VULNERABILITY ASSESSMENT OF BUILT INFRASTRUCTURE NEAR COASTAL BAYS USING THREE SEA LEVEL RISE SCENARIOS – GUAM

Romina King, PhD,
University of Guam
Pacific Islands Climate Adaptation Science Center
email: roking@triton.uog.edu

Contributors: Marcel Higgs, Kaylyn Bautista, Edward Leon Guerrero

Presented by:
Evangeline Lujan, Chair of the Climate Change Resilience Commission

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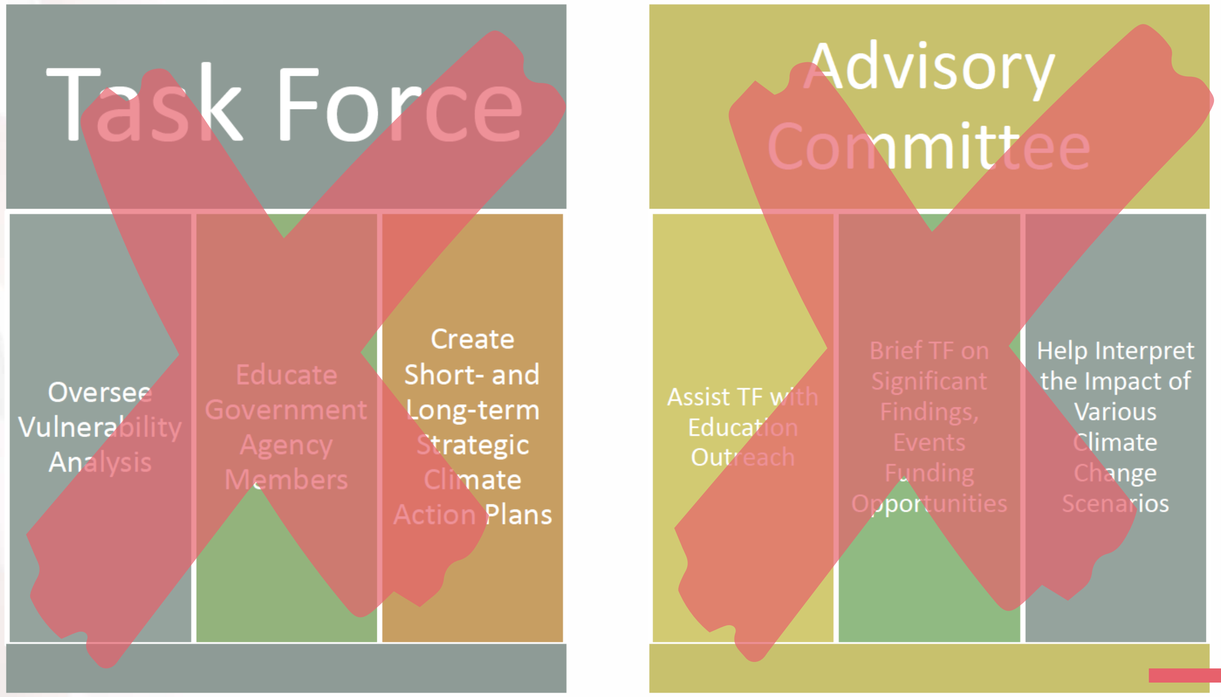


Courtesy of Tricee Limtiaco, Former GovGuam POC for CC

CATEGORY	PROJECT
OVERALL / INFRASTRUCTURE / ECONOMY	Vulnerability Analysis of Built Environment at Coastal Bays[4]
UTILITIES / NATURAL RESOURCES	Update and Plan Storm Water Program Implementation[2]
EDUCATION / TRAINING	All-Planners Training for Sustainability[1]
GIS / DATA COLLECTION	Pilot GIS Climate Project[3]
EDUCATION/ OUTREACH	Village Resiliency Workshops[1] Business Resiliency Workshops[4]

Funding Source: OIA TAP 2016

POLITICAL BACKGROUND

2014 - Former Governor Calvo was appointed on the Presidential Task Force on Climate Preparedness and Resilience

2015 - Former Assistant Secretary of the Office of Insular Affairs, Esther Kia'aina visits Guam makes climate change a priority for DOI OIA

2015 - Climate Change Planning E.O. 2015-08 is signed. Establishes a Climate Change Task Force accompanied with a Science Advisory Committee

2016 - GovGuam is awarded a TAP award from OIA

2019 - Governor Leon Guerrero issues E.O. to establish the Climate Change Resilience Commission. This replaces E.O. 2015-08

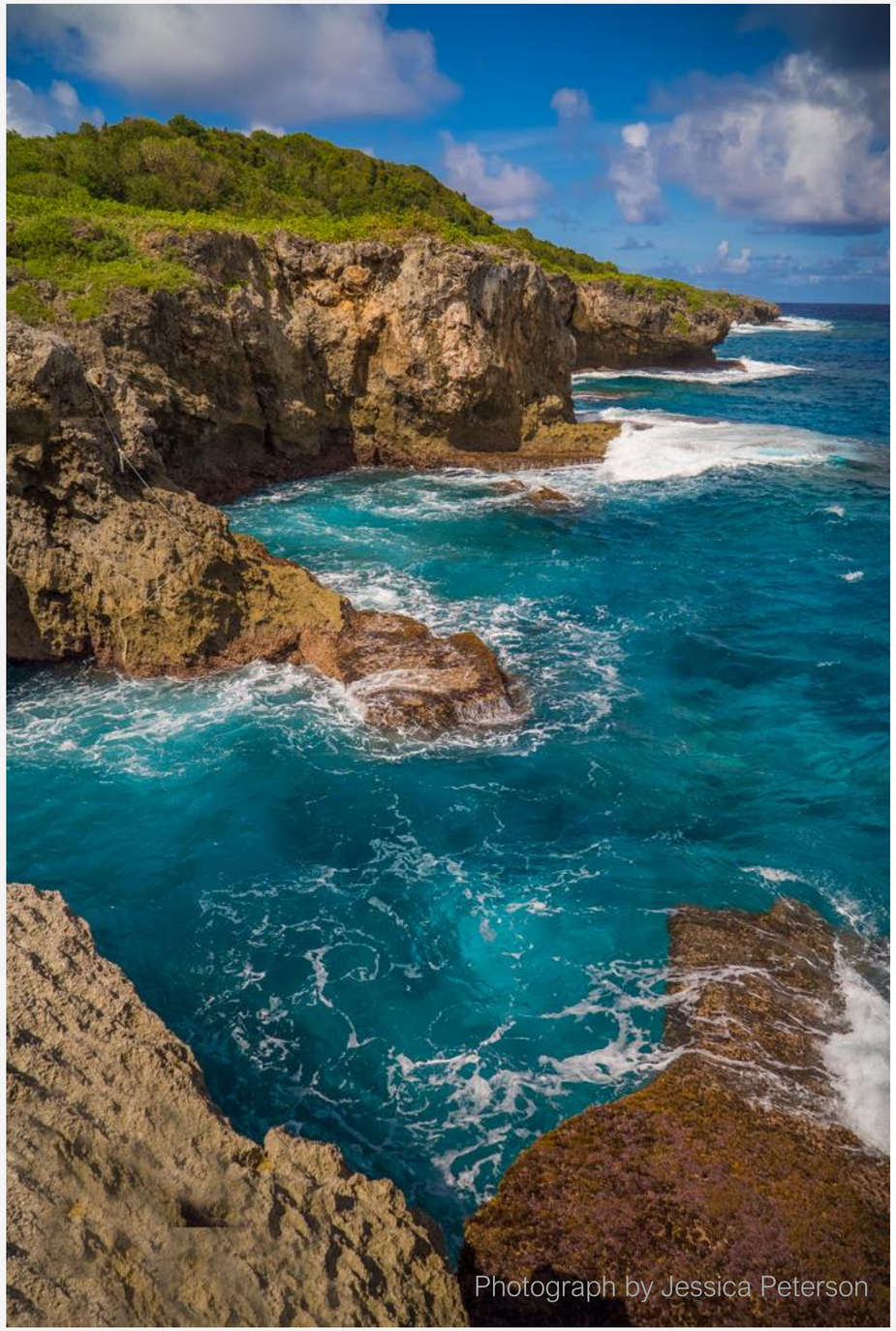
Merizo, GU

Merizo, GU

VULNERABILITY

noun. refers to the degree to which people or the things they value are susceptible to, or are unable to cope with, the adverse impacts of ***climate change****. There are three dimensions of vulnerability to climate change:* ***exposure, sensitivity, and adaptive capacity****.*

Source: International Panel for Climate Change


Photograph by Jessica Peterson

VULNERABILITY ANALYSIS OF INFRASTRUCTURE AT COASTAL BAYS

Main questions:

- What infrastructure are we concerned with?
- How will sea level rise affect that infrastructure?
- Bonus: what villages are the most socially vulnerable?

We used three scenarios: **3ft, 5ft, and 10ft.** Datasets were downloaded from NOAA digital coast viewer. They were overlayed on the **power network, the water network, the wastewater network, the road network, and buildings**.

Mixed methods:

GIS Analysis and Participatory GIS - Kaylyn Bautista

LEAP - Marcel Higgs

Social Vulnerability Index - Edward Leon Guerrero

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APPROACH

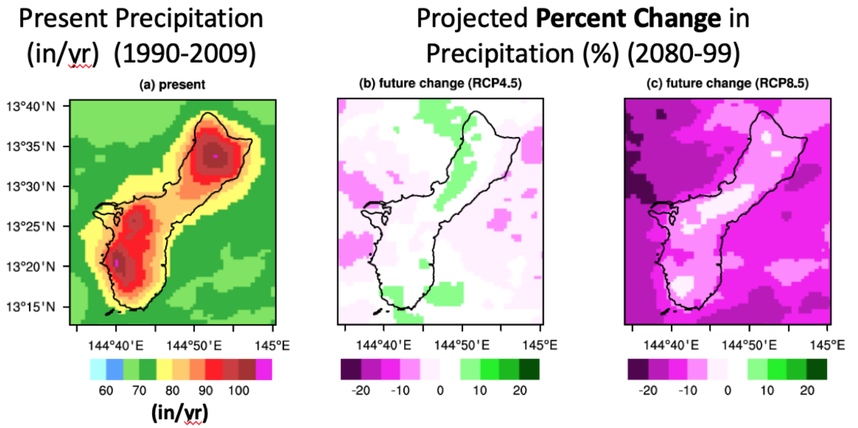
1:45,000

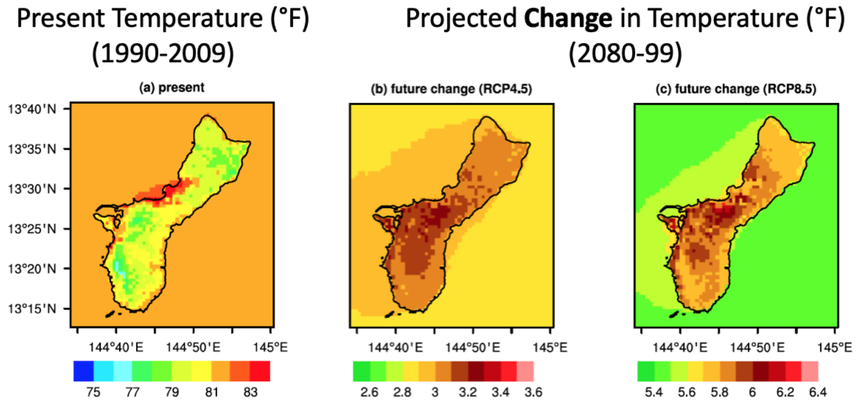
Guam - 10 Feet Sea Level Rise

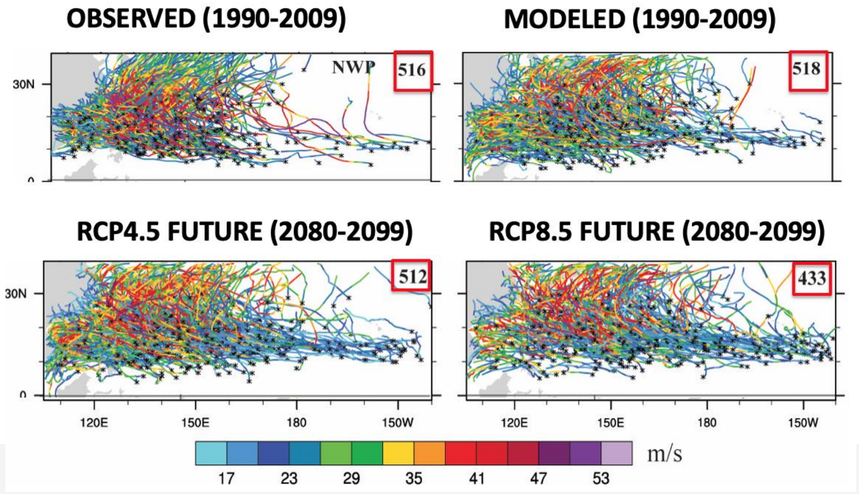
Map was created by Romina King on 04 April 2019 to depict the land affected by a ten foot sea level rise.
Sea level rise data is provided by NOAA and may be obtained at https://coast.noaa.gov/slrdata/.
This map is for planning purposes only.

