Economics and LifeSIM

Appendix B

Guam Watershed Plan

US Army Corps of Engineers ®
Honolulu District

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1 Study Area

The study area encompasses the entire island of Guam, the southernmost island in the Marians archipelago, the Territory encompasses 212 miles with 78 miles of coastline in the western Pacific Ocean. The northern part of the island is a forested limestone plateau with sheer coastal cliffs. The southern part contains volcanic peaks covered in forest and grassland. Coral reef surrounds most of the island, expect in the areas where bays exist that provide access to small rivers and streams. The Northern Guam Lens Aquifer is the main source of drinking water for the island.

Guam experiences two seasons, the dry season beginning in December and lasting through June, and the wet season when three-quarters of the annual rainfall occurs. Guam is exposed to the effects of typhoons three times a year on average. The typhoons come within 180 nautical miles of the island.

1.1 Population

The 2020 Census estimates the population of Guam at approximately 154,000. The 2010 Census showed an increase of 2.9% in population from 2000, however, the 2020 estimates show a decrease of 3.5% from the previous decennial census estimates. The population at risk (PAR) is the population that lives within the extent of the 1% recurring storm surge inundation hazard. Exposed PAR is the population exposed to flooding given the inundation data and assumptions of the structure inventory for Guam. The northern portion of Guam, where the terrain lends itself more easily to development, sees population distributed generally across the landscape, whereas the more mountainous southern half of Guam sees population and development more concentrated near the coastlines.

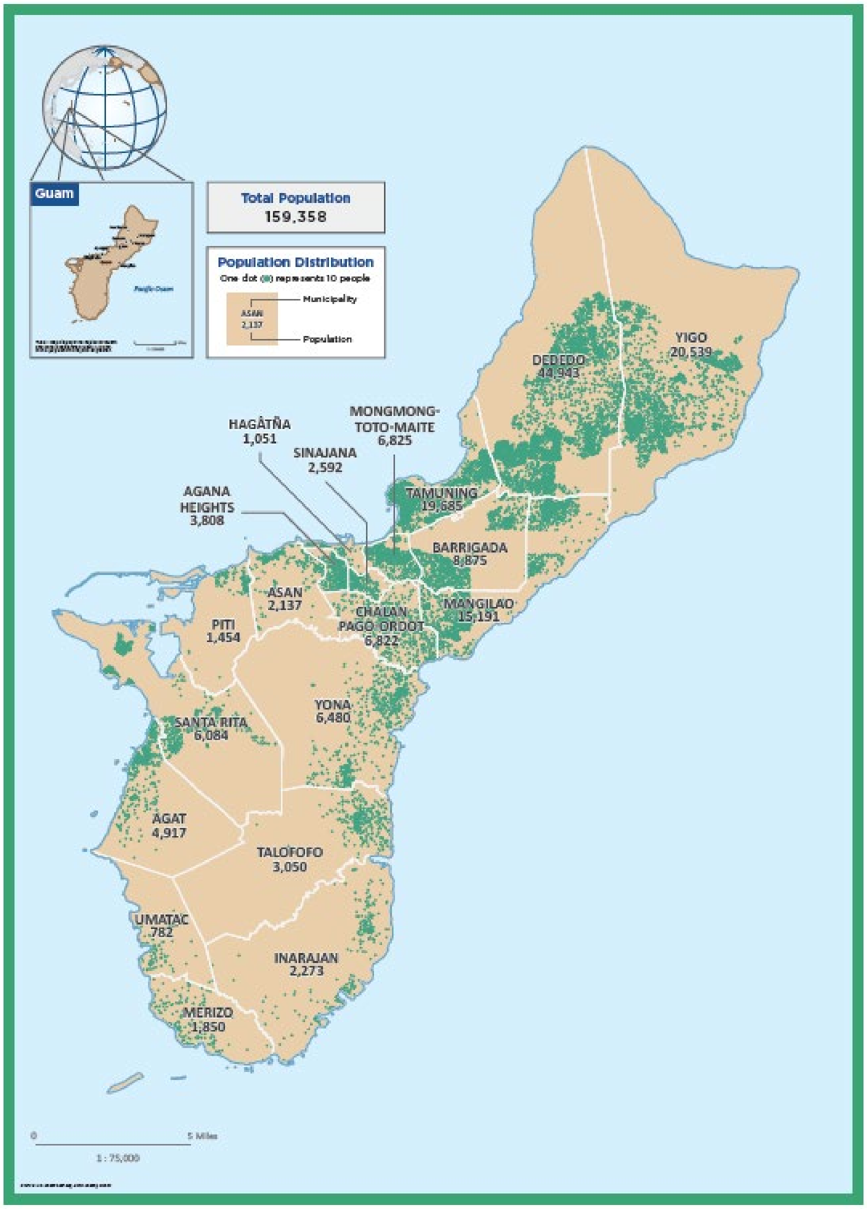

Figure 1-1: Population Distribution of Guam. Source: [U.S. Census Bureau, 2010 Census: Understanding the Population of Guam]

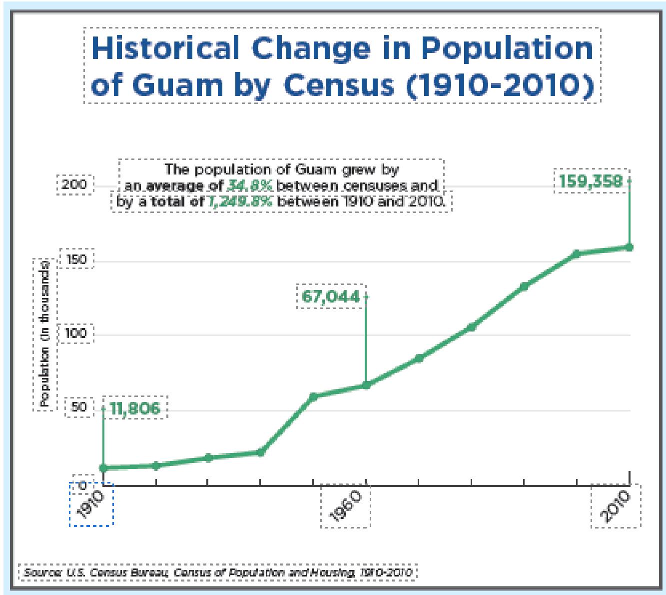

Figure 1-2: Historical Change in Population of Guam. Source: [U.S. Census Bureau, 2010 Census: Understanding the Population of Guam.]

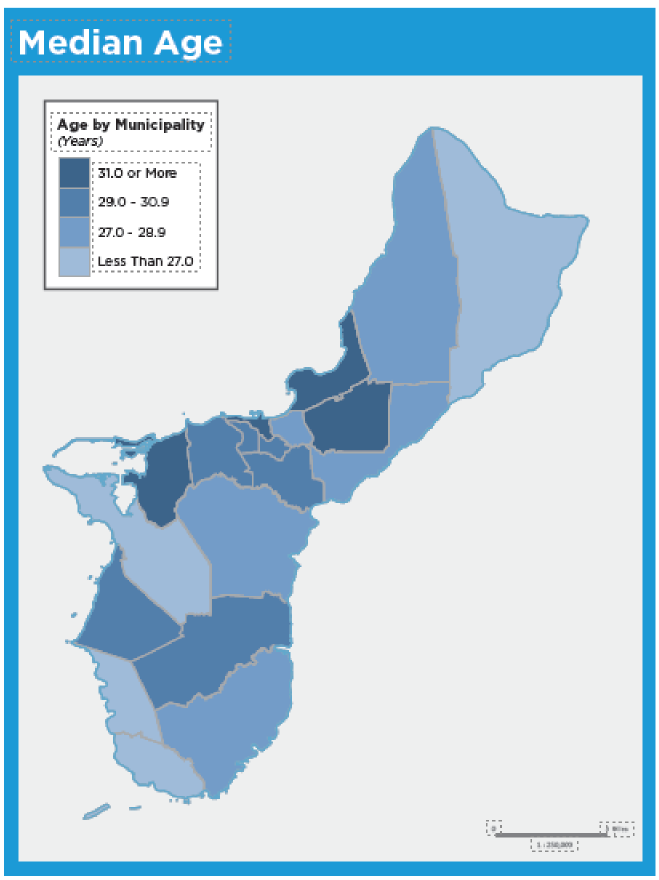

Figure 1-3: Median Age Distribution of Guam. Source: [U.S. Census Bureau, 2010 Census: Understanding the Population of Guam]

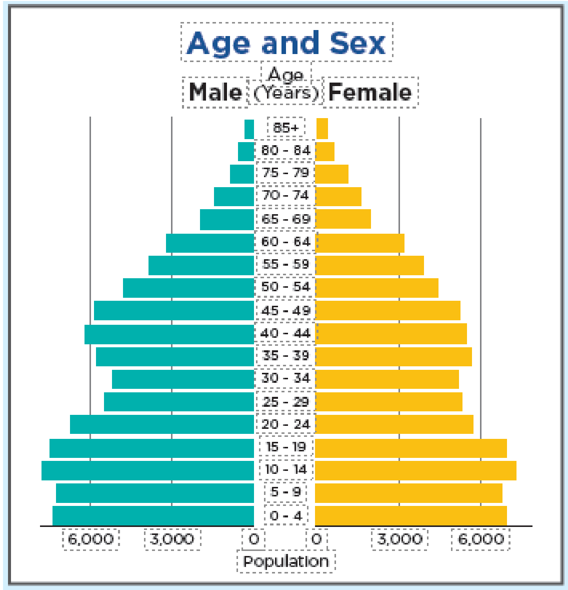

Figure 1-4: Age and Sex Distribution of Guam Population. Source: U.S. Census Bureau, 2010 Census: Understanding the Population of Guam

1.2 Economy

The economy of Guam is strongly tied to 2 sectors (Federal Government including Military & Tourism) for most of the economic activity. The Bureau of Economic Analysis (BEA, 2021), released the GDP for Guam for 2019, showing an increase of 2%. There was an increase in exports, private fixed investment, federal government spending, and consumer spending. Spending by tourists increased by 15.6% because of the increased number of Korean and Japanese tourists. Consumer spending increased on goods and services attributable to health care services and retail trade. A major economic driver is tourism, a huge number of tourists come mainly from Japan and Korea. Guam will see an increase in cruise ship activity that will bring ships onto the island to stimulate the economy because of the new Hotel Wharf rehabilitation project.

