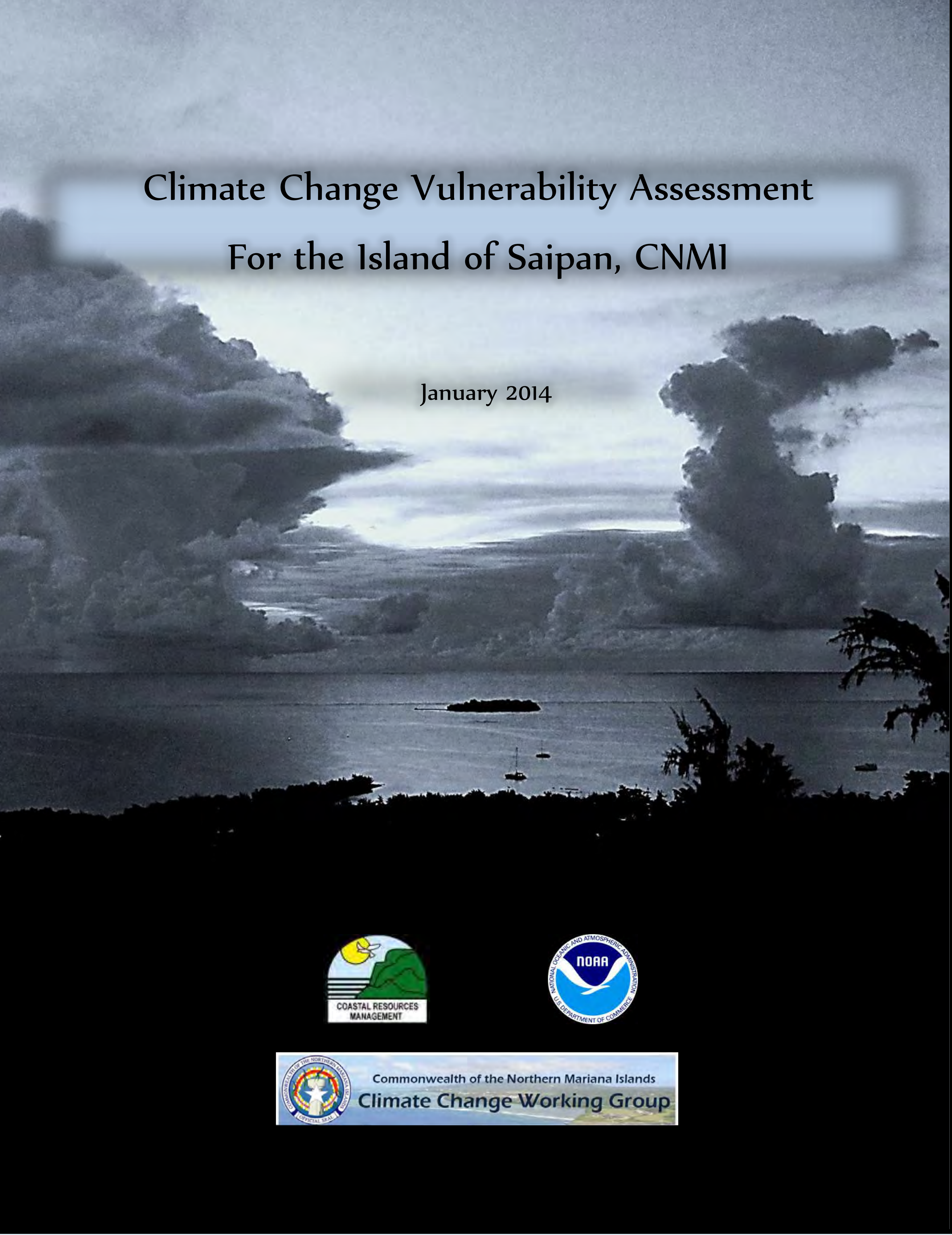
Climate Change Vulnerability Assessment
For the Island of Saipan, CNMI

January 2014



COASTAL RESOURCES MANAGEMENT

Commonwealth of the Northern Mariana Islands
Climate Change Working Group

About This Document

The Climate Change Vulnerability Assessment for the island of Saipan is the product of a year-long collaboration between the CNMI Division of Coastal Resources Management and the participating agencies and organizations of the CNMI Climate Change Working Group. Ongoing support for the Vulnerability Assessment and Climate Change Working Group was provided by the U.S. National Oceanic and Atmospheric Administration, and contributions to the assessment stem from a wide range of federal and CNMI government agencies, non-governmental organizations, and community groups. Additional technical resources, tools, and expertise were leveraged from organizations throughout the Insular Pacific and beyond.

The cumulative result of this diverse input is a project that meshes a community-based assessment and local knowledge with technical analysis and inquiry. This document presents the Vulnerability Assessment by highlighting its findings, as well as the process and information used to arrive at conclusions and recommendations. It is as much a framework for a mixed-methods assessment process as it is community narrative and practical study.

Document Usage and Limitations

This document is intended as an initial screening tool for prioritization of climate adaptation work on the island of Saipan. Usage of the Vulnerability Assessment should be limited to broad planning and policy purposes. Analysis of specific resources and geographic areas was conducted under potential future scenarios, which introduces inherent uncertainties and complicates field verification. As such, the findings, recommendations, and data within this document are not appropriate for application to site-specific engineering or other projects involving alterations to the physical landscape. As with any study, the results of the assessment are limited by the quality and quantity of obtainable data, as well as available technical capacities. The project was undertaken with the expectation that it would provide a baseline for continued study, data collection, and overall enhancement of future assessments. It is the author's hope that this document finds practical application in the near-term, while continuing to spur useful inquiries as climate adaptation work in the CNMI is implemented.

Contact

Additional information concerning the Vulnerability Assessment can be found at the CNMI Climate Change Working Group Website (www.ClimateChangeCNMI.net), or through the CNMI Division of Coastal Resources Management (www.crm.gov.mp). This document was assembled and edited by NOAA Fellow Robbie Greene. All inquiries and correspondence concerning the acquisition or use of vulnerability assessment data should be directed to the Division of Coastal Resources Management (670-664-8300).

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Cover Photo: Managaha Island and the Philippine Sea, looking west from Navy Hill Lighthouse (Saipan). R. Greene

Contributions and Acknowledgements

This project would not have been possible without sustained participation and contributions from countless individuals and institutions. The eight members of the CCWG Planning Committee provided valuable leadership and guidance throughout this process. Through their role on the Planning Committee they devoted significant time to guiding the community-based assessment process and will continue to shape the direction of climate change adaptation work in the CNMI. Each of their respective agencies – CRM, CUC, DEQ, DPL, DPW, HSEM, MVA, and Zoning – deserve recognition for investing time, resources, and meeting space to this project.

In addition, much of the information contained within this report was developed and contributed by the experts and technical staff from agencies and organizations who have been involved in the CCWG. Over seventy individuals representing 28 different institutions have participated in CCWG meetings and trainings over the past year and a half. These institutions include local and federal government agencies, business associations, non-governmental organizations, and the local colleges. Their participation and insight were critical for the development of the community-based assessment contained within this document.

Finally, the CCWG would like to thank the experts from around the world who have provided technical support to the CCWG and its member organizations. NOAA's Coastal Services Center hosted a three day training that provided members of the CCWG a foundation and important context for climate adaptation work in the CNMI. PIMPAC hosted a five day training that helped the CCWG transition into an actual assessment of resources. Experts from WERI at University of Guam, University of Hawaii Sea Grant, Micronesia Conservation Trust, NOAA-NESDIS, and Pacific RISA have all provided technical support throughout the development of the CCWG and the Vulnerability Assessment and also deserve recognition. And finally, NOAA's Office of Ocean & Coastal Resource Management funded a majority of this project through the Coral Reef Conservation Program and the Coastal Zone Management Program.

Executive Summary

In the summer of 2012 a climate change working group convened on the Island of Saipan to begin climate change adaptation planning in the Commonwealth of the Northern Mariana Islands. In the year following this formation, the government agencies, non-governmental organizations, business associations and community groups that comprise the Working Group developed a distinct collaborative structure and process to achieve a series of goals and objectives. The first objective, which served as a source of cohesion and guidance for the Working Group, was to identify the social, physical, and natural features in the CNMI that are most susceptible to the impacts of climate change. To achieve this objective, a community-based vulnerability assessment was conducted. The assessment focuses on projected changes to sea level and rainfall patterns in the CNMI, the exposure and sensitivity of Saipan to these changes, and the Island's capacity to respond to possible impacts. This document summarizes the process, results, and recommendations of the assessment.

* * *

The most recent climate models and projections suggest a wide range of changes to the global climate system over the next century and beyond. The potential impacts of these changes vary greatly across space and time, and are by no means geographically uniform. However, there is a high level of confidence that the Western North Pacific will experience rising sea levels, increasing air and sea surface temperatures, and shifting precipitation patterns. This change constitutes a deviation from the atmospheric and oceanic conditions that Micronesian Islands have built their economies, infrastructure, and natural heritage upon. The Northern Mariana Islands, and Saipan in particular, should expect implications from this change.

This vulnerability assessment used a variety of tools and techniques to explore levels of exposure and sensitivity to future sea levels and changing rainfall on Saipan. The Climate Change Working Group participated in a series of stakeholder inventories and community mapping workshops to qualitatively assess the Island's vulnerabilities. The community-based assessment was supplemented with the development and analysis of sea level rise and coastal flooding maps, as well as a quantitative evaluation of social vulnerability among Saipan's villages.

Cumulatively, the results of these assessment techniques suggest that the villages and infrastructure on Saipan's western coastal plain are the most vulnerable to the effects of sea level rise and possible shifts in rainfall. While the entire island will likely see some impacts from climate change in the coming decades, the villages and stakeholder resources that are located between Susupe and Tanapag are expected to be impacted the most. Specifically, the low lying areas, critical infrastructure, residential and commercial districts, and habitats that are located within Garapan and Lower Base should be prioritized as climate change adaptation planning moves forward in the CNMI.

The immediate advancement of climate adaptation on Saipan should include the integration of sea level rise considerations into current and future flood control studies, public works projects, and assessments of proposed development impacts. Opportunities to streamline adaptation actions with existing CNMI projects and initiatives should be explored. While this vulnerability assessment identifies vulnerabilities and recommends adaptation priorities, effective progress and prioritization of climate change adaptation hinges on the collaboration and support of CNMI decision makers, policy makers, and government agencies.

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Contents

List of Figures, Maps, and Photos

List of Acronyms

AMP	American Memorial Park
CAP	Conservation Action Plan
CCWG	Climate Change Working Group
CHC	Commonwealth Health Center
CHCC	Commonwealth Healthcare Corporation
CIP	Capital Improvement Projects
CNMI	Commonwealth of the Northern Marianas Islands
COC	Chamber of Commerce
CPA	Commonwealth Ports Authority
CRMO	Coastal Resources Management Office
CSC	Coastal Services Center
CUC	Commonwealth Utilities Corporation
CZMP	Coastal Zone Management Program
DCCA	Department of Community & Cultural Affairs
DEQ	Division of Environmental Quality
DFW	Division of Fish and Wildlife
DLNR	Department of Lands and Natural Resources
DOC	Department of Commerce
DPL	Department of Public Lands
DPS	Department of Public Safety
DPW	Department of Public Works
DRC	Disaster Recover Center
ENSO	El Nino-Southern Oscillation
GIS	Geographic Information Systems
GMSL	Global Mean Sea Level
HPO	Historic Preservation Office
HSEM	Homeland Security and Emergency Management
MINA	Marianas Islands Nature Alliance
MMT	Marine Monitoring Team
MVA	Marianas Visitors Authority
NESDIS	National Environmental Satellite, Data, and Information Service
NMC	Northern Marianas College
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PDO	Pacific Decadal Oscillation
PIMPAC	Pacific Islands Marine Protected Areas Community
PMRI	Pacific Marine Resources Institute
PSS	Public School System
RISA	Regional Integrated Sciences and Assessments
SLC	Sea Level Change
SLR	Sea Level Rise
SST	Sea Surface Temperature
VA	Vulnerability Assessment
WERI	Water and Environmental Research Institute
WNP	Western North Pacific

1. Introduction

Warming of the earth's climate system is plainly evident. Since the 1950s, changes have been observed that have not occurred for millennia. The atmosphere and oceans have warmed, enormous amounts of snow and ice have diminished, sea levels have risen, and concentrations of greenhouse gases have increased (IPCC 2013). The effects that these changes have on the Earth's oceanic and atmospheric phenomena are varied and complex, and the subsequent impacts that changes have on marine and terrestrial ecosystems, social and cultural constructs, and economic systems are myriad. Amidst these complex interactions, the island of Saipan continues to evolve in its own unique manner.

While many resources and initiatives are at work attempting to understand the current state and dynamics of Saipan's social and natural systems, there is an additional need to identify potential future changes and impacts to these systems. One of the first steps in this endeavor is to identify the island's susceptibilities to current climate-related threats, as well as projected changes to these threats in the coming decades. The Saipan Climate Change Vulnerability Assessment (herein referred to as the VA) constitutes one of the first efforts to do this in the Commonwealth of the Northern Mariana Islands (CNMI). This document summarizes the VA, focusing on the following discussions:

- Section 1:
    - This section introduces the concept and purpose of the VA, and the approach and methods that were used in conducting it. A summary of global and regional climate change projections and impacts is included to set context.
- Section 2:
    - This section discusses the community-based participatory process that was used to conduct an initial qualitative assessment of Saipan's vulnerabilities to climate change. The CNMI Climate Change Working Group is introduced, a stakeholder engagement process is described, participatory mapping workshops are detailed, and the results of a year-long assessment process are summarized.
- Section 3:
    - This section details a more technical assessment of social vulnerability and potential inundation from sea level change scenarios. The construction of a social vulnerability index for Saipan's villages is discussed, along with results. Inundation maps are highlighted, along with results from map analysis. Focal points include the types of land uses, land cover, and socially-vulnerable villages that could be impacted from various sea level scenarios.
- Section 4:
    - This section includes a brief summary of the results from both community-based and technical assessments. The concepts of exposure, sensitivity and adaptive capacity are discussed by highlighting a few examples of vulnerable resources and features (as identified in sections 2 and 3). A set of geographic focus areas are identified for further assessment and adaptation efforts.
- Section 5:
    - The final section of the VA is simply a discussion of potential opportunities for adaptation, and next steps for climate change adaptation planning in the CNMI.

1.1. Introduction to the Vulnerability Assessment

Adaptation and Vulnerability Assessments

Changes in global, regional and sub-regional climate have been observed with increasing frequency and confidence over the past decade (IPCC 2001, 2007, 2012, 2013). Paralleling these changes, a shift in national and international climate discourse has taken place. The climate conversation has moved beyond mitigation policies and established an additional focus on *adaptation*. Climate change adaptation refers to the adjustment of a human or natural system in response to current and/or future impacts from climate phenomena. The primary aim of adaptation is to identify impacts that may be unavoidable (regardless of mitigation efforts), and temper any harmful effects from climate change (IPCC 2007, NOAA 2010). By responding to expected changes, adaptation initiatives allow for more immediate, actionable outcomes in climate change work.

Climate change adaptation is most effective where a solid foundation of knowledge and information has been established (Snover et al. 2007, NOAA 2010). In the CNMI, this foundation will be built upon a baseline assessment of risk and vulnerability. This VA constitutes the groundbreaking for a sustained, effective climate adaptation initiative, and is intended to inform the development and implementation of a long-term climate change adaptation strategy (Figure 1).

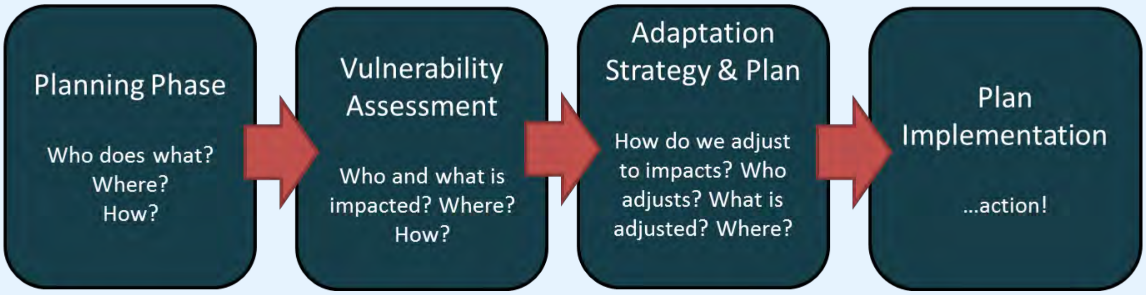


Figure 1: Workflow for climate adaptation planning in the CNMI

Vulnerability assessments are not a new concept. In the CNMI, simple VAs have been conducted with respect to natural disasters such as earthquakes and tsunamis (see CNMI Standard State Mitigation Plan, 2010). Nationally and internationally, VAs are conducted in the context of a variety of social, natural and physical threats, and more recently for climate change. These assessments are intended to identify levels of potential impact, investigate susceptibilities of human and natural systems, and explore any capacities for responding to identified impacts; however, they do not always result in immediate actions. Rather, they serve as a *basis* for action. This role is especially important in the CNMI, where climate change is a fairly new concept to many audiences. The continued investment of time and resources in climate change adaptation will require a catalyst (such as a VA) to demonstrate the significance and relevance of climate change to policy makers, resource managers, community leaders, and educational institutions throughout the Commonwealth.

Purpose and Need

The Saipan VA is the result of significant contributions of time and resources from multiple individuals and institutions. While the original source driving the VA was focused on establishing an improved understanding of coastal hazards in the CNMI, expectations for the document evolved to include benefits to all participating agencies and organizations in the CCWG. With this increased participation and evolved perception of what the VA will contribute come two concerns:

1. There are uncertainties in climate change projections. What if no change occurs?
2. The VA was initially guided by a regulatory agency with its own mission. How will the study benefit other collaborators?

The Saipan VA was designed to satisfy these concerns, but even recent climate science can address the first issue. One source of unease about the investment of time and resources into climate change adaptation is the prospect of greenhouse emissions trends subsiding or reversing, eliminating the need for adaptation. A crucial consideration here is the persistence of changed climate conditions, even after troubling emissions trends have ceased. A large fraction of climate change resulting from anthropogenic emissions is irreversible on a multi-century to millennial time scale, except in the case of a long, sustained net removal of CO2 from the atmosphere. Surface temperatures would remain approximately constant at elevated levels for many centuries, even after a complete cessation of net CO2 emissions (IPCC 2013). Elevated levels of surface temperatures feed into other climate variables such as sea level and sea surface temperature, implicating continued impacts regardless of greenhouse gas mitigation.

The VA itself addresses concerns about uncertainties or misinformed projections by embracing a “no-regrets” approach to impact assessment. This approach rests upon the idea that the assessment will provide useful information about vulnerabilities, regardless of the time-span within which conditions change or impacts occur. The VA accomplishes this by focusing on sea level changes due to both long-term trends and short-term extremes, as well as considering the potential for an increase in extreme precipitation events, which also pose current threats. Any adaptation plan that is informed by the VA would likely carry this “no-regrets” approach into its strategy. In other words, a climate-smart adaptation might also pass as a storm-smart adaptation.

Through consideration of some more immediate climate-related impacts, the VA also addresses concerns about what the study will contribute to CCWG collaborators. For example, in the 2010 CNMI Standard State Mitigation Plan (SSMP), a threat assessment was conducted to identify impacts related to a variety of natural and anthropogenic hazards, with a notable section on typhoons. The storm surge and coastal inundation analysis for the SSMP utilized a single contour line derived from coarse elevation data to identify the “zone of vulnerability”. The VA offers a more refined approach to the SSMP’s inundation analysis, providing a possible enhancement to future updates of the plan. Linkages to such complimentary efforts as the SSMP create a strong incentive for the VA. Other agencies may find additional uses for the assessment, including updates to coastal development regulations, zoning code improvements, or ecological restoration priorities.

The VA is by no means a static product, and allows many opportunities for updates and enhancements to the study itself. These may come in the form of improved climate projections, new modelling capacities, improved data on local infrastructure, or increased participation in the CCWG. It also provides a baseline methodology and scale, whereby additional assessments can be conducted over larger or smaller spatial extents (e.g. CNMI-wide or Garapan) using a compatible approach.

Scope and Scale

This project varied in both breadth and depth depending on the climate change impact under consideration and the element of vulnerability being examined. The primary focus is on the potential impacts of sea level change on the island of Saipan. The most detailed assessment of vulnerability is concentrated on the level of exposure and sensitivity that Saipan’s west coast has to coastal inundation. This focus is a result of a combination of influences, including the availability of technical resources, the compatibility of results to other planning efforts, and the existence of data that could be processed and analyzed within a reasonable amount of time.

In addition to the emphasis on coastal inundation and flooding, the VA briefly addresses the potential for increases in extreme precipitation events, projected increases in sea surface temperatures and consequent coral bleaching, and changing ocean wave conditions. These components of climate change are not thoroughly analyzed in the VA, but were mentioned frequently by CCWG participants and are therefore included in the document where appropriate. Additional assessment of these variables is certainly warranted, particularly with respect to marine resources and impacts of changing ocean chemistry. Not only were these issues brought up consistently by CCWG participants, but considerable work on reef resilience and responses to climate stimuli has been initiated by project collaborators. It would be an egregious error to omit any discussion of this work from the VA, but nevertheless a thorough assessment is outside the project’s scope.

A comprehensive review of recent literature and research concerning climate science in the Western North Pacific was also outside the scope of this project; however, a summary of projections and general impacts on both global and regional levels is included as background.

1.2. Climate Change Phenomena and Potential Impacts

Global Summary

As with any summary or application of scientific findings, varying uncertainty and confidence is involved throughout this document, and thus a disclaimer is warranted. Confidence in projecting changes in the direction and magnitude of climate phenomena depends on many factors, including the variable in question, region, season, the quantity and quality of observational data, the level of understanding of underlying processes, and the reliability of simulations and models (IPCC 2012). Varying confidence and inherent uncertainties should be kept in mind in the following summaries.

While anthropogenic (human induced) changes in climate are the primary focus of climate change conversations on a global scale, it should be noted that natural variability is an important factor in shaping future conditions, particularly those of extreme events occurring within particular regions and sub-regions. A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather, and can result in unprecedented events. Some extremes (e.g. droughts) may continue to be the result of natural climate variability, but could strengthen or weaken relative to current and historic events (IPCC 2012).

Natural variability aside, the figure below summarizes expected long-term changes in climate variables at a global scale. Figure 2 is a simplified version of more specific climate projections, and distills multiple scenarios used in the IPCCs fourth and fifth Assessment Reports (primarily RCPs from AR5) into generalized statements (see IPCC 2013 for more information). This figure is adapted from the 2012 Pacific Islands Regional Climate Assessment (Keener et al. 2012a). A brief chat concerning climate variables and projections follows.

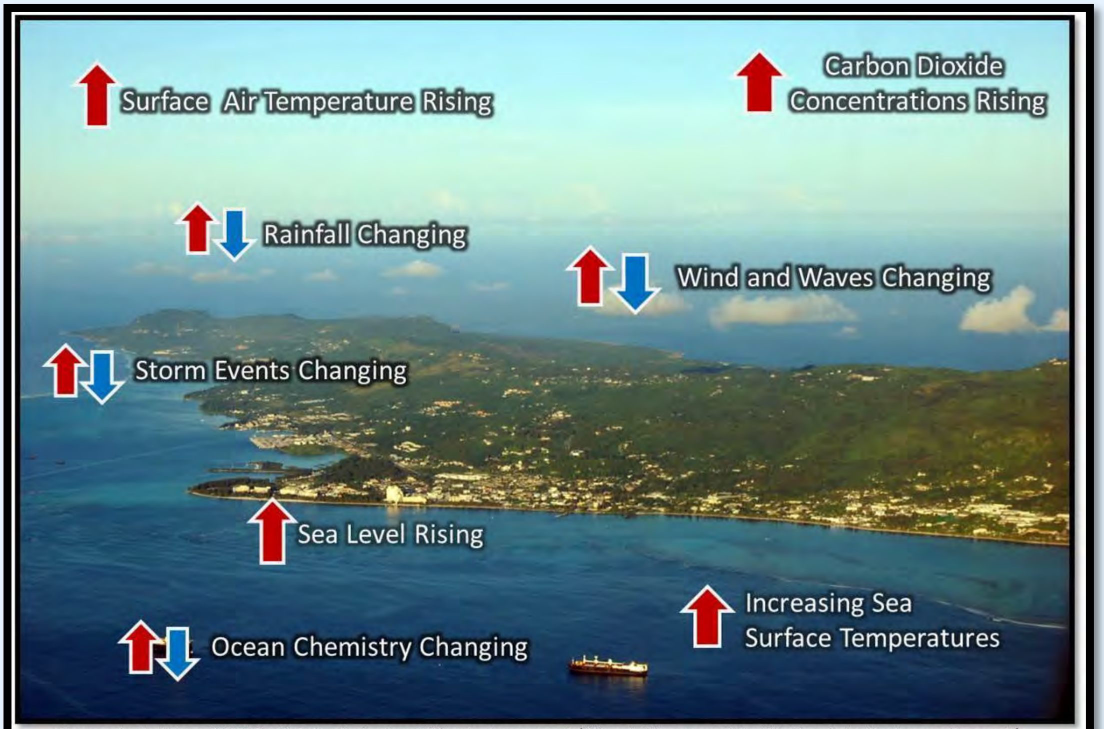


Figure adapted from 2012 Pacific Islands Regional Climate Assessment (*Climate Change and Pacific Islands: Indicators and Impacts*) and NOAA National Climatic Data Center's *State of the Climate 2009*

Figure 2: General climate change effects in the Western North Pacific

Temperature and Precipitation

The global mean surface air temperature has risen over the last century, and there is very high confidence that temperatures will continue to rise, with up to a 3.6º F increase by the end of the century (up to 5º F with lower confidence). Projections suggest regional variation in the rate of temperature increase, but the overall impact will likely involve more extreme high temperatures and less extreme cold days (relative to current conditions). Heat waves are expected to become more frequent over large land masses, while relative warming rates will likely have their most severe impacts near the poles (IPCC 2013).

The frequency of heavy precipitation and the proportion of mean annual rainfall from extreme precipitation events will likely increase over the 21st century across much of the globe. Higher latitudes and tropical regions are most likely to experience this increase. In tropical and sub-tropical regions, heavy precipitation associated with cyclones may increase provided continued warming of the oceans, though this will vary regionally.

The potential for increases of heavy precipitation in *isolated* events poses some interesting implications as there is medium confidence that this could occur in regions where mean annual precipitation is projected to *decrease* (IPCC 2012). This phenomenon could expose an area with water shortages to temporary flood scenarios. Freshwater resources and groundwater will likely become a focus area for adaptation efforts in many areas. While changes in precipitation will impact these resources, long-term shifts in sea level may alter salinity and the chemistry of coastal aquifers and groundwater.

Sea Level Rise and Change

In this document the term “Sea Level Rise” (SLR) is generally used in reference to long-term increases in mean sea level due to climate change. The term “Sea Level Change” (SLC) is also used, but refers to changes in mean sea level due to any variety or combination of short-term variability, extreme storm events, and long-term changes. These terms are used interchangeably in later sections of this report as combinations of short and long-term scenarios are assessed.

Climate change induces SLR through heating of the ocean surface, causing water to expand, and through heating and melting of glaciers and ice sheets, which transfer water from the land to the ocean. Collectively, these actions increase the volume of the ocean. Sea level can also change relative to a specific landmass if that land is moving vertically (Marra et al. 2012).

Changes to sea level will pose a variety of challenges globally, and particularly within island regions. Elevated water levels are projected for most regions around the world, and the chance of more frequent extreme water level events could threaten coastal structures, groundwater, ports and commerce, residential and public property, and critical infrastructure. Short- to medium-term impacts will vary with location depending on how natural sea-level variability combines with less extreme increases of sea levels; however, over longer time scales projected SLR is likely to exceed critical elevations in low lying areas. Combined with possible climate-related changes in storm patterns, SLR could result in frequent flooding and inundation scenarios (Marra et al. 2012).

Global mean sea level (GMSL) has risen over the past century, with the highest rates of rise (3.2mm/year) measured by tide-gauges and satellite altimeter data between 1993 and 2010 (IPCC 2013). The recent acceleration has been attributed to natural variability in some areas; however, the overall trend shows a gradual increase. GMSL trends are complicated by a number of regional climate variables and forces that recur on varying time scales. The Pacific Decadal Oscillation (PDO), for example, has a significant effect on SLC in the Pacific Ocean. Removing the influence of the PDO from GMSL trends results in a decrease in the acceleration of SLR observed over the past 60 years (Hamlington et al. 2013). These complications become important when sub-regional SLR trends are discussed.

According to the most recent IPCC projections, GMSL is expected to rise between 0.24 - 0.3 meters by 2065, and 0.40 – 0.63 by 2100. The upper end of these projections that retains a reasonable level of confidence (>66% probability) shows a rise of 0.82 m. A range of other global projections have been proposed over the least two decades, resulting in estimates that hover as low as a tenth of a meter (IPCC 2001) to as high as 2 meters (Pfeffer et al. 2008) and beyond. The SLR and SLC scenarios chosen for assessment in the VA are discussed in greater detail in Section 3 and Appendix F.

Wave Environments and Climate

Concerns over coastal inundation and flooding are not limited to potential SLR and SLC scenarios. Evidence of enhanced wave energy and more extreme ocean wave environments has garnered attention recently (Ruggiero 2013), particularly in the North Pacific and Atlantic oceans where wave heights have increased over the past several decades (Iwao et al. 2012;

Graham & Diaz 2001; Allan & Komar 2000). Some studies suggest that intensified wave environments may pose an equal, if not greater coastal threat over the next century than SLR, particularly in locations exposed to waves from extratropical storms (Ruggiero 2013). As with other climate phenomena, intensification of wave environments will vary regionally, but the ability of waves to increase overall total water levels in any given location translates into great erosive and inundation potential. Global increases in wave intensity will likely parallel that of increased storminess. Both of these stressors are driven by increased warming and energy in the Earth's climate system.

Ocean Warming and Acidification

Ocean warming accounts for over 90% of the increased energy accumulated in the Earth's climate system between 1971 and 2010 (IPCC 2013). This warming has, and will continue to have major impacts on marine resources and ecosystems. Globally, the ocean surface is expected to be impacted by varying increases in sea surface temperatures (SSTs), ocean acidification (OA), oxygen depletion, and changes to biological productivity. While there are inherent implications for natural resources and ecological communities, there are also approximately 470-870 million people living in coastal communities that rely on ocean productivity and services for their livelihoods (Mora et al. 2013a).

Global increases in ocean acidity have been observed, and are expected to continue through the 21st century, with a decrease in global surface pH of up to 0.30 (IPCC 2013). The impacts that OA may have are likely to be vast, and are the subject of further investigation at regional and sub-regional scales. Impacts of OA on biological productivity are of particular concern.

Paralleling the increase in ocean acidity is a steady rise in SSTs. While SSTs vary on a regional, seasonal, and interannual basis, an overall increasing trend spells trouble for many marine ecosystems. One of the most well-documented and studied examples of this is through coral bleaching events. It is becoming apparent that there are few; if any areas of tropical reef on a global scale that will not experience significant increases in bleaching events. Of all tropical reef locations, 90% are expected to suffer severe annual bleaching by 2055 (van Hooidonk et al. 2013). Projected increases in global SSTs, along with OA, SLR, and other climate stressors constitute a significant threat, particularly to coastal communities. The Pacific Islands region is especially exposed to this threat. The following section examines these same climate stressors on a regional and sub-regional level.

Climate Change in the Western Pacific and Implications for the CNMI

An understanding of regional variation in climate forces is absolutely essential in a spatially-explicit assessment of climate change impacts and vulnerability. The regional projections referred to in this document are particular to the Western North Pacific (WNP). This area includes Guam, CNMI, Republic of Palau (RP), Federated States of Micronesia (FSM), and Republic of the Marshall Islands (RMI). Downscaled projections specific to the CNMI were not available for most climate variables.

The WNP is experiencing changes to its climate through both natural changes on an interannual and decadal basis, and through long-term anthropogenic change. Some shifts are subtle, and difficult to detect, while others are more pronounced. These changes are indicated by observed rising carbon dioxide in the atmosphere, increases in air and sea temperatures, rising sea levels, increased ocean acidity, and shifts in rainfall distribution (Keener et al. 2012a). The following table (Figure 3) summarizes expected long-term impacts to the climate system in the WNP through the 21st century. This is followed by a more detailed discussion of a few key climate variables.

Climate Change Variable	**Projection**	**Potential Impacts**
Temperature	Steady increase, with seasonal extreme highs	Increase of extreme temperatures leading to stress on habitat and public health. Increase of potential storm energy in atmosphere and ocean.
Precipitation	Small increase in *average* rainfall. Increase in *extreme* rainfall events. Wet season gets wetter; dry season gets drier.	Impact on overall freshwater supply uncertain. Potential for short-term flooding increased in rainy season.
Sea Level	Gradual increase, with interannual and decadal fluctuations.	Possible inundation of low-lying areas over extended periods of time, with increased flooding impact of short-term events such as storms. Damage to infrastructure, property, tourism.
Sea Surface Temperature	Steady increase, with interannual variations depending on El Nino-Southern Oscillation. Increase in degree heating weeks to induce coral bleaching on an annual basis before 2050.	Decline of overall coral health and increase frequency of bleaching events. Decrease in both ecosystem value and tourism appeal.
Ocean Acidity	Steady increase, with declining pH of up to 0.3 by the end of the century.	Threats to coral structure and health; uncertain impacts on ocean food chains.
Ocean Waves	Intensification in extratropical wave environments, and potential increase in overall storminess.	Exacerbated impacts from storm surge and sea level change. Short-term flooding and erosion. Potential hazard to public.

Figure 3: Potential impacts of climate change in the CNMI

A few notable phenomena that dominate climate pattern in the WNP are worth mentioning prior to a discussion of individual climate stressors. One of the most important drivers of climate in the region is the large-scale east-west tropical circulation and overturning of air known as the Walker circulation. This circulation is one of the primary drivers for seasonal winds and associated movement of weather systems across the equatorial Pacific. The Walker Circulation is one of the main reasons for Saipan's comfortable conditions from ~December – February. Observed Pacific sea level pressure over the last century suggests that this circulation is weakening a bit, and some climate models indicate that the consequent weakened surface winds have altered the thermal structure and circulation of the tropical Pacific Ocean (Vecchi et al. 2006). Because this circulation affects all the various components that make up the CNMI's seasonal climate, the potential for further weakening of circulation in the WNP during the 21st century poses some interesting implications regarding more specific climate variables.

On a shorter time scale the El Nino-Southern Oscillation (ENSO) introduces some of the most extreme variability to WNP climate patterns. During El Nino events the east-west circulation and trade winds that bring the CNMI its normal seasonal variation (cooler temperatures, regular rainfall and consistent winds) weaken, and the CNMI faces greater potential for drought and typhoons. The opposite phase of El Nino, La Nina, is characterized by a strengthening of the trade winds and east – west flow across the tropical Pacific. These events can increase rainfall in the region, and bring higher sea levels as the enhanced east-west flow pushes surface water from the eastern Pacific toward the WNP.

Because of the extreme changes that ENSO can cause, any assertions concerning short-term impacts to regional climate come with uncertainty; however, long-term projections appear to place the average climate conditions of the future outside the range of current observed variability (Mora et al. 2013b). For example, the mean high temperature experienced now in the CNMI will be similar to, if not less than, the *average* temperature in the CNMI in 2080. Keeping this concept in mind, a closer look at long-term climate change in the WNP is warranted, despite significant short-term variability.

Air Temperature and Precipitation

In the WNP, observed temperatures over the past 60 years have been characterized by increasing trends (Lander and Guard 2003, Keener et al. 2013b). Annual surface air temperature in the region is projected to increase another 1.1° to 1.3°F by 2030, 1.9° to 2.6°F by 2055, and 2.7° to 5.1°F by 2090 (Australian Bureau of Meteorology & CSIRO 2011).

While the trend in WNP air temperature is increasing at a similar rate to that of general Northern Hemisphere temperatures, changes in precipitation have much greater variation, and are more difficult to distinguish from changes in response to interannual and decadal fluctuations (Keener et al 2012b). Inter-annual variations of rainfall in the CNMI are closely linked to ENSO. Saipan is in an ENSO core region that tends to experience very dry conditions in the year following El Niño, and an increase in threats from typhoons during an El Niño year (Lander 2004). In fact, the driest year on record in Saipan over the last several decades was in the wake of the strong 1997 El Niño event. Without a solid understanding of the relationship between climate change and ENSO, it will be difficult to make confident projections regarding rainfall trends in the CNMI.

Despite the difficulties in distinguishing near-term variability from long-term trends, overall WNP rainfall projections suggest that the wet season will get wetter and the dry season drier, with overall increases in mean annual rainfall in the western portion of the region (e.g. Palau). Changes to mean annual rainfall in the CNMI do not appear to be significant; however, both the intensity and frequency of days of *heavy* rainfall are projected to increase over the 21st century (Australian Bureau of Meteorology & CSIRO*,* 2011). This presents significant flooding possibilities, especially when compounded by increases in sea level and potential coastal inundation.

Sea Level Change and Rise

Between 1993 and 2010, sea levels in the WNP rose at a rate of over 10mm per year. This is over three times the rate of the GMSL average during that time (Keener et al. 2012a). While this extreme rate of rise is not expected to continue, and has been attributed to natural variation (PDO), it is an example of how sea levels in the region can change relatively rapidly.

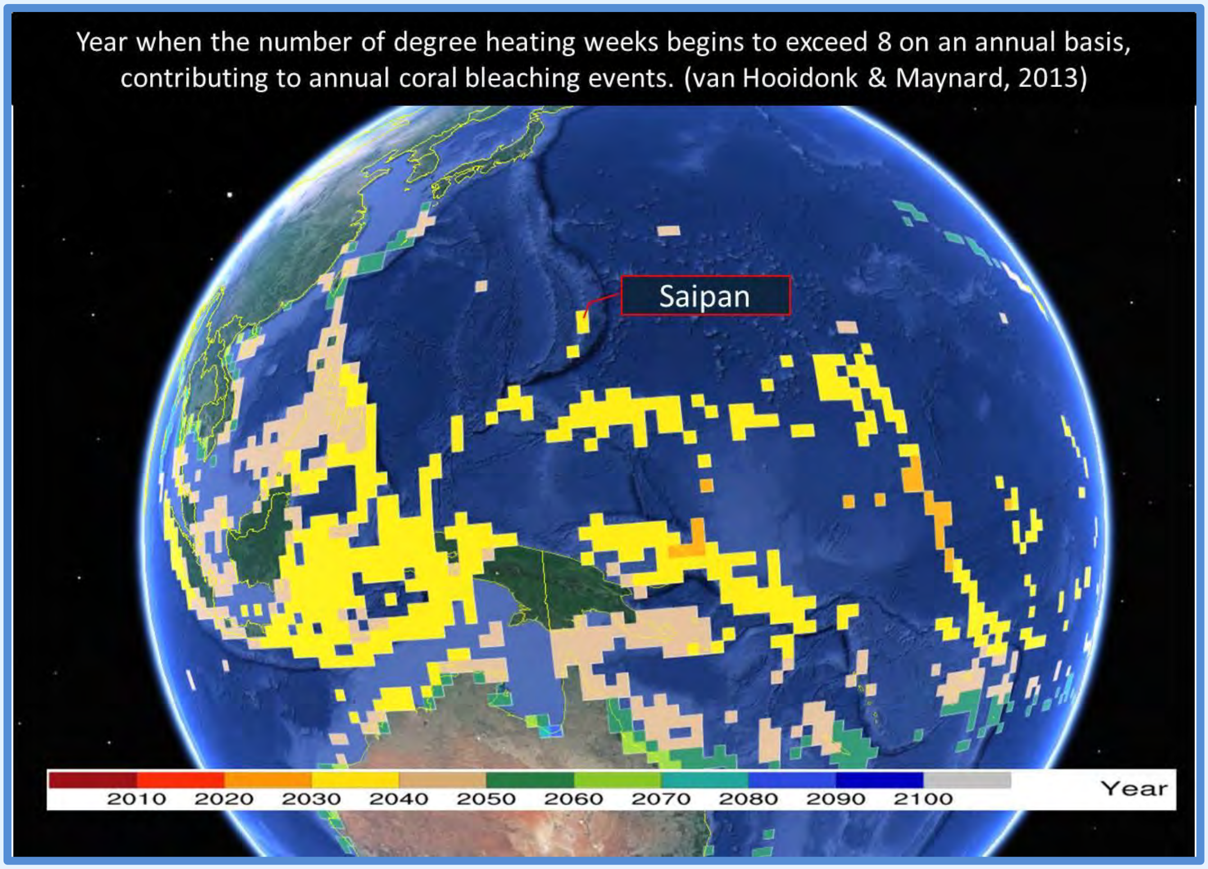
This begs consideration of SLC in adaptation work, regardless of time frame. Strong ENSO phases, for example, have been linked to temporary changes in sea level of up to 10-20 centimeters in the Western Pacific (Marra et al. 2012). When daily, seasonal, interannual, and decadal shifts in sea level are combined with long term projections a more accurate representation of an extreme sub-regional scenario can be achieved. A simple example of this would be to combine the effects of a high tide, a strong low pressure system, and a strong La Nina in the WNP with a long term SLR projection of 0.63 meters. The total water level resulting from this scenario could exceed 1 meter. While the sea would not remain at this level permanently, it would create temporary hazards to coastal infrastructure, properties, beach resorts, and low-lying development in the CNMI. Understanding these hazards and how climate change may exacerbate them is essential for adaptation planning.

Coastal erosion, as a naturally occurring process, has always been a paramount concern for Pacific Islands, and the impacts of SLR are likely to increase the impacts of coastal erosion processes (Mimura 1999, Mimura et al. 2007, Fletcher & Richmond, 2010). Many low-lying islands and atolls in the WNP have already reported issues with erosion and occasional inundation. While the islands of the CNMI are significantly higher than some Pacific atolls, many of the considerations for low islands apply to the nearshore and coastal portions of high islands. In fact, impacts to lowest lying portions of high islands can be quite similar to those experienced on low islands (Marra et al. 2012). Comparable impacts such as this are a necessary consideration for Saipan given its concentration of built environment on the western coastal plain.

