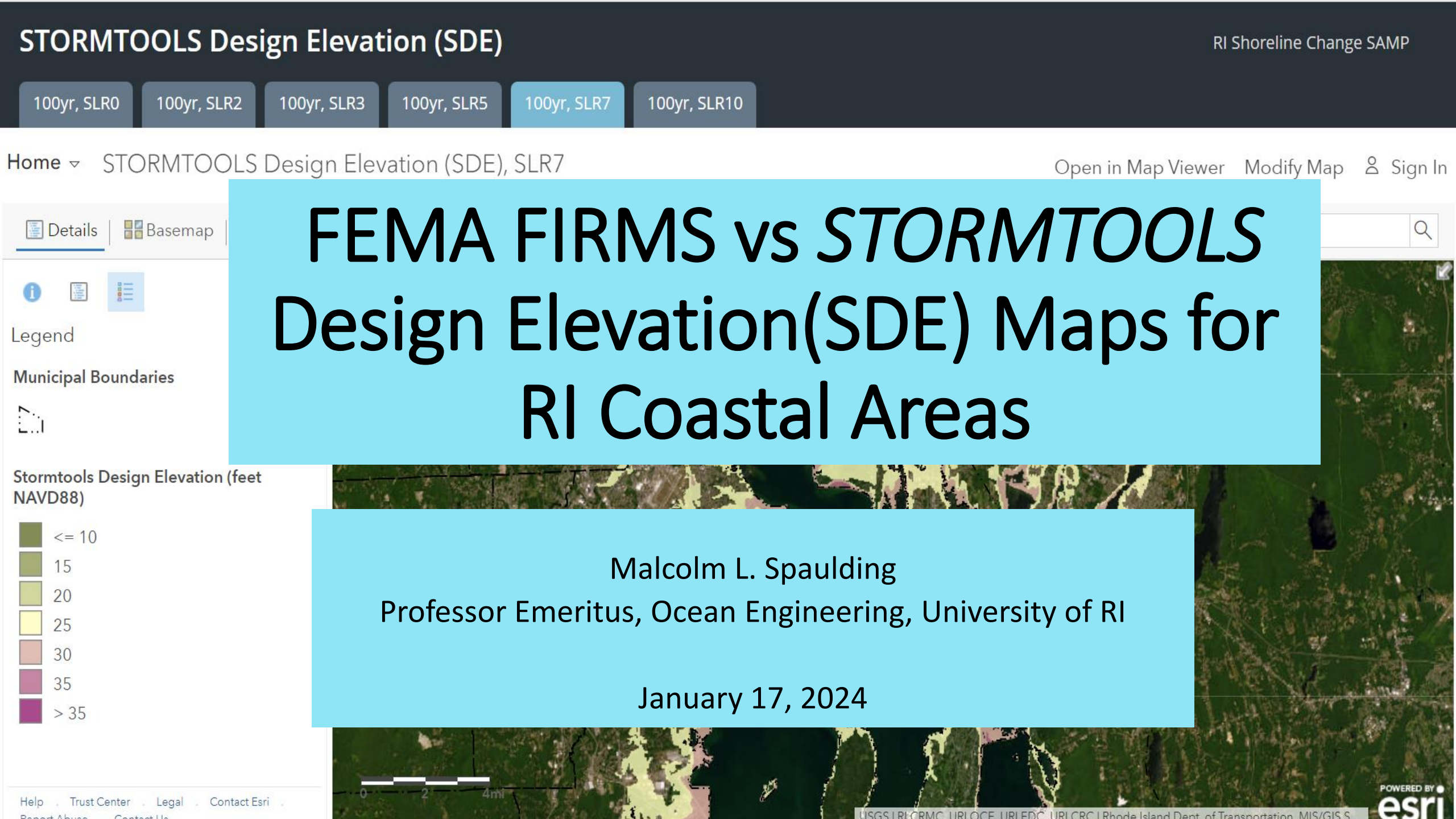


FEMA FIRMS vs *STORMTOOLS* Design Elevation(SDE) Maps for RI Coastal Areas

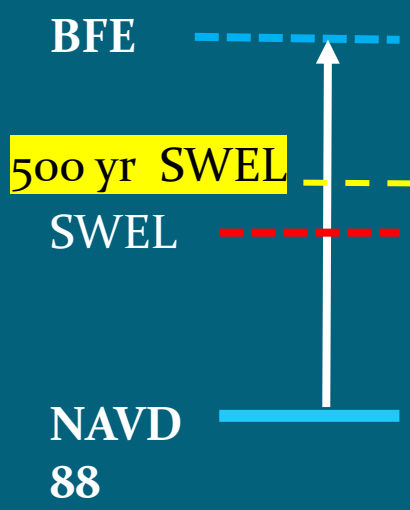
Malcolm L. Spaulding
Professor Emeritus, Ocean Engineering, University of RI

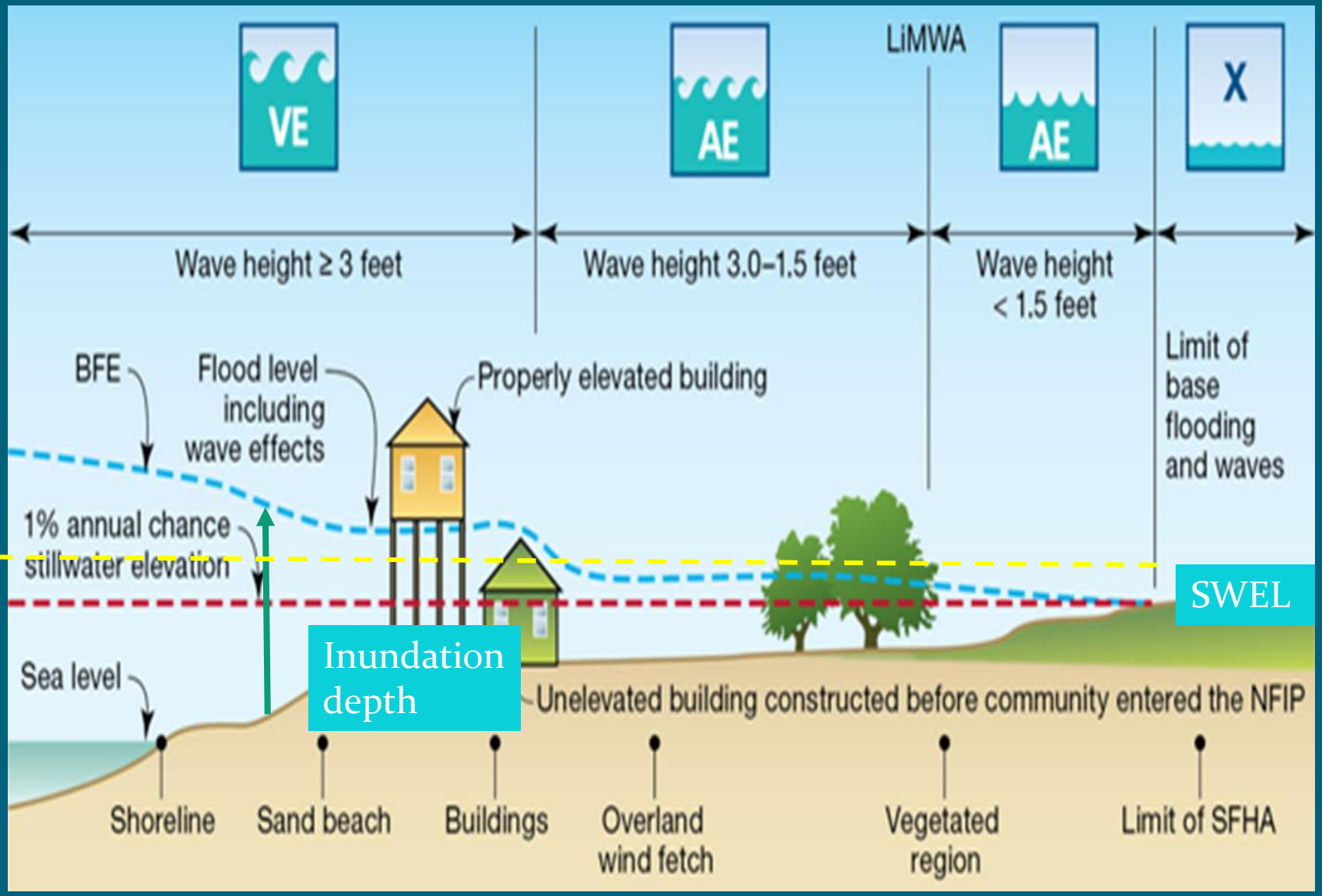
January 17, 2024

FEMA flood zones associated water levels and waves

BFE: referenced to NAVD88

Depth of inundation, referenced to grade elevation





FEMA FIRMS 100 and 500 yr events, do not consider sea level rise or change in precipitation.

Issues of concern with FEMA FIRMS

1. No consideration of climate change effects (sea level rise for coastal areas or enhanced precipitation for inland areas). (Outside scope of FIRM design but maps used extensively for design of structures, embedded in state building codes).
2. Surge levels for 100 yr based on linear interpolation between sparse water level observations in study area. FEMA, Region I (New England) does not use state of the art modeling methods or its results (only one in the US not to do so). High resolution modeling available from USACE North Atlantic Coastal Comprehensive Study (NACCS) for RI (2015).
3. Surge levels based on return period analysis at NOAA NOS observation stations, ignores uncertainty in return period analysis. Use of mean value 100 yr. Mean does not represent key storms 1938 and Carol (1954) and hence under-represents risk.

Issues of concern with FEMA FIRMS

4. The wave analysis for the flood impacted areas relies on a one dimensional (1-D) transect method (***Coastal Hazard Analysis Modeling Program - CHAMP***) from the 1980s and doesn't account for two dimensional effects available in more recent model development (STWAVE). The method is hence unable to assess 2D effects (refraction, diffraction) and is highly sensitive to the location and spacing of transects. Transect spacing is too coarse (miles) to represent key features.
5. The approach for estimating both the flood water level and waves are not based on the recent *state of practice* in flood inundation and wave modeling methodologies (ADCIR, STWAVE, SWAN, XBeach).

Issues of concern with FEMA FIRMS

6. Spatial resolution is very low and doesn't account for substantial variations likely occurring during storm events (surge channels, over wash areas, erosion of barriers, etc).
7. Erosion of the southern shoreline using FEMA method has not been verified for the study area, uses default value for erosion rates. Transect spacing is too coarse to capture breaching areas along southern RI shoreline.

SUMMARY: FEMA FIRM substantially under-represent the risk for coastal flooding for the state.

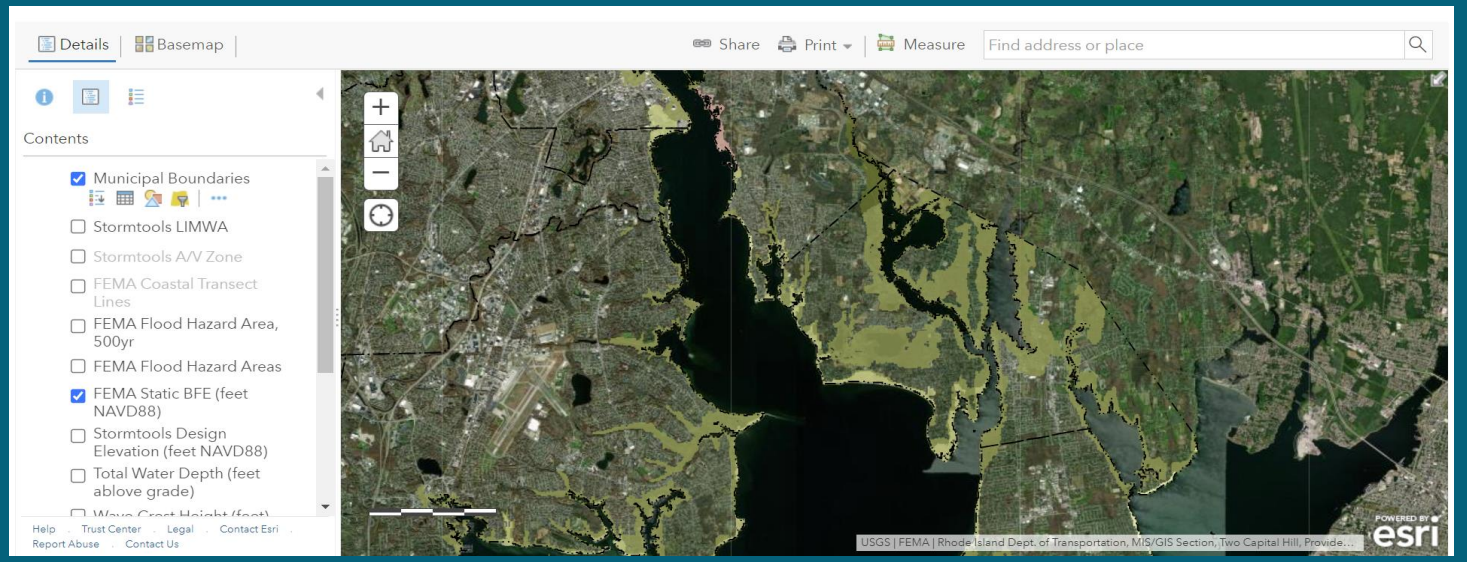
Issues of concern with FEMA FIRMS

ASCE 7-22 flood standards updated in May 2023. Design standards for residential structures changed from 100 yr to 500 yr and now includes sea level rise(SLR). These standards are embedded in RI state building code.