As of March 2019, there were 65,220 individuals that employed according to the Current Employment Survey (CES) conducted by the Guam Department of Labor-Bureau of Labor Statistics (2019, Guam Economic Report). There was also an increase in total employment from 2018 to 2019 of +.52% and an unemployment rate of 4.3%. The Government of Guam receives most of their revenue from taxes such as Income Tax, Gross Receipts or Business Privilege Tax, Federal Income Taxes, and other taxes. In 2019, there was a decrease in income tax revenue because of the Tax Cut and Jobs Act (2019, Guam Economic Report). This policy reduced tax rates dramatically and therefore decreased the amount of revenue that the Government of Guam received.

The military presence in Guam is substantial with plans for its increase with the relocation of Marines from the U.S. Marine Corps Futenma Air Station on Okinawa currently delayed due to higher than expected relocation costs. There are pros and cons that come with the relocation of the Marines. The pros are that there may be a chance to create new jobs, new small businesses, new tax revenues, and an increase in spending. Cons include possible social impacts that come with large population shifts such as sufficient housing to facilitate the incoming population of about 35,000 people (GCHS, 2009).

1.3 Infrastructure

1.3.1 Structure Inventory

The PDT was unable to acquire a comprehensive GIS based structure inventory for the island of Guam for use in the watershed assessment. To evaluate risk, the PDT used existing data for building footprints and parcels to create a general structure inventory for use in the assessment. The total number of structures recorded was 38,264. Housing units differ from structures, as they can be any single separate living quarter, such as an apartment or single room within a larger structure. Often, the number of housing units outnumbers the structure counts for areas surveyed. The 2020 Census estimated 51,555 housing units: a 2% increase in the number of housing units within Guam since 2010, despite the 3.5% decrease in population. This increase in housing units, as paired with an estimated decrease in population could possibly mitigate shortages in housing expected with the planned increases in military personnel mentioned in section 1.2.

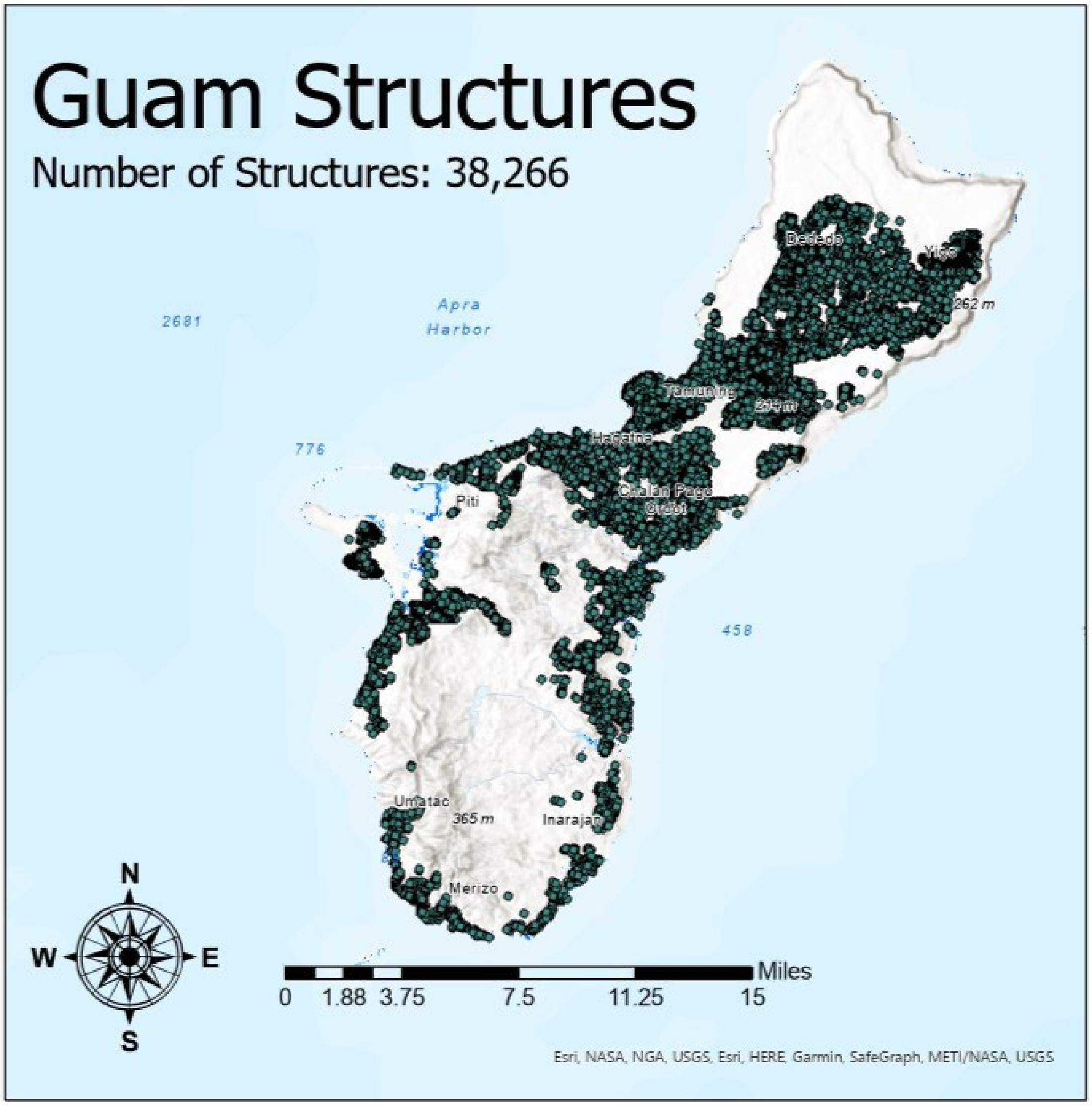

Figure 1-5: Guam Structures. Source: USACE 2021.

1.3.2 Energy Infrastructure

According to the U.S. Energy Information Administration, Guam currently meets its energy needs with imported petroleum products. These imported petroleum products are received through the port located at Apra and are used as gasoline, jet fuel, and to generate electricity. Power within Guam is overseen by the Guam Power Authority (GPA). Residents of Guam are charged a fuel surcharge for using electricity every six months determined by the cost of petroleum. Users of electricity in Guam include hotels, restaurants, private office buildings, residential households, the U.S. military, and the government. Solar power via the Dandan facility is the primary supply of renewable energy on Guam. The installation of wind turbines is also under consideration. However, wind generation sees additional challenges from environmental impacts, typhoons, and earthquakes, requiring additional research and development before they will be well suited for the island (EIA, 2021).

1.3.3 Healthcare Infrastructure

Guam Memorial Hospital (located in Tamuning) and Guam Regional Medical City (located in Dededo) provides health care services to the population of Guam (2017, Guam WHO). There are also many private medical and dental clinics on Guam. The Naval Hospital Guam is responsible for providing health care services to the military population, as well as voluntary services to the population of Guam. With the relocation of the military base from Japan to Guam, there is going to be a shortage of dental care because of the increase of population. (2011, Inspector General U.S. DOD).

2 LifeSim Model

The economic analysis for the Post-Disaster Watershed Assessments will focus on direct, event-based economic damages to structures due to flooding in an existing condition and a future condition that will account for relative sea level change (RSLC). The Corps Institute of Water Resources, Risk Management Center's LifeSim 2.0.1 model (LifeSim) will be the analytical tool used to estimate structure damages, road inundation, and areas with PAR.

Using LifeSim with the available data inputs will generate outputs highlighting areas vulnerable to future conditions, and aid in the prioritization of measures to help identify and reduce future risk. LifeSim will analyze storm surge of existing conditions and future conditions that incorporate RSLC based on the USACE high curves.

2.1.1 Analytical Tool:

The Hydrologic Engineering Center's LifeSim 2.0.1 will be used to estimate event-based damages under both the existing and FWOP conditions. The team received verification that a waiver for use of the LifeSim model would not be necessary for use in this study given the broad nature of its use as a planning aid and mapping tool.

2.1.2 Economic Uncertainty

The Watershed Assessment is meant to be a screening level analysis to broadly show the changes to economic damages and PAR estimates due to RSLC. Essentially, the goal is to show changes, and not exact results for tests of feasibility. Since the base and future inventories and populations will be held constant, the change in damages and PAR can be attributed solely to estimated RSLC. It is recognized by the PDT that the input data is imperfect, and any opportunity to improve the accuracy of the input data will be taken as it arises and is achievable within scope and budget.

Within the model all depth damage functions, and stability criteria utilized standard functions within the LifeSim model. All life safety and evacuation calculations such as warning issuance delay, first alert, and protective action initiation were defined as built-in "unknown" options for maximum uncertainty. Under the guidance of subject matter experts, public warning issuance was set to be 96 hours prior to the storm event to ensure that identified risk does not capture the evacuation process itself, but the exposed population that remains during an event. Due to model limitations, visualizations of exposed PAR (individuals the model estimates will physically experience flooding depths) are used to represent the larger overall PAR.

2.1.3 Analysis Years:

The analysis year for the existing condition will be defined as the calendar year 2022. The future analysis year will be 50 years after the existing condition year to account for the 50-year projections of RSLC in the H&H data. In other words, an existing condition year of 2022, and a FWOP year of 2072 were selected.

2.1.4 LifeSim Engineering Inputs:

Engineering inputs for depth were taken from NOAA storm surge Maximum Envelope of Water (MEOW) data for Guam with future levels of inundation with RSLC based on the USACE high curves. More detail regarding this data can be found in Appendix C, Section 3.2. This is a composite product representing the maximum height of storm surge in each basin grid cell using hypothetical storms run with the same attributes (NOAA).

