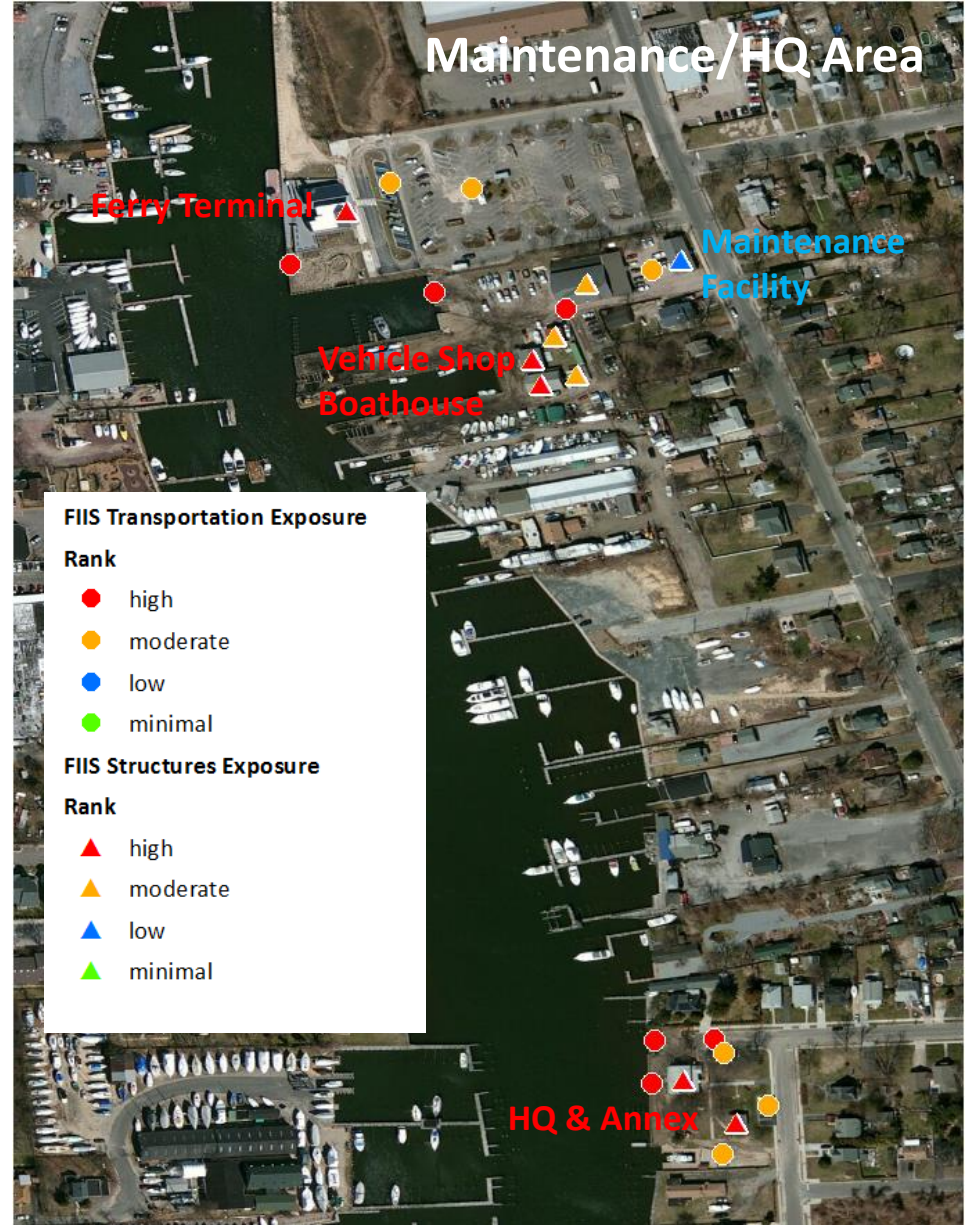
EXPOSURE MAPS



William Floyd Area



Maintenance/HQ Area





COASTAL HAZARD & SLR **SENSITIVITY** INDICATORS



INDICATORS: FACTORS/DATA TO CONSIDER WHEN ANALYZING SENSITIVITY OF AN ASSET

INDICATOR		COMMON DATA SOURCES
<input checked="" type="checkbox"/>	FLOOD DAMAGE POTENTIAL	<ul style="list-style-type: none">• Direct field measurement: threshold elevation, park personnel surveys/interviews, field surveys
<input checked="" type="checkbox"/>	STORM RESISTANCE & CONDITION	<ul style="list-style-type: none">• Park personnel surveys/interviews, FMSS
<input checked="" type="checkbox"/>	HISTORICAL DAMAGE	<ul style="list-style-type: none">• Park personnel surveys/interviews, park documents/reports
<input checked="" type="checkbox"/>	PROTECTIVE ENGINEERING	<ul style="list-style-type: none">• Park personnel surveys/interviews, coastal engineering inventory (WCU/OSU), field surveys