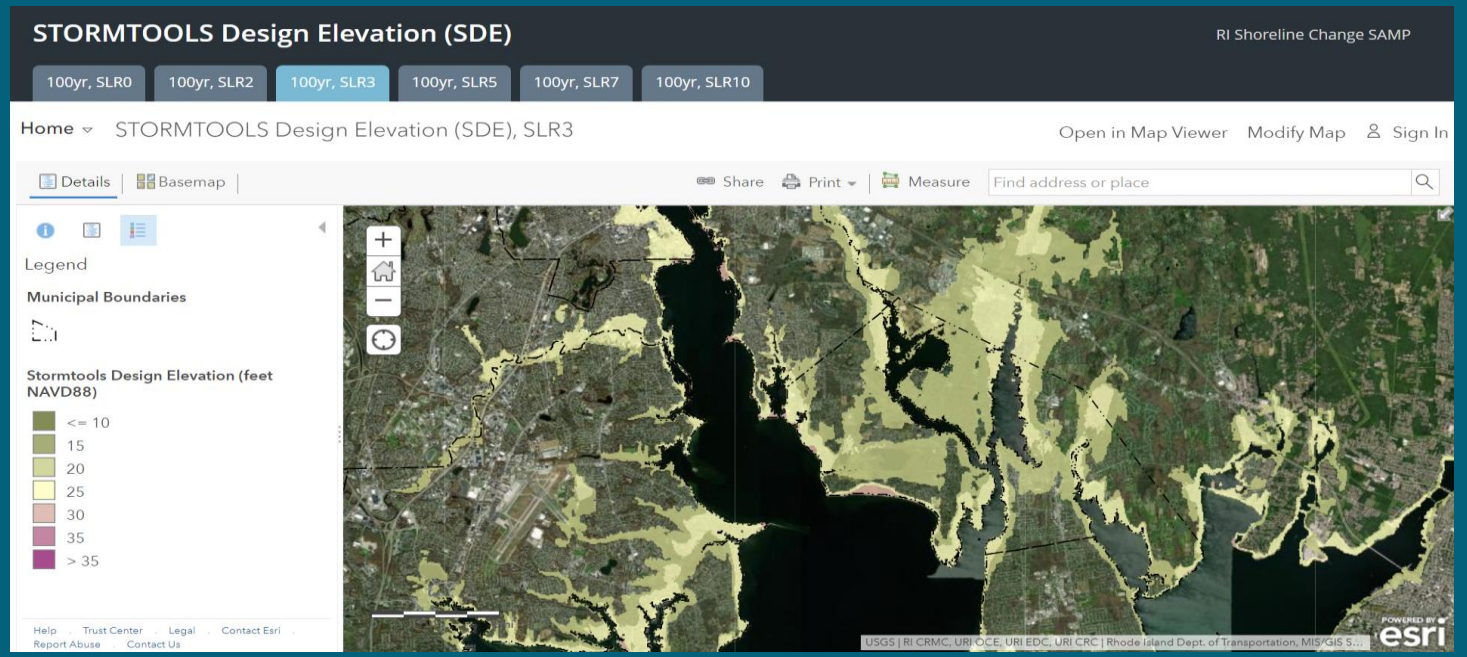
Why the update? FEMA 100 yr maps under-represent flood risk.

- FEMA 500 yr inundation levels not shown on maps, no wave estimates provided, so not possible to determine BFE values. No SLR considered.
- ASCE suggests scaling based on USACE NACCS study with scale value from 100 yr to 500 yr = 1.25. FEMA 500/100 yr scaling varies from 1.47 to 1.89 depending on location. FEMA values show surge levels decrease from mouth to head of the bay, observations show the opposite.

FEMA FIRMs



STORMTOOLS SDE



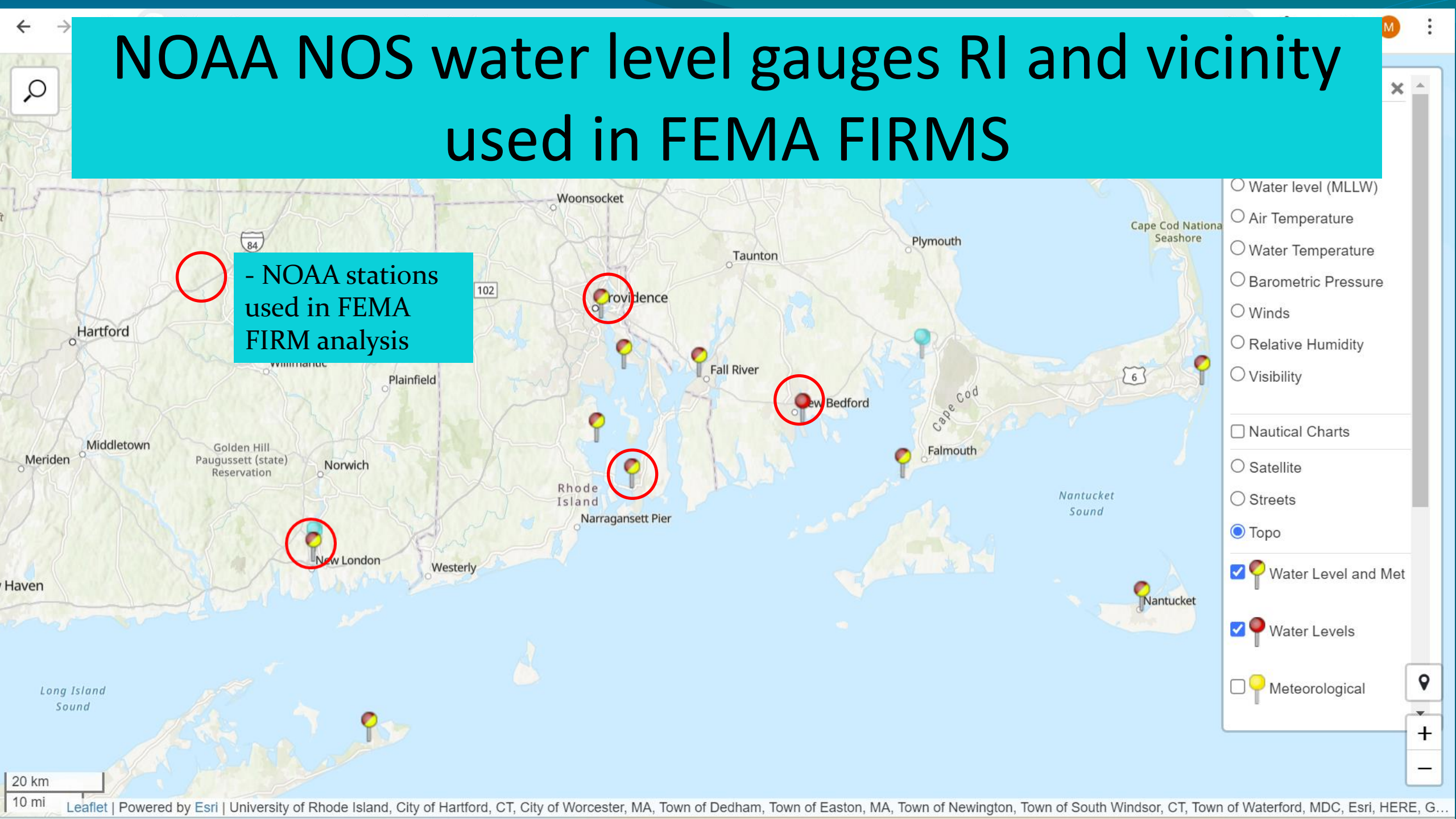
FEMA FIRMS

Surge levels for 100 yr based on linear interpolation between sparse water level observations in study area. FEMA, Region I (New England) does not use state of the art modeling results (only one in the US not to do so). High resolution modeling available from USACE North Atlantic Coastal Comprehensive Study (NACCS), 2014.

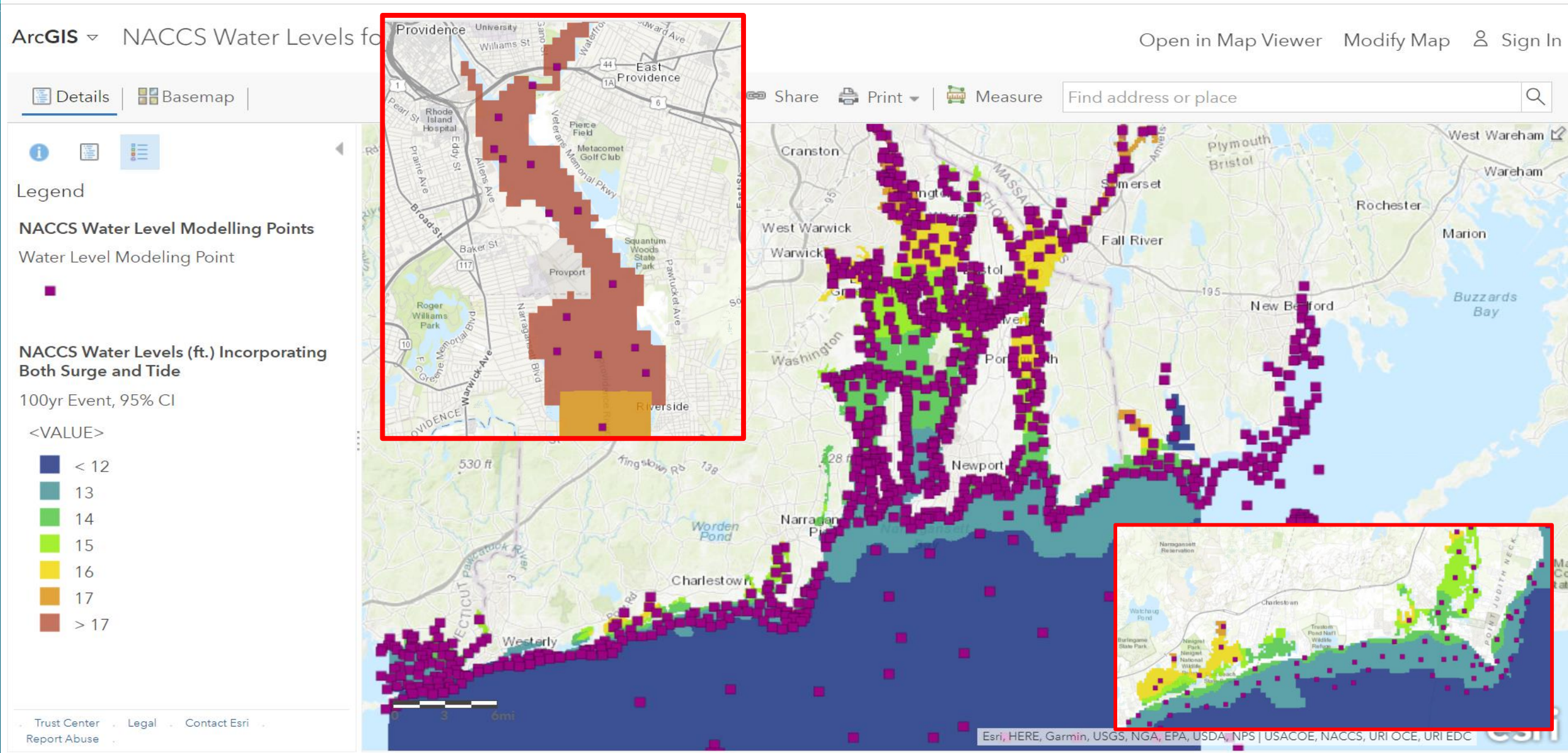
STORMTOOLS Design Elevation Maps (SDE)

Surge levels for SDE maps based on study by the US Army Corp of Engineers, North Atlantic Coast Comprehensive Study(NACCS). Use state of the art models (ADCIRC, STWAVE, XBeach), high resolution, 1000 synthetic tropical storms, 100 historical extratropical storms, 1000 save points in RI (available via STORMTOOL Hub).

NOAA NOS water level gauges RI and vicinity used in FEMA FIRMS



USACE NACCS save points used in STORMTOOLS SDE Maps



FEMA FIRM

Surge levels based on return period analysis at NOAA NOS observation stations (Providence and Newport), ignores uncertainty in return period analysis. Use mean value 100 yr. Mean does not represent key storms 1938 and Carol (1954) and hence under-represents risk.