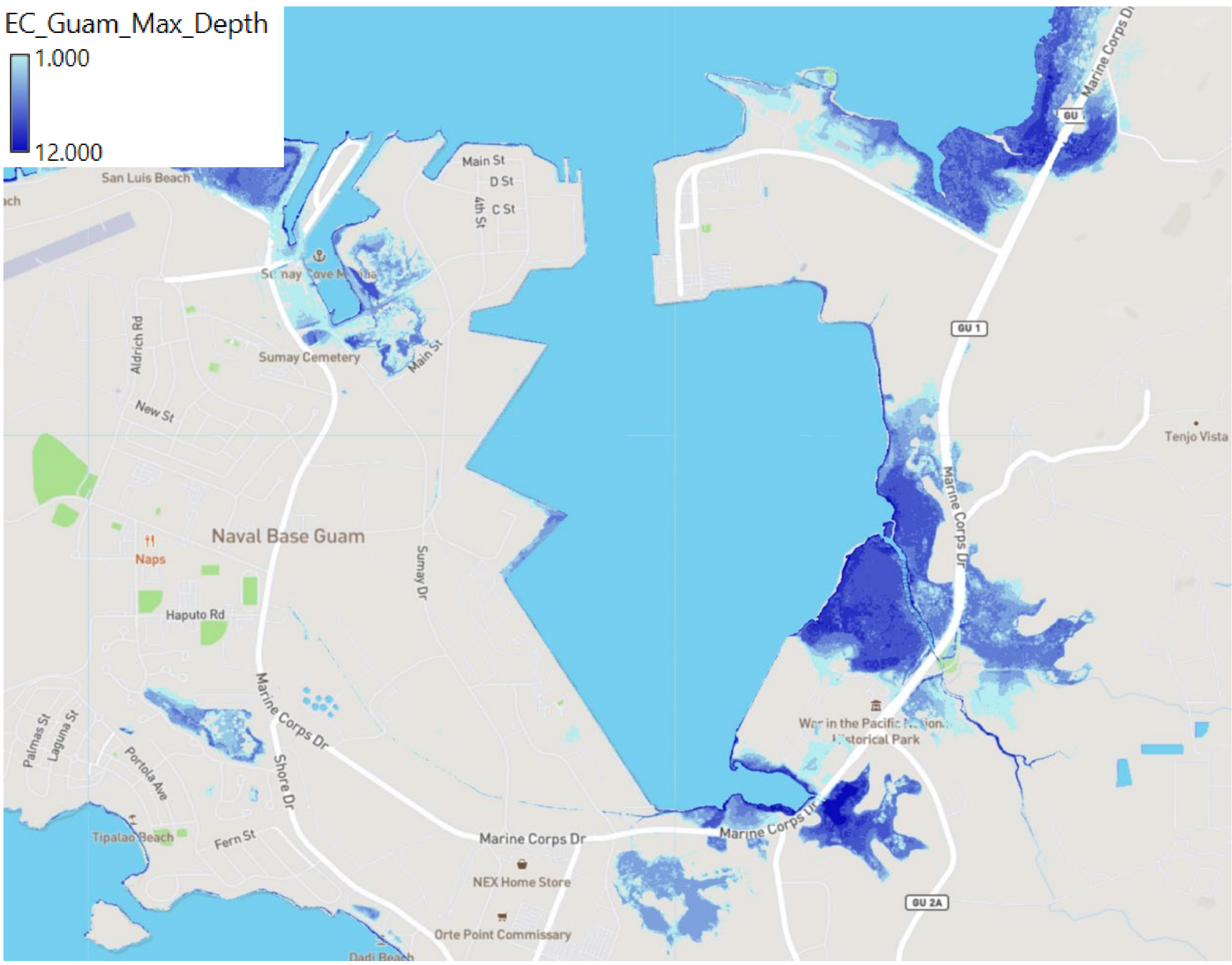

Figure 2-1: NOAA MEOW with Storm Surge Inundation on Guam. Source: USACE, 2021.

2.1.5 Structure Inventory

The territory of Guam had available existing data via parcel and building footprint shapefiles. Those shapefiles were used to create a template point shapefile for structure locations and establish a baseline structure inventory file for attributes to be added. This process created standardized point shapefiles for the use in LifeSim. Attributes were then populated based on the NSI2 structure inventory for Maui, HI. The Maui inventory was selected as the template for the watershed inventories based upon team judgement and conversations with PDT members familiar with Guam and the Pacific Islands.

2.1.5.1 General Inventory Construction

As stated previously, the NSI2.0 structure inventory for Maui, HI was used to generate attributes for the structures of the watershed study structure inventory. Structure inventory data were randomly assigned to physical structure locations based on the values and distributions of the NSI2.0 of Maui, HI. This results in some structures, by randomness alone, being assigned attributes such as foundation height which could misrepresent the true risk to that structure. We recognize the limiting nature of the resulting data from this technique, however given the nature of the watershed study, and use of the LifeSim outputs as a planning guide and not for rigorous assessment of damages as a test for feasibility or alternatives or life loss for project evaluation, the level of accuracy from this general inventory was seen as appropriate to identify areas of potential risk and compare baseline existing to future values.

Standard occupancy types used in the NSI2.0 were combined in some cases to reduce the number of calculations needed to generate attributes for the general inventories. Generally, occupancy types most similar were combined, such as all single-family occupancy types were combined into one occupancy type (RES1). This resulted in 16 Occupancy Types with specific distributions for generating the general inventory:

Table 2-1: Occupancy Type Distributions

Occupancy Type	Distribution Within Inventory
Single-family Dwelling (RES1)	48.22%
Single-family Dwelling (RES1 (2 Story))	29.72%
Multi-Family Dwelling 3-4 units (RES3B)	1.06%
Multi-Family Dwelling 20-49 units (RES3E)	3.22%
Retail Trade (COM1)	4.23%
Wholesale Trade (COM2)	6.69%
Hospital (COM6)	0.04%
Medical Office/Clinic (COM7)	0.83%
Entertainment & Recreation (COM8)	2.03%
Theaters (COM9)	0.03%
Heavy Industry (IND1)	2.00%
Agriculture (AGR1)	0.42%
Church/Non-Profit (REL1)	0.65%
General Services (GOV1)	0.45%
Emergency Response (GOV2)	0.07%
Schools/Libraries (EDU1)	0.32%
Colleges/Universities (EDU2)	0.02%

Once Occupancy Types were generated, the associated attributes selected for evaluation in LifeSim were also generated from the Maui NSI2.0 structure inventory distributions. The attributes generated are listed in the table below.

Table 2-2: Structure Inventory Generated Attributes

Attribute	Label	Type of Calculation
Foundation Type	Found_Type	Randomly Generated from Maui NSI2.0 Distribution using @Risk assuming normal distribution
Foundation Height	Found_Ht	Randomly Generated from Maui NSI2.0 Distribution using @Risk assuming normal distribution
Year Built	YrBuilt	Randomly Generated from Maui NSI2.0 Distribution using @Risk assuming normal distribution
Building Type (Construction Class)	BldgType	Randomly Generated from Maui NSI2.0 Distribution using @Risk assuming normal distribution
Number of Stories	Num_Story	Randomly Generated from Maui NSI2.0 Distribution using @Risk assuming normal distribution
Square Feet	SqFt	Generated via the Excel random number generator and descriptive statistics of the attribute in the Maui NSI2.0
Structure Value	Val_Struc	Generated via the Excel random number generator and descriptive statistics of the attribute in the Maui NSI2.0
Population (Day)	Day_Pop	Calculated using Hazus formulas for population per square foot
Population (Night)	Night_Pop	Calculated using Hazus formulas for population per square foot

Table 2-3: Summary of Values for Number of Stories

Type	Number of Stories			
	Max	**Min**	**Range**	**Average**
SFR1	1	1	0	1
SFR2	3	2	1	2
MFR1	3	1	2	2
MFR2	36	1	35	2
COM1	13	1	12	1
COM2	51	1	50	1
HOS	1	1	0	1
MED	15	1	14	2
REST	35	1	34	2
COM9	4	1	3	3
IND1	5	1	4	1
AG	4	1	3	1
REL1	3	1	2	1
GOV1	15	1	14	2
GOV2	15	1	14	2
EDU1	9	1	8	1
EDU2	3	1	2	1

Table 2-4:Summary of Values for Foundation Height

Type	**Foundation Height**			
	Max	**Min**	**Range**	**Average**
SFR1	**8**	**1**	**7**	**4**
SFR2	**8**	**1**	**7**	**4**
MFR1	**8**	**1**	**7**	**4**
MFR2	**8**	**1**	**7**	**5**
COM1	**8**	**1**	**7**	**4**
COM2	**8**	**1**	**7**	**3**
HOS	**7**	**1**	**6**	**2**
MED	**8**	**1**	**7**	**3**
REST	**8**	**1**	**7**	**4**
COM9	**7**	**1**	**6**	**5**
IND1	**8**	**1**	**7**	**3**
AG	**8**	**1**	**7**	**3**
REL1	**8**	**1**	**7**	**3**
GOV1	**8**	**1**	**7**	**3**
GOV2	**8**	**1**	**7**	**2**
EDU1	**8**	**1**	**7**	**3**
EDU2	**7**	**1**	**6**	**2**

Table 2-5: Summary of Values for Year Built

Type	Year Built			
	Max	Min	Range	Average
SFR1	2016	1852	164	1978
SFR2	2016	1899	117	1989
MFR1	2012	1920	92	1978
MFR2	2014	1920	94	1980
COM1	2015	1910	105	1978
COM2	2016	1909	107	1978
HOS	1997	1914	83	1970
MED	2015	1914	101	1978
REST	2015	1910	105	1977
COM9	2003	1914	89	1979
IND1	2015	1914	101	1978
AG	2015	1914	101	1978
REL1	2015	1914	101	1978
GOV1	2015	1914	101	1978
GOV2	2013	1914	99	1970
EDU1	2015	1914	101	1977
EDU2	1997	1914	83	1968

Table 2-6: Summary of Values for Square Feet of structures

Type	Sq Ft			
	Max	Min	Range	Average
SFR1	1,640	939	701	1,253
SFR2	4,132	1,678	2,454	2,639
MFR1	15,278	896	14,382	3,708
MFR2	226,142	347	225,795	12,475
COM1	198,613	62	198,552	6,277
COM2	198,859	13	198,847	2,756
HOS	33,514	10	33,504	8,225
MED	98,037	33	98,004	3,184
REST	308,076	69	308,008	8,365
COM9	17,056	316	16,741	7,525
IND1	196,353	14	196,338	3,612
AG	99,159	9	99,150	2,538
REL1	137,678	30	137,648	4,083
GOV1	147,592	23	147,570	4,392
GOV2	147,453	91	147,362	12,858
EDU1	307,146	31	307,115	8,866
EDU2	11,402	15	11,387	3,828

Table 2-7: Summary of Values for Structure Value

Type	Structure Value			
	Max	**Min**	**Range**	**Average**
SFR1	$368,896	$71,553	$297,343	$169,552
SFR2	$849,873	$154,672	$695,201	$368,543
MFR1	$1,859,130	$103,001	$1,756,129	$439,461
MFR2	$59,016,145	$34,420	$58,981,725	$2,299,426
COM1	$22,006,367	$6,852	$21,999,515	$696,334
COM2	$33,936,548	$2,049	$33,934,498	$460,348
HOS	$9,708,587	$2,753	$9,705,833	$2,382,574
MED	$24,195,144	$8,002	$24,187,142	$784,289
REST	$71,442,507	$15,692	$71,426,815	$1,930,553
COM9	$2,922,352	$54,098	$2,868,254	$1,289,227
IND1	$25,274,244	$1,503	$25,272,741	$436,020
AG	$10,809,653	$1,018	$10,808,635	$276,175
REL1	$25,672,684	$5,411	$25,667,273	$755,338
GOV1	$20,603,664	$3,182	$20,600,482	$614,708
GOV2	$35,187,872	$21,614	$35,166,259	$3,068,386
EDU1	$55,116,455	$5,516	$55,110,939	$1,586,264
EDU2	$2,255,883	$3,030	$2,252,853	$757,392

Foundation type, foundation height, year built, building type, and number of stories were all randomly generated directly from the Maui NSI2.0 distributions of those attributes using @Risk software, assuming normal distributions.