- Data Gathering
  - NOAA Flood Exposure Mapper
  - NOAA Sea Level Rise viewer
  - NOAA Tide Gauges
  - PI-CASC Downscaled models
  - US Census data
  - GovGuam agencies (BSP, EPA, Dept Ag) - Inventory Assessment
  - NOAA NWS data - Chip Guard
  - Traditional ecological knowledge
- Data Analysis
- Report

PI-CASC DOWNSCALED MODEL







	Mid Scenario (RCP 4.5)	High Scenario (RCP 8.5)
Avg Annual Temperature	↑ 3°F	↑ 6°F
Avg. Annual Rainfall	0-10% wetter	10%-15% drier
Avg. Annual Rainfall - Wet season (image not shown)	10% drier - 10% wetter	10%-20% drier
Avg. Annual Rainfall - Dry season (image not shown)	10% drier - 10% wetter	10%-20% wetter
Avg. Annual Typhoons	Slight decrease	Decrease

From Zhang & Wang 2016

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SEA LEVEL RISE

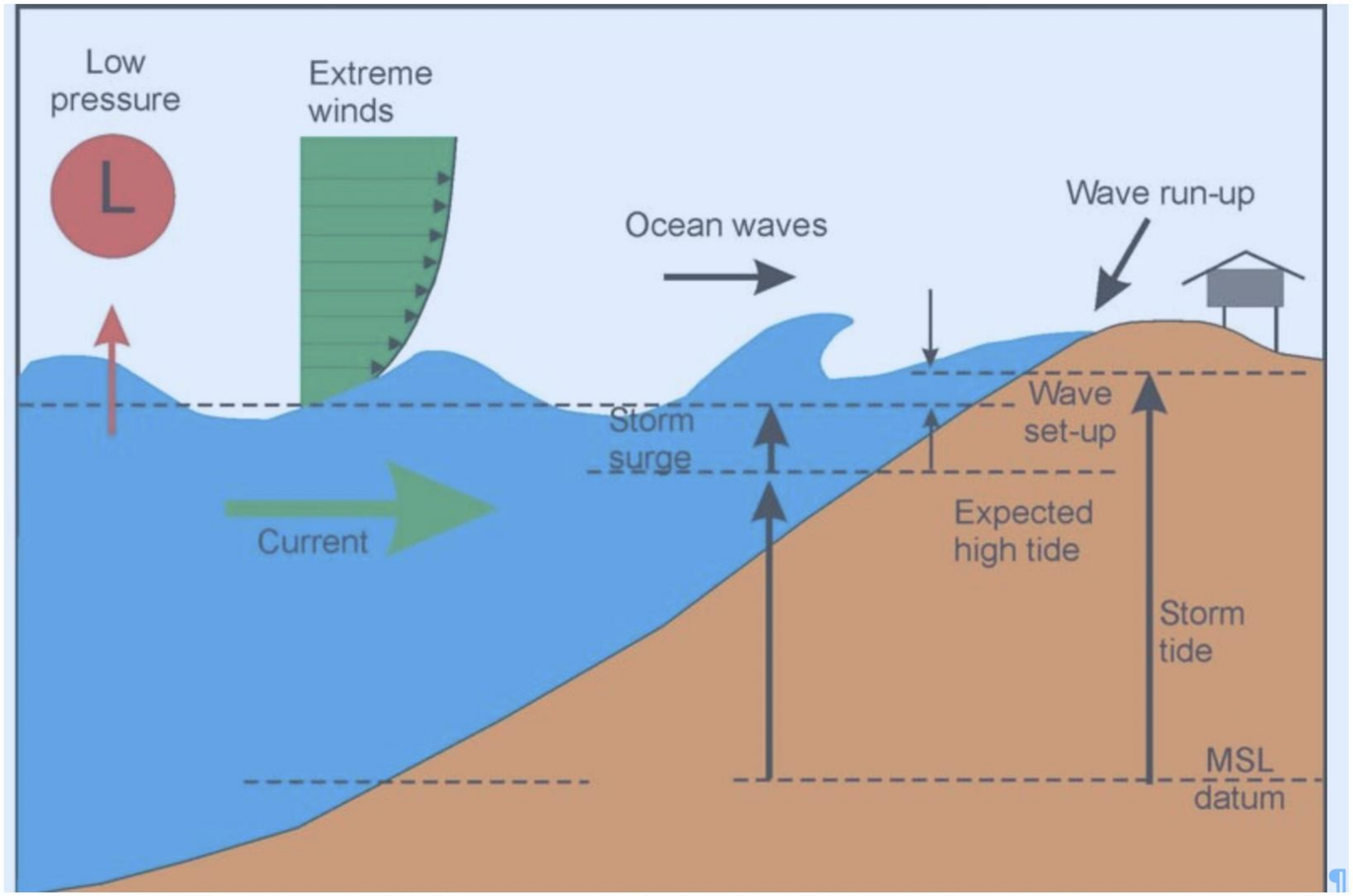


Figure 1: Schematic illustrating how SLR is an increase in the baseline of the ocean (assuming the land is not significantly uplifting). MHHW, Tides, Storm surge, wave runup, low-barometric pressure inducing rise all 'sit' on this baseline. During typhoons coastal flooding my increase. Reprinted from (Mullan et al., 2019).

Specifically, for Guam, the mean sea level (MSL) trend is 8.60 millimeters/year with a 95% confidence interval of +/- 4.88 mm/yr (NOAA CO-OPS, 2014a), which is equivalent to a change of .88 meters (2.82 ft) in 100 years.

Essentially, we are expecting approximately 3 foot of SLR by the end of century.

Higher sea level can increase inundation during tropical storms and typhoons.


Photograph by Jessica Peterson

RESULTS - GIS ANALYSIS

Kaylyn Bautista, MSc, WERI, University of Guam

- 58% of total infrastructure impacted by a 3-ft SLR,
- 74% impacted by a 5-ft SLR, and
- 84% impacted by a 10-ft SLR.

Of the villages, the greatest percentage of infrastructure impacted were southern villages:

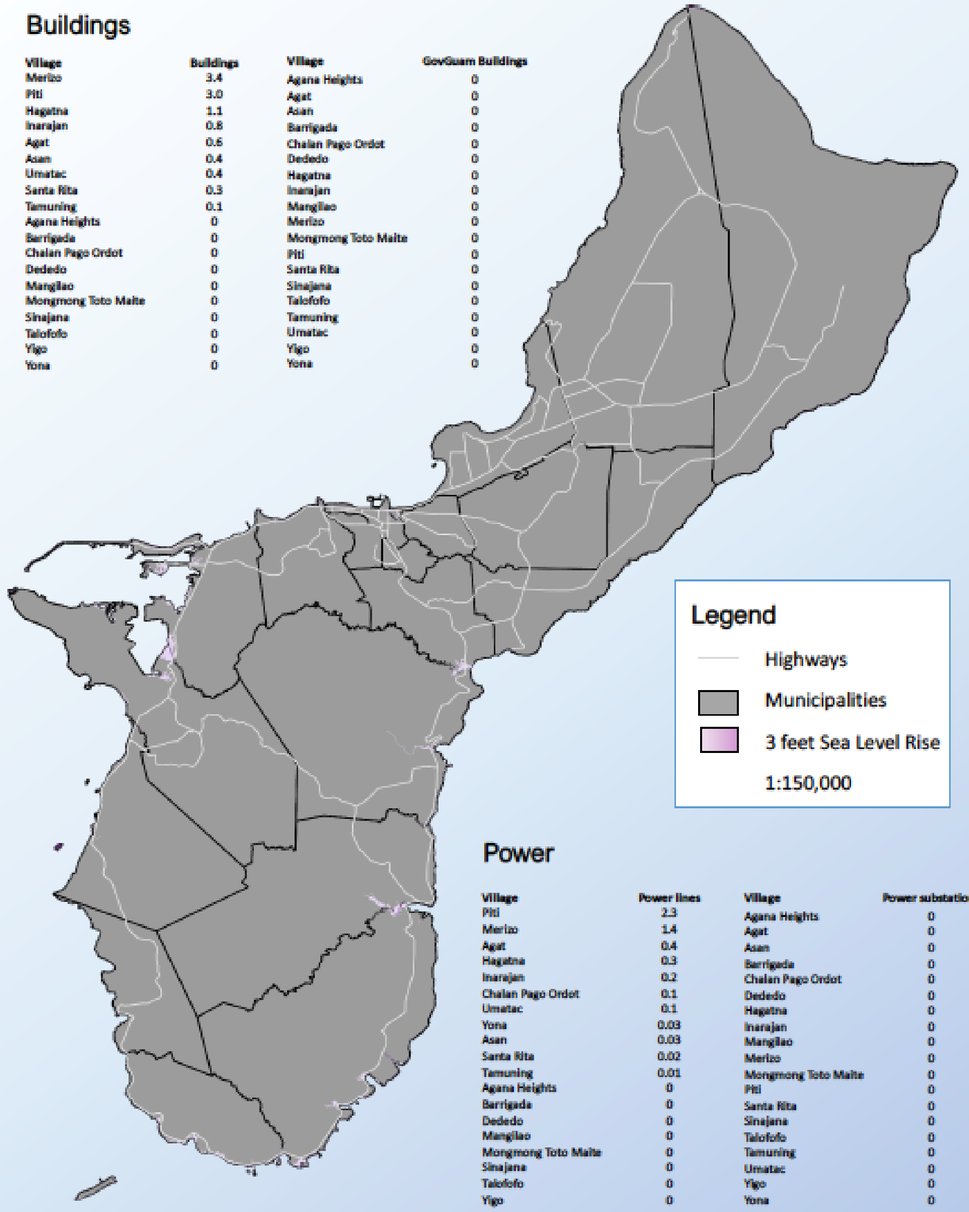
- **3ft SLR – southern 73% and central 27%;**
- **5-ft SLR – 64% southern, 29% central, and 7% northern; and**
- **10-ft SLR – 56% southern 31% central, and 13% northern.**

The remaining villages with zero percent impact in the 13 infrastructure categories to all three SLR scenarios were Agana Heights, Barrigada, and Mangilao

3 feet Sea Level Rise Impact on Guam Built Infrastructure

Buildings

Village	Buildings	Village	GovGuam Buildings
Merizo	3.4	Agana Heights	0
Piti	3.0	Agat	0
Hagatna	1.1	Asan	0
Inarajan	0.8	Barrigada	0
Agat	0.6	Chalan Pago Ordot	0
Asan	0.4	Dededo	0
Umatac	0.4	Hagatna	0
Santa Rita	0.3	Inarajan	0
Tamuning	0.1	Mangilao	0
Agana Heights	0	Merizo	0
Barrigada	0	Mongmong Toto Maite	0
Chalan Pago Ordot	0	Piti	0
Dededo	0	Santa Rita	0
Mangilao	0	Sinajana	0
Mongmong Toto Maite	0	Talofofo	0
Sinajana	0	Tamuning	0
Talofofo	0	Umatac	0
Yigo	0	Yigo	0
Yona	0	Yona	0



Transportation

Village	Streets	Village	Highways	Village	Bridges
Merizo	1.6	Merizo	3.4	Merizo	100
Piti	1.2	Inarajan	0.4	Inarajan	75
Agat	0.4	Yona	0.3	Umatac	50
Inarajan	0.4	Hagatna	0.3	Agana Heights	0
Santa Rita	0.3	Umatac	0.2	Agat	0
Yona	0.2	Asan	0.1	Asan	0
Asan	0.2	Agat	0.1	Barrigada	0
Umatac	0.1	Agana Heights	0	Chalan Pago Ordot	0
Hagatna	0.1	Barrigada	0	Dededo	0
Yigo	0.03	Chalan Pago Ordot	0	Hagatna	0
Tamuning	0.01	Dededo	0	Mangilao	0
Chalan Pago Ordot	0.004	Mangilao	0	Mongmong Toto Maite	0
Agana Heights	0	Mongmong Toto Maite	0	Piti	0
Barrigada	0	Piti	0	Santa Rita	0
Dededo	0	Santa Rita	0	Sinajana	0
Mangilao	0	Sinajana	0	Talofofo	0
Mongmong Toto Maite	0	Talofofo	0	Tamuning	0
Sinajana	0	Tamuning	0	Yigo	0
Talofofo	0	Yigo	0	Yona	0

Water

Village	Water lines	Village	Water pump station	Village	Production wells
Merizo	1.6	Agana Heights	0	Agana Heights	0
Piti	1.1	Agat	0	Agat	0
Hagatna	0.2	Asan	0	Asan	0
Inarajan	0.2	Barrigada	0	Barrigada	0
Umatac	0.2	Chalan Pago Ordot	0	Chalan Pago Ordot	0
Asan	0.1	Dededo	0	Dededo	0
Agat	0.1	Hagatna	0	Hagatna	0
Yona	0.03	Inarajan	0	Inarajan	0
Agana Heights	0	Mangilao	0	Mangilao	0
Barrigada	0	Merizo	0	Merizo	0
Chalan Pago Ordot	0	Mongmong Toto Maite	0	Mongmong Toto Maite	0
Dededo	0	Piti	0	Piti	0
Mangilao	0	Santa Rita	0	Santa Rita	0
Mongmong Toto Maite	0	Sinajana	0	Sinajana	0
Santa Rita	0	Talofofo	0	Talofofo	0
Sinajana	0	Tamuning	0	Tamuning	0
Talofofo	0	Umatac	0	Umatac	0
Tamuning	0	Yigo	0	Yigo	0
Yigo	0	Yona	0	Yona	0

