Vulnerability and Adaptation to Climate Change in Guam –

A case-study of the perceptions, attitudes, behaviors, and knowledge of a small rural community towards their watershed

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Abstract

This thesis argues that examining the attitudes, perceptions, behaviors, and knowledge of a community towards their specific watershed can reveal their social vulnerability to climate change. Understanding and incorporating these elements of the human dimension in coastal zone management will lead to efficient and effective strategies that safeguard the natural resources for the benefit of the community. By having healthy natural resources, ecological and community resilience to climate change will increase, thus decreasing vulnerability.

In the Pacific Ocean, climate and SLR are strongly modulated by the El Niño Southern Oscillation. SLR is three times the global average in the Western Pacific Ocean (Merrifield and Maltrud 2011; Merrifield 2011). Changes in annual rainfall in the Western North Pacific sub-region from 1950-2010 show that islands in the east are getting much less than in the past, while the islands in the west are getting slightly more rainfall (Keener et al. 2013). For Guam, a small island owned by the United States and located in the Western Pacific Ocean, these factors mean that SLR is higher than any other place in the world and will most likely see increased precipitation.

Knowing this, the social vulnerability may be examined. Thus, a case-study of the community residing in the Manell and Geus watersheds was conducted on the island of Guam. Measuring their perceptions, attitudes, knowledge, and behaviors should bring to light their vulnerability to climate change. In order to accomplish this, a household survey was administered from July through August 2010. Approximately 350 surveys were analyzed using SPSS. To supplement this quantitative data, informal interviews were conducted with the elders of the community to glean traditional ecological knowledge about perceived climate change. A GIS analysis was conducted to understand the physical geography of the Manell and Geus watersheds. This information about the human dimension is valuable to CZM managers. It may be incorporated into strategic watershed plans, to better administer the natural resources within the coastal zone. The research conducted in this thesis is the basis of a recent watershed management plan for the Guam Coastal Management Program (see King 2014).

Declaration

I, Romina King, certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution and to the best of my knowledge, contains no material previously published or written by another person, except where due reference has be made in the text.

SIGNED_____ DATE_____

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I am dedicating this thesis to Lily and Ciara, my raison d'etre. They have taught me the meaning of patience and have given the unbelievable joy of motherhood.

Abbreviations and Acronyms

AOSIS	Alliance of Small Island States
BSP	Bureau of Statistics and Plans (GovGuam)
CAP	Conservation Action Plan
CBDAMPIC	Capacity Building for the Development of Adaptation Measures in Pacific Island Countries
CCTF	Climate Change Task Force
CCU	Guam Consolidated Commission on Utilities
CDN	Canadian dollar
CITES	Convention of International Trade of Endangered Species
cm	centimeter
CNMI	Commonwealth of the Northern Mariana Islands
CO_2	carbon dioxide
COFA	Compact of Free Association
CO-OPS	Center for Operational Oceanographic Products and Services (division of NOAA)
CZM	Coastal zone management
DAg	Department of Agriculture (GovGuam)
DAWR	Division of Aquatics and Wildlife Resources (GovGuam DAg)
DLM	Department of Land Management (GovGuam)
DOC	US Department of Commerce
DOI	US Department of the Interior
DOT	US Department of Transportation
EBM	Ecosystem-based management
ENSO	El Niño Southern Oscillation
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FEMA	U.S. Federal Emergency Management Agency
FSM	Federated States of Micronesia
GBPR	Guam Business Partners for Recycling
GCM	Global Circulation Models
GCMP	Guam Coastal Management Program (part of GovGuam BSP)
GDP	Gross Domestic Product
GED	General Education Diploma
GEF	Global Environment Facility
GIP	Gross Island Product
GIS	Geographical Information Systems/Science
GovGuam	Government of Guam

GPA	Guam Power Authority
GU	Guam
GWA	Guam Water Authority
HCA	Hawaii Conservation Alliance
IGCI	International Global Change Institute
IIED	International Institute for Environment and Development
IREI	Island Research & Education Initiative
IWM	Integrated Watershed Management
JALBTCX	Joint Airborne LiDAR Bathymetry Technical Center of Expertise
km	kilometer
LiDAR	Light Detection and Ranging
LNG	Liquid Natural Gas
MIRAB	Migration, Remittances, Aid, Bureaucracy
m	meter
mm	milimeters
MSL	Mean Sea Level
NEP	New Environmental Paradigm
NOAA	National Oceanic Atmospheric Administration
NRCS	Natural Resource Conservation Service (part of USDA)
NREL	National Renewable Energy Laboratory
OHA	Overseas Housing Allowance
OIA	Office of Insular Affairs (part of DOI)
PDO	Pacific Decadal Oscillation
pH	power of Hydrogen (concentration of hydrogen ions in an aqueous substance)
PIC	Pacific Island Country
PICSC	Pacific Islands Climate Science Center (part of USGS)
PIGGAREP	Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project
POTUS	President of the United States
ppm	parts per million
PROFIT	People considerations, Resource management, Overseas engagement, Finance, and Transportation (economic model)
PUAG	Public Utility Agency of Guam
RMI	Republic of the Marshall Islands
SHPO	Guam State Historic Preservation Office
SITE	Small Island Tourist Economy
SIDS	Small Island Developing States
SLR	sea-level rise

SOPAC	South Pacific Islands Applied Geoscience Commission
SPREP	South Pacific Regional Environment Programme
STEM	Science, Technology, Engineering, and Mathematics
TEV	Total Economic Value
TNC	The Nature Conservancy
UH	University of Hawaii
UN	United Nations
UNDP	United Nations Development Program
UOG	University of Guam
UOG ML	University of Guam Marine Laboratory
US	United States
USA	United States of America
USAPI	United States Affiliated Pacific Islands
USD	United States dollar
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WERI	Water Energy Research Institute (UOG)

Chapter 1: Introduction

Humanity's most pressing concern this century is vulnerability to climate change. Anthropogenic climate change is the concept that excessive carbon dioxide (CO_2) emitted from human activities is changing the Earth's atmosphere. There is a global consensus among scientists that the observed changes in climate are due to anthropogenic causes (IPCC 2001, IPCC 2007, IPCC 2014). These changes to the composition of the atmosphere (i.e., increased levels of CO_2) will adversely impact ecological conditions conducive to the survival and existence of human beings. Understanding the extent and nature of this vulnerability to anthropogenic climate change is crucial for humankind to effectively safeguard their society.

The most direct way to mitigate climate change is to cut carbon emissions. According to Hansen et al. (2008), "If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from [current levels] to at most 350 ppm." As of August 2014, CO_2 levels are at 397 ppm (NOAA 2014). While efforts have been made to cut the levels of CO_2, the climate is slow to respond. Anthropogenic climate change is largely irreversible for 1000 years, even after greenhouse gas emissions stop (Solomon et al. 2009). The climate impacts observed today will continue to increase at least into the next several decades, regardless of whether emissions are limited (Solomon et al. 2009). While mitigation of carbon emmisions is imperative, adaptation to climate change is unavoidable in order to foster a sustainable future for humans.

Some people, such as inhabitants of small Pacific islands, are least responsible for anthropogenic climate change (i.e., they emit neglible amounts of CO_2 compared to large countries like the U.S. and China), but are the most vulnerable. They must adapt by enhancing the social, economic, and ecological resilience of their islands and respective coastal zones. Vulnerability to climate change differs spatially and temporally (IPCC 2007, IPCC 2014). The three elements in the current accepted conceptual framework of vulnerability are exposure, sensitivity, and resilience (IPCC 2007, IPCC 2014). Vulnerability is later discussed in greater detail in Chapter 3: Vulnerability and Adaptation. One way to understand these factors of vulnerability for a specific place at a specific time under certain circumstances is to conduct a vulnerability assessment. The

ultimate aim of a vulnerability assessment is to provide information and evidence to support the development of policies that reduce climate risks to communities (Füssel and Klein 2006) and increase adaptive capacity.

Again, small islands are generally the least responsible and yet, the most vulnerable to impacts of climate change. Chapter 2: Impacts of Climate Change on Small Island States and Guam provides a comprehensive discussion of climate change, as it relates to small islands. To examine vulnerability and adaptation in small islands, a case study is conducted in the small Pacific Island of Guam. Guam is located in the western Pacific Ocean, south of Japan, north of Australia, and east of the Philippines (see Figure 1). Guam is part of the region of Micronesia (see Figure 2). Guam is one of the remaining 17 colonies recognized by the United Nations. It is an unincorporated territory of the United States, acquired after the Spanish-American War of 1898. This tie to the United States is evident with the presence of two military bases and a local governance structure that mirrors the American federal government. From a military perspective, Guam is strategically important to the United States due to its proximity to Asia. Because of its geographic location and abundant natural groundwater supply, it is unlikely Guam will achieve self-determination in the near future. The people of Guam do not have complete control over their natural resources and this is unlikely to change so long as Guam's political status remains as an unincorporated territory.

Furthermore, Guam will be experiencing additional changes that the majority of small islands will not have to face. For example, population increase from an impending military build-up will change the demographic make-up of the community, add additional stress on an overtaxed infrastructure, and impact natural resources. These factors could exacerbate the effects of climate change for a seemingly vulnerable community. Studying this vulnerability and the stressors that are not related to climate change will be valuable for natural resource managers and planning agencies.