COASTAL HAZARD & SLR SENSITIVITY INDICATORS



THRESHOLD ELEVATION DATA COLLECTION

NPS Resource Information Services Division (Brian Diethorn & Tim Smith)

WCU: Verifying Sensitivity Indicator (Q1: Elevated)



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Sensitivity Analysis Data Results

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

ID	Location	Area	Flood Damage Potential (Elevated) (Q2)	BFE (ft, NAVD88)	Threshold Elev (ft, NAVD88)	Threshold Above or Below BFE	Storm Resist; Condition (Q3, Q4)		Historical Damage (Q5)	Protective Engineering (Q6)	Flagged Asset	Sensitivity Score	Sensitivity Rank
28	BU-SH-107 Comfort Station	SH	4	9.0	6.430	Below	4	1	1	4	Q2/BFE. & Q6. See Notes	3	moderate
29	BU-SH-104 Visitor Center	SH	1	8.0	12.467	Above*	4	1	1	1		2	low
30	BU-OP-51 Wilderness Visitor Center	OP	1	16.0			4	1	1	4	Q2/BFE. See notes	3	moderate
31	BU-TA-156 Maintenance Shop	TA	4	13.0	8.169	Below	4	4	1	4		4	high
32	BU-TA-157 Comfort Station	TA	4	10.0	8.465	Below	4	1	1	4		3	moderate
33	BU-TA-158 Pump House	TA	4	16.0	8.071	Below	4	1	1	4		3	moderate
34	BU-WH-13 Marina Store	WH	1	7.0	7.415	Above	4	1	1	1	Q2/BFE. & Q6. See Notes	2	low
35	BU-LS-94 Annex Garage	LS	4	9.0	3.707	Below	4	1	4	4		4	high
36	BU-LS-96 Store House	LS	4	8.0	5.217	Below	4	1	1	4		3	moderate
37	BU-LS-97 Oil House	LS	4	8.0	5.807	Below	4	1	1	4		3	moderate
38	BU-LS-98 Tool House	LS	4	8.0	5.840	Below	4	1				3	moderate
39	BU-LS-99 Lighthouse Boat House	LS	1	7.0	8.924	Above*	4	1				3	moderate
40	BU-WH-20 Maintenance Shop	WH	4	8.0	3.773	Below	4	1				3	moderate
41	BU-WH-22 Flammable Storage Bldg.	WH	4	8.0	3.215	Below	4	1				3	moderate
42	BU-LS-91 Fire Island Light House	LS	1	7.0	15.486	Above*	4	1				3	moderate
43	BU-LS-92 Keepers Qtrs	LS	1	8.0	13.845	Above*	4	1				3	moderate
44	BU-LS-95 Check Station	LS	4	9.0	8.235	Below	4	1				3	moderate
45	Q-00SHBARN-HO-SH-105 Horse Barn	SH	4	13.0	4.035	Below	4	1				3	moderate
46	BU-SH-106 Gift Shop & Snack Bar	SH	4	8.0	5.052	Below	4	1				3	moderate
47	BU-SH-109 Maintenance Shop	SH	4	9.0	3.609	Below	4	1				3	moderate
48	BU-SH-111 Garbage Bldg.	SH	4	9.0	2.100	Below	4	1				3	moderate
49	BU-WF-222 Turf Equipment Storage Building	WF	4	-	20.112		4	1				3	moderate
50	BU-WF-223 Fire Cache Storage Building	WF	4	-	19.324		4	1				3	moderate
51	BU-WF-221 Flammable Storage Building	WF	4	-	17.848		4	1				3	moderate
52	BU-WH-14 Dockmaster Office	WH	4	7.0	5.085	Below	4	1				3	moderate
53	BU-WH-15 Storage Bldg	WH	4	7.0	2.854	Below	4	1				3	moderate
54	BU-WH-16 Visitor Center	WH	1	7.0	7.087	Above	4	1				3	moderate
55	BU-WH-17 Marina Restroom	WH	1	7.0	7.119	Above	4	1				3	moderate
56	BU-WH-21 First Aid Room	WH	4	7.0	2.920	Below*	4	1			Q2/BFE. & Q6. See Notes	3	moderate