Power

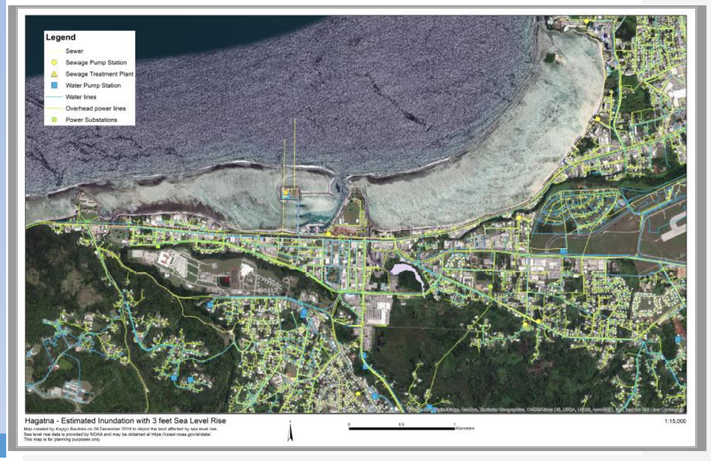
Village	Power lines	Village	Power substations
Piti	2.3	Agana Heights	0
Merizo	1.4	Agat	0
Agat	0.4	Asan	0
Hagatna	0.3	Barrigada	0
Inarajan	0.2	Chalan Pago Ordot	0
Chalan Pago Ordot	0.1	Dededo	0
Umatac	0.1	Hagatna	0
Yona	0.03	Inarajan	0
Asan	0.03	Mangilao	0
Santa Rita	0.02	Merizo	0
Tamuning	0.01	Mongmong Toto Maite	0
Agana Heights	0	Piti	0
Barrigada	0	Santa Rita	0
Dededo	0	Sinajana	0
Mangilao	0	Talofofo	0
Mongmong Toto Maite	0	Tamuning	0
Sinajana	0	Umatac	0
Talofofo	0	Yigo	0
Yigo	0	Yona	0

Sewer

Village	Sewer lines	Village	Sewage treatment plant	Village	Sewage pump stations
Chalan Pago Ordot	0.9	Agana Heights	0	Merizo	8.3
Umatac	0.6	Agat	0	Agana Heights	0
Merizo	0.5	Asan	0	Agat	0
Inarajan	0.3	Barrigada	0	Asan	0
Hagatna	0.3	Chalan Pago Ordot	0	Barrigada	0
Tamuning	0.3	Dededo	0	Chalan Pago Ordot	0
Asan	0.2	Hagatna	0	Dededo	0
Agat	0.1	Inarajan	0	Hagatna	0
Santa Rita	0.1	Mangilao	0	Inarajan	0
Dededo	0.02	Merizo	0	Mangilao	0
Agana Heights	0	Mongmong Toto Maite	0	Mongmong Toto Maite	0
Barrigada	0	Piti	0	Piti	0
Mangilao	0	Santa Rita	0	Santa Rita	0
Mongmong Toto Maite	0	Sinajana	0	Sinajana	0
Piti	0	Talofofo	0	Talofofo	0
Sinajana	0	Tamuning	0	Tamuning	0
Talofofo	0	Umatac	0	Umatac	0
Yigo	0	Yigo	0	Yigo	0
Yona	0	Yona	0	Yona	0

Figure 18: Summary Information Graphic displaying percentage of buildings, roads, power, water, and sewer affected by a three-foot SLR. Geospatial databases were provided by GWA, GPA, and the Bureau of Statistics and Plans.

- 58% of total infrastructure impacted by a 3-ft SLR



If you zoom into the map, you will see this.

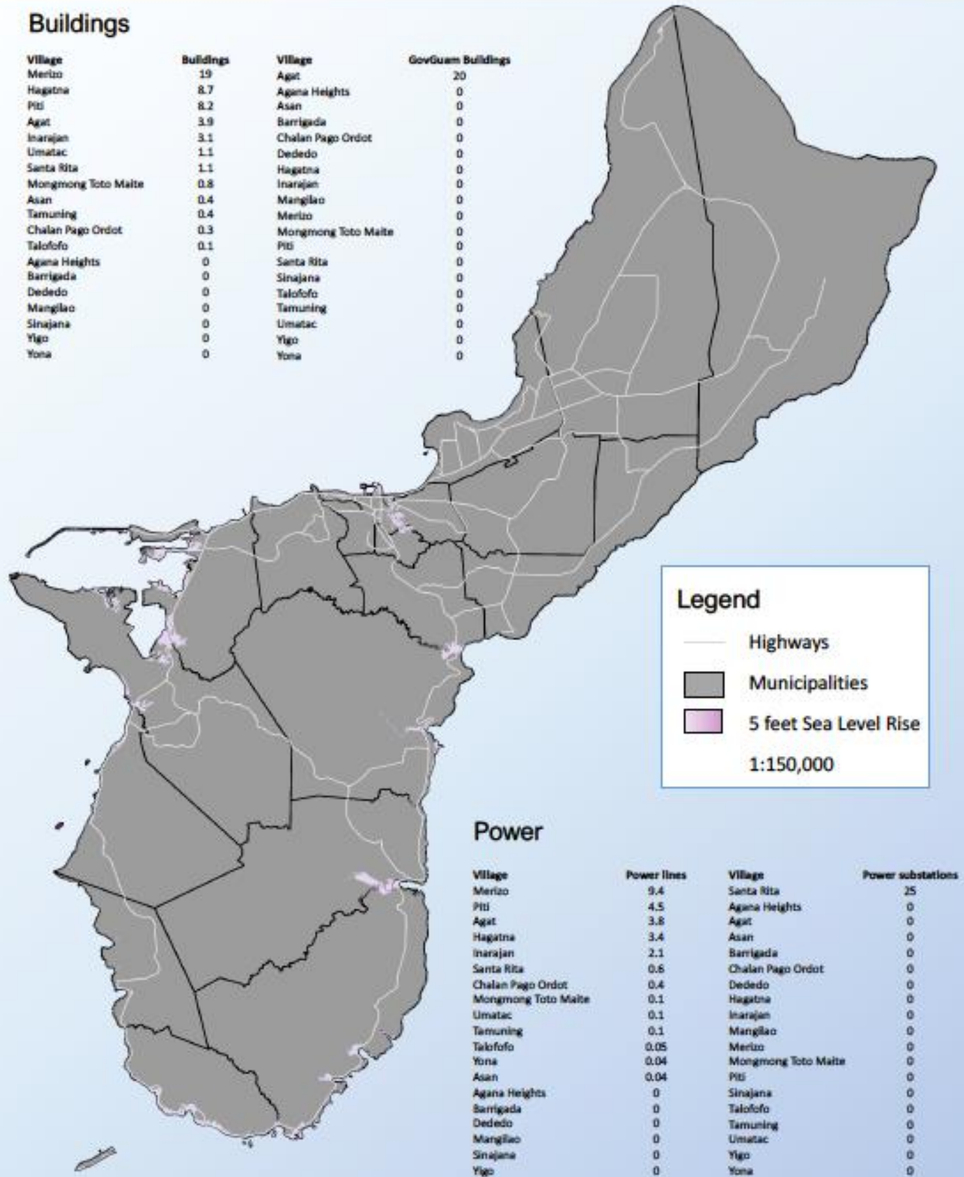
Table 19: Percentage of infrastructure impacted within each municipality under a three -foot SLR scenario.

Village	Streets (feet)	Highways (feet)	Bridges	Buildings	GovGuam buildings	Power lines (feet)	Power substations	Water lines (feet)	Water pump stations	Production wells	Sewer lines (feet)	Sewage pump stations	Sewage treatment plants
Agana Heights	0	0	0	0	0	0	0	0	0	0	0	0	0
Agat	4.8	1.5	0	9.4	0	9.5	0	4.9	0	0	7.5	0	0
Asan	1.4	2.8	0	3.5	0	0.43	0	4.1	0	0	2.8	0	0
Barrigada	0	0	0	0	0	0	0	0	0	0	0	0	0
Chalan Pago Ordot	0.17	0	0	0	0	5.6	0	0	0	0	28	0	0
Dededo	0	0	0	0	0	0	0	0	0	0	4.6	0	0
Hagatna	2.1	5.5	0	8.2	0	4.1	0	5.4	0	0	5.8	0	0
Inarajan	5.4	12	60	9.4	0	6.9	0	11	0	0	5.5	0	0
Mangilao	0	0	0	0	0	0	0	0	0	0	0	0	0
Merizo	30	66	20	27	0	26	0	39	0	0	11	100	0
Mongmong Toto Maite	0	0	0	0	0	0	0	0	0	0	0	0	0
Piti	28	0	0	28	0	44	0	30	0	0	0	0	0
Santa Rita	19	0	0	11	0	0.54	0	0	0	0	2.1	0	0
Sinajana	0	0	0	0	0	0	0	0	0	0	0	0	0
Talofofo	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamuning	0.21	0	0	2.4	0	1	0	0	0	0	28	0	0
Umatac	1.1	2.8	20	1.2	0	0.61	0	2.3	0	0	4.7	0	0
Yigo	3.0	0	0	0	0	0	0	0	0	0	0	0	0
Yona	4.9	10	0	0	0	1.6	0	2.6	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**0**	**100**	**0**	**100**	**0**	**0**	**100**	**100**	**0**

5 feet Sea Level Rise Impact on Guam Built Infrastructure

Buildings

Village	Buildings	Village	GovGuam Buildings
Merizo	19	Agat	20
Hagatna	8.7	Agana Heights	0
Piti	8.2	Asan	0
Agat	3.9	Barrigada	0
Inarajan	3.1	Chalan Pago Ordot	0
Umatac	1.1	Dededo	0
Santa Rita	1.1	Hagatna	0
Mongmong Toto Maite	0.8	Inarajan	0
Asan	0.4	Mangilao	0
Tamuning	0.4	Merizo	0
Chalan Pago Ordot	0.3	Mongmong Toto Maite	0
Talofofo	0.1	Piti	0
Agana Heights	0	Santa Rita	0
Barrigada	0	Sinajana	0
Dededo	0	Talofofo	0
Mangilao	0	Tamuning	0
Sinajana	0	Umatac	0
Yigo	0	Yigo	0
Yona	0	Yona	0



Transportation

Village	Streets	Village	Highways	Village	Bridges
Merizo	10	Merizo	16	Chalan Pago Ordot	100
Inarajan	6.3	Inarajan	2.1	Merizo	100
Piti	3.9	Yona	0.4	Inarajan	75
Hagatna	3.6	Mongmong Toto Maite	0.4	Umatac	50
Santa Rita	2.9	Hagatna	0.3	Yona	50
Agat	1.1	Umatac	0.2	Hagatna	25
Yona	0.3	Santa Rita	0.2	Agana Heights	0
Asan	0.3	Asan	0.1	Agat	0
Umatac	0.2	Agat	0.1	Asan	0
Tamuning	0.2	Agana Heights	0	Barrigada	0
Chalan Pago Ordot	0.2	Barrigada	0	Dededo	0
Yigo	0.1	Chalan Pago Ordot	0	Mangilao	0
Mongmong Toto Maite	0.1	Dededo	0	Mongmong Toto Maite	0
Talofofo	0.01	Mangilao	0	Piti	0
Agana Heights	0	Piti	0	Santa Rita	0
Barrigada	0	Sinajana	0	Sinajana	0
Dededo	0	Talofofo	0	Talofofo	0
Mangilao	0	Tamuning	0	Tamuning	0
Sinajana	0	Yigo	0	Yigo	0

Water

Village	Water lines	Village	Water pump stations	Village	Production wells
Merizo	8.1	Agana Heights	0	Agana Heights	0
Piti	2.6	Agat	0	Agat	0
Inarajan	1.7	Asan	0	Asan	0
Agat	0.7	Barrigada	0	Barrigada	0
Hagatna	0.4	Chalan Pago Ordot	0	Chalan Pago Ordot	0
Umatac	0.2	Dededo	0	Dededo	0
Asan	0.2	Hagatna	0	Hagatna	0
Yona	0.1	Inarajan	0	Inarajan	0
Chalan Pago Ordot	0.1	Mangilao	0	Mangilao	0
Mongmong Toto Maite	0.1	Merizo	0	Merizo	0
Talofofo	0.01	Mongmong Toto Maite	0	Mongmong Toto Maite	0
Agana Heights	0	Piti	0	Piti	0
Barrigada	0	Santa Rita	0	Santa Rita	0
Dededo	0	Sinajana	0	Sinajana	0
Mangilao	0	Talofofo	0	Talofofo	0
Santa Rita	0	Tamuning	0	Tamuning	0
Sinajana	0	Umatac	0	Umatac	0
Tamuning	0	Yigo	0	Yigo	0
Yigo	0	Yona	0	Yona	0