Climate change is a 'social science problem' (Vinthagen 2013), especially with regard to adaptation and vulnerability. Thus, using social science tools would be a practical approach in addressing these issues. The efficiency and efficacy of adaptation to climate change may be improved by integrating vulnerability assessments into overall land use planning and coastal zone management (Burkett and Davidson 2012). The entire island of Guam is regarded as a coastal zone under U.S. law (NOAA 2004). Coastal zone management is discussed thoroughly in Chapter 4: Coastal Zone Management, within

this thesis. Briefly, the local government agency, the Guam Coastal Management Program, a section of the Bureau of Statistics and Plans, oversees the coastal zone. All actions and laws must be consistent with U.S. federal laws. Guam is distinct. Unlike the majority of the other participants of the voluntary program designated by the U.S. Coastal Zone Management Act, Guam's entire land mass is part of the coastal zone. This provides a rare opportunity to not only manage an entire coastal zone using ecosystem-based management (EBM), but an entire island. Generally, the most accepted method of employing EBM is to use watersheds as spatial units. Integrated watershed practices benefit ecosystems connected to the watershed such as coral reef ecosystems (Richmond et al. 2007).

This introductory chapter states the purpose of the study; clarifies the aim of this research; outlines the objectives and research questions of this dissertation; provides a rationale for choosing this topic; deliberates the research gaps; gives an overview of key terms; and discusses the significance of this research. The chapter concludes with a brief background of the island of Guam.

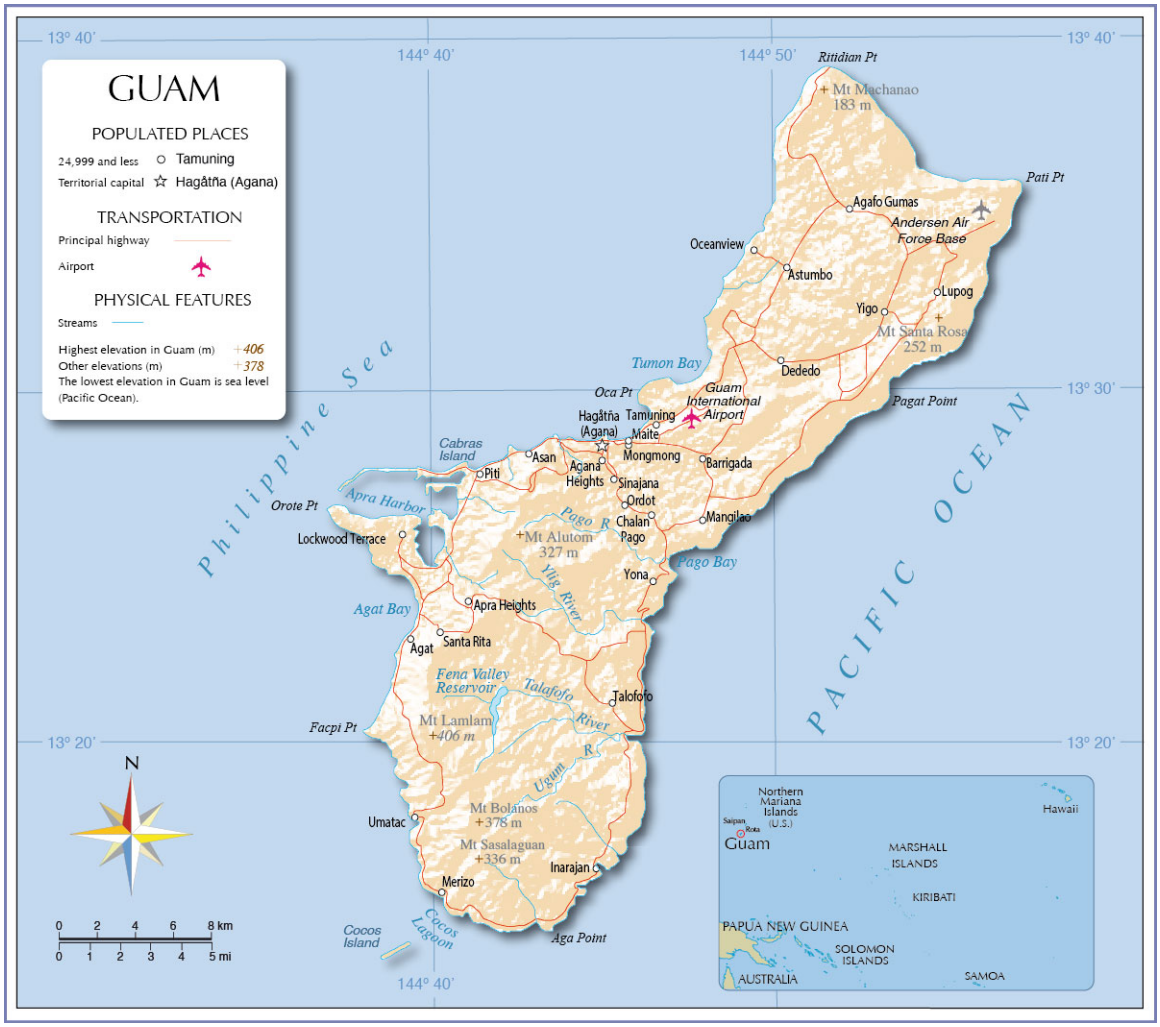


Figure 1: Location map of Guam

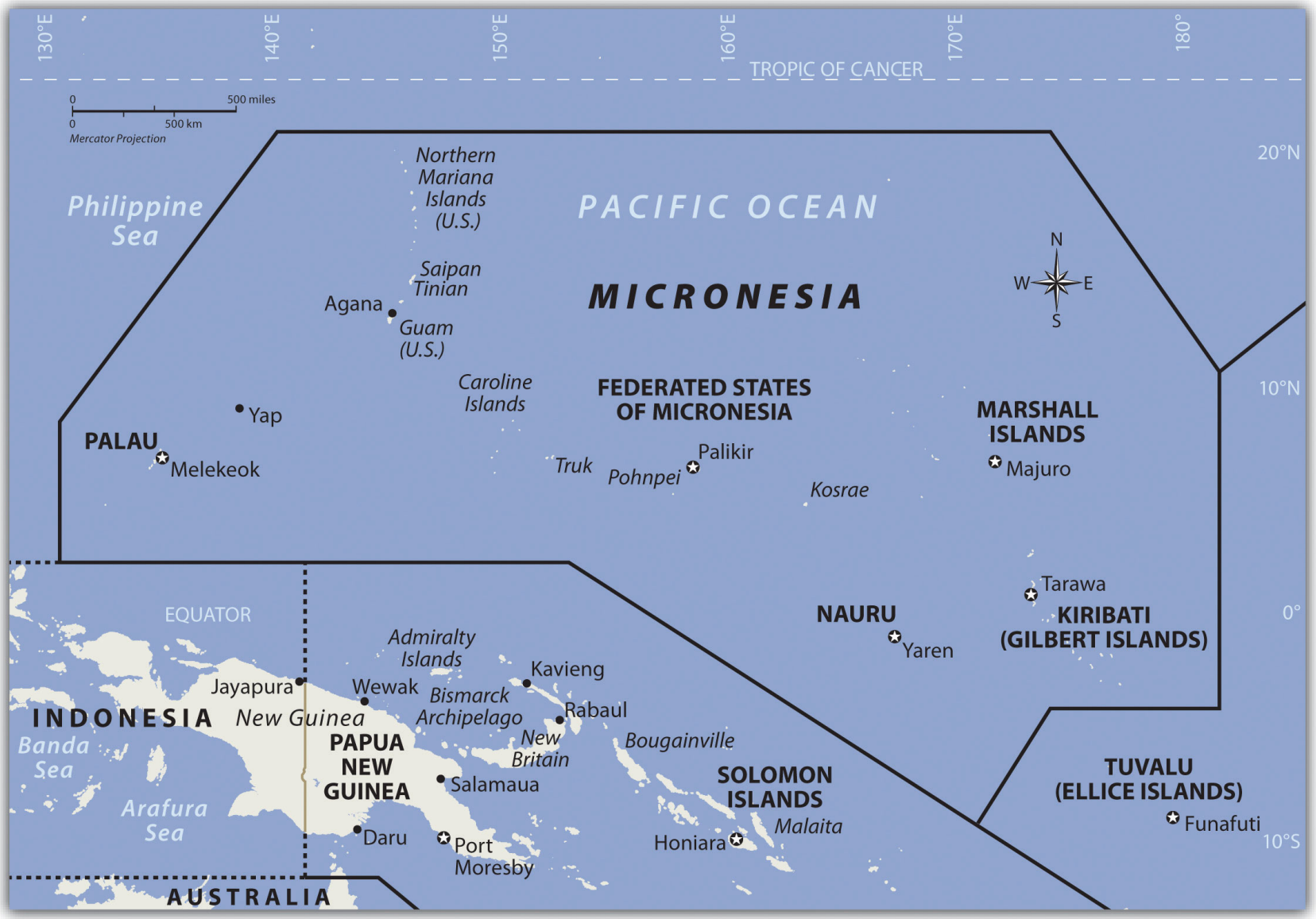


Figure 2: Regional map of Micronesia. Micronesia is a geopolitical construct composed of Guam, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia (Yap, Chuuk, Pohnpei, Kosrae); Nauru, Kiribati; and the waters that surround these island nations. Reprinted from (Berglee 2012)

1.1 Purpose of the study

1.1.1 Aim

This thesis aims to enhance coastal zone management for small islands by examining community perceptions, attitudes, knowledge, and values within a specific watershed. Inclusion of these social science elements will assist in facilitating local adaptation to climate change and shift coastal zone management to seek and incorporate community input. The thesis critically assesses the vulnerability of two specific watersheds on Guam with a focus on the impacts of climate change to freshwater. The research and results from this dissertation are the basis for the Manell and Geus Watershed Management Plan (see King 2014).

1.1.2 Objectives and Research Questions

In order to determine the vulnerability of the communities residing within the Manell and Geus watersheds on Guam, the objectives are as follows:

1. Profile the physical characteristics of the watershed by using Geographic Information Science (GIS).
2. Profile the socioeconomic characteristics of the watershed through an analysis of 2010 United States Census data.
3. Determine the attitudes, behaviors, perceptions, values, and knowledge of the people residing in the watershed through a household survey.
4. Determine the traditional knowledge about the local environment through informal interviews with respected elders.