STORMTOOLS Design Elevation Maps (SDE)

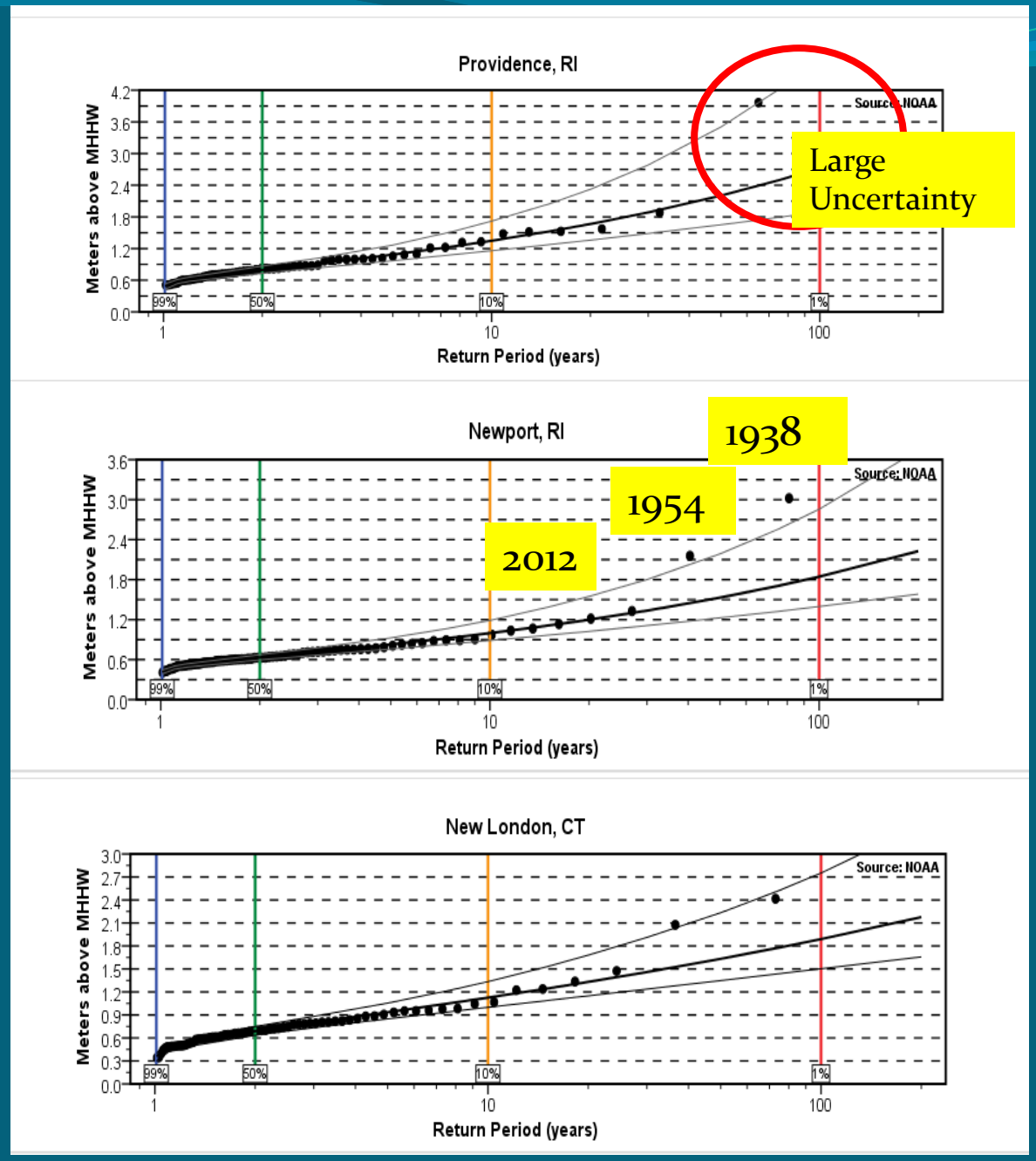
Surge levels derived from return period analysis of NACCS simulations. Explicitly considers uncertainty in results by use of upper 95% return period values. Considers 1938 and 1954 storms.

Extremal Analysis based on storm water level data at NOAA NOS stations

Storms in rank order (relative to MHHW and NAVD88), Newport, RI

	MHHW	NAVD88
1938 –	9.44 ft	11.25 ft
1954 -	6.75 ft	8.56 ft
2012 -	4.21 ft	6.02 ft
1991 -	3.97 ft	5.78 ft
1944 -	3.95 ft	5.76 ft
1978 -	3.6 ft	5.41 ft

1954 missing at Providence



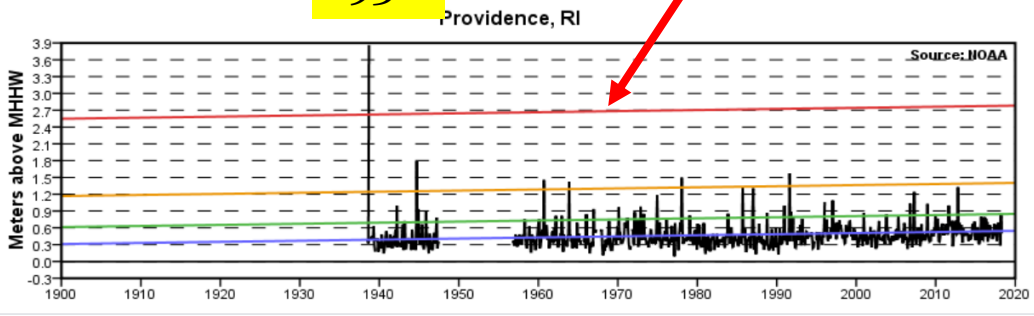
Extreme water levels

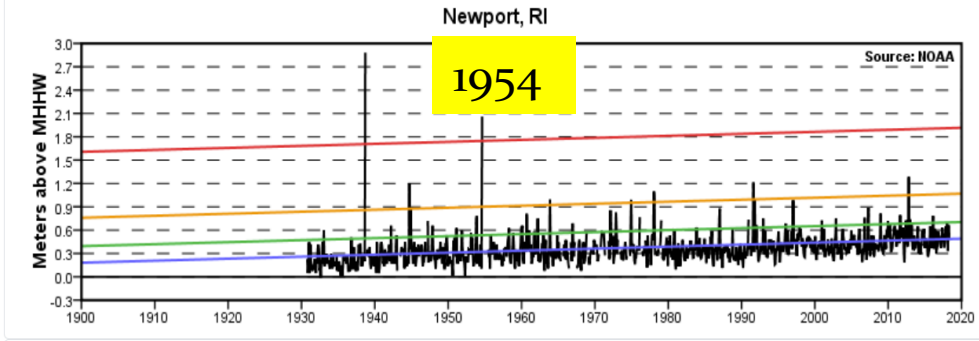
Water level comparisons New London, CT and Newport & Providence, RI, Datum: NAVD88

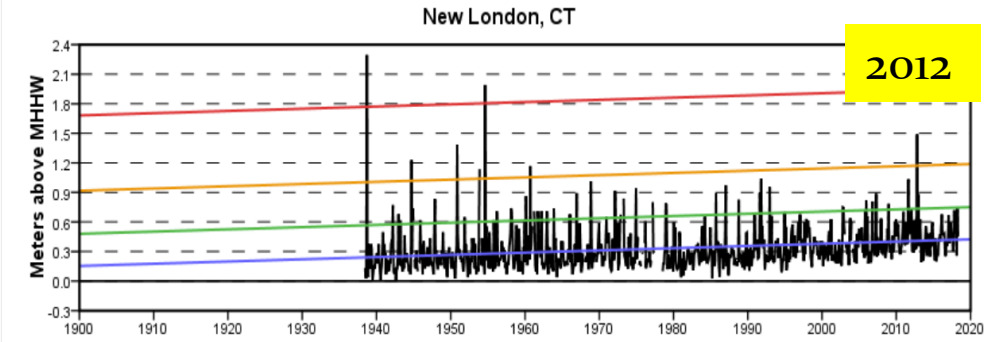
NOAA Station Location	100 yr FEMA (L Moment)	100 yr NOAA GEV		Observations	
	Mean (ft)	Mean (ft)	Upper 95%(ft)	1938 Surge (ft)	Carol 1954 Surge(ft)
Providence, RI	13.78	11.42	18.24	15.16	-
Newport, RI	10.53	8.1	11.38	11.25	8.56
New London, CT	9.42	7.58	10.4	9.08	8.73

NOAA mean 100 yr return period water level

1938



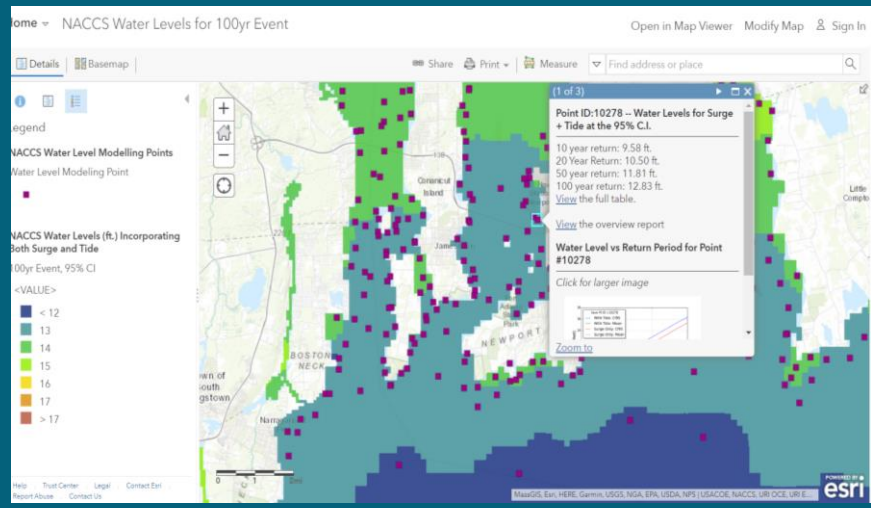


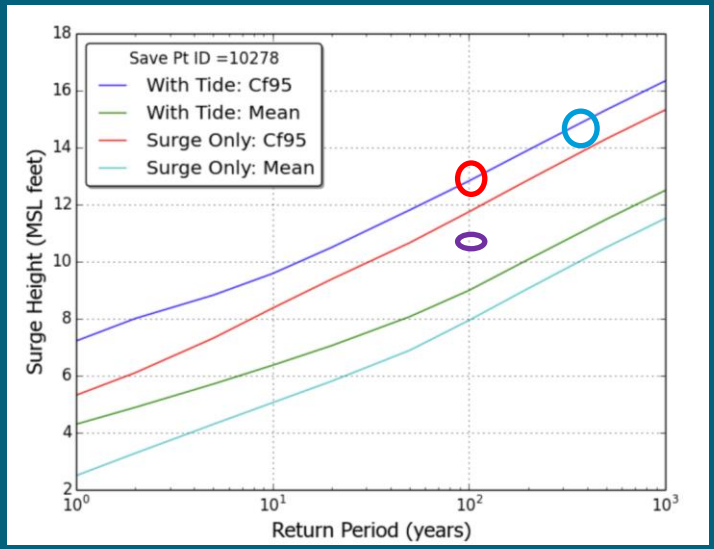


NACCS Save Pt # 10278, Newport, RI

Storm surge height vs return period based on NACCS estimates
Save Point #10278
Latitude 41.50391
Longitude -71.32487

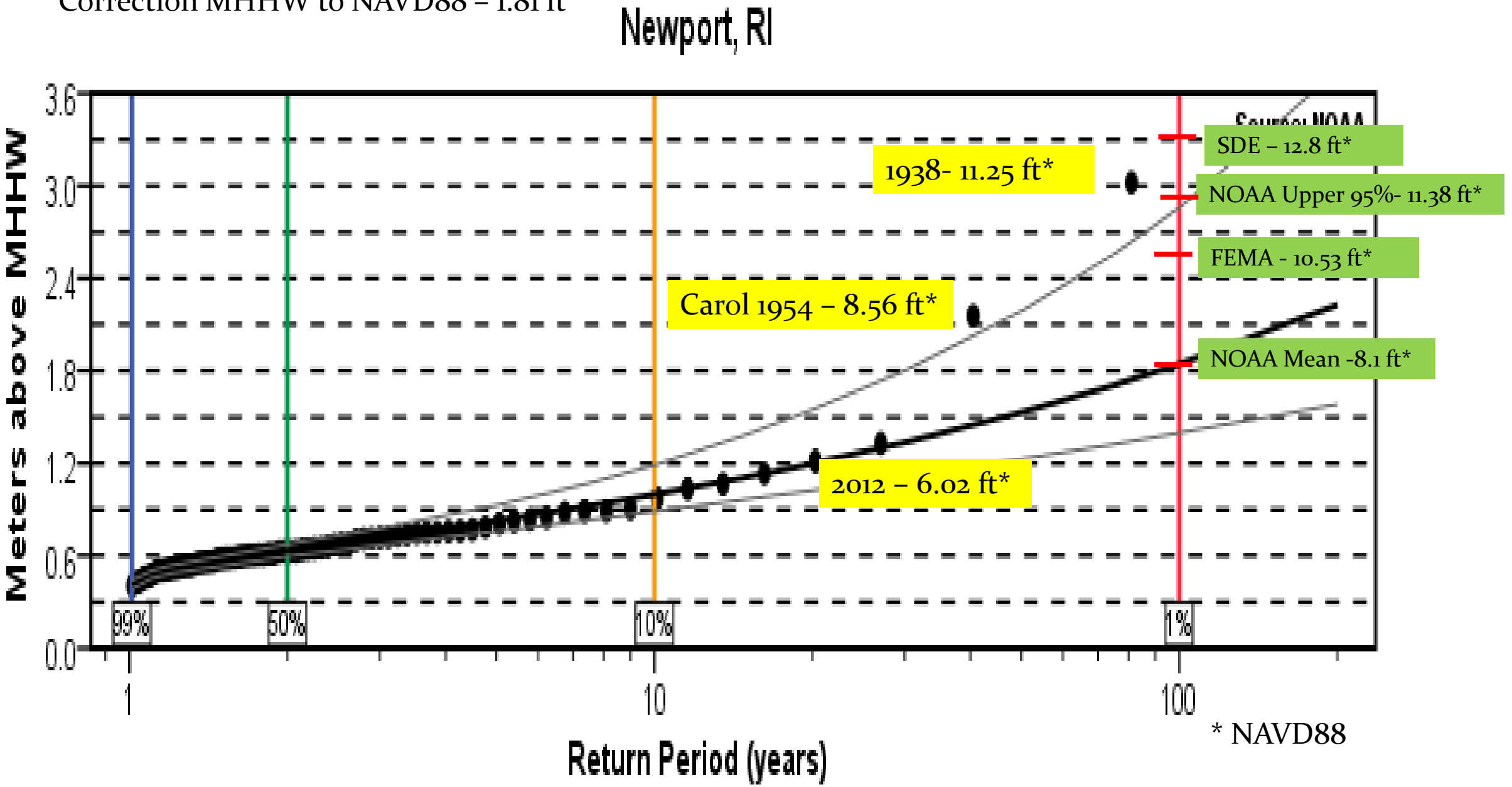
Return Period (yrs)	Surge Only – Mean (m)	Surge Only – Mean (ft)	Surge Only – Upper 95% Confidence (m)	Surge Only – Upper 95% Confidence (ft)	With Tide – Mean (m)	With Tide – Mean (ft)	With Tide – Upper 95% Confidence (m)	With Tide – Upper 95% Confidence (ft)
1	0.76	2.5	1.62	5.3	1.31	4.3	2.20	7.2
2	1.00	3.3	1.86	6.1	1.49	4.9	2.44	8.0
5	1.31	4.3	2.23	7.3	1.74	5.7	2.69	8.8
10	1.54	5.1	2.55	8.4	1.94	6.4	2.92	9.6
20	1.77	5.8	2.86	9.4	2.15	7.1	3.20	10.5
50	2.10	6.9	3.25	10.7	2.46	8.1	3.60	11.8
100	2.42	7.9	3.58	11.7	2.74	9.0	3.91	12.8
200	2.76	9.1	3.92	12.9	3.07	10.1	4.24	13.9
500	3.20	10.5	4.36	14.3	3.50	11.5	4.67	15.3
1000	3.51	11.5	4.67	15.3	3.81	12.5	4.98	16.3
2000	3.77	12.4	4.93	16.2	4.10	13.5	5.27	17.3
5000	4.06	13.3	5.22	17.1	4.43	14.5	5.60	18.4
10000	4.24	13.9	5.41	17.7	4.64	15.2	5.81	19.1