Power

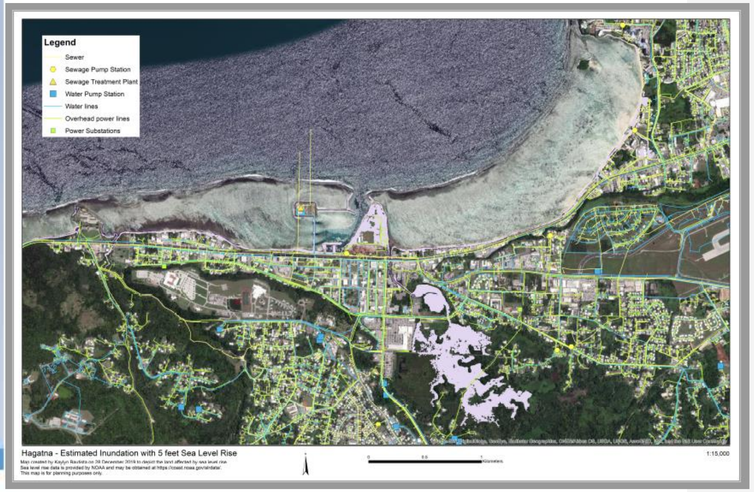
Village	Power lines	Village	Power substations
Merizo	9.4	Santa Rita	25
Piti	4.5	Agana Heights	0
Agat	3.8	Agat	0
Hagatna	3.4	Asan	0
Inarajan	2.1	Barrigada	0
Santa Rita	0.6	Chalan Pago Ordot	0
Chalan Pago Ordot	0.4	Dededo	0
Mongmong Toto Maite	0.1	Hagatna	0
Umatac	0.1	Inarajan	0
Tamuning	0.1	Mangilao	0
Talofofo	0.05	Merizo	0
Yona	0.04	Mongmong Toto Maite	0
Asan	0.04	Piti	0
Agana Heights	0	Sinajana	0
Barrigada	0	Talofofo	0
Dededo	0	Tamuning	0
Mangilao	0	Umatac	0
Sinajana	0	Yigo	0
Yigo	0	Yona	0

Sewer

Village	Sewer lines	Village	Sewage treatment plant	Village	Sewage pump stations
Merizo	5.6	Agana Heights	0	Merizo	17
Inarajan	5.1	Agat	0	Tamuning	8.3
Santa Rita	1.8	Asan	0	Agana Heights	0
Chalan Pago Ordot	1.1	Barrigada	0	Agat	0
Umatac	0.8	Chalan Pago Ordot	0	Asan	0
Tamuning	0.8	Dededo	0	Barrigada	0
Agat	0.8	Hagatna	0	Chalan Pago Ordot	0
Asan	0.6	Inarajan	0	Dededo	0
Hagatna	0.4	Mangilao	0	Hagatna	0
Piti	0.2	Merizo	0	Inarajan	0
Mongmong Toto Maite	0.1	Mongmong Toto Maite	0	Mangilao	0
Dededo	0.03	Piti	0	Mongmong Toto Maite	0
Agana Heights	0	Santa Rita	0	Piti	0
Barrigada	0	Sinajana	0	Santa Rita	0
Mangilao	0	Talofofo	0	Sinajana	0
Sinajana	0	Tamuning	0	Talofofo	0
Talofofo	0	Umatac	0	Umatac	0
Yigo	0	Yigo	0	Yigo	0
Yona	0	Yona	0	Yona	0

Figure 19: Summary Information Graphic displaying percentage of buildings, roads, power, water, and sewer affected by a five-foot SLR. Geospatial databases were provided by GWA, GPA, and the Bureau of Statistics and Plans.

- 74% impacted by a 5-ft SLR



If you zoom into the map, you will see this.

Table 20: Percentage of infrastructure impacted within each municipality under a five-foot SLR scenario.

Village	Streets (feet)	Highways (feet)	Bridges	Buildings	GovGuam buildings	Power lines (feet)	Power substations	Water lines (feet)	Water pump stations	Production wells	Sewer lines (feet)	Sewage pump stations	Sewage treatment plants
Agana Heights	0	0	0	0	0	0	0	0	0	0	0	0	0
Agat	2.0	0.52	0	14	100	18	0	8.2	0	0	10	0	0
Asan	0.40	0.67	0	0.76	0	0.11	0	1.3	0	0	1.7	0	0
Barrigada	0	0	0	0	0	0	0	0	0	0	0	0	0
Chalan Pago Ordot	1.0	0	11	1.5	0	4.1	0	1.4	0	0	7.7	0	0
Dededo	0	0	0	0	0	0	0	0	0	0	1.3	0	0
Hagatna	8.8	1.5	11	14	0	9.4	0	2.3	0	0	1.6	0	0
Inarajan	13	14	33	8.1	0	14	0	22	0	0	18	0	0
Mangilao	0	0	0	0	0	0	0	0	0	0	0	0	0
Merizo	30	77	11	32	0	33	0	45	0	0	28	67	0
Mongmong Toto Maite	0.25	1.0	0	2.8	0	0.60	0	0.64	0	0	0.50	0	0
Piti	14	0	0	16	0	16	0	16	0	0	0.72	0	0
Santa Rita	26	1.5	0	7.1	0	3.3	100	0	0	0	11	0	0
Sinajana	0	0	0	0	0	0	0	0	0	0	0	0	0
Talofofo	0	0	11	0.25	0	0.27	0	0.13	0	0	0	0	0
Tamuning	1.2	0	0	3.3	0	1.0	0	0	0	0	19	33	0
Umatac	0.29	0.84	11	0.76	0	0.21	0	0.58	0	0	1.4	0	0
Yigo	1.1	0	0	0	0	0	0	0	0	0	0	0	0
Yona	1.1	3.5	11	0	0	0.40	0	2.2	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**100**	**100**	**0**

10 feet Sea Level Rise Impact on Guam Built Infrastructure

Buildings

Village	Buildings
Hagatna	85
Merizo	50
Piti	40
Agat	32
Inarajan	14
Santa Rita	8.8
Umatac	8.3
Tamuning	7.3
Asan	3.8
Mongmong Toto Maite	1.2
Chalan Pago Ordot	0.9
Talofofo	0.3
Agana Heights	0
Barrigada	0
Dededo	0
Mangilao	0
Sinajana	0
Yigo	0
Yona	0

Village	GovGuam Buildings
Agat	60
Piti	29
Hagatna	25
Agana Heights	0
Asan	0
Barrigada	0
Chalan Pago Ordot	0
Dededo	0
Inarajan	0
Mangilao	0
Merizo	0
Mongmong Toto Maite	0
Santa Rita	0
Sinajana	0
Talofofo	0
Tamuning	0
Umatac	0
Yigo	0
Yona	0

Transportation

Village	Streets
Agat	80
Hagatna	73
Piti	46
Inarajan	45
Merizo	37
Santa Rita	20
Tamuning	18
Sinajana	3.5
Yona	3.3
Chalan Pago Ordot	1.8
Umatac	1.7
Mongmong Toto Maite	0.7
Asan	0.6
Talofofo	0.4
Yigo	0.2
Agana Heights	0
Barrigada	0
Dededo	0
Mangilao	0

Village	Highways
Hagatna	61
Merizo	58
Agat	52
Piti	45
Inarajan	30
Tamuning	15
Chalan Pago Ordot	5.1
Yona	2.6
Santa Rita	2.4
Umatac	0.3
Mongmong Toto Maite	0.2
Asan	0.2
Agana Heights	0
Barrigada	0
Dededo	0
Mangilao	0
Sinajana	0
Talofofo	0
Yigo	0

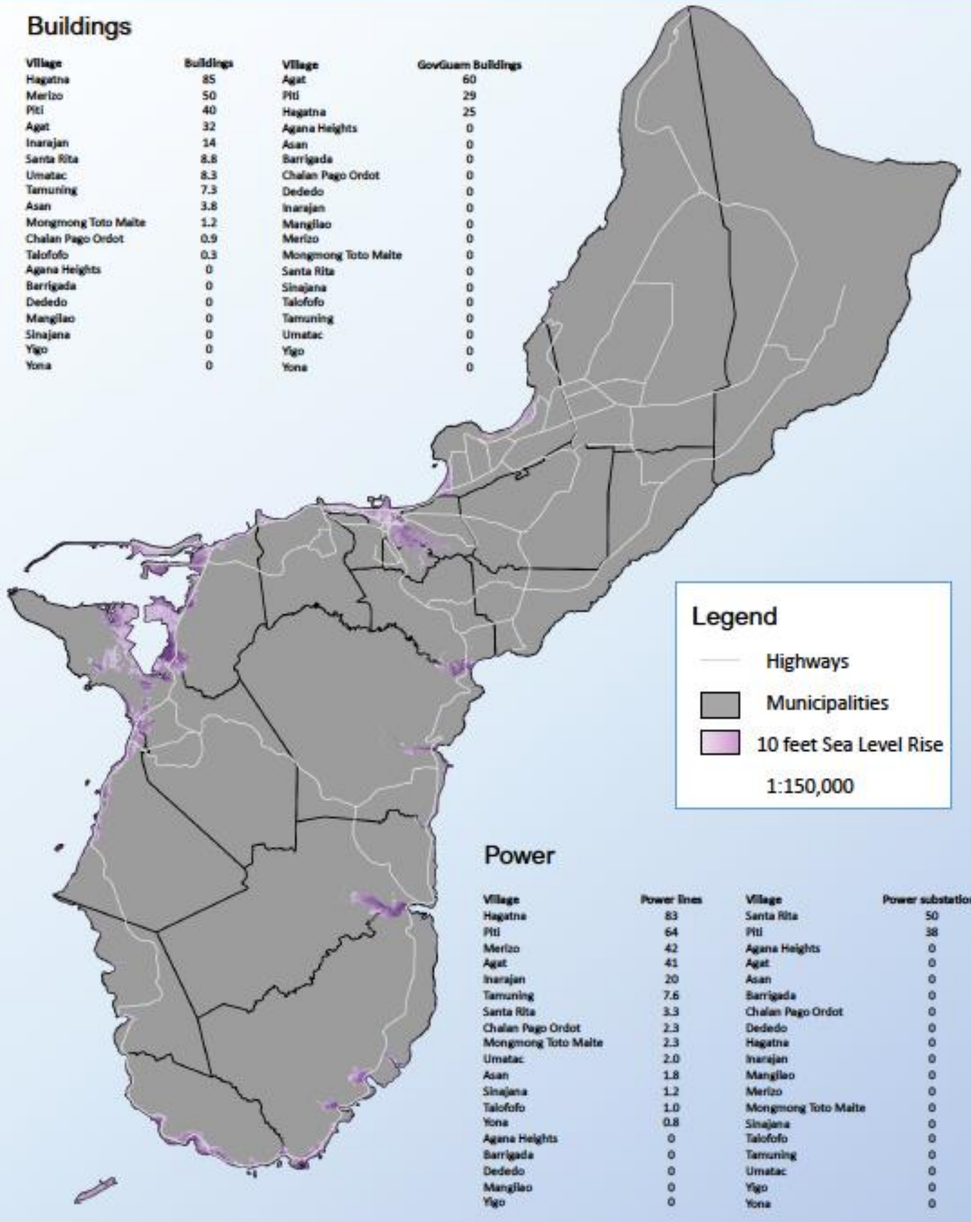
Village	Bridges
Chalan Pago Ordot	100
Merizo	100
Inarajan	75
Hagatna	50
Umatac	50
Yona	50
Agana Heights	0
Agat	0
Asan	0
Barrigada	0
Dededo	0
Mangilao	0
Mongmong Toto Maite	0
Piti	0
Santa Rita	0
Sinajana	0
Talofofo	0
Tamuning	0
Yigo	0

Water

Village	Water lines
Hagatna	87
Piti	66
Merizo	47
Agat	35
Inarajan	19
Tamuning	12
Yona	5.6
Chalan Pago Ordot	3.6
Asan	1.8
Umatac	1.4
Mongmong Toto Maite	0.6
Talofofo	0.04
Barrigada	0
Dededo	0
Mangilao	0
Santa Rita	0
Sinajana	0
Tamuning	0
Yigo	0

Village	Water pump stations
Inarajan	7.7
Agana Heights	0
Agat	0
Asan	0
Barrigada	0
Chalan Pago Ordot	0
Dededo	0
Hagatna	0
Mangilao	0
Merizo	0
Mongmong Toto Maite	0
Piti	0
Santa Rita	0
Sinajana	0
Talofofo	0
Tamuning	0
Umatac	0
Yigo	0
Yona	0

Village	Production wells
Tamuning	17
Agana Heights	0
Agat	0
Asan	0
Barrigada	0
Chalan Pago Ordot	0
Dededo	0
Hagatna	0
Inarajan	0
Mangilao	0
Merizo	0
Mongmong Toto Maite	0
Piti	0
Santa Rita	0
Sinajana	0
Talofofo	0
Umatac	0
Yigo	0
Yona	0



Power

Village	Power lines
Hagatna	83
Piti	64
Merizo	42
Agat	41
Inarajan	20
Tamuning	7.6
Santa Rita	3.3
Chalan Pago Ordot	2.3
Mongmong Toto Maite	2.3
Umatac	2.0
Asan	1.8
Sinajana	1.2
Talofofo	1.0
Yona	0.8
Agana Heights	0
Barrigada	0
Dededo	0
Mangilao	0
Yigo	0