Fulfilling these objectives will help answer the following research questions pertaining to the vulnerability of small island coastal communities to climate change. While it is anticipated that climate change will impact many sectors (Parry et al., 2007), it is useful to frame the research questions with a specific sector in mind. In this case, the freshwater sector provides an appropriate context for the investigation. The importance of freshwater to small islands is discussed extensively in Section 2.2.6 Small Islands and Freshwater. The main research questions are, as follows:

- how will climate change affect freshwater resources on the Manell and Geus watershed?

- who are the most vulnerable? Who are the least vulnerable?
- what is the adaptive capacity of the community residing within the Manell and Geus watershed?

By attempting to answer the main research questions, the following research questions should also be answered:

1. How knowledgeable is the community with respect to climate change? With regards to traditional knowledge, what responses or approaches have been taken in the past to major disruptive climatic events? How can cultural practices contribute to generating or implement effective reactive and proactive adaptation?
2. How resilient are coastal communities, particularly small Micronesian island-states such as Guam, in the face of global climate change?
3. How could the political relationship of Guam with the United States affect the island's adaptive capacity?
4. How will the global emission scenarios manifest locally and how will that affect freshwater resources?
5. What types of factors (e.g., infrastructure, distance above sea level, erosion potential, economy, community cohesion, demography, government, strength of culture, and distance to markets) must be considered in terms of being adequately resilient?
6. How much consideration must be given to changes (e.g., population increase, negative economic forecasts, political change) other than anticipated climate change?
7. What types of proactive and reactive resilient strategies with regard to water are economically feasible?

1.1.3 Rationale

These research questions are important because it will allow a deeper understanding of vulnerability and resilience of small islands under unique circumstances, such as Guam. In order to achieve this, a case study, at the local level (i.e., a watershed scale) has been conducted. This case study examines the ecological resilience of the selected

watersheds[1] by analyzing the physical characteristics (e.g., geology, vegetation, elevation, freshwater, soil, climate). To determine the social vulnerability, an inquiry into what the attitudes, knowledge, perceptions, and behaviors of the residents living within the selected watershed is performed. Using an interdisciplinary, mixed-methods methodology that includes GIS, household surveys, informal interviews, and personal observations, ensures a holistic investigation into this particular community's level of adaptive capacity, as well as contributes to the current notions of adaptation of small islands.

The specific site within Guam chosen for this case study is the Manell and Geus watersheds (see Figure 21). The community that resides within these two watersheds comprises the village of Merizo. Merizo straddles these two watersheds and is generally regarded as one of the more traditional villages on Guam. The Manell and Geus watersheds are one of the nineteen recognized watersheds on the island of Guam (Watershed Professionals Network 2010). They are located in the southernmost portion of the island and contain a variety of ecosystems (e.g., mangroves, sea grass beds, fluvial systems, barrier reefs, fringing reefs). The GCMP identified the Manell and Geus river basins as priority watersheds as part of the Guam Coral Reef Initiative. Of all the reefs in Guam, it was hypothesized that the reefs within these watersheds would be the most resilient to impacts (e.g., bleaching) from climate change because of low anthropogenic stressors (i.e., low population, limited development).

Examining vulnerability to climate change at a highly detailed scale (i.e., watershed level) provides valuable information for successful, manageable, and strategic natural resource and coastal management planning and restoration. The use of a watershed as a spatial unit is extremely useful for natural resource management (Easter, Hufschmidt, and McCauley 1985) because the ecosystem is closely interconnected around a basic resource—water. See Chapter 5: Section 5.3.2.1 Watersheds, for a more detailed discussion about watersheds and the justification for using it as the spatial unit of study for this research.

This work is a beneficial addition to vulnerability studies that focus on small islands. Most of the literature revolves around small islands that are sovereign. Guam is not. Building adaptive capacity on small islands is challenging, but to do so without full

[1] The American definition for the term 'watershed' differs from the European definition. This difference is thoroughly discussed in 5.3.2.1 Watersheds.

control over natural resources is much more complex and demanding. Consideration of the social indicators of vulnerability within different watersheds will strengthen overall strategic coastal zone management. This is an imperative step to reducing vulnerability and increasing adaptive capacity for the entire island.

By using social science tools (e.g., household surveys, informal interviews, personal observations), it is possible to analyze aspects of social vulnerability for one or all of an island's watersheds. Incorporating that information into current local planning efforts will strengthen natural resource and coastal zone management. The attitudes, perceptions, knowledge, and values of the residents of Merizo, the southernmost village of Guam, toward their watersheds (Manell and Geus) reveal the vulnerabilities of this community, allowing them to be addressed by local and federal government agencies. Finally, this research contributes to the current understanding of the adaptive capacity of small island communities, at a watershed scale.

1.1.4 Research Gaps

While adaptation planning activities have increased, there are technical and data gaps that exist (Burkett and Davidson 2012). It is difficult to plan accordingly when there is uncertainty of what the specific future impacts of climate change are at the scale of small Pacific Islands. Technically, global models still do not provide an accurate picture of future climate scenarios at the scale of small islands. There have been several approaches to address this for small Pacific islands, such as statistical downscaling of coarse-resolution global circulation model (GCM) projections and simulating regional atmospheric circulation projections (Keener et al. 2013).

There is also a need for detailed information about human coastal communities. According to Barnett, Lambert, and Fry (2008), there is a very small amount of climate impacts research that reflects local concerns and contexts. Moser (2009) calls for the research community to make a "concerted effort…to assess vulnerabilities, ascertain adaptation options, and determine relevant governance barriers at and across scales and build the necessary capacity, skill, resource base, institutional mechanisms, and political will to help reduce and overcome." It is important to understand the real-world context and potential severity of climatic change for Guam. In order to achieve this, conducting this case study that investigates community vulnerability at a very localized scale is the first step in identifying future adaptation options.

Hay & Mimura (2005) argue that the impacts of climate change (e.g., SLR) are likely to be felt disproportionately in certain areas, reflecting both natural and socio-economic factors that enhance the levels of risks. Managing the risks to water resources associated with climate change will require adaptive capacity, mainstreaming adaptation, and strengthening local and federal coordination responses to extreme events (Hay and Mimura 2005).

1.1.5 Value of the study

Learning the attitudes, perceptions, knowledge, and values of the residents of Merizo toward their watersheds (Manell and Geus) reveals whether this community has a high adaptive capacity to the impacts of climate change. This is a contribution to the current interpretation of the underlying determinants of adaptive capacity in small island communities. The quantitative portion of this thesis can assist natural resource managers in the evaluation of potential success of possible solutions to problems such as flooding, erosion, and wildfires. Place-based, evidence-based, empirically derived social science information is desperately needed to support policies that increase natural ecosystem resilience to climate change.

Furthermore, this research was funded under NOAA CRI-GU-10[2]. The data collected and compiled for this thesis feeds directly into a watershed management plan for the Manell and Geus watersheds (see King 2014). The incorporation of these social science data from this study on community vulnerability distinguishes the watershed management plan of King (2014) from previous ones because of the marked emphasis on the human dimension. This research also provides baseline data that future work can be compared to over time. Finally, the interdisciplinary work conducted for this dissertation is an example of bridging the gap between academia and management.

1.2 Background - General Overview of Guam

This section gives a brief, general overview of the physical and human geography of Guam. The Manell and Geus watersheds, site of the case study, are thoroughly discussed in Chapter 6: Results – Geospatial Analysis of Manell and Geus Watersheds.

[2] NOAA-CRI-GU-10 is the federal grant that provided funding for this research.

1.2.1 Location

The United States Territory of Guam is the southernmost volcanic island of the Mariana Archipelago, located at 13° 28' N, 144° 45' E (see Figure 4). Guam is an organized, unincorporated territory of the United States. The territory elects its Governor and a 15-member Senate, as well as a non-voting delegate to the US Congress. The island's capital is Hagatna (formerly Agana). The indigenous people are Chamorros, while long-term residents are referred to as Guamanians. Citizens of Guam hold a U.S. passport, but may not vote in U.S. federal elections. Guam is also the largest (541 km^2) and most populated island (159,358 people)[3] in Micronesia. The island is divided into 19 municipalities, called villages, with distinct historic origins. The village of Merizo is the southernmost village and straddles the Manell and Geus watersheds.

Guam has an approximate total shoreline length of 244 km, and a maximum elevation of approximately 405 m. The northern half of the island is flat and composed primarily of uplifted limestone; this is where the principal aquifer (i.e., the Northern Guam Lens) is located (see Figure 5). The Northern Guam Lens is the main source of drinking water. The southern half of the island is comprised of volcanic rock and has considerably more topographic relief (see Figure 5) and high erosion potential. From this topography, 19 watersheds have been delineated (Watershed Professionals Network 2010).

[3] Figure is according to the US 2010 Census (U.S. Census Bureau 2011a).