Sea Surface Temperatures

While increasing sea levels present direct challenges to coastal communities and shorelines, increasing sea surface temperatures (SSTs) pose imminent threats to the near-shore environments and coral reefs of the WNP. In addition to the general global increase in SSTs, regional phenomena also contribute to the potential for coral bleaching. Historically, the occurrence of significant ENSO events has been linked to increased SSTs, consequent bleaching, and in many cases widespread mortality of reef-building corals in the WNP. The CNMI's location within an ENSO core zone means that inter-annual SST changes associated with ENSO translate into cyclical coral bleaching threats (Starmer et al. 2008).

Regardless of ENSO variation, bleaching is expected to increase at a relatively rapid rate in the Western Pacific, with bleaching occurring on an annual basis before 2050 (van Hooidonk et al. 2013). Figure 4 illustrates the years in which annual bleaching on tropical reefs is expected to begin in the WNP, based on a future scenario in which greenhouse gas emission rates continue at their current rate (RCP 8.5).



Year when the number of degree heating weeks begins to exceed 8 on an annual basis, contributing to annual coral bleaching events. (van Hooidonk & Maynard, 2013)

Figure 4: Timeline for coral bleaching threats in the Western Pacific

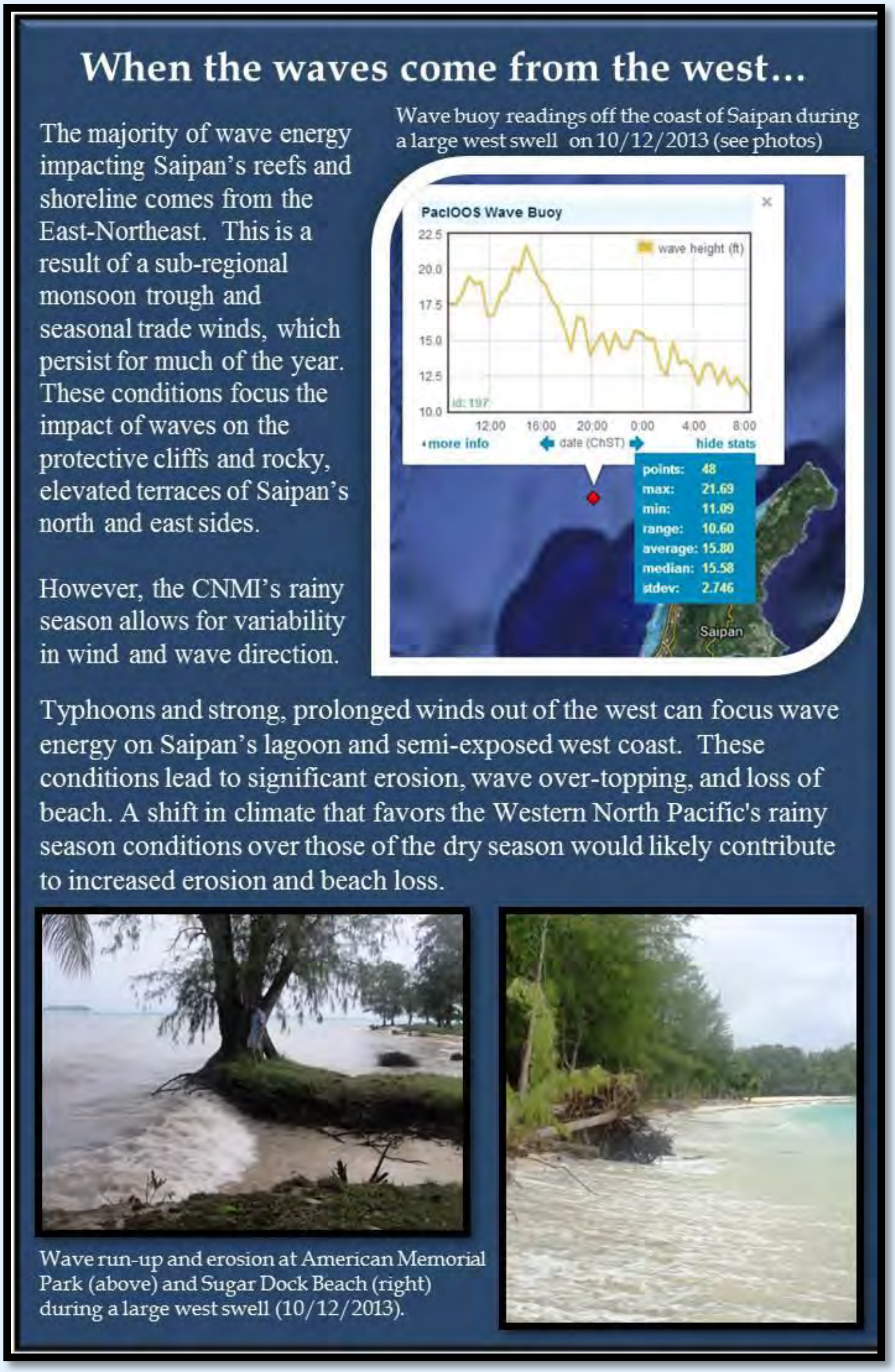
There is a basic understanding and consensus among most of the scientific community that changes are taking place in our climate system, and that these changes will continue down particular paths. There is even some agreement as to what potential effects a changing climate might have on various components such as sea levels, ocean chemistry, and precipitation patterns, and there is some harmony in predicting how these effects will manifest on regional and sub-regional scales. Unfortunately this comprehension does not extend universally to impacts of climate change on a local level. Deciphering how climate change and variability will interact with a specific locality requires a more intimate understanding of that place that is best established by experts within the community itself. The following section briefly highlights a couple physical characteristics of Saipan, and how these features situate the island to deal with the stresses that climate change may present.

1.3. What's the Physical Situation on Saipan?

> "Low islands and coastal communities in the WNP sub-region are especially vulnerable due to their low elevation, small land mass, geographic isolation, and limited potable water sources and agricultural resources. Sea-level rise and more frequent inundation by king tides and tropical cyclones may not only contaminate limited groundwater resources but also overcome basic sanitary systems and agricultural fields" (Keener et al. 2012b).

While the above quote is primarily a reference to small, low-lying islands and atolls, Saipan's size and elevation advantage does not excuse it from these climate stresses. This is especially true of the island's west side, where a coastal plain hosts the majority of coastal populations, services and infrastructure. The coastal plain is physically similar to the lower-elevation islands of the WNP.

Figure 5: Wave exposure on the west side of Saipan



When the waves come from the west...

The majority of wave energy impacting Saipan's reefs and shoreline comes from the East-Northeast. This is a result of a sub-regional monsoon trough and seasonal trade winds, which persist for much of the year. These conditions focus the impact of waves on the protective cliffs and rocky, elevated terraces of Saipan's north and east sides.

However, the CNMI's rainy season allows for variability in wind and wave direction.

Wave buoy readings off the coast of Saipan during a large west swell on 10/12/2013 (see photos)

Typhoons and strong, prolonged winds out of the west can focus wave energy on Saipan's lagoon and semi-exposed west coast. These conditions lead to significant erosion, wave over-topping, and loss of beach. A shift in climate that favors the Western North Pacific's rainy season conditions over those of the dry season would likely contribute to increased erosion and beach loss.

Wave run-up and erosion at American Memorial Park (above) and Sugar Dock Beach (right) during a large west swell (10/12/2013).

The geology of the island itself partially addresses concerns about both groundwater resources and exposure to low-lying areas. Saipan is characterized by slightly sloping plateaus, separated by seaward-facing scarps and cliffs. Over 90% of the surface of the island is covered with limestone formations and alluvium derived from the erosion of these formations (USGS 1998). The high percentage of limestone cover translates into high porosity and groundwater infiltration rates over the majority of the island (Caruth 2003). This creates a fairly reliable freshwater basal lens, assuming precipitation rates don't fall drastically and sea level does not rise rapidly. Unfortunately these assumptions cannot be made in light of recent climate projections.

Saipan's geology also provides for some coastal protection via limestone terraces and high elevations. However, the western side of the island is characterized by a low-lying coastal plain. Any deleterious impacts of SLR, SLC, and waves will likely be focused on this area (Figure 5).

Currently the primary forces behind coastal erosion and inundation on the island are storm surges caused by tropical storms and cyclones. These storms are characterized by very low atmospheric pressure, which can cause sea level to rise a centimeter for every millibar drop in pressure. Storm winds can drive sea level and waves to rise up to several meters upon landfall and breaking waves can cause water levels to rise at the shoreline by up to 20% to 30% of the breaking-wave height (Marra et al. 2012).

Saipan's lagoon and fringing reef afford it some protection from coastal inundation as wave energy dissipates on the outer reefs and across wide stretches of the shallow lagoon; however, a number of channels and breaks in the reef allow wave energy to pass through in select locations. Fortunately there have been few flooding events due to tropical cyclones in recent years. Despite being located in the world's most productive typhoon basin, the CNMI has experienced a relative period of calm since 2000 (Knapp et al. 2010), with only a couple notable exceptions in 2002 and 2004.

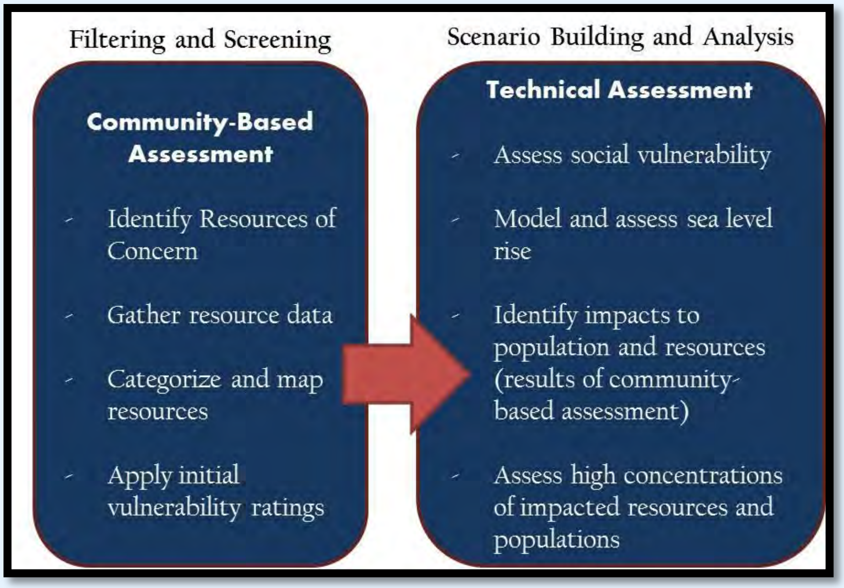
Prior to this calm period the CNMI has been subject to a more consistent and occasionally severe typhoon season. While some damage reports and assessments of storm impacts are available for the larger typhoons, a more comprehensive narrative of impacts from coastal inundation, heavy precipitation, flooding, and community responses is available from the people who experienced these storms. The value of this local knowledge is immense, and is strengthened by the expertise that members of the community have to offer. This is particularly true for the development of an understanding of the responses of specific systems, resources, or villages to climate stresses and phenomena. In light of this body of knowledge, and some readily observable climate vulnerabilities of the island (e.g. the low-lying west side), a climate change VA is merited that integrates the community's knowledge. Section 1.4 addresses the methodology used in the Saipan VA to achieve this integration.

1.4 Approach and Methods

Multiple approaches and methodologies have been used to conduct climate change VAs, ranging from basic compilations of local knowledge concerning observed changes, to highly technical analyses of climate projections and economic impacts. These assessments result in products that reflect the knowledge of the communities that generated them and the level of expertise and technical capacities at their disposal.

The island of Saipan is fortunate to have a community characterized by a wide range of expertise and local understanding, and varying levels of technical skills. This composition is reflected in the CNMI's Climate Change Working Group (CCWG), and the VA attempts to leverage the strengths offered by this diversity. In doing so, the VA required two methods of acquiring information: one to gather community insight, and another to integrate this insight with empirical observations and simulated future scenarios (Figure 6).

Figure 6: Mixed-methods approach to the Vulnerability Assessment



This VA attempts to do this by posing inquiries to the community concerning a spectrum of historic and current observations, and placing the answers to these inquiries into a format compatible with modeled impacts from climate change. This hybrid approach was implemented concurrently, using a geographic information system (GIS) to organize SLC/SLR models and qualitative information gathered from stakeholders.

Leveraging the Community

The community-based assessment involved the development of a climate change working group, and multiple meetings, trainings and workshops with this group to gather information about Saipan's vulnerabilities. An inventory of stakeholder resources was built. From there the working group participated in a series of workshops to map these resources and analyze their vulnerabilities. This information was then digitized in GIS in order to identify geographic focus areas within the community, and render the information compatible with the more technical side of the VA.

Technical Assessment

While the community-based VA process was underway, a series of SLR and SLC mapping layers were developed using GIS. These layers reflected possible coastal flooding scenarios based on previously modeled total water levels during typhoons and projected levels of future SLR. The data was used to help the working group visualize potential impacts of SLC, and also to analyze the types and amounts of land cover and land uses that could be impacted by the SLC scenarios.

The SLC analysis was accompanied by an attempt to assess the social vulnerability of Saipan's population. A social vulnerability index was built off of 2010 U.S. Census data and 2005-2009 American Community Survey responses, and the island's villages were assigned vulnerability values based off of the index. This assessment of social vulnerability was also constructed using GIS, allowing for comparisons of coastal flooding scenarios and the populations that would be most affected by these scenarios.

The cumulative product of this approach is an enriched perspective into the vulnerable populations, resources, and areas on Saipan that are of greatest concern to the community.

2. Community-Based Assessment

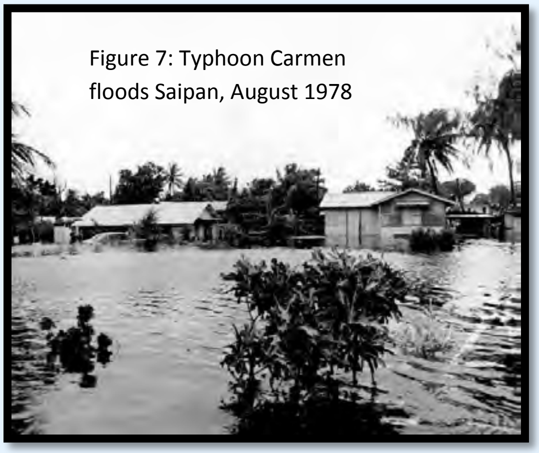


Figure 7: Typhoon Carmen floods Saipan, August 1978

In 1978, Saipan experienced severe flooding from Typhoon Carmen (Figure 7). While limited data is available concerning localized flooding extents or specific impacts that Carmen had on infrastructure, there are many members of the community that are able to vividly recall impacts to various areas of Saipan, and community responses to the storm. This type of knowledge, amassed over decades of experience with local climate phenomena and variability, amounts to a fundamental understanding of Saipan's exposure, sensitivity and adaptive capacities. This body of knowledge is precisely why community participation is crucial to a comprehensive assessment of vulnerability.

A strong foundation for participatory projects can be most successfully established where a diverse and motivated cross-section of the community is engaged. Such diversity allows for incorporation of a range of interests and expertise that is grounded in local context. The CNMI Climate Change Working Group (CCWG) represents the participatory foundation for the Saipan VA.

2.1. Climate Change Working Group

Introduction to the Working Group

The CCWG was originally conceived as a means of comprehensively addressing the issues and opportunities that climate change poses to the CNMI. The group is supported by funding from the NOAA's Coastal Zone Management Program (CZMP), therefore its focus is on climate change impacts and actions within coastal communities. Given that all communities within the CNMI are essentially "coastal", the CCWG has implemented no restrictions on participation, and has thus become an evolving collection of interests with few gaps in multi-sector engagement. The Saipan Fisherman's Association sits at the table with the Tinian Cattlemen's Association.

The CCWG first convened in June 2012, with participants from CNMI government agencies, federal agencies, and the CNMI legislature in attendance. The group was introduced to the concept of the CCWG, and the niches that their respective organizations could fill within the Working Group. Climate change, as a scientific phenomenon was a fairly new consideration to most CNMI organizations outside of natural resource management agencies, therefore several follow-up meetings were held in the following months to foster a more cohesive understanding of climate change science and relevance to the community. This included a three day training from NOAA's Coastal Services Center, "Climate Adaptation for Coastal Communities" (Figure 8), in which 31 participants were provided with the knowledge and tools to begin addressing climate change both within their professional associations, and as members of the CCWG. Materials from this training are available on the CCWG website (www.climatecnmi.net).

Equipped with a broad understanding of climate change and adaptation, the Working Group identified a need for a specific guiding purpose and set of CCWG goals.

Working Group Vision and Goals

Two meetings were held in August and September 2012 in which the CCWG established a set of goals for the group (Figure 9). These goals ranged from broad intentions to "build capacity" and "develop a unified approach" to more specific aims such as development of a vulnerability assessment. A vision statement was also crafted at the September meeting (Figure 10), primarily as a declaration of intent and purpose to interested members of the community or government.

Figure 8: NOAA climate adaptation training

Goals of the Climate Change Working Group

- To develop a unified CNMI plan and approach to climate change adaptation
- To facilitate inter-agency coordination and capacity building to address climate change
- To identify gaps in knowledge and provide technical resources for climate change assessment and planning
- To identify the communities, livelihoods, and ecosystems in the CNMI that are most vulnerable to climate change through development of a vulnerability assessment
- To coordinate a CNMI-wide community education and outreach strategy

Figure 9: Working Group Goals

CCWG Vision Statement

- The CNMI is ready and able to proactively adapt to climate change in order to maintain the integrity and resiliency of our communities and ecosystems. The community is aware of the threats posed by climate change, and is implementing a comprehensive adaptation plan to preserve our cultural, natural and economic resources for current and future use.

Figure 10: Working Group Vision

The goal to develop a VA provided key guidance during an initial growth phase of the CCWG. The VA represented a concrete product, with a variety of data needs and information sharing, thus effectively mobilizing the group into action. The simultaneous Working Group growth and VA-related activity also created a need for member roles and responsibilities, thus a participatory structure for the Working Group emerged.

Working Group Structure

The CCWG has a simple organization, shaped to provide direction for the group, as well as technical assistance. A planning committee, consisting of representatives from eight government agencies, serves as the key decision-making body. Staff from NOAA and CRMO provides technical guidance and facilitation for the planning committee. Three sub-groups, consisting of technical members of the Working Group, function as the primary means of data collection and coordination, and also serve as a hub for expertise and consultation. Figure 11 (below) illustrates the CCWG structure, as well as composition of the data sub-groups.

Data Grouping and Organizations		
Ecological	**Socio-Economic**	**Physical/Infrastructure**
NOAA	Commonwealth Ports Authority	Commonwealth Ports Authority
Division of Environmental Quality	Commonwealth Utilities Corporation	Commonwealth Utilities Corporation
National Park Service	Division of Environmental Quality (2)	Division of Environmental Quality (2)
Pacific Marine Resources Institute		
Division of Fish and Wildlife	CNMI Chamber of Commerce	CNMI Capital Improvement Projects
Coastal Resources Management Office		CNMI Public School System
		Department of Homeland Security - Emergency Management Office

Figure 11: Working Group structure and composition

2.2. Identification of Stakeholder Resources and Data Needs

Working Group Meetings

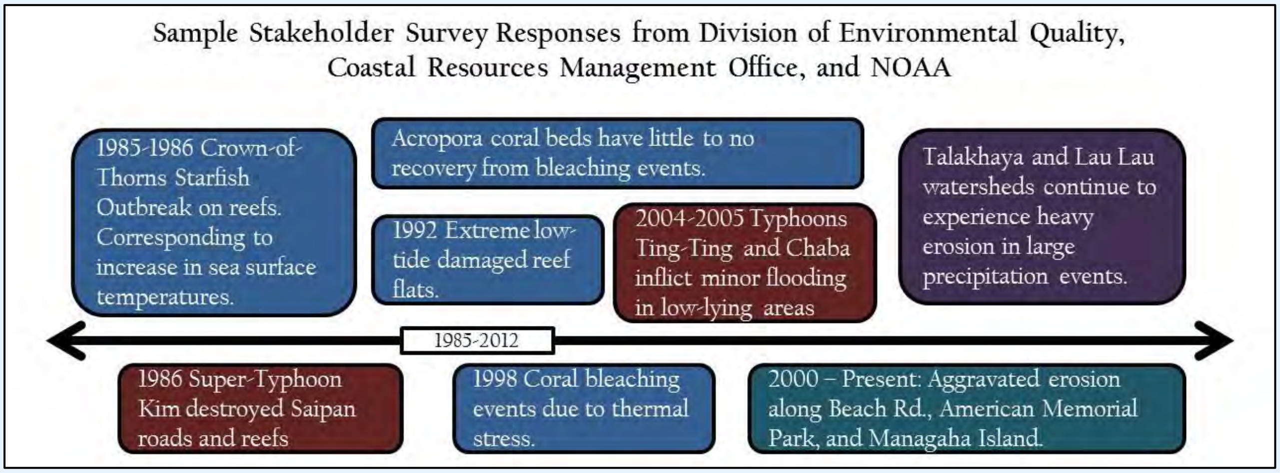
The initial phase of the VA involved a general identification and categorization of stakeholder resources. In the context of the VA, the term “stakeholder” refers to the 30+ government agencies, non-governmental organizations, community-groups and business associations that are actively represented in the CCWG, and usage of the term “stakeholder” itself has been adopted in spite of various semantic arguments over its appropriate application in participatory frameworks.

The CCWG held a series of meetings to identify stakeholder “resources of concern”, that is the infrastructure, facilities, services, social constructs and natural systems that each Working Group member entity manages. With over thirty stakeholders, a robust compilation of resources was expected; therefore several filtering and organizing tools were utilized.

Stakeholder Resources Survey

A survey was distributed to members of the CCWG planning committee and technical sub-groups in October 2012. The survey was intentionally broad, and posed open-ended inquiries into the members’ respective agency/organization missions, resources of concern, and observed impacts of climate phenomena on those resources (see Appendix C).

Figure 12: Sample stakeholder survey responses



Sample Stakeholder Survey Responses from Division of Environmental Quality, Coastal Resources Management Office, and NOAA

1985-1986 Crown-of-Thorns Starfish Outbreak on reefs. Corresponding to increase in sea surface temperatures.

Acropora coral beds have little to no recovery from bleaching events.

1992 Extreme low-tide damaged reef flats.

2004-2005 Typhoons Ting-Ting and Chaba inflict minor flooding in low-lying areas

Talakhaya and Lau Lau watersheds continue to experience heavy erosion in large precipitation events.

1986 Super-Typhoon Kim destroyed Saipan roads and reefs

1998 Coral bleaching events due to thermal stress.

2000 – Present: Aggravated erosion along Beach Rd., American Memorial Park, and Managaha Island.

This open-ended survey utilized a sort of snowball approach. Informants provided a wealth of narrative and information that resulted in an initial sample of resources of concern (Figure 12). In turn, this sample provided a baseline from which additional CCWG members could add resources to, or provide guidance in categorization. A second CCWG meeting was held in December 2012 to solidify an inventory of resources of concern, and sort those resources to facilitate data collection.

Resource Groupings and Data Requests

The CCWG grouped resources of concern into a hierarchical scheme, stemming from two primary categories: Bio-physical Environment, and Socio-Economic Resources/Infrastructure. These broad categories were broken into underlying systems, and individual resources were then placed as components of those systems. CCWG stakeholders were also grouped as a third tier according to the system (and associated resources) that the agency or organization addressed. The resource groupings are illustrated on the following page (Figure 13).

It should be noted that significant overlap exists in the stakeholder groupings within this resource inventory, and this served to strengthen the data collection process by providing multiple sources of information and expertise for individual resources.

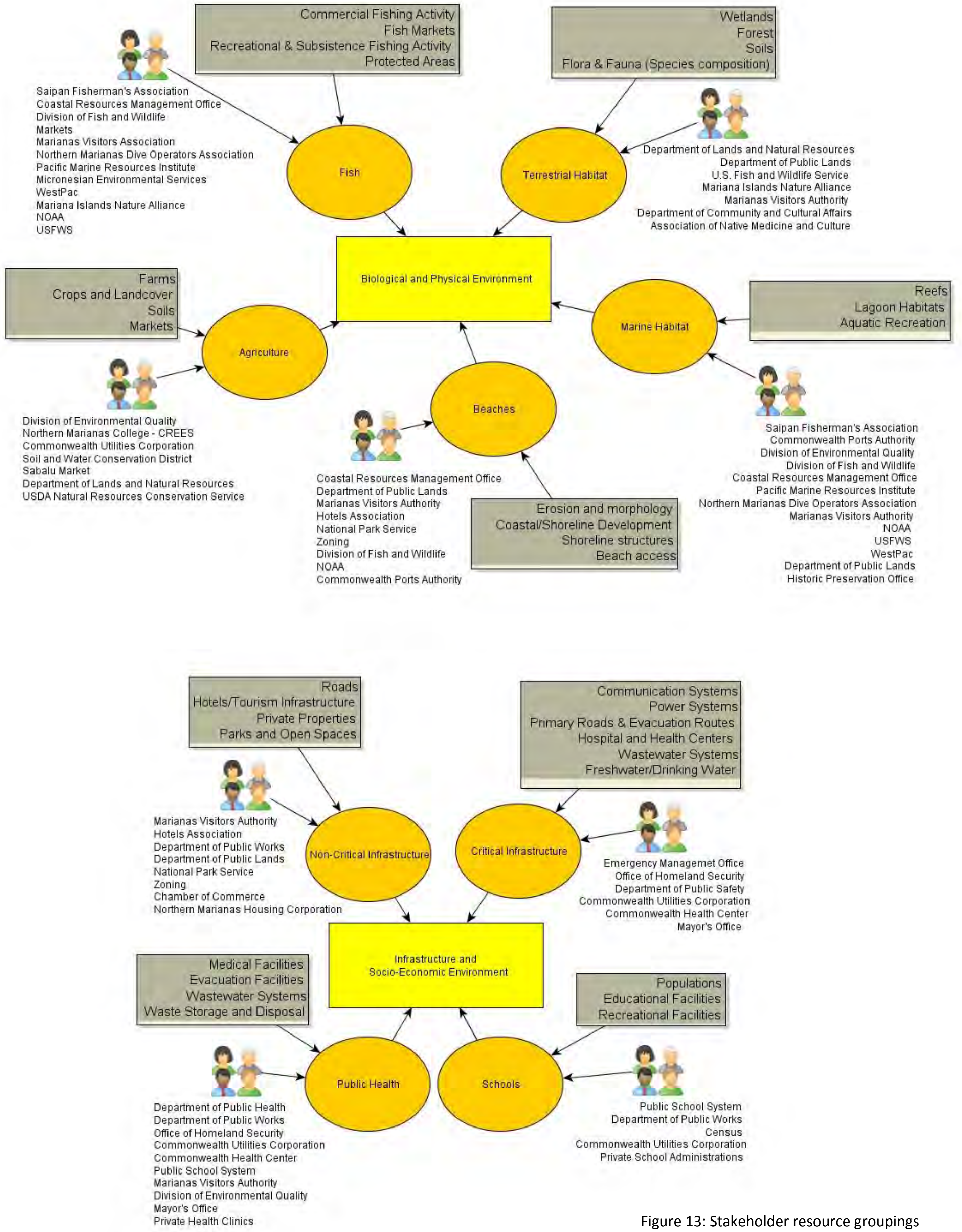


Figure 13: Stakeholder resource groupings

Due to the VA's use of GIS as a data organization and analysis tool, the key format for information requests was through spatial data. Requests were made for spatial data relating to each individual resource within the stakeholder inventory. Each CCWG technical sub-group (ecological, socio-economic, infrastructure) was leveraged as a data provider (see Appendix C). Where spatial data was unavailable, technical reports and associated data were requested, and inquiries were sent to additional data providers outside of the sub-groups (i.e. beyond those listed in the inventory).

This wide-ranging data collection effort provides the foundation for additional participatory activities to filter and screen resources for vulnerabilities. CCWG members now had a basis to geographically reference their collective knowledge about various resources, and associated data to support initial assessments of resource vulnerability.

The initial phase of the community-based assessment addressed the following questions:

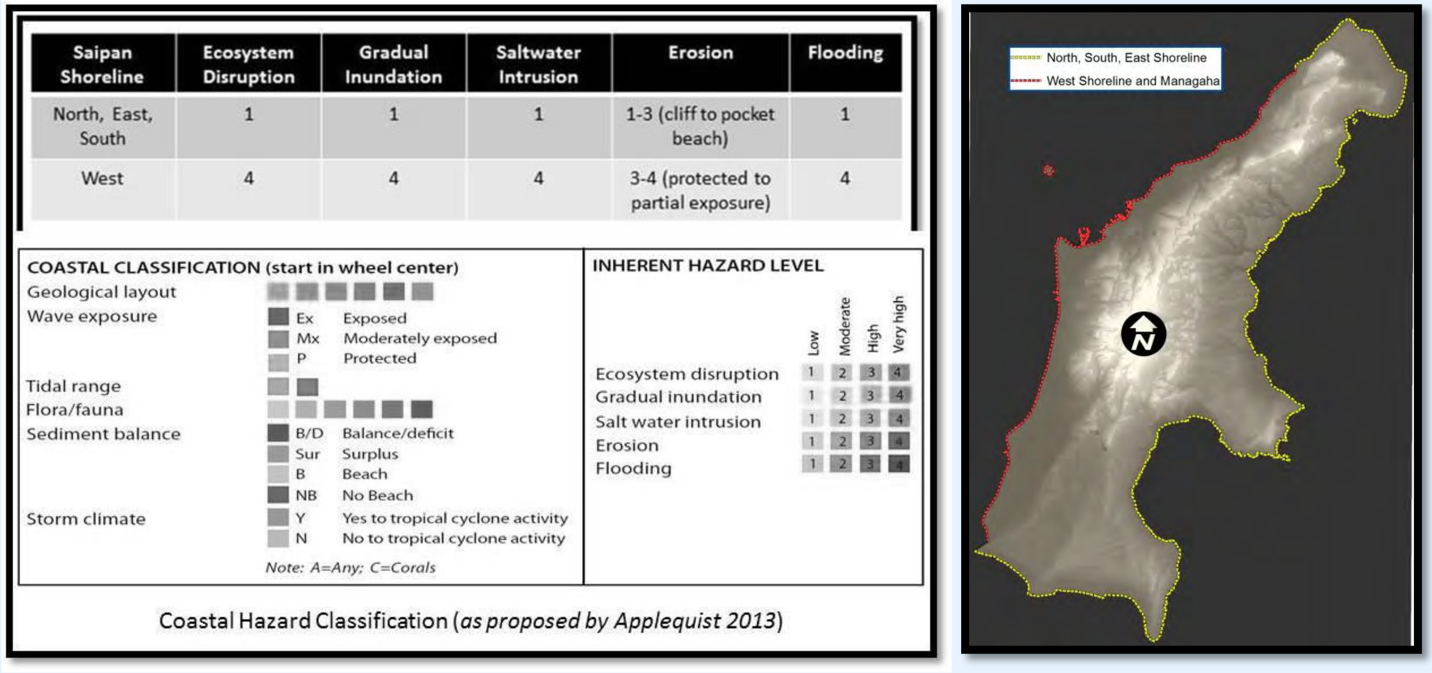
- **Who is concerned about climate impacts and climate change?**
- **What particular resources are they concerned about?**
- **Where are these resources located?**
- **Is there any information about past or current climate impacts on these resources?**

Collectively, the answers to these questions paint a picture of the current configuration and status of Saipan's most important (to stakeholders and the community) biological, physical and socio-economic features. Section 2.3 summarizes this picture.

2.3. Resources of Concern: Character and Configuration

Beaches and Shoreline

Saipan's beaches and shoreline can be classified in two morphological types and associated hazard levels. The north, east, and south sides of the island are dominated by exposed, rocky cliffs and bluffs, with scattered, small pocket beaches. A few exceptions to this shoreline type exist on the south side of the island, notably at Obyan Beach and Coral Ocean Point Beach. These two beaches, along with the remainder of Saipan's west coast and Managaha Island are characterized by low to moderate sloping sand/coral beaches with a fringing reef and shallow lagoon offering varying degrees of protection. Application of a generic coastal hazard typology (Applequist 2013, Appendix D) suggests low hazard levels for Saipan's north, south and east shoreline, and moderate-very high hazard levels on Saipan's west side (Figure 14).



Saipan Shoreline	Ecosystem Disruption	Gradual Inundation	Saltwater Intrusion	Erosion	Flooding
North, East, South	1	1	1	1-3 (cliff to pocket beach)	1
West	4	4	4	3-4 (protected to partial exposure)	4

COASTAL CLASSIFICATION (start in wheel center)

Geological layout

Wave exposure: Ex Exposed; Mx Moderately exposed; P Protected

Tidal range

Flora/fauna

Sediment balance: B/D Balance/deficit; Sur Surplus; B Beach; NB No Beach

Storm climate: Y Yes to tropical cyclone activity; N No to tropical cyclone activity

Note: A=Any; C=Corals

INHERENT HAZARD LEVEL

	Low	Moderate	High	Very high
Ecosystem disruption	1	2	3	4
Gradual inundation	1	2	3	4
Salt water intrusion	1	2	3	4
Erosion	1	2	3	4
Flooding	1	2	3	4

Coastal Hazard Classification (*as proposed by Applequist 2013*)

Figure 14: Inherent hazard levels for Saipan coastline

These hazard profiles are consistent with stakeholder input and community narrative concerning past impacts to shoreline from typhoons and erosion processes.

Significant physical modification of the shoreline has occurred in the Garapan area and Managaha Island due to natural processes (Fletcher et al. 2007, U.S. Army Corps of Engineers 2004), economic activities (tourism, fishing access, port commerce), and historical alterations to World War II-era military structures (Dean 1991). These modifications, along with removal of submerged and partially submerged structures, have influenced localized shifts in coastal processes, particularly erosion and accretion patterns in Garapan and on Managaha Island.

In considering observed shoreline changes and the climate variables driving them, it is likely that Saipan's shoreline morphology will have an overwhelming influence on spatial variation of climate change impacts, particularly those associated with SLC and changing wave environments. The west-facing shoreline of Saipan will face more daunting challenges than other areas of the island, as it has in the past. This is complicated by the fact that the majority of Saipan's population and associated village services are situated along the west shoreline of the island, with a few exceptions (Figure 15).

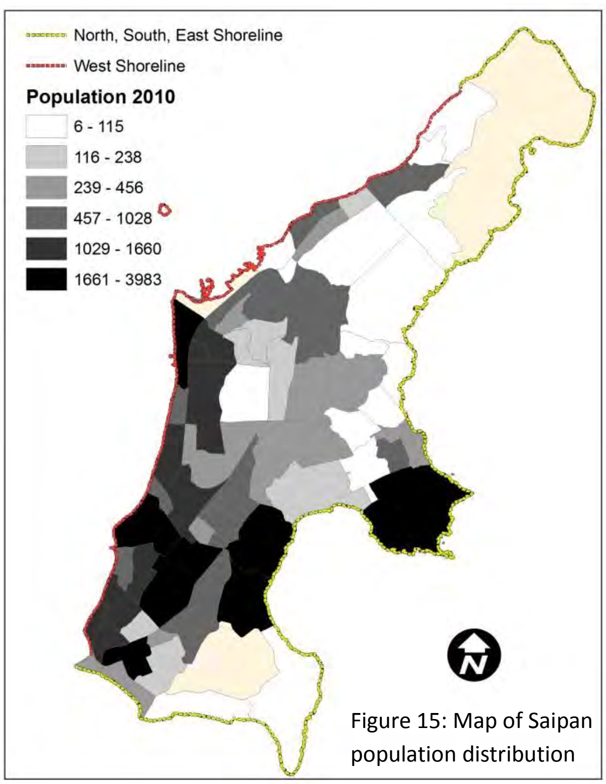


Figure 15: Map of Saipan population distribution

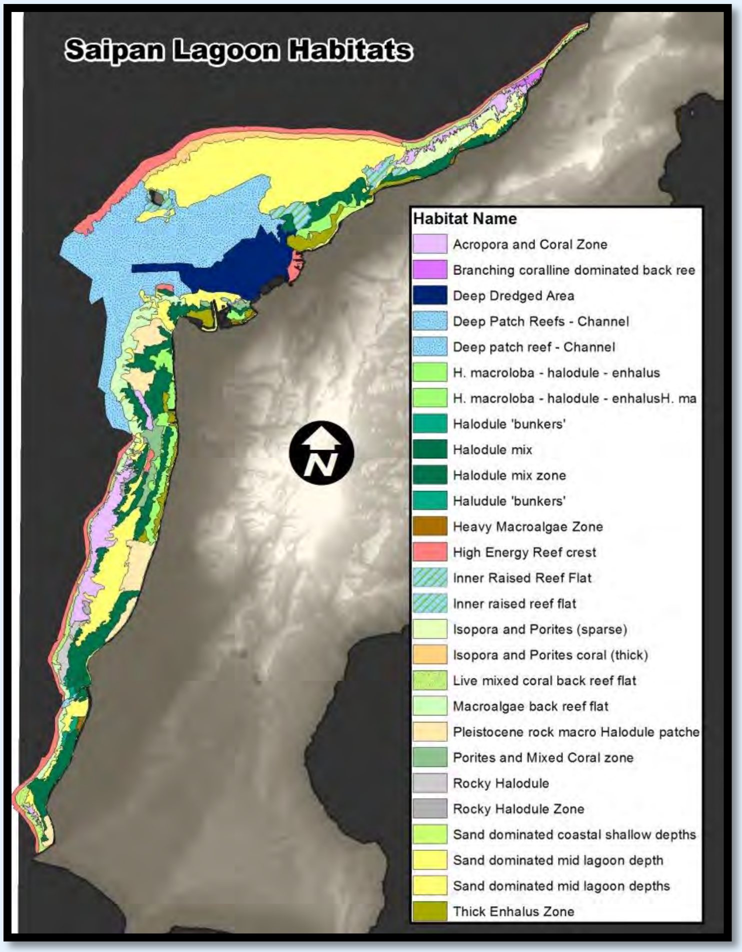


Figure 16: Map of Saipan lagoon habitat

Informed by local knowledge of Saipan's shoreline characteristics and observed changes, the CCWG highlighted specific areas to focus VA efforts. These locations include shoreline that is significant to the tourist sector, shoreline with high concentrations of residential parcels, and beaches that play important ecological roles. These areas are detailed in section 2.5 (Participatory Mapping).

Marine Habitat and Corals

The marine habitats and reef systems around Saipan comprise what is perhaps the most dynamic and significant resource for the island (Figure 16). The ocean environment is indispensable as a source of Saipan's tourist economy, cultural tradition, and biological health, and this significance is reflected in the amount of research and management efforts devoted to surrounding waters.

However, the overwhelming value placed on marine resources does not make their study in the context of climate change any less complex. The biological communities in Saipan's surrounding waters respond strongly to a number of factors that are influenced both directly and indirectly by climate variables. Sediment loads from stormwater runoff, nutrients and land-based pollution, turbidity, and even variable wave energy/surge can impact the structure and health of marine habitat and communities.

For the purpose of understanding the factors contributing to vulnerability (e.g. exposure, sensitivity), comprehension of local habitat variation and response to the impacts of various climate variables is paramount.

Variation in coral health and resilience exists along Saipan's fringing reefs, with those within or in close proximity to Saipan lagoon experiencing particularly high impacts from both anthropogenic and climate stressors (Maynard et al. 2012). Both richness and abundance of coral species are quite sensitive to land based pollution, with measures of population density and watershed development on both west and east sides of the island closely related to coral community health (Starmer et al. 2008, Maynard et al. 2012).

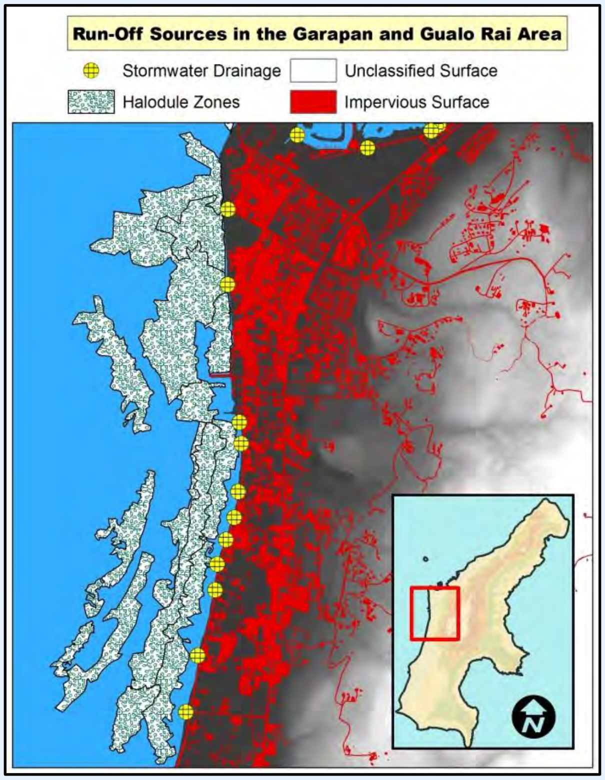


Figure 17: Map of seagrass beds and stormwater run-off outlets

Seagrass beds also play a vital role in the biological communities in Saipan's lagoon. In some parts of the lagoon, *Halodule* beds may provide a valuable service as a buffer for beaches from increased wave energy and potential coastal erosion (Dean 1991), and on a larger scale the sea grass acts as a carbon sink, helping (in a limited capacity) to counteract ocean acidification trends (Kennedy et al. 2010). Relationships have been observed between the extent and health of different *Halodule* beds around Saipan and the degree and density of development in corresponding watersheds (Houk & van Woesik 2008), and some members of the community were able to pinpoint areas with the greatest change in benthic cover and composition.