Village	Power substations
Santa Rita	50
Piti	38
Agana Heights	0
Agat	0
Asan	0
Barrigada	0
Chalan Pago Ordot	0
Dededo	0
Hagatna	0
Inarajan	0
Mangilao	0
Merizo	0
Mongmong Toto Maite	0
Sinajana	0
Talofofo	0
Tamuning	0
Umatac	0
Yigo	0
Yona	0

Sewer

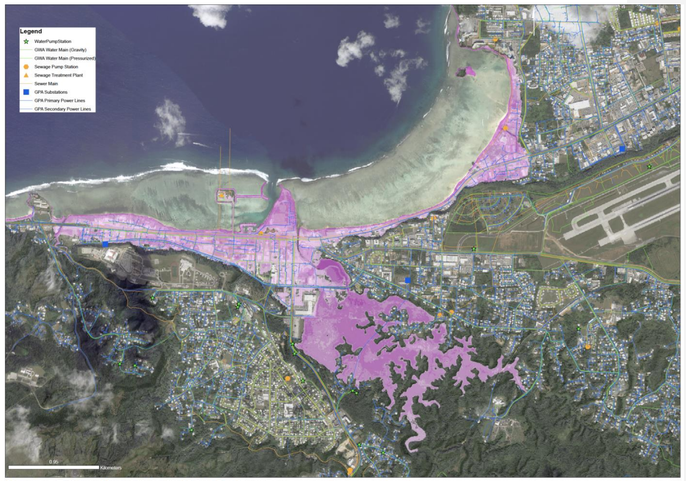
Village	Sewer lines
Hagatna	90
Piti	66
Santa Rita	59
Agat	45
Merizo	42
Inarajan	33
Umatac	19
Tamuning	16
Asan	11
Chalan Pago Ordot	6
Dededo	1.0
Yona	0.7
Mongmong Toto Maite	0.2
Agana Heights	0
Barrigada	0
Mangilao	0
Sinajana	0
Talofofo	0
Yigo	0

Village	Sewage treatment plant
Agana Heights	0
Agat	0
Asan	0
Barrigada	0
Chalan Pago Ordot	0
Dededo	0
Hagatna	0
Inarajan	0
Mangilao	0
Merizo	0
Mongmong Toto Maite	0
Piti	0
Santa Rita	0
Sinajana	0
Talofofo	0
Tamuning	0
Umatac	0
Yigo	0
Yona	0

Village	Sewage pump stations
Agat	100
Hagatna	100
Merizo	67
Piti	67
Inarajan	50
Umatac	20
Chalan Pago Ordot	11
Tamuning	8.3
Agana Heights	0
Asan	0
Barrigada	0
Dededo	0
Mangilao	0
Mongmong Toto Maite	0
Santa Rita	0
Sinajana	0
Talofofo	0
Yigo	0
Yona	0

Figure 20: Summary Information Graphic displaying percentage of buildings, roads, power, water, and sewer affected by a ten-foot SLR. Geospatial databases were provided by GWA, GPA, and the Bureau of Statistics and Plans.

- 84% impacted by a 10-ft SLR



If you zoom into the map, you will see this.

Table 21: Percentage of infrastructure impacted within each municipality under a ten-foot SLR scenario.

Village	Streets (feet)	Highways (feet)	Bridges	Buildings	GovGuam buildings	Power lines (feet)	Power substations	Water lines (feet)	Water pump stations	Production wells	Sewer lines (feet)	Sewage pump stations	Sewage treatment plants
Agana Heights	0	0	0	0	0	0	0	0	0	0	0	0	0
Agat	14	16	0	19	38	18	0	17	0	0	24	16	0
Asan	0.071	0.066	0	1.2	0	0.48	0	0.58	0	0	1.3	0	0
Barrigada	0	0	0	0	0	0	0	0	0	0	0	0	0
Chalan Pago Ordot	1.1	1.4	0	0.68	0	2.0	0	2.0	0	0	1.7	5.3	0
Dededo	0	0	0	0	0	0	0	0	0	0	1.7	0	0
Hagatna	18	18	22	23	38	21	0	22	0	0	16	5.3	0
Inarajan	9.3	13	33	6.0	0	12	0	11	100	0	4.9	11	0
Mangilao	0	0	0	0	0	0	0	0	0	0	0	0	0
Merizo	11	18	11	14.3	0	13	0	11	0	0	8.8	42	0
Mongmong Toto Maite	0.27	0	0	0.68	0	1.1	0	0.26	0	0	0.051	0	0
Piti	16	20	0	14	25	21	60	18	0	0	9.4	11	0
Santa Rita	18	1.2	0	10	0	1.8	40	0	0	0	14.7	0	0
Sinajana	0.27	0	0	0	0	0.13	0	0	0	0	0	0	0
Talofofo	0.18	0	0	0.13	0	0.53	0	0	0	0	0	0	0
Tamuning	10	12	0	11	0	9.1	0	14	0	100	15.4	5.3	0
Umatac	0.21	0.066	11	0.94	0	0.36	0	0.18	0	0	1.4	5.3	0
Yigo	0.24	0	0	0	0	0	0	0	0	0	0	0	0
Yona	1.0	1.4	11	0	0	0.64	0	4.5	0	0	0.25	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**0**

RESULTS - PGIS

Kaylyn Bautista, MSc, WERI, University of Guam

Of 180 responses, frequency ranking by concern resulted as:

- 102 for infrastructure – *high concern*,
- 41 for natural – *moderate concern*, and
- 37 for culture – *low concern*.

Concerns were organized into subcategories and ranked from highest to lowest frequency of responses:

Built environment

- infrastructure – utilities (40),
- commercial building displacement (39),
- highway loss (19), and
- residential displacement (11);

Natural Environment

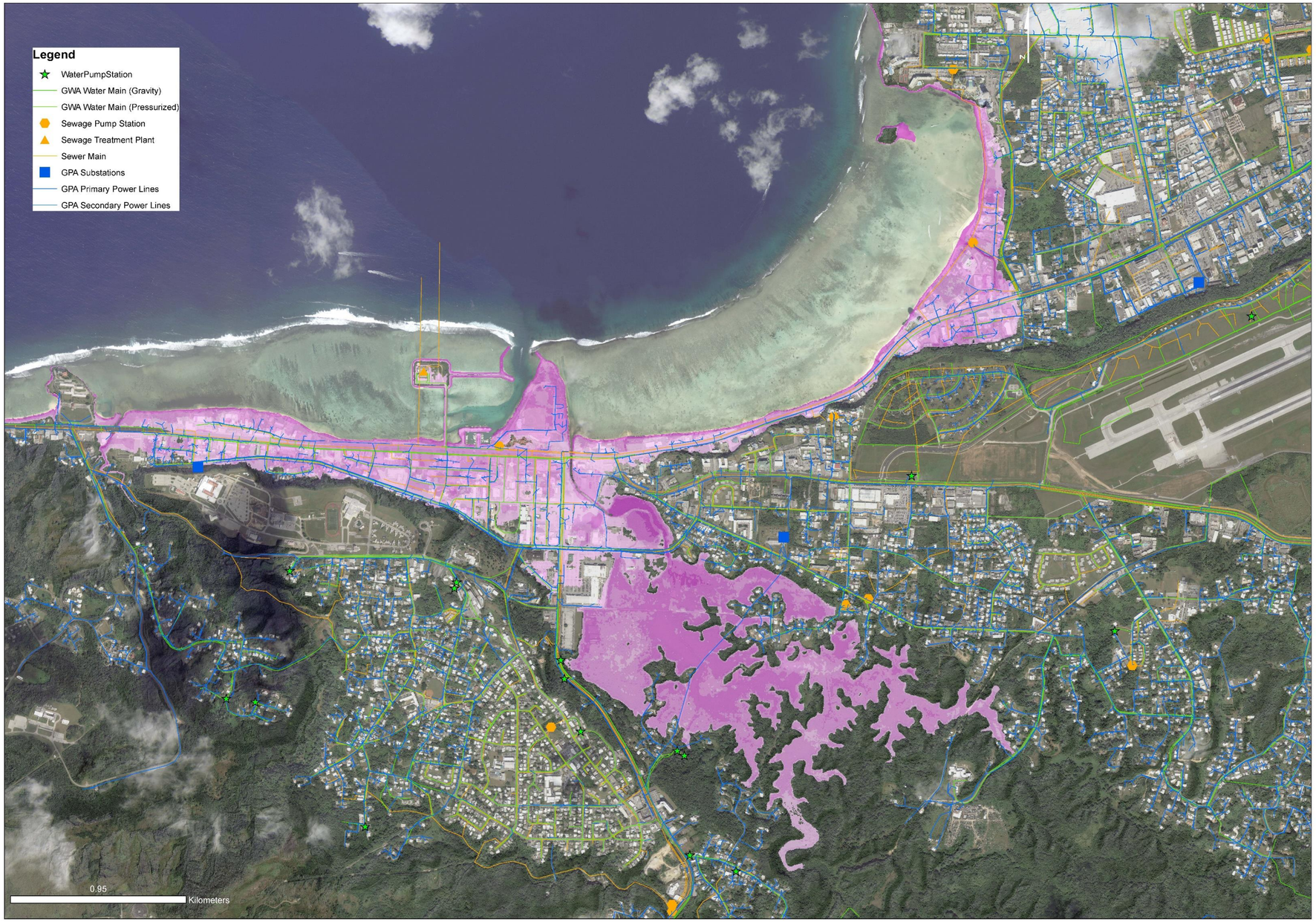
- natural – marine ecosystem change or loss (15),
- freshwater ecosystem change or loss (12),
- beach or natural landmark loss (9),
- erosion or landslide (4),
- and unfavorable upland conditions (1);

Cultural Resources

- cultural – historical site loss (15),
- cemetery displacement (8),
- tourism loss (5),
- aquaculture displacement (4),
- farmland loss (4), and
- fishing site loss (1).

ALL PLANNERS CLIMATE CHANGE WORKSHOP

A PGIS exercise on Guam



Hagatna - Estimated Inundation with 10 foot Sea Level Rise

1:6,000

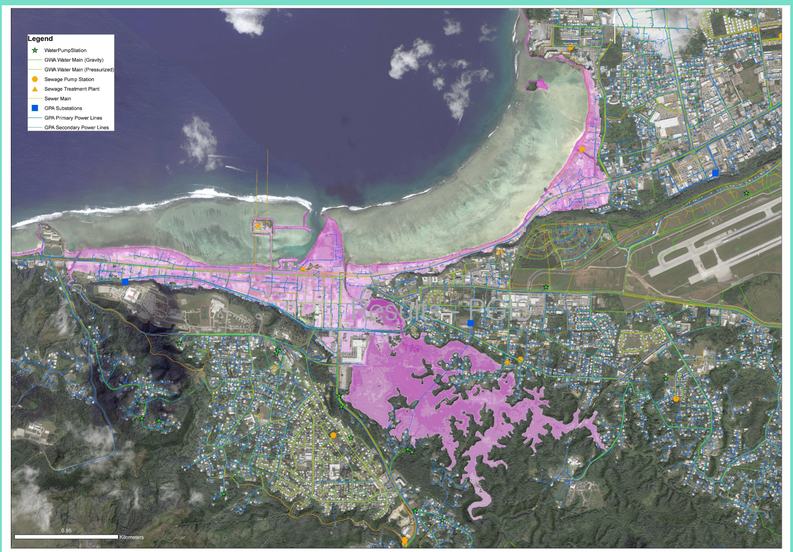
Map was created by Romina King on 04 April 2019 to depict the land affected by a ten foot sea level rise.
Sea level rise data is provided by NOAA and may be obtained at https://coast.noaa.gov/slrdata/.
This map is for planning purposes only.

RESULTS - PGIS

Guam - 10 Feet Sea Level Rise

1:45,000

Map was created by Romina King on 04 April 2019 to depict the land affected by a ten foot sea level rise.
Sea level rise data is provided by NOAA and may be obtained at https://coast.noaa.gov/slrdata/.
This map is for planning purposes only.



Hagatna - Estimated Inundation with 10 foot Sea Level Rise

1:6,000

Map was created by Romina King on 04 April 2019 to depict the land affected by a ten foot sea level rise.
Sea level rise data is provided by NOAA and may be obtained at https://coast.noaa.gov/slrdata/.
This map is for planning purposes only.

Category	Concern	Frequency	Solution
Infrastructure	Utilities	40	Protect or relocate upland
	Commercial building displacement	39	Build seawall or relocate
	Highway loss	19	Build seawall or relocate
	Residential displacement	11	Relocate upland
Environmental	Marine ecosystem change, or loss	15	
	Freshwater ecosystem change, or loss	12	Buffer
	Beach or natural landmark loss	9	
	Erosion or landslide	4	
	Unfavorable upland conditions	1	
Cultural	Historical site loss	15	
	Cemetery displacement	8	Relocate upland
	Tourism loss	5	
	Aquaculture displacement	4	Relocate upland
	Farmland loss	4	Land exchange program
	Fishing site loss	1	

Photograph by Jessica Peterson

LOCAL EARLY ACTION PLANNING

Taking a look at perceived climate history on Guam

Marcel Higgs, University of Guam

On 08 April 2019, the Nature Conservancy conducted a LEAP training for the All Planners Climate Change Conference at the Hyatt Hotel in Tumon. The results from this workshop have been collected and aggregated into a single timeline.