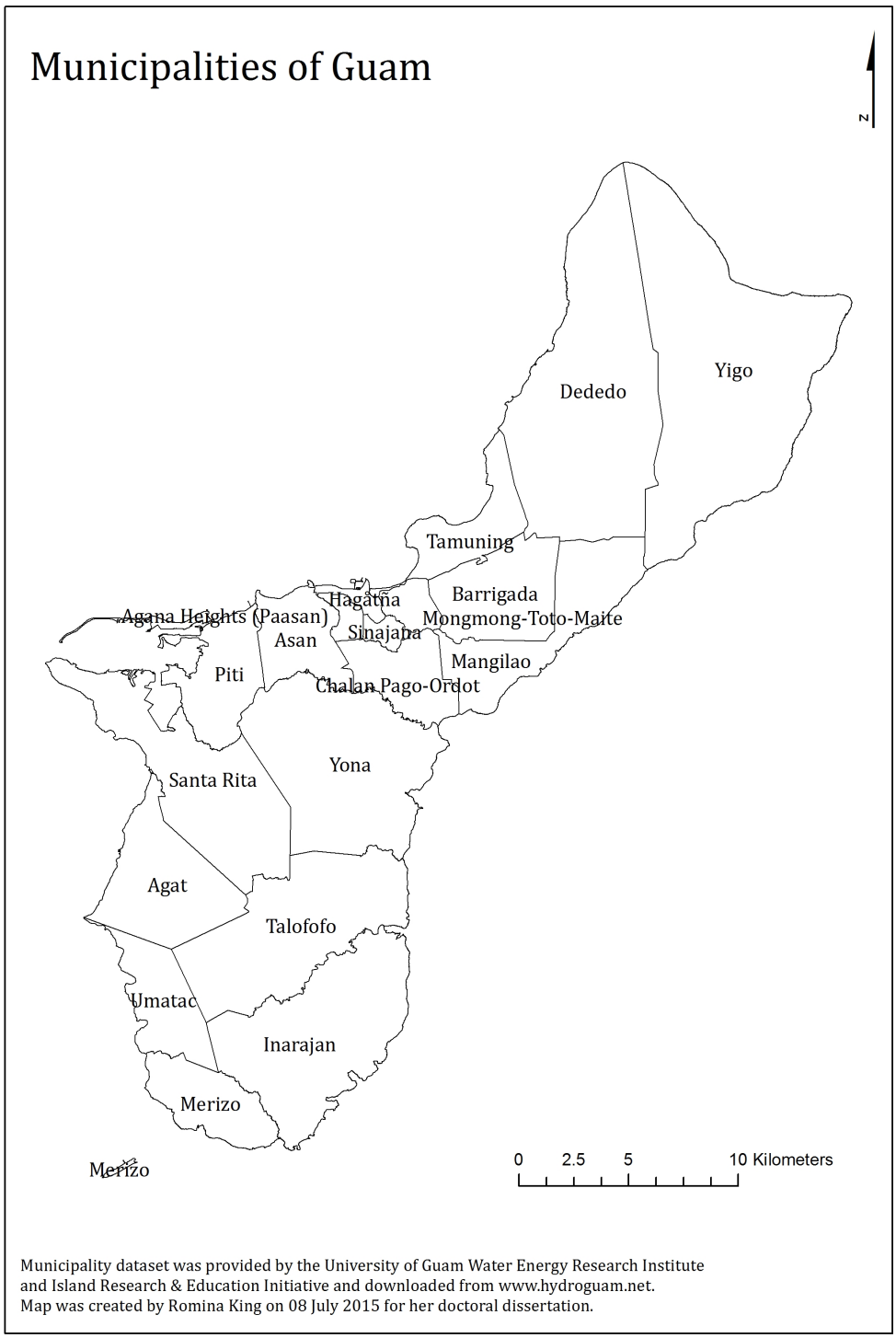


Figure 3: Map showing the 19 municipalities of Guam.

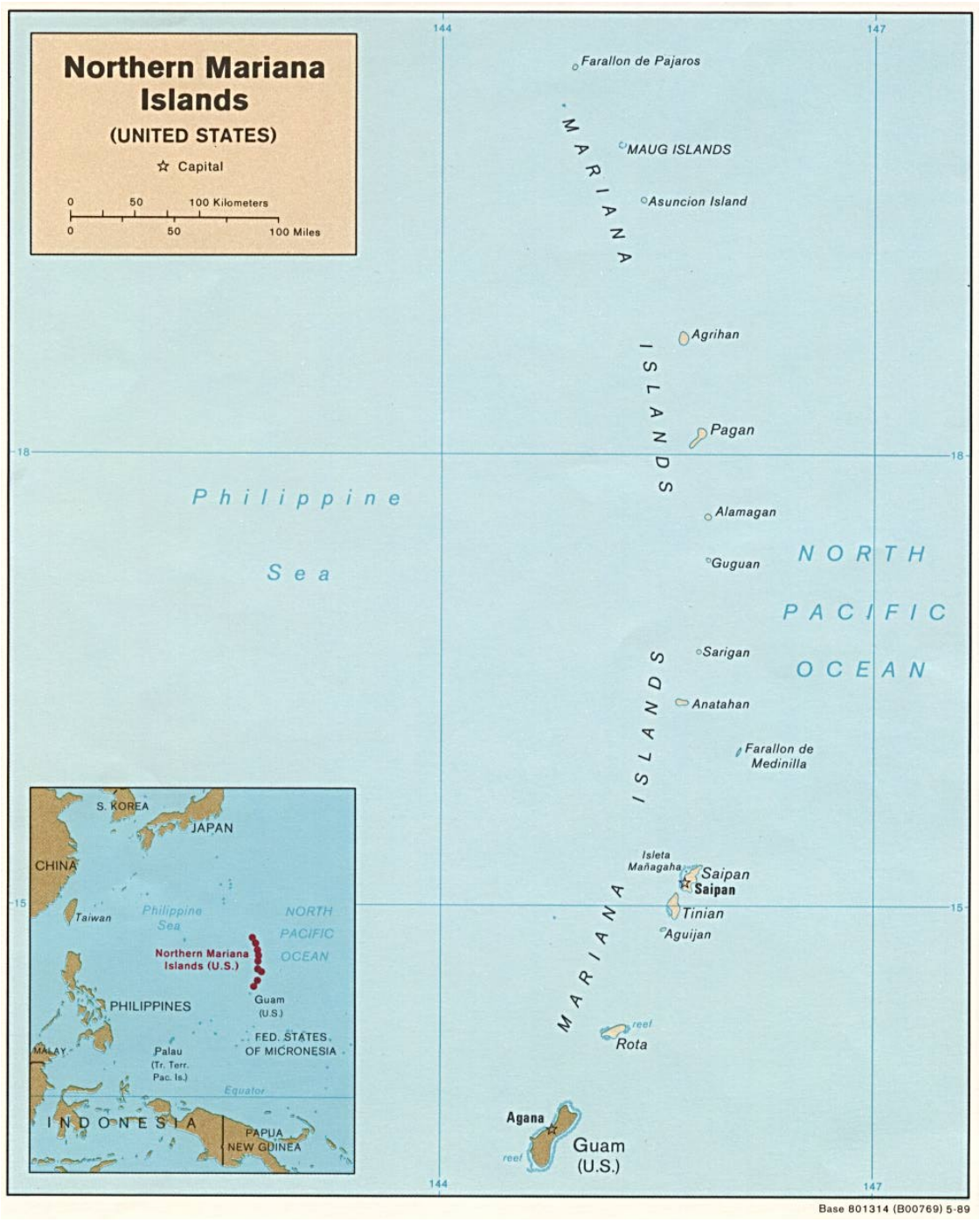


Figure 4: Map of the Mariana Islands (USGS 1989)



Figure 5: Topographical Relief Map of Guam created using 2007 LIDAR data. LiDAR dataset was provided by the Bureau of Statistics and Plans Guam Coastal Management Program. The map was created by Romina King in 2010 for her doctoral dissertation proposal.

1.2.2 Geology

Understanding the geological history of Guam explains the present-day geological characteristics of the island. According to Tracey et al. (1964), the formation of Guam happened in the mid-Eocene Epoch, along the Palau-Kyushu Ridge, as a result of the Pacific plate subducting under the Philippine plate. The emerging magma slowly formed an underwater volcano that became the volcanic basement bedrock of Guam. The rocks of this event are part of the Facpi formation and are not only the oldest rocks on Guam, but may be characterized as submarine lava flows in the form of pillow basalt (Siegrist

and Randall 1992). The Facpi formation formed over the course of 3-4 million years (from 43-39 Ma) (Siegrist and Randall 1992).

This gentle volcanism transitioned to a more violent volcanism involving explosive underwater pyroclastic eruptions forming what is now known as the Alutom formation (from 32-29 Ma) (Siegrist and Randall 1992). At the end of the Alutom period, the underwater volcano split from its location along the Palau Kyushu Ridge and migrated farther east in the direction of the Pacific plate and began its third and final episode of major volcanic construction along the West Mariana Ridge (Siegrist and Randall 1992). This final volcanic explosion resulted in the Umatac formation (Siegrist and Randall 1992). Volcanism then ceased and Guam began rifting away from the West Mariana Ridge to its present location (Siegrist and Randall 1992). By the end of the major volcanic episodes, the top of the volcano was near the ocean surface and there was a period of sedimentary limestone deposition. Around 1-2Ma, Guam experienced tectonic uplift, so the ancient corals are now 100-200 m above sea level (Siegrist and Randall 1992).

1.2.3 Climate

On a regional scale, "changes in annual rainfall (inches/month) in the Western North Pacific sub-region from 1950-2010 show that the islands in the west are getting slightly more rainfall than in the past, while islands in the east are getting much less (Keener et al. 2013). Guam's climate is loosely characterized by a wet season (July-November) and a dry season (December-June). Annual rainfall is high; average precipitation varies from 85 – 115 inches (215.9 – 292.1 cm) per year (Lander 1994). Rainfall is not uniformly distributed temporally (Lander 1994) or spatially (Mylroie et al. 1999); rainfall distribution patterns are fairly complex (Lander and Guard 2003) (see Figure 7).

Generally, two-thirds of annual rainfall occurs during the wet season and the heaviest rainfall is associated with tropical cyclones (Lander 1994). Lander & Guard (2003) analyzed all available rainfall data collected by federal and local agencies from 1950-2003 and found that the rainfall gradients and the patterns are strongly influenced by the northeast-southwest orientation of the island, the shape of the island, and the terrain of the island. There is a significant orographic effect that causes rainfall totals from stations throughout the island to differ by as much as 30 inches (76.2 cm) in one year (Lander and Guard 2003).