Over the past 50 years, there has been a general decline in the extent of Saipan Lagoon coral habitat, and an increase in algae habitat (as a result of watershed discharge and associated nutrients). It is apparent that habitat within Saipan's lagoon, especially in near-shore shallow areas, is impacted most heavily by watershed factors and anthropogenic stresses (Figure 17). Meanwhile, periodic increases in SSTs over the years have resulted in high mortality rates within back reef coral systems. Thus two climate-related variables, precipitation (and run-off) and SSTs, have demonstrated implications for Saipan's marine habitat vulnerability. Other indicators of climate change will undoubtedly pose additional concerns, particularly SLC, shifting wave environments, and ocean acidification (the "elephant in the room" according to one local marine biologist).

As with many climate change vulnerability considerations, adequate assessment requires coupling of natural climate disturbances and changes with more immediate human-based threats. This concept is elaborated on through a discussion of relative reef resilience and its implications for vulnerability (section 3.4).

Land Cover, Terrestrial Habitat and Wetlands

Saipan's marine habitats garner much well-deserved attention, yet a complete understanding of the marine ecosystem is not possible without a clear picture of terrestrial influences on that system, particularly the impacts that land cover and habitat configuration have on watershed qualities. Saipan's watershed-focused Conservation Action Plans (CAPs) for Lao Lao Bay (2009) and Garapan-West Tapochau (2013) emphasize this linkage, directly addressing sources of stormwater run-off and the role of land-cover. While impervious surfaces function as the primary culprit for run-off in the low-lying developed tourist areas and villages (e.g. Susupe, Beach Road), semi-*pervious* surfaces, in the form of coral and gravel roads in the upland areas, transform into conduits for large volumes of run-off during precipitation events. According to one CCWG participant, the coral roads are “Saipan’s river system”.

Cleared land in the upper watersheds also yields significant sediment loads during heavy precipitation events. CCWG participants were quick to mention the issues that specific clearings posed for run-off in particular sub-watersheds and select reefs. Much of the upland areas of the island are dominated by either mixed-introduced forest, or a patchwork of agricultural, scrub-shrub, or cleared grassland areas. These areas are generally zoned as “rural”, and as such may involve small livestock operations and agricultural practices that may lead to contamination of both groundwater and surface run-off. Piggeries have emerged as a topic of concern to some CCWG participants as a few isolated operations are not buffered from adjacent drainages. With potential for more extreme precipitation events and/or droughts in the CNMI’s future, the issue of run-off was not taken lightly by Working Group participants.

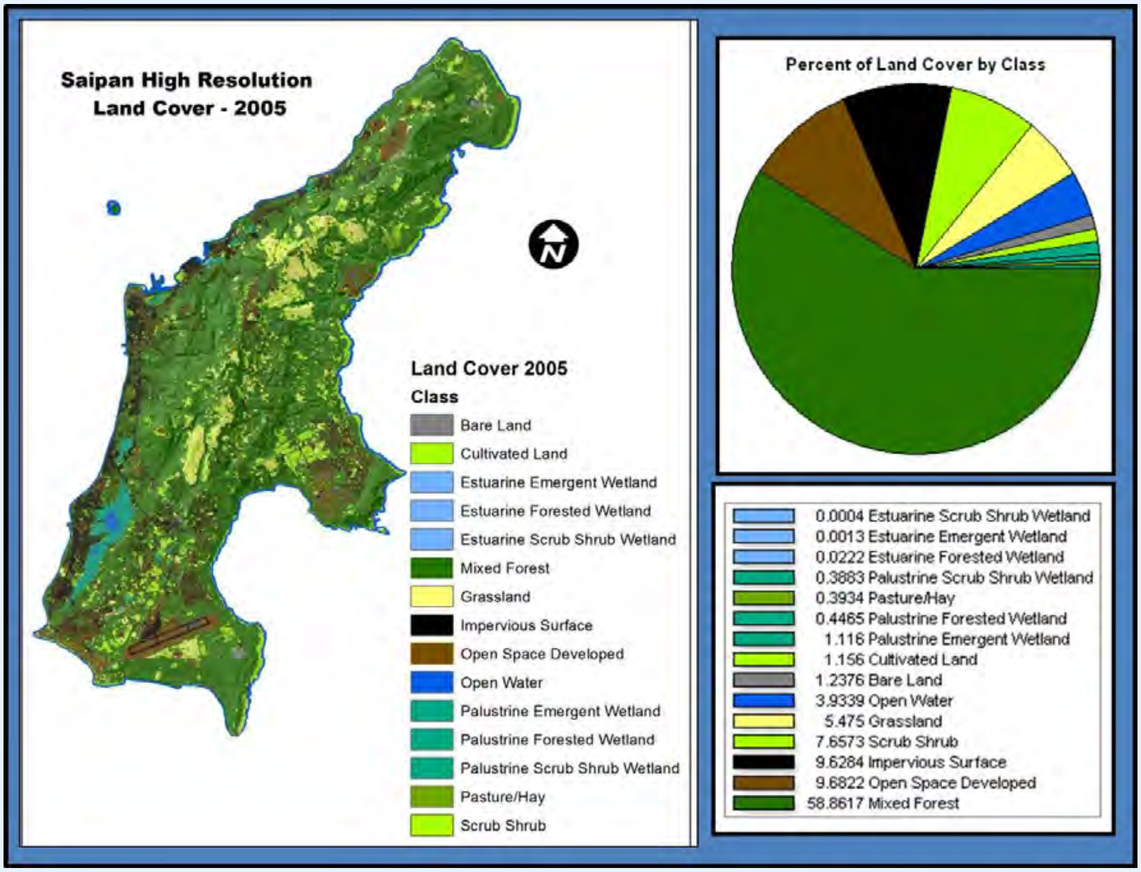


Figure 18: Map of Saipan land cover

The Working Group and community members also expressed concern over what climate change impacts may be felt within the small, fragmented remains of native limestone forest and mangroves. Immediate threats to native forest posed by invasive species and anthropogenic influences (development, agro-forestry, unintentional species introductions, and land cover change) may place this feature on the table for more short-term assessments and management. However, the wetlands and mangrove habitat of Saipan are a primary concern as the hydrological features underlying and surrounding the wetlands may be quite sensitive to changes in sea level, salinity, and sedimentation.

Within American Memorial Park, a 35 acre complex of estuarine wetlands and palustrine secondary forest contain the largest remaining patches of mangroves on Saipan (Williams et al. 2007). These mangroves were noted by CCWG participants as inherently valuable for their ecological role as an estuarine transition habitat, and as one of the few remaining native habitats on Saipan. However, it is their potential to mitigate climate change through extremely efficient carbon sequestration (Gilman et al. 2008), as well as their possible role in adaptation to reduce exposure to SLC and changing wave environments (Spalding et al. 2013, Duarte et al. 2013) that gives Saipan’s mangroves significant added value.

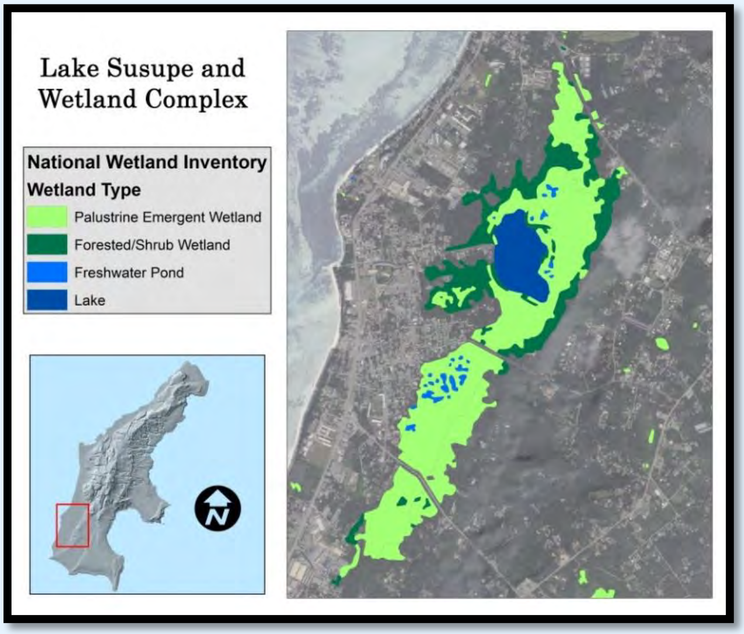


Figure 19: Map of Lake Susupe and surrounding wetlands

The CCWG also highlighted the large palustrine wetland complex surrounding Lake Susupe (Figure 19) as a resource of concern. This area, covering roughly two square kilometers adjacent to Susupe and Chalan Kanoa villages, provides valuable services as critical bird habitat, and in stormwater catchment, allowing for infiltration and significant groundwater recharge.

The lake and surrounding wetlands present potential implications in the context of climate change. The lake is slightly brackish, and directly connected to the island's basal lens, causing some concern about saltwater infiltration and shifting of suitable salinity levels in the wetland system. The low-lying wetlands are also prone to short-term flooding during large precipitation events, and threats posed by SLC have given rise to inquiries among the Working Group about increased flood frequencies and extents. The lake and wetlands' proximity to densely populated areas, high-volume traffic routes, and drainages to the lagoon make the entire feature a paramount concern for multiple stakeholders and community members.

Critical and Non-Critical Infrastructure

Saipan's infrastructure may best be thought of as a patchwork of systems, with coverage, reliability, and modernization varying across different villages and sections of the island. CCWG participants from the Commonwealth Utilities Corporation (CUC) noted that periodic updates to existing infrastructure (especially wastewater) have left some features in good condition, while others remain antiquated. This range of conditions makes an assessment of the factors contributing to vulnerability quite complex.

Saipan's road system demonstrates this complexity quite well, with roads and streets frequently shifting between newly-paved stretches and dilapidated sections. In 2012 a particularly troublesome pothole in Garapan made the front page of the newspaper, begging attention to the degraded condition of some streets. Substantial, long-term increases in both sea level and extreme precipitation events have the potential to exacerbate many of the problems with Saipan's road system, placing long-term stresses on island circulation, and in some scenarios cutting off access to basic resources.

The CCWG was particularly concerned with stretches of Beach Road that routinely flood during heavy precipitation events, and portions of that road that have been damaged or threatened by coastal erosion and storm surge in the past. Other streets in the Lower Base–Tanapag area were noted for their tendency to flood, and secondary streets in upland areas that are composed of gravel and/or coral were also pinpointed for erosion issues. Unfortunately both Beach Road and the Lower-Base area overlap with key corridors that the CNMI Comprehensive Highway Master Plan (1997) has identified as priority transportation routes. According to the Plan, the most important long-range transportation priority for the island of Saipan is the preservation of two key transportation routes: (1) Maintaining circulation among tourism activities, especially between the airport and resort locations along Beach Road and in Garapan, and (2) continuing to maintain or enhance corridors serving freight movement from the cargo terminals in Lower-Base/Tanapag Harbor to distribution points around the island.

Power facilities and associated transmission systems also suffer some precarious placements with respect to topography, and exist in states of varying condition, with demonstrated susceptibilities to unexpected and undesirable weather. CUC operates an integrated system, consisting of three diesel generation facilities that supply much of the island's power. In 2010 the installed capacity on the island was 98.2 MW, however, only 61.7 MW was operational. In situations where operational power levels are lower than normal, or weather has disrupted some services, temporary blackouts are not uncommon, and in the past have been scheduled on a rotating basis through the island's villages. Past experiences with "rolling blackouts" were sufficient to sustain CCWG participant concerns over future conditions.

Saipan's water supply systems were also of great concern to some CCWG participants. On the island of Saipan, freshwater is derived primarily from deep wells and springs. The CUC operates 145 wells on Saipan, one spring, and a rainwater catchment facility. Water is pumped to reservoirs where the water is treated as chlorinated groundwater or spring water (infused with chlorinated groundwater). Unfortunately many wells are subject to threats of contamination, with increased threat levels during extreme precipitation events. The most prevalent contamination sources are from inorganic contaminants (salts and metals from stormwater runoff, discharge from septic tanks, or industrial wastes); organic chemical contaminants (volatiles from gas stations, septic systems, and stormwater runoff); microbial contaminants (bacteria, viruses and protozoa derived from sewage treatment plants, agricultural livestock, and septic systems); pesticides and herbicides (discharge from agricultural operations, stormwater runoff, or residential users of such chemicals); and radioactive contaminants (can be naturally occurring from gas operations or mining) (See Appendix and 2010 CNMI Standard State Mitigation Plan).

In the context of climate change, Saipan's potable water wells, freshwater supply, and their vulnerability to shifts in both precipitation and sea levels are of major concern. The inland limestone aquifers and freshwater lens have demonstrated responses to changes in precipitation patterns. In the past, the thickness of the freshwater lens changed at select monitoring wells as a result of seasonal recharge and a drought. Freshwater thickness decreased by about 10 to 12 ft. at some of the wells after a period of significantly less than average rainfall associated with the 1997-98 El Niño. Meanwhile, non-tidal fluctuations in sea levels due to the same El Niño event caused changes in freshwater levels among wells located on Saipan's coastal plain (Caruth 2003). CCWG members suggested future study of the potential impact of projected regional SLC on well uptake and chloride levels. Existing issues with saltwater-intrusion into wells have already been noted at several locations on the island. This intrusion can occur without the influence of SLC or drought conditions, triggered by prolonged pumping of water near the saltwater/freshwater transition zone and excessively deep intake (Figure 20, Caruth 2003). Adjustment of well intake and updates to existing well infrastructure may solve some issues associated with saltwater intrusion; however these modifications must compete for priority with updates to other water infrastructure such as Saipan's wastewater system.

Figure 20: Diagram of saltwater intrusion on freshwater wells

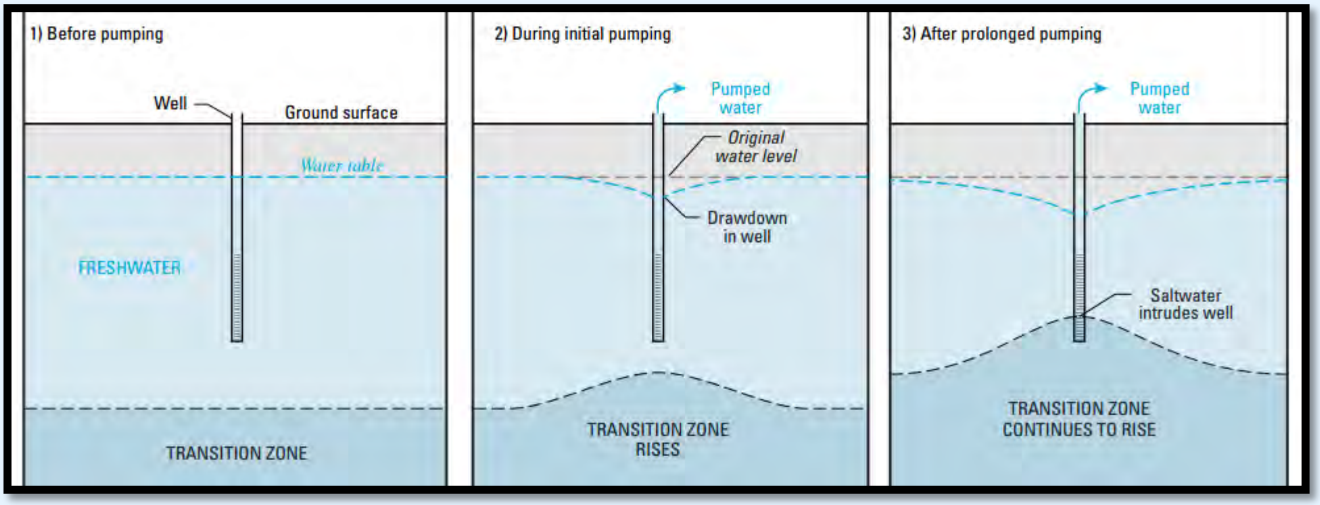
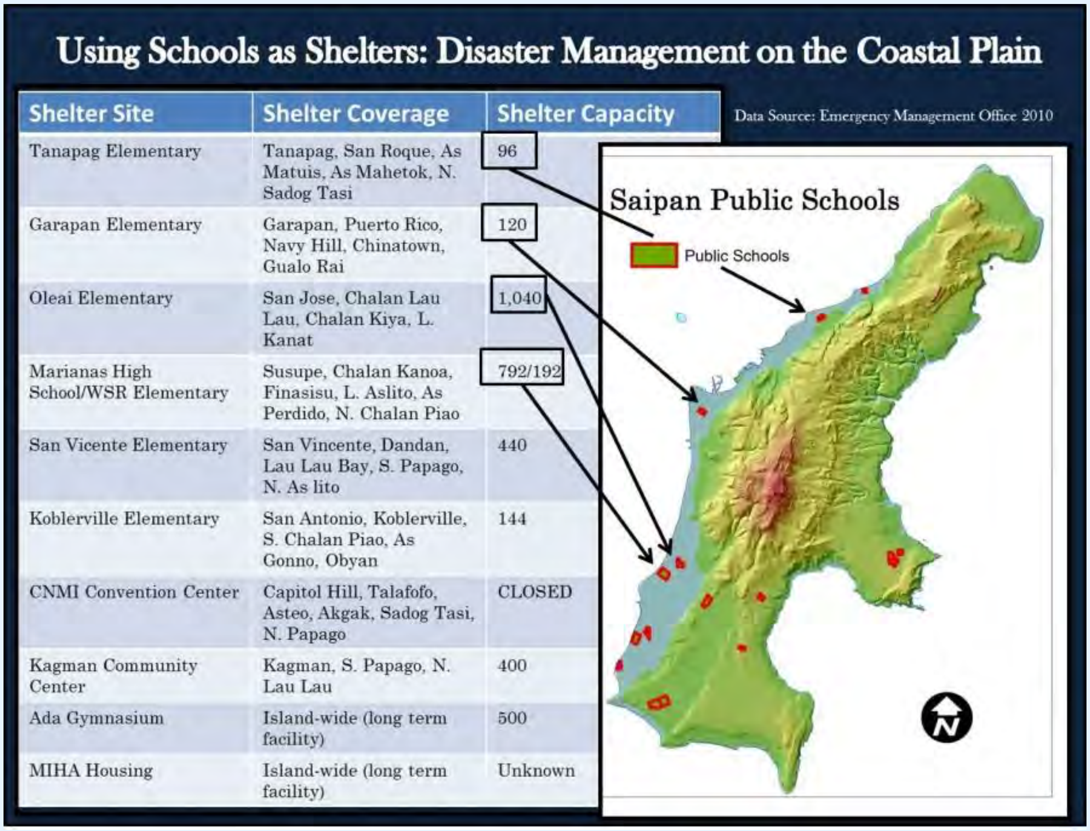


Figure sourced from USGS Water-Resources Investigation Report 03-4178

Wastewater systems on Saipan vary widely with respect to system type and level of compliance with DEQ regulations. Wastewater is provided with secondary treatment in DEQ regulated facilities. Private and commercial users not served by municipal sewer lines are required to have an approved and permitted on-site wastewater treatment system, however this has caused problems around the island where many families are only able to afford latrines or individual waste disposal pits. In addition, facilities that generate more than 5,000 gallons per day of wastewater are not allowed to install a traditional septic system, but the more advanced systems are sometimes prohibitively expensive. Some CCWG members suggested that climate change impacts could lead to complications with non-compliant waste disposal systems, allowing for potential groundwater contamination.

CUC and DEQ have reported additional issues of concern with the municipal wastewater system, including a lack of funding to extend the existing wastewater system and to afford the regular maintenance of lift station pumps, as well as the seepage of rainfall into the collection systems during heavy precipitation events (EMO 2010). The wastewater system in Garapan is a topic of ongoing concern as certain areas contain crumbling infrastructure, requiring ongoing updates to wastewater lines and lift stations. CCWG members were quick to point out the occasional olfactory assaults that come with a dysfunctional wastewater system. As history has repeatedly demonstrated, ineffective transfer of waste (and accompanying periodic stenches) through municipal water systems often translate into a significant public health hazard. Garapan's low-elevation profile compounds the potential for such hazards to manifest. Under extreme SLC scenarios, both short (storms) and long-term (CC-induced), wastewater systems will be susceptible to hydrologic complications and back-ups from coastal inundation. An outbreak of water-borne health consequences from such a scenario would expose Saipan's medical infrastructure to significant stresses.

The primary medical facilities on Saipan are limited to one public facility and several full-service private clinics. The Commonwealth Health Center (CHC) is a 156,000 square foot, two-level Medicare certified unit that accommodates 74 inpatient beds, 4 adult ICU beds, auxiliary services, extensive outpatient facilities, public health offices and clinics. As of 2010 CHC had a staff of about 45 doctors, 150 nurses, and a well-equipped inpatient pharmacy. Staff numbers and tenure has seen drastic fluctuations in recent years due to administrative changes and funding circumstances. The primary concern that CCWG participants noted with CHC (aside from issues with service reliability) was its single location and proximity to flood-prone areas of Garapan and Middle Road. While access to the facility is limited in some cases by cultural and financial barriers, the potential for physical access to be blocked also exists. Both entrances to the facility require passage through one of the lowest-lying stretches of Middle Road. Under disaster scenarios (e.g. Typhoons), additional medical services can be called into action through the EMO and Red Cross. The public has the option of using evacuation centers and disaster recovery centers (DRC) as a means of coping with disasters such as Typhoons, however, CCWG participants noted potential issues related to coastal flooding with several of the large-capacity shelters (Figure 21). These particular shelters also happen to be schools, thus intensifying concerns of flooding at these locations. This expanded the range of flooding threats from isolated disaster management situations to the daily operation of elementary and high schools. Even though some of the schools and DRCs


Using Schools as Shelters: Disaster Management on the Coastal Plain

Data Source: Emergency Management Office 2010

Shelter Site	Shelter Coverage	Shelter Capacity
Tanapag Elementary	Tanapag, San Roque, As Matuis, As Mahetok, N. Sadog Tasi	96
Garapan Elementary	Garapan, Puerto Rico, Navy Hill, Chinatown, Gualo Rai	120
Oleai Elementary	San Jose, Chalan Lau Lau, Chalan Kiya, L. Kanat	1,040
Marianas High School/WSR Elementary	Susupe, Chalan Kanoa, Finasisu, L. Aslito, As Perdido, N. Chalan Piao	792/192
San Vicente Elementary	San Vincente, Dandan, Lau Lau Bay, S. Papago, N. As lito	440
Koblerville Elementary	San Antonio, Koblerville, S. Chalan Piao, As Gonno, Obyan	144
CNMI Convention Center	Capitol Hill, Talafofo, Asteo, Akgak, Sadog Tasi, N. Papago	CLOSED
Kagman Community Center	Kagman, S. Papago, N. Lau Lau	400
Ada Gymnasium	Island-wide (long term facility)	500
MIHA Housing	Island-wide (long term facility)	Unknown

Figure 21: Map of Saipan's emergency shelters in low-lying areas

may be situated at reasonably safe elevations, the streets and corridors used to access them can be cut off due to localized flooding along critical stretches.

Saipan's seaport facilities face similar challenges, being located in an extremely low-lying area with access corridors occupying the lowest points on Saipan's road system. CCWG participants suggested that the Port was by far one of the most integral assets for Saipan's economic and social well-being, and simultaneously one of the most exposed resources to changing ocean conditions.

The Port of Saipan is part of a high concentration of industrial-sector operations and crucial services, including the adjacent Exxon-Mobil Tank Farms, which collectively demand a detailed assessment of vulnerability. The dock is over 1,000 feet long and has a capacity of three large cargo vessels (250-300 feet long) that can be docked simultaneously. The port facility features 2,600 linear feet of berthing space, a 22-acre container yard, a water line, an underground fuel line protected by a concrete vault, and an underground sewage removal system. The channel, turning basin, and berthing areas have been widened and deepened to a uniform -40 feet to support medium to deep draft vessels into port, further enhancing facility services. This entire complex is partially exposed to wave and surge action during periods of southwest swell and storm conditions. The ship channel is oriented toward the west-southwest (leaving the docking facilities), and any prolonged extreme wave event associated with a passing typhoon or shift in wind conditions could impact the Port.

The resources and assets that were summarized in this section provide a quick glimpse into the stakeholder's landscape. Throughout the years naturally occurring processes and climate variables have had impacts on a variety of stakeholder resources. CCWG members were able to draw out the linkages between past impacts and future vulnerabilities, and this was reflected in the Working Group's selection of resources of concern. Where CCWG participants placed particular emphasis on specific features, this section attempted to summarize them. However, a more detailed portrait of the configuration and condition of stakeholder resources is warranted. Unfortunately that endeavor is outside the scope of this document. The following sections (2.4 & 2.5) detail a vulnerability "screening" process that CCWG members used in making their initial assessment.

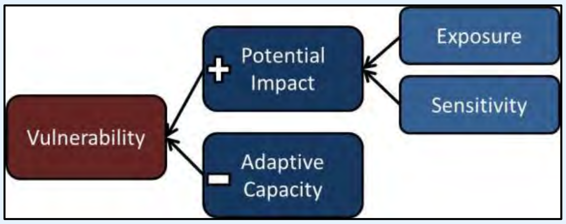
2.4. Qualitative Vulnerability Screening

PIMPAC Training and Vulnerability Assessment

In March 2013, the Pacific Islands Managed and Protected Areas Community (PIMPAC) facilitated a training for 31 members of the CCWG with a dual focus on outreach and assessing vulnerability. The training was tailored to incorporate all CCWG work up to that point, and assist the group in transitioning from an information-gathering phase into actual assessment of resources. To this end, three days were spent applying a vulnerability formula (Figure 22) and assessment process to the Working Group's stakeholder resource inventory, with the Garapan area as a focal point for resource assessment.

Figure 22: Definitions and formula for assessing vulnerability

Definitions and formula as defined in the Micronesia Conservation Trust's *Guide to Vulnerability Assessment*, detailed by Marshall et al. (2009), and adopted more generally by the IPCC (2001, 2007).



Vulnerability: The degree to which a human or natural system is susceptible to, or unable to cope with, adverse effects of climate change. This is a function of exposure, sensitivity, and adaptive capacity.

- **Sensitivity:** The degree to which a built, natural, or human system is negatively affected by changes in climate conditions or specific climate change impacts.
- **Exposure:** The extent to which a system comes into contact with climate hazards or specific climate impacts.
- **Potential Impact:** The cumulative effects of exposure and sensitivity
- **Adaptive Capacity:** The potential capability of built, natural, and human systems to adapt to impacts of climate change with minimal potential damage or cost.

This assessment was built off a framework detailed in Micronesia Conservation Trust's *Guide to Vulnerability Assessment and Local Early Action Planning* (2012). The assessment process was originally designed for developing island communities lacking technical resources or capabilities, therefore its application by the Saipan CCWG is best understood as a screening exercise in which Working Group members were able to practically apply the concept of vulnerability.

To complete a qualitative vulnerability assessment, the group developed a list of 4-5 priority targets out of the stakeholder inventory. The targets where chosen keeping in mind the availability of experts in the room. The group decided to focus on the following targets:

- Fresh Water Resources
- Fish/Marine Ecosystems
- Coastlines/Beaches
- Water Systems/Infrastructure (both stormwater and wastewater)

The CCWG formed breakout groups based on target resources and respective areas of expertise, and conducted a field-based assessment targets considering the following:

- Current condition of the target
- Non-climate threats and root causes of those threats
- Existing and potential climate hazards that could impact the target
- Exposure, Sensitivity, Potential Impact, Adaptive Capacity and Vulnerability of the target to climate hazards
- Vulnerability of the community to potential changes in the resource (particularly highly vulnerable resources)
- Actions that could be taken to reduce vulnerability or prevent future vulnerability of the resource target or community

Results of this assessment are summarized in the following pages.

Qualitative Vulnerability Assessment Results:

TARGET	Current Status of Target	Threats (non-climate)	Root Causes of Non-Climate Threats	Climate Events	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Resource Vulnerability	Community Vulnerability
Coastline	20 years ago: fair - but constantly changing 10 years ago: poor - but constantly changing Now: fair - but constantly changing Changes are due to natural sea level fluctuations and erosion processes, possible influence of removed structures from lagoon	Removal of offshore structures or dredging that impacts sediment budget & transport Intensive recreation	Engineering to aid navigation Possible tourism incentives (aesthetics)	Sea level change Extreme events (storms)	All - 90-100%	High/Severe - the target area is already impacted by natural climate variations	High - the resource is fully exposed and unprotected and shoreline is highly sensitve	Medium/Low: There is high capacity to inform adaptation actions through research, but rehabilitation, relocation and structural solutions are difficult due to: 1) money, and 2) cross jurisidctional decision making. The resource in iteself adapts to changes. In the past this has been acceptable and community has adapted. Sea level change could complicate this.	High: Based on answers to other questions this resource has a high vulnerability. There is potential for adaptive capacity to increase, especially if "soft engineering" solutions look feasible in a 20 year time frame	High: If future changes impact or limit tourism infrastructure there is a high vulnerability

TARGET	Current Status of Target	Threats (non-climate)	Root Causes of Non-Climate Threats	Climate Events	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Resource Vulnerability	Community Vulnerability
FISH	20 years ago: fair 10 years ago: poor Now: fair	Fishing Pressure Water Quality	Population Increase Depressed Economy Unsustainable Coastal Development	1. Sea Surface Temperature - impact on life cycle, habitat, seagrass ecology, coral bleaching	1. all	1. moderate	1. high	1. low	1. high	1. medium
				2. rainfall changes - habitat degredation, poor water quality	2. all	2. moderate	2. high	2. medium	2. medium	2. medium
				3. extreme weather - damage to coral, poor water quality	3. most	3. moderate	3. high	3. medium	3. medium	3. medium
				4. ocean acidification- habitat degredation, coral life history, seagrass life history	4. all	4. moderate	4. high	4. medium	4. medium	4. medium
				5. sea level rise - change in currents, coral can't photosynthesize	5. most	5. moderate	5. high	5. medium	5. medium	5. medium

TARGET	Current Status of Target	Threats (non-climate)	Root Causes of Non-Climate Threats	Climate Events	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Resource Vulnerability	Community Vulnerability
Infrastructure- wastewater	Now: fair and improving	Age of pipes/material Deterioration Saltwater infiltration Leaks in Pipes	lack of funding illegal connections lack of prosecution stuck with judicial system Mismanaged facility	sea level rise rain events storms extreme weather	Moderate	severe	high	medium	medium	high - due to health hazards

TARGET	Current Status of Target	Threats (non-climate)	Root Causes of Non-Climate Threats	Climate Events	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Resource Vulnerability	Community Vulnerability
Infrastructure - stormwater	now: poor to fair and deteriorating	lack of maintenance sand and water blockages poor design pollution from sewage	lack of funding lack of capacity to maintain confusion over whose mandate it falls undere lack of awareness and prioritization people don't see it as a problem	sea level rise increased rain events extreme weather	All	moderate	high	medium	medium	medium

TARGET	Current Status of Target	Threats (non-climate)	Root Causes of Non-Climate Threats	Climate Events	Exposure	Sensitivity	Potential Impact	Adaptive Capacity	Resource Vulnerability	Community Vulnerability
Drinking Water Resources	20 years ago: fair/good 10 years ago: fair/good now: fair/poor	exploitation overuse theft contamination	lack of funding low levels of awareness lack of enforcement apathy	sea level rise - intrusion due to changes in water table storms: damaged systems	High	Moderate	high	medium	medium	high
					sea level rise - frequent storms - sometimes rainfall - frequent	high impact in the past		The resource is not self-adaptive Has a fair amount of adaptive capacity provided there is effective management		high dependence - everyone needs water - fair/low adaptive capacity

2.5. Participatory Mapping

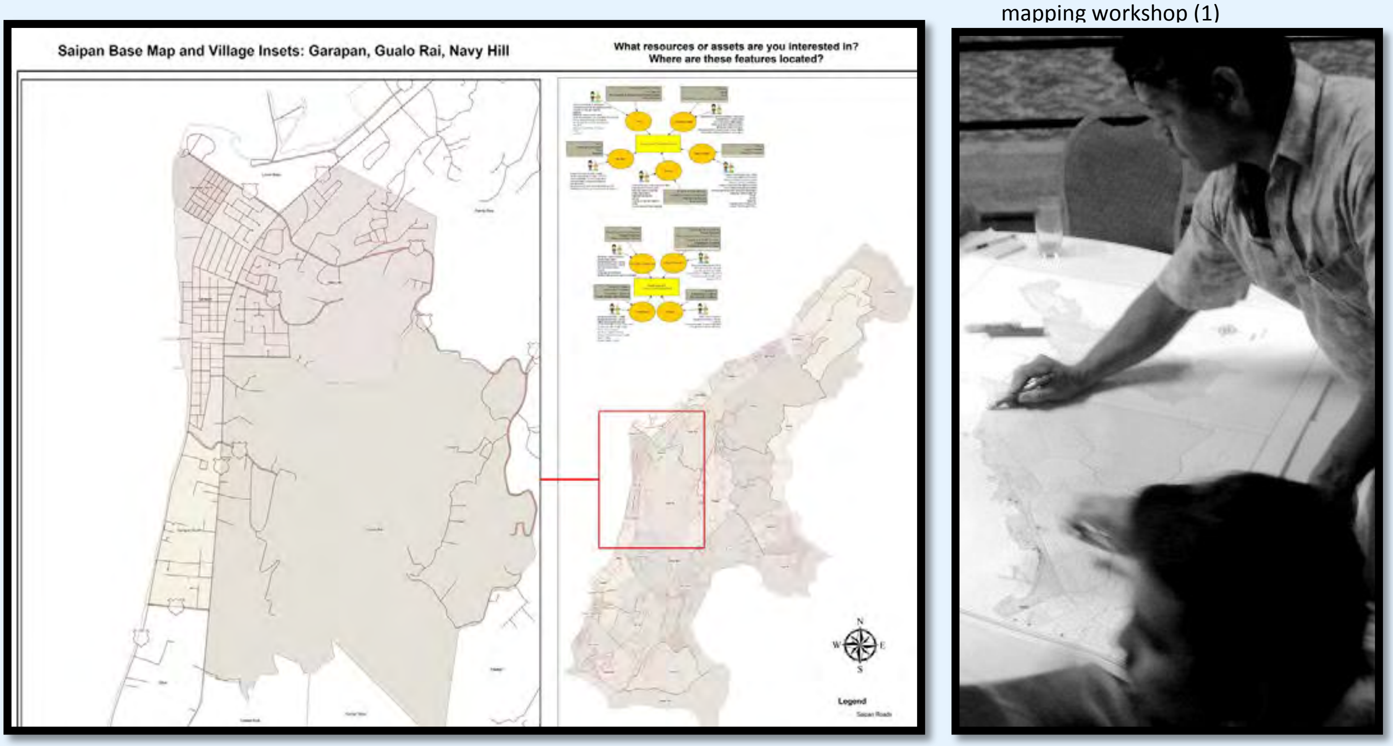
Following the PIMPAC workshop, CCWG members had a more solid grasp of a standard vulnerability formula and how it could be applied to social, ecological and physical systems on Saipan. This was useful in the PIMPAC exercises to broadly address groupings of resources, but a more detailed, spatially explicit application of the formula was necessary to assess individual features and geographic concentrations of resources. The Saipan VA was designed with the intention of using community-based assessment results as input for a more technical, GIS-based assessment; therefore the results also required compatibility with spatial data. These requirements for more specific, GIS-compatible results led to the use of participatory mapping as a means of geo-referencing CCWG knowledge.

Two participatory mapping workshops were held in March and June 2013, focusing on assessing exposure, sensitivity, and adaptive capacities. Workshops resulted in a series of paper basemaps, with the resources of greatest concern pin-pointed on the maps, and sticky-notes identifying components of vulnerability associated with each resource. Maps were scanned, and resources/features that participants had mapped were related to their corresponding feature data in GIS. This allowed for information concerning resource vulnerability to be transferred into a spatial data layer. These workshops and the digitization process are summarized here. Additional detail on these workshops and the CCWG meetings that framed them can be downloaded from the CCWG website.

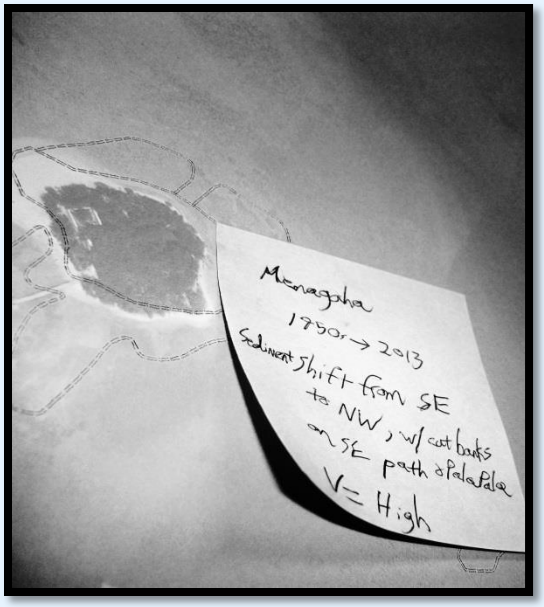
Mapping Workshop 1: Exposure and Sensitivity

On March 18th 2013, CCWG members participated in a two-step mapping workshop to (1) locate important stakeholder resources, and (2) assess their exposure and sensitivity, with a focus on **sea level change** and **changes in precipitation**. In the first half of the workshop participants broke into groups of 4-6, and were provided with nearly-bare base maps of the island, with only a few features pre-mapped for guidance. The groups were asked to use pencils, pens and/or markers to map out the individual features that their agencies or organizations originally cited as resources of concern. The stakeholder resource inventory was provided on the map for reference (Figure 23).

Figure 23: Base maps for community mapping workshop (1)



Following the initial resource mapping, participants were provided with a second set of base maps featuring high resolution satellite imagery and limited layers of basic infrastructure (e.g. streets, drainages). The new base maps were set adjacent to the maps completed in the first portion of the meeting. The groups outlined their resources of concern on the satellite imagery, and then used sticky-notes/post-it notes to explain and rate the exposure and sensitivity of each feature. Exposure and sensitivity were considered together as “potential impact”, and the groups were asked to adhere to a simple rating system of “low”, “medium”, and “high”. Participants were allowed to provide as much detail as they wanted concerning justification for their rating. The result of this exercise was an imagery-based map with three significant components: (1) Locations of *individual* resources, (2) post-it note narratives concerning resource vulnerabilities, and (3) a simple rating of resource exposure and sensitivity.

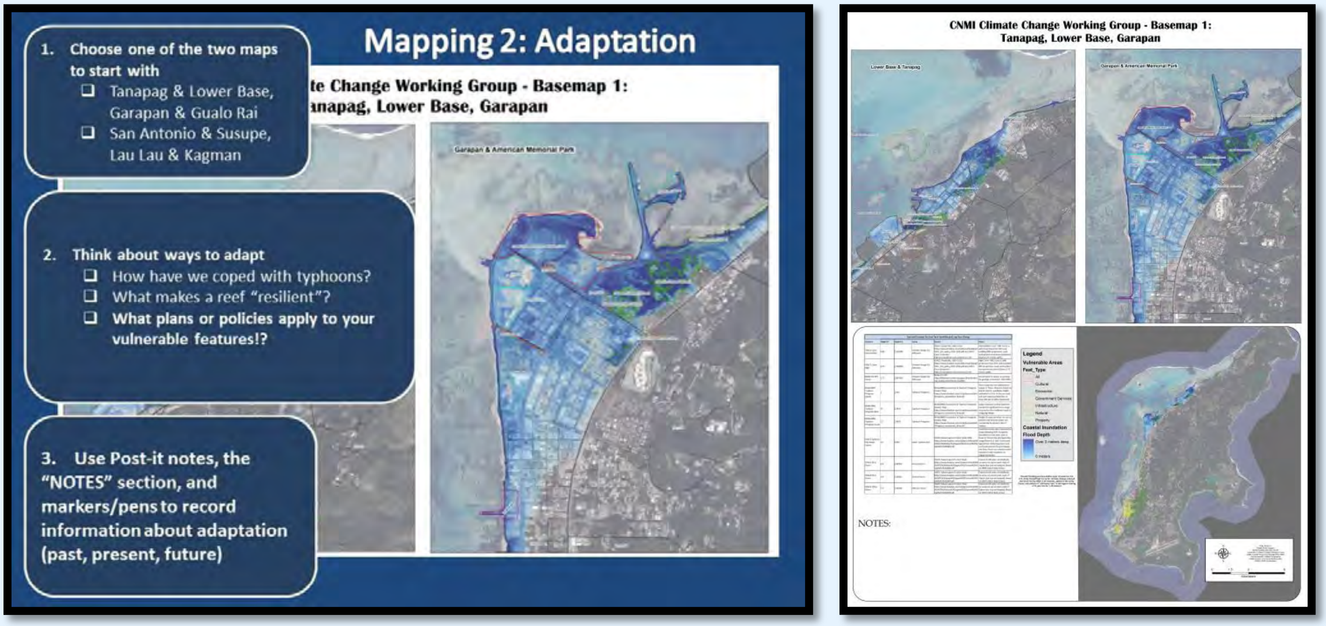


This workshop provided the necessary foundation for addition of more details concerning resource vulnerabilities. In particular, adaptive capacity of resources was not addressed in this workshop, primarily due to time restrictions and intentional limitations on the scope of the meeting. A second mapping workshop was planned for June to complete the Working Group’s transfer of vulnerability knowledge.

Mapping Workshop 2: Adaptive Capacity

On June 13th 2013, CCWG members participated in a second round of mapping exercises. This meeting was designed to refine the results of the first mapping workshop, and add information concerning adaptive capacity to the results of March’s meeting. Once again, breakout groups of 4-6 were formed, and each group was presented with a large base map. The base maps included much more detail than the first workshop’s maps (Figure 24). High resolution satellite imagery was used in combination with two key layers:

1. Vulnerable Features: All the resources and features that were mapped in March were represented on the map, having been digitized as a GIS layer in between meetings. These features were labeled and symbolized according to a simple resource categorization (natural, socio-economic, or infrastructure).
2. Sea Level Rise: The base maps also included a “flood depth and extent” layer to help participants visualize the potential impacts of SLR. In this case, 50 years of accelerated SLR was added to the potential still-water rise of the Saipan Lagoon during a 10 year storm, and the resulting coastal flood extent was added to the map. This scenario was chosen as participants had been using past experience with typhoon-induced flooding as a reference point for SLC exposure. (NOTE: *In preparation for more technical queries into SLC impacts (see section 3), spatial data layers for nine different SLC scenarios were developed. The process of SLC mapping is discussed in detail in section 3.2 of this document, and both methods and scenario development are addressed in the Appendix*).