3 Coastal Flooding Impacts Existing Scenario

To assist in the planning process, the LifeSim 2.0.1 model (LifeSim) was used to identify areas of risk within the coastal flooding areas under the Existing Scenarios. The general structure inventory developed for this study and NOAA MEOW Storm Surge depth grids were used to show rough order of magnitude impacts along the coast of Guam.

3.1.1 Vulnerability of Critical Facilities

The 2019 Guam Hazard Mitigation Plan (HMP) lists 355 essential facilities with the largest numbers of those facilities located in Hagåtña, Agat, and Merizo. The method of the HMP differs from the LifeSim modeling within this assessment by not considering additional criteria such as water surface elevations at the structures and foundation heights. To avoid miscommunicating potential risk to critical facilities, data from the HMP is used to describe risk to critical facilities in Guam. The analysis of the HMP was considered as an appropriate indication for the vulnerability of critical facilities located within coastal flooding extents, while overall impacts were modeled via LifeSim using additional data such as foundation heights and construction types. Using the HMP analysis was appropriate in identifying the vulnerability of communities because: (1) it avoids contradicting a risk communication by other government agencies; and (2) the HMP analysis captures the location of critical infrastructure, which is important in identifying at risk communities.

3.2 Existing Scenario LifeSim Results

It is important to caveat the nature of the results in this analysis. Due to the broad assumptions made to the applicability of the underlaying data such as the structure inventory and NOAA MEOW Storm Surge data which is a synthetic storm showing a possible worst-case scenario all results must be viewed as very rough order magnitude potential results and should not be taken as accurate depictions of real scenarios or used beyond a planning aid. Underlying structure inventory data were randomly assigned to physical structure locations based on the values and distributions of the NSI2.0 of Maui, HI. This results in some structures, by randomness alone, being assigned attributes such as foundation height which could misrepresent the true risk to that structure.

Due to the inability of the model to portray coastal dynamics of wave forces and severe velocities, the results of the LifeSim analysis are limited in the level of detail. In essence, the model will show what PAR, infrastructure, and depths exist in the current and future scenarios. These results can be overlaid with other risk maps, such as landslides, and inland/flash flooding maps to highlight where compounding risks may occur today and in the future with RSLC.

3.2.1 Population at Risk and Structure Impacts

Results show the majority of exposed PAR are located primarily near the communities of Agat and Merizo on the central and southern portions of Guam, where development is more concentrated near the shoreline. These communities are also somewhat isolated from the northern portion of Guam by limited road networks and transportation options. As with many pacific islands, development and populations often happens near the coastline to benefit from the aesthetics provided by the ocean which causes additional exposure to coastal hazards.

Table 3-1: Guam PAR under Existing Scenario. Estimates of PAR are rough order of magnitude values and should not be used beyond screening level. Source: USACE, 2021.

Village/County	PAR
- Agat	3,253
- Asan	1
- Chalan Pago-Ordot	48
- Hagåtña	3
- Inarajan	216
- Merizo	911
- Piti	124
- Tamuning	9
- Umatac	32
- Yona	3
Total	**4,600**

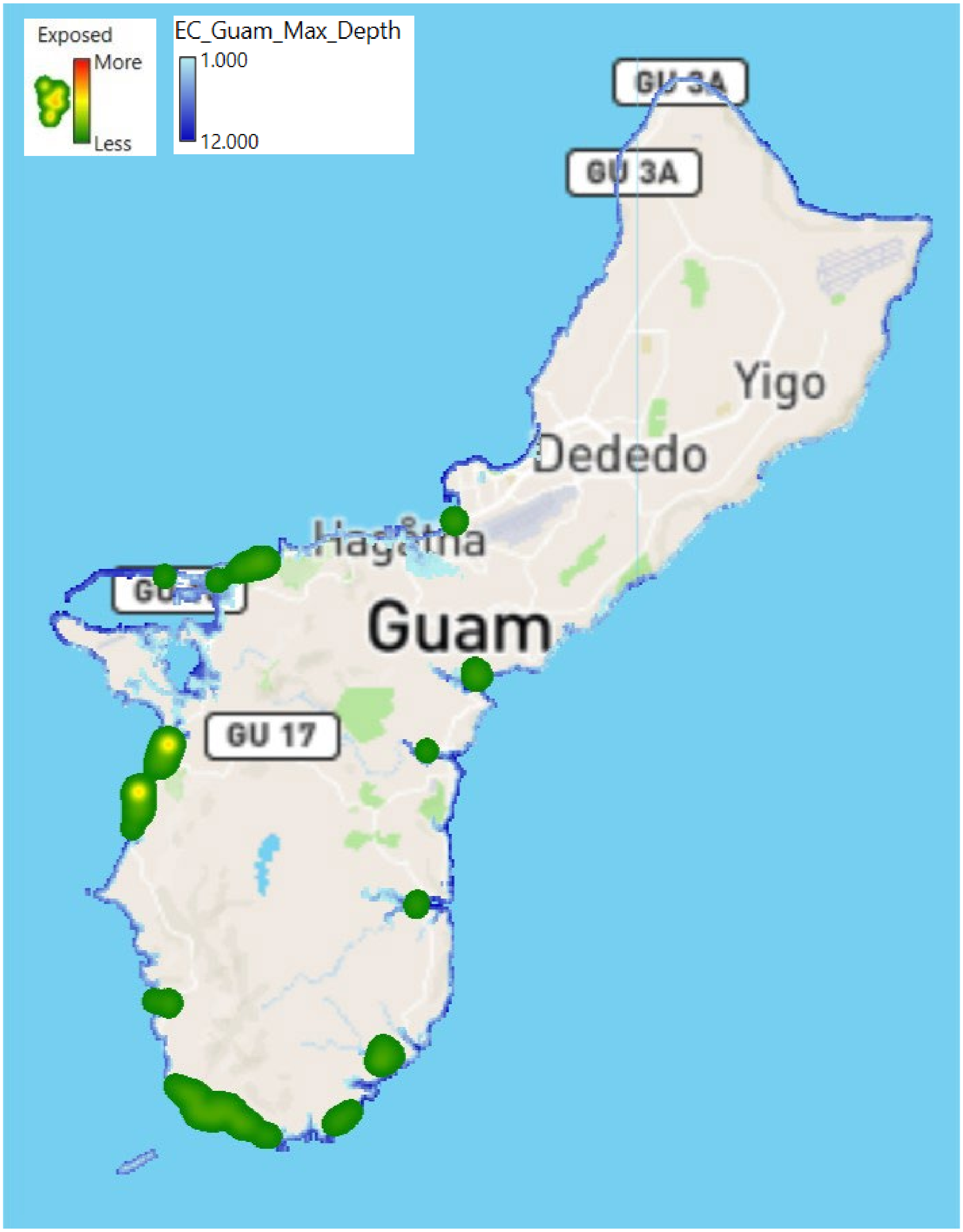

Figure 3-1: Heat map of areas with exposure to flooding for Guam under the NOAA MEOW Storm Surge event. Source: [USACE, 2021.]

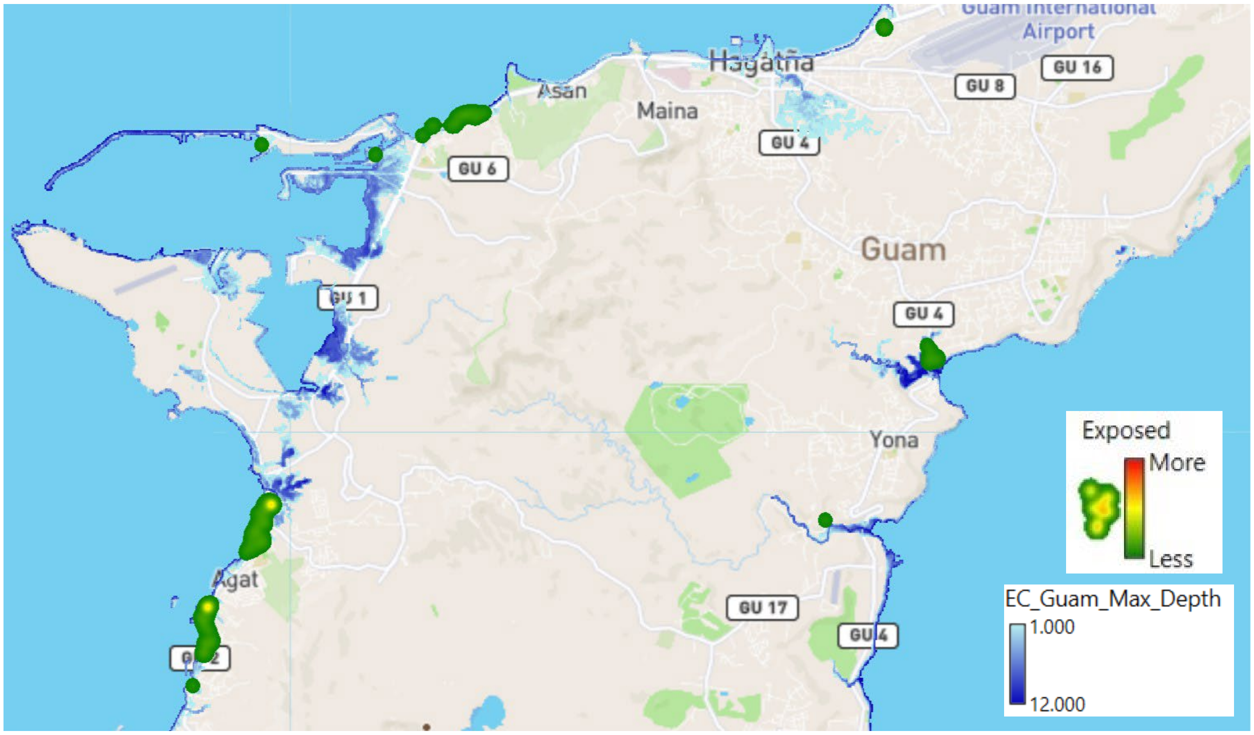

Figure 3-2: Heat map of areas with exposure to flooding for Guam (center) under the NOAA MEOW Storm Surge event. Source: USACE, 2021.