Typhoons and tropical storms pose the most frequent and visible threat to the island of Guam. Guam is in "Typhoon Alley". From 1945-2004, approximately 208 tropical storms and typhoons came within 180 nautical miles of Apra Harbor Guam (Brand 2009). See Table 1 for a monthly breakdown of the frequency and motion of all 208 storms. See Figure 6 for the tracks of all 208 tropical storms. A typhoon vulnerability study conducted by Guard et al (1999) indicated that the seaports are highly vulnerable to wind, storm surge, coastal inundation, high seas and flooding. It is expected for the frequency of typhoons to decrease and the intensity to increase (Keener et al. 2013).

Table 1: Frequency and average motion of the 208 tropical storms and typhoons that passed within 180 nmi of Apra Harbor, Guam from 1945-2004, according to month. Table is modified version from (Brand 2009).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Total No. of storms passing within 180 n mi	8	1	2	8	8	7	16	23	33	49	36	17
No. of storms having at least typhoon intensity at CPA	3	1	1	6	6	0	5	5	7	14	18	8
No. of storms having less than typhoon intensity at CPA	5	0	1	2	2	7	11	18	26	35	18	9
Average heading direction storms were moving at CPA (degrees)	282	*	*	340	308	294	299	295	298	293	282	288
Average storm speed at CPA (knots)	14	*	*	9	9	13	11	10	12	13	14	12

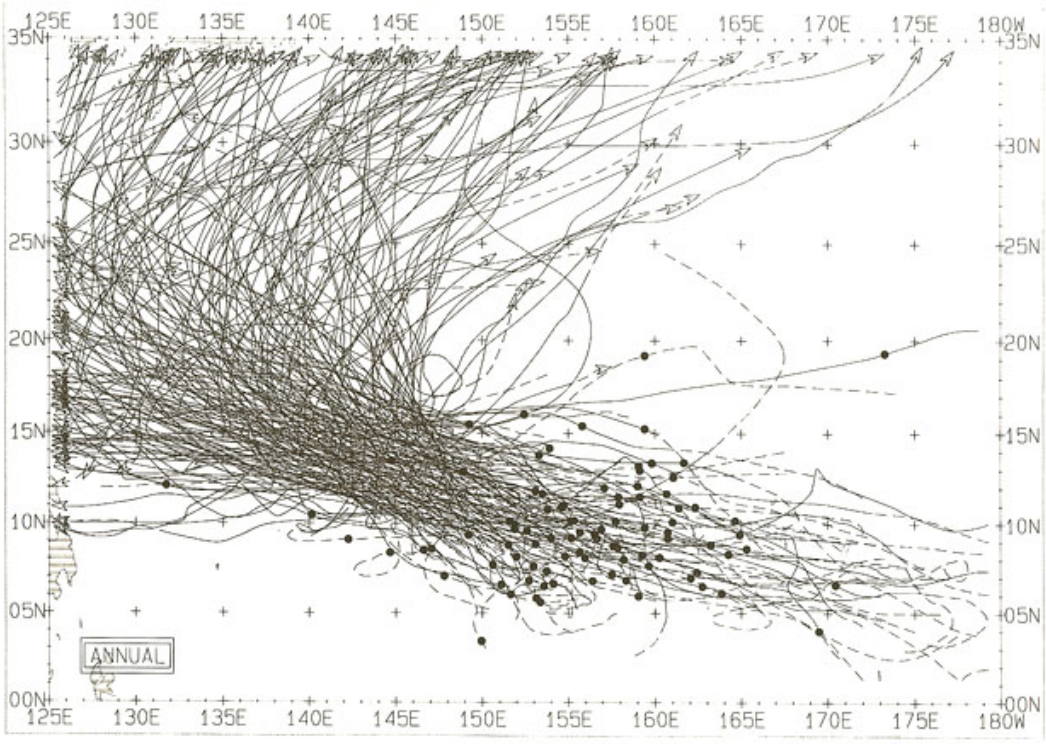


Figure 6: Tracks of the 208 tropical cyclones that passed within 180 nmi of Guam from 1945-2004. Dashed track indicates maximum winds less than 34 kt. Circular markers along track indicate positions of tropical cyclones 72 hours before reaching the closest point of approach. Reprinted from Brand (2009). Guam is located at approximately 13.5°N and 144.8°E.

ENSO has a major effect on the Pacific region's climate, including Guam (Keener et al. 2013). After the 1997/1998 El Niño, Guam experienced one of the most severe droughts in its relative history (Lander 1994). Exceptionally dry years seem to recur in correlation with episodes of El Niño (Lander 1994). The Government of Guam pledged research, development, and maintenance of a long-term drought management plan (Lander, personal communication 2013). With the impending military build-up and subsequent population growth, the water resources research needs identified by the Guam Advisory Council include the development of water budgets for Guam's surface and groundwater watersheds; a re-evaluation of sustainable development estimates for the Northern Guam lens (Guam's principle aquifer); and expanding Guam's rainfall database of Guam to include long-term rainfall variability (Lander, personal communication 2013). However, for long-term planning, having an extended record of past climatic cycles may provide insights as to what to expect in the future. The historical record of El Niño/La Niña related rainfall and drought is very limited (Lander 1994); the earliest data is from 1945 (end of World War II) (Lander and Guard 2003).

Climate research has shown that trends such as rainfall and sea surface temperature in tropical regions correlate well with chemical signatures in the annual growth layers of local corals (Druffel 1997; Dunbar et al. 1994). In Guam, El Niño brings higher sea surface temperatures and lower precipitation (Lander 1994). Researchers at the University of Guam Water Energy Research Institute extracted a coral core off the West coast of Guam and sent it to the University of Texas, Austin for isotope analysis in order to reconstruct past sea surface temperature history and thus, previous El Niño events (Jensen, personal communication, 2014). Partin et al. (2012) are using stalagmites in order to reconstruct past precipitation. Accurate past sea surface temperature and past precipitation is crucial in reconstructing the paleo-climate. Understanding the paleoclimate as it relates to early human settlement on Guam can provide CZM planners insights as to what the coping range is for this island.

Madrid (2013) identified and extracted climate data from ethnographic Spanish records for the Marianas Islands from the 16th – 19th centuries. Reports from the 19th century contained a wealth of meteorological data and are currently being reviewed by researchers at WERI (Lander, personal communication 2014). However, as the age of a record increased, specificity of climate metrics decreased (Madrid (2013), making it difficult for modern day meteorologists to plot trends over time (Lander, personal communication, 2014).

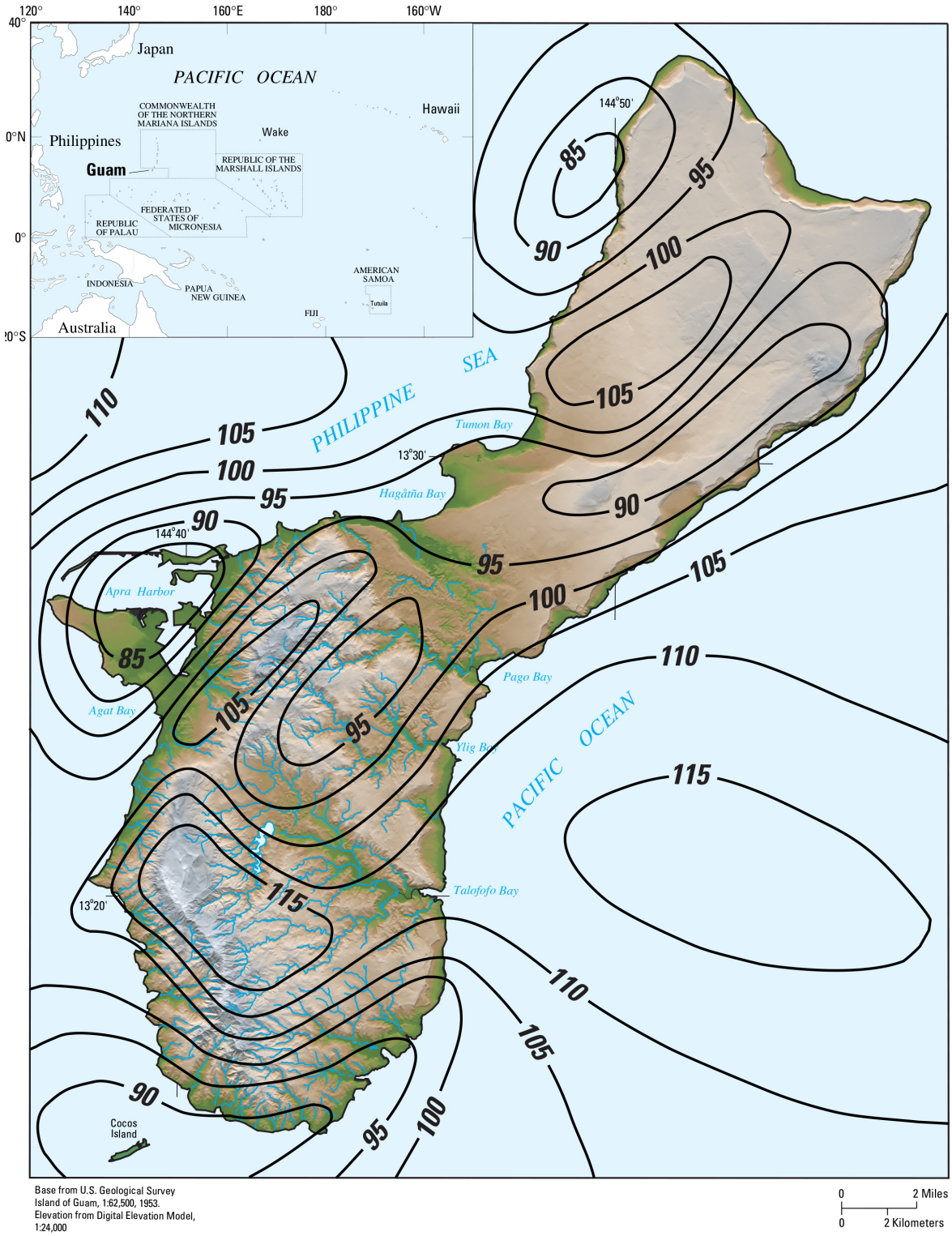


Figure 7: Map showing the distribution of average annual rainfall on Guam. Isohyets are in inches. Reprinted with permission from Lander and Guard (2003).