Mapping 2: Adaptation

1. Choose one of the two maps to start with
   - ☐ Tanapag & Lower Base, Garapan & Gualo Rai
   - ☐ San Antonio & Susupe, Lau Lau & Kagman
2. Think about ways to adapt
   - ☐ How have we coped with typhoons?
   - ☐ What makes a reef "resilient"?
   - ☐ **What plans or policies apply to your vulnerable features!?**
3. **Use Post-it notes, the "NOTES" section, and markers/pens to record information about adaptation (past, present, future)**

Figure 24: Base maps for community mapping workshop (2)

The participants were first asked to review the existing vulnerable features on the base maps, and were given time to append any notes to those features concerning exposure and sensitivity (some new participants were not present at the March meeting and therefore given time to "catch up"). Once again, the focus was on **sea level change** and **precipitation**. Time was also allotted for the groups to add any additional resources to the maps that they felt were left out. Participants were then asked to shift their focus toward adaptive capacities of resources. This shift required a significant adjustment in thinking as the concept of "adaptive capacity" changes in response to the type of resource or feature in question. The ability of mangroves to migrate in response to SLC is quite different from the ability to change the intake depth of freshwater wells.

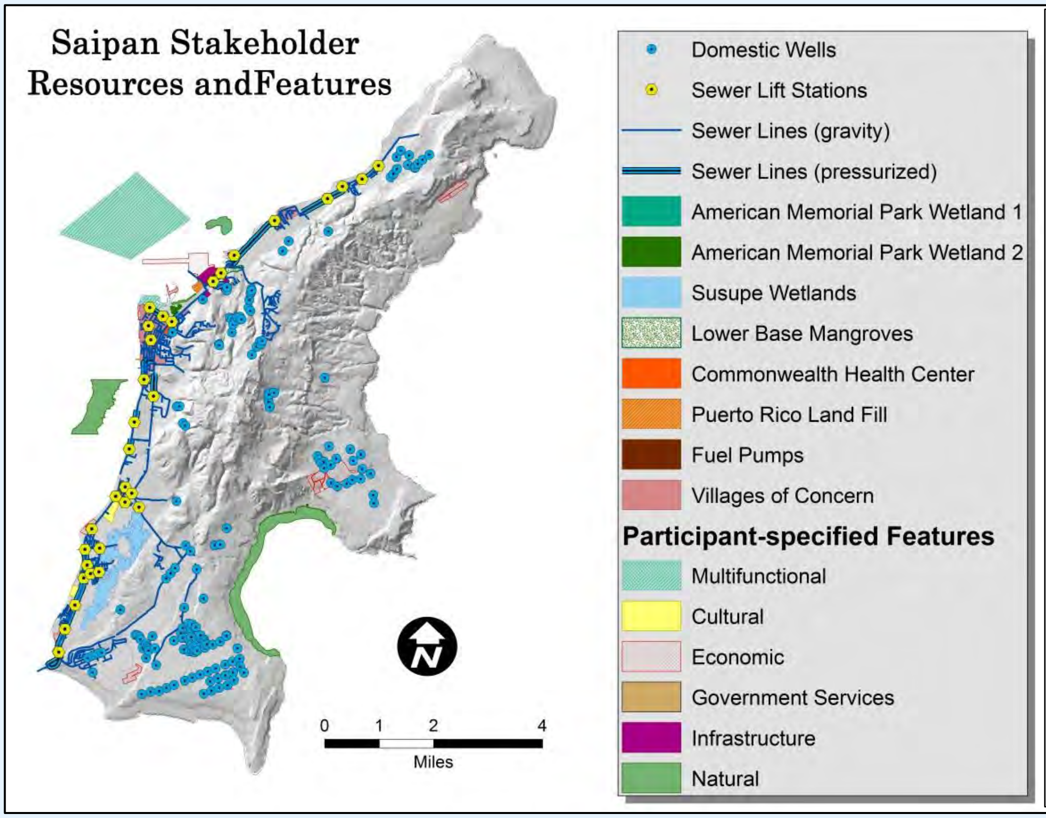
Acknowledging that a basic rating scale for "adaptive capacity" would not be feasible, participants were instead asked to simply fill the maps with narrative. Instead of marking features as "low", "medium" or "high", the groups attached post-it notes referencing any capabilities or tools that a resource had to reduce exposure and sensitivity. Participants were asked to make note of the plans and policies governing the management of specific resources, emphasizing those that offered strategic opportunities to integrate adaptation into existing management efforts. The groups were also asked to make note of how various features, resources, or even entire areas coped with past climate-related impacts (e.g. coral bleaching recovery, engineering solutions to make infrastructure more resilient, etc…). In this way "adaptive capacity" was not so much *assessed* or measured as it was *inventoried*.

The results of this workshop included a more detailed and complete set of vulnerable resources to be integrated into GIS, and a collection of tools and information that could form the basis for adaptation strategies. At the very least the workshop formed a richer perspective into what adaptive capacities exist on Saipan.

Digitization and Results

The mapping workshops resulted in a distilled, geo-referenced version of the CCWG's original stakeholder resource inventory. Specific geographic concentrations of resources became apparent, and participant notes began to tell stories about those features' vulnerabilities. Instead of being just "concerned with reefs", the CNMI Marine Monitoring Team was able to highlight a specific patch of reef that is highly responsive to thermal stresses, and has not recovered from bleaching.

After all participatory map features were matched to corresponding parcels or relevant feature data in GIS, the individual GIS features (e.g. selected parcels, selected wetlands, selected wells, etc…) were merged into a single feature data set (vulnerable_features). Vulnerability ratings of "low", "medium", and "high" for the various features (per CCWG participant input) were included as attribution, however not all features were rated by the participants. The following pages highlight the results of the participatory mapping workshops, rating the vulnerability of ***focus areas***, taking into account the density of vulnerable features in each area and their relative significance to CCWG participants/stakeholders.



A brief note on map features:

The mapping workshops resulted in a large quantity of features being drawn on the map in varying levels of detail. In some instances a specific feature such as "the Fiesta drainage corridor" was pin-pointed on the map. Features such as this were included in a set of digitized polygons referred to in the maps as "**Participant-specified Features**". These features are categorized and labeled in the detail maps, but not listed individually in the legend.

In other cases, participants were interested in an entire set of features as part of a system, such as "sewer lift stations", or in a major stand-alone resource such as the hospital. These resources are displayed in the maps as their own feature class.

Resources of concern are distributed unevenly around the island, with the majority concentrated along the western coastal plain. Outside of this area features are clustered around isolated patches of a specific resource type. Two notable concentrations (aside from the western coastal plain) consist of the freshwater well fields near the airport at the southern end of the island, and in the Lao Lao Bay area along a strand of shoreline with significant recreational and cultural features. Individual descriptions of clustered resources and vulnerable areas throughout the island are provided here, but the reader is encouraged to first take note of the map description above, which explains the breakdown of items in the following map legends.

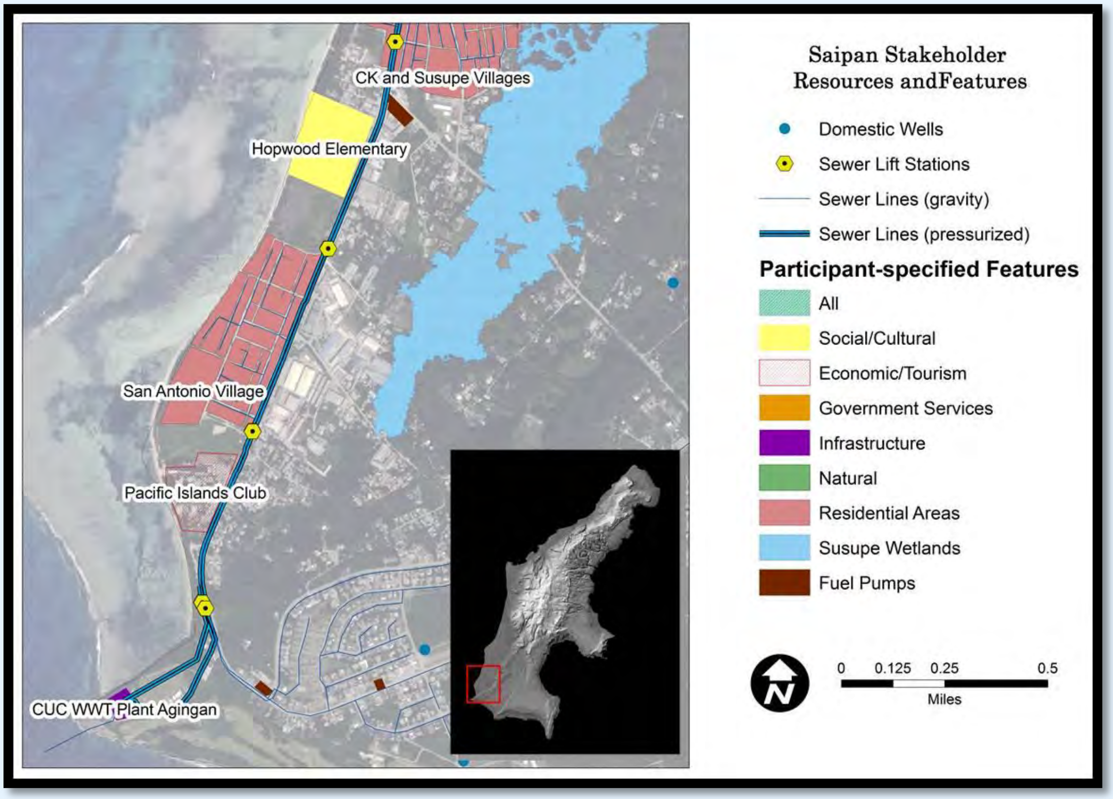
Southwest Saipan (San Antonio Area)
Vulnerability = Medium-Low

The primary concern in the San Antonio area is the high concentration of low-lying residential parcels within the village itself. These parcels occupy a strip of low-elevation land in between a stable, low-moderate sloping shoreline and Beach Road (see red shaded area on map). An elementary school is also situated within this shaded area, and coastal properties have minimal setbacks. The village as a whole had a vulnerability rating of "medium".

Throughout the focus area a pressurized sewer main runs parallel to Beach Road, and a lift station at its southern extent was noted by participants as moderately vulnerable due to past maintenance issues. The sewer main remains a concern as flooding from both precipitation and coastal inundation during storms could complicate ongoing maintenance efforts.

A small beach park with a semi-stable shoreline separates the village from the Pacific Islands Club resort. The resort includes a restaurant and recreational amenities directly adjacent to a moderately-sloping beach that experiences periodic erosion. This feature also had a vulnerability rating of "medium".

Hopwood Junior High School is situated at the north end of this focus area, with beach front property. The school is at a slightly higher elevation than the features to its south, and has a natural buffer between school structures and the shoreline. It was rated as medium-low vulnerability.



Inland from these coastal features, the southern extent of the Susupe wetland system was noted for its potential to flood nearby roadways during heavy precipitation events. Some participants were concerned with an increase in flooding around this area in the event of combined increases in precipitation and sea level. While some participants suggested that the wetland has a high level of vulnerability, it should be noted that this was primarily due to its sensitivity and exposure to changes in climate variables, and not a low adaptive capacity. "Adaptive capacity" is a tricky concept to apply to a large wetland system.

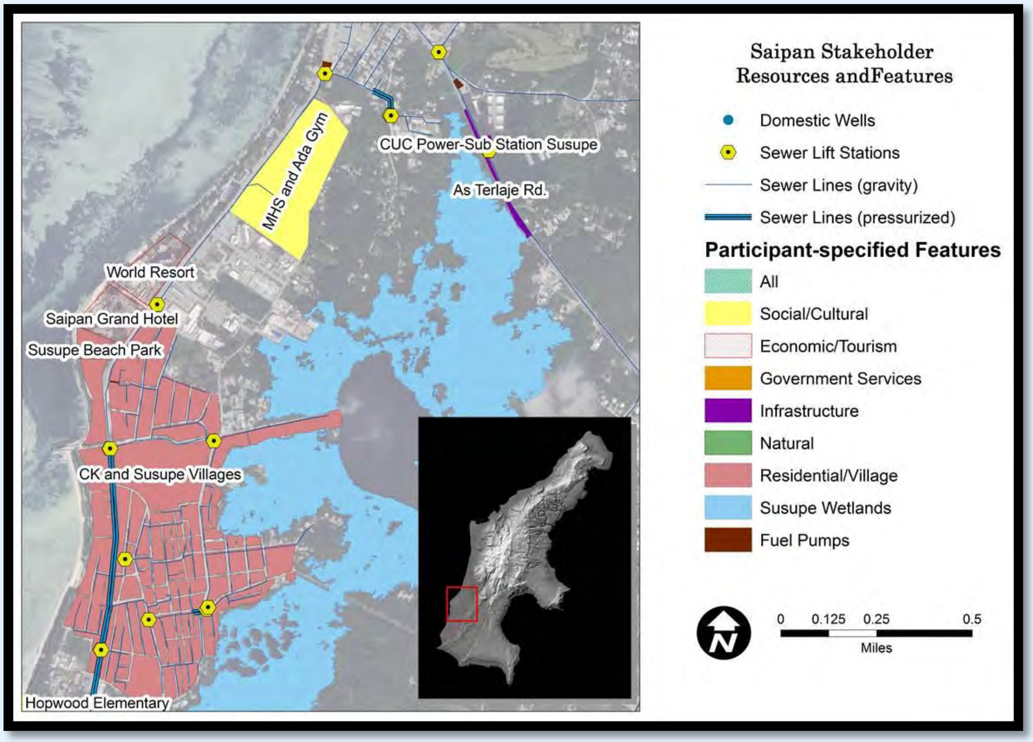
The final feature in this focus area is the wastewater treatment plant on Agingan Point. The plant is not expected to be particularly susceptible to climate change impacts based on its location, which is along a raised, stable bluff. It was given a low vulnerability rating; however, it is important to note that impacts to more vulnerable sections of the sewer and lifts have the potential to affect overall movement through the system.

Susupe and Chalan-Kanoa
Vulnerability = Medium

The villages of Susupe and Chalan Kanoa are situated in a particularly troublesome location. The highest concentrations of residential parcels and businesses occupy a low-lying stretch of land, sandwiched in between a semi-stable shoreline and the largest wetland system in the CNMI.

This area is prone to short-term flooding during extreme precipitation events, and there are some concerns about potential overflow of Lake Susupe and surrounding wetlands. Meanwhile, the stretch of shoreline from Susupe Beach Park south to the Aquarius Beach Towers has experienced significant shifts, with short-term coastal erosion occurring during large swell events and tropical storms. This phenomenon is especially evident near the Sugar Dock boat launch, and directly in front of the Aquarius. At the former, long-shore processes have created sand buildup in certain areas, while large west swells have eroded the shoreline and destroyed vegetation and stands of trees in front of the Beach Towers.

While the villages were given an overall vulnerability rating of "medium", several features deviated from this rating. The Saipan Grand Hotel and World Resort were rated as "high", with the assumption that SLR would create a situation in which no retreat or physical adaptation options existed.



A low-lying section of As Terlaje Road was also rated "high", as it intersects (divides) the northern extent of the Lake Susupe wetland. Flooding over this section of road under certain SLC and precipitation scenarios would effectively cut-off one of the primary means of access between the east and west sides of the island. A CUC sub-station is located near this section, complicating any prolonged flooding scenario.

The Marianas High School and Ada Gymnasium sit at the northern extent of this focus area. The school and gym are located inland from Beach Road, albeit at similar (and in some cases lower) elevations. These two features and Beach Road have been protected from coastal inundation in the past by a buffer of low-moderate sloping shoreline. The shoreline here is notable for several cultural and recreational features, including the Sabalo Market and Kilili Beach; though these were regarded as adaptable by CCWG participants (recreation and activities can relocate).

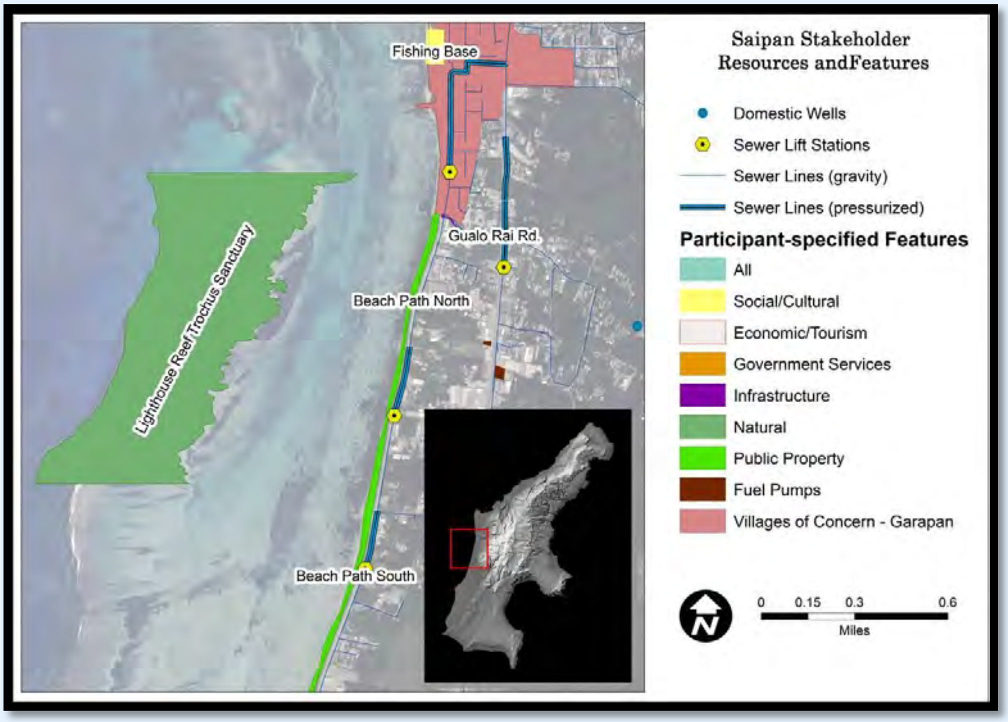
The gym and high school were rated "low-medium", but it is important to note that these features are designated as the highest capacity disaster recovery centers on-island, serving populations from numerous villages on the western coastal plain. Any potential threats to these features would place the island's shelter and disaster recovery plans in a troubling scenario.

Cumulatively, the Susupe and Chalan Kanoa focus area faces a disconcerting scenario under extreme SLC. With the wetland and Lake Susupe in place, there is little in the way of retreat for residents and businesses. Extreme scenarios present the possibility of a large, displaced student population and loss of significant recreational facilities.

Oleai Beach to Fishing Base (Including Gualo Rai)
Vulnerability = Medium-High

Travelling north from Oleai Beach to the southern extent of Garapan (Fishing Base area), the two primary stakeholder resources are the Beach Path and Beach Road. These two features parallel each other and the shoreline, separated by a narrow strip of green space. Beach Road ranges from 20ft.-100ft. inland from the high water mark, at elevations of 5-10 feet, while the Beach Path is often within a few feet of the water, and in some cases meets the high water mark. The physical situation of these features alone (high exposure) led workshop participants to rate them as highly vulnerable. Sections of the road have been eroded and damaged in typhoons, and the pathway is subject to over-topping during large swells and minor storm surges.

Figure 25: High tide and low atmospheric pressure along Beach Road, September 2012



In addition to high exposure, there is no room for these features to retreat or adapt. As a major conduit of north-south transport on the island, Beach Road's traffic volume would overwhelm the only alternate route, Middle Road. Similarly, the beach pathway is the only major pedestrian commuter corridor on the island, which complicates any attempt to re-route.

While the road and pathway are the most visible features in this focus area, participants also took note of the issues caused by erosion during heavy rainfall. Many of the coral and gravel roads connecting Beach Road to Middle Road have a moderate slope, and collect the vast majority of stormwater runoff from respective watersheds. This run-off enters the lagoon at multiple drainage outlets along Beach Road, and is a major concern for benthic habitat health and issues related to non-point source pollution and sedimentation in the lagoon. The lower section of Gualo Rai Road demonstrates this phenomenon quite well, and workshop participants made note that increases in precipitation or storm events would exacerbate run-off throughout this focus area.

Increased run-off and sedimentation in the lagoon is also a concern for the fringing reef. Within this focus area, the Lighthouse Reef and Trochus Sanctuary constitutes significant marine habitat, and workshop participants were concerned about its susceptibility to watershed influences (run-off, sedimentation) as well as increases in SSTs. The group suggested a moderate vulnerability rating for the Sanctuary, acknowledging that most marine habitat is fully exposed to changing ocean conditions by default.

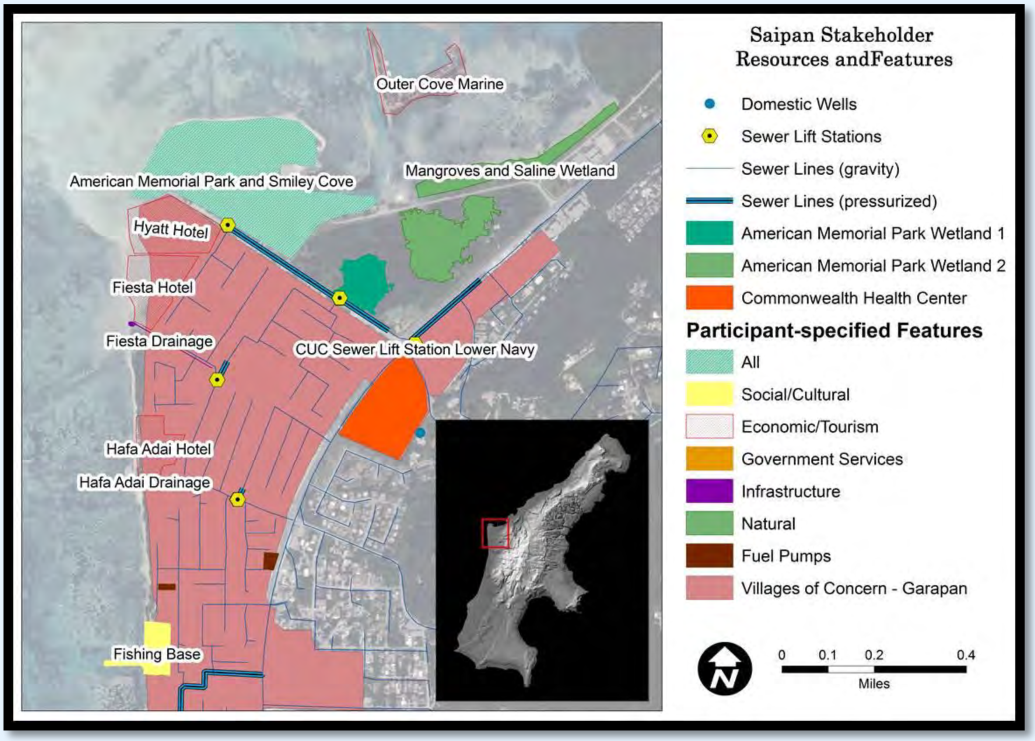
While Fishing Base and the southern portion of Garapan are visible in the map extent for this focus area, those resources are addressed in the next focus area (Garapan).

Garapan
Vulnerability = High

The village of Garapan and neighboring American Memorial Park have the highest density of resources of concern on Saipan. Garapan is characterized by a very low elevation profile, and serves as the outlet for a major watershed. This, in combination with a dynamic shoreline, large areas of impervious surface, and a densely built urban core sets the stage for multiple vulnerabilities.

At the southern end of the focus area, Fishing Base serves as both a recreational and cultural feature. A low-lying concrete jetty and boat ramp allow for small-boat access, and the entire open space is utilized for Tuesday and Thursday night markets. Both the jetty and open-space near the shoreline have been partially submerged in storm surges, and are fully exposed to changes in sea level and wave conditions. Participants associated these features with a high level of vulnerability.

The stretch of shoreline between Fishing Base and the border of American Memorial Park is populated by a cluster of large hotels, beach recreation facilities, and two notorious drainage outlets. The latter features were emphasized by CCWG members as the primary culprits in the dispersal of land-based pollution during large precipitation events. The drainages (Fiesta and Hafa Adai) remain stagnant until their outlets into the lagoon have been breached by a large volume of stormwater run-off, or short-term coastal erosion processes that remove any sand barriers. The result of this breaching is often a “red flag” designation from DEQ’s water quality monitoring program, signaling unsafe swimming conditions (not to mention habitat degradation). The drainages and their outlets were rated as highly vulnerable by CCWG participants.



The three main hotels along the beach (Hyatt, Fiesta and Hafa Adai) are all set back a sufficient amount from the high water mark to avoid inundation during small storm surges, and their shorelines have been *mostly* stable over the last decade. Yet these hotels have very few physical adaptation options in the event of extreme SLR scenarios or accelerated erosion. Participants assigned Hafa Adai and Fiesta hotels a vulnerability rating of “medium”, while Hyatt’s rating escalated to “medium-high” based on its proximity to American Memorial Park’s retreating beaches. While the main hotel structures are not perceived as highly exposed or sensitive, the hotels’ recreational facilities and beach amenities are susceptible to changing shoreline conditions. Some semi-permanent structures such as Hyatt’s marine recreation rental facility were noted for their heightened vulnerabilities.

American Memorial Park is situated just north of the Hyatt property, and occupies a large, low-lying point of land. The north and west sides of the park are essentially a sand spit, which has been thoroughly documented and studied for its dynamic shoreline and shifting beaches. Beach erosion and accretion at the park is addressed in more detail in section 3.3 of this document, but CCWG participants stressed that the behavior of this shoreline contributes greatly to the parks

Figure 26: Photo of storm surge and eroding shoreline at American Memorial Park

vulnerability to SLC. The park's beaches are already highly exposed and sensitive to short-term variation in sea levels, currents, and wave environments. Adaptation actions thus far have consisted of periodic retreat and acceptance of structural loss. American Memorial Park is where the sidewalk ends… abruptly (Figure 26).

In addition to its beaches, CCWG participants noted the presence of critical wetlands in the park. Several wetlands exist, including a constructed wetland and a complex of estuarine and palustrine wetlands along the southeast and east sides of the property. Invasive species and potential contamination from adjacent sewer infrastructure already impair the wetlands' ecological functions, and any increase in sea levels, flood periods, or adjacent sewer backup could cause further degradation to the wetlands. These features were given a rating of medium-high vulnerability. It is uncertain what adaptive capacity these wetlands have given their current threats, but the establishment of mangroves and maintenance of existing (albeit fragmented) mangrove habitat was cited as both a vulnerable feature and a potential resource for adaptation/coastal protection.

Garapan's sewer infrastructure was one of the most popular topics in the workshops, being renowned among Garapan's denizens and visitors for its peculiar scents, and infamous among CUC engineers for imminent upgrade needs. Several lift stations along the pressurized main that borders American Memorial Park were noted for proving problematic in recent years, especially the lift station at the intersection of Navy Hill Road and Middle Road. The sewer infrastructure in this area was given a rating of medium-high. While participants felt that a large potential impact to the system exists, CUC engineers also noted that planned upgrades to the system constitute a high adaptive capacity. Participants suggested that this system be a focal point for early adaptation opportunities.

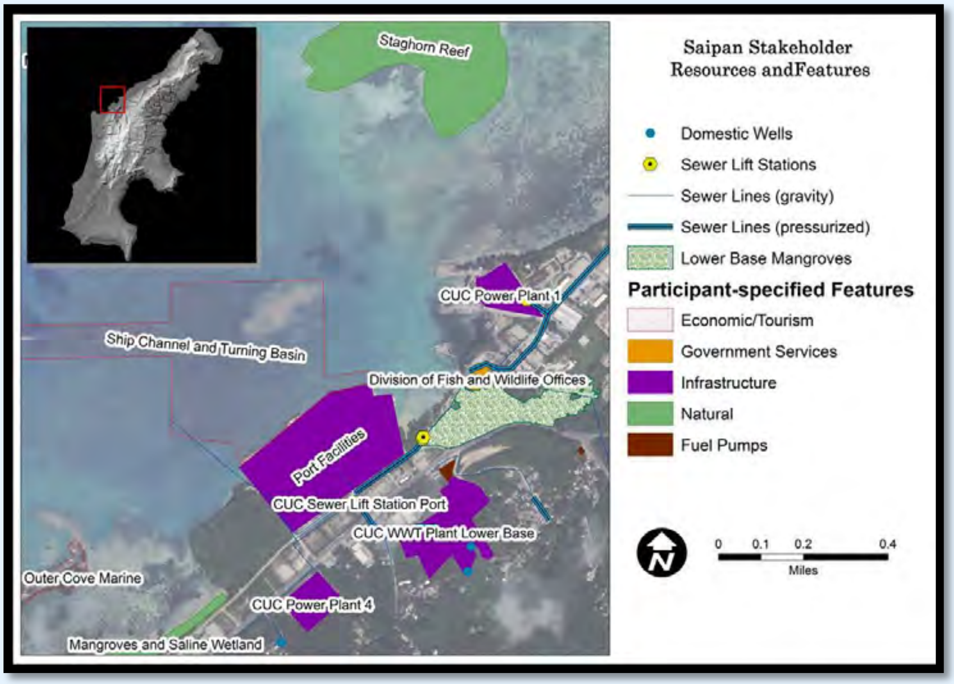
The Garapan focus area also includes the Commonwealth Health Center. While local media headlines and administrative changes would suggest that the general population of Saipan is concerned for CHC's future, CCWG participants also noted its physical location next to an extremely low-lying area. The structure itself is not necessarily fully exposed to flooding, but the roads used to access the facility (especially the Navy Hill/Middle Road intersection) were noted for their high vulnerabilities, and access options beyond these roads are virtually non-existent. Under extreme SLR scenarios CHC was rated as highly vulnerable.

Any SLC scenario that would threaten access to CHC would also effectively cut off access to Smiling Cove and Outer Cove Marinas. These two features are the primary hubs for marine recreation and tourism activities on Saipan, and rely on a single, low-lying entrance road for vehicular access. The marinas are also dependent on maintenance of channels and dredged areas. Even a slight shift in coastal processes and sediment drift near Smiling Cove would have the potential to fill the boat channel, requiring significant resources for ongoing dredging or adaptation. CCWG members noted past shifts in coastal processes within the lagoon that resulted in threats to the marinas, as well as the resource-heavy solutions that were placed on the table to address those threats. With this in mind, participants rated the marinas as highly vulnerable.

In summary, Garapan hosts the majority of the island's tourism infrastructure, one of its largest public recreation spaces, some of its most popular beaches, and most commercial and recreational marina services. These roles translate into a dynamic space that CCWG members and workshop participants emphasized as a focal point for future adaptation work.

Lower-Base and Port Facilities Vulnerability = High

The area around Lower-Base, Puerto Rico, and Saipan's commercial port facilities is characterized by substantial exposure to SLC.



The port itself is fully exposed to any swell or storm-induced surge that may enter the ship channel from the south-southwest. Participants did not feel that the port facilities were excessively sensitive, primarily due to significant shoreline modification and hardening, but the area also affords few adaptation options. Any modifications to docking arrangements and port infrastructure would likely require a corresponding shift to the ship channel and turning basin. This dependent relationship, and the massive amount of resources that adaptive initiatives would demand, inspired CCWG participants to assign both the port facility and the docking arrangements a rating of "medium-high".

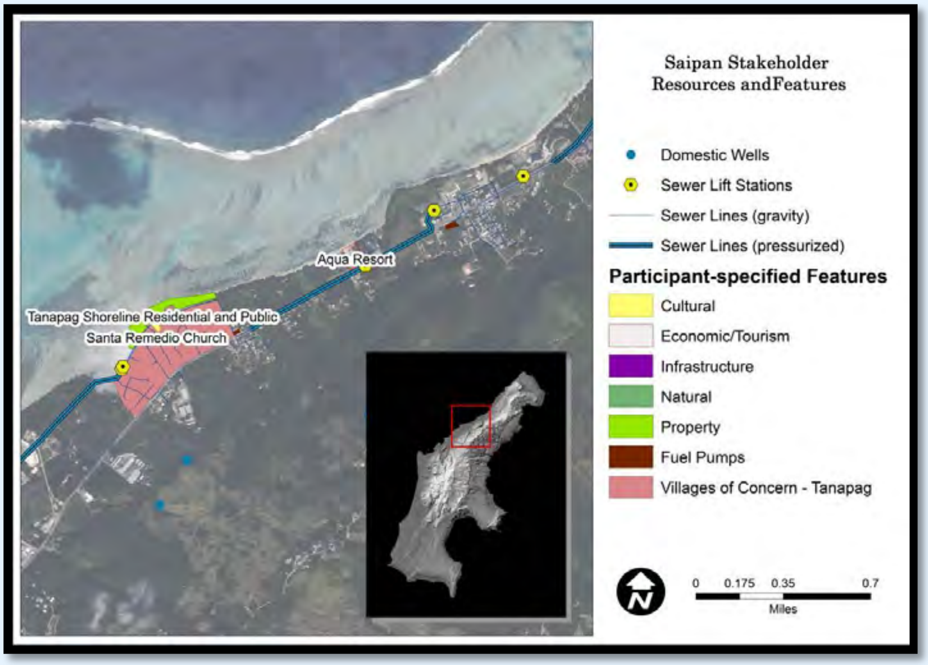
This focus area also hosts a high concentration of CUC critical facilities, including two primary power plants, a sewer lift station, and the Lower-Base wastewater treatment facility. Only an extreme SLC scenario would threaten these structures, but access to them for ongoing operations and maintenance already faces threats from large storm surges. Their exposure was rated "medium", but some participants felt that flooding from both coastal inundation and precipitation events could reveal high sensitivity. Adaptation options for the facilities are few, with limited areas outside of Lower-Base that are zoned/suitable for industrial activity and complications associated with altering access roads. Cumulatively these facilities were given a rating of medium, but some participants noted that CUC Power Plant 1 had a higher level of vulnerability due to greater exposure.

In stark contrast to the surrounding industrial activity, an intact patch of mangroves is situated on the inland side of one of the port's access roads. This wetland has a direct hydrological connection to the lagoon via a small drainage, and is fully exposed to changes in sea level. Participants did not rate the feature's sensitivity or adaptive capacity, as the mangroves' ability to migrate in response to SLC or increased flooding is not known. CCWG members noted that unknown vulnerability did not detract from the feature's significance as one of the last remaining mangrove stands on Saipan.

The CNMI DLNR and DFW offices are located directly adjacent to the mangroves. Such close proximity to an estuarine wetland is telling of the offices' low elevation profile. The DFW office is directly across the street from a semi-exposed shoreline, with high potential impact in the event of combined SLR and storms. The office's main adaptation option, relocation, would be more feasible for a government office than the re-construction of nearby industrial facilities. Despite this capacity, participants asserted that the office's extreme exposure produced high vulnerability.

Concerns about the land fill at the southern extent of this focus area were also expressed. The "Puerto Rico dump", located just south of the industrial port facilities, was shut down in 2003 without proper sealing or de-contamination efforts on adjacent areas. Both groundwater and the lagoon are contaminated from consequent chemical leaching (Denton et al., 2009). While the dump's fill affords it a higher elevation profile, SLR around the base would exacerbate leaching. Relocation of the dump, or armoring of its base were not deemed feasible by CCWG members, leaving the dump with a high vulnerability rating.

Tanapag
Vulnerability = Medium-Low



The Village of Tanapag occupies a stretch of shoreline and low-lying land at the northern extent of Saipan's western coastal plain. Mapping workshop participants advised that the village itself, including residential properties and cultural/recreational features, should be a focal point for assessing vulnerability, however few features outside of the village were emphasized as significant to stakeholders (or vulnerable).

Within village boundaries, participants identified the Santa Remedio Church as a culturally significant feature with moderate exposure and sensitivity. Adaptive capacity for the Church was not addressed; however any effort to significantly modify or relocate the feature would likely detract from its social and cultural value.

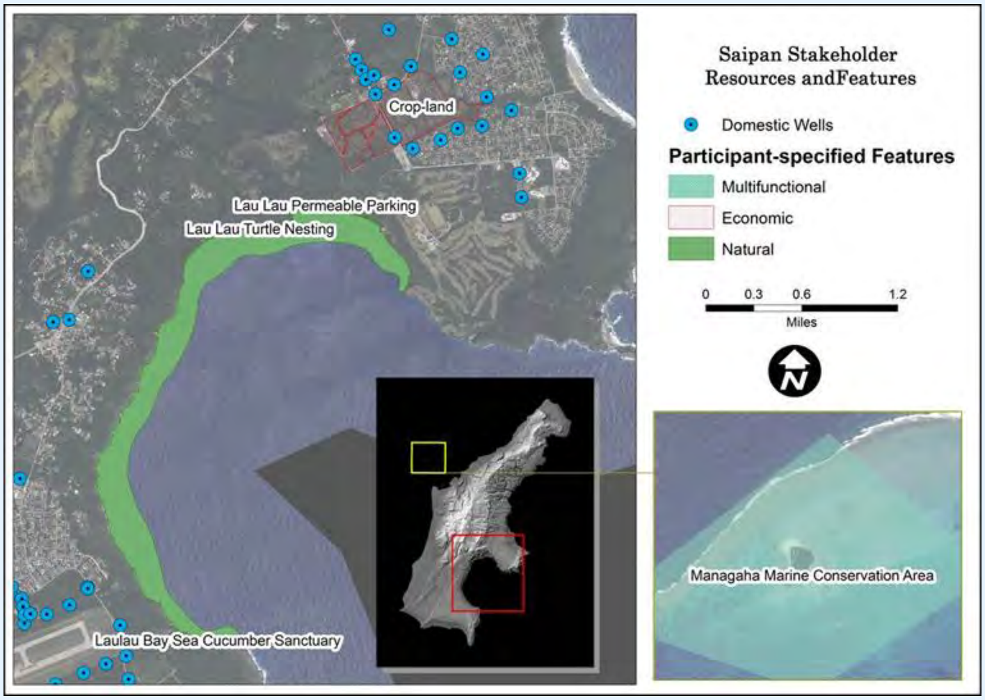
Along the village shoreline a boat ramp and series of pala palas offer recreational opportunities, but are fully exposed to SLC. These features were assigned a vulnerability rating of medium. Continuing north along the shoreline, private residential properties meet the high water mark, and are fully exposed to SLC and periodic wave action. Some properties have hardened their shoreline in an effort to mitigate storm surge, but CCWG members had little information concerning the effectiveness of this measure. Such an approach was suggested as a moderate adaptive capacity, though shoreline hardening does not fully address the symptoms of an extremely low elevation profile. If the ocean cannot come through the front door, it will work its way around the sides.

Tanapag Elementary School is also located within the focus area; however its elevated situation and considerable distance from the shoreline led participants to assign it a low vulnerability rating. Some concern remained that potential impacts to the low-lying residential areas and roads in the village would impact access to features that would otherwise not be vulnerable (e.g. elementary school).

Some CCWG participants also proposed that the Aqua Hotel and Resort was mildly vulnerable, due primarily to its location on the shoreline. The actual facilities at Aqua are situated at a higher elevation than those of the hotels in Garapan, and the shoreline has historically been more stable around the Aqua Resort. Due to this relatively low potential impact the hotel was provided a vulnerability rating of "low". Overall, most features within this focus area were also assessed as having low vulnerability, with the exception of the village shoreline in Tanapag.

Lao Lao Bay and Kagman

Vulnerability = Medium-Low



The stretch of beach lining the shoreline of Lao Lao Bay is one of the most culturally and recreationally celebrated segments of coast on Saipan. While CCWG participants placed little emphasis on the east side of the island, the beach and reef at Lao Lao was a notable exception.

With respect to changes in sea level, participants posed inquiries concerning decreases in sea turtle nesting habitat. A combination of SLR and a more extreme wave environment would greatly reduce the suitability of Lao Lao's beaches for turtle nesting. Workshop participants rated this feature as highly vulnerable, noting that a decrease in turtle nesting habitat would likely be an island-wide phenomenon, assuming the impacts were uniformly distributed, and therefore turtles could not easily adapt by shifting to a nearby beach.

The fringing reef at Lao Lao (and the associated sea cucumber sanctuary) is also of concern to the CCWG. This feature is the subject of ongoing monitoring and management actions as it is currently impacted by sedimentation from terrestrial run-off. Participants stressed that any significant increase in precipitation, particularly through extreme events, would exacerbate run-off in the Lao Lao watershed. Therefore, the reef's "adaptive capacity" lay in the ability to mitigate run-off in the watershed. With mitigation efforts already underway, the reef's high exposure and sensitivity to anthropogenic stressors like run-off are slightly counteracted, leading to a vulnerability rating of "medium".

Potential changes in precipitation, whether it is an increase or decrease, also led to concerns about the vulnerability of nearby agricultural land and freshwater wells. Given the significant uncertainty associated with changes to ENSO, the possibility of droughts (following a strong El Nino) led some participants to rate the agricultural land near Kagman as moderately vulnerable.

These same concerns guided CCWG members in applying a vulnerability rating of "medium" to the freshwater well fields in the Kagman area, and farther south around the airport. While the wells are extremely exposed to changes in precipitation, Saipan's freshwater lens and groundwater system is less sensitive to limited-term events (e.g. drought) than smaller islands or atolls are. In addition, the wells on the east side of the island are generally not affected by changes in sea level (as wells on the western coastal plain are), thus the potential impact to the wells in this focus area is not as great as other parts of the island.

Managaha Island
Vulnerability = High

Managaha Island displays what are perhaps the most tangible vulnerabilities of any focus area in this assessment. The impacts that changes in oceanographic conditions have on the small sand cay are immediate and well pronounced. During the mapping workshops a post-it note was placed directly on top of the island that read "MANAGAHA!" The high vulnerability rating was implied.