Elevation = 5+ ft above FEMA BFE (Base Flood Elevation)

Elevation = 5+ ft
above FEMA BFE
(Base Flood
Elevation)





SENSITIVITY & VULNERABILITY SCORING



Flood Damage Potential Indicator
Storm Resistance/Condition Indicator
Historical Damage Indicator
Adaptive Protection Indicator


TOTAL SENSITIVITY SCORE



EXPOSURE SCORE
SENSITIVITY SCORE

TOTAL VULNERABILITY SCORE

**Formula for Structures (slightly different for bridges/transportation)*




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Sensitivity Analysis Data Results

Definitions of WCU Columns on Next Sheet (Click Here to View)

ID	Location	Area	Flood Damage Potential (Elevated) (Q2)	BFE (ft, NAVD88)	Threshold Elev (ft, NAVD88)	Threshold Above or Below BFE	Storm Resist; Condition (Q3, Q4)		Historical Damage (Q5)	Protective Engineering (Q6)	Step 2		Step 4	
											Flagged Asset	Sensitivity Score	Sensitivity Rank	
1	Q-00000154-HO-TA-154 Ocean Qtrs	TA	1	17.0	16.995	Above	4	1	1	4	Q2/BFE. See notes	3	moderate	
2	BU-HQ-76 Park Headquarters	HQ	4	6.0	5.938	Below	4	1	4	1	Q6. See Notes	3	moderate	
3	BU-HQ-72 Headquarters Annex													
4	Q-00000103-HO-SH-103 Sailors Haven Housing Unit													
5	BU-HQ-73 Patchogue Boat House													
6	BU-HQ-77 PMF Maintenance Facility													
7	BU-HQ-78 Vehicle Vessel Shop													
8	Q-00000006-HO-WH-06 Qtrs #6													
9	Q-00000002-HO-WH-02 Qtrs #2													
10	BU-HQ-79 PMF Warehouse													




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Vulnerability Assessment Data Results

Definitions of WCU Columns on Next Sheet (Click Here to View)

ID	Location	Area	Metrics of Vulnerability		Vulnerability			Geospatial Data		Location Code	Asset Code
			Exposure	Sensitivity	Raw Score	Final Score	Final Rank	Latitude	Longitude		
1	Q-00000154-HO-TA-154 Ocean Qtrs	TA	4	3	7	4	high	40.671489	-73.042135	15935	4100
2	BU-HQ-76 Park Headquarters	HQ	4	3	7	4	high	40.755070	-73.017100	18216	4100
3	BU-HQ-72 Headquarters Annex	HQ	4	3	7	4	high	40.754854	-73.016833	18749	4100
4	Q-00000103-HO-SH-103 Sailors Haven Housing Unit	SH	3	4	7	4	high	40.656735	-73.103130	18750	4100
5	BU-HQ-73 Patchogue Boat House	HQ	4	4	8	4	high	40.758529	-73.017806	18751	4100
6	BU-HQ-77 PMF Maintenance Facility	HQ	2	4	6	3	moderate	40.759152	-73.017112	18752	4100
7	BU-HQ-78 Vehicle Vessel Shop	HQ	4	3	7	4	high	40.758651	-73.017852	18753	4100
8	Q-00000006-HO-WH-06 Qtrs #6	WH	3	3	6	3	moderate	40.690210	-72.990711	18756	4100