1.2.4 Pre-history

Within the past 1200 years, Pacific Island societies have been vulnerable to sea-level change and drought which may have caused fundamental societal changes (Nunn 2007b; Nunn 2007a). Archeological records have shown that sea levels have changed over time and humans have adapted and responded by migrating and shifting resource bases (Nunn 2007b). Understanding the pre-history of Guam can prepare present generations with the knowledge of the climatic conditions the early settlers experienced. How the initial inhabitants of Guam adapted to a prehistoric climate may offer ideas that may be modified for adaptation strategies for the present. The pre-history of Guam is commonly referred to as the "Pre-Contact" period and most of what is known about this time originates from archaeological evidence, early accounts from whalers and traders, Jesuit missionary accounts, and observations from scientist/explorers such as Louis de Freycinet.

Russell (1998) provides a comprehensive overview of the prehistory of the *Chamorro*[4] people based on archaeological reports and historical accounts. Based on ceramic analysis of prehistoric shards and radiocarbon dating, Chamorro prehistory may be divided into four major cultural periods, Early *Prelatte* Phase (1485 BC – 500 BC); the Intermediate *Prelatte* Phase (500 BC – 1 AD); the Transitional Period (1 AD to 500-1000 AD) and the *Latte* Period (1000 AD – 1521 AD) (D. Moore 1983). The term *latte* refers to the stone foundations of prehistoric Chamorro dwellings. *Latte* stones are composed of a limestone column with a limestone cap and were first described in great detail in the historic records of a 1742 British naval expedition under the command of Commodore George Anson (Barratt 1988). Dwellings were elevated, on top of these *latte* stones (see Figure 8). This early design of houses is conducive for flooding events.

Based on information collected on Guam in the 1800s, one reconstruction of prehistoric Chamorro society organizes the people into three distinct social classes—the *matua* (chiefly class); the *atchoat* (demi-noble class); and the *mangatchang* (low class) (Freycinet 1943; Thompson 1945). However, some scholars argue that prehistoric Chamorro society was less stratified and should be organized as *magaraie* or *chamuri* (high status-chiefs) and the *mangachane* (low status) (Driver 1993).

[4] *Chamorro* is the term used to describe the indigenous culture and people of Guam.

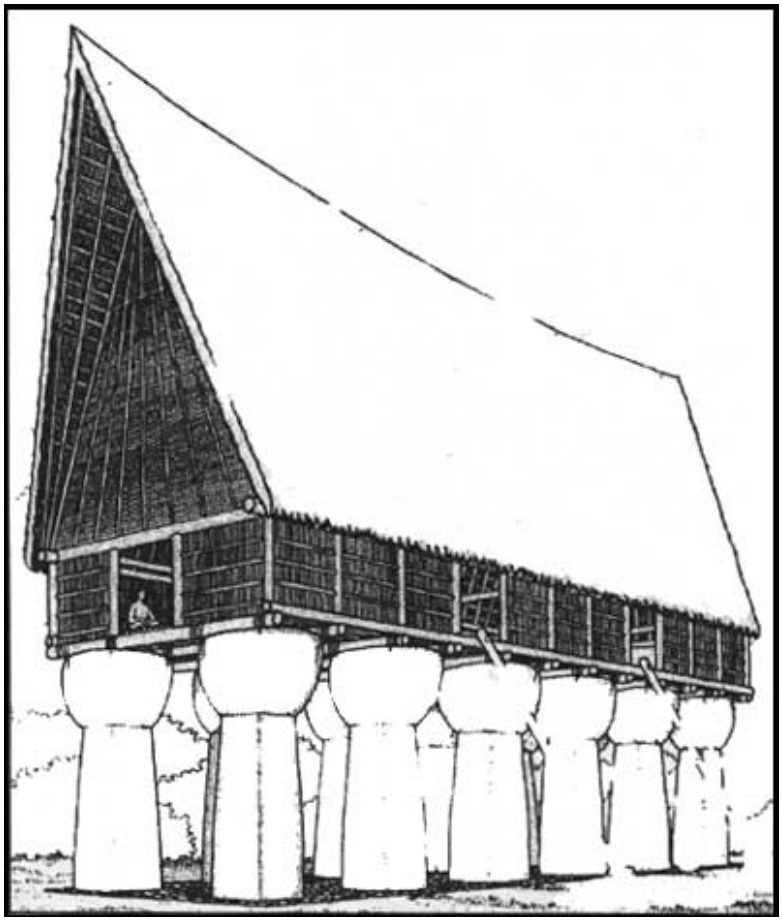


Figure 8: Chamorro multi-family residence. Pole-and-woven mat structure rests atop latte stone columns. Source: Micronesian Area Research Center, University of Guam.

1.2.5 History

Guam was claimed by Spain in 1565, but was not colonized until 1668 (R. F. Rogers 1995). However, with Spain's defeat in the 1898 Spanish-American War, the island, in addition to Puerto Rico and the Philippines, was ceded to the United States. During World War II, Guam was invaded and occupied by Japan for three years. The United States liberated the island in 1944. After the war, through the Guam Organic Act of 1950 (48 U.S.C. § 1421 et seq), a United States federal law that transferred the governance of Guam from the United States Navy to the Department of the Interior, Guam was established as an unincorporated territory of the United States. For the first time in over three hundred years, the people of Guam had some limited measure of self-governance. But despite this small advance, Guam is ultimately still a colonial possession of the United States. Any local laws on Guam must be in compliance with

United States federal laws. Citizens of Guam are naturalized American citizens, but may not vote in U.S. federal elections.

Four consequences of the Guam Organic Act of 1950 (48 U.S.C. § 1421 et seq) are as follows:

1. An executive branch headed by a governor appointed by the President of the United States. (It was not until the Elective Governor Act of 1968 that the residents of Guam were given the right to vote for their own governor)
2. A unicameral legislature of up to 21 senators (which was reduced to 15 members in 1996), elected by the residents of Guam. Senators serve two year terms and there is no limit on the number of terms a senator may serve.
3. A judicial branch consisting of a court system with judges appointed by the Governor of Guam and re-elected by Guam voters;
4. United States citizenship for the residents of Guam.

Prior to the Organic Act, Guam residents were not citizens of any country, except for those who were naturalized in the U.S. mainland or who had served in the U.S. military. Guam has one elected, non-voting delegate to the U.S. House of Representatives. The Guam delegate is an official part of Congress and can serve on committees, but cannot vote on legislation. As of 2015, the current Guam delegate is Madeleine Bordallo.

The political history of Guam plays a role in how natural resources within watersheds are managed. The centralization of power means that one main institution of authority controls all the natural resources of the entire island. Resources are no longer locally managed. The elected Governor of Guam has the power to appoint anyone as the Director, or Administrator of a Government of Guam line agency. The heads of the Guam Environmental Protection Agency, the Guam Department of Agriculture, the Bureau of Statistics and Plans, the Guam Water Authority, the Guam Energy Office are all political appointees and do not need advanced qualifications, much less experience, to serve. They must be approved by the Guam legislature. The politically appointed heads of agencies have substantial power to influence how that agency functions, or in some cases, malfunction. These agencies are primarily responsible for enforcing local laws that protect the water, air, and biota of Guam.

1.2.6 Governance

Unlike many of the islands in Micronesia, there is currently no traditional leadership (i.e., chiefs) on Guam. Governance is centralized on Guam. Guam is an organized, unincorporated territory of the U.S. Policy relations between Guam and the U.S. are under the jurisdiction of the Office of Insular Affairs (OIA), U.S. Department of the Interior (DOI). Guam has a governor, elected by the local population and subject to a maximum of two four-year terms. Four-year, at most eight-year, terms are a relatively short time span, thus making it easy to disregard long-term ecological, social, and economic consequences of decisions on natural resources—consequences can be the burden of future administrations. Traditional leaders tend to focus more on legacy and would be more concerned with how their action would affect future generations, as opposed to short-term rewards (Richmond et al. 2007).

During the time of this research (2010), the Governor of Guam, Republican Felix P. Camacho was in the last year of his term and was ineligible for re-election. During the period of fieldwork (2010), campaigning for gubernatorial elections was in full swing. The Republican party retained the governorship; Republican Eddie Calvo was elected to lead Guam for the next four years in a very close race. With a change in governorship on Guam, there is a subsequent change in the politically appointed officials. The changes may either be minor or major but may have a subsequent effect on the way things are administered and executed within a specific agency. While the administration may change every four to eight years, the communities, particularly those in Southern Guam remain. Understanding their attitudes, values, perceptions, behaviors, and knowledge will help coastal zone and natural resource managers (who are not appointed) carry on longer-term planning. The local government agencies relevant to this thesis are discussed in the subsequent paragraphs.

1.2.6.1 Office of the Governor

During the time of this research, the elected governor of Guam was Felix Camacho. His terms were from 2003-2011. The current governor-elect is Eddie Calvo and the lieutenant governor is Ray Tenorio.

1.2.6.2 Bureau of Statistics and Plans - Guam Coastal Management Program

Because one of the topics central to this thesis is coastal zone management, the Guam Coastal Management Program is discussed in great detail in Chapter 4: Section 4.2 CZM from a Local Perspective (Guam).