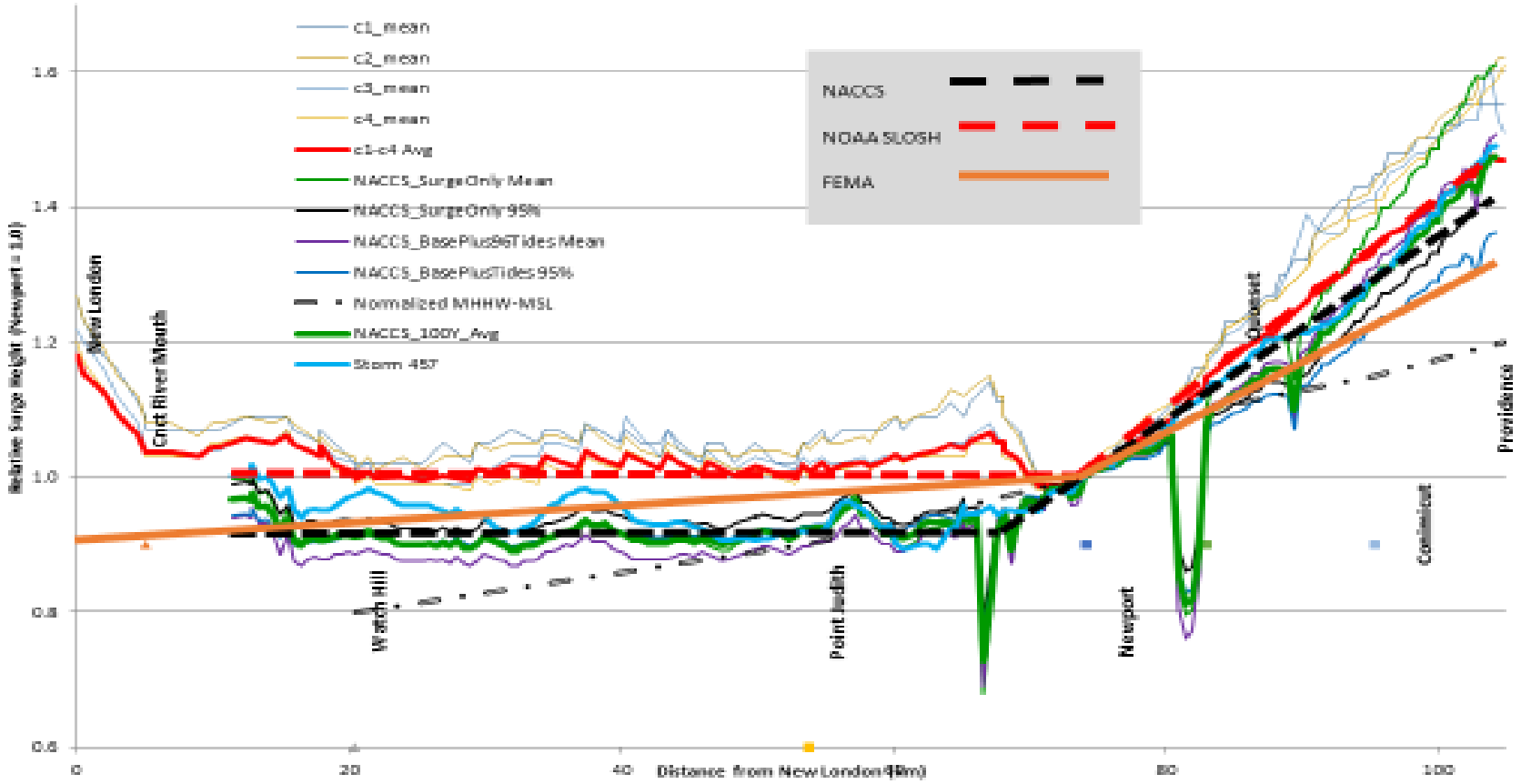
100 yr FEMA FIRM – 10.53 ft vs NACCS – 12.8 ft

MHHW- 3.85 ft, NAVD88- 2.04 ft
Correction MHHW to NAVD88 – 1.81 ft



* NAVD88

FEMA vs NACCS 100 yr surge levels southern RI coastal line and Narragansett Bay



FEMA FIRMs

The wave analysis for the flood impacted areas relies on a one dimensional (1-D) transect method (CHAMP) from the 1970s and 1980s and doesn't account for two dimensional effects available in more recent model development (STWAVE). The method is hence unable to assess 2D effects and is highly sensitive to the location and spacing of transects. Transect spacing (miles) too coarse to represent key features (surge channels, over-wash fans, breaches in barriers)

STORMTOOLS Design Elevation(SDE) Maps

SDE use state of the art models (XBeach and STWAVE) to predict shoreline erosion and associated wave dynamics. Model predictions inherently 2D at very high resolution (30 ft).

STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR0

FEMA Transects, Charlestown, RI

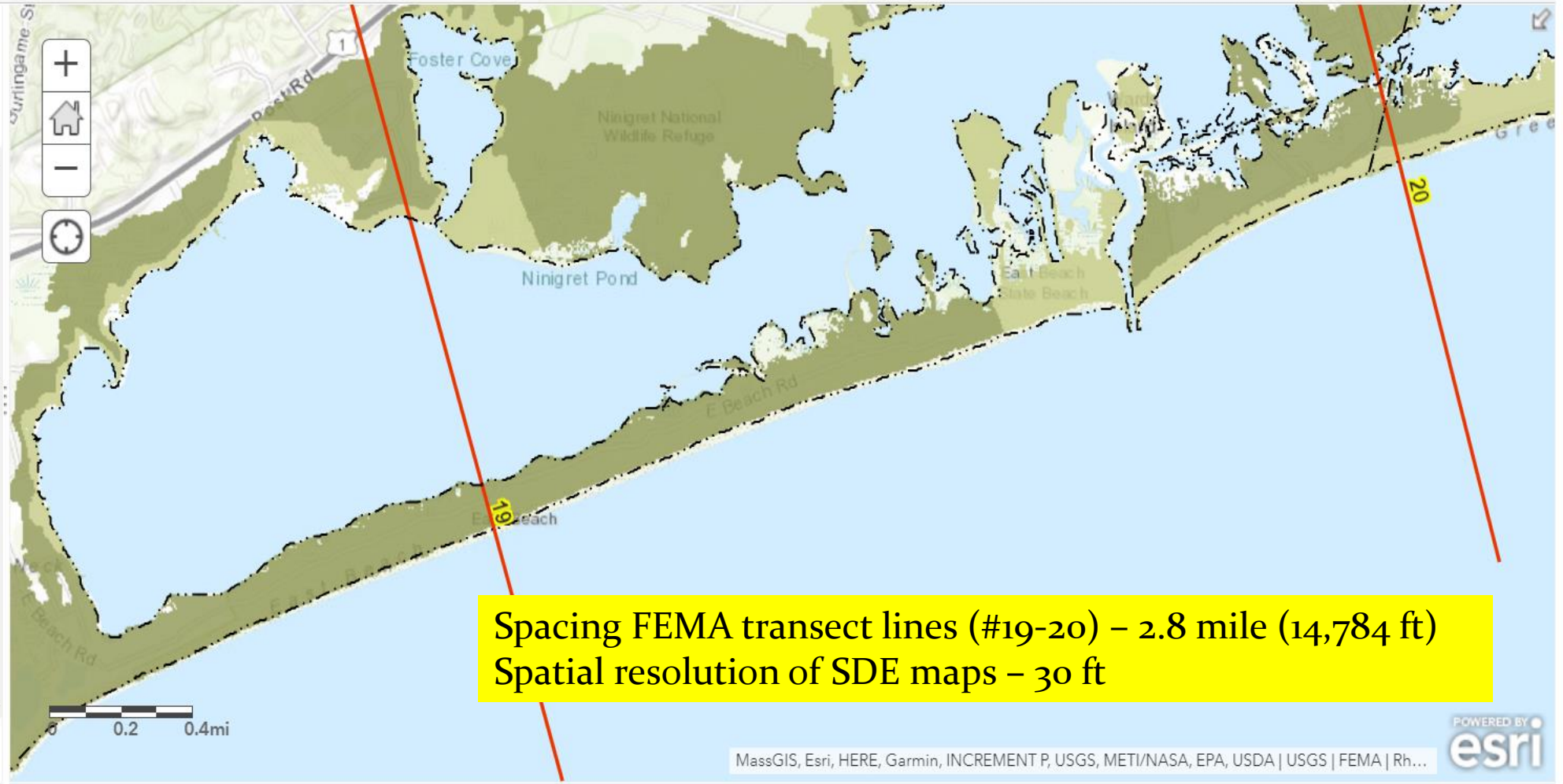
Open in Map Viewer | Modify Map | Sign In

Details | Basemap | Share | Print ▾ | Measure | Find address or place

Contents

- FEMA Static BFE (feet NAVD88)
  - <= 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - > 35
- Stormtools Design Elevation (feet NAVD88)
- Total Water Depth (feet ablove grade)
- Wave Crest Height (feet)

Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us



Spacing FEMA transect lines (#19-20) – 2.8 mile (14,784 ft)
Spatial resolution of SDE maps – 30 ft

STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR0

Open in Map Viewer | Modify Map | Sign I

Details | Basemap | Share | Print ▾ | Measure | Find address or place



Legend

Municipal Boundaries

Stormtools Design Elevation (feet NAVD88)

- <= 10
- 15
- 20
- 25
- 30
- 35
- > 35

Foster Cove

Ninigret National Wildlife Refuge

Ninigret Pond

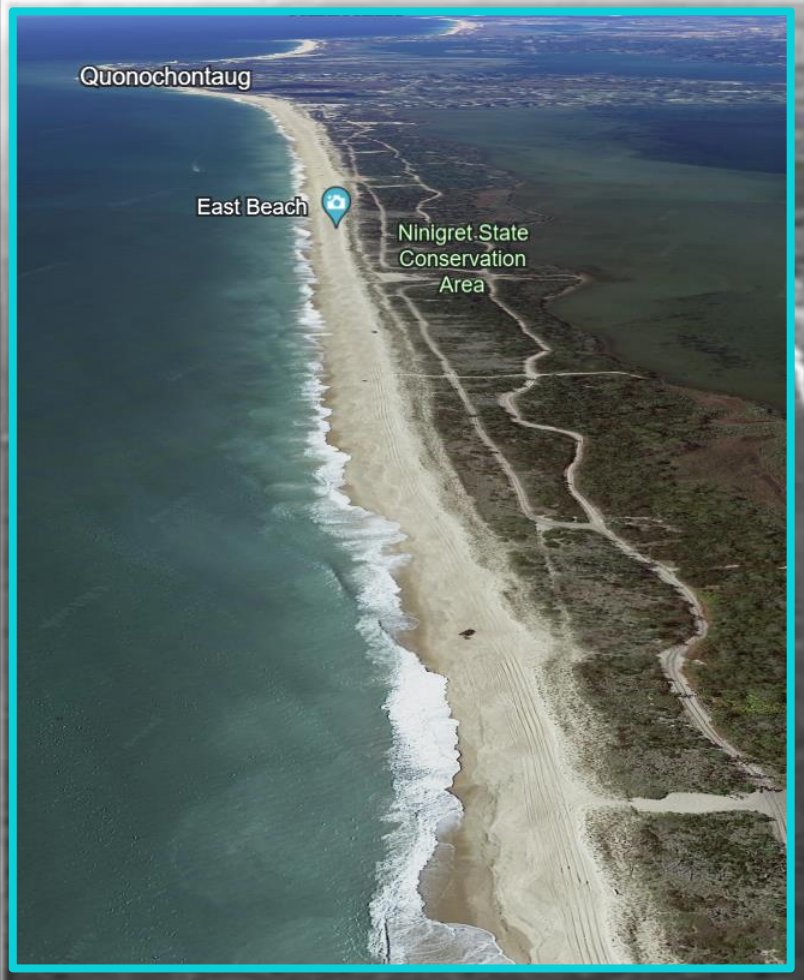
Over-wash fans

0 0.2 0.4mi

Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us

MassGIS, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA | USGS | RI CRMC, ...