Most CCWG members could confirm established trends of erosion and accretion around the island (eroding swiftly from the north-northeast and accreting to the northwest), but some participants also cited recent studies demonstrating a net loss of island volume (Fletcher et al. 2007). The latter change places Managaha in a precarious position with the prospect of SLC looming. Natural processes are already revealing the high levels of exposure and sensitivity that render features vulnerable to climate change.

Figure 27: Photo of chronic erosion on Managaha Island, May 2013

In addition to the excessive potential impact that SLC and changing wave/current patterns might have on the island itself, the reefs surrounding the island are also exposed to the thermal stresses associated with increasing SSTs. This combination of terrestrial and marine threats spells trouble for the massive tourism construct that has been built around the island.

Aside from a prohibitively expensive sand replenishment program or the installment of shoreline structures to alter coastal processes, the island has few adaptive options. Establishment and protection of vegetation on the accreting sides of the island may facilitate the temporary formation of "new land"; however, this may not counteract long-term SLR and continued net-loss of sand. Considering its lack of adaptive capacity and high levels of exposure and sensitivity, the "gem of Saipan" was rated highly vulnerable. CCWG members suggested ongoing monitoring of island morphology and exploration of adaptation opportunities.

Collectively, these focus areas and the vulnerabilities identified by CCWG participants provide a sketch of Saipan's susceptibilities to climate change impacts. The community-based VA identified features that were both significant to stakeholders and potentially at risk. The geo-referencing of these features and risks allowed the CCWG to distill the assessment of Saipan's climate change vulnerability down to a set of critical locations. In doing so, the stage is set for a more detailed assessment of specific impacts in specific areas. Section 3 (Technical Assessment) adopts a more meticulous approach to assessing exposure to changes in sea level. By establishing a set of stakeholder-specific focal points, the community-based VA ensures that the following technical assessment is instilled with significance to the individuals and organizations that have guided this project.

3. Technical Assessment

This section explores two lines of inquiry that are central to an understanding of Saipan's vulnerabilities to climate change:

- What is exposed to the potential impacts of climate change? In particular, what features are susceptible to flooding and coastal inundation as a result of sea level changes?
- Who is vulnerable? In particular, what makes this population vulnerable, and where is this population located?

These questions are explored both separately and in combination, ultimately providing a preliminary glimpse into the level of exposure and vulnerability characterizing the community-identified resources of concern, as well as the community itself.

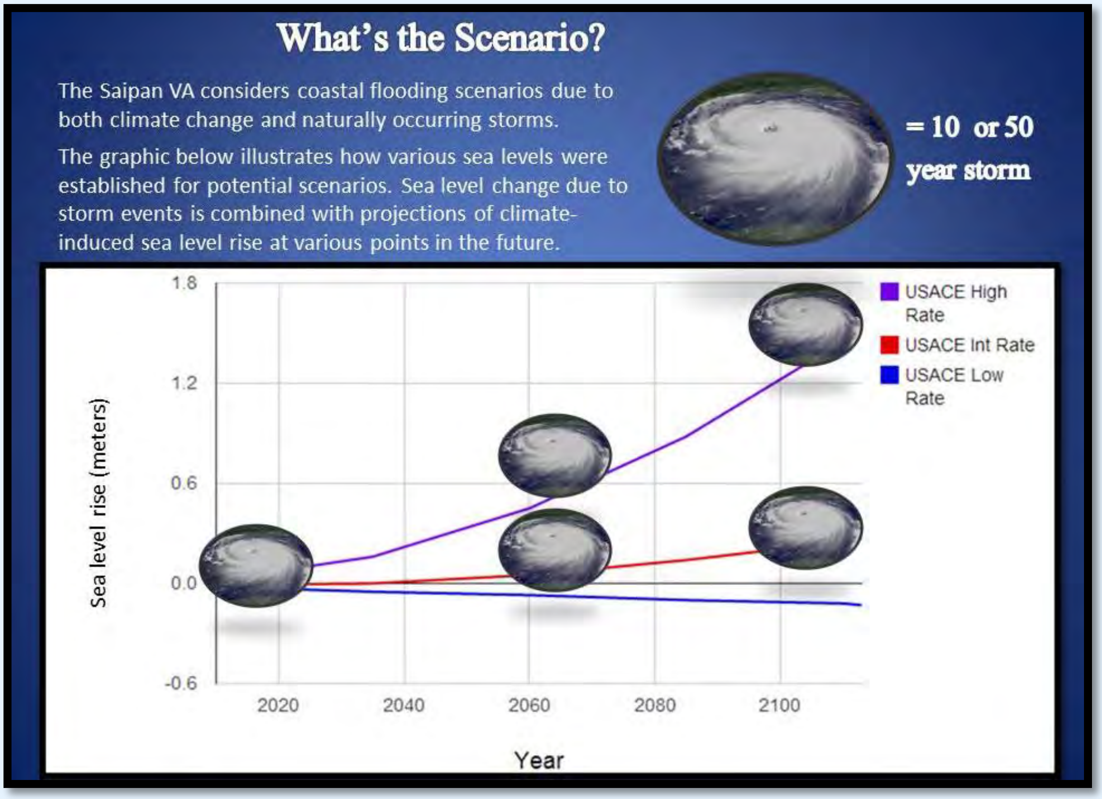
3.1. Mapping Sea Level Change Scenarios

With new insight into the qualitative vulnerability of stakeholder resources a portrait of Saipan's overall vulnerability to climate stressors begins to form. A more detailed look at exposure to coastal flooding and inundation helps us distill these vulnerabilities, and further delineate focus areas for future adaptation planning. This section outlines the process and results of this inquiry into flooding exposure.

Coastal inundation can result from a variety of scenarios that occur at varying temporal scales. While long-term SLR caused by climate change has the potential to impact Pacific Islands with varying severity, the combination of extreme events (storms, king tides, etc…) and long-term SLR will have more damaging and widespread effects (Chowdhury et al. 2010). The mapping approach taken in the VA acknowledges this range of coastal flooding threats, and attempts to integrate a variety of scenarios that represent them.

Mapping Approach

Nine coastal flooding and inundation scenarios were chosen for analysis. These scenarios included long-term sea level shifts corresponding to the U.S. Army Corps of Engineers (USACE) SLR curve calculations for civil works projects (2011), and additional short-term adjustments to sea level due to 10 and 50 year storms (storms with a 1 in 10 or 1 in 50 chance of occurring in a given year) (Figure 28).



What's the Scenario?

The Saipan VA considers coastal flooding scenarios due to both climate change and naturally occurring storms.

The graphic below illustrates how various sea levels were established for potential scenarios. Sea level change due to storm events is combined with projections of climate-induced sea level rise at various points in the future.

Figure 28: Scenario building for future sea level situations

- Sea level rise curve calculations are based on methods developed by NOAA, USGS, and USACE to calculate future *local* mean sea level, and include adjustments that factor in vertical land movement and regional sea level variation.
- The 10 and 50 year storm sea levels were modeled by the USACE for the Saipan lagoon (Chou 1989), and accounted for a total water level increase during typhoons of varying severity.

These total water levels and SLR calculations were assessed separately and in combination to identify the degree to which climate change might exacerbate naturally occurring inundation due to storms. Detailed methodology for this mapping process and scenario development is available in the appendices.

GIS layers were developed to represent two flooding extents and associated depths for each of the nine scenarios. These layers included flooding extents that were either (1) hydraulically connected to the shoreline, or (2) a result of an expansion of Lake Susupe and the Susupe wetland area.

While Lake Susupe's water surface elevation may not change at the same rate as sea levels (particularly during short-term events), there is evidence of changing water chemistry and salinity due to shifts in past sea levels (Caruth 2003). Therefore the area that could be potentially *affected* by changes in sea level was calculated, albeit separately from coastal flooding. This area is termed "wetland flooding" in summary maps and statistics, whereas flood extents that are connected to the shoreline are termed "coastal flooding". In situations where both *coastal* and *wetland* flooding are considered, the term "combined inundation" is used.

GIS data for land parcels and land cover were clipped to the boundaries of the flooded areas for each of the nine *coastal* inundation extents. Frequency and summary statistics were calculated for the clipped land uses and land cover, showing the occurrence and acreage of impacted land uses and types of vegetation/land cover.

The following pages summarize the results of the mapping process and analysis.

Note:

- *A coding scheme was developed to represent the SLR/SLC scenarios (Appendix E) .The scenario codes used for different sea levels and flooding extents (e.g. A1, C2, etc…) do not reference any future* CO^2 *or emissions scenarios from SRES or IPCC assessment reports (see AR4), and were used simply as a naming convention to keep numerous data layers organized and packaged.*

- *Readers are encouraged to keep in mind the uncertainty inherent in the following figures, lest they draw frightening conclusions about Saipan's future. The maps and numbers were generated through analysis of scenarios that are within the realm of possibility, but are stories nevertheless, and may not represent reality. As the statistician George Box so eloquently put it: "all models are wrong, but some are useful" (Box & Draper 1987).*

Summary of Inundation Scenarios

Scenario	**Rise (Ft.)**	**Rise (Meters)**	**Scenario Code**	**Inundated Area - Coastal (km^2)**	**Inundated Area - Coastal (acres)**	**Wetland Flood (km^2)****	**Wetland Flood (acres)**	**Combined Inundation Area (km^2)**	**Combined Inundation Area (acres)**
10 year Storm; no Sea Level Change	4.89	1.49	**A1**	0.93	229.81	1.27	313.83	2.2	543.64
USACE Curve Intermediate - 50 yrs. + 10 yr. Storm	5.10	1.554	**A2**	1.23	303.95	1.36	336.07	2.59	640.01
USACE Curve Intermediate - 100 yrs.	0.89	0.27	**B1**	0.11	27.18	0.02	4.94	0.13	32.12
USACE Curve Intermediate - 100 yrs. + 10 yr. Storm	5.77	1.76	**B2**	1.78	439.86	1.92	474.45	3.7	914.31
USACE Curve High - 50 yrs.	1.64	0.5	**C1**	0.2	49.42	0.06	14.83	0.26	64.25
USACE Curve High - 50 yrs. + 10 yr. Storm	6.53	1.99	**C2**	2.49	615.30	2.27	560.94	4.76	1176.24
USACE Curve High - 100 yrs.	5.02	1.53	**D1**	1.2	296.53	1.31	323.71	2.51	620.25
USACE Curve High - 100 yrs. + 10 yr. Storm*	9.91	3.02	**D2**	9.7	2396.97			9.7	2396.97
USACE Curve High - 100 yrs. + 50 yr. Storm*	11.91	3.63	**D3**	11.27	2784.93			11.27	2784.93

* Coastal Inundation in scenarios D2 and D3 extends into wetland area, Wetland flood extent is included in coastal inundation calculation.

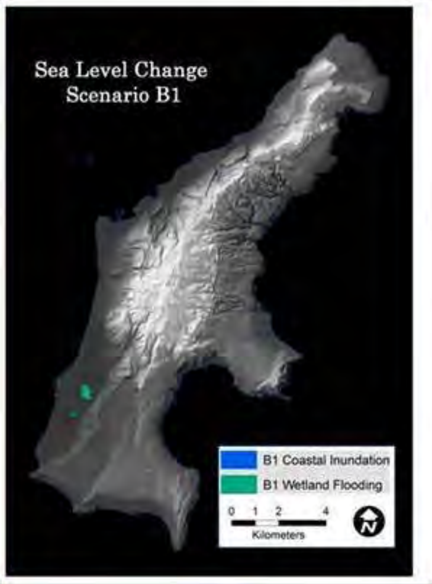
** The area of existing surface water in Susupe wetlands is subtracted from flood extent area (i.e. Wetland flood area = (wetland inundation area - 0.19 km^2))

The areas of inundation vary widely depending on the scenario used. If SLC due to a storm is factored in, these areas expand greatly. An important consideration is that some of the less-extreme SLR scenarios, while not visually striking in figures or the maps on the following pages, will still have a significant impact on the island. Because these maps adopted a “bathtub” approach to inundation mapping, the models do not account for additional coastal flooding factors such as wave run-up, erosion, and other dynamic coastal forces (additional information concerning these considerations is available in the appendix *Sea Level Change Mapping Methods*). These forces will have an impact on all the areas that are directly adjacent to the coastal flood extent, and if taken into account in a model, would likely increase the area of inundation.

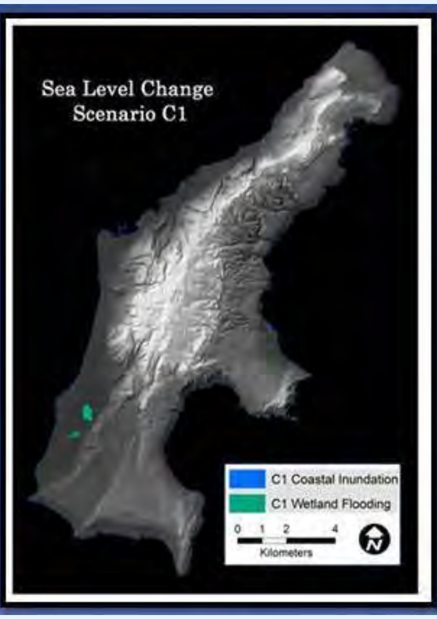
A good example of this is Scenario B1, which is a somewhat conservative estimate of SLR by the end of this century (at the low end of IPCC AR5 RCP 8.5 projections). In this scenario, only a small margin of shoreline is inundated (27 acres). However, this is the same part of the shoreline that currently reduces the energy of waves, and bears the brunt of erosive processes from long-shore currents and seasonal adjustments in sea level. With this shoreline rendered inadequate as far as coastal protection is concerned, the areas directly adjacent to the shoreline are placed within a new zone of erosion and/or wave run-up. On Saipan, this means features identified in the community-based VA such as Beach Road, the Beach Pathway, tourism facilities, American Memorial Park, and Port Facilities will have increased threat levels, and suffer impacts from minor wave and storm events at greater frequencies.

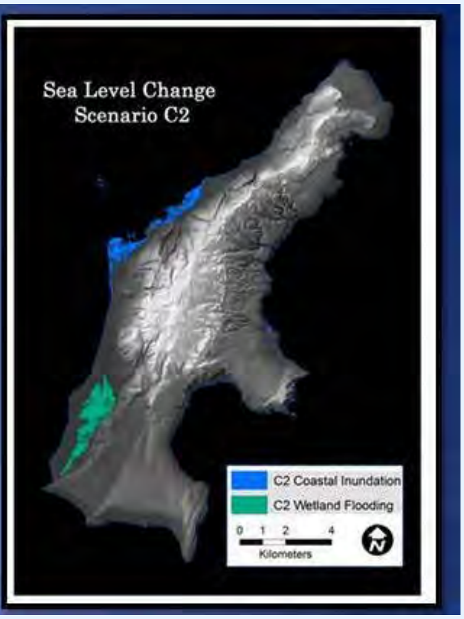

Sea Level Change
Scenario A1
A1 Coastal Inundation
A1 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario A2
A2 Coastal Inundation
A2 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario B1
B1 Coastal Inundation
B1 Wetland Flooding
0 1 2 4
Kilometers
N

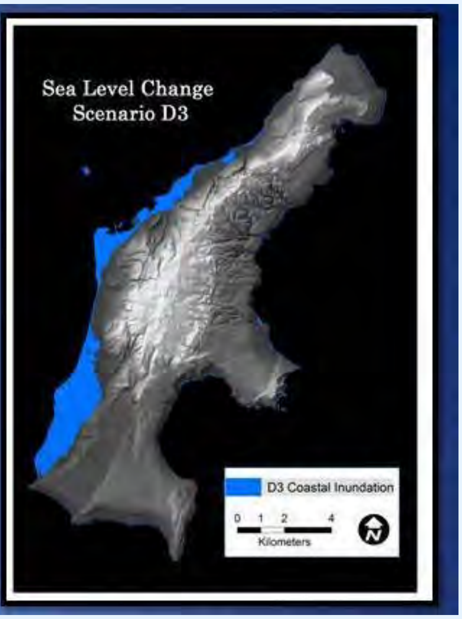

Sea Level Change
Scenario B2
B2 Coastal Inundation
B2 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario C1
C1 Coastal Inundation
C1 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario C2
C2 Coastal Inundation
C2 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario D1
D1 Coastal Inundation
D1 Wetland Flooding
0 1 2 4
Kilometers
N


Sea Level Change
Scenario D2
D2 Coastal Inundation
0 1 2 4
Kilometers
N


Sea Level Change
Scenario D3
D3 Coastal Inundation
0 1 2 4
Kilometers
N

Taking a look at the basic flood extent calculations, it is apparent how rapidly the area of *storm-induced* flooding expands when *climate-induced* SLR is brought into the picture. Along Saipan's lagoon shoreline there is generally 4-8 feet of gentle-moderate sloping beach and shoreline vegetation before the land levels off into the coastal plain and low-lying developed areas. The top of this slope forms a sort of inundation thresh hold for the low lying communities on Saipan's west side. In the more extreme scenarios explored in the VA, sea level overtops a critical elevation contour along the shoreline, and coastal flooding expands inland to cover a much greater area as the inundation thresh hold is breached.

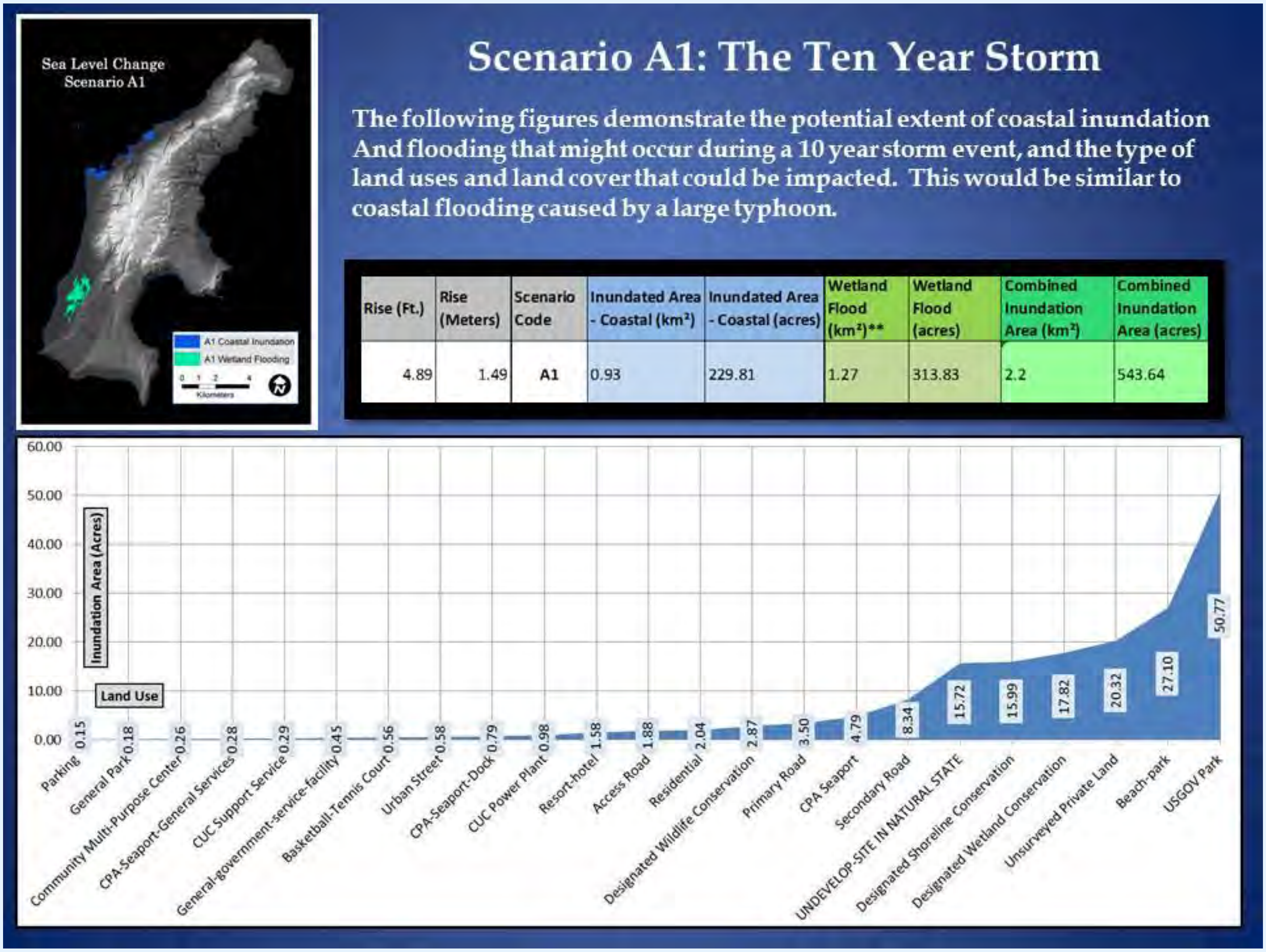
Thus climate change-induced SLR simply enables the 10 year storm to breach that critical point at which the sea moves beyond the beach and into populated areas. The last column in the table below shows the percent increase in coastal flooding area that occurs during a 10 year storm as a result of climate-induced increases in sea level. If the USACE high curve is used to calculate 50 years of SLR (C2), a 10 year storm in 2063 might flood over twice the area that it currently would. This increase in flooded area is not proportionate to the increase in water level. In that particular scenario, increasing sea level by ~30% leads to a 116% increase in coastal inundation.

Scenario Code	Scenario	Combined Inundation Area (km^2)	Combined Inundation Area (acres)	Increase in Flooded Area from 10 year storm baseline (km^2)	Increase in Flooded Area from 10 year storm baseline (acres)	Percent Increase in Flooded Area from 10 year storm baseline
A1	10 year storm without sea level rise (SLR)	2.2	543.64	0	0.00	0.00
A2	10 year storm with 50 years of SLR (intermediate curve)	2.59	640.01	0.39	96.37	17.73
B2	10 year storm with 100 years of SLR (intermediate curve)	3.7	914.31	1.5	370.67	68.18
C2	10 year storm with 50 years of SLR (high curve)	4.76	1176.24	2.56	632.60	116.36
D2	10 year storm with 100 years of SLR (high curve)	9.7	2396.97	7.5	1853.33	340.91

The significant changes that SLR can make to naturally-occurring SLC are also evident in the following detail figures. These figures illustrate the land uses and land cover that could potentially be inundated by a given scenario, and provide some detail maps at a larger spatial scale to highlight impacts of inundation on some of the stakeholder resources identified in Section 2. Scenarios A1, C2 and D1 are shown within this section of the document to illustrate three possible states of sea level:

- A naturally occurring elevated sea level due to a large typhoon (Scenario A1)
- A naturally occurring elevated sea level due to a large typhoon that is exacerbated by SLR (Scenario C2)
- An extreme case of SLR due solely to climate change, with no influence from a typhoon (Scenario D1)

A1: The 10 Year Storm



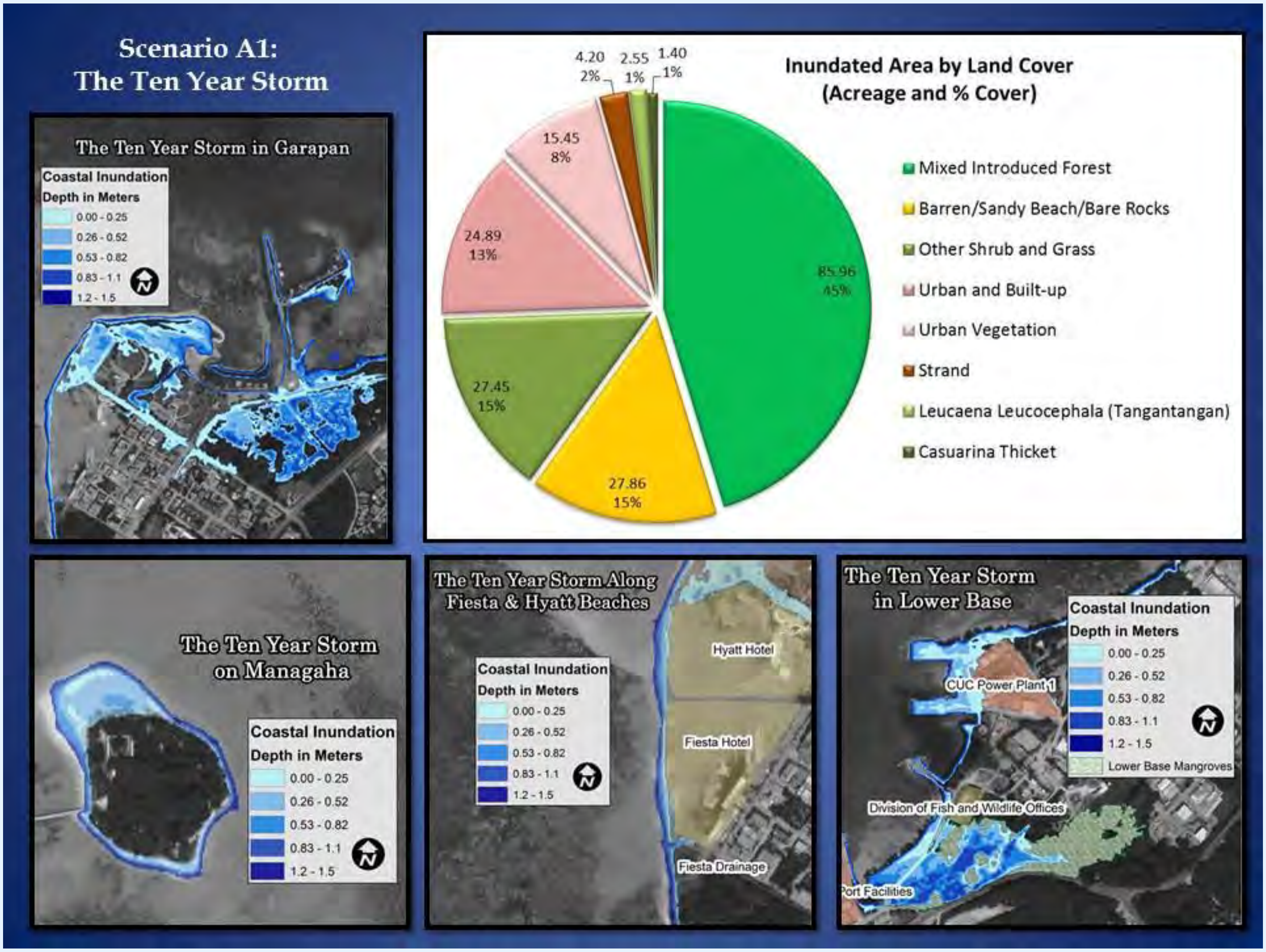
Scenario A1: The Ten Year Storm

The following figures demonstrate the potential extent of coastal inundation And flooding that might occur during a 10 year storm event, and the type of land uses and land cover that could be impacted. This would be similar to coastal flooding caused by a large typhoon.

Rise (Ft.)	Rise (Meters)	Scenario Code	Inundated Area - Coastal (km²)	Inundated Area - Coastal (acres)	Wetland Flood (km²)**	Wetland Flood (acres)	Combined Inundation Area (km²)	Combined Inundation Area (acres)
4.89	1.49	A1	0.93	229.81	1.27	313.83	2.2	543.64

The ten year storm, which would be similar to a moderately sized typhoon, places a large amount of stress on parcels and land use directly adjacent to the shoreline, but flooding extent does not extend inland for more than 100 meters or so in all but a few locations. The most heavily impacted parcel, labeled USGOV Park in the CNMI land use coding scheme, is American Memorial Park, and has over 50 acres inundated. The remaining parcels that are heavily impacted or that experience flood depths greater than a few tenths of a meter are publicly-accessible shoreline areas, parks, and undeveloped sites, as well as a few parcels of private land.

It is important to note that a few key features identified by stakeholders in the community-based assessment are marginally impacted. This is the case in almost all the scenarios as these are directly adjacent to the lagoon waters. These features are shown in the following figure.



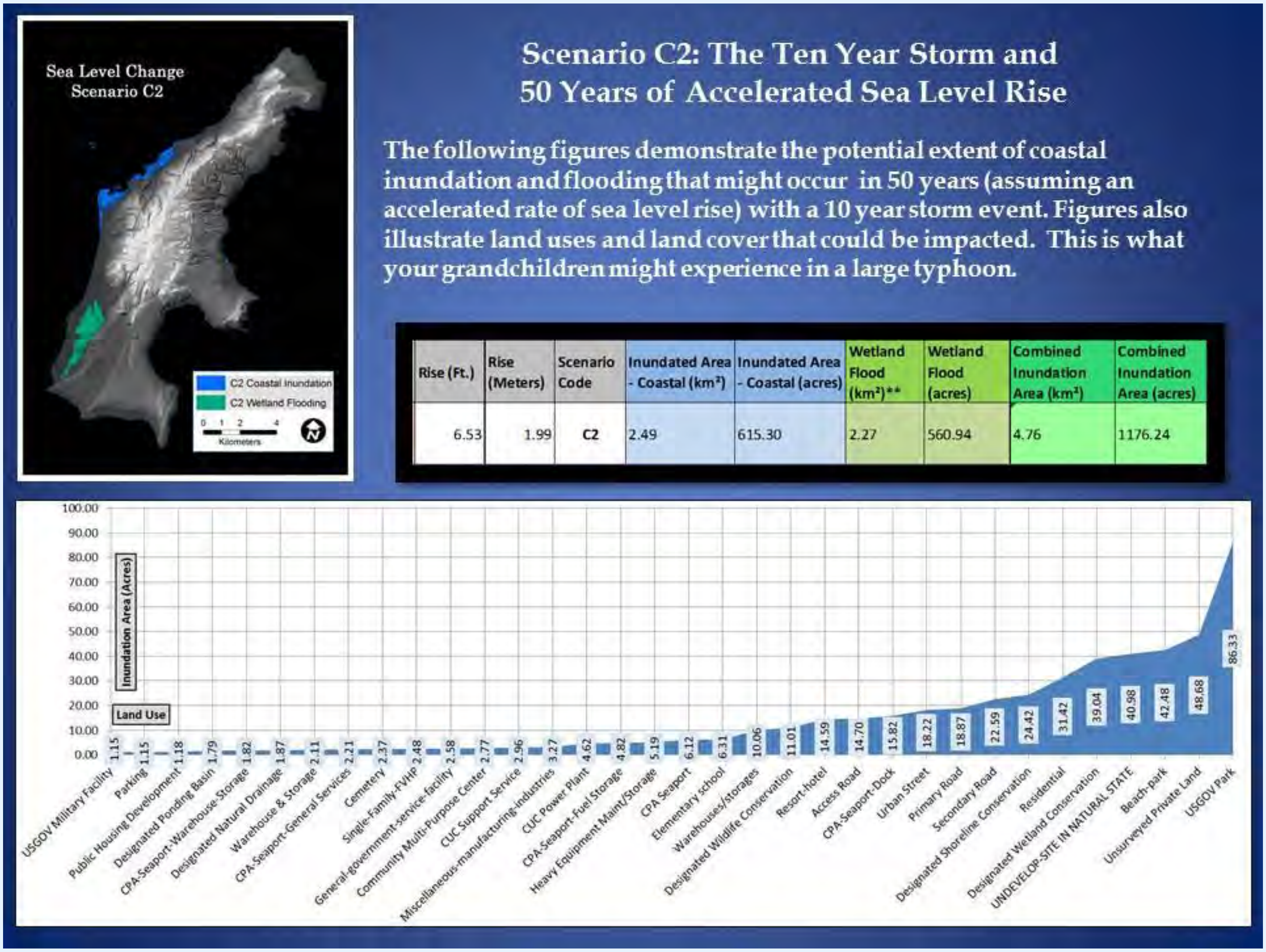
Here we see several key features impacted by severe flooding. Most of American Memorial Park's wetlands are completely inundated, while flooding occurs along the streets separating the Park from Garapan's core business area and the Hyatt Resort. On the shoreline side of Hyatt and Fiesta Hotel, the sea level is raised to a point just below the elevation contour that marks the top of the beach slope. Along this line wave over-topping and run-up would impact the recreational features along the resorts' beaches, but they would likely avoid permanent flooding. More severe flooding of these features is demonstrated in scenario C2.

The mangroves and wetlands present in Lower Base are also completely inundated in this scenario. This would likely create a backwater effect in which any run-off or drainage from precipitation in the Capitol Hill area would build up behind the wetlands, creating additional inland flooding.

The detail map of Lower Base also illustrates multiple threats to industrial and government facilities. Notably, primary access to the CUC Power Plant and DFW Offices is cut off near the Port, and the Power Plant itself is partially inundated along the shoreline.

The percentage of impacted land cover types also demonstrates the *composition* of inundated land. The primary area of "mixed introduced forest" in the figure above is actually the land cover class assigned to the flooded vegetation in American Memorial Park. Next to this the major impacts occur on beaches and strand vegetation located along the shoreline. About 20% of the impacted area is characterized by urban and impervious surfaces, posing additional flooding threats within more developed villages.

C2: The 10 Year Storm in 50 Years



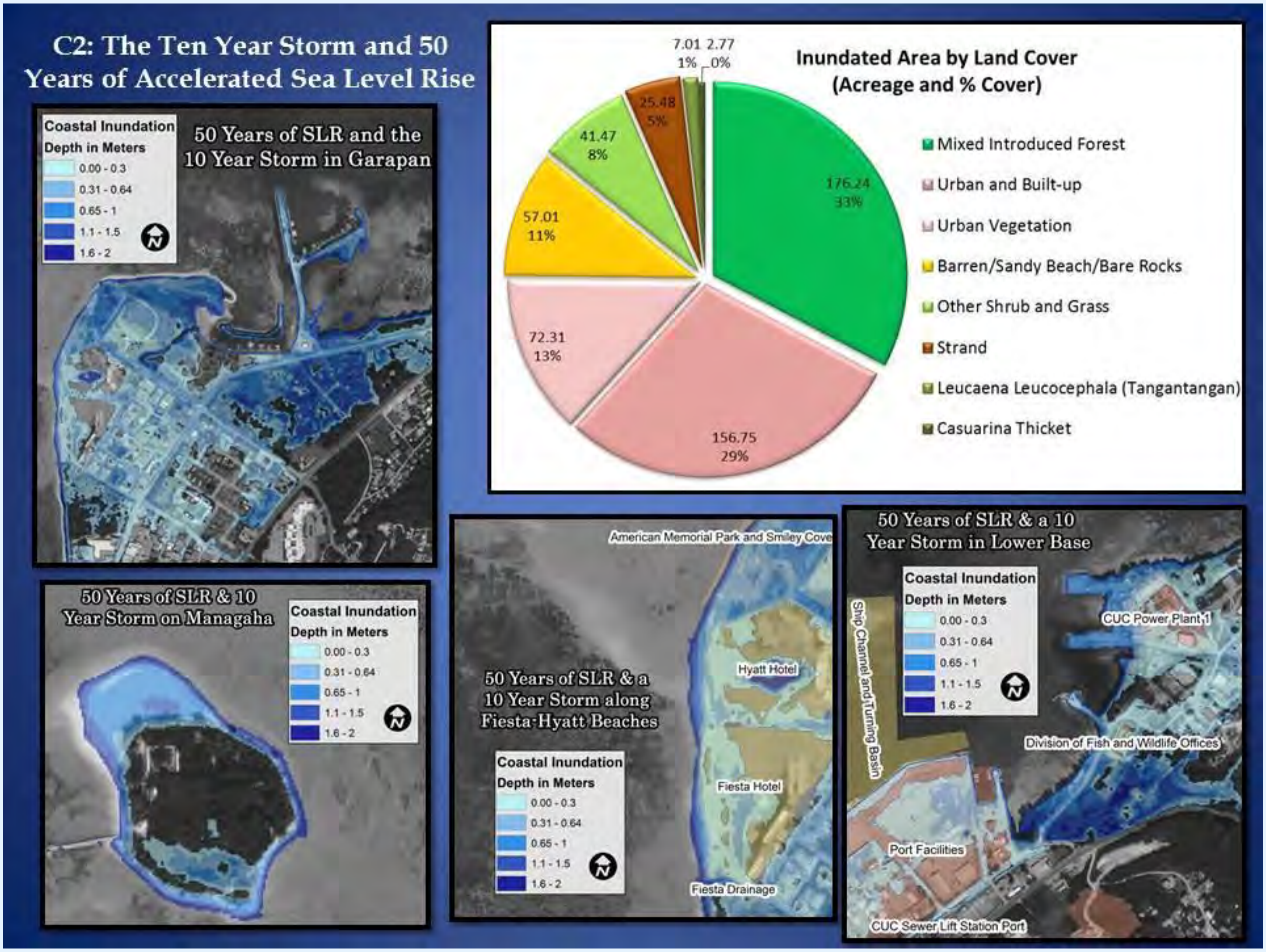
Scenario C2: The Ten Year Storm and 50 Years of Accelerated Sea Level Rise

The following figures demonstrate the potential extent of coastal inundation and flooding that might occur in 50 years (assuming an accelerated rate of sea level rise) with a 10 year storm event. Figures also illustrate land uses and land cover that could be impacted. This is what your grandchildren might experience in a large typhoon.

Rise (Ft.)	Rise (Meters)	Scenario Code	Inundated Area - Coastal (km²)	Inundated Area - Coastal (acres)	Wetland Flood (km²)**	Wetland Flood (acres)	Combined Inundation Area (km²)	Combined Inundation Area (acres)
6.53	1.99	C2	2.49	615.30	2.27	560.94	4.76	1176.24

In scenario C2, we see 50 years of accelerated SLR added to the 10 year storm from scenario A1. The results from a simple analysis of this scenario demonstrate the great potential of climate change to amplify the impacts of natural climate stressors such as storms.

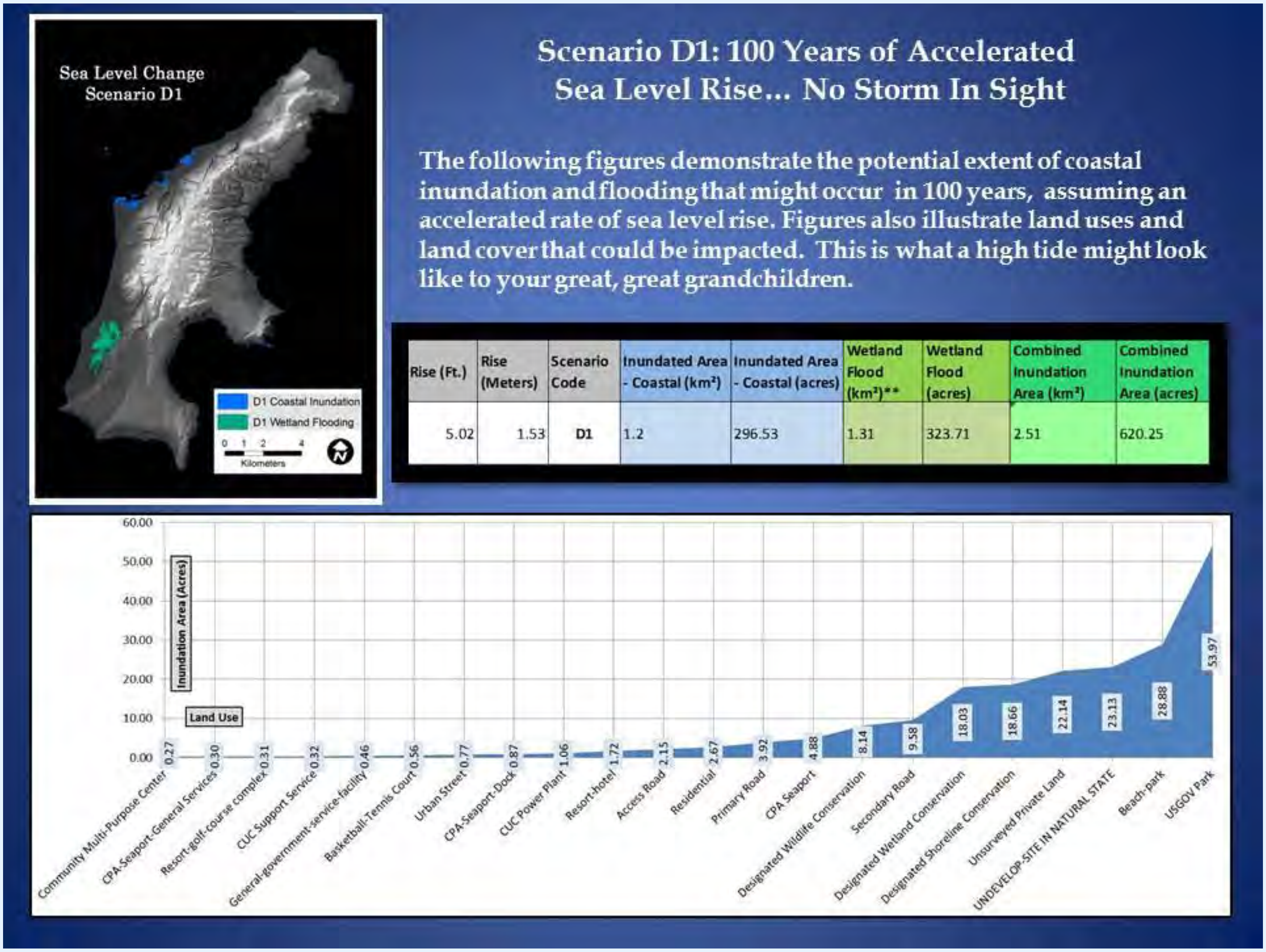
In the context of land use, the major parcels suffering from flooding remain largely the same as in scenario A1; however, roughly twice the area is inundated. Perhaps what is most significant in this scenario is a change in the second tier of impacted parcels (between ~4 - ~20 acres) from A1. The land uses that are now impacted due to the addition of 50 years SLR include more critical infrastructure, such as primary, secondary and access roads, the CPA Seaport, and CUC Power Plant. Tourist facilities, residential areas in Garapan and Tanapag, and Garapan Elementary School also experience flooding.



The composition of impacted land cover also changes drastically from scenario A1 to C2. While the mixed-introduced forest of AMP still constitutes the largest percentage of flooded area, over 40% of additional inundated area is either part of an urban core, or a developed space within a village. This reflects flooding through Garapan, the Lower Base industrial area, and Tanapag. In the detail maps we see that the safety of Port Facilities, DFW offices, and the CUC Power Plant are fully compromised. The core of Garapan is thoroughly flooded, with some notable flood depths along the Fiesta drainage. The primary tourism facilities in Garapan also become flooded.