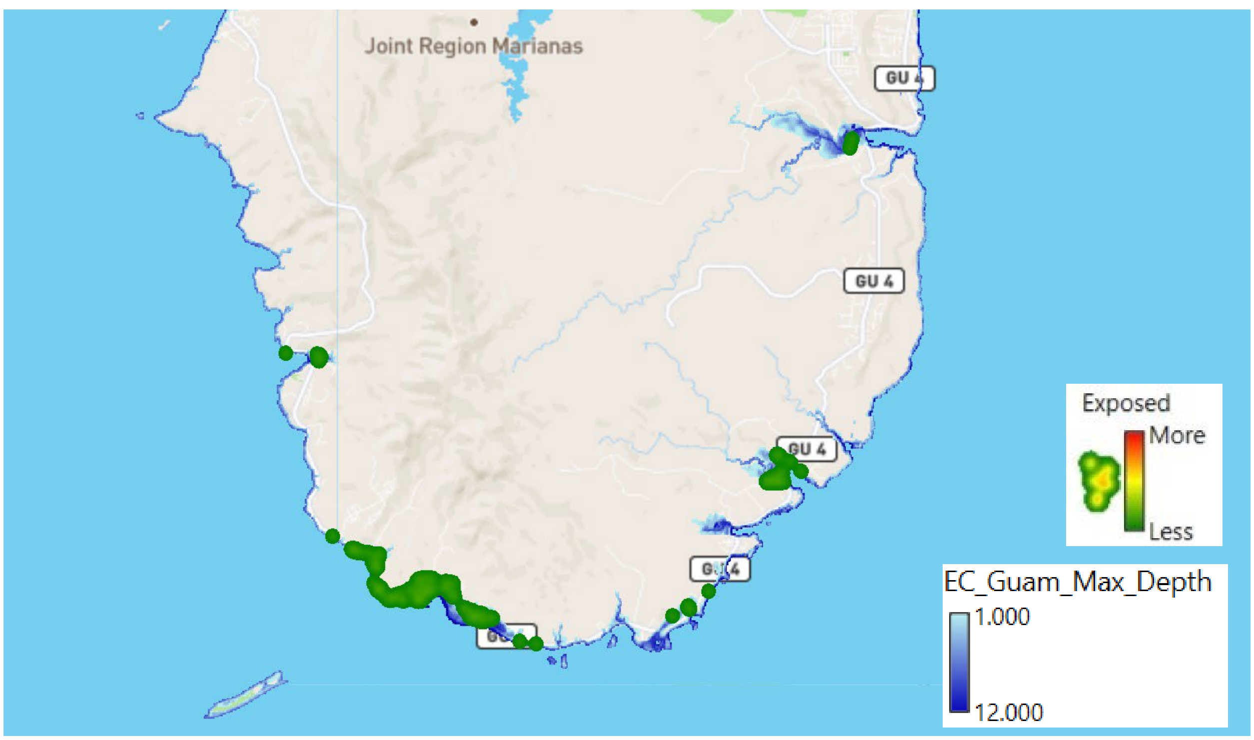

Figure 3-3: Heat map of areas with exposure to flooding for Guam (South) under the NOAA MEOW Storm Surge event. Source: USACE, 2021.

As seen with the PAR, structures impacted by coastal flooding are highest in the villages of Agat and Merizo, where the limited availability of easily developable land has resulted in structures located within areas at risk to coastal flooding.

Table 3-2: Structures Impacted under the Existing Scenario. Estimates of impacted structures are rough order of magnitude values and should not be used beyond screening level. Source: USACE, 2021.

County	Structures Experiencing Flooding
- Agat	156
- Asan	1
- Chalan Pago-Ordot	13
- Hagåtña	3
- Inarajan	62
- Merizo	185
- Piti	32
- Tamuning	5
- Umatac	8
- Yona	2
Total	**467**

Table 3-3: Structure Damages under the Existing Scenario. Damage values are rough order of magnitude estimates based on general structure inventory values and should not be used beyond screening level. Source: USACE, 2021.

County	Structure Damage Estimates
- Agat	$2,184,163
- Asan	$16,408
- Chalan Pago-Ordot	$256,097
- Inarajan	$941,167
- Merizo	$4,510,906
- Piti	$95,967
- Tamuning	$55,696
- Umatac	$260,262
- Yona	$75,031
Grand Total*	**$8,395,697**[1]

3.2.2 Exposed Road Infrastructure

The island of Guam has a network of roads that connects the island's villages. The Northern areas of the island see broad road development throughout, whereas the southern and more remote areas have much more limited road infrastructure and are often located in areas with exposure to coastal flooding due to steeper topography and less easily developable land. Hwy 2 along the western coast, and Hwy 4 along the eastern coast are the only thoroughfares connecting the southern villages to the critical infrastructure, such as hospitals located to the

[1] Values are based on the Maui, HI national structure inventory and are intended to represent changes in possible risk from existing to future scenarios and not for use in feasibility analysis.

north. When these routes become inundated, the ability for the population to travel by vehicle becomes limited.

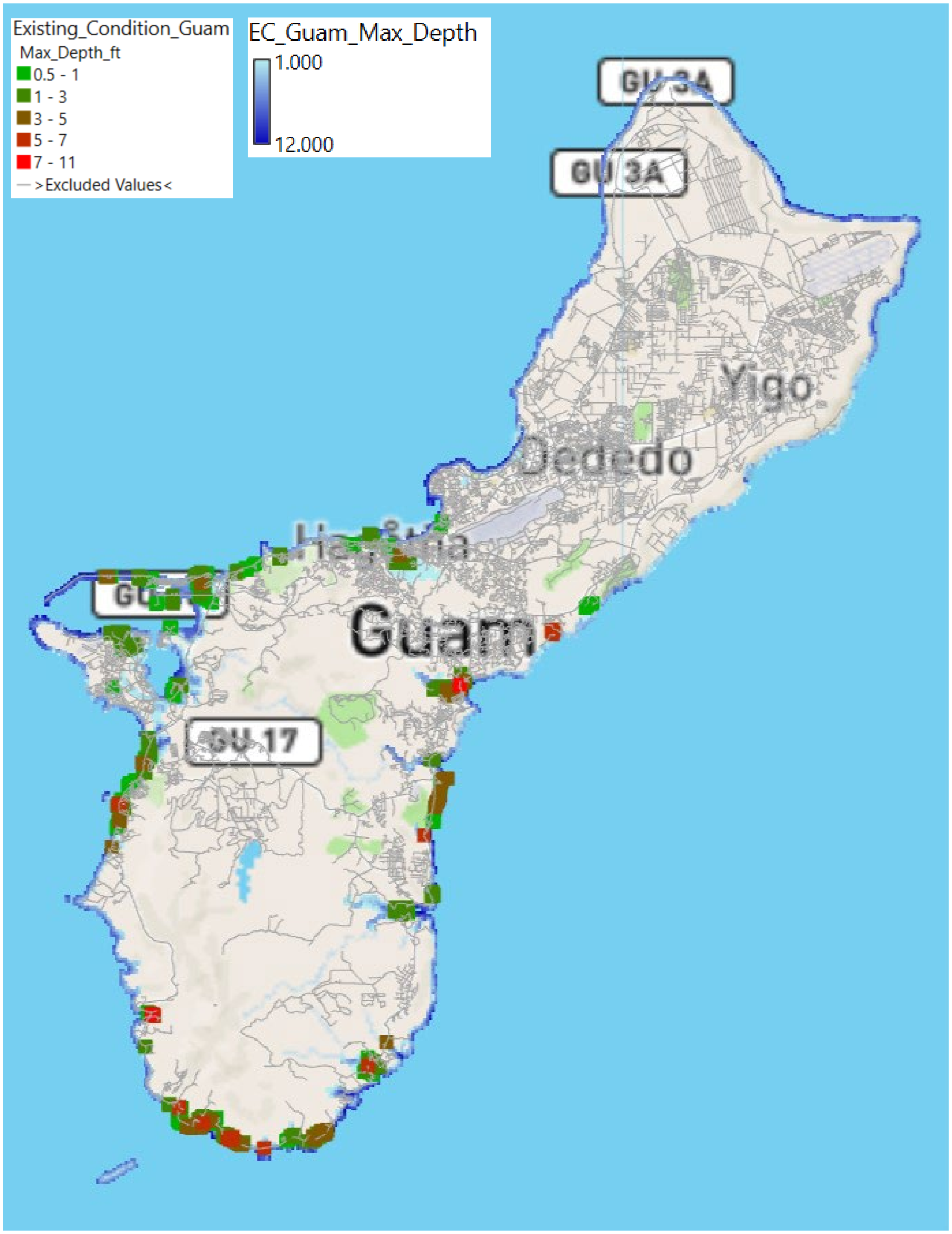

Figure 3-4: Map of Existing Scenario inundation hazard on Guam roads under the NOAA MEOW Storm Surge event. Source: [USACE, 2021]