POWERED BY esri



Quonochontaug Pond

Over-wash fans,
Charlestown Beach,
Hurricane Carol 1954

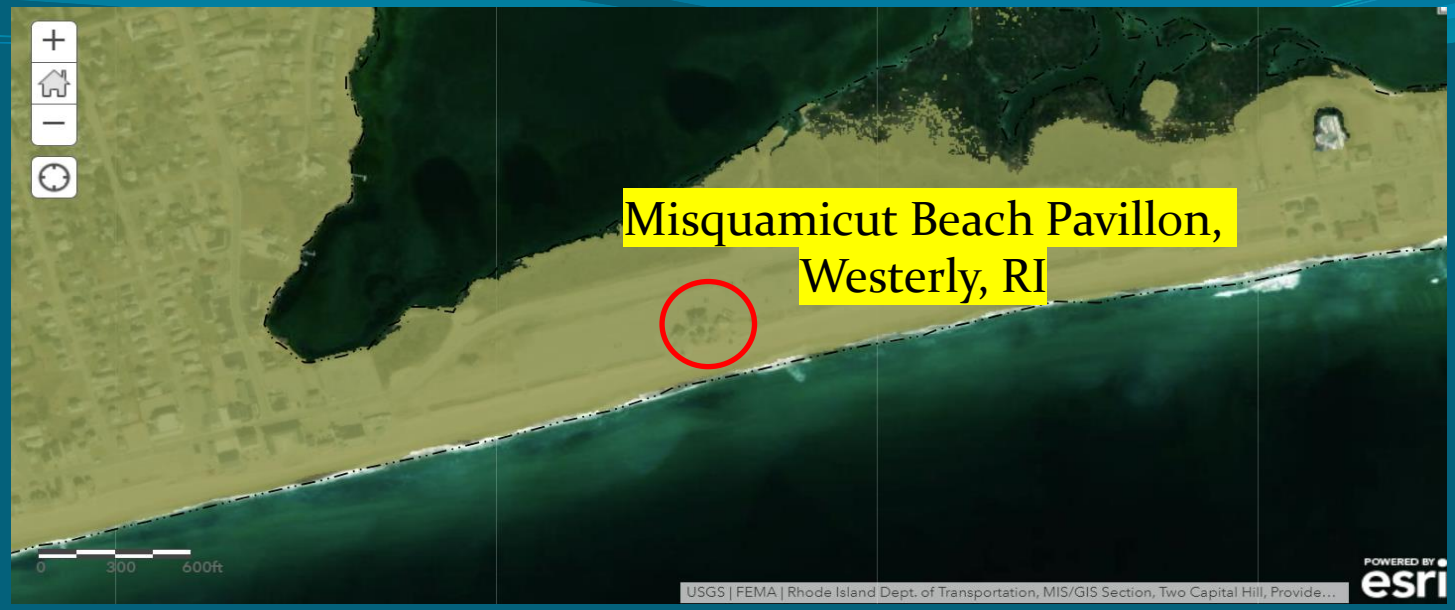
Ninigret Pond

East Beach Barrier after 1954 Hurricane

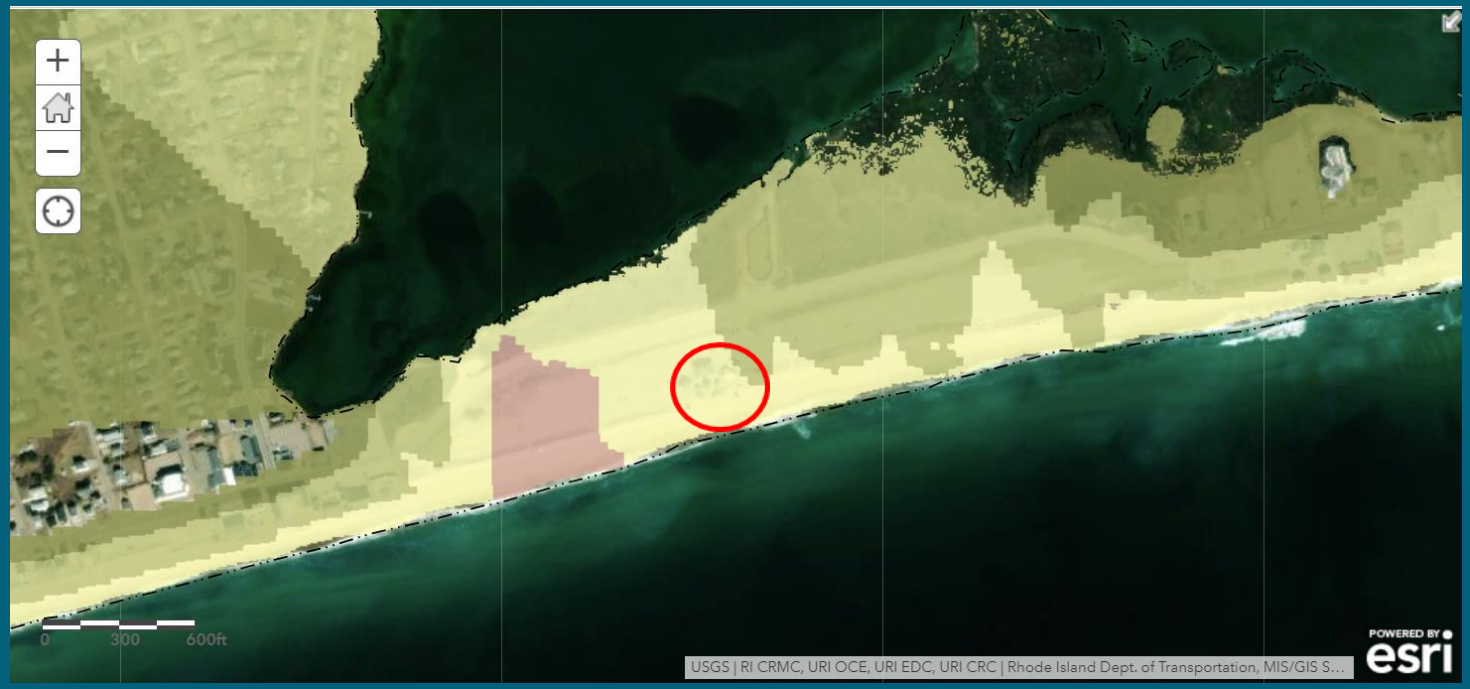

NINIGRET POND
EAST BEACH BARRIER
September 1938 Hurricane
3 Days After
Washover Fan
Surge Channel
Chimney
Swash Bar
Road
Seawall
QUONOCHONTAUG


Misquamicut Beach,
Hurricane Sandy 2012
RI DOT

FEMA FIRM 100 yr



SDE 100 yr 0 SLR



STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR0

Open in Map Viewer | Modify Map | Sign In

Details | Basemap | Share | Print ▾ | Measure | Find address or place

Contents

- [x] Municipal Boundaries
- [ ] Stormtools LIMWA
- [ ] Stormtools A/V Zone
- [x] FEMA Coastal Transect Lines
- [ ] FEMA Flood Hazard Area, 500yr
- [ ] FEMA Flood Hazard Areas
- [x] FEMA Static BFE (feet NAVD88)
- [ ] Stormtools Design Elevation (feet NAVD88)
- [ ] Total Water Depth (feet ablove grade)
- [ ] Wave Crest Height (feet)



Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us

FEMA FIRMS

- Erosion of the southern shoreline has not been verified for the study area, uses default value for erosion rates. Transect spacing is too coarse to capture breaching areas along southern RI shoreline (0.6 miles average)

STORMTOOLS Design Elevation(SDE) Maps

- SDE use state of the art modeling techniques (XBeach and STWAVE) to predict change in shoreline morphology (erosion and accretion) and wave field. Model validated with field observations. Model predictions show surge channels and over-wash fans consistent with observations.

STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR0

Open in Map Viewer | Modify Map | Sign In

Details | Basemap | Share | Print ▾ | Measure | Find address or place

Contents

- [x] Municipal Boundaries
- [ ] Stormtools LIMWA
- [ ] Stormtools A/V Zone
- [x] FEMA Coastal Transect Lines
- [ ] FEMA Flood Hazard Area, 500yr
- [ ] FEMA Flood Hazard Areas
- [x] FEMA Static BFE (feet NAVD88)
- [ ] Stormtools Design Elevation (feet NAVD88)
- [ ] Total Water Depth (feet ablove grade)
- [ ] Wave Crest Height (feet)

Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us



STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR0

Open in Map Viewer | Modify Map | Sign In

Details | Basemap | Share | Print ▾ | Measure | Find address or place

Legend

Municipal Boundaries

Stormtools Design Elevation (feet NAVD88)

- <= 10
- 15
- 20
- 25
- 30
- 35
- > 35



Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us

STORMTOOLS Design Elevation (SDE)

RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR3

Open in Map Viewer | Modify Map | Sign In

Details | Basemap | Share | Print ▾ | Measure | Find address or place

Legend

Municipal Boundaries

Stormtools Design Elevation (feet NAVD88)

- <= 10
- 15
- 20
- 25
- 30
- 35
- > 35



Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us

STORMTOOLS Design Elevation (SDE)

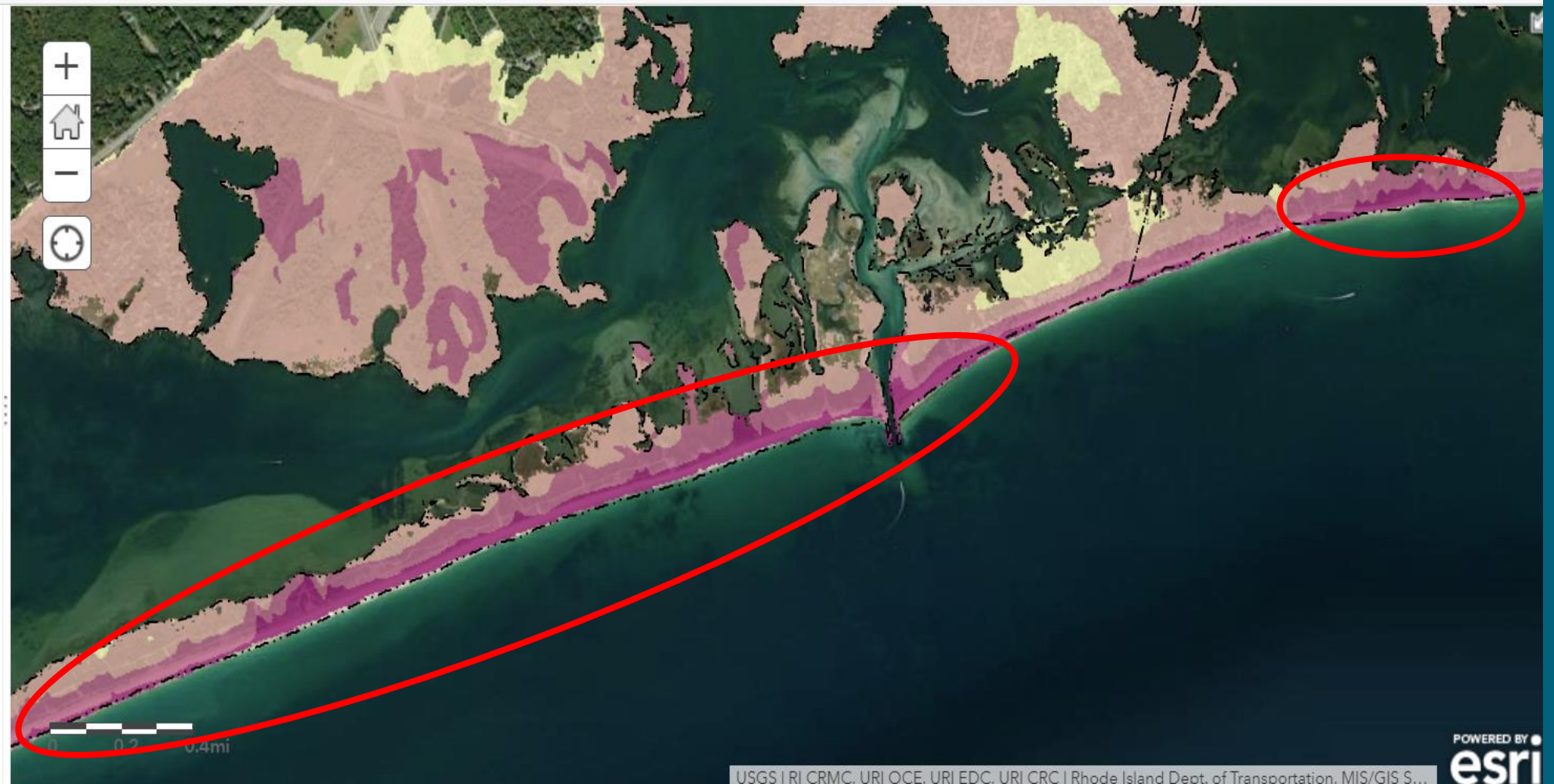
RI Shoreline Change SAMP

100yr, SLR0 | 100yr, SLR2 | 100yr, SLR3 | 100yr, SLR5 | 100yr, SLR7 | 100yr, SLR10