TIMELINE - Perceived Guam Climate History

Group 1 Group 2 Group 3

Perceived

1976
Typhoon Pamela
No power: 4 months; water buffelos

1990
Typhoon Russ

1991
Typhoon Yuri(sic)
Biggest waves, storm surge .

1992
Typhoon Omar
$500 mil. in damages

1993
Earthquake
First Address of Tsunamis

Actual

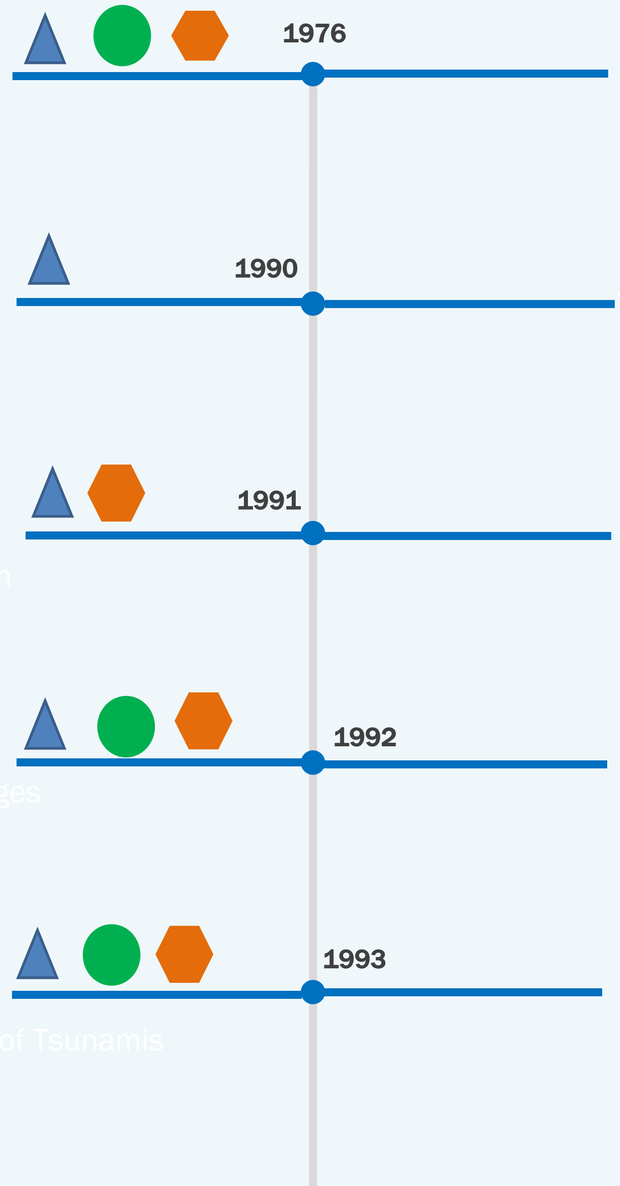
May 20, 1976
Typhoon Pamela
Power outages were only reported to last over a month

December 20-21, 1991
Typhoon Russ

November 27-28, 1991
Typhoon Yuri
Waves as tall as two-story buildings (Retrieved 2019, WERI.com)

August 28-29, 1992
Typhoon Omar
$457 million in damages

August 8, 1993
8.0 Earthquake
Tsunamis hit Guam in 1849, 1892, and in 1993



Constant FEMA involvement & improvement

TIMELINE - Perceived Guam Climate History

Group 1 Group 2 Group 3

Perceived		Actual
1996 **Typhoon Dale**	1996	**November 03, 1996** **Typhoon Dale**
1997 **Typhoon Paka** $800 mil. in damages	1995	**December 16, 1997** **Typhoon Paka** $500 million in damages
2002 **Typhoon Chata'an** $50 mil. in damages. 100-year rainfall.	2002	**July 5, 2002,** **Typhoon Chata'an** $60.5 mil in damages
2002 **Typhoon Pongsona(sic)** $800 mil. in damages and fuel farm caught on fire	2002	**December 8, 2002** **Typhoon Pongsona** $730 mil and fuel farm caught on fire, Dec. 9, 2002
2003 **Typhoon Ting-ting** 100-year Rainfall	2003	**June 27-28, 2003** **Typhoon Ting-ting** 100-year Rainfall

Constant FEM involvement & improvement

TIMELINE - Perceived Guam Climate History

Perceived

Actual

2013-2017

2013-2017
Coral Bleaching

2017-2018
Coral reef condition status report for Guam(Burdick at el., 2018)

2008
Typhoon Dolphin

2018

May 15, 2018
Typhoon Dolphin

2018
Typhoon Mangkhut

2018

Sept. 10, 2018,
Typhoon Mangkhut

2018
Typhoon Yutu

2018

Oct. 23, 2018
Typhoon Yutu

Group 1 Group 2 Group 3

Discussion & Take-away

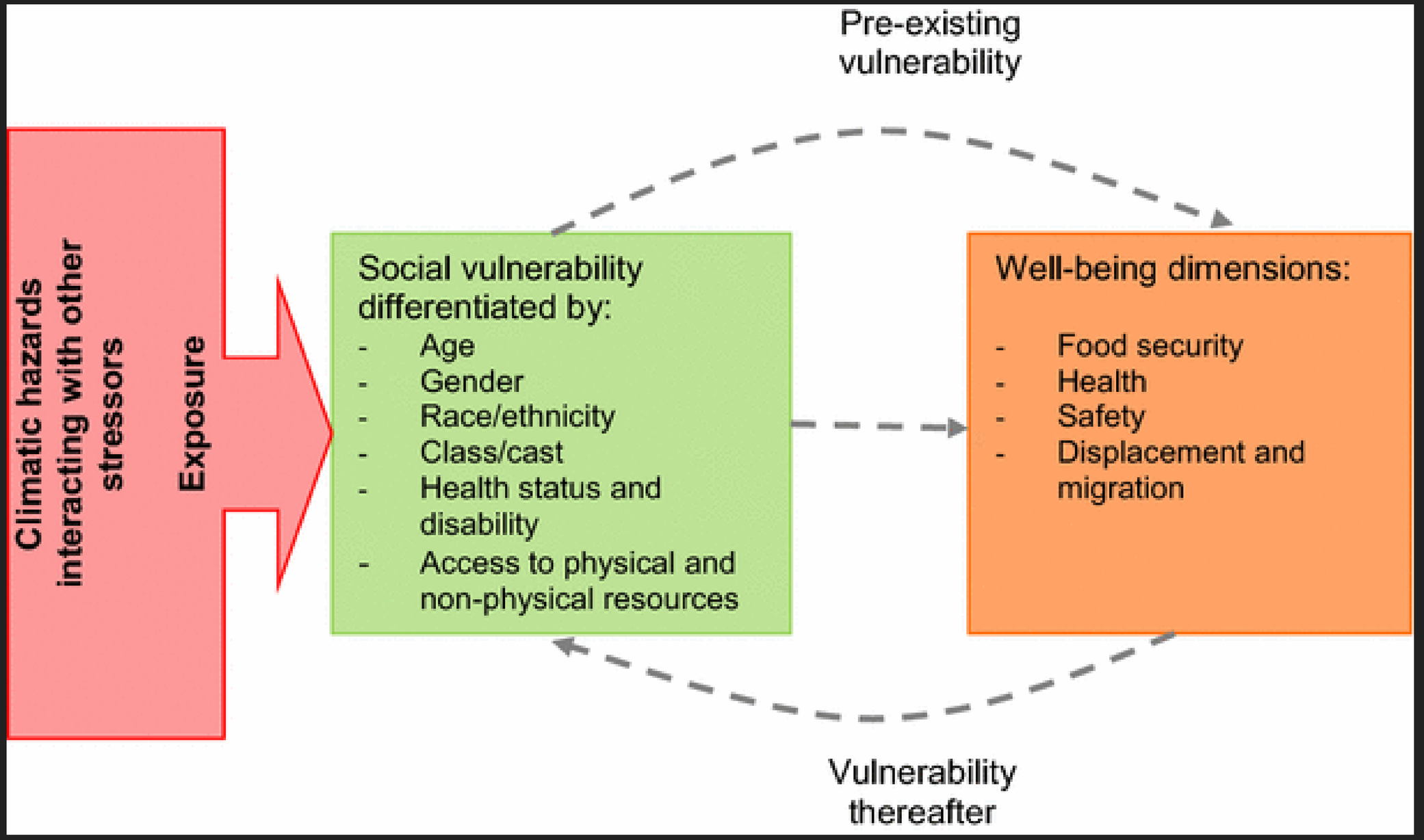
* Typhoons are key markers for Guam's climate history
* LEAP may not be the best choice for urban settings or communities with complex social/governance structures