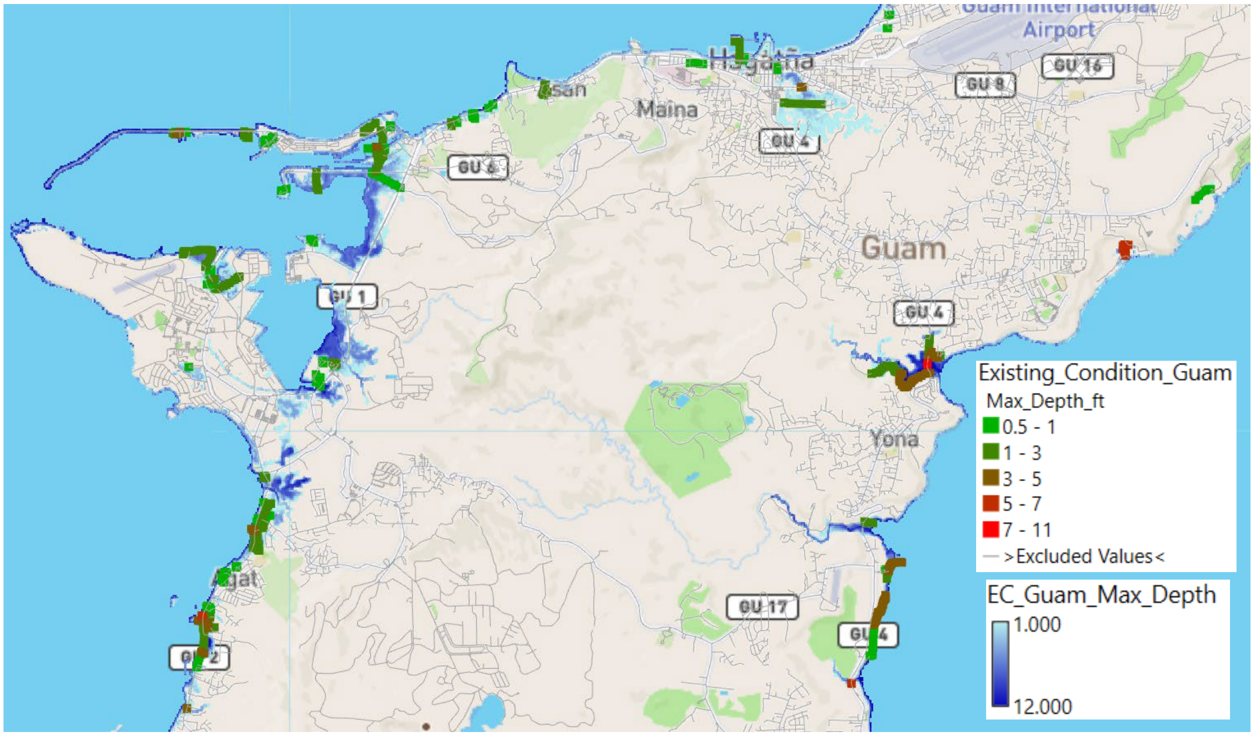

Figure 3-5: Map of Existing Scenario inundation hazard on Guam (Center) roads under the NOAA MEOW Storm Surge event. Source: USACE, 2021

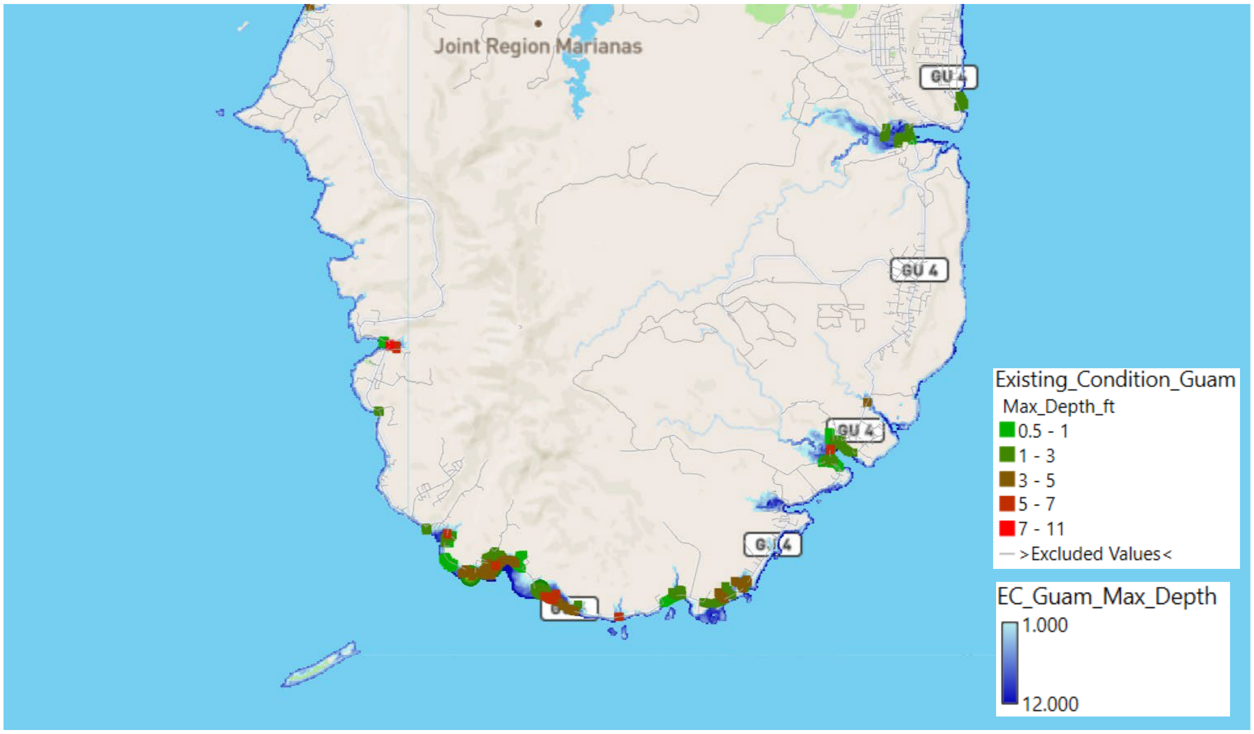

Figure 3-6: Map of Existing Scenario inundation hazard on Guam (South) roads under the NOAA MEOW Storm Surge event. Source: [USACE, 2021]

4 Coastal Flooding Impacts, Future Scenario

To assist in the planning process, the USACE LifeSim 2.0.1 model was used to identify areas of increasing consequences within the coastal flooding areas under the Future Scenario which adds RSLC to surge elevations based on the USACE RSLC high curve. The same general structure inventory was used in both the Existing and Future Scenario to highlight the risk and vulnerability to the impacts of RSLC. All changes in impacts from the Existing Scenario to the Future Scenario are attributable to the difference in water surface elevations from the Existing Scenario. Again, estimates are rough order of magnitude and should not be used for feasibility level of analysis or damage forecasts. The focus of interest is the percent changes that occur from the existing to future Scenario. These changes, such as additional structures inundated, or additional PAR are the basis for identifying the vulnerability of Guam to storm surge inundation depths increasing due to RSLC.

4.1.1 Future Scenario LifeSim Results

Figure 4-1 below shows the heat map of risk areas for Guam under the MEOW storm surge event with RSLC.

Depths and risk to PAR in the future scenario are increased due to RSLC, however the inundation data used does not have an expanded footprint which causes the PAR to be equal in both the existing and future scenarios. It is assumed that consequences to PAR and structure damages will increase with RSLC. To show areas where consequences increase, structure damage estimates are used at an indicator of possible consequences. Table 4-1 uses structure damage estimates to highlight areas with new and increased consequences under the future scenario due to RSLC. One area showing new consequences under the future scenario that did not previously occur in the existing scenario is in the existing scenario is the village of Hagåtña. As seen in Table 4-1, all of the villages that receive damages in the existing scenario see an increase in damages under the future scenario, with the largest increases being in the villages of Piti and Tamuning. Overall, the model results show a 212% increase in the amount of damage due to RSLC.

Structures that reside near the margins of the inundation footprint boundary are possibly at risk to future flooding, even if not captured in this analysis. It can be assumed that with an additional 3ft of depth, the inundation footprint would also expand. Figure 4-1 is an example of two structures which are located near the flood boundary. This proximity without inclusion in the future estimates could result in low estimates of future PAR as well as structure damages.

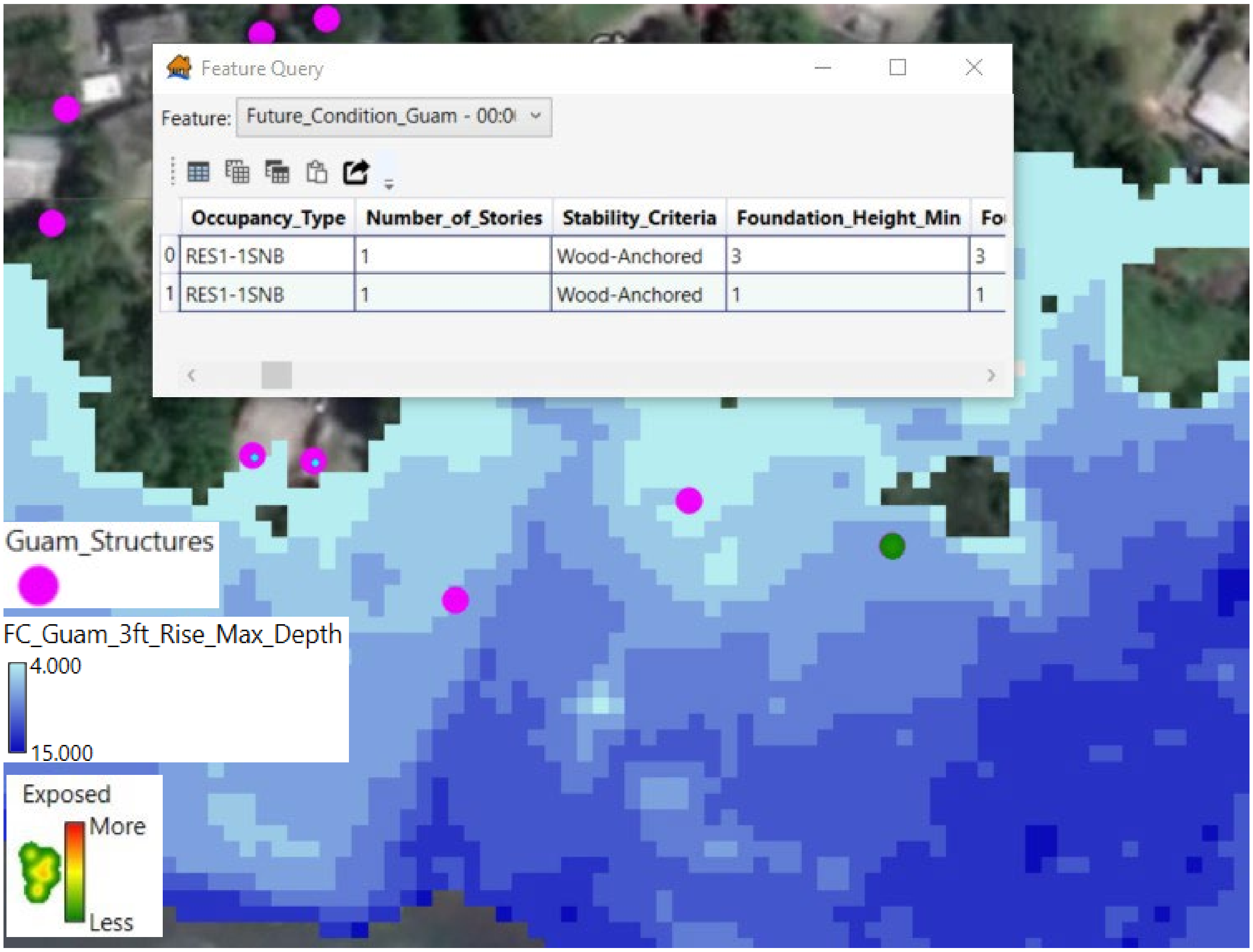

Figure 4-1: Possible future consequences of structures located on the flood boundary margin.