Home ▾ STORMTOOLS Design Elevation (SDE), SLR7

Open in Map Viewer | Modify Map | Sign In

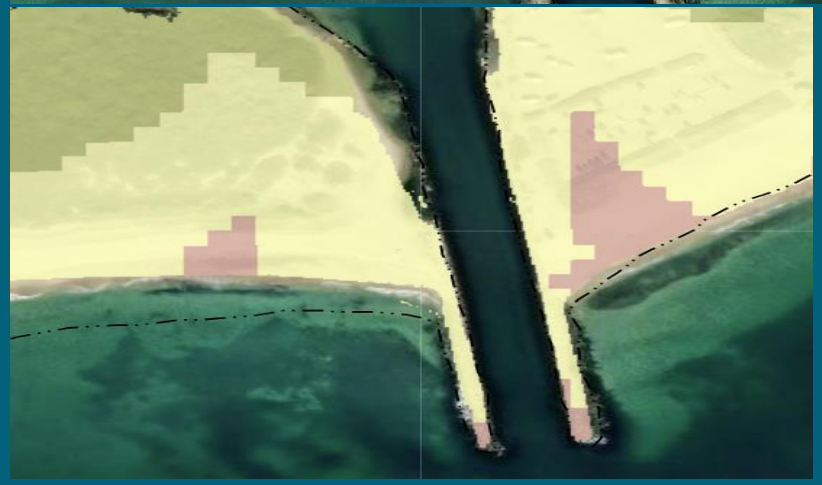
Details | Basemap | Share | Print ▾ | Measure | Find address or place



Help . Trust Center . Legal . Contact Esri . Report Abuse . Contact Us

Charlestown Breachway, Jan 15, 2023







ASCE 7-22 flood standards updated in May 2023. Design standards for residential structures changed from 100 yr to 500 yr and now includes sea level rise.

FEMA FIRMS

FEMA 500 yr inundation levels not shown on maps, no wave estimates provided, so not possible to determine BFE values. Surge levels not shown. No SLR adjustments. Scaling from 100 yr to 500 yr significantly larger (1.5 to 1.9) than ASCE 7-22 recommendation (1.25).

STORMTOOLS Design Elevation(SDE) Maps

Simplified scaling method shows SDE 100 yr, 3 ft SLR is approximately equivalent to 500 yr with no SLR maps. Proposal to generate 500 yr with varying SLR maps submitted FEMA BRIC 2023, in review.

ASCE 7-22 Flood Standards Updated



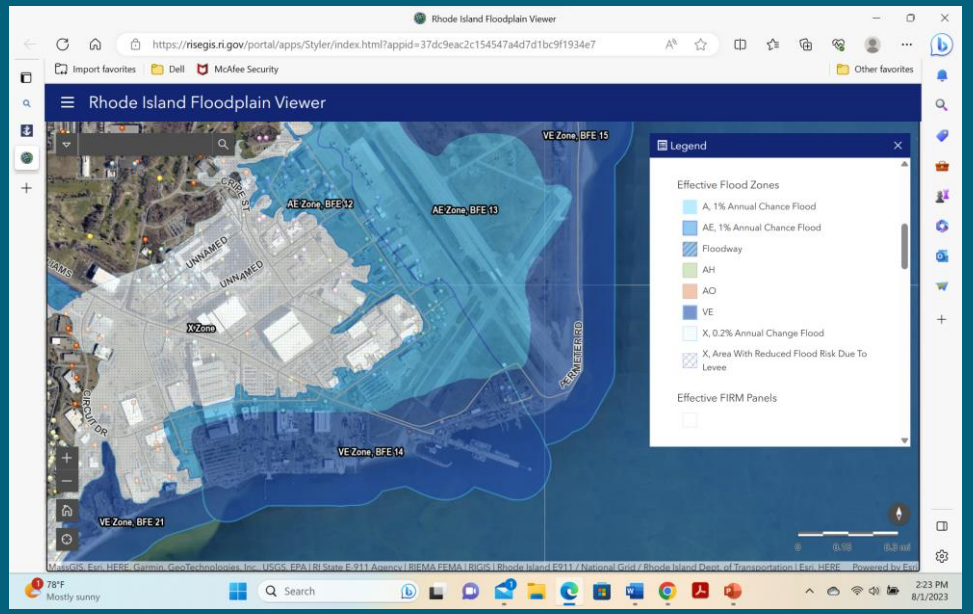
New flood standard requires ASCE 7-22 class II (residential homes) to use 500 yr FEMA FIRM flood maps (for class (I, III, & IV) structures, mean return intervals(MRI) are 100, 750, and 1000 yr, respectively) and to consider sea level rise(SLR) over the design life of the structure.

Updated ASCE 7-22 standard now available | ASCE

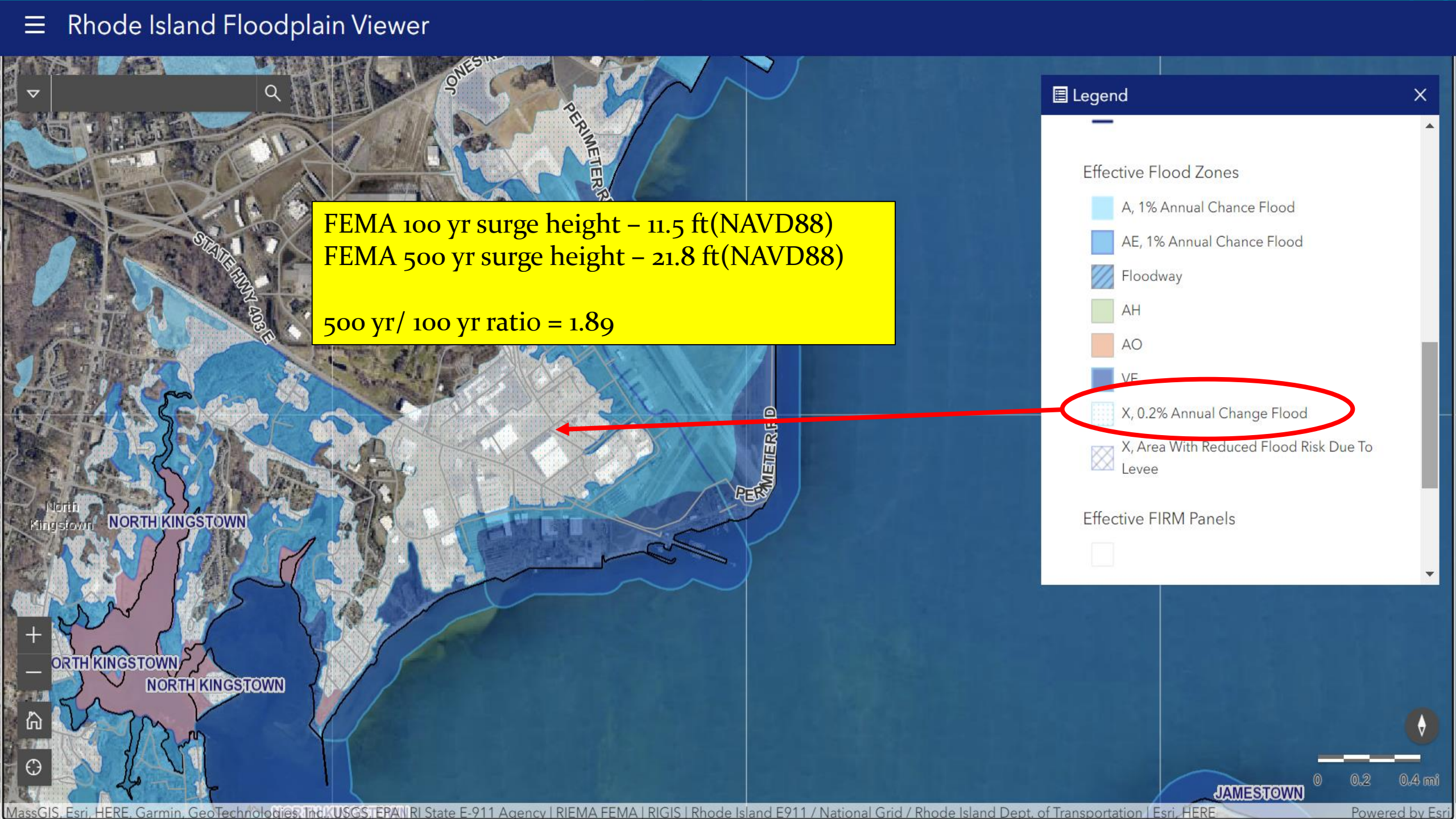
New ASCE 7-22 supplement on flood loads now available as free download | ASCE

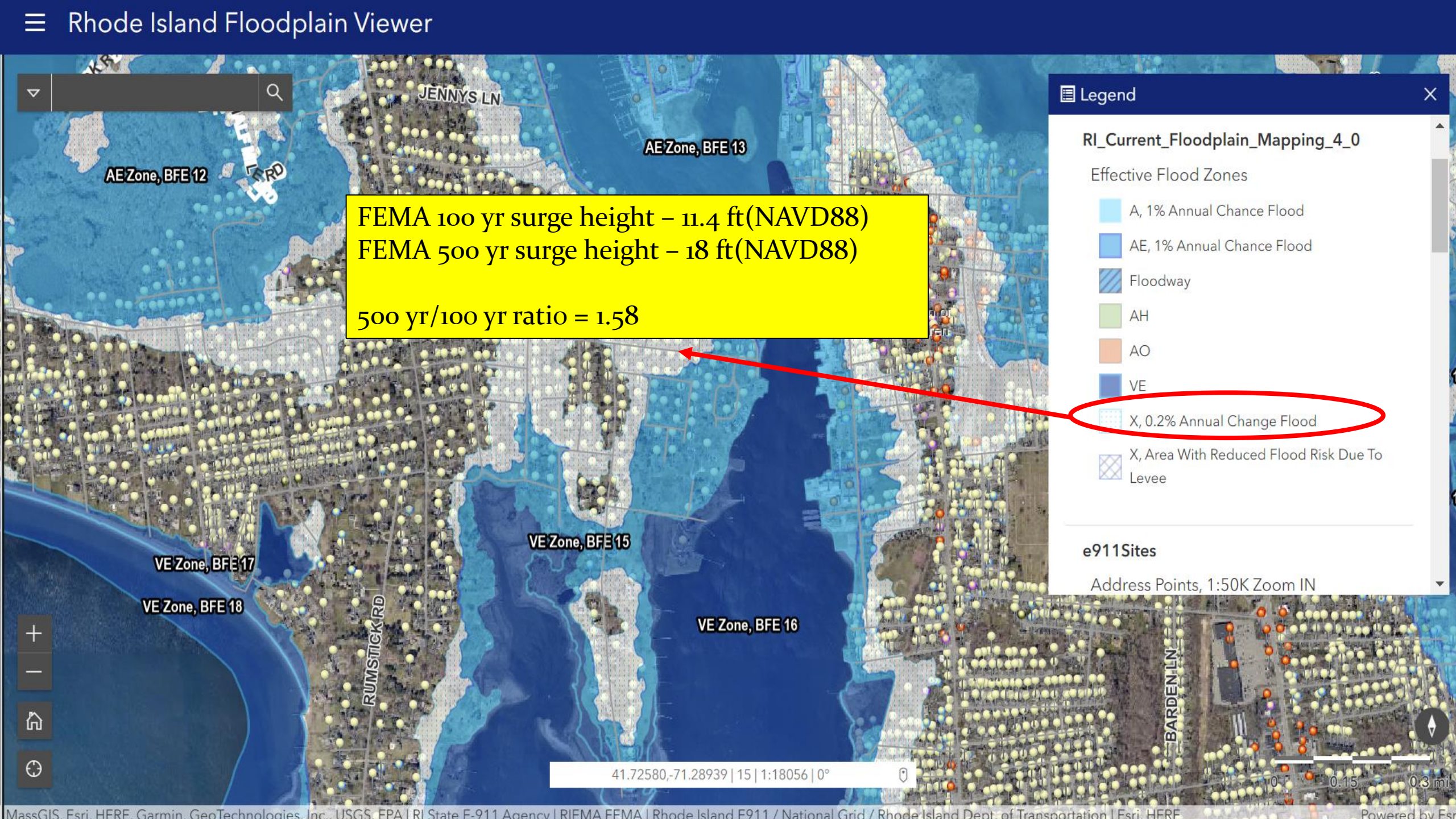
Impact of updates (May 2023) to ASCE 7-22 on hazard analysis