VULNERABILITY RESULTS & MAPS



Lighthouse Area

FIIS Transportation Vulnerability

- high
- moderate
- low
- minimal

FIIS Structures Vulnerability

- ▲ high
- ▲ moderate
- ▲ low
- ▲ minimal

West
Entrance
Comfort &
Pavilion

Fresnel Lens

Boat House

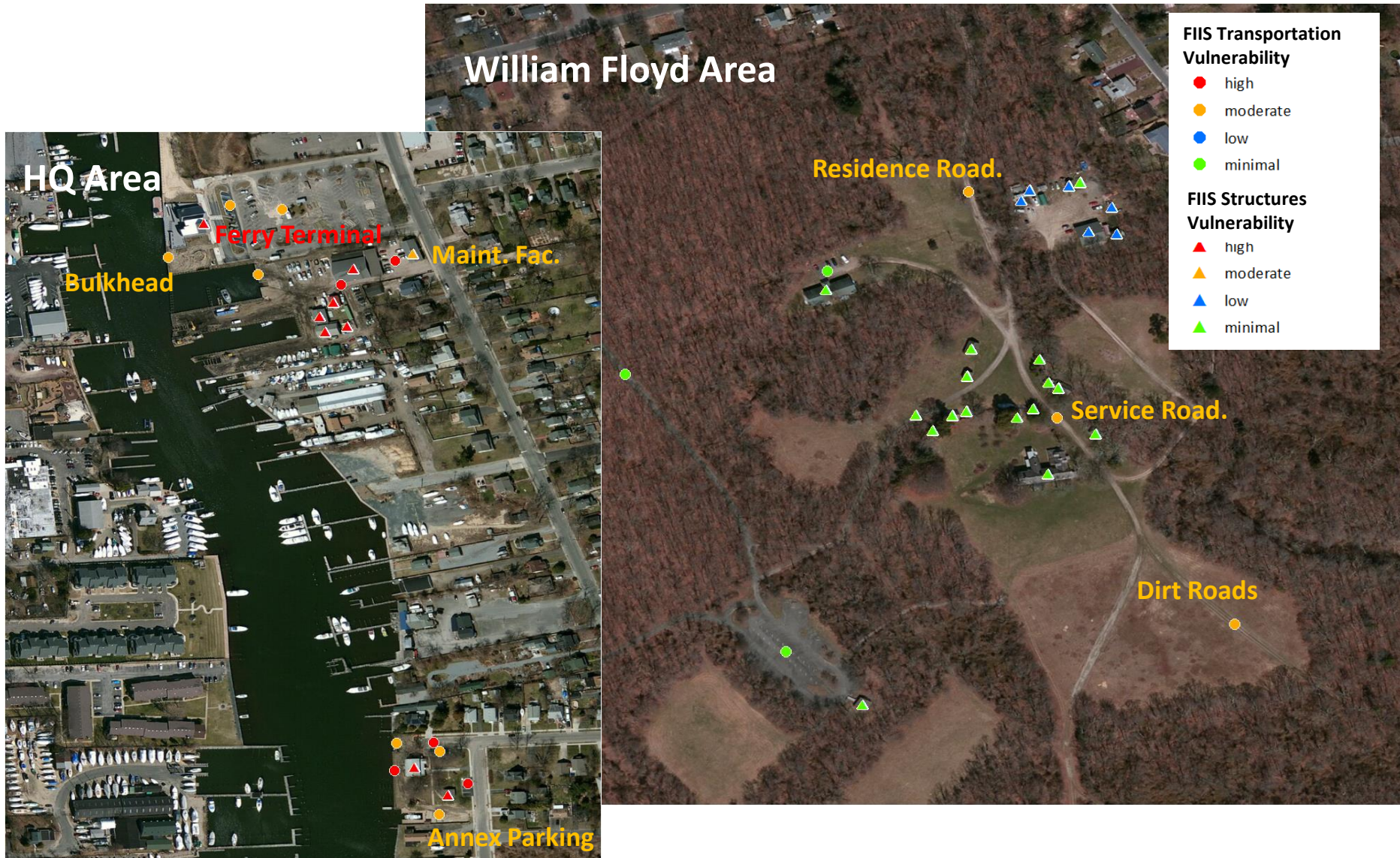
Lighthouse

Store, Oil,
Tool House

Annex, Garage, Check
Station, Comfort



VULNERABILITY RESULTS & MAPS





ADAPTATION STRATEGIES



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

ADAPTATION ACTION	ASSET TYPE	EFFECT ON VULNERABILITY & RATIONALE
✓ ELEVATE	Structures & Transportation	Reduces the sensitivity of the asset; elevating an asset (pilings or artificial fill) reduces the risk of flood damage.
✓ RELOCATE	Structures & Transportation	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	Structures & Transportation	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	Structures & Transportation	Eliminates the vulnerable asset
✓ STORM-RESISTANT REDESIGN	Structures & Transportation	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	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.

Dauphin Island, Alabama post Katrina