Managaha Island also suffers inundation. Compared to scenario A1, flooding in C2 has overcome a critical contour line along the shore, and inundated a significant portion of the developed area on the island, not to mention cut off tourist access via the docking facility. While there is no chance that tourists or staff would be on the island in a storm such as this, the combined short-term action of increased sea levels, currents, and waves on the island's unstable shoreline would likely alter the shape and volume of the island in a manner that would require serious physical modification to continue tourist activities.

D1: Normal Conditions in 100 Years



Scenario D1: 100 Years of Accelerated Sea Level Rise… No Storm In Sight

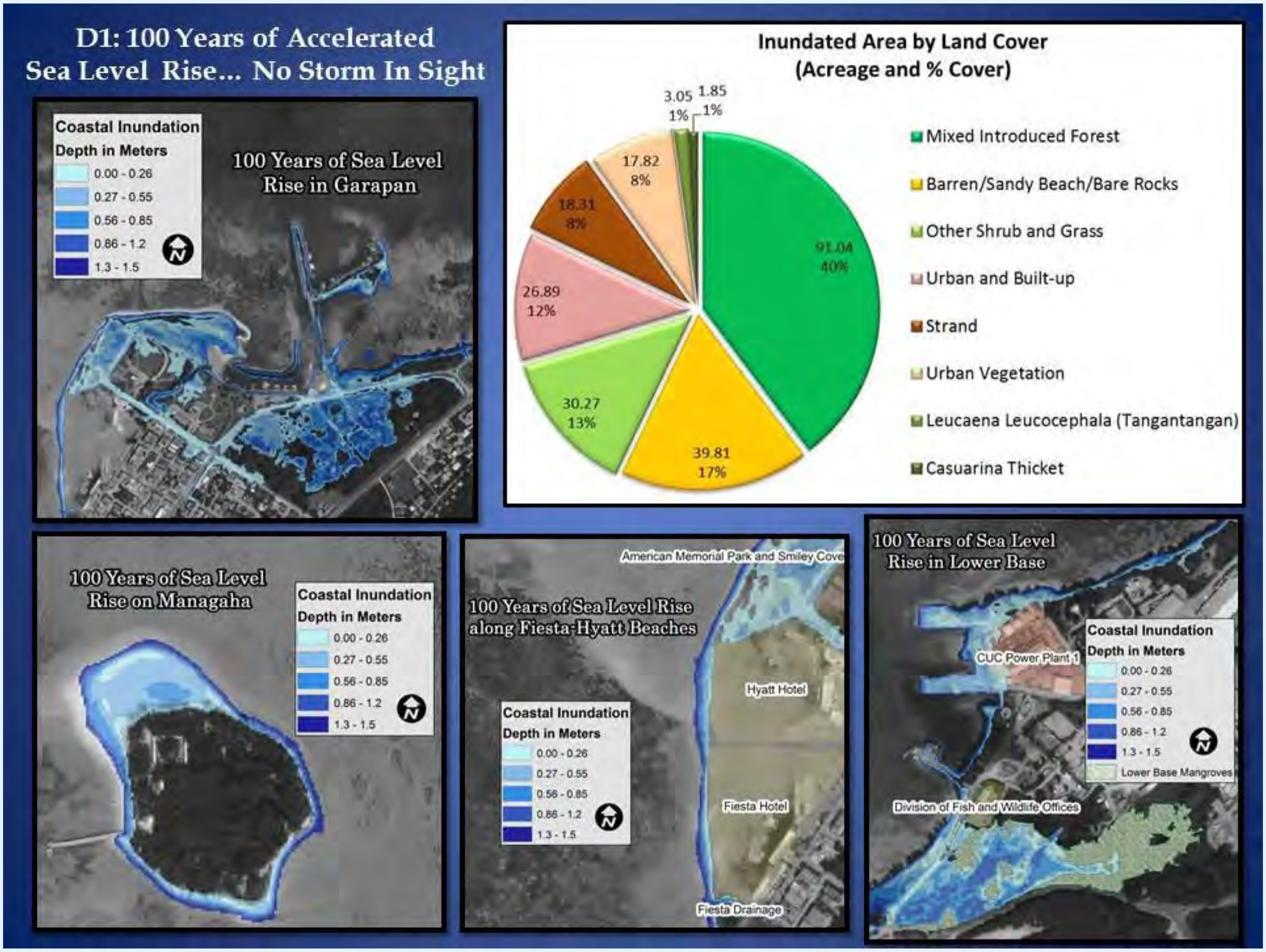
The following figures demonstrate the potential extent of coastal inundation and flooding that might occur in 100 years, assuming an accelerated rate of sea level rise. Figures also illustrate land uses and land cover that could be impacted. This is what a high tide might look like to your great, great grandchildren.

Rise (Ft.)	Rise (Meters)	Scenario Code	Inundated Area - Coastal (km²)	Inundated Area - Coastal (acres)	Wetland Flood (km²)**	Wetland Flood (acres)	Combined Inundation Area (km²)	Combined Inundation Area (acres)
5.02	1.53	**D1**	1.2	296.53	1.31	323.71	2.51	620.25

Scenario D1 is an extreme scenario built upon the upper end of SLR projections for the 21st century, but regardless of probability, such an increase in sea level remains within the realm of possible futures, and therefore merits consideration. The scenario is also of interest due to the similarities it shares with scenario A1. D1 illustrates conditions in which the extent of coastal inundation during high tide by the end of the century (D1) exceeds that of a large typhoon at the beginning of the century (A1). The axiom "today's flood is tomorrow's high tide" is embodied quite well in this scenario.

Examining the impacts of flooding on parcels, American Memorial Park faces a flood extent similar to that of A1, though this time the park is compromised permanently (as opposed to short-term flooding via a typhoon). Saipan's publicly accessible shoreline is inundated, although by the end of the century the shoreline is more likely to be re-arranged or retreated after decades of gradually increasing sea levels. In this scenario a significant amount of physical modification over a span of many decades would be required to maintain existing public shoreline access or park facilities.

A similar level of physical alteration to infrastructure and the shoreline would be necessary to maintain the Seaport and Power Plant facilities at their current locations, and a relocation of the Lower Base Power Plant might be a viable option in the face of permanent inundation. Conservation areas and wetlands would also be permanently inundated, necessitating new restoration priorities.

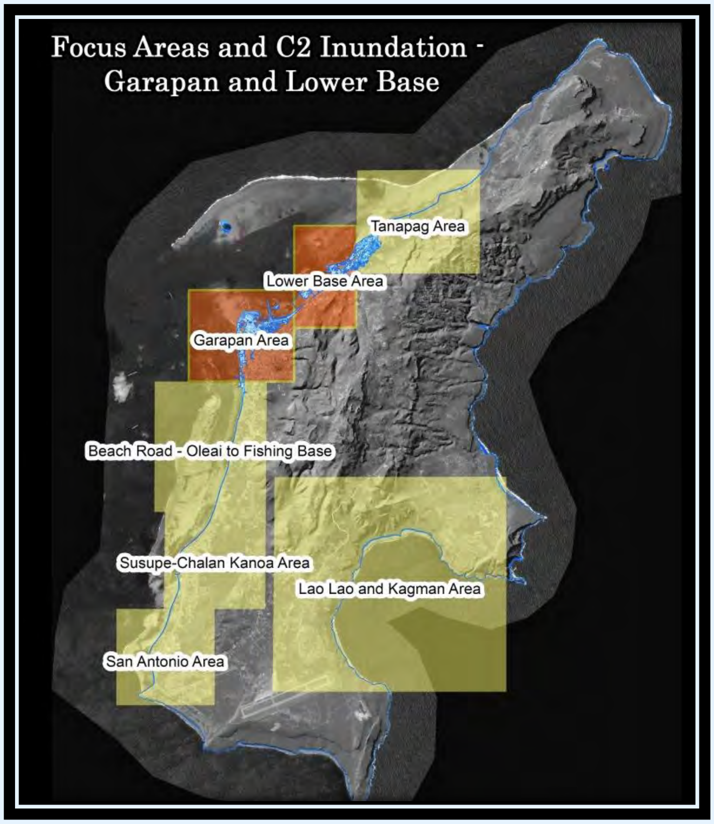


The detail maps for scenario D1 further highlight the implications of an extreme, long-term SLR scenario. While Managaha's current tendency toward instability and re-shaping would lead to a different configuration of the island by 2100, any areas currently susceptible to erosion would certainly be exacerbated. If vegetation is not allowed to establish in areas that are currently accreting (e.g. the northwest section of beach), there would be a major loss of the island's ability to migrate and adapt to natural coastal processes.

Resort facilities would also face a retreating and re-arranged shoreline (provided significant hardening and modification of the shoreline was not implemented), and the DFW Offices would certainly require relocation. While the maps do not illustrate permanent inundation of Garapan's core *at the surface*, there would likely be chronic flooding of the low-lying stormwater and waste-water infrastructure due to a back-water effect within drainage systems. Lift stations and any non-pressurized sewer mains could face permanent impairment as a result of this effect.

The following section explores the severity of flood scenarios in two of the most vulnerable focus areas: Garapan and Lower Base.

3.2. Flood Severity and Focus Areas

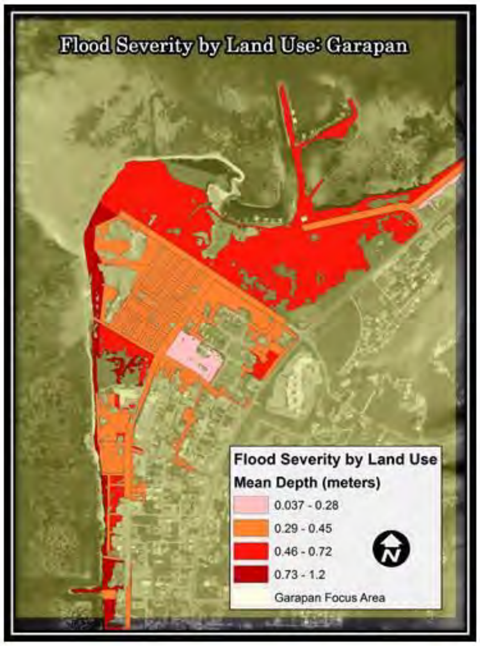


The cumulative potential impact of coastal flooding in Garapan and Lower Base is a result of both the *extent* and *depth* of flood waters. This combination can be thought of as flood *severity*. Figure 29 focuses on coastal flood severity in Scenario C2 by examining the mean depth of flood waters within individual land parcels. While flood depths vary greatly over large parcels, visualization of average depths allow for a quick assessment of spatial variation in flood impacts.

Both Garapan and Lower Base exhibit significant susceptibilities to flooding. The physical configuration of the landscape allows for a great degree of hydraulic connectivity, especially where storm water drainages and impervious surfaces occupy low-lying areas. In these situations, a primary or secondary road (or its parallel drainage) may act as a conduit for coastal flooding, connecting basins or "sinks" that are critically impacted.

Ultimately, this connectivity enhances the ability of flood waters to move inland and impact properties and facilities that were previously set back a sufficient distance from the shoreline.

Figure 29: Map of coastal flood severity by land use in Garapan and Lower Base



Garapan faces severe flooding both adjacent to the shoreline, as well as along its northern boundary with American Memorial Park. In this scenario it is interesting to note severe inundation along the parcels that border CHC and down Beach Road.

Flooding in Lower Base could be most severe along the shoreline and wetland areas north of the CPA Seaport. Flood connectivity via access roads allows for more severe inundation along the inland parcels at the northern extent of this focus area. CUC facilities are also subject to severe inundation.

3.3. Coastal Flooding and Socially Vulnerability

While Saipan's physical exposure to coastal flooding is a significant component of its overall vulnerability to climate change, a comprehensive picture of vulnerability is not possible without consideration of the people who will be affected. Identifying the most sensitive populations is a complex task, requiring due consideration of the factors that enable individuals, households, and entire communities to respond and adapt to both short-term extremes and long-term changes. Intimate knowledge of the community, and in-depth investigation into how climate variables affect livelihoods is necessary at household and community levels.

For this project, a social vulnerability index was built for the island of Saipan as an initial attempt to assess social vulnerability. While the index does not achieve the nuanced knowledge required to develop detailed adaptation priorities, it does provide a preliminary glimpse into the composition of factors contributing to social vulnerability on Saipan.

The variables used in constructing the Saipan social vulnerability index are primarily based on the findings of *Human Links to Coastal Disasters* (Heinz Center 2002), *The Hidden Costs of Coastal Hazards* (Heinz Center 2000), and *Indicators to Assess Community Level Social Vulnerability to Climate Change* (Wongbusakarum & Loper 2011).

The latter document is an addendum to the regional socioeconomic monitoring guidelines produced by the Global Socioeconomic Monitoring Initiative for Coastal Management (SocMon) and its Pacific counterpart. The guidelines set forth in that document provide a set of indicators for social vulnerability including demographic characteristics of vulnerable groups.

The Heinz Center studies were originally conducted to support the construction of a metric that examines the differences in social vulnerability to environmental hazards among U.S. counties. A county-level index using 30 socioeconomic variables was originally constructed by the Heinz Center to graphically display geographic variation in social vulnerability across the continental U.S. That product was leveraged by NOAA's Coastal Services Center to develop visualizations of the social vulnerability of coastal counties that might be impacted by SLC or SLR.

For the Saipan VA, 22 socio-economic variables were selected based on both the Heinz Center's findings, the SocMon guidelines, and consultation with CCWG planning committee members. While there is significant overlap between the Saipan index and the original indices it was informed by, there are a few important distinctions. In particular, Saipan's unique situation in terms of political status, as well as geographic isolation, needed to be taken into account when choosing variables for the index. An attempt at this was made by considering the following:

- Saipan's economic structure has a history of changing rapidly in response to shifts in political relations and labor laws. In some cases, the mobility and flexibility to either relocate from the island, or adapt to a shuffling of economic bases would be essential.
- Going along with the previous consideration, the advantages that citizenship status affords on an island with a large guest-worker population and uncertain future with regard to resident-status also play a major role in social vulnerability.

Data from the 2010 U.S. Census and 2005-2009 American Community Surveys were analyzed in GIS for U.S. Census "place" geographies (villages) on Saipan. Data values for each variable were grouped into five classes using a natural breaks method, and re-classified to reflect a value of 1-5. The variables were weighted according to relative contribution to vulnerability, and overlaid to reflect cumulative vulnerability. Reclassifications for individual variables are available as an appendix.

There are some inherent complications with applying a county-level metric to Saipan's village-scale, not to mention applying a study of mainland socioeconomic factors to those of Saipan, which has a uniquely structured economy. Nevertheless, the concept that the demographic composition of an area contributes to its sensitivity to natural hazards and ability to adapt to them is a reasonable one. Furthermore, the economic and educational elements that contribute to disaster preparedness were found to be fairly universal across U.S. counties. Given the diversity of socioeconomic conditions across all of these counties, the transfer of the social vulnerability index concepts to Saipan was deemed feasible.

The 22 variables included in the index are listed here, along with a brief description of how these factors affect vulnerability. Some variables are grouped under a broader indicator category.

Factors Impacting Vulnerability

Socioeconomic status: Socioeconomic status affects a population's ability to absorb and recover from losses. Wealth increases one's resilience to coastal hazards and improves access to recovery aids such as insurance and social safety nets.

- *Median Household Income*
- *Percentage of Population Below Poverty Line*
- *Median Rent as a Percentage of Median Household Income*
- *Per Capita Income*
- *Percentage of Population Over 16 Unemployed*
- *Median Rent*
- *Percentage of Population with No Health Insurance*

Average Household Size: Large households tend to have a larger number of dependents and less flexibility in their ability to relocate to areas that are safe from coastal hazards, thereby decreasing these households' resilience and ability to recover.

Percentage of Population Over 16 Relying Solely on Subsistence Activities: Occupations that rely heavily on natural resources may be severely affected by a hazard event, or by gradual change that limits the availability of those resources. Those who rely solely on subsistence activities for their livelihoods may not have alternative means of support if the natural resources that they rely on are no longer available.

Education: Higher education is linked to socioeconomic status and earning potential. Limited education is linked to a lower earning potential and limits the ability to access and understand disaster warnings.

- *Percentage of Population 25 and Older with Bachelor's Degree*
- *Percentage of Population 25 and Older with High School Education*

Percentage of Population Disabled: People with disabilities tend to have more reliance on their families and social services and therefore are more vulnerable in the face of hazards and disasters.

Type of Housing Material: The quality of housing material affects how easily a home may be destroyed by a storm or rising sea level. Less durable building materials such as corrugated metal and wood decrease a home's resiliency to hazards and increase vulnerability. Super Typhoon Keith, which produced sustained winds of over 160 mph in the CNMI in November 1997, caused significant damage on Saipan, Tinian, and Rota. Over 106 homes were destroyed and another 477 homes sustained significant damage. These homes were primarily constructed out of metal or wood (CNMI SSMP 2010).

- *Percent of Houses with Metal Roof*
- *Percent of Houses with Metal Wall*
- *Percentage of Houses with Wood Roofs*
- *Percentage of Houses with Wood Walls*
- *Percentage of Houses Built on Wood Pilings*
- *Percent of Houses Mobile or Non-permanent*

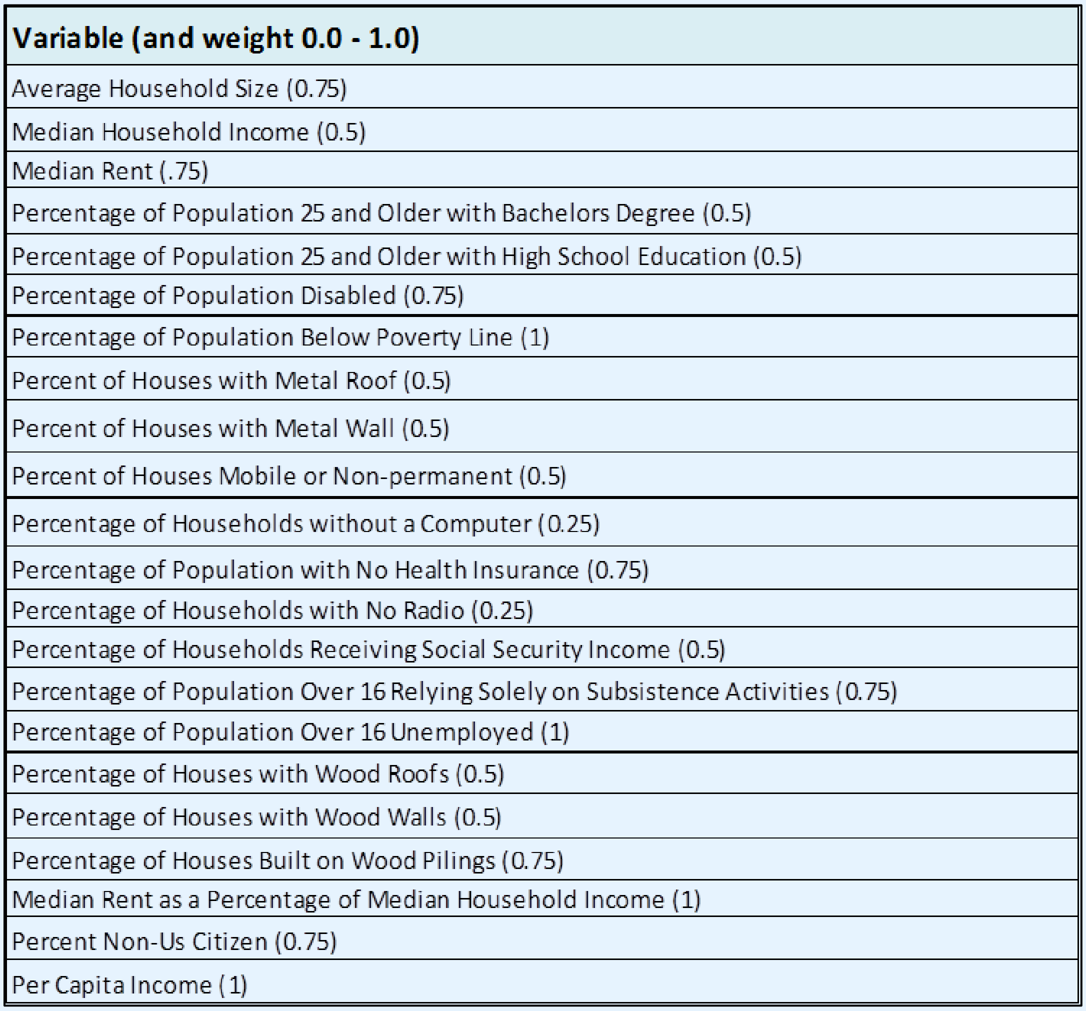
Access to warning information systems: Households without access to disaster warnings and evacuation information are less able to prepare and therefore less resilient. While "warning information systems" are often thought of in the context of extreme events (e.g. typhoons, tsunamis), additional information systems in the Pacific Region may be developed or enhanced to raise awareness of potential long-term events or trends such as droughts or sub-regional changes in sea level. Both radios and computers are important means of accessing this type of information in the Pacific Islands.

- *Percentage of Households without a Computer*
- *Percentage of Households with No Radio*

Percentage of Households Receiving Social Security Income: People who are eligible for social security benefits are most likely elderly, disabled, or otherwise unable to support themselves. Therefore they tend to be more reliant on others for support, and have less resilience to natural disasters and climate stressors.

Percent Non-Us Citizen: Non-US citizens may be unable to access and understand disaster/climate-related warnings due to language or cultural barriers, and may be unable to access government provided disaster relief and funding due to immigration status. In addition, any future changes in political or legal situations pertaining to non-resident workers may limit non-U.S. citizens' entire livelihoods, thus reducing their performance among other vulnerability indicators such as employment or education.

The table below lists the individual variables, along with the weights that were applied to each. The reclassification tables for data values can be found in the appendices.



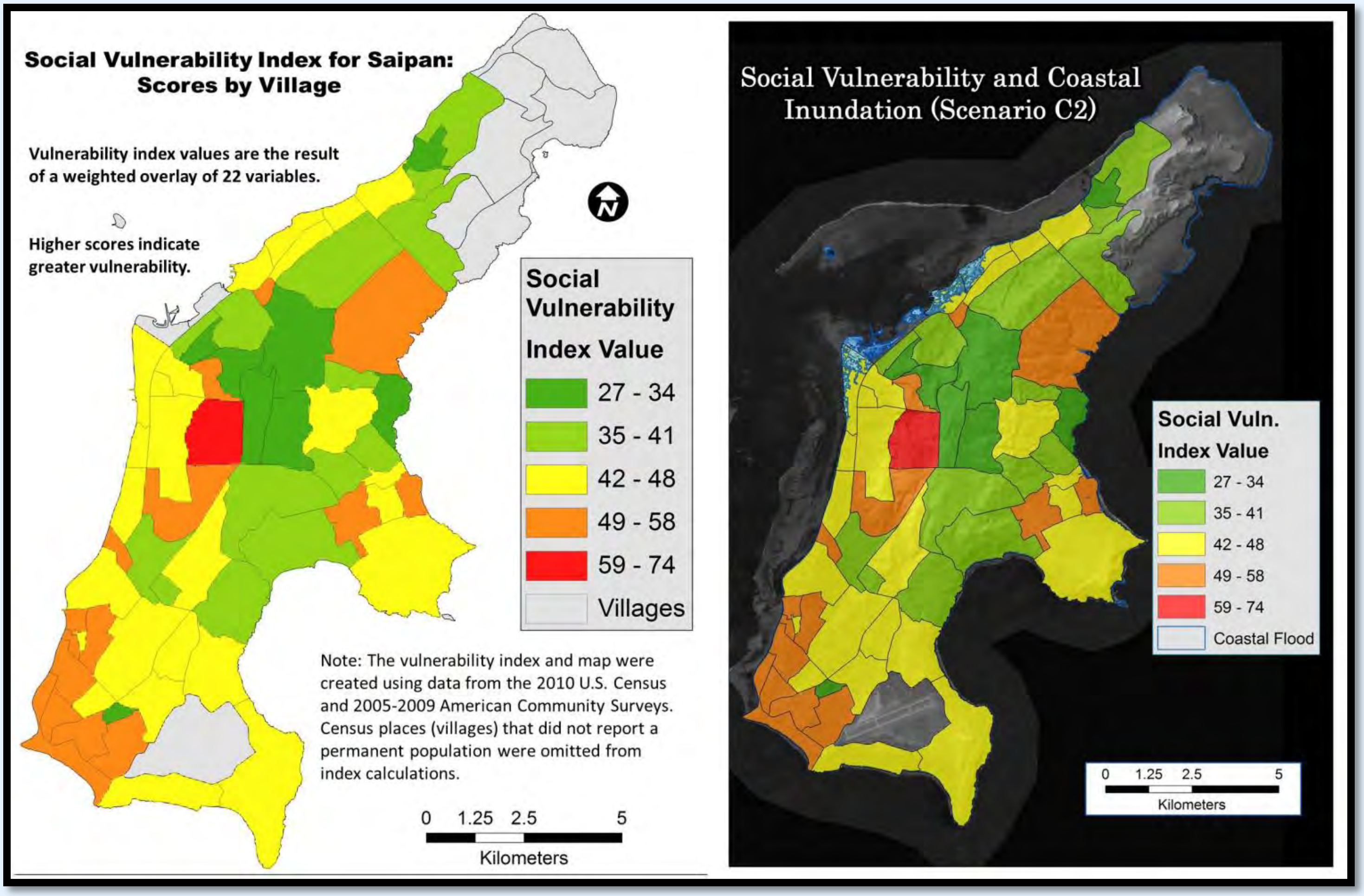
Variable (and weight 0.0 - 1.0)
Average Household Size (0.75)
Median Household Income (0.5)
Median Rent (.75)
Percentage of Population 25 and Older with Bachelors Degree (0.5)
Percentage of Population 25 and Older with High School Education (0.5)
Percentage of Population Disabled (0.75)
Percentage of Population Below Poverty Line (1)
Percent of Houses with Metal Roof (0.5)
Percent of Houses with Metal Wall (0.5)
Percent of Houses Mobile or Non-permanent (0.5)
Percentage of Households without a Computer (0.25)
Percentage of Population with No Health Insurance (0.75)
Percentage of Households with No Radio (0.25)
Percentage of Households Receiving Social Security Income (0.5)
Percentage of Population Over 16 Relying Solely on Subsistence Activities (0.75)
Percentage of Population Over 16 Unemployed (1)
Percentage of Houses with Wood Roofs (0.5)
Percentage of Houses with Wood Walls (0.5)
Percentage of Houses Built on Wood Pilings (0.75)
Median Rent as a Percentage of Median Household Income (1)
Percent Non-Us Citizen (0.75)
Per Capita Income (1)

The index results (Figure 30 on the following page) suggest that the most socially vulnerable villages are concentrated on the west side of Saipan, with particularly vulnerable areas around San Antonio and Chalan Kanoa. The Kagman area is also characterized by high social vulnerability. The lowest social vulnerability scores are found in the Capitol Hill area and among the interior of the island where population density is low and households are spread out among the highest elevations.

It should be noted that simply re-weighting some of the variables would likely re-arrange the composition of results, as would normalizing for population density. If population density were factored into the index it is likely that both Susupe and the Garapan area's vulnerability ratings would become significantly higher.

Regardless, the results of this index suggest socially vulnerable populations are clustered in the low-lying areas on the west side of the island, and minor adjustments to variable weights would not change this.

Figure 30: Map of social vulnerability index results by village on Saipan



The index is a first attempt at gauging the socio-economic layout of the island as it relates to coastal hazard resiliency and climate change, and will benefit from future modifications and iterations. Extended consultation with a wide range of community members is warranted, as is a field-based study of specific factors contributing to vulnerability. This additional inquiry would greatly enhance our understanding of different villages on Saipan, and their abilities to adapt and respond to natural stressors such as climate change.

4. Summary of Vulnerability

The Saipan VA investigated vulnerability through an array of assessment processes. The approach utilized both qualitative and quantitative tools, and involved varying levels of depth as far as inquiries into different climate stressors are concerned. This section summarizes the overall vulnerability of Saipan to climate change, highlighting a few examples of resources that illustrate significant aspects of the island's vulnerability.

4.1. Cumulative Vulnerability: Focus Areas

In this summary the term "cumulative vulnerability" is used to refer to the overall vulnerability of a specific area on Saipan and its stakeholder resources, as rated by three distinct assessment tools:

The Community-Based Participatory Assessment: This year-long process provided an initial qualitative rating of vulnerable resources and systems around the island. Using stakeholder input and local expertise, clusters of potentially vulnerable resources were identified. These resources were mapped, and the CCWG applied a basic vulnerability formula (*exposure + sensitivity – adaptive capacity*) to assign vulnerability ratings to both individual resources, as well as entire areas. Seven geographic focus areas on Saipan were delineated around these resources (eight if Managaha Island is included), providing guidance for additional analysis.

Sea Level Rise Visualization and Flood Assessment: Nine different sea level scenarios were mapped and analyzed. Flood extent and depths were calculated for each scenario, and potential impacts to specific land uses and land cover types were explored within focus areas.

Social Vulnerability Index: A metric was developed using best available demographic data to rank the social vulnerability of Saipan's villages to climate change. Socio-economic information relating to the ability of the island's population to adapt to climate stressors was built into an index. This index allowed for application of a vulnerability rating to Saipan's human dimensions.

The table below summarizes the cumulative vulnerability of Saipan's focus areas on a scale of 1-5, as well as the ratings from the individual assessment tools. A description of how the rating scale was applied within each assessment tool follows the table.

Focus Area	Community VA Rating	Coastal Inundation Vulnerability	Social Vulnerability	Cumulative Vulnerability
San Antonio Area	2	2	4	2.7
Susupe-Chalan Kanoa Area	3	2	3	2.7
Beach Road - Oleai to Fishing Base	4	3	3	3.3
Garapan Area	5	5	2	4.0
Lower Base Area	5	5	3	4.3
Tanapag Area	2	4	3	3.0
Lao Lao and Kagman Area	2	1	2	1.7
Managaha Island	5	5	N/A	N/A

- "Community VA Rating" refers to the qualitative rating that the CCWG assigned to each of the focus areas. A rating of "Low" was re-classified as '1', "Medium-Low" to '2', "Medium" to '3' and so on.

- The "Coastal Inundation Vulnerability" rating was developed taking into account both the *extent* of potential flooding, as well as the *depth* of that flood scenario. Areas with a large expanse of flooded area, with greater flood depths, and with greater inland reach were assigned higher ratings.

- The Social Vulnerability rating is a re-classification of the five classes developed in the Social Vulnerability Index. A higher range of index scores (e.g. 59-74) were assigned a high rating (e.g. ‘5’). Index scores for villages within each focus area were assessed, with greater consideration given to villages that bordered the shoreline.

- The Cumulative Vulnerability score is simply the average (mean) of the three ratings (Community VA, Coastal Inundation, and Social Vulnerability).

Summary:

The Saipan Vulnerability Assessment suggests that the villages and infrastructure on Saipan’s western coastal plain are the most vulnerable to the effects of sea level rise and possible shifts in rainfall. While the entire island will likely see some impacts from climate change in the coming decades, the villages and stakeholder resources that are located between Susupe and Tanapag are expected to be impacted the most. These impacts are specific to the effects of coastal inundation, flooding of wetlands and low-lying areas, and exacerbation of precipitation-induced flooding.

The low lying areas, critical infrastructure, residential and commercial districts, and habitats that are located within Garapan and Lower Base should be prioritized in further assessments and adaptation work.

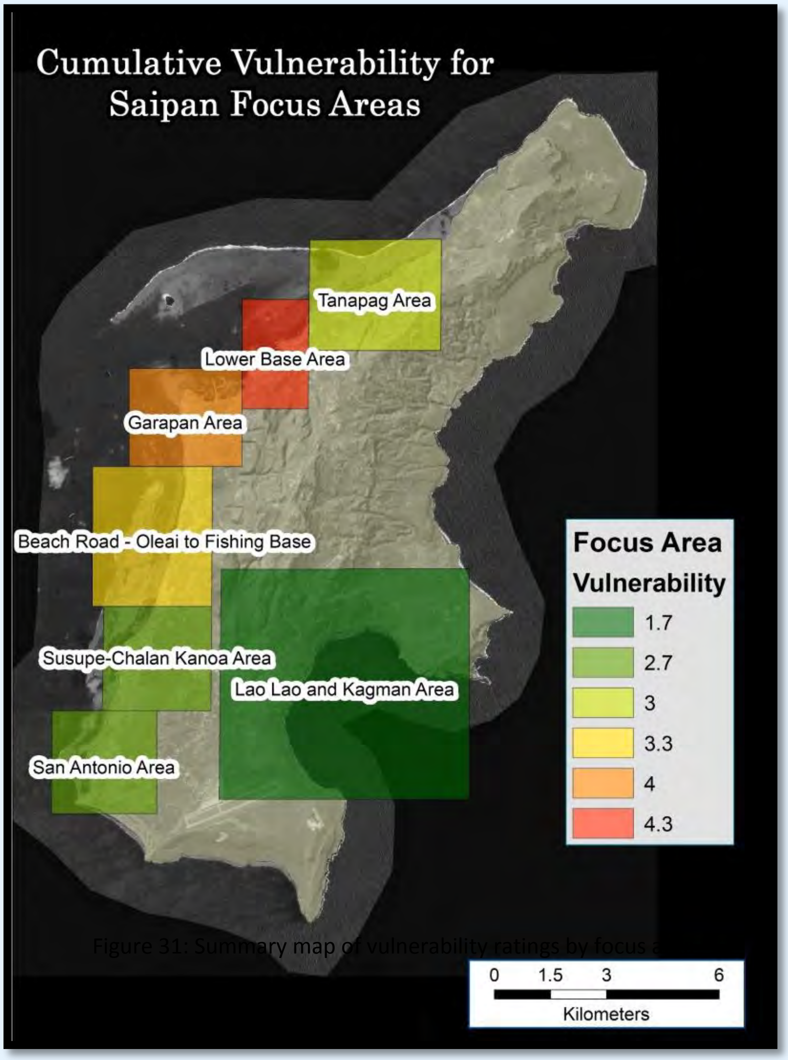


Figure 31: Summary map of vulnerability ratings by focus a

There are many potential impacts of climate change relevant to Saipan that were simply outside the scope of this assessment. Perhaps the most notable implications of a changing climate that have not been discussed in detail are the shifts in ocean heat content and chemistry. Much of Saipan’s economic and cultural value is based upon the marine environment. The reefs, fisheries and benthic habitat around the island deserve greater attention with respect to climate stressors.

Likewise, additional study of Saipan’s agricultural resources and their responses to climate variability and change is warranted. Future assessments may benefit from adopting a resource-based approach, in which a particular category of resources such as “reefs” or “agricultural land” is analyzed in the context of a well-defined array of climate stressors.

There are also numerous climate change VAs and adaptation strategies for other Pacific Islands and U.S. jurisdictions that focus analysis on broad *systems* or *sectors*, (e.g. “transportation” or “terrestrial ecosystems”). However, Saipan’s relatively small size offered an opportunity to assess climate vulnerabilities by *geographic area* at a detailed level. Whereas the general “systems-approach” encourages the development of broad adaptation strategies which can be interpreted and implemented at smaller scales, the Saipan VA’s explicit attention to location is intended to facilitate the development of site-specific or feature-specific adaptations and actionable items. The Saipan VA revealed several features that should be emphasized as climate adaptation planning in the CNMI moves forward.

Saipan’s Exposure and Sensitivity

Saipan's lagoon shoreline and groundwater resources on the coastal plain are prime examples of features that are exposed and sensitive to climate stressors. These features provide an excellent starting point for more detailed analysis of particular systems, and may provide focus for the CCWG as an adaptation strategy for Saipan and the CNMI begins to take form.

Shoreline Erosion

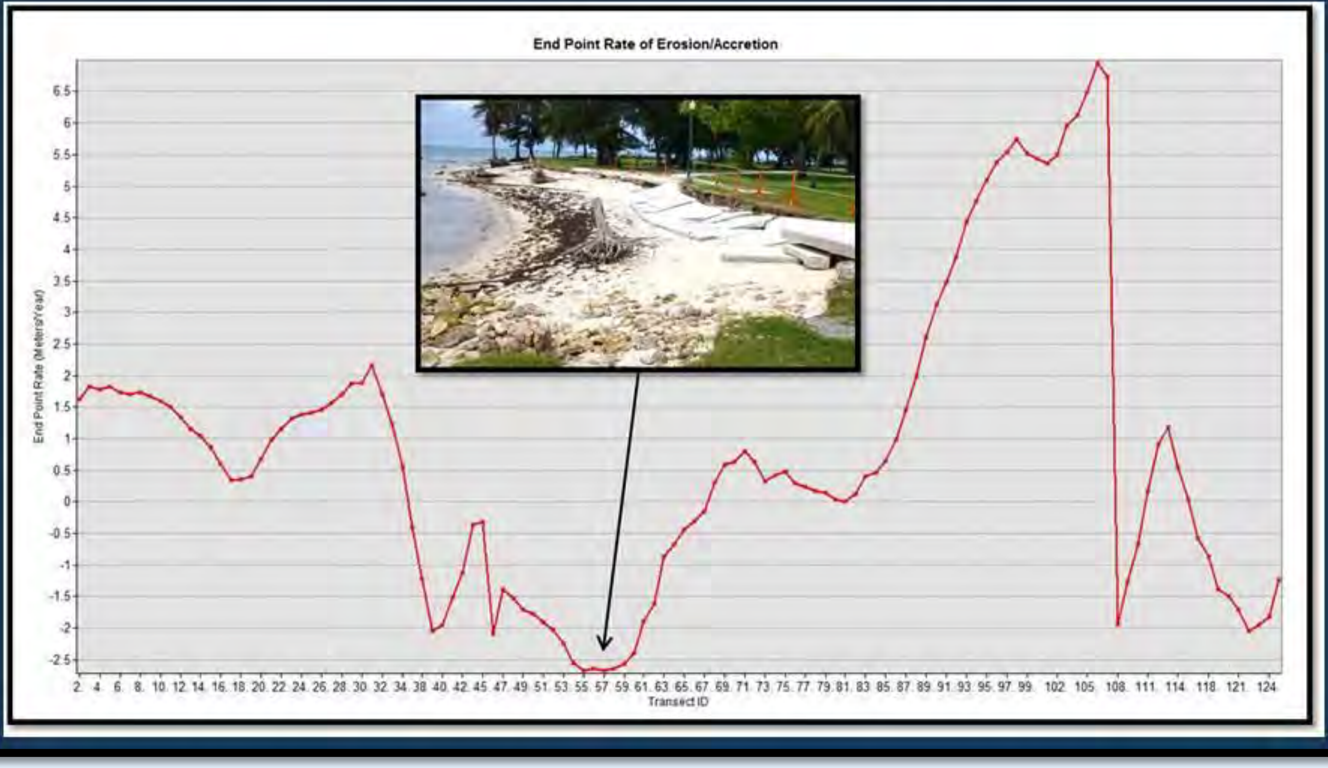
Much of Saipan's shoreline is fairly stable, owing to resistant limestone terraces, cliffs, and protective fringing reefs. However, a few sections of beach in the Saipan lagoon and Managaha Island exhibit signs of chronic erosion and instability. Figure 32 describes a case study of shoreline instability in American Memorial Park in which shoreline movement was assessed for both the VA and to support the Garapan Conservation Action Plan (Office of the Governor 2013).

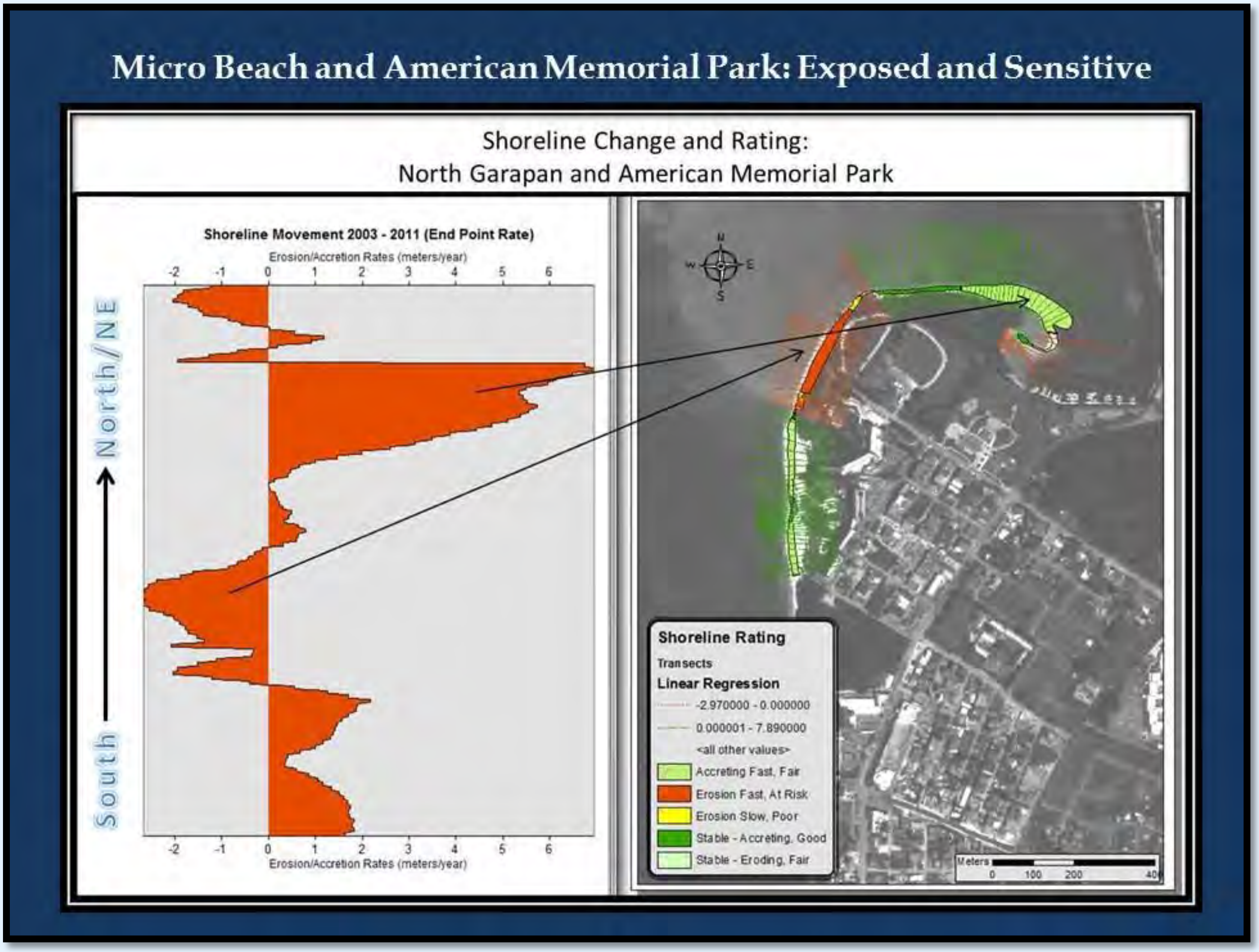
Figure 32: Case study quantifying shoreline erosion in American Memorial Park

The CNMI's Most Sensitive Shoreline?