Photograph by Jessica Peterson

SOCIAL VULNERABILITY

Edward Leon Guerrero, University of Guam

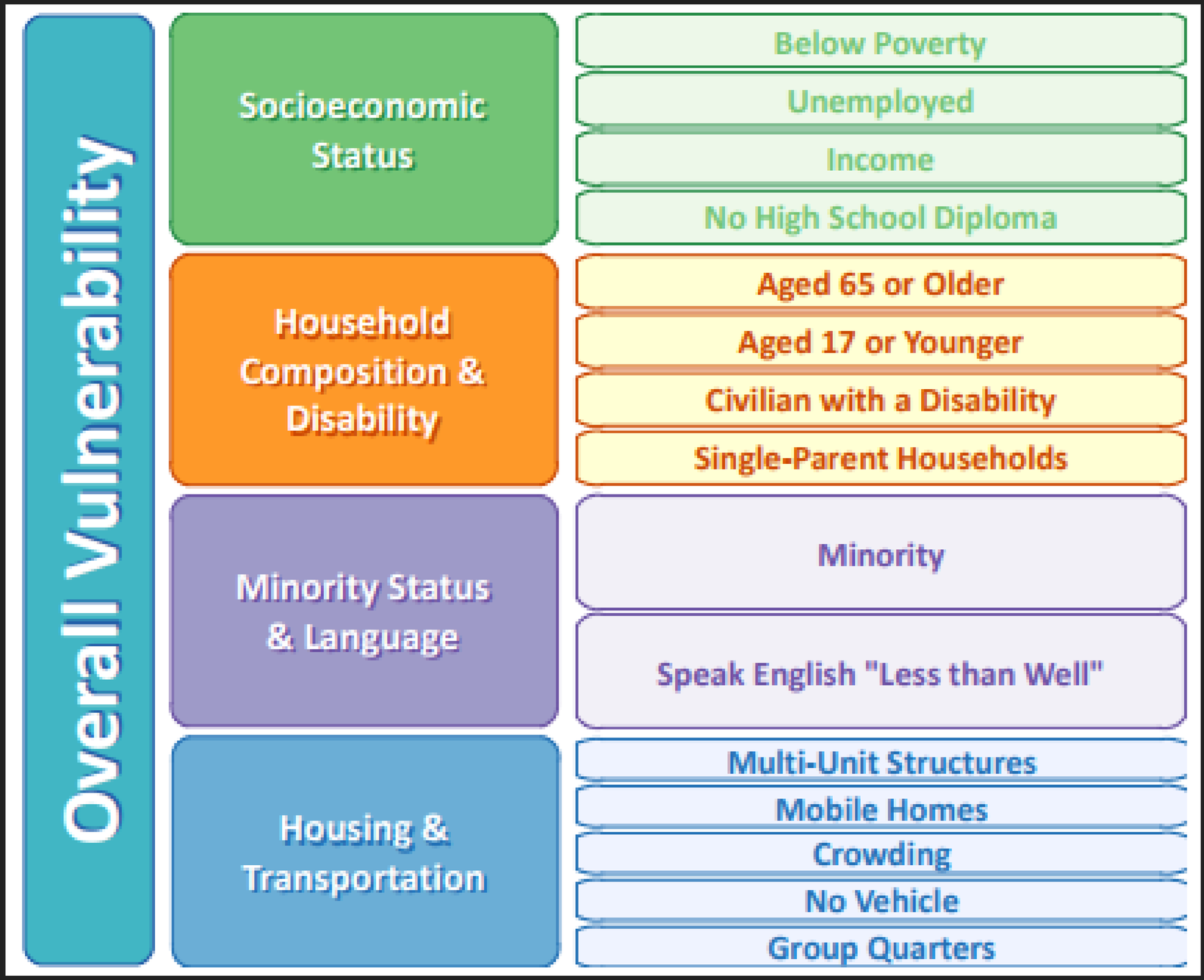
Social Vulnerability



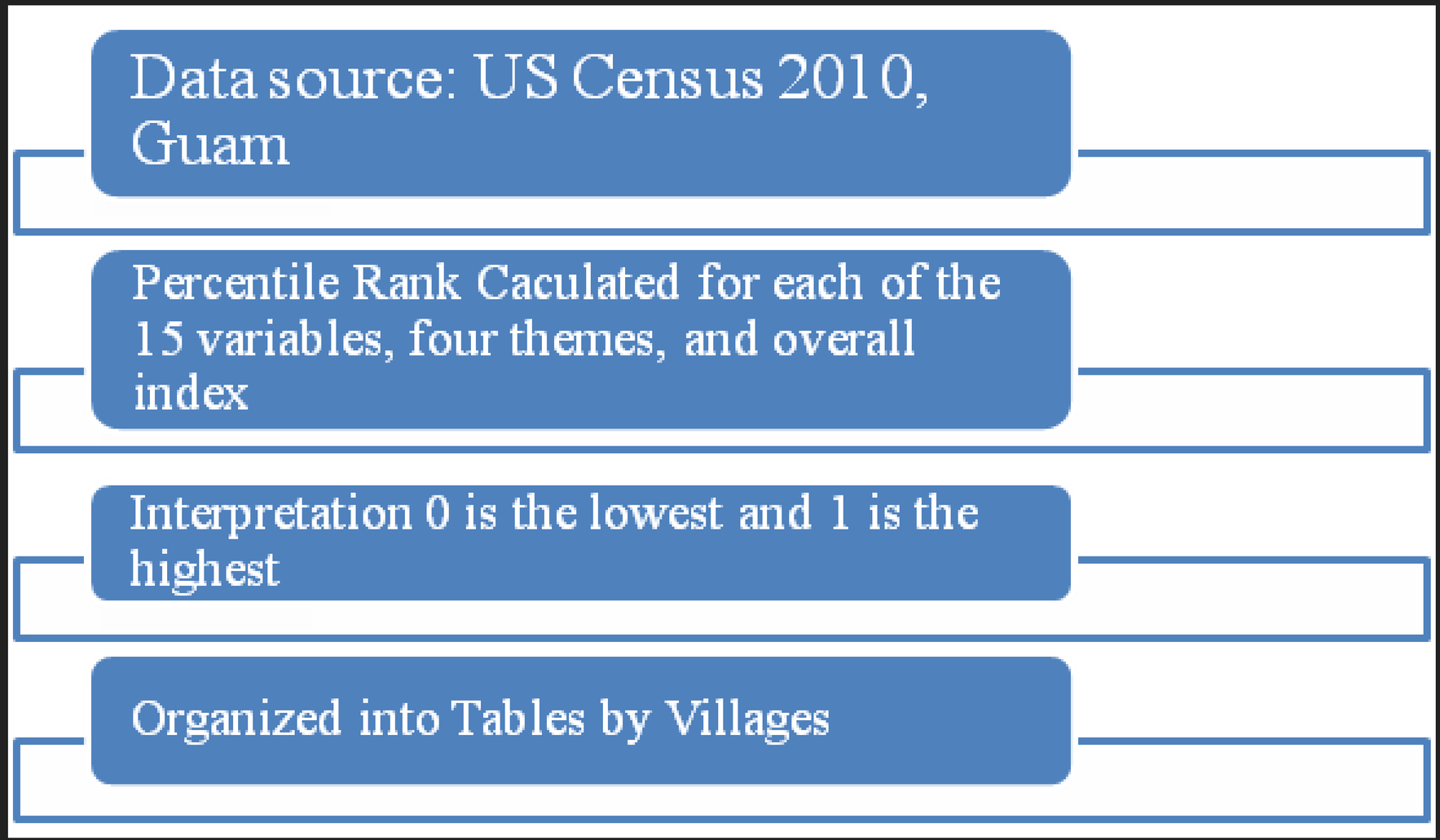
CDC SVI

Four Themes

15 variables



Methodology - Taken from



Percentile Rank Process

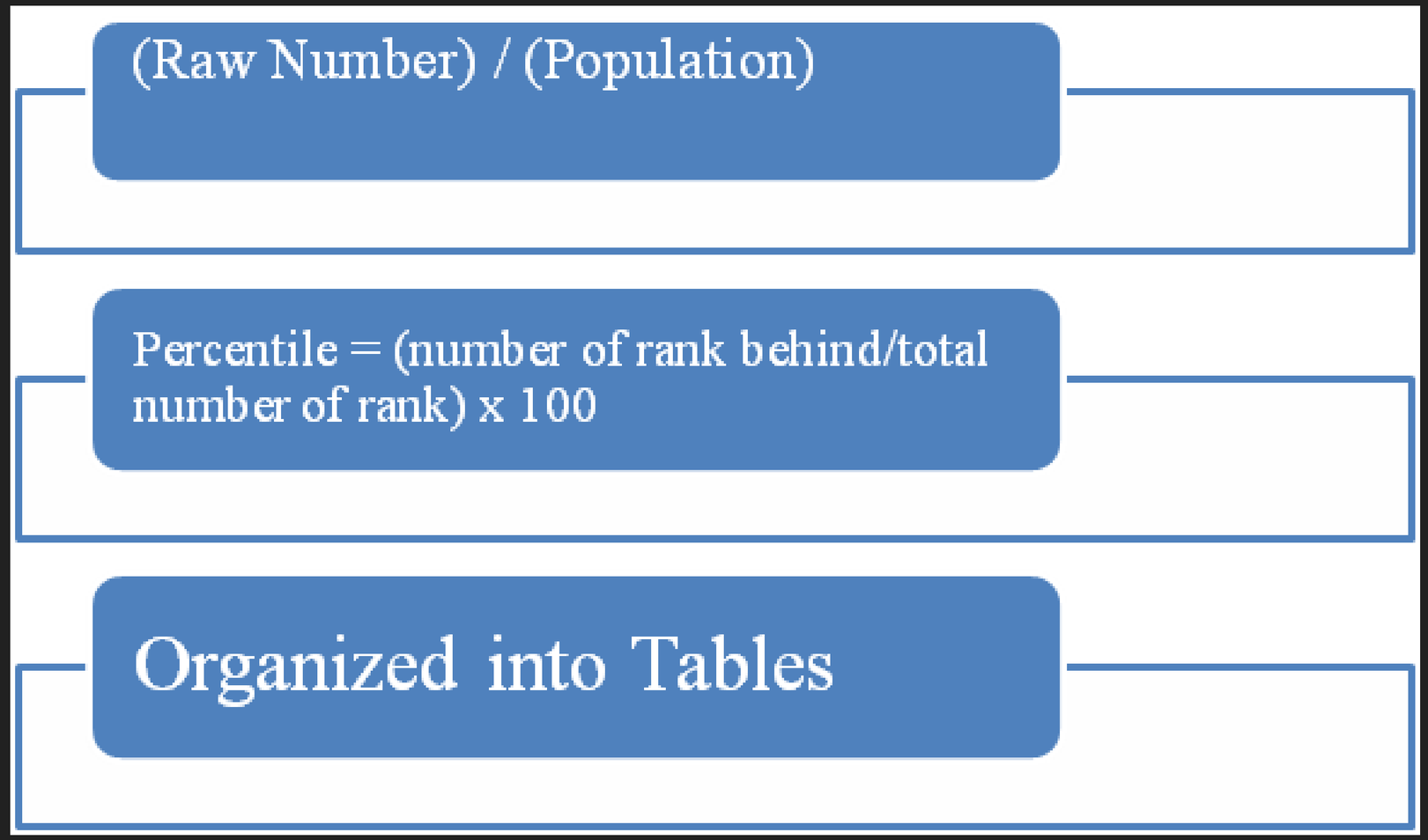


Table 22. Social Vulnerability Index. Higher percentile rank represents higher vulnerability. Source U.S. Census 2010, Guam.

	Non-Percentile Rank	Percentile Rank	
Piti	1	5.26	Least Vulnerable
Santa Rita	2	10.53	
Asan-Maina	3	15.79	
Talofofo	4	21.05	
Inarajan	5	26.32	
Yona	6	31.58	
Chalan Pago-Ordot	7	36.84	
Tamuning	8	42.11	
Agana Heights	9	47.37	
Yigo	10	52.63	
Sinajana	11	57.89	
Barrigada	12	63.16	
Umatac	13	68.42	
Dededo	14	73.68	
Mangilao	15	78.95	
Merizo	16	84.21	
Hagatna	17	89.47	
Mongmong-Toto-Maite	18	94.74	
Agat	19	100	Most Vulnerable