4.1.2 Future Scenario Population at Risk

Table 4-1: Existing and Future with RSLC Damages. Estimates are rough order of magnitude and should not be used beyond screening level. Source: USACE, 2021.

Place	Damage Existing	Damage Future	Increased Damage in Future
- Agat	$2,184,163	$7,986,350	266%
- Asan	$16,408	$49,158	200%
- Chalan Pago-Ordot	$256,097	$703,748	175%
- Hagåtña	$0	$80,038	**New Consequences**
- Inarajan	$941,167	$3,033,755	222%
- Merizo	$4,510,906	$12,210,745	171%
- Piti	$95,967	$788,929	722%
- Tamuning	$55,696	$373,560	571%
- Umatac	$260,262	$800,076	207%
- Yona	$75,031	$198,151	164%
Total	**$8,395,697**	**$26,224,511**	**212%**

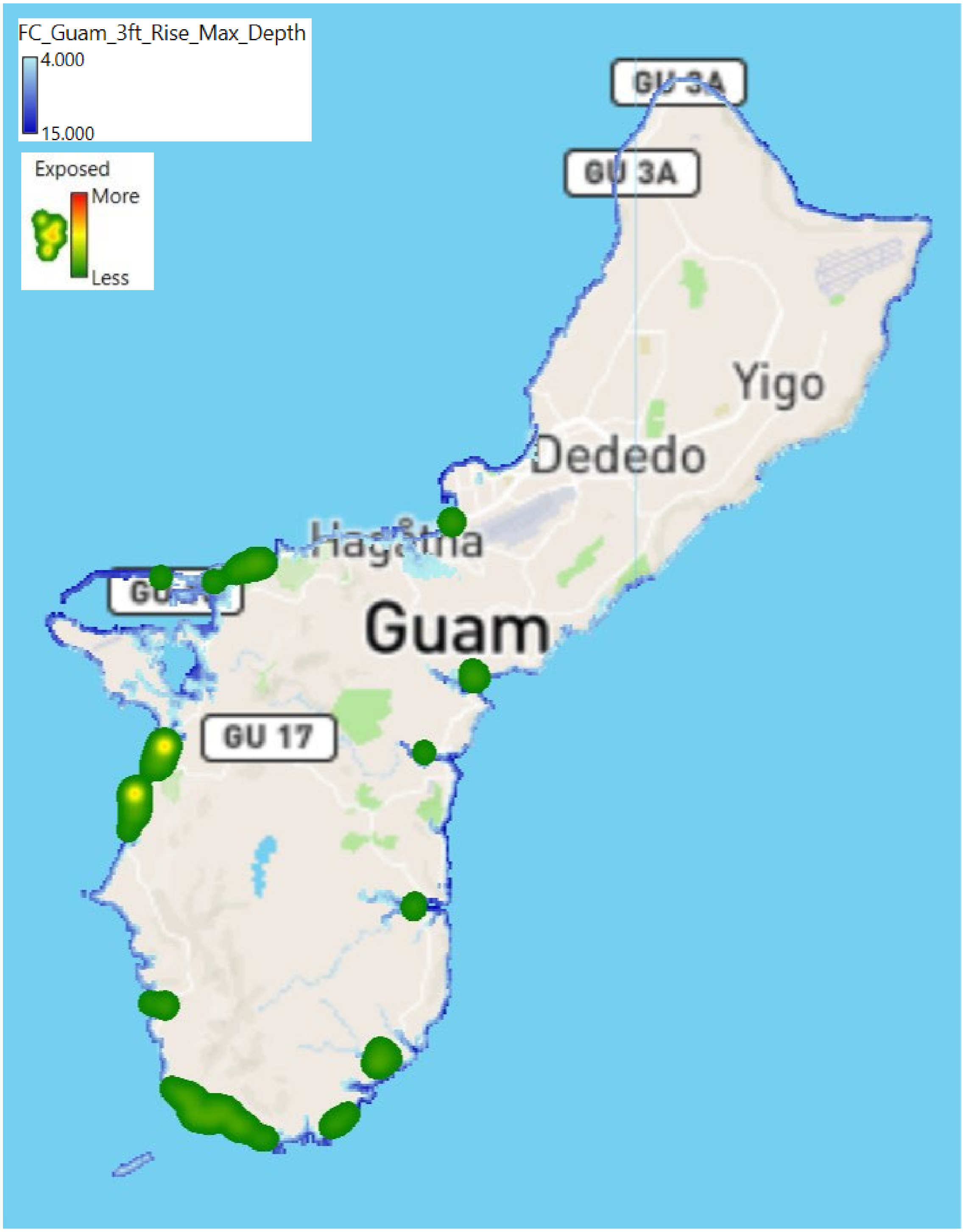

Figure 4-2: Heat map of consequence areas for Guam under the MEOW Storm Surge event with Future Scenario RSLC. Solid red indicates new exposure in the Future Scenarios. Source: [USACE, 2021]

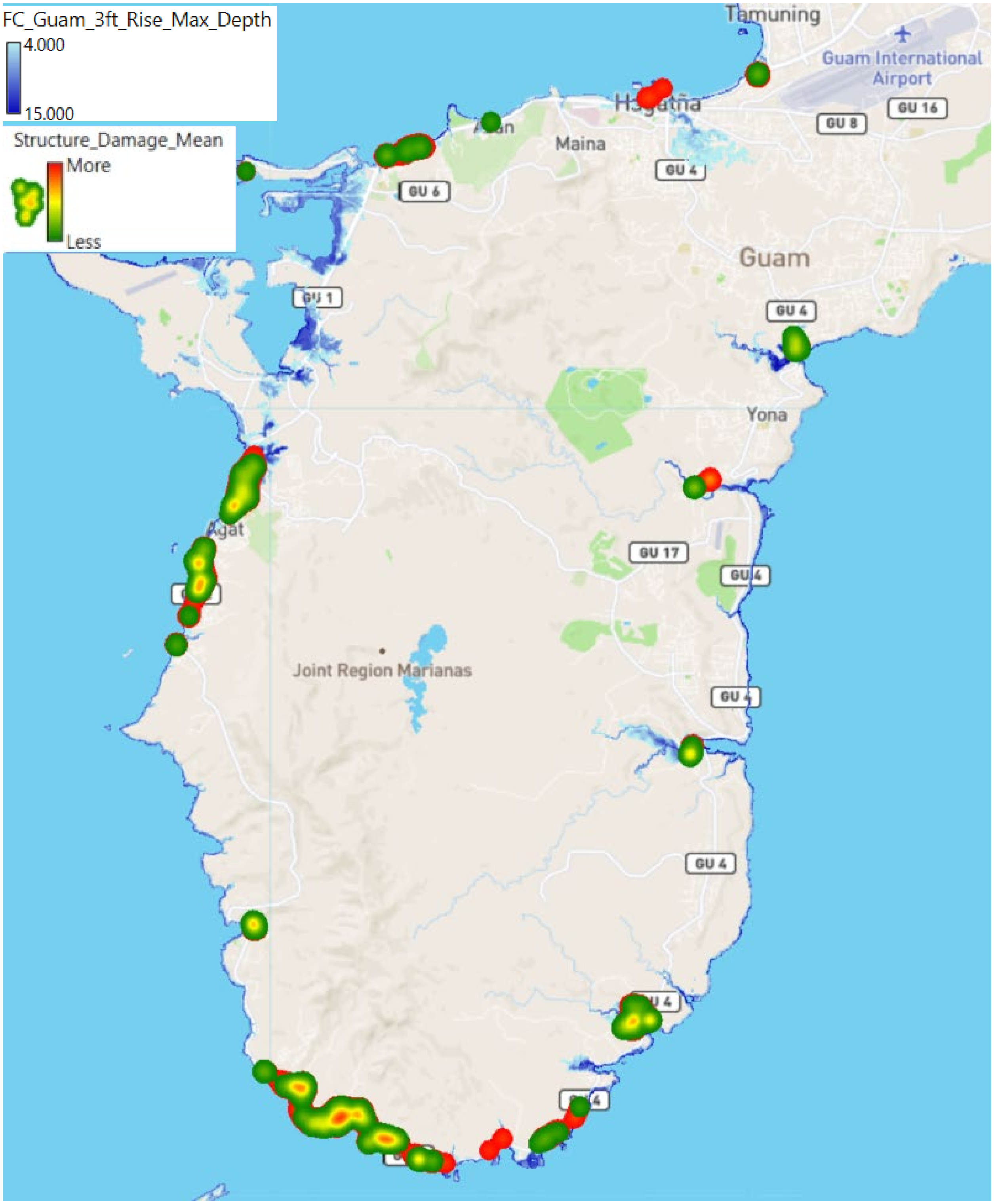

Figure 4-3: Existing and Future Structure Damages in Guam. New damages shown as solid red. Source: USACE, 2021.

4.1.3 Exposed Road Infrastructure Future Scenario

As stated previously, roads in southern Guam are highly exposed to coastal flooding and inundation. Given the bathtub nature of the Future Scenario inundation, all previous depths impacting the road network continue to exist in the Future Scenario, with additional areas of inundation due to the expanded MEOW attributable to the impacts of RSLC/SLC. Additional analysis of impacts of the road network due to coastal erosion can be found in Engineering Appendix C.

An important risk from flooding on roads in Guam is that when a main route is inundated such as Hwy 4, essentially all vehicle traffic from the village of Merizo is unable to reach the northern parts island where critical infrastructure such as the hospital and airport are located.