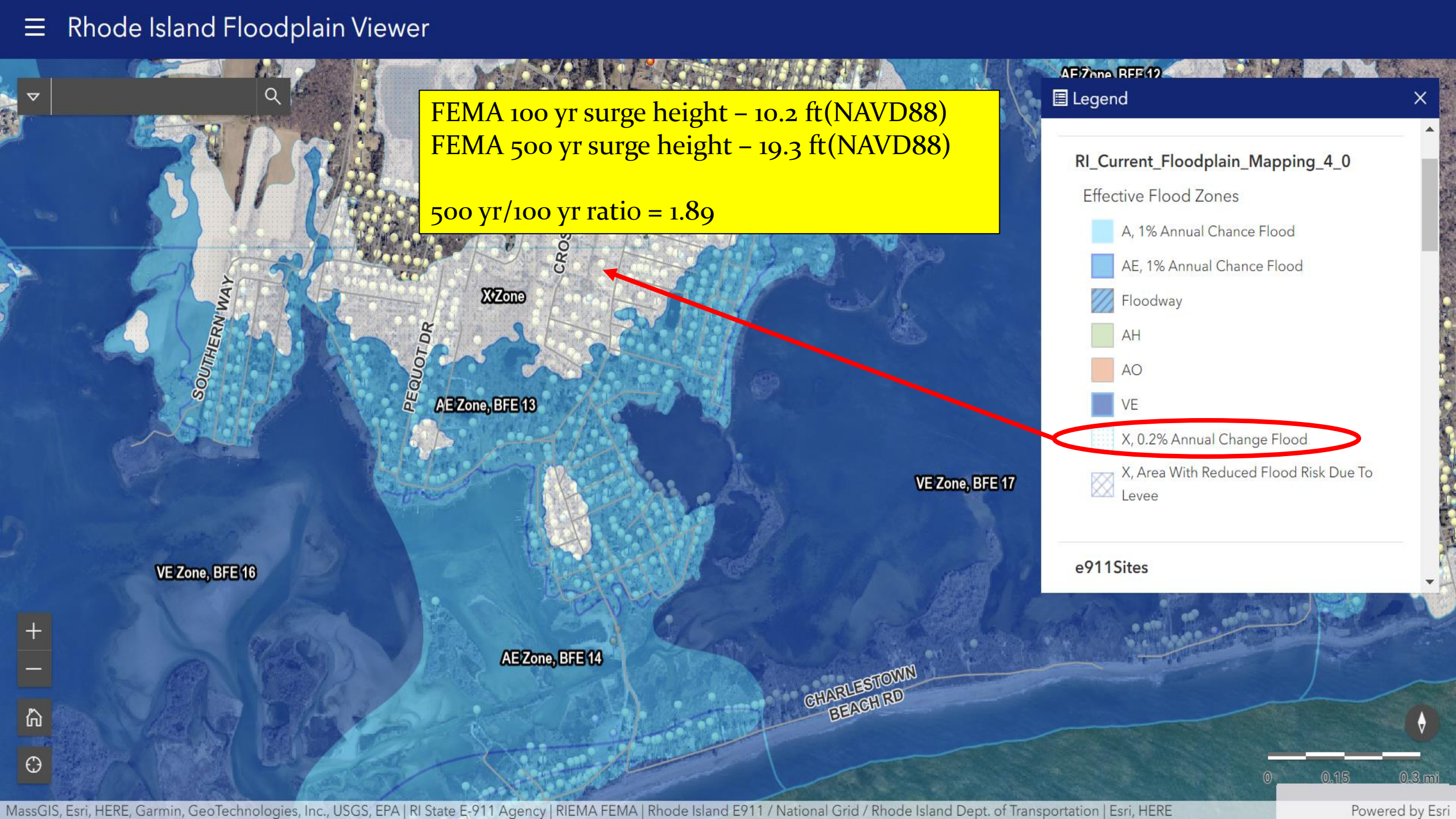
- New standard for flooding is 500 yr (0.2%, X event) for Class II (residential structures), including adjustment for sea level rise (SLR). For other classes: Class I (warehouse), III (apartment bldg.), and IV(hospital) - 100, 750, and 1000 yr, respectively.
- Current FEMA flooding maps show 1 and 0.2%, (X zones) but don't provide BFEs for 0.2% case, just show surge levels. Need to add SLR and determine wave conditions.
- X zone values are available from FEMA Flood Insurance Studies(FIS) but show significant spatial inconsistencies in Narragansett Bay
- Need to generate SDE maps 500 yr with SLR for state.



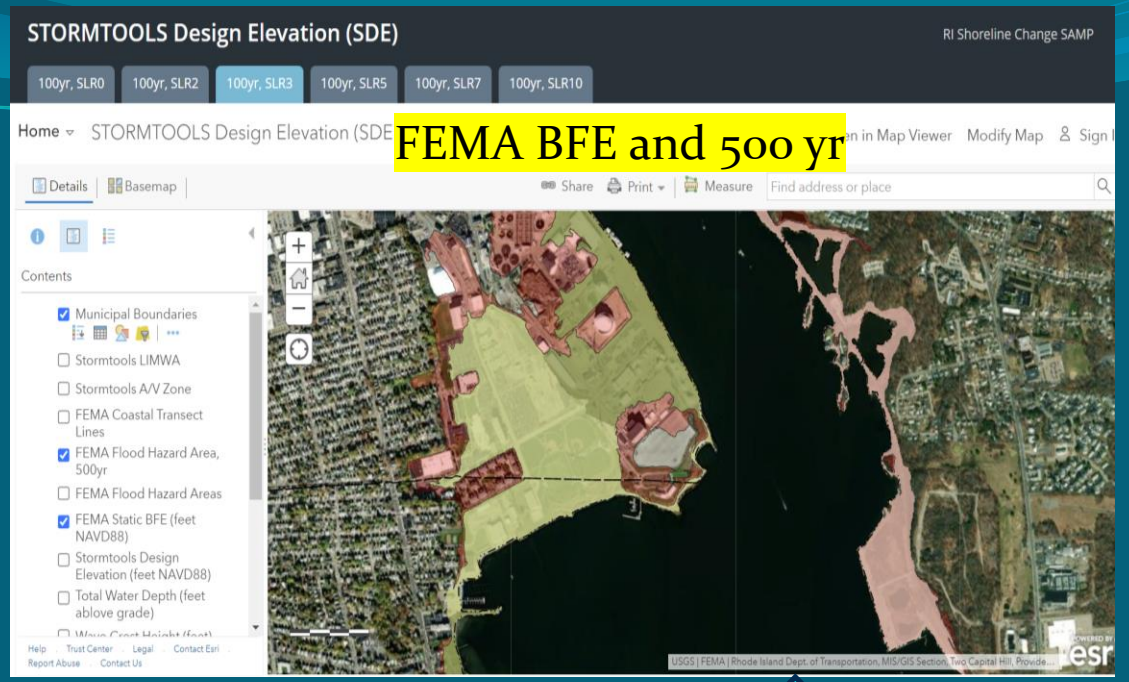

Rhode Island Floodplain Viewer
FEMA 100 yr surge height – 12 ft (NAVD88)
FEMA 500 yr surge height – 19 ft(NAVD88)
500 yr/100 yr ratio = 1.58
Legend
Effective Flood Zones
A, 1% Annual Chance Flood
AE, 1% Annual Chance Flood
Floodway
AH
AO
VE
X, 0.2% Annual Change Flood
X, Area With Reduced Flood Risk Due To Levee
Effective FIRM Panels
e911Sites
VE Zone, BFE 14
X Zone
I95 S
I95 N
SHIPYARD ST
AE Zone, BFE 17
VE Zone, BFE 17
SAVE THE BAY DR
SQUANTUM RD
VE Zone, BFE 26
0
0.15
0.3 mi

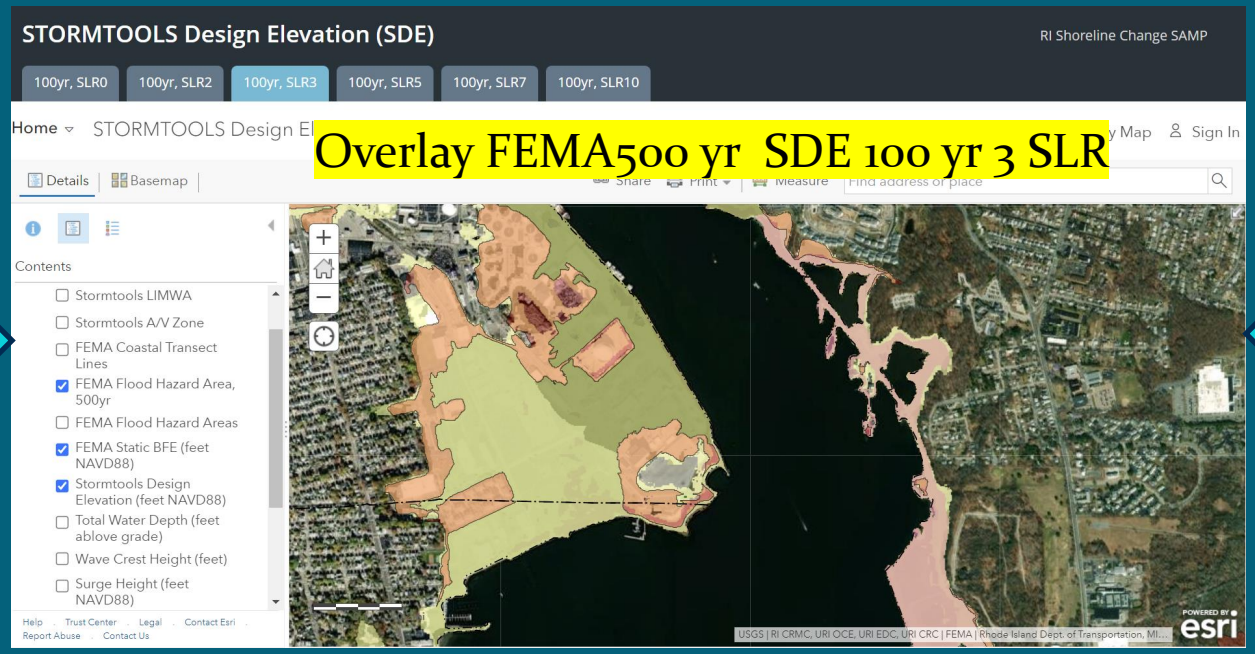

Rhode Island Floodplain Viewer
FEMA 100 yr surge height – 11.5 ft(NAVD88)
FEMA 500 yr surge height – 21.8 ft(NAVD88)
500 yr/ 100 yr ratio = 1.89
Legend
Effective Flood Zones
A, 1% Annual Chance Flood
AE, 1% Annual Chance Flood
Floodway
AH
AO
VE
X, 0.2% Annual Change Flood
X, Area With Reduced Flood Risk Due To Levee
Effective FIRM Panels
STATE HWY 403 E
PERIMETER RD
NORTH KINGSTOWN
JAMESTOWN
0
0.2
0.4 mi
MassGIS, Esri, HERE, Garmin, GeoTechnologies, Inc, USGS, EPA | RI State E-911 Agency | RIEMA FEMA | RIGIS | Rhode Island E911 / National Grid / Rhode Island Dept. of Transportation | Esri, HERE
Powered by Esri


Rhode Island Floodplain Viewer
JENNYS LN
AE Zone, BFE 12
AE Zone, BFE 13
FERRY RD
FEMA 100 yr surge height – 11.4 ft(NAVD88)
FEMA 500 yr surge height – 18 ft(NAVD88)
500 yr/100 yr ratio = 1.58
Legend
RI_Current_Floodplain_Mapping_4_0
Effective Flood Zones
A, 1% Annual Chance Flood
AE, 1% Annual Chance Flood
Floodway
AH
AO
VE
X, 0.2% Annual Change Flood
X, Area With Reduced Flood Risk Due To Levee
e911Sites
Address Points, 1:50K Zoom IN
VE Zone, BFE 15
VE Zone, BFE 17
VE Zone, BFE 18
VE Zone, BFE 16
RUMSTICK RD
BARDEN LN
41.72580,-71.28939 | 15 | 1:18056 | 0°
0 0.15 0.3 mi
MassGIS, Esri, HERE, Garmin, GeoTechnologies, Inc., USGS, EPA | RI State E-911 Agency | RIFMA FEMA | Rhode Island E911 / National Grid / Rhode Island Dept. of Transportation | Esri, HERE
Powered by Esri