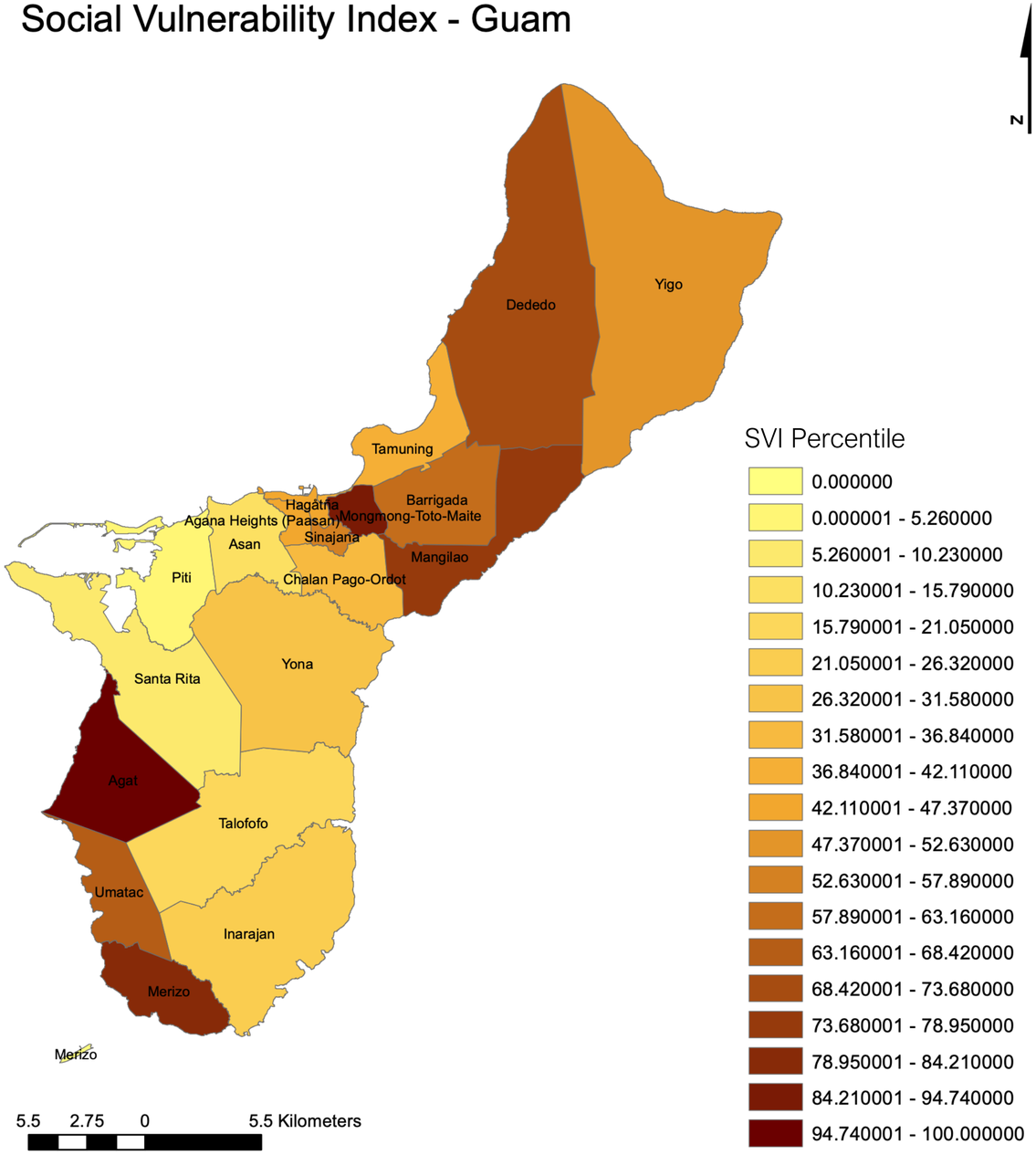
Top Three Most Vulnerable

1. Agat
2. MTM
3. Hagatna

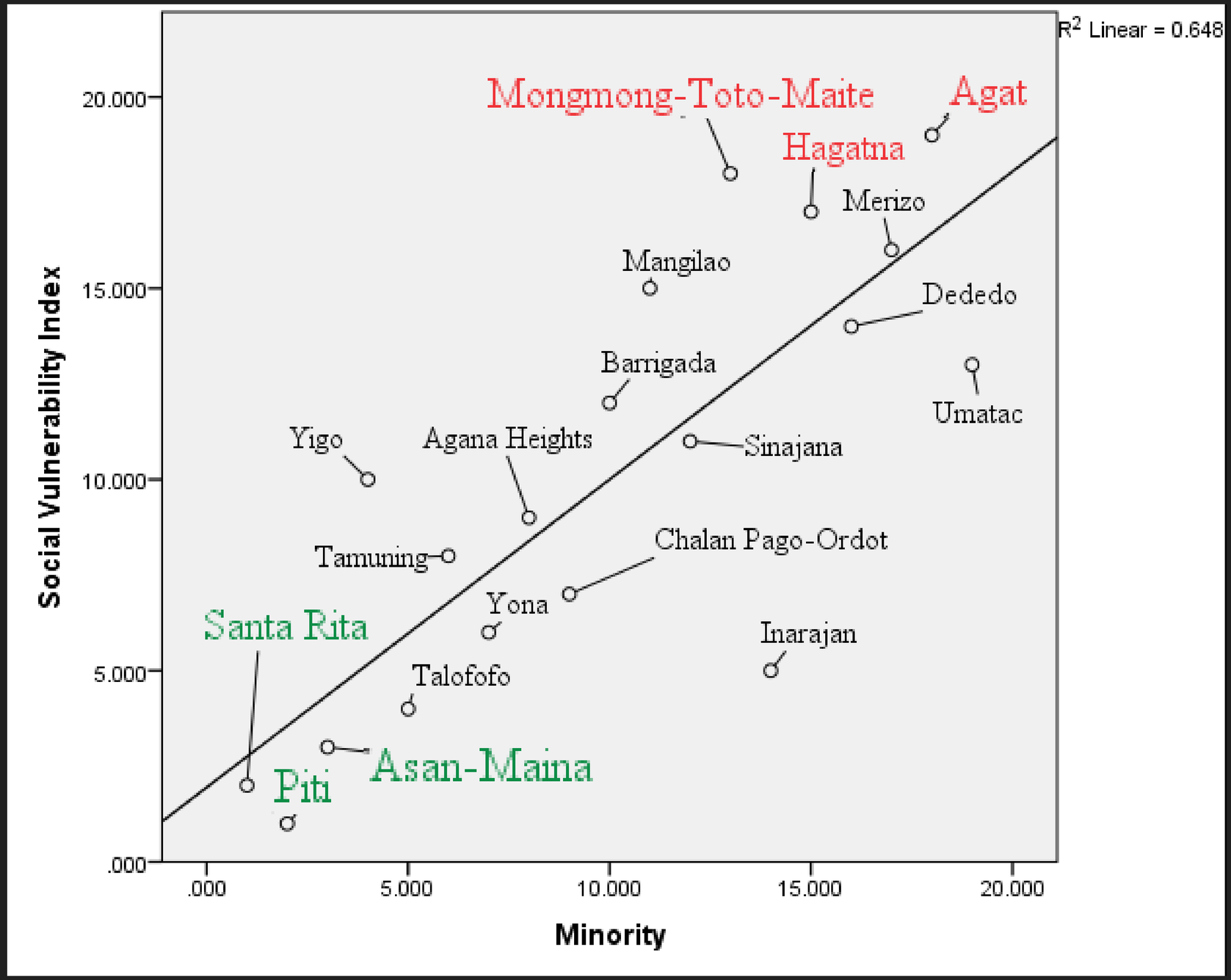
Top Three Least Vulnerable

1. Piti
2. Santa Rita
3. Asan-Maina

Social Vulnerability Index - Guam



Map was created on 06 August 2019 by Romina King for the Climate Change Vulnerability Assessment - Guam. Social Vulnerability Index was calculated by Edward Leon Guerrero using 2010 Census Data for Guam and the methodology set forth by the US Center for Disease Control.


R2 Linear = 0.648
Mongmong-Toto-Maite
Agat
Hagatna
Merizo
Mangilao
Dededo
Barrigada
Umatac
Yigo
Agana Heights
Sinajana
Tamuning
Chalan Pago-Ordot
Yona
Inarajan
Santa Rita
Talofofo
Asan-Maina
Piti
Social Vulnerability Index
20.000
15.000
10.000
5.000
.000
.000
5.000
10.000
15.000
20.000
Minority

Limitations

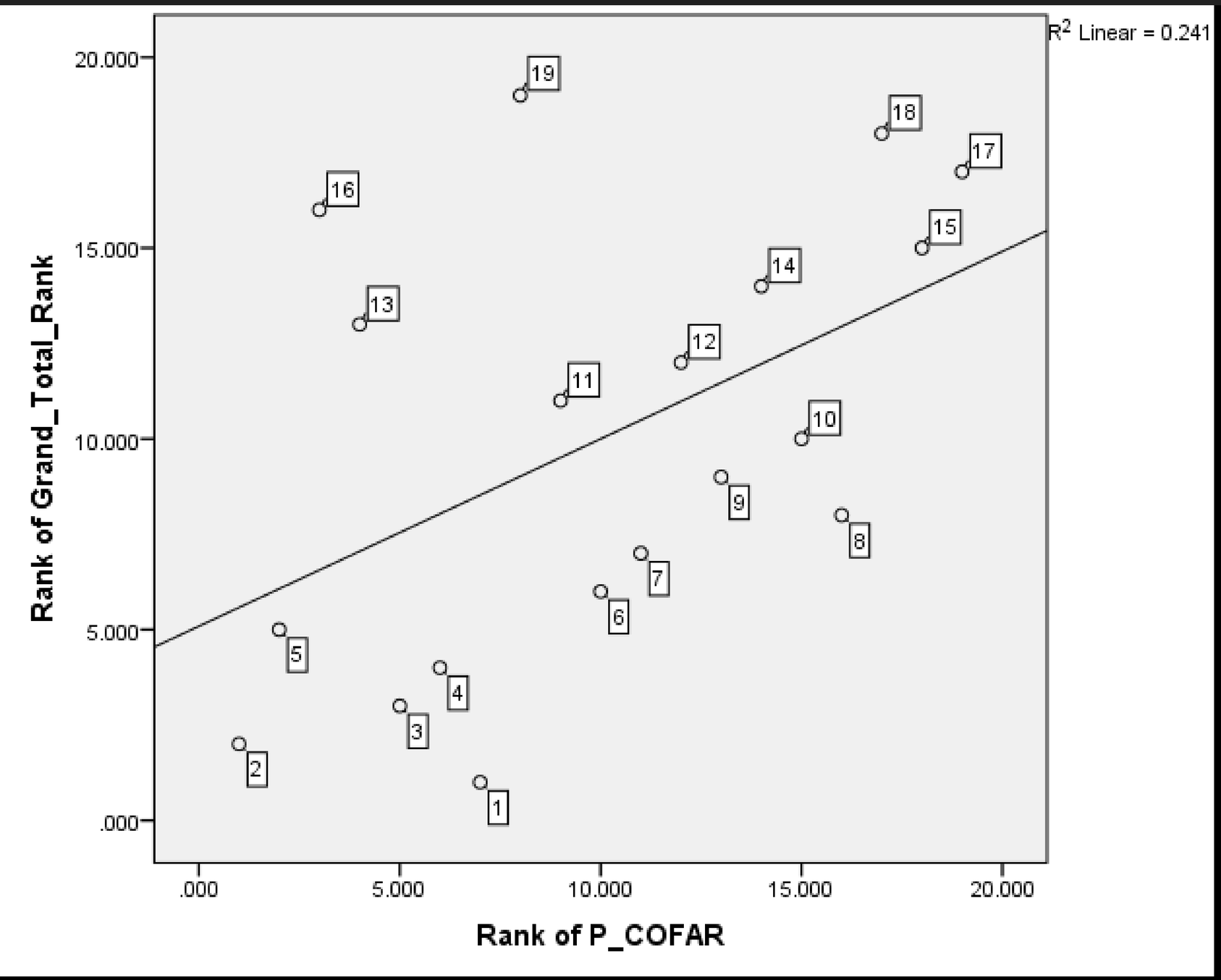
- The CDC SVI analyzes and emphasizes certain variables over others
- The CDC SVI homogenizes population
- The CDC SVI may not entirely reflect the unique social and physical environment of Guam

Conclusion

- The CDC SVI is a useful tool that pinpoints individual villages social vulnerabilities
- Whites strongly influence the overall SVI as they are generally of higher socioeconomic status relative to the non white population
- Agat, MTM, and Hagatna are the most socially vulnerable villages and must be prioritized in any action plan for reducing social vulnerability

Future Research

- Adapt the CDC SVI to the environment of Guam
- Finding explanations for villages' individual SVI rankings (e.g. What explains why Merizo is in the 100 percentile for total disability population)
- Socioeconomic and social vulnerability studies must distinguish between the white population and non white population as whites inflate the socioeconomic status of villages



Testing

Does the amount of COFA residents influence overall SVI ranking?

RECOMMENDATIONS

Create a **climate change adaptation plan** that addresses the vulnerabilities identified in this technical report. It is suggested that the adaptation plan incorporate the following goals for the coastal zone:

1) Maintain functioning and healthy coastal ecosystems
2) Reduce exposure and vulnerability of the built environment
3) Strengthen governance frameworks for coastal adaptation
4) Maintain livelihood opportunities and diversify options
5) Reduce risks to human health and safety

Further research be conducted on the **viability of nature-based solutions (NBS)** as potential adaptation responses to SLR.

Aligning with the **United Nations' sustainability development goals (SDGs)** to future adaptive measures, with a focus on reducing poverty (SDG 1). Reducing poverty can increase socioeconomic status which can decrease overall social vulnerability to climate change.

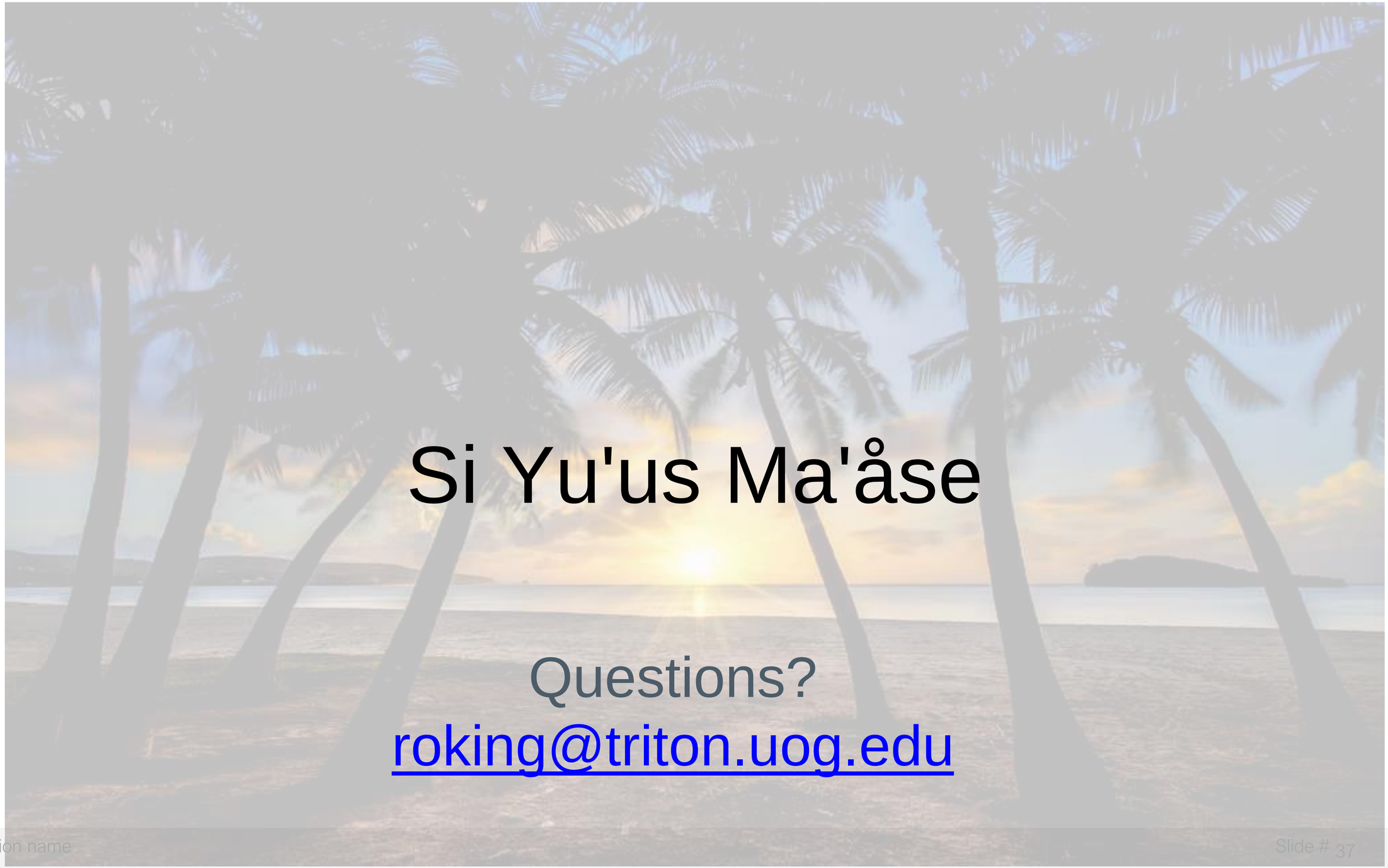
EO 2019-19: Establish a Climate Change Resiliency Commission

- **Appointed Members:** Chair, Vice Chair, Administrator of GEPA, Director of BSP, and 2 members of the public

- **Mission of the CCRC** – Develop an Integrated Strategy to build resiliency against effects of climate change.

- **Working Groups:** Energy, Water Resources, Ocean and Land, Infrastructure and Community Resiliency, Development Planning, Food security, Public Health and Safety and Green House Emission and Carbon Footprint

- **Status: Working on the plan coordinating our effort with Guam Green Growth as we develop the integrated plan.**



Si Yu'us Ma'åse

Questions?

roking@triton.uog.edu