1.2.6.3 Guam Waterworks Authority

The Guam Waterworks Authority (GWA) is a semi-autonomous, self-supporting agency responsible for water and wastewater utilities on Guam. GWA was created by Public Law 23-119 on 31 July 1996. Prior to the creation of the GWA, the Public Utility Agency of Guam (PUAG) was responsible for the water and wastewater utilities in addition to telephone and power. PUAG was created by Public Law 1-88 on 06 June 1952.

Through Public Law 26-76, passed in 2003, GWA is managed by an elected, non-partisan, five-member Consolidated Commission on Utilities (CCU) to oversee the operations of GWA and the Guam Power Authority (GPA). The CCU was initially faced to deal with 25 million USD in debt and several federal lawsuits regarding violations to laws protecting the water and wastewater system. As of 2014, GWA is responsible for 41,000 customers for water and approximately 25,000 customers for wastewater (Guam Waterworks Authority 2014).

1.2.6.4 Department of Public Works

The Department of Public Works (DPW) was established by Public Law 1-88 and enacted in 1952 under section 5104. DPW is responsible for providing the people of Guam five major and essential services: public safety, transportation, highway maintenance, government-wide support, and capital improvement projects.

1.2.6.5 Department of Agriculture

The Guam Department of Agriculture (DoAg) was established under Public Law 3-103, effective 01 August 1956 in order to protect and promote the agricultural resources and economy of Guam through research, quarantine, control, and conservation. The responsibilities of DoAg include developing and protecting the island's agriculture, natural resources, aquatic, and wildlife resources and is accomplished through the functions of five divisions, each headed by a Chief. The five divisions include Animal and Plant Industry; Agricultural Development Services, Wildlife and Aquatic Resources; and Forestry and Soil Resources. The chiefs of each respective division answer to the Director and Deputy Director, politically appointed positions.

1.2.6.6 Guam Environmental Protection Agency

The Guam Environmental Protection Agency (GEPA) was established under Public Law 11-191 on 07 December 1972 in order to provide an integrated and comprehensive territory wide program of environmental protection. The purpose of GEPA is,

> "a high quality environment be maintained at all times to guarantee an enjoyable life for all people at present and in the future, and that environmental degradation of the quality of land, water and air by any pollutants, including all physical, chemical and biological agents, should not be allowed." (Guam Environmental Protection Agency 2014)

GEPA has five divisions that carry out this mission and vision of the agency. These divisions include Administration; Air and Land Division; Environmental Monitoring and Analytical Division; and Water Division. Within each division are several programs. GEPA is responsible for enforcing all environmental laws.

Clearly, the political geography of Guam is complex. Understanding the main players is necessary for the context of this thesis because it is linked to coastal governance.

1.2.7 Population

The population of Guam has been steadily increasing since 1910 (see Table 2). The latest official population count (2010) for Guam was 159,358 , only a 2.9% increase from the 2000 census (see Table 2). The spatial distribution of the 2010 census data indicates that most of the population is concentrated in the Northern half of Guam, and the village of Dededo has the highest population (see Figure 9). This is also true for the 2000 census data (see Figure 10). However, the population in the Northern municipalities has grown from 2000-2010, more so than the southern villages (see Figure 11). Yigo, the northern-most municipality has the highest population density (see Figure 12).

Table 2: Population of Guam for each decade from 1910 – 2010. Data is from the U.S. Census Bureau.

Census Year	Total Population	Percent Change in Population (%)
1910	11,806	—
1920	13,275	12.4
1930	18,509	39.4
1940	22,290	20.4
1950	59,498	166.9
1960	67,044	12.7
1970	84,996	26.8
1980	105,979	24.7
1990	133,152	25.6
2000	154,805	16.3
2010	159,358	2.9

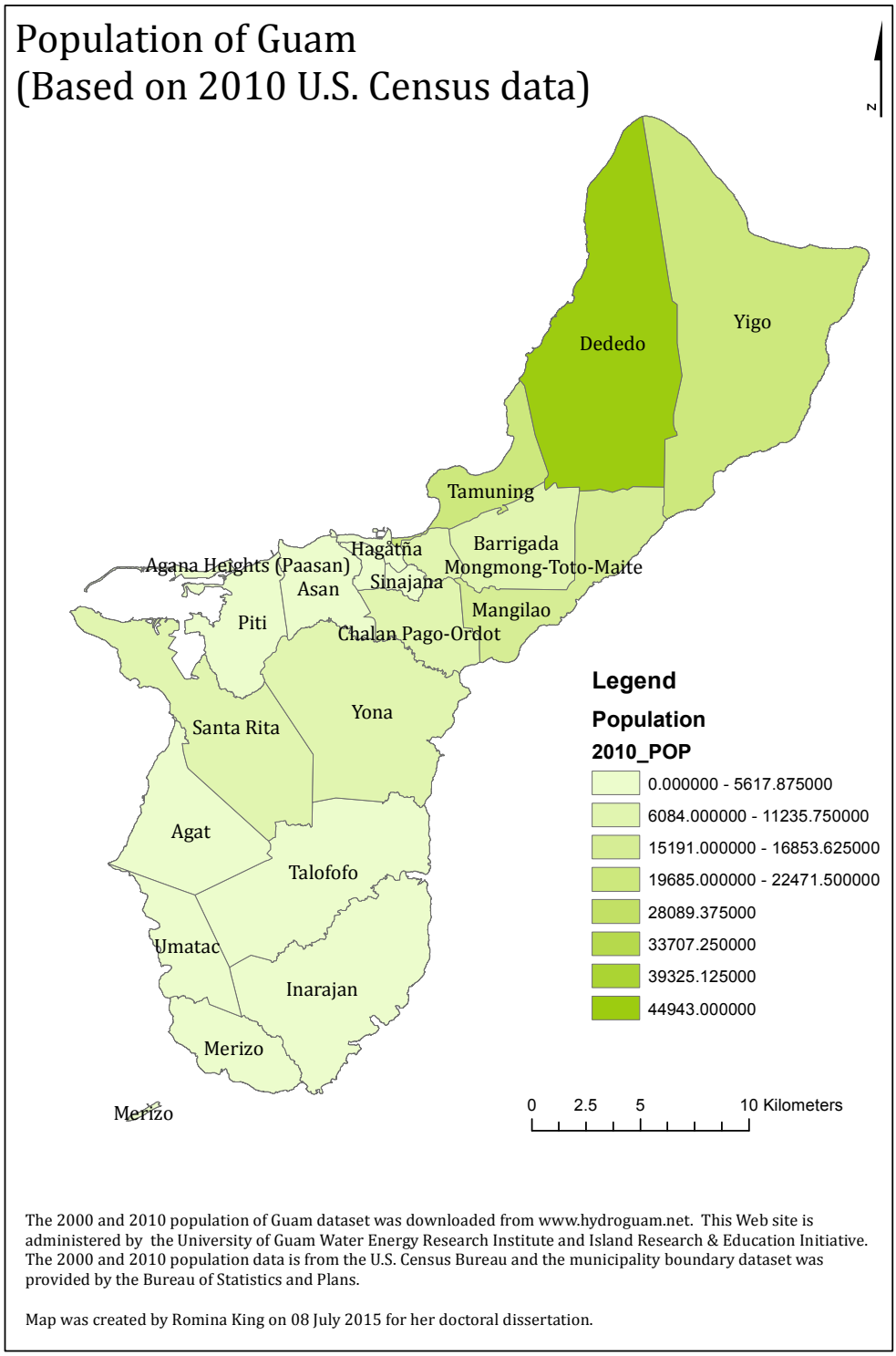


Figure 9: Chloropleth map showing the 2010 population of Guam according to municipality.