Saipan's American Memorial Park has a long history of erosion and accretion. The north and west sides of the park are essentially a sand spit, and are subject to mass movement of sand and re-arranging beaches on an annual basis. Over the past decade the west side of the park has eroded significantly, resulting in loss of recreational area and non-critical structures, while the northeast end of the park has seen significant accretion and beach development.

In March 2013 the U.S. Geological Survey's Digital Shoreline Analysis System was used to analyze the movement of the park's shoreline between 2003 and 2011. While the park's eroding beaches are partially restored on a seasonal basis, the results of the shoreline analysis illustrate a dominant trend of erosion from the west side of the park and accretion to the northeast. Potential sea level rise poses severe implications for this dynamic shoreline. The following figures highlight the park shoreline's troubling behavior.





As discussed in Sections 2 and 3 of the VA, infrastructure and stakeholder resources that are located within the vicinity of unstable shorelines (such as American Memorial Park) have been rated as highly vulnerable.

While American Memorial Park is perhaps the most visible example of a beach that is sensitive and exposed to coastal processes and erosion, there are additional areas throughout Saipan's lagoon that will require continued monitoring as sea levels vary. Changing sea levels have also impacted resources beneath the surface of Saipan, thus compounding the island's overall level of exposure and sensitivity.

Groundwater and Freshwater Resources

From 1998 through 2000 the sea level at Saipan's Sea Port varied between 0.55 ft. and 2.15 ft. above mean sea level. During this same period of time water levels in the coastal aquifers underneath the western coastal plain of Saipan ranged from 1.45 ft. to 2.55 ft. (Carruth 2003). This relationship demonstrates a strong hydraulic connection between sea levels and Saipan's coastal freshwater supply. Our groundwater resources have an inherent sensitivity and exposure to SLR via the island's freshwater lens and aquifers. The closer one gets to the coastline from the island's interior, the thinner the freshwater lens gets, increasing the chances of saltwater intrusion. Potential increases to sea level due to climate change may increase these chances.

However, coastal aquifers and groundwater are also equally, if not more susceptible to saltwater intrusion due to human use of Saipan's well systems (Wong & Hill 1990; Carruth 2003). This sensitivity hints toward a potential adaptive capacity. While some mixing of saltwater and freshwater is unavoidable in the context of SLC and SLR, intentional changes to well withdrawal rates, pumping levels, and withdrawal locations (in relation to the saltwater-freshwater transition zone) could ease some of the stress that climate change and SLR pose.

Deliberate changes to infrastructure in response to climate stressors such as this are examples of climate change adaptation, and capitalize on opportunities that existing systems offer. While a built system (e.g. freshwater pump facilities) can be altered through intentional actions, natural systems (e.g. coral reef ecosystems, wetlands, etc…) may have the ability to autonomously change in response to climate stressors. Together, the abilities to respond to climate through inherent natural properties or through physical alterations are referred to as adaptive capacities.

The participation of a variety of community members, scientists, engineers and resource managers in this VA allowed for identification of many potential adaptive capacities on Saipan.

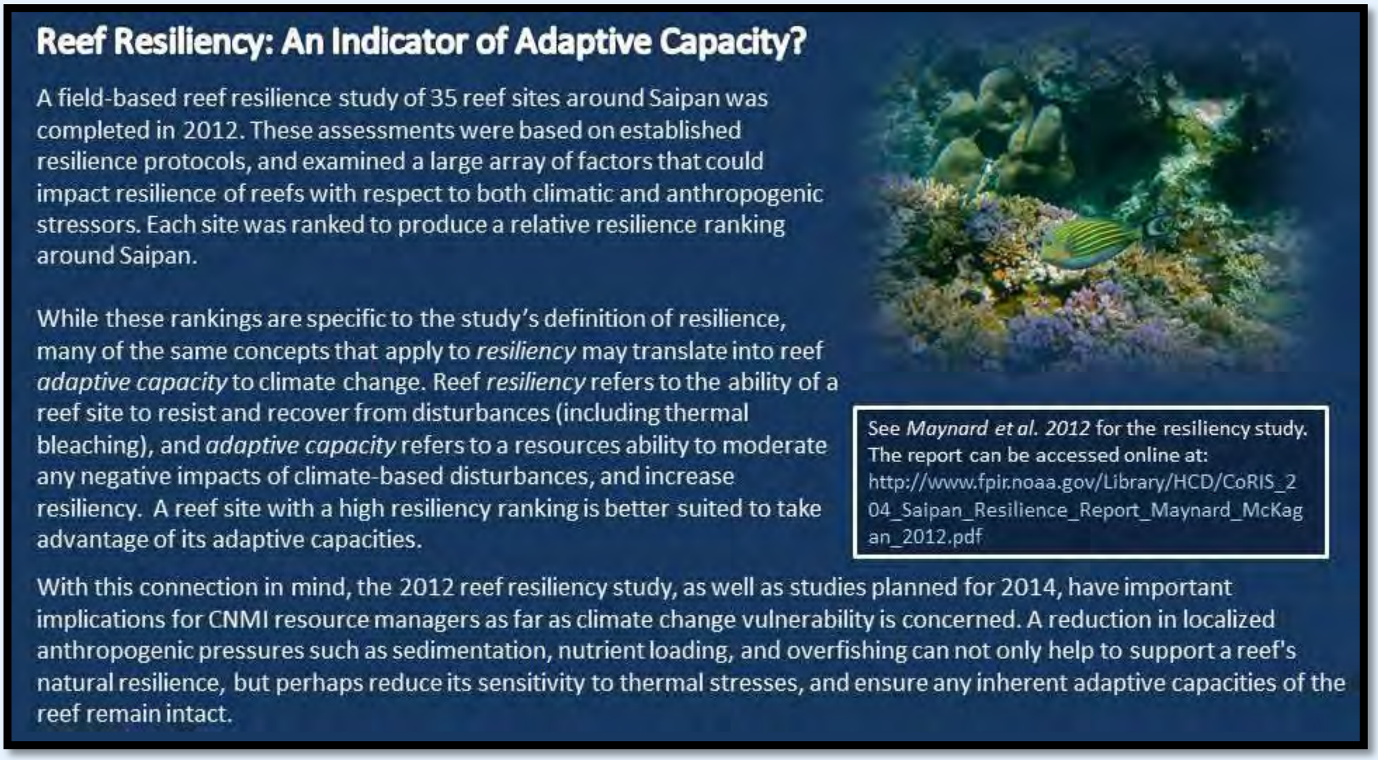
Saipan's Adaptive Capacities

Natural Capacities

Among the natural systems of the CNMI, coastal and marine ecosystems exhibit several traits that may increase adaptive capacity with respect to SLR and changes to ocean chemistry. In particular, the health and resilience of the archipelago's coral reefs, wetlands and shoreline vegetation have implications for coastal protection.

Under normal sea level conditions the fringing reefs around Saipan provide a barrier against beach erosion by dissipating wave energy over the fore reef and reef crest. When storm surge or extreme low atmospheric pressure allows for an increase in sea levels around Saipan, the reef crest loses some of its ability to reduce wave energy, resulting in increased wave run-up and coastal erosion. This loss of functionality is a major concern in the face of projected SLR scenarios. SLR of 0.5 – 1.0 meters by the end of the century would increase mean wave height and associated wave energy that crosses our protective fringing reefs, leading to increased coastal erosion, turbidity within the lagoon, and sediment transport across reef flats (Storlazzi et. al 2011).

However, coral reefs have an innate adaptive capacity with respect to this threat. Healthy, resilient reefs *may* grow (vertically) at a rate that matches, or at least partially offsets the effects of rising sea levels, thus allowing the fore reef and crest to provide continued coastal protection. This capacity for growth is complex, and heavily reliant on a variety of factors, including the relative resiliency of reefs in the face of both anthropogenic and climate stressors (Figure 33).



Reef Resiliency: An Indicator of Adaptive Capacity?

A field-based reef resilience study of 35 reef sites around Saipan was completed in 2012. These assessments were based on established resilience protocols, and examined a large array of factors that could impact resilience of reefs with respect to both climatic and anthropogenic stressors. Each site was ranked to produce a relative resilience ranking around Saipan.

While these rankings are specific to the study's definition of resilience, many of the same concepts that apply to *resiliency* may translate into reef *adaptive capacity* to climate change. Reef *resiliency* refers to the ability of a reef site to resist and recover from disturbances (including thermal bleaching), and *adaptive capacity* refers to a resources ability to moderate any negative impacts of climate-based disturbances, and increase resiliency. A reef site with a high resiliency ranking is better suited to take advantage of its adaptive capacities.

See *Maynard et al. 2012* for the resiliency study. The report can be accessed online at: http://www.fpir.noaa.gov/Library/HCD/CoRIS_204_Saipan_Resilience_Report_Maynard_McKagan_2012.pdf

With this connection in mind, the 2012 reef resiliency study, as well as studies planned for 2014, have important implications for CNMI resource managers as far as climate change vulnerability is concerned. A reduction in localized anthropogenic pressures such as sedimentation, nutrient loading, and overfishing can not only help to support a reef's natural resilience, but perhaps reduce its sensitivity to thermal stresses, and ensure any inherent adaptive capacities of the reef remain intact.

Figure 33: Case study of reef resiliency around the Island of Saipan

As other climate change threats such as thermal bleaching and ocean acidification increasingly impact the CNMI's marine ecosystems, resource managers and stewards will need to actively promote the adaptive capacity of coral reefs. This can be done through reduction of anthropogenic stressors to increase reef resilience, and through continued research into additional adaptive capacities within the marine environment. In the context of Saipan, this could include mitigating land use practices within the Garapan sub-watershed that contribute to sedimentation and nutrient loading (USACE 2013), while promoting sea cucumber populations to reduce local impacts of ocean acidification (Schneider et al. 2011).

While the protection offered by fringing reefs to unstable beaches and shoreline is crucial, the shoreline itself holds some additional adaptive capacities. Managaha Island serves as an excellent example of this. As noted in Sections 2 and 3 of this document, Managaha is constantly changing in both shape and volume. Erosion and accretion occurs at rapid rates along various sides of the island on seasonal and annual bases. While there is volatility in this change, the dominant trend over the last few decades is for the island to build on its northwest shoreline while eroding from the east. There are concerns as to how SLR might exacerbate the current shoreline erosion; however, the island itself can adapt if new vegetation is allowed to establish on the growing portions of the beach. In this way, the island may not be preserved "as-is", but it may adapt to changing conditions by establishing a new, stable shoreline where there was previously none. Managaha's potential for adaptation is discussed further in Section 5 of this document.

Establishment and growth of shoreline and strand vegetation may also provide adaptive capacity for Saipan's lagoon shoreline, particularly along the Beach Road pathway and at Micro Beach/AMP. In these areas beach vegetation and isolated patches of wetlands provide important stabilizing properties for soil and sand, protecting from erosion and impacts of occasional wave run-up (Feagan 2008, Swann 2008). Over longer time periods these stabilized areas could offer a foundation for accretion or deposition of additional sand and sediments (Gedan et al. 2011). The latter capacity will be particularly important in the context of long-term gradual SLR. While it is uncertain how Saipan's shoreline will respond in the long-term to SLR, encouraging stabilization through natural capacities may attenuate erosive processes to avoid any accelerated impacts.

Capacities in the Built Environment

Adaptive capacities along Saipan's shoreline are not limited to the inherent capabilities of natural systems such as vegetation-based erosion control. Deliberate actions may be taken by those businesses and land managers with shoreline property to moderate the impacts of SLR, and short-term SLC. Private actors and individual government agencies such as the Department of Public Lands may encourage strategic landscaping along threatened beaches, or promote the rotational use of non-permanent structures for beach-side recreational facilities. The latter measure would, at the very least, ensure that new facilities are not placed in situations that face future losses under extreme SLR scenarios.

These actions constitute an extremely important adaptation opportunity, and in some cases can be implemented on an individual basis, without policy-driven guidance (Monnereau & Abraham 2013). Autonomous adaptation may be a viable short-term option in the event that public sector guidance or policy for broader adaptation initiatives is slow to take effect.

Upgrades to freshwater infrastructure and well facilities also offer an adaptive capacity. Provided there is further study of the impacts that SLR will have on coastal aquifers, future adjustments to well locations, withdrawal rates, and pumping depths create an opportunity to adapt to threats from saltwater intrusion. Given the uncertainties in future changes to precipitation patterns in the WNP, modifications that account for potential droughts or unpredictable groundwater recharge may also serve as adaptation opportunities.

Similar adaptive capacities are found within planned or proposed upgrades to stormwater and sewer arrangements by CUC or DPW. Projects that channel and filter run-off, or modernize antiquated sewer infrastructure could consider possible sea level scenarios or the possibility of more volatile precipitation events.

The following section explores opportunities to capitalize on adaptive capacities through examples of adaptation outside of the CNMI, as well as recommendations for next steps and actions within the CNMI.

5. Recommendations for Adaptation

Why Adapt?

One of the primary purposes of this VA is to provide the basis for more immediate responses to possible climate change impacts, without getting caught up in the conflict-ridden policy arena surrounding the mitigation of greenhouse gas emissions. We'd like to avoid any additional controversies on the island of Saipan for the time being. In addition, there is a financial incentive to focus climate change responses on adaptation. Simply put, it is more efficient and inexpensive to explore mutually beneficial opportunities for adaptation now than it is to pay for possible damages and extreme system modifications later (ECA 2009a). This is true in the context of both long-term climate threats and immediate disaster risks.

With this preference and rationale for adaptation in mind, a VA becomes a crucial first step in an ongoing, informed climate change initiative. It provides a foundation of information that can guide further strategizing and implementation of actionable items. While there are certainly aspects of assessment that can be continually improved or updated, new information should ultimately feed into a broad adaptation process and plan (Center for Science in the Earth System 2007). The information contained in sections 1-4 of this document offers a first glimpse into Saipan's vulnerabilities and prioritizes areas for adaptation planning. The following pages present a few ideas as to how Saipan's resource managers, land owners, policy-makers, and the community in general can use this information.

5.1. Exploring Adaptation Opportunities

Where can we adapt? What can be adapted?

As the CNMI moves forward with adaptation planning it will be extremely important to balance investment in adaptation measures with some of the more immediate, visible needs of the islands. One way of achieving this balance is to identify and prioritize actions that are mutually beneficial to other programs, as well as cost-effective.

In Samoa, a financial portfolio of potential adaptation measures was compiled to assess the cost-effectiveness of different opportunities (ECA 2009b). This project revealed interesting findings related to the benefits of individual measures, as well as impracticalities associated with some more common regulatory-based options. In particular those measures that favor protection from SLR through the use of natural adaptive capacities such as coastal vegetation and wetland growth were found to be not only cost-effective (requiring little maintenance or investment), but addressed more immediate threats from natural disasters such as typhoons. These types of actions are prime examples of "no-regrets" strategies, and similar opportunities should be explored in the CNMI.

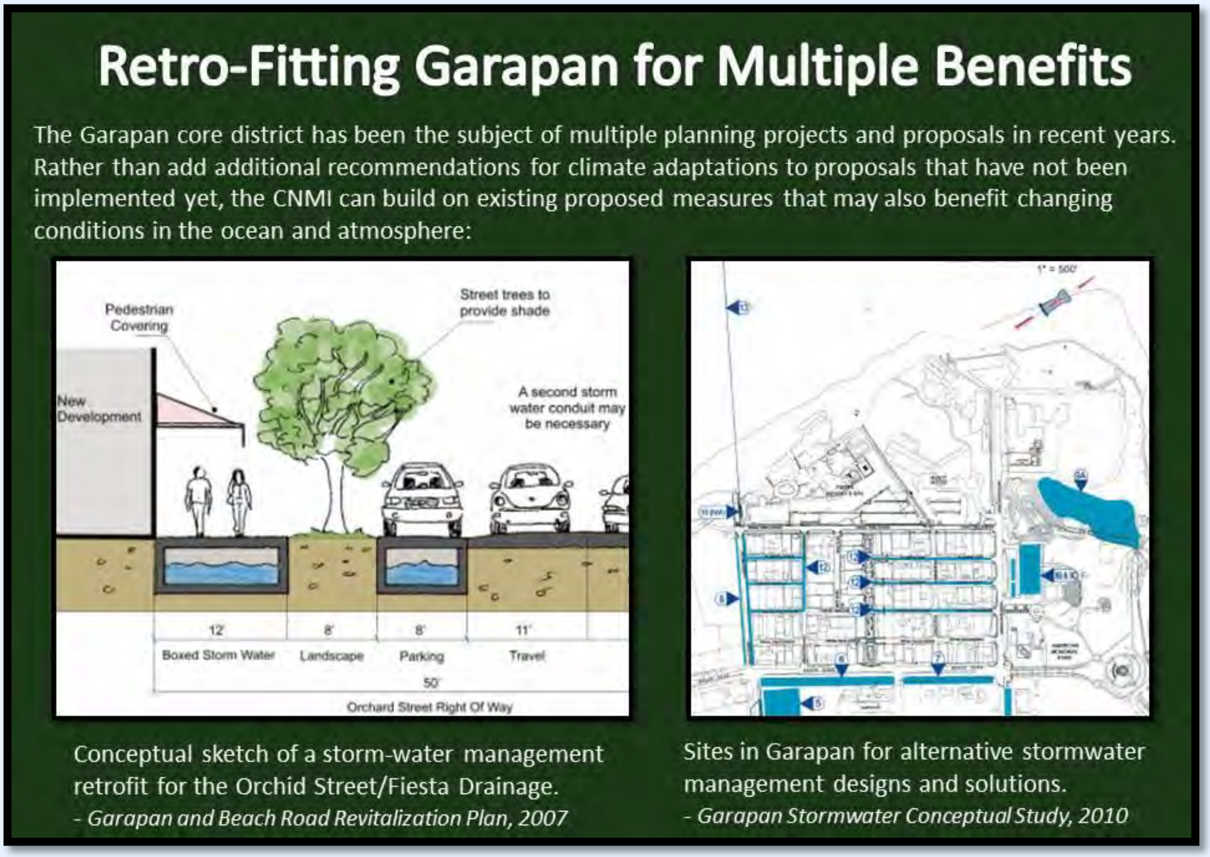
The Samoan study also found that policy options related to increases in coastal setbacks or mandatory retreat from the coastline, as opposed to shoreline armoring, are often difficult to implement due to influence from private actors and landowners. This does not mean that regulatory and policy options such as this should be avoided. Instead, planners and decision-makers should identify novel ways of integrating these climate change considerations and adaptations into appropriate plans. For example, setback requirements could be adjusted to reflect varying degrees of vulnerability along the shoreline, as opposed to static, broad application of a single setback measure.

There are also multiple opportunities within land use policies and zoning to streamline climate change adaptation. This is especially true where existing or proposed guidelines have originated as disaster risk reduction and hazard mitigation measures. Such measures may be compatible with adaptation priorities. The U.S. Environmental Protection Agency's Smart Growth Implementation Assistance Project (2013) offers a number of recommendations for such streamlining, including:

- Adopting revised flood hazard zoning that increases specificity of vulnerable areas and provides more detailed guidance on development within these areas. The standard FEMA-designated flood plains and National Flood Insurance Program may not provide satisfactory or site-specific guidance to reduce risks.

- Creating new flood storage capacity within redevelopment in vulnerable areas by promoting parks and other open spaces in vulnerable locations as opposed to large structural development, replacing a vertical wall along a drainage bank with a more gradual slope to create increased channel area, creating shallow depression in properties that can accommodate isolated inundation events, or redesigning buildings to enable the first floor or basement to flood rather than armoring the buildings to repel rising waters.
- Offering incentives within zoning codes or variances such as increased density or building height in exchange for new developments voluntarily adopting flood-resistant building codes.
- Prioritizing capital improvement projects and plans in areas designated as less vulnerable, thus providing incentives for development in safer locations.
- Ensuring that future community plans and studies consult existing hazard mitigation and disaster risk reduction plans or studies (including climate change vulnerability assessments).

Specific actions can also be planned for implementation on a more detailed level. The Garapan Stormwater Conceptual Study (2010) highlights retro-fitting strategies as important adaptations that can be made to mitigate existing water quality and flood hazards. In addition, the Garapan and Beach Road Revitalization Plan (2007) offers design alternatives for stormwater management and aesthetic purposes. These modifications to the stormwater infrastructure could certainly serve as adaptations to potential future conditions (e.g. raised sea levels, isolated extreme precipitation events) as well. Addressing current issues with "backwater effects" in the Fiesta (Dai Ichi) and Hafa Adai drainages may alleviate future aggravation of these issues due to raised sea levels.



Retro-Fitting Garapan for Multiple Benefits

The Garapan core district has been the subject of multiple planning projects and proposals in recent years. Rather than add additional recommendations for climate adaptations to proposals that have not been implemented yet, the CNMI can build on existing proposed measures that may also benefit changing conditions in the ocean and atmosphere:

Conceptual sketch of a storm-water management retrofit for the Orchid Street/Fiesta Drainage.
- Garapan and Beach Road Revitalization Plan, 2007

Sites in Garapan for alternative stormwater management designs and solutions.
- Garapan Stormwater Conceptual Study, 2010

Figure 34: Adaptation opportunities through retrofitting infrastructure in Garapan

Figure 34 (above) illustrates an extremely important aspect of climate adaptation efforts. It promotes adaptation as an attractive option, as opposed to a burden on policy and management. Innovative adaptations to infrastructure, buildings and open-spaces can increase growth potential, attracting investment and funding sources where aesthetics and multiple functions (e.g. green-space, stormwater management, tourist & pedestrian corridor) are highlighted. The City of Copenhagen Climate Adaptation Plan (2011) emphasizes the opportunities for its utility company *Copenhagen Energy* to capitalize on adaptation planning efforts, taking advantage of funding or investments that require new types of knowledge, occupational expertise, and jobs for long-term projects. The City has taken great efforts to ensure compatibility between its Climate Adaptation Plan and Green Growth Strategy (2011). From this perspective, climate change adaptation is directly linked to economic growth. This linkage may serve as a crucial incentive for inclusion of both public and private actors in adaptation efforts.

While there appear to be numerous opportunities and avenues for adaptation, these will not come to fruit without an enhanced awareness and conversation of climate change in the CNMI's planning and policy arenas, as well as the community in general. This spread of awareness and dispersal of climate dialogue throughout the Commonwealth should be a priority for immediate actions on climate change.

5.2. Next Steps for the CNMI

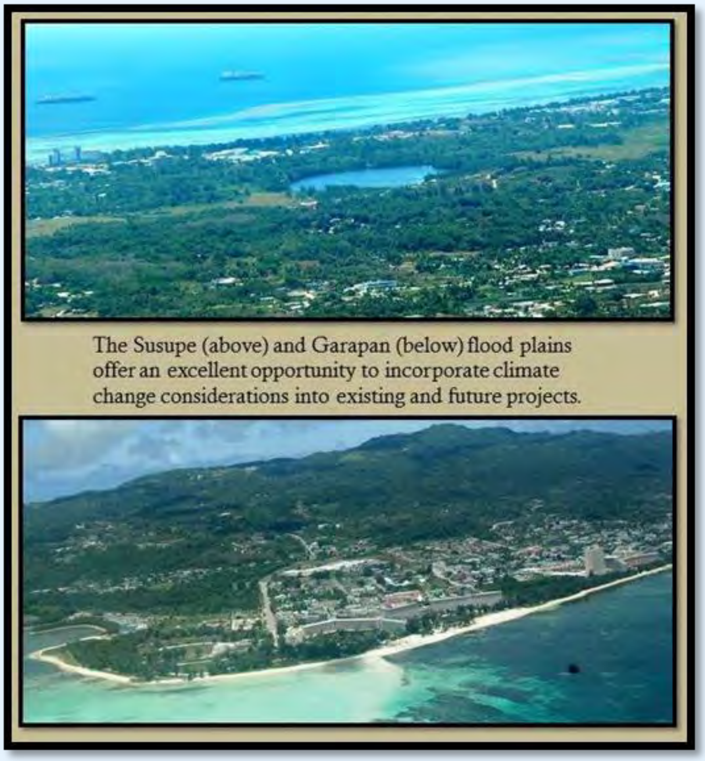
Expanding the Climate Discussion

As of 2011 eleven states had included thorough discussions of climate change and future climate conditions as "hazards" within their FEMA-mandated State Hazard Mitigation Plans. An additional ten states had mentioned climate change as a potential hazard, and suggested future inclusion of a more in-depth climate discussion within their plans (Babcock 2013). With the growth of climate discussions over the past several years, and expansion of this discussion into new sectors, the integration of climate change into hazard mitigation policy will undoubtedly escalate. This may increasingly be the case in the wake of extreme weather events (e.g. Super-Storm Sandy on the U.S. East Coast, King Tides in Kosrae) that the media tend to link to climate change.

The CNMI is poised to include climate change in its 2015 update to its Standard State Mitigation Plan (SSMP), drawing from some of the findings of this VA, and planned VAs for Tinian and Rota. The inclusion of *future* hazards from climate change, which are informed by multiple potential scenarios, will require a unique approach as far as the actual SSMP is concerned. Due to the range of implications that climate change poses, it may be more appropriate to append climate change considerations to existing, applicable hazards within the plan such as droughts or coastal flooding, as opposed to setting aside a stand-alone section for climate. While this expansion of the CNMI climate discussion may prove difficult, it will provide a novel precedent for additional inclusion in other plans and policies.

Beyond documents related to flooding and weather hazards (SSMP, CNMI Flood Hazard Mitigation Plan, Garapan Flood Control Study, Susupe-Chalan Kanoa Flood Control Study), climate change can be incorporated into community plans and policies that are not always immediately associated with climate change. Updates and proposals related to island transportation systems and utilities are an excellent occasion for SLR or precipitation patterns to enter the discussion. Likewise, studies and projects related to agricultural development on the island, especially through Northern Marianas College – Cooperative Research, Extension and Education Service (NMC-CREES) provide an opportunity to not only discuss climate change, but make it a central topic in future funding proposals. Even small-scale revitalization and beautification projects offer opportunities to expand the climate discussion into attractive community development, such as the Saipan Mayor's Office 2014 "Sunset Garden" installations along Beach Road.

Figure 35: Aerial photos of Garapan and Susupe flood plains



The Susupe (above) and Garapan (below) flood plains offer an excellent opportunity to incorporate climate change considerations into existing and future projects.

The expanded climate discussion is crucial to continued efforts, and any ongoing discussion or incorporation of climate change into plans should be flexible to accommodate updated information. This is especially true of a discussion that is initially built off of this VA. While the assessment provides a basic foundation for adaptation planning, there are numerous opportunities to improve and grow the VA.

VA limitations and opportunities for improvement

Improvements in Climate Projections and Scenario-Building

A more refined understanding of future climate changes and impacts in the CNMI is one of the most important components for any future update to the VA. Models and projections are being continuously updated and in many cases improved. It will be crucial for adaptation efforts to incorporate this new information, and policy changes may need to be considerate of both the scale and probability of future scenarios (Dessai & Hulme 2004). These considerations may become increasingly feasible as data services and research is expanded to the Pacific Islands region.

Downscaled climate projections for the coterminous U.S. have been developed by NASA at the *county* level (Trasher et al. 2013). Such downscaling of models in the WNP may be difficult due to the complex mix of regional oceanic and atmospheric influences on climate variability; however, any enhancements in precision or scale to sub-regional climate projections will be a key component to future analysis of vulnerability and risk. Access to and communication of trends and projections for precipitation patterns should be a priority as far as future climate services in the WNP are concerned.

Likewise, a better understanding of regional SLR is necessary. As additional research and scenario-building occurs, it will be important for the CNMI to consider how regional changes in sea level due to surface winds differ from long-term SLR due to thermal expansion and ice sheet contributions (Moon et al. 2013).

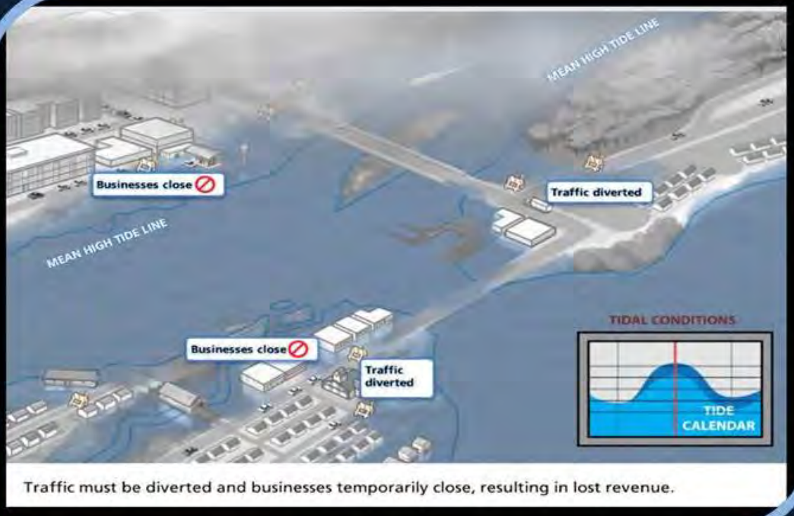
Understanding Coastal Inundation and Shoreline Change

With more accessible SLR information on regional and sub-regional scales, the CNMI will have opportunities to enhance visualization and modeling of coastal flooding, erosion, and shoreline resiliency.

Figure 36: Screenshot of NOAA Tidal Flooding Animation

Additional communication tools are necessary to translate technical climate information and impacts to resource managers and decision makers. The NOAA Tidal Flooding Impacts Animation (screenshot below) provides a user-friendly means of communicating climate-related threats to multiple audiences.

The CNMI should explore the development of island-specific tools such as this.



Traffic must be diverted and businesses temporarily close, resulting in lost revenue.

New, high-resolution elevation data coupled with local field data concerning shoreline characteristics, bathymetry and coastal processes may further enable these improvements. This could involve fine-scale efforts such as enhancing an existing hydrodynamic model of the Saipan lagoon system (Damlamian & Kruger 2010), or the assessment of CNMI-wide shorelines with respect to established coastal vulnerability indices and dynamic hazard assessment models (Ramieri et al. 2011).

Improved technical information will need to be paired with new communication tools and techniques in order to bridge the science-practice interface. While this VA offered some static visualization of flooding impacts due to SLR and SLC scenarios, a CNMI-focused tool that could communicate multiple climate stressors and their impacts should be considered, especially as the CNMI CCWG embarks on outreach initiatives to raise awareness of climate change. This might include an interactive tool or visualization that allows resource managers and decision makers to understand both surface *and sub-surface* impacts of SLC and precipitation patterns.

Understanding Changes in Groundwater Resources

Multiple studies of Saipan's sub-surface freshwater and groundwater resources have been conducted by the USGS and USACE over the past three decades. These studies have stressed the significance of seasonal and annual precipitation patterns, tidal variation, and well depth/placement as influences on Saipan's freshwater resources. Because these influences are subject to change in response to both climate variables and population demands, consideration of changes to future sea levels and precipitation patterns should be integrated into any future studies of groundwater.

The USACE is already required to consider future sea level scenarios in its coastal civil works projects (U.S. Army Corps of Engineers 2011), therefore a study of climate-induced changes to the community's freshwater resources would not be out of line with current policy. In fact, such a study would provide critical baseline information for future development on Saipan, and could potentially streamline evaluation of environmental impacts. As proposals for tourism and commercial development continue to focus on Saipan's western coastal plain, this information will be increasingly relevant.

Understanding Social Vulnerability and Impacts to Livelihoods

Comprehension of physical impacts and vulnerabilities, while significant to any VA, cannot achieve practical application without a thorough grounding in social and economic context. A flooded building is fairly insignificant if there are no people or businesses occupying it. With this principle in mind, it is imperative that the CCWG and other organizations in the CNMI continue to work with villages, community groups, and business associations to assess their susceptibilities to long-term climate stressors. The social vulnerability index that was applied in this VA provides a starting point for such an undertaking, but is by no means a comprehensive solution. Additional indicators of social vulnerability deserve attention.

Beyond demographic variables, Pacific island communities can assess perceptions of climate change risk, access to climate-related services and information networks, abilities for community-reorganization, and dependence on vulnerable resources. In relatively small communities such as the vulnerable focus areas identified in this VA, these indicators can be analyzed at the household level. A variety of techniques can be adopted here, including surveys, interviews with key informants, focus groups and community workshops (Wongbusakarum & Loper 2011).

From a broader perspective, climate change will influence the trajectories of Saipan's current economic drivers and community structure. Comprehensive adaptation planning will require that future assessments of vulnerability take into account a much wider array of factors that determine sectoral impacts and adaptation options. These determinants include government agency access to resources, distribution of information and technology within the guiding institutions of the CCWG, risk perceptions among policy-makers and business associations, and the overall capacity for policy change within the institutions that are driving adaptation efforts (Dolan and Walker 2006).

There is undoubtedly a need for additional information to inform adaptation; however, it is also important that the CNMI begin to focus on actionable adaptation options.

Long-term considerations and short-term actions

The CNMI can begin climate change adaptation in a time-sensitive manner, stratifying its actions based on short-term concerns and feasible projects as well as possible long-term scenarios. This can be done most efficiently by streamlining adaptation with current initiatives while feeding new information into continued assessments and communication strategies. Saipan should not hesitate to adapt, but this adaptation must address uncertainty by capitalizing on opportunities with benefits outside of climate change considerations.

With respect to shoreline change, erosion, instability and shifting sea levels, Saipan could adopt a time-sensitive approach that encourages “soft protection” measures in the short-term, and, if necessary, more invested “hard protection” measures in the long-term should extreme SLR scenarios manifest. In adopting this approach, immediate action items such as shoreline re-vegetation and managed retreat can be implemented without extensive policy changes or resource commitment in the face of future sea level uncertainties (Hawaii Sea Grant 2013).

The National Fish, Wildlife and Plants Climate Adaptation Partnership (2012) recommends jurisdictions and resource managers adopt an integrated “seascape/landscape” approach to climate adaptation. This approach involves addressing existing anthropogenic drivers that have the potential to increase vulnerability of both terrestrial and marine ecosystems to climate stressors. This approach is consistent with the existing “Ridge-to-Reef” principle that guides some of the current resource management efforts on Saipan. Opportunities to streamline adaptation with these efforts will help multiply the benefits of any projects that address issues such as flood hazard control, stormwater management, sedimentation and nutrient loading.

While some adaptation opportunities appear clear through streamlining efforts and integration with existing management and policy, taking advantage of these opportunities will require a deeper mode of action within the respective political institutions and management units. CNMI government agencies will need to adopt climate change as a standard consideration in project development and decision-making processes. Legislative bodies will need to evaluate policies that impact community structure, taking into account potential effects on income sources that rely on natural resources. This consideration also applies to the tourism industry and private enterprises in the CNMI, which are ultimately dependent on natural and physical systems that this VA identified as vulnerable.

* * *

Within its villages, along its shoreline, and distributed throughout its natural, physical and social systems, the island of Saipan has varying levels of vulnerability to climate change. Embracing adaptation opportunities provides a means of reducing some of this vulnerability while improving community resiliency. The findings of this VA strongly encourage Saipan’s stakeholders to assume responsibility for their future interests and adapt.

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Primary Data Sources and Technical Support*:

- United States Army Corps of Engineers
- United States Census Bureau
- National Oceanic and Atmospheric Administration

**all data sources for specific GIS datasets listed in Appendix B*

Appendices

A. Stakeholder Resources Survey

Survey for Resources and Assets of Concern

Thank you for taking the time to complete the CNMI Climate Change Vulnerability Assessment *Survey to Identify Resources and Assets of Concern*. This survey is a crucial step in the development phase of the vulnerability assessment process.

The purpose of this survey is to capture a broad, representative sample of the natural, cultural, economic and infrastructure-based assets that are of greatest concern to the CNMI Climate Change Working Group members and stakeholders. The results of this survey will be used as a baseline to further identify and group a comprehensive list of *resources and assets of concern** at a Climate Change Working Group Meeting.

> ***For the purpose of this initial survey, a *resource or asset of concern* is broadly defined:**
>
> Assets and resources of concern are the services, facilities, activities and systems that you and your agency/organization plan for, operate and/or manage. Examples of resources and assets might include the site of a tourist activity, a wastewater treatment facility, a harbor, a neighborhood, a watershed, or segment of beach.

Within this survey you may choose to address resources and assets broadly as an entire system (e.g. wetlands, sewers, reefs, housing), and/or specifically as a particular location or feature (e.g. an individual constructed wetland, section of sewer in a village, segment of reef). Your name and agency/organization will not be published in association with any of your responses. Responses will not be directly quoted in any reports or publications.