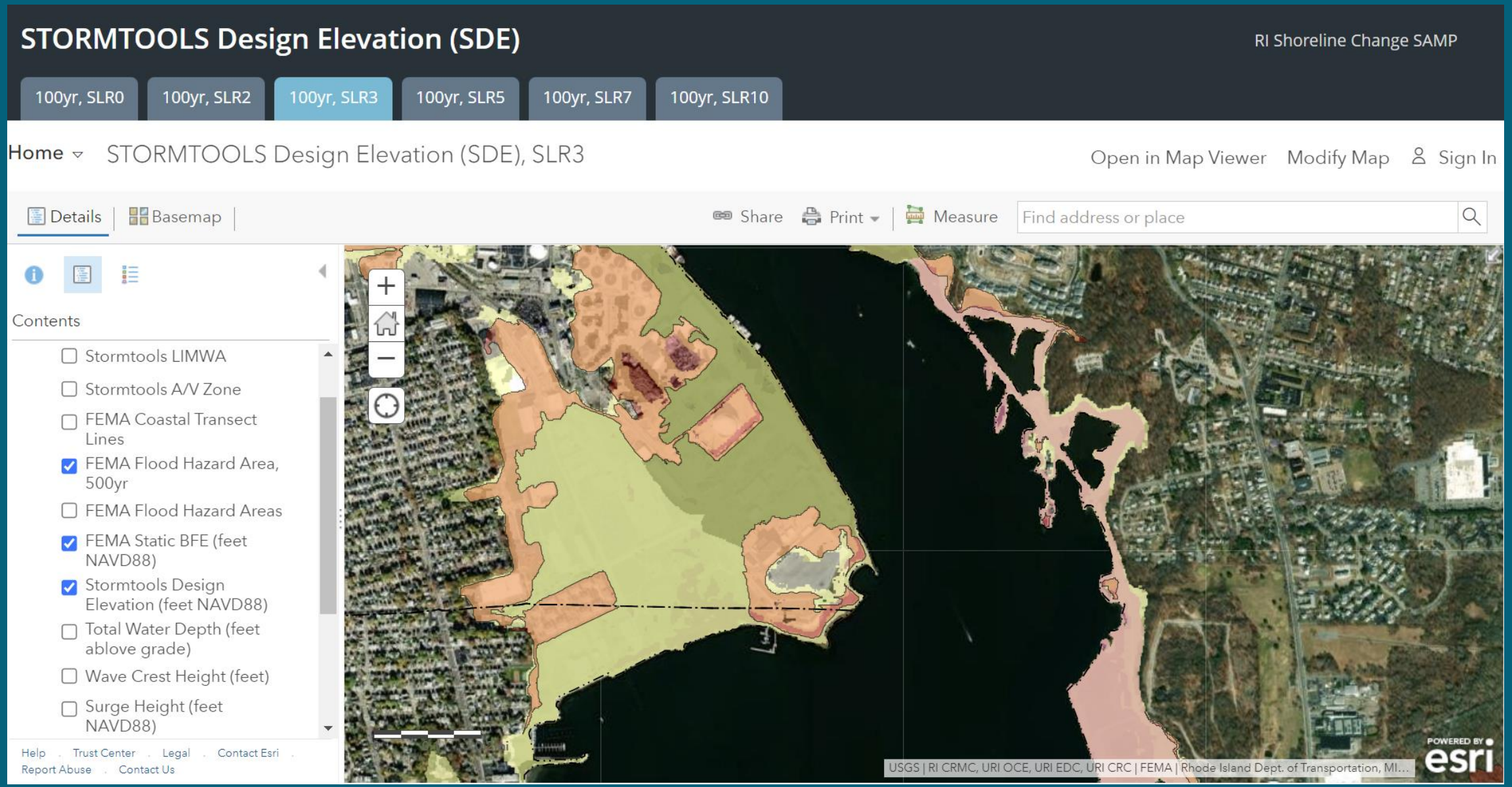

Rhode Island Floodplain Viewer
FEMA 100 yr surge height – 10.2 ft(NAVD88)
FEMA 500 yr surge height – 19.3 ft(NAVD88)
500 yr/100 yr ratio = 1.89
Legend
RI_Current_Floodplain_Mapping_4_0
Effective Flood Zones
A, 1% Annual Chance Flood
AE, 1% Annual Chance Flood
Floodway
AH
AO
VE
X, 0.2% Annual Change Flood
X, Area With Reduced Flood Risk Due To Levee
e911Sites
X Zone
AE Zone, BFE 13
VE Zone, BFE 17
VE Zone, BFE 16
AE Zone, BFE 14
SOUTHERN WAY
PEQUOT DR
CHARLESTOWN BEACH RD
0
0.15
0.3 mi
MassGIS, Esri, HERE, Garmin, GeoTechnologies, Inc., USGS, EPA | RI State E-911 Agency | RIEMA FEMA | Rhode Island E911 / National Grid / Rhode Island Dept. of Transportation | Esri, HERE
Powered by Esri


STORMTOOLS Design Elevation (SDE)
RI Shoreline Change SAMP
100yr, SLR0
100yr, SLR2
100yr, SLR3
100yr, SLR5
100yr, SLR7
100yr, SLR10
Home
STORMTOOLS Design Elevation (SDE), SLR3
SDE 3 SLR
Open in Map Viewer
Modify Map
Sign In
Details
Basemap
Share
Print
Measure
Find address or place
Contents
Municipal Boundaries
Stormtools LIMWA
Stormtools A/V Zone
FEMA Coastal Transect Lines
FEMA Flood Hazard Area, 500yr
FEMA Flood Hazard Areas
FEMA Static BFE (feet NAVD88)
Stormtools Design Elevation (feet NAVD88)
Total Water Depth (feet above grade)
Help
Trust Center
Legal
Contact Esri
Report Abuse
Contact Us
esri


STORMTOOLS Design Elevation (SDE)
RI Shoreline Change SAMP
100yr, SLR0
100yr, SLR2
100yr, SLR3
100yr, SLR5
100yr, SLR7
100yr, SLR10
Home
FEMA BFE and 500 yr
Modify Map
Details
Basemap
Share
Print
Measure
Find address or place
Contents
Municipal Boundaries
Stormtools LIMWA
Stormtools A/V Zone
FEMA Coastal Transect Lines
FEMA Flood Hazard Area, 500yr
FEMA Flood Hazard Areas
FEMA Static BFE (feet NAVD88)
Stormtools Design Elevation (feet NAVD88)
Total Water Depth (feet above grade)
Help
Trust Center
Legal
Contact Esri
Report Abuse
Contact Us
esri

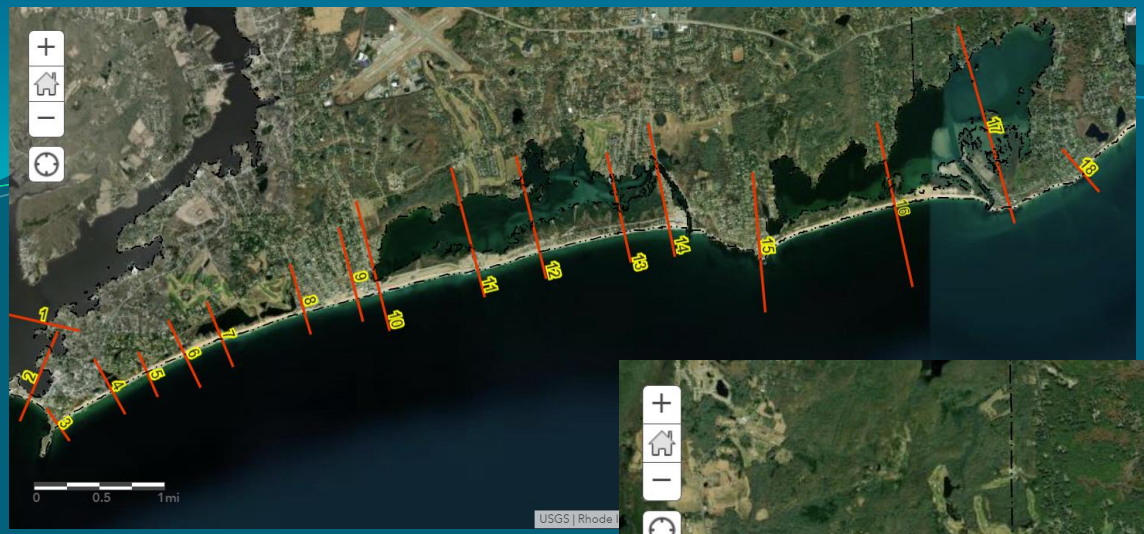

STORMTOOLS Design Elevation (SDE)
RI Shoreline Change SAMP
100yr, SLR0
100yr, SLR2
100yr, SLR3
100yr, SLR5
100yr, SLR7
100yr, SLR10
Home
Overlay FEMA500 yr SDE 100 yr 3 SLR
Sign In
Details
Basemap
Share
Print
Measure
Find address or place
Contents
Stormtools LIMWA
Stormtools A/V Zone
FEMA Coastal Transect Lines
FEMA Flood Hazard Area, 500yr
FEMA Flood Hazard Areas
FEMA Static BFE (feet NAVD88)
Stormtools Design Elevation (feet NAVD88)
Total Water Depth (feet above grade)
Wave Crest Height (feet)
Surge Height (feet NAVD88)
Help
Trust Center
Legal
Contact Esri
Report Abuse
Contact Us
esri

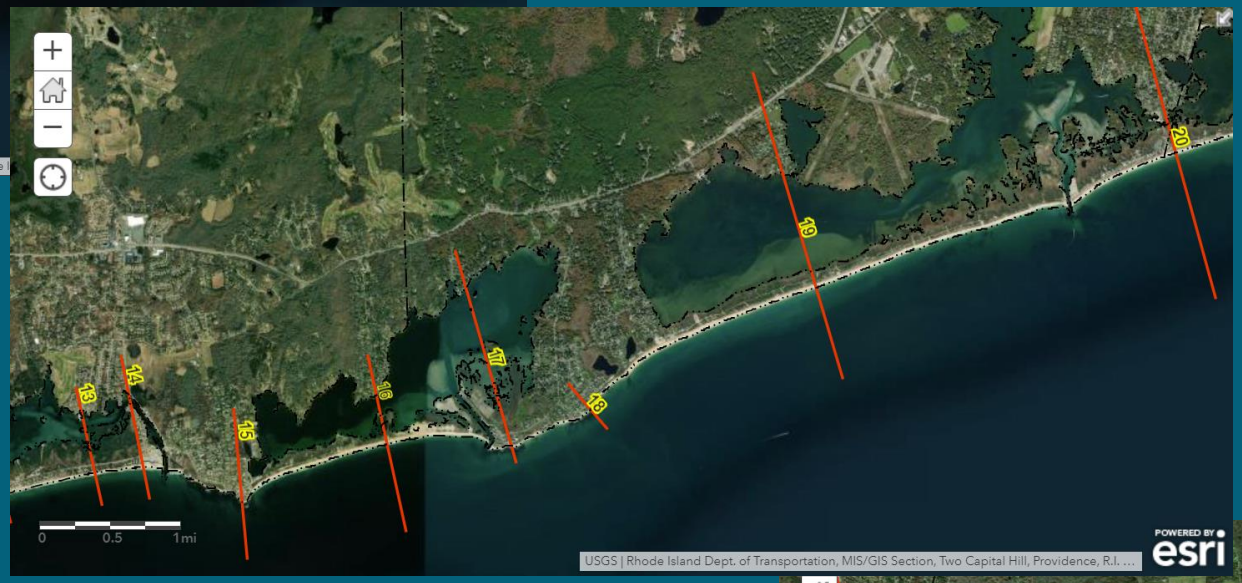
Overlay FEMA 500 yr flooding with SDE 100 yr 3 SLR

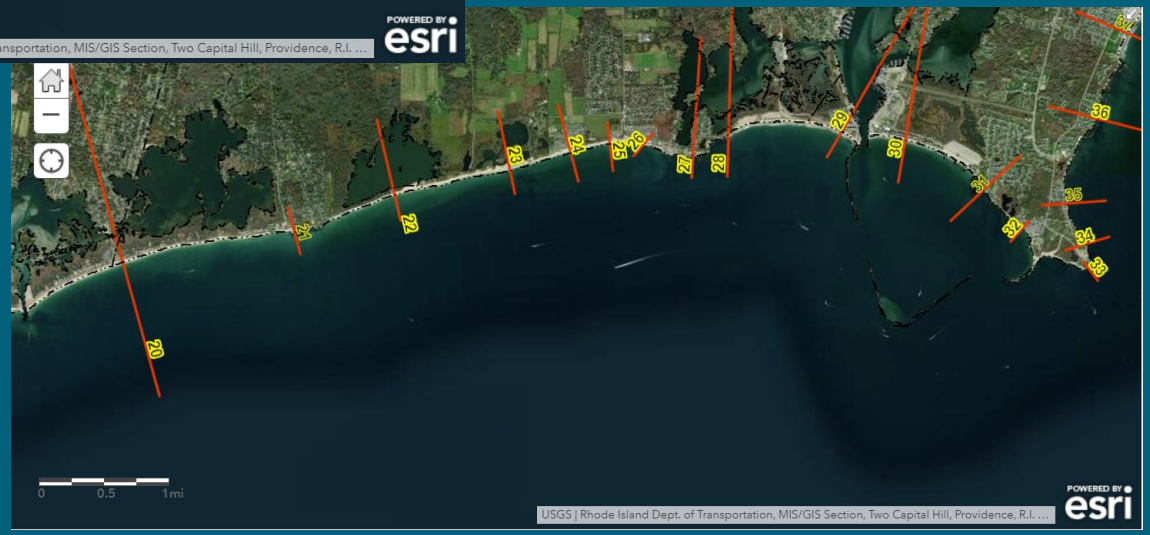


SUPPLEMENTAL MATERIAL

FEMA Transect Lines







Mean transect spacing = 20 miles/30 transects = 0.6 mile per transect

Charlestown Beach Rd
Charlestown, RI

Storm Reporter Report
by **Elise Torello**

12/23/2022 | 10:16 am