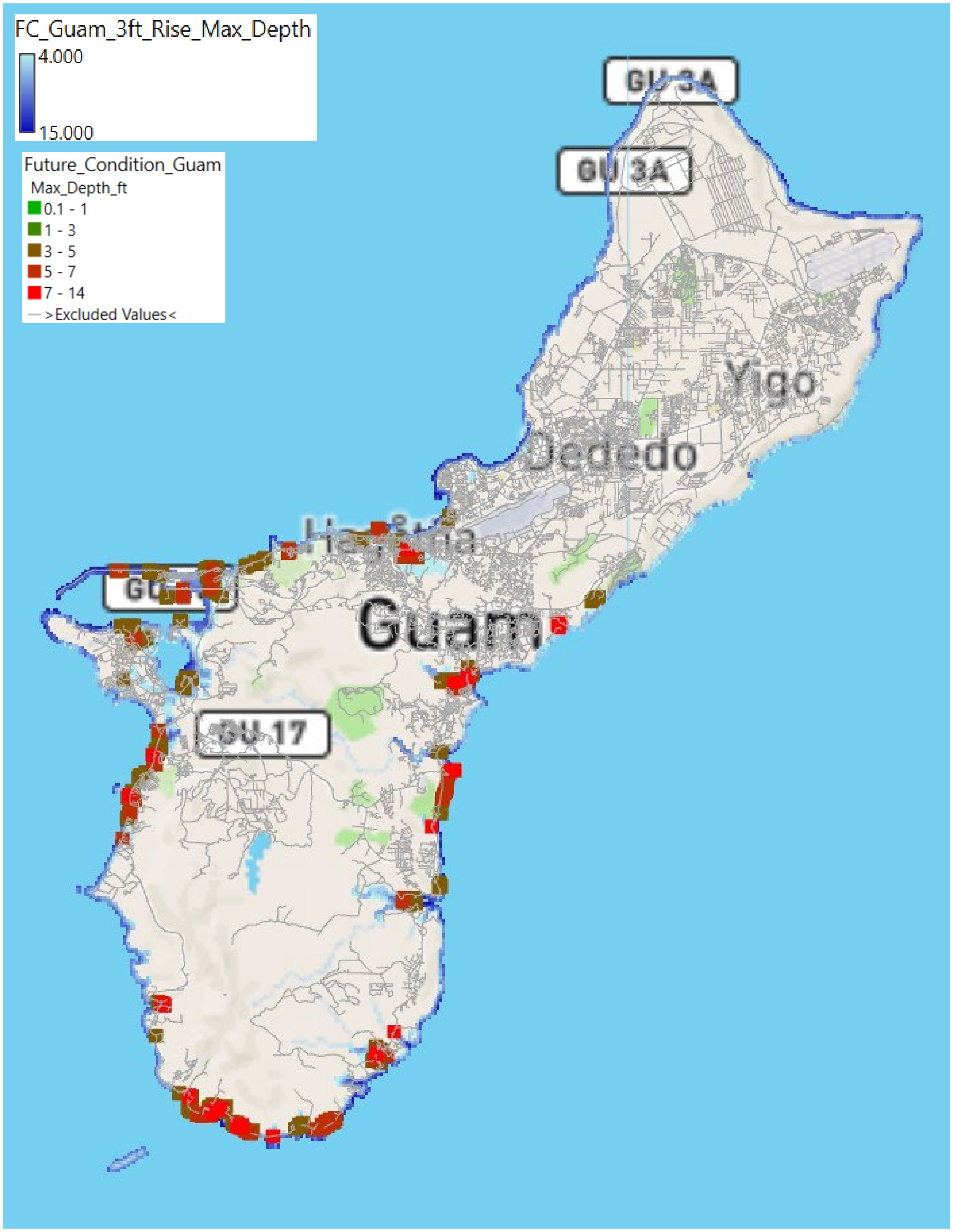

Figure 4-4: Map of Future Scenario inundation hazard on roads under the MEOW Storm Surge event in Guam. Source: [USACE, 2021.](#)

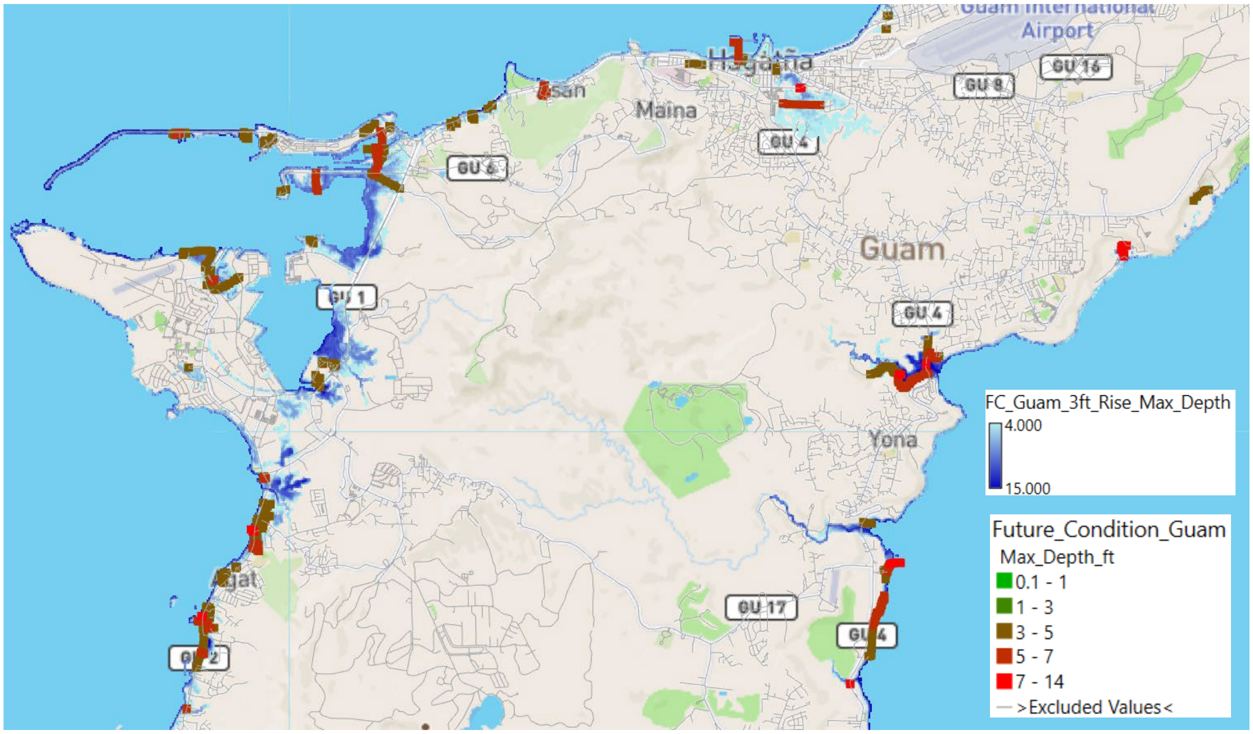

Figure 4-5: Map of Future Scenario inundation hazard on roads under the MEOW Storm Surge event in Guam (Center). Source: USACE, 2021.

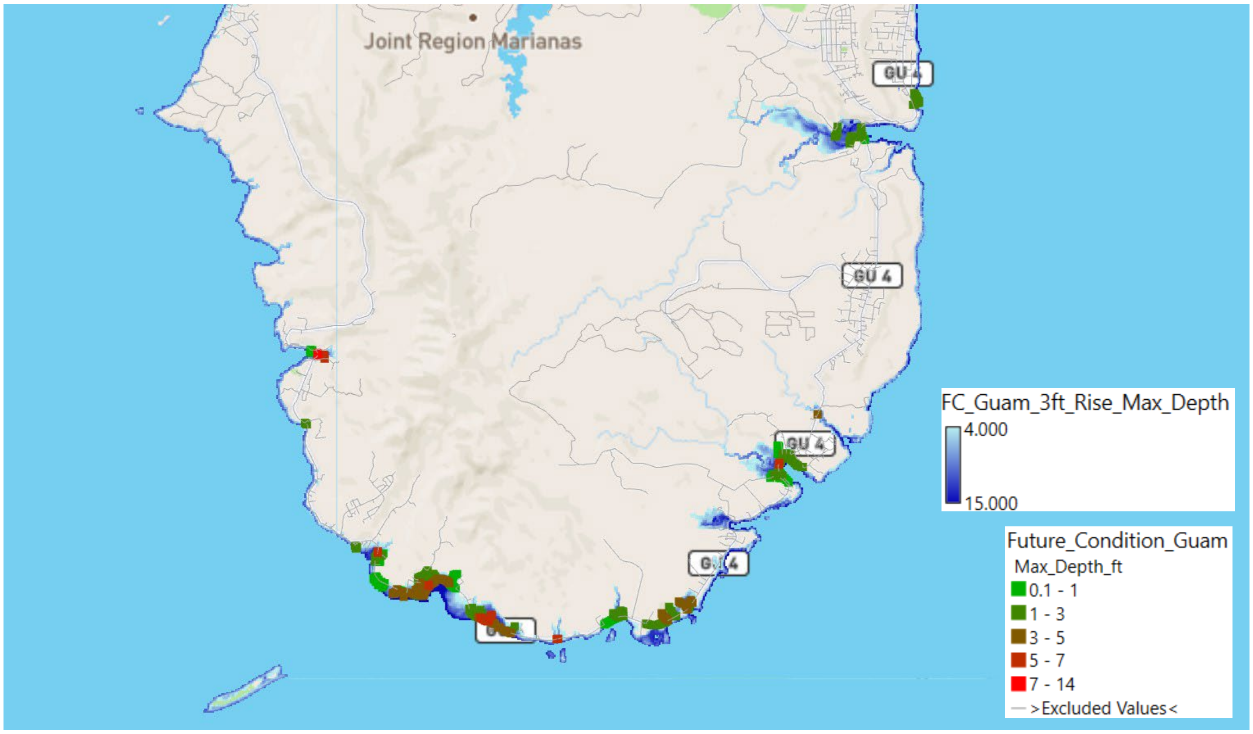

Figure 4-6: Map of Future Scenario inundation hazard on roads under the MEOW Storm Surge event in Guam (South). Source: USACE, 2021.

4.2 Findings and Discussion

From the results, it is clear that an increase in RSLC leads to increased risk on the island of Guam. The villages of Piti and Tamuning along the western shore experience the largest increases in risk of coastal flooding in the future scenario. The Villages of Agat and Merizo are home to the largest PAR, and also experience structure damage increases of 266% and 171% respectively.

4.2.1 Changes to PAR

As stated in 3.2.1 Agat and Merizo are the villages with the most PAR under the existing conditions. These villages also see large increases in structure damages from the existing to future scenarios leading to the assumption that the PAR will face higher lethality depths of inundation in the future, but due to data limitations, estimates for future PAR values could not be established via the model.

4.2.2 Changes to Structure Damages

The results pertaining to structure damages are less about exact numbers, and more about showing which areas receive the greatest change and are therefore vulnerable to RSLC. For example, the village of Piti receives over 7x damage in the future scenario, highlighting the vulnerability to the risk of RSLC at those structures.

Overall, Guam experiences very large increases of consequences in the future scenario represented by a 212% increase in structure damage values. Unfortunately, due to data limitations in this effort, increases in PAR and number of structures impacted could not be estimated. However, using structure damages as an indicator of what areas see an increased risk, the assumption is made that these areas’ PAR will face higher depths of inundation in the future, due to RSLC.

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