1. **Background Information**

   a. **What is your name?**

   b. **What agency or organization do you work for?**

   c. **What is your title?**

2. **Resources and Assets**

   a. **Based on the definition of *resources and assets* provided above, what resources or assets of concern do you and/or your agency/organization work with?**
   (*ex: CRM works with beaches, reefs, boat launches/ramps, beach access roads, etc…*)

   b. **What is the geographic focus or extent of the resources and assets you've listed?**
   (*ex: CRM is concerned with the Beaches of Saipan, Tinian and Rota; CRM is concerned with beach access infrastructure on Saipan in particular*)

   c. **Of the resources or assets you've listed, are you aware of any that have been impacted in the past due to climate-related phenomena? If so, please list and briefly describe.**
   (*ex: Some beach access roads were severely eroded following Typhoon Pongsona)*

   d. **Of the resources or assets you've listed, are you aware of any that are currently impacted due to climate-related phenomena? If so, please list and briefly describe.**
   (*ex: Some beach access roads are quickly eroding during heavy precipitation*)

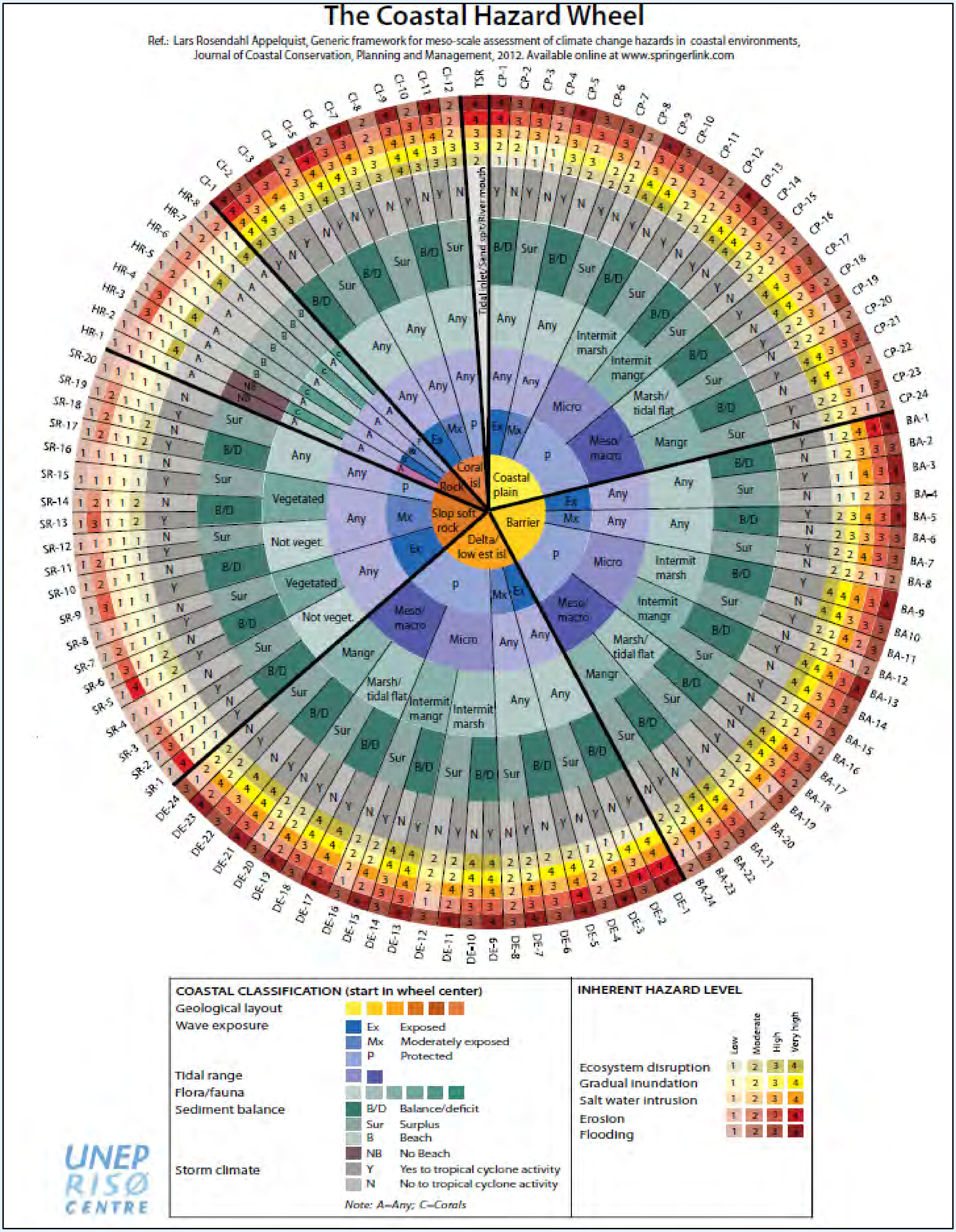
B. Data Requests and Stewards

Data Requests					
Data Set	Data Collection Group for Request			Status	Source(s)
	Ecological	Socio-Economic	Infrastructure		
Critical Infrastructure					
Roads			x	2010 Primary, secondary and village roads. Shapefile.	OHS
Evacuation Routes			x	Incomplete shapefile from unkown source. Also marked in 2010 Standard State Mitigation Plan. Needs digitization.	OHS
Power Facilities			x	2008 Utility pole locations Shapefile. 2008 CUC Powerlines shapefile. 2008 Locations of all CUC utilities - power plants, power sub-stations, wells, reservoirs, waste water treatment plants - extracted from 2008 parcel shapefile. 2008 fuel pump stations - shapefile.	CUC
Wastewater Systems			x	2006 Waste Line System. Shapefile.	CUC
Freshwater Systems			x	2006 Fresh water line system. Shapefile.	CUC
Medical Facilities		x	x	Hospital shapefile - no metadata	OHS
Emergency Response Facilities			x	Radio towers - unknown date.	OHS
Non-Critical Infrastructure and Properties					
All Saipan Parcels		x	x	2010 Parcels for Saipan. May have used 2004 polygons. Shapefile.	DPL
Urban Areas		x	x	2004 Villages and population centers. Shapefile.	MPLA
Historic Preservation		x		2006 Historic districts. Shapefile.	Zoning Office
Hotels		x	x	2008 Hotel parcels - Shapefile.	DPL
Parks and Green Space			x	2006 Public resources - shapefile.	DLNR
Public Right-of-Way			x	2008 Public Lands - Shapefile. 2006 Parks - Shapefile.	DPL
Private Property		x	x	2006 Private parcels - Shapefile.	DPL
Schools					
School facilities		x	x	2008 Public schools parcels - Shapefile.	DPL
Bus routes		x	x	None - needs digitization	

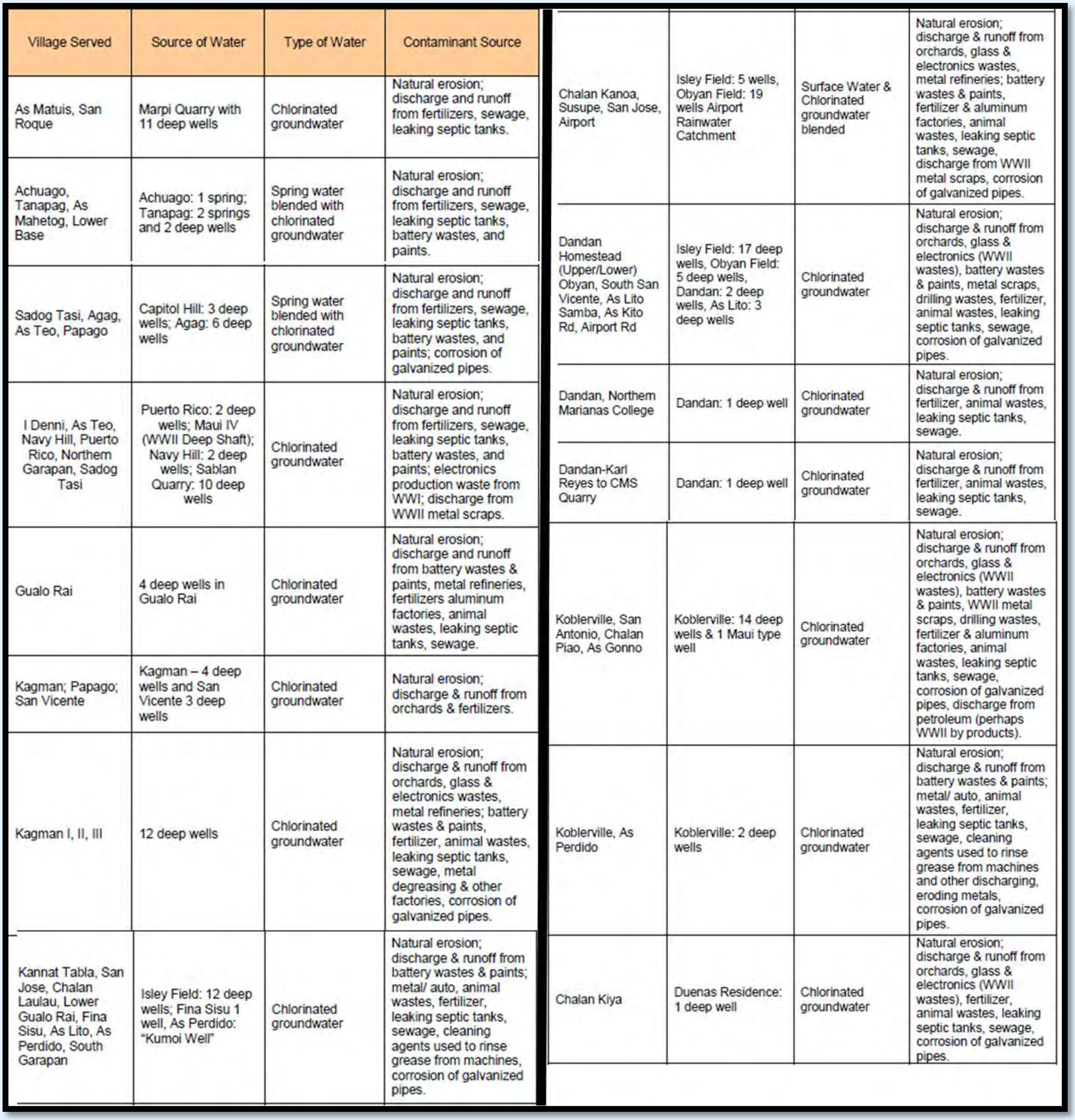
Recreational facilities		**x**	**x**	See parks and green spaces	
Public Health					
Waste Facilities	**x**		**x**	see Infrastructure and CUC data	
Storage Tanks	**x**		**x**	see Infrastructure and CUC data	
Pesticide Application and Ag.	**x**			2010 Agriculture Parcels - shapefile.	DLNR, DPL
Toxics	**x**		**x**	see Infrastructure and CUC data	
Agriculture					
Farms	**x**			2010 Agriculture Parcels - shapefile.	DLNR, DPL
Crops/Land Cover	**x**			2005 High Resolution Landcover - Raster and polygon	NOAA CSC/Digital Coast
Soils	**x**			Soils shapefile (no date)	USDA NRCS (at CRM)
Markets and Distribution	**x**			No spatial data other than market locations	
Terrestrial Habitat					
Wetlands	**x**			2005 High Resolution Landcover - Raster and polygon. 2010 National Wetlands Inventory - Shapefile. 1997 Watershed and Streams Shapefiles.	NOAA CSC/Digital Coast, U.S. Fish and Wildlife Service, USDA NRCS
Forest	**x**			2005 High Resolution Landcover - Raster and polygon. High value habitat shapefile (no date or author, selected polygons of specific landcover types).	NOAA CSC/Digital Coast
Soils & Geology	**x**			2011 Geology (Field work 2006-2007). See *Agriculture* for soils.	USGS (via DEQ)
Wildlife Distribution	**x**			1999-2005 Environmental Sensitivity Index spatial data for turtle habitat and nesting site, bird nesting and roosting sites, and high concentrations of shore birds.	NOAA
Beaches					
Erosion (patterns & rates)	**x**			1996-1999 Shoreline profiles for American Memorial Park and N. San Jose - Susupe - Shapefile, Microstation, and Report. - Shoreline outlines for American Memorial Park and Managaha: for use in DSAS from 1945 through 2003. *2011 satelite imagery currently being brought into DSAS.*	USACE, CRM
Shoreline Access	**x**			2006 Shoreline shapefile with access attribution	CRM
Marine Habitat					
Reefs	**x**			1997 reef polygons (derived from 1989 National Wetland Inventory shapefile). Shapefile and associated tabular data for 2012 CNMI Reef Resiliency Study.	USFW, NOAA

Lagoon Habitats	**x**			Shapefile of marine habitat types in Saipan Lagoon (unknown date)	DEQ, CNMI Marine Monitoring Team
Aquatic Recreation	**x**	**x**		Mid-2000s shapefiles for all CRM-Regulated aquatic sports in lagoon	CRM
Fisheries					
Protected Areas	**x**			MPA Shapefiles (unknown date)	NOAA
Commercial and Subsistence Activity	**x**	**x**		data unavailable	
Markets and Distribution	**x**	**x**		data unavailable	

C. Coastal Hazard Classifications and Hazard Assessment Wheel



D. Saipan Wells and Contaminant Sources



Village Served	Source of Water	Type of Water	Contaminant Source
As Matuis, San Roque	Marpi Quarry with 11 deep wells	Chlorinated groundwater	Natural erosion; discharge and runoff from fertilizers, sewage, leaking septic tanks.
Achuago, Tanapag, As Mahetog, Lower Base	Achuago: 1 spring; Tanapag: 2 springs and 2 deep wells	Spring water blended with chlorinated groundwater	Natural erosion; discharge and runoff from fertilizers, sewage, leaking septic tanks, battery wastes, and paints.
Sadog Tasi, Agag, As Teo, Papago	Capitol Hill: 3 deep wells; Agag: 6 deep wells	Spring water blended with chlorinated groundwater	Natural erosion; discharge and runoff from fertilizers, sewage, leaking septic tanks, battery wastes, and paints; corrosion of galvanized pipes.
I Denni, As Teo, Navy Hill, Puerto Rico, Northern Garapan, Sadog Tasi	Puerto Rico: 2 deep wells; Maui IV (WWII Deep Shaft); Navy Hill: 2 deep wells; Sablan Quarry: 10 deep wells	Chlorinated groundwater	Natural erosion; discharge and runoff from fertilizers, sewage, leaking septic tanks, battery wastes, and paints; electronics production waste from WWI; discharge from WWII metal scraps.
Gualo Rai	4 deep wells in Gualo Rai	Chlorinated groundwater	Natural erosion; discharge and runoff from battery wastes & paints, metal refineries, fertilizers aluminum factories, animal wastes, leaking septic tanks, sewage.
Kagman; Papago; San Vicente	Kagman – 4 deep wells and San Vicente 3 deep wells	Chlorinated groundwater	Natural erosion; discharge & runoff from orchards & fertilizers.
Kagman I, II, III	12 deep wells	Chlorinated groundwater	Natural erosion; discharge & runoff from orchards, glass & electronics wastes, metal refineries; battery wastes & paints, fertilizer, animal wastes, leaking septic tanks, sewage, metal degreasing & other factories, corrosion of galvanized pipes.
Kannat Tabla, San Jose, Chalan Laulau, Lower Gualo Rai, Fina Sisu, As Lito, As Perdido, South Garapan	Isley Field: 12 deep wells; Fina Sisu 1 well, As Perdido: "Kumoi Well"	Chlorinated groundwater	Natural erosion; discharge & runoff from battery wastes & paints; metal/ auto, animal wastes, fertilizer, leaking septic tanks, sewage, cleaning agents used to rinse grease from machines, corrosion of galvanized pipes.
Chalan Kanoa, Susupe, San Jose, Airport	Isley Field: 5 wells, Obyan Field: 19 wells Airport Rainwater Catchment	Surface Water & Chlorinated groundwater blended	Natural erosion; discharge & runoff from orchards, glass & electronics wastes, metal refineries; battery wastes & paints, fertilizer & aluminum factories, animal wastes, leaking septic tanks, sewage, discharge from WWII metal scraps, corrosion of galvanized pipes.
Dandan Homestead (Upper/Lower) Obyan, South San Vicente, As Lito Samba, As Kito Rd, Airport Rd	Isley Field: 17 deep wells, Obyan Field: 5 deep wells, Dandan: 2 deep wells, As Lito: 3 deep wells	Chlorinated groundwater	Natural erosion; discharge & runoff from orchards, glass & electronics (WWII wastes), battery wastes & paints, metal scraps, drilling wastes, fertilizer, animal wastes, leaking septic tanks, sewage, corrosion of galvanized pipes.
Dandan, Northern Marianas College	Dandan: 1 deep well	Chlorinated groundwater	Natural erosion; discharge & runoff from fertilizer, animal wastes, leaking septic tanks, sewage.
Dandan-Karl Reyes to CMS Quarry	Dandan: 1 deep well	Chlorinated groundwater	Natural erosion; discharge & runoff from fertilizer, animal wastes, leaking septic tanks, sewage.
Koblerville, San Antonio, Chalan Piao, As Gonno	Koblerville: 14 deep wells & 1 Maui type well	Chlorinated groundwater	Natural erosion; discharge & runoff from orchards, glass & electronics (WWII wastes), battery wastes & paints, WWII metal scraps, drilling wastes, fertilizer & aluminum factories, animal wastes, leaking septic tanks, sewage, corrosion of galvanized pipes, discharge from petroleum (perhaps WWII by products).
Koblerville, As Perdido	Koblerville: 2 deep wells	Chlorinated groundwater	Natural erosion; discharge & runoff from battery wastes & paints; metal/ auto, animal wastes, fertilizer, leaking septic tanks, sewage, cleaning agents used to rinse grease from machines and other discharging, eroding metals, corrosion of galvanized pipes.
Chalan Kiya	Duenas Residence: 1 deep well	Chlorinated groundwater	Natural erosion; discharge & runoff from orchards, glass & electronics (WWII wastes), fertilizer, animal wastes, leaking septic tanks, sewage, corrosion of galvanized pipes.

E. Sea Level Change Mapping Methodology

Saipan Climate Vulnerability Assessment: Methodology for Sea Level Change Mapping

This appendix summarizes the regional sea level data used to develop inundation scenarios, and outlines the basic geospatial processing steps used to derive inundation layers

Introduction

The primary means of assessing Saipan's exposure to changes in sea level was through a simple inundation mapping approach. Inundation mapping required data processing and analysis using Geographic Information Systems (GIS). Geospatial data layers for nine sea level change (SLC) scenarios, in the form of raster and vector data types, were developed using ESRI ArcGIS 10.1 software and processing methods originally developed by NOAA Coastal Services Center (see Marcy et al. 2011, NOAA Digital Coast, and the document "Detailed Methodology for Mapping Sea Level Rise Inundation" NOAA CSC, 2011). The NOAA methods were modified and applied to sea level data specific to the Mariana Islands.

It should be noted that several elements of the mapping approach introduce significant limitations and caveats to exposure analysis. While these limitations present obstacles to visualizing accurate representations of future conditions, they also offer opportunities for enhanced modeling as inundation scenarios on Saipan continue to be studied. Enhanced efforts could integrate more detailed hydrologic features, updated elevation and shoreline positions, or adopt numerical models that incorporate wave run-up and other coastal processes.

For the Saipan VA, a modified bathtub model was utilized, which allows for mapping of changes in still-water levels over a high-resolution, conditioned digital elevation model. The bathtub approach does not consider future changes in shoreline due to coastal processes such as erosion and accretion, nor does it account for wave run-up or the influence of certain hydraulic features such as stormwater/sewer infrastructure. More information concerning the specifications of this approach can be found on the NOAA CSC website (www.csc.noaa.gov) in the FAQ for "Digital Coast Sea Level Rise and Coastal Flooding Impacts Viewer". A detailed comparison of the bathtub approach to a dynamic, numerical wave run-up model is provided in USGS Open Report 2013-1069 (Storlazzi, et al. 2013).

Sea Level Scenarios and Data Sources

Nine scenarios were used to map inundation depths on Saipan (see table), using both projected and observed changes in sea level. Each scenario is summarized below, along with references to source data. ***Scenario codes were used for data organization purposes during the VA development, and do not refer future global CO2 or emissions scenarios.***

Sea Level Scenarios for Saipan

Scenario	Rise (Ft.)	Rise (Meters)	Scenario Code	Sources
10 year Storm; no Sea Level Change	4.89	1.49	**A1**	Chou, Lucia W. (1989). *Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands* . U.S. Army Corps Paper CERC-89-12.
USACE Curve Intermediate - 50 yrs. + 10 yr. Storm	5.10	1.554	**A2**	- IPCC and modified NRC Curve 1 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) - USACE Sea Level Change Curve Calculator (http://corpsclimate.us/ccaceslcurves.cfm)***** - Chou, Lucia W. (1989). Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands. U.S. Army Corps Paper CERC-89-12.
USACE Curve Intermediate -				- IPCC and modified NRC Curve 1 (http://corpsclimate.us/docs/EC_1165-2

Continued on following page…

USACE Curve Intermediate - 100 yrs.	0.89	0.27	**B1**	- IPCC and modified NRC Curve 1 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf)
USACE Curve Intermediate - 100 yrs. + 10 yr. Storm	5.77	1.76	**B2**	- IPCC and modified NRC Curve 1 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) - Chou, Lucia W. (1989). Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands. U.S. Army Corps Paper CERC-89-12.
USACE Curve High - 50 yrs.	1.64	0.5	**C1**	- IPCC and modified NRC Curve 3 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf)
USACE Curve High - 50 yrs. + 10 yr. Storm	6.53	1.99	**C2**	- IPCC and modified NRC Curve 3 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) - Chou, Lucia W. (1989). Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands. U.S. Army Corps Paper CERC-89-12.
USACE Curve High - 100 yrs.	5.02	1.53	**D1**	- IPCC and modified NRC Curve 3 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf)
USACE Curve High - 100 yrs. + 10 yr. Storm	9.91	3.02	**D2**	- IPCC and modified NRC Curve 3 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) - Chou, Lucia W. (1989). Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands. U.S. Army Corps Paper CERC-89-12.
USACE Curve High - 100 yrs. + 50 yr. Storm	11.91	3.63	**D3**	- IPCC and modified NRC Curve 3 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) - Chou, Lucia W. (1989). Typhoon Water Surface Analysis for West Coast of Saipan, Mariana Islands. U.S. Army Corps Paper CERC-89-12.
*Sea Level Curve Calculator used for all subsequent curve calculations				

CNMI Climate Change Working Group members expressed concern over both long-term SLC due to climate change, as well as short-term changes in response to large storm events. Accordingly, the SLC scenarios reflect sea levels resulting from these two independent drivers separately, and in combination.

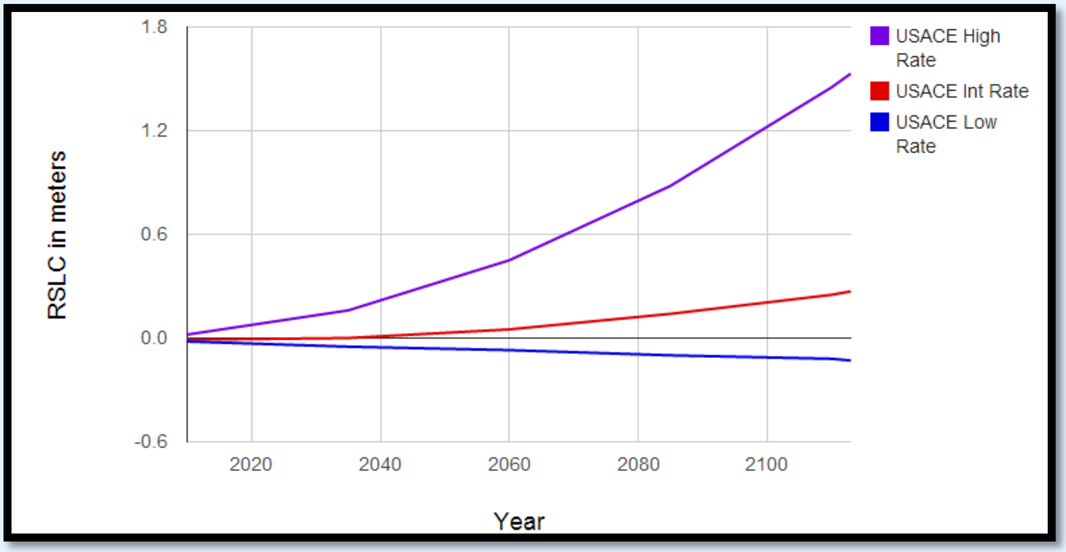
SLC Scenarios Due to Storm Events

SLC scenarios based on storm events were informed by the U.S. Army Corps of Engineers (USACE) analysis of water surfaces along Saipan's west coast for typhoons (Chou 1989). The study summarized still-water rise (not reflecting wave run-up or geographic tidal variation) for 10, 50 and 100 year storms. Because these modeled surfaces resulted in *still water rise* values, they were consistent with the Saipan VA's modified bathtub approach.

SLC Scenarios Due to Climate Change

SLC scenarios due to climate change were based on a curve calculator developed by the U.S. Army Corps of Engineers, in collaboration with NOAA's National Ocean Service and the USGS. This effort was driven by a 2011 mandate requiring the USACE to integrate SLC scenarios into its coastal civil works projects. The calculator uses an adjusted mean sea level (MSL) trend, based on differences between global eustatic MSL trends and a local MSL trend as measured by the closest NOAA tide gauge.

For the Saipan VA, the local MSL trend was established with the calculator using the NOAA tide gauge on Guam, adjusting for rates of vertical land movement. A lack of consistent and thorough sea level records at the Saipan Tanapag station (#1633227) inspired the use of the Guam station, and the vertical rate of land movement due to tectonic uplift on Guam (rising) is assumed for Saipan as well. Note that the factor of vertical land movement explains negative SLC scenarios where modified NRC Curves are not considered (i.e. "Low Rate"). Application of this rate of land movement to Saipan introduces a large amount of uncertainty, but does reflect the regional tectonic uplift.



The original NRC curves result in global SLC values, by the year 2100, of 0.5 meters, 1.0 meters, and 1.5 meters. The USACE SLC calculator modified these curves to include the historic global MSL change rate of 1.7 mm/year and the start date of 1992 (which is the midpoint of the current National Tidal Datum Epoch of 1983-2001), instead of 1986 (the start date used by the NRC). This resulted in updated values for the calculator coefficients.

The USACE "Intermediate Curve" and "High Curve" were used. The intermediate curve is computed from the modified NRC Curve I considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added. The high curve is computed from the modified NRC Curve III, using the same considerations of NRC projections and vertical land movement as the intermediate curve.

Detailed documentation concerning these calculations can be found in USACE Circular 1165-2-2012 (http://corpsclimate.us/docs/EC_1165-2-212%20-Final_10_Nov_2011.pdf) and on the USACE Sea Level Change website: http://corpsclimate.us/ccacesl.cfm .

Mapping Methods

Inputs:

- Digital Elevation Model (DEM)
  - The DEM for Saipan is based on 2007 USACE high-resolution lidar data. Hydrographic breaklines in the DEM were derived from lidar intensity images, and the DEM is hydro-flattened so that water elevations are set to 0 meters.
  - Source lidar has a horizontal accuracy of 1 meter, and vertical accuracy root mean square error of 20 cm. DEM resolution is 2.69 meters. The source data meets FEMA standards for flood hazard mapping.
  - DEM was conditioned and distributed by NOAA CSC. Metadata for the DEM, including process steps and software used is available upon request to CNMI Coastal Resources Management Office.

- Tidal surface in NAVD88 values
  - NOAA methodology suggests the use of VDATUM software to develop a tidal surface that captures spatial variation in water levels. The VDATUM tool and associated data packages did not include coverage of the CNMI at the time that SLC layers were developed, and therefore was not used. The alternative recommended method for creating a tidal surface involves interpolation of sea level values at different tide gauges within the area of interest. Saipan has only one tide gauge, therefore a single value tidal surface was generated.

- Sea level change values
    - Values (in meters) for each of the SLC scenarios listed in this appendix were used.

Workflow in ESRI ArcGIS Desktop (as detailed by NOAA CSC; all modifications to NOAA process are noted in *italics*)

1. Add SLC value to the tidal surface grid

Spatial Analyst > Math > Plus
- Input raster or constant value 1 = tidal surface
- Input raster or constant value 2 = SLC value for A1
- Output raster = **surface_A1**

2. Subtract DEM values from water surface to derive initial inundation depth grid

Spatial Analyst > Single Ouput Map Algebra
- Map Algebra expression: con(DEM <= surface_A1, surface_A1 – DEM)
- Output raster = **depth_A1**

3. In preparation for evaluating connectivity, create single value DEM to show inundation extent

Spatial Analyst > Single Output Map Algebra
- Map Algebra expression: con(DEM <= surface_A1, 1)
- Output raster = **single_A1**

4. Evaluate connectivity of extent raster

Spatial Analyst > Generalization > Region Group
- Input raster = single_A1
- Number of neighbors to use = 8
- Zone grouping method = Within
- Output raster = **clumped_A1**

5. Extract connected inundation surface to be used as a mask for the original depth grid

Spatial Analyst > Extraction > Extract by Attributes
- Input raster = clumped_A1
- Where clause: "Count" = maximum value
- Output raster = **connect_A1**

For Saipan

- The 'Count' values were manually identified due to presence of small islands (Managaha) and pocket beaches, which have smaller clump counts. These "pockets" of inundation would otherwise be eliminated from the "connected area" based on use of the maximum count value, per NOAA methods.

- The primary area of connected inundation will usually be the 2nd or 3rd largest 'Count' values, as the Lake Susupe-Wetland complex generally comprises the largest 'count' value.

*- A second extraction of the max value and/or 'Count' values associated with surface water in the Susupe area was performed to create a connected Susupe-wetland surface (**Susupe_mask_A1**). This area, while not connected to the coast through surface hydrology in most scenarios, is of major concern, and is connected via groundwater through the island's basal lens. While a corresponding rise in Susupe Wetland water levels is uncertain under most scenarios, there have been documented changes in salinity and consequent habitat suitability from historic sea level change.*

6. Derive low-lying areas greater than an acre

Spatial Analyst > Extraction > Extract by Attributes
- Input raster = clumped_A1
- Where clause: "Count" > 40
- Output raster = **lowlying_A1**

For Saipan

- The value of 40 is based on the use of 10 meter grid cells (1 acre = 4046.85m2, 4046.85 m2 / 100 m2 = 40.46).

- The DEM has ~3 meter cells, therefore 'Count' value was 450 (1 acre = 4046.85m2, 4046.85 m2 / 9 m2 = 449.65)

7. Create depth grid for connected areas

Spatial Analyst > Extraction > Extract by Mask
- Input raster = depth_A1
- Input raster or feature mask data = connect_A1
- Output raster = **con_depth_A1**

For Saipan – Additional Step
-Input raster = depth_A1
- Input raster or feature mask data = Susupe_mask_A1
*- Output raster = **Susupe_A1***

Additional steps in Saipan VA

To derive polygons with "con_depth_A1" depth values (for additional analysis using spatial queries, etc…), Convert from floating point raster to polygon without losing significant figures (to the third decimal)

Spatial Analyst -> Map Algebra
- Int([con_depth_A1]*1000) *or* Int([Susupe_A1]*1000)
- New Raster has integer values that are 1000 times larger than original depths
- Output Raster = **integer_A1** (or **int_susupe_A1**)

Conversion Tools -> From Raster -> Raster to Polygon
- Input raster: integer_A1 *or* int_susupe_A1
- Field = 'value'
- Simplify Polygons = unchecked
- New Polygon = **A1_Poly** (or **A1_susupe_poly**)

- In A1_Poly: Create new depth field to match original continuous raster values
- In attribute table for A1_Poly, Create new field "depth", field type 'double'
- Field Calculator: "depth" = 'grid_code'/1000

To create single polygons for quick display of inundation extent, excluding flood depth values

Cartography Tools -> Generalization -> Aggregate Polygons
- Input: A1_Poly (or A1_susupe_poly)
- Distance: 0.5 meters (other search distances will work, but must be less than original raster cell resolution to avoid aggregation across areas that are not inundated)
- Output: **A1_aggregate (A1_susupe_agg)**

For a more nuanced discussion pertaining to choices made in the Saipan VA mapping methodology contact the CNMI Coastal Resources Management Office at (670) 664-8300, or request correspondence through the CNMI CCWG website contact page: http://www.climatecnmi.net/p/contact.html .

SLC Mapping Methods - References

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F. Social Vulnerability Index – Variable Weights and Re-classifications

Variable (and weight 0.0 - 1.0)	**Original Classification Values**	**New Value**

Average Household Size (0.75)	FROM	TO	OUT
	1.590000033	1.590000033	1
	1.590000033	2.846705991	2
	2.846705991	3.411647202	3
	3.411647202	3.953529587	4
	3.953529587	4.53000021	5

Median Household Income (0.5)	FROM_	TO	OUT
	9375	20000	5
	20000	32361	4
	32361	51667	3
	51667	70000	2
	70000	138750	1

Median Rent (.75)	FROM_	TO	OUT
	0	125	5
	125	376	4
	376	592	3
	592	1167	2
	1167	2000	1

Percentage of Population 25 and Older with Bachelors Degree (0.5)	FROM_	TO	OUT
	0	5.696470507	5
	5.696470507	16.45647035	4
	16.45647035	23.84078398	3
	23.84078398	32.49097993	2
	32.49097993	53.58901885	1

Percentage of Population 25 and Older with High School Education (0.5)	FROM_	TO	OUT
	58.79999924	66.5552935	5
	66.5552935	78.83450941	4
	78.83450941	85.94352915	3
	85.94352915	90.79058806	2
	90.79058806	99.9999	1

Percentage of Population Disabled (0.75)	FROM_	TO	OUT
	0	2.301790163	1
	2.301790163	5.063938358	2
	5.063938358	7.168432221	3
	7.168432221	9.733284116	4
	9.733284116	16.77018547	5

Percentage of Population Below Poverty Line (1)	FROM_	TO	OUT
	12.9032259	35.33103466	1
	35.33103466	45.88529761	2
	45.88529761	55.34015816	3
	55.34015816	62.37633346	4
	62.37633346	68.9727478	5

Percent of Houses with Metal Roof (0.5)	FROM_	TO	OUT
	4.651163101	18.48609238	1
	18.48609238	32.32102165	2
	32.32102165	46.52986794	3
	46.52986794	70.0866394	4
	70.0866394	100	5

Percent of Houses with Metal Wall (0.5)	FROM_	TO	OUT
	0	1.140819953	1
	1.140819953	5.704099767	2
	5.704099767	13.68983944	3
	13.68983944	24.81283399	4
	24.81283399	72.72727203	5

Percent of Houses Mobile or Non-permanent (0.5)	FROM_	TO	OUT
	0	0.392156893	1
	0.392156893	1.045751714	2
	1.045751714	2.15686291	3
	2.15686291	4.117647373	4
	4.117647373	16.66666794	5

Percentage of Households without a Computer (0.25)	FROM_	TO	OUT
	17.64705849	23.03515039	1
	23.03515039	38.7849575	2
	38.7849575	47.69603258	3
	47.69603258	59.92285652	4
	59.92285652	70.49180603	5

Percentage of Population with No Health Insurance (0.75)	FROM_	TO	OUT
	16.69442177	20.48211498	1
	20.48211498	26.8820104	2
	26.8820104	35.11044738	3
	35.11044738	41.5103428	4
	41.5103428	50	5

Percentage of Households with No Radio (0.25)	FROM_	TO	OUT
	0	10.2970295	1
	10.2970295	21.1881184	2
	21.1881184	29.30693012	3
	29.30693012	39.99999922	4
	39.99999922	50.29702872	5

Percentage of Households Receiving Social Security Income (0.5)	FROM_	TO	OUT
	2.887700406	5.240641478	1
	5.240641478	7.486630683	2
	7.486630683	11.22994602	3
	11.22994602	18.18181737	4
	18.18181737	27.27272606	5

Percentage of Population Over 16 Relying Solely on Subsistence Activities (0.75)	FROM_	TO	OUT
	0	0.261437899	1
	0.261437899	1.045751594	2
	1.045751594	1.960784239	3
	1.960784239	3.442265664	4
	3.442265664	11.11111069	5

Percentage of Population Over 16 Unemployed (1)	FROM_	TO	OUT
	0	2.364308077	1
	2.364308077	5.836885564	2
	5.836885564	7.38846274	3
	7.38846274	11.89542501	4
	11.89542501	18.84057999	5

Percentage of Houses with Wood Roofs (0.5)	FROM_	TO	OUT
	0	0.692041509	1
	0.692041509	2.698961886	2
	2.698961886	4.982698867	3
	4.982698867	9.965397734	4
	9.965397734	17.64705849	5

Percentage of Houses with Wood Walls (0.5)	FROM_	TO	OUT
	1.799307924	4.290657358	1
	4.290657358	7.335639998	2
	7.335639998	11.76470566	3
	11.76470566	20.06920377	4
	20.06920377	35.29411697	5

Percentage of Houses Built on Wood Pilings (0.75)	FROM_	TO	OUT
	0	0.968858113	1
	0.968858113	2.906574339	2
	2.906574339	6.297577735	3
	6.297577735	11.76470566	4
	11.76470566	17.64705849	5

Median Rent as a Percentage of Median Household Income (1)	FROM_	TO	OUT
	0	5.462514645	1
	5.462514645	15.50173075	2
	15.50173075	20.07843221	3
	20.07843221	28.19838641	4
	28.19838641	37.64706039	5

Percent Non-Us Citizen (0.75)	FROM_	TO	OUT
	13.7096777	23.90866564	1
	23.90866564	34.93459855	2
	34.93459855	44.58228985	3
	44.58228985	58.36470598	4
	58.36470598	84	5

Per Capita Income (1)	FROM_	TO	OUT
	6083	8298	5
	8298	10391	4
	10391	13306	3
	13306	23696	2
	23696	54328	1

G. American Memorial Park Digital Shoreline Analysis System Results

Transect ID	Azimuth	End Point Rate	Shoreline Change Envelope	Net Shoreline Movement	Linear Regression Rate	R Squared of Linear Regression
2	258.8	1.62	13.48	13.19	1.23	0.46
3	260.47	1.83	14.88	14.88	1.53	0.69
4	261.87	1.78	14.48	14.48	1.62	0.9
5	265.77	1.83	14.92	14.92	1.68	0.91
6	269.74	1.73	14.04	14.04	1.55	0.87
7	273.25	1.71	13.9	13.9	1.47	0.77
8	273.9	1.74	14.18	14.18	1.5	0.77
9	274.09	1.68	13.7	13.7	1.45	0.77
10	271.99	1.6	13.03	13.03	1.38	0.77
11	269.85	1.5	12.22	12.22	1.3	0.78
12	267.52	1.34	10.89	10.89	1.16	0.78
13	265.76	1.16	9.4	9.4	1.02	0.84
14	264.45	1.05	8.53	8.53	0.95	0.89
15	263.14	0.86	7	7	0.8	0.93
16	261.78	0.6	4.87	4.87	0.53	0.86
17	259.78	0.35	2.81	2.81	0.28	0.64
18	258.9	0.36	2.96	2.96	0.28	0.52
19	258.01	0.41	3.36	3.36	0.34	0.68
20	256.88	0.68	5.52	5.52	0.58	0.77
21	255.78	0.99	8.08	8.08	0.87	0.81
22	255.52	1.16	9.44	9.44	1.05	0.89
23	256.62	1.32	10.72	10.72	1.22	0.94
24	258.02	1.38	11.2	11.2	1.27	0.92
25	259.68	1.42	11.59	11.59	1.25	0.82
26	261.53	1.46	11.9	11.9	1.25	0.75
27	267.4	1.56	12.68	12.68	1.31	0.7
28	271.96	1.71	13.87	13.87	1.44	0.72
29	280.13	1.87	15.21	15.21	1.58	0.71
30	288.48	1.89	15.37	15.37	1.53	0.6
31	296.44	2.17	17.66	17.66	1.76	0.61
32	300.43	1.7	13.82	13.82	1.48	0.79
33	304.36	1.25	10.13	10.13	1.09	0.8
34	301.22	0.55	4.44	4.44	0.45	0.66

37	290.71	-0.4	3.43	-3.28	-0.44	0.93
38	287.25	-1.22	9.94	-9.94	-1.21	1
Transect ID	**Azimuth**	**End Point Rate**	**Shoreline Change Envelope**	**Net Shoreline Movement**	**Linear Regression Rate**	**R Squared of Linear Regression**
39	286.96	-2.05	16.66	-16.66	-2.11	0.99
40	286.52	-1.95	15.87	-15.87	-2.05	0.97
41	285.75	-1.51	12.32	-12.32	-1.62	0.95
42	282.13	-1.12	10.13	-9.13	-1.25	0.9
44	274.82	-0.36	5.97	-2.94	-0.51	0.51
45	273.41	-0.32	9.16	-2.63	-0.6	0.29
46	273.37	-2.09	24.8	-16.98	-2.55	0.73
47	276.2	-1.38	23.27	-11.23	-1.95	0.5
48	279.04	-1.53	23.46	-12.43	-2.07	0.56
49	281.86	-1.71	25.05	-13.94	-2.27	0.59
50	283.62	-1.77	25.59	-14.37	-2.33	0.59
51	285.74	-1.9	25.49	-15.48	-2.43	0.64
52	287.86	-2.03	24.87	-16.54	-2.51	0.71
53	289.99	-2.24	24.39	-18.23	-2.65	0.78
54	292.11	-2.55	24.23	-20.73	-2.88	0.87
55	293.47	-2.67	23.49	-21.74	-2.94	0.91
56	293.41	-2.64	23.05	-21.48	-2.9	0.91
57	293.15	-2.67	23.85	-21.73	-2.96	0.9
58	292.9	-2.64	24.9	-21.45	-2.97	0.87
59	292.64	-2.57	24.3	-20.89	-2.9	0.87
60	294.86	-2.39	19.48	-19.48	-2.56	0.95
61	301.65	-1.89	15.41	-15.41	-1.97	0.98
62	309.01	-1.61	13.1	-13.08	-1.73	0.94
63	316.53	-0.86	9.24	-6.97	-1.01	0.79
64	323.86	-0.66	8.08	-5.37	-0.81	0.71
65	328.38	-0.44	3.82	-3.59	-0.48	0.92
66	328.62	-0.3	2.42	-2.42	-0.29	0.98
67	328.76	-0.14	2.45	-1.12	-0.05	0.04
68	328.76	0.31	7.15	2.51	0.51	0.36
69	328.76	0.59	10.79	4.76	0.86	0.46
70	328.76	0.64	10.16	5.17	0.88	0.53
71	328.76	0.8	9.82	6.51	0.99	0.7

72	333.27	0.64	8.43	5.17	0.81	0.65
73	339.32	0.32	6.25	2.61	0.49	0.43
74	345.46	0.42	5.5	3.43	0.53	0.66
Transect ID	Azimuth	End Point Rate	Shoreline Change Envelope	Net Shoreline Movement	Linear Regression Rate	R Squared of Linear Regression
75	351.56	0.48	4.94	3.94	0.56	0.83
76	357.5	0.3	5.05	2.43	0.42	0.5
77	358.81	0.23	5.09	1.88	0.37	0.38
78	358.81	0.18	5.45	1.46	0.35	0.27
79	358.81	0.14	6.27	1.14	0.35	0.19
80	358.81	0.03	6.74	0.21	0.28	0.09
81	358.81	0	7.22	-0.01	0.28	0.08
82	358.81	0.13	8.18	1.06	0.41	0.16
83	358.81	0.4	10.2	3.27	0.7	0.32
84	359.34	0.47	10.1	3.8	0.74	0.38
85	0.95	0.65	10.25	5.3	0.89	0.54
86	2.55	0.99	11.06	8.03	1.18	0.76
87	4.16	1.46	13.65	11.86	1.64	0.88
88	5.77	1.99	16.16	16.16	2.13	0.95
89	6.84	2.6	21.11	21.11	2.67	0.99
90	6.84	3.12	25.37	25.37	3.12	1
91	6.84	3.48	28.28	28.28	3.37	0.99
92	6.84	3.88	31.57	31.57	3.67	0.96
93	6.84	4.44	36.11	36.11	4.11	0.93
94	6.84	4.77	38.84	38.84	4.37	0.91
95	6.84	5.1	41.52	41.52	4.63	0.89
96	6.84	5.37	43.64	43.64	4.82	0.87
97	6.84	5.55	45.17	45.17	4.94	0.85
98	6.84	5.74	46.72	46.72	5.05	0.82
99	12.12	5.52	44.92	44.92	4.86	0.82
100	19.8	5.43	44.17	44.17	4.75	0.81
101	27.7	5.36	43.58	43.58	4.7	0.82
102	35.54	5.49	44.62	44.62	4.84	0.83
103	43.03	5.95	48.38	48.38	5.41	0.9
104	48.35	6.13	49.89	49.89	6.18	1
105	54.91	6.49	57.75	52.82	7.18	0.9

106	61.65	6.95	67	56.56	7.89	0.86
107	77.2	6.74	69.63	54.84	7.83	0.82
108	100.97	-1.94	19.29	-15.76	-1.35	0.31
109	138.66	-1.27	10.45	-10.33	-0.97	0.47
Transect ID	Azimuth	End Point Rate	Shoreline Change Envelope	Net Shoreline Movement	Linear Regression Rate	R Squared of Linear Regression
110	182.33	-0.66	5.81	-5.39	-0.49	0.41
111	206.02	0.18	2.2	1.5	0.11	0.19
112	218.84	0.91	10.36	7.38	0.58	0.21
113	220.55	1.18	13.52	9.57	0.75	0.21
114	210.94	0.55	5.27	4.47	0.39	0.34
115	200.6	0.03	2.26	0.27	0.11	0.15
117	169.13	-0.58	6.59	-4.69	-0.37	0.21
118	152.74	-0.86	8.58	-7	-0.6	0.31
119	142.04	-1.39	13.57	-11.28	-0.97	0.32
120	128.62	-1.5	15.61	-12.21	-1.02	0.28
121	115.31	-1.71	15.95	-13.89	-1.23	0.36
122	109.69	-2.04	18.34	-16.57	-1.49	0.39
123	104.08	-1.95	17.35	-15.86	-1.43	0.4
124	98.58	-1.82	15.84	-14.8	-1.35	0.42
125	104.12	-1.24	12.26	-10.1	-0.87	0.32