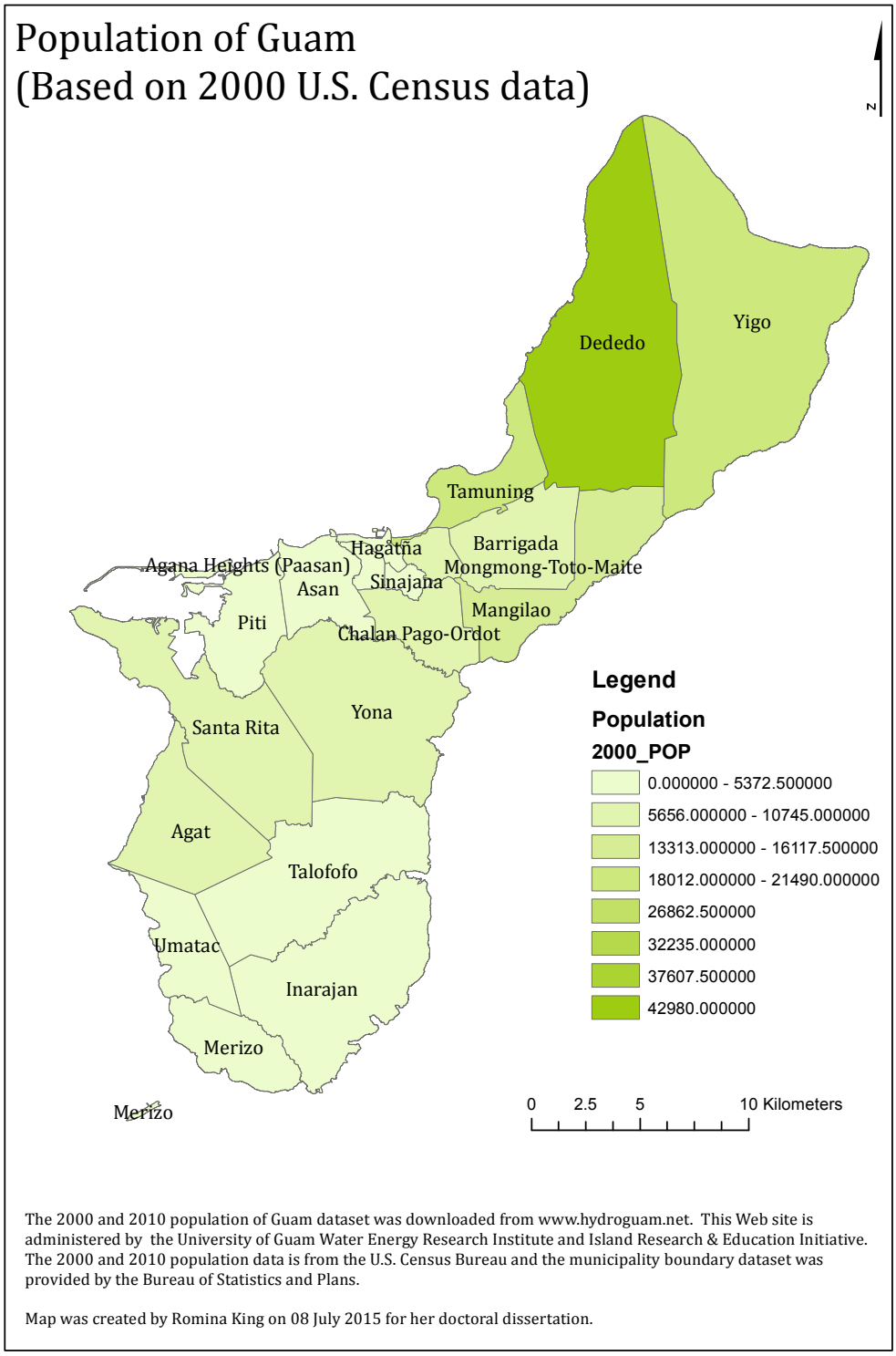


Figure 10: Chloropleth map of Guam showing the 2000 population according to municipality.

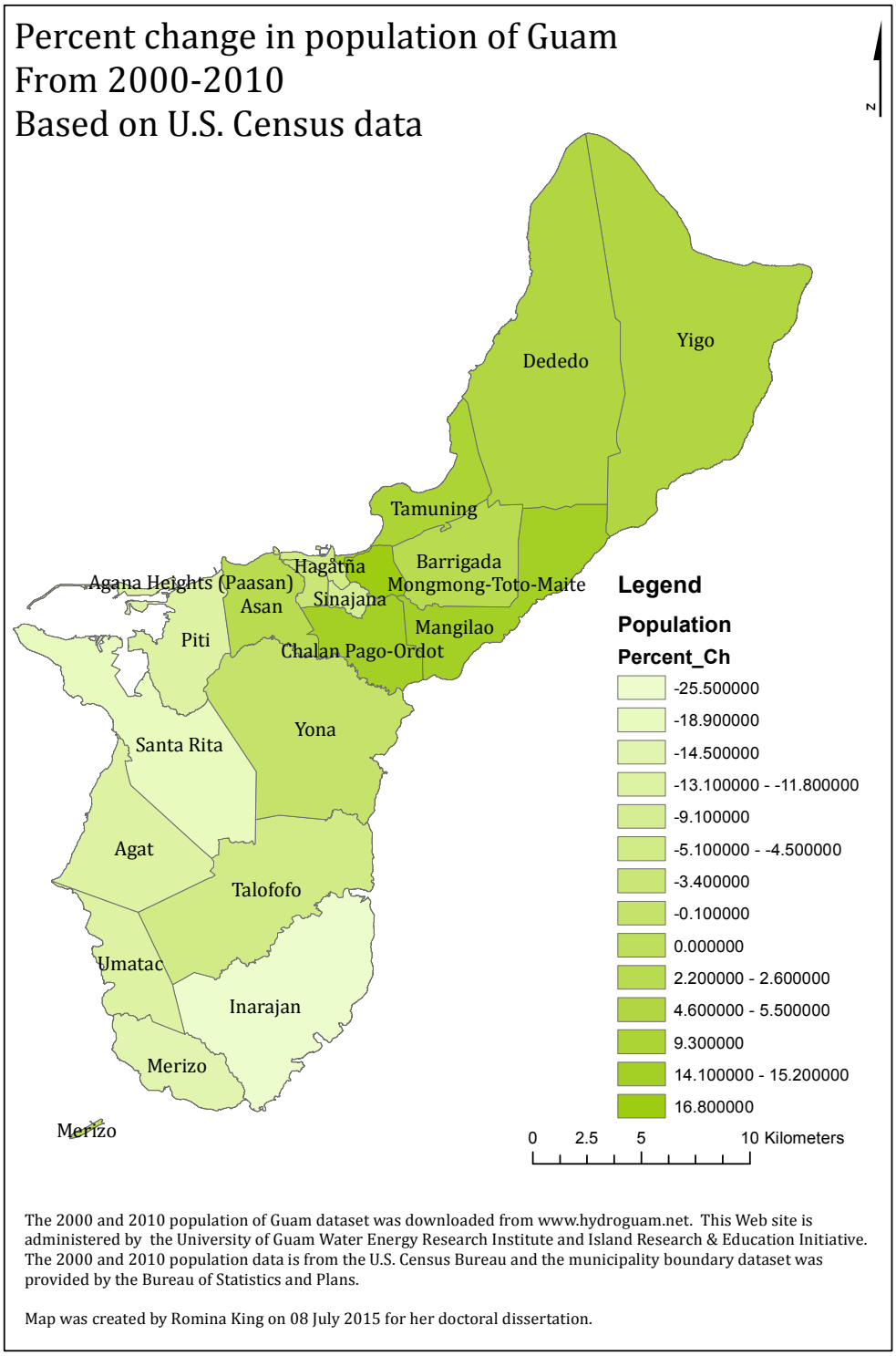


Figure 11: Chlorpleth map depicting the change in population between 2000 and 2010 U.S. Census data.

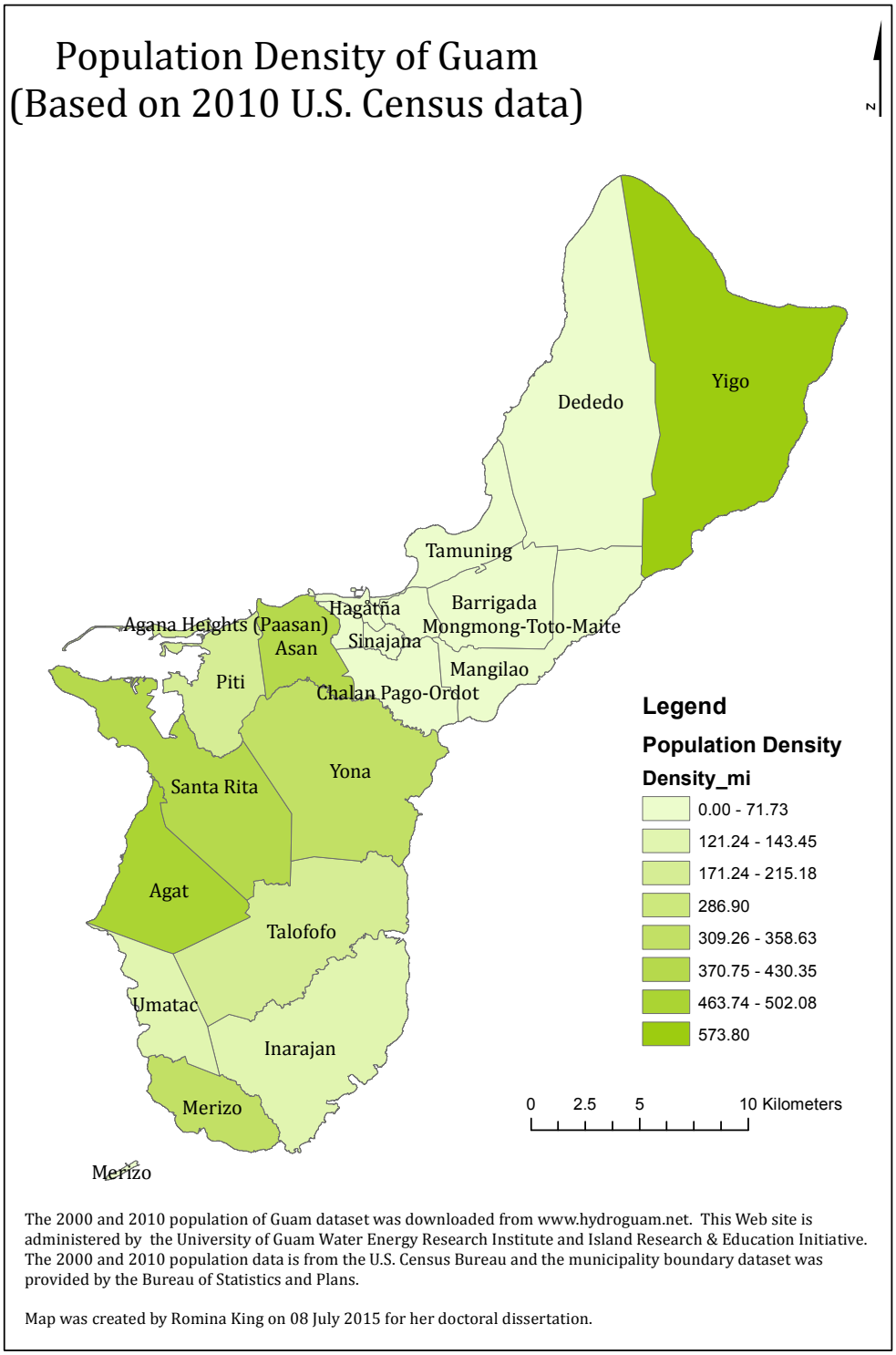


Figure 12: Chloropleth map showing population density according to municipality. Population density was calculated by dividing the total population of each municipality by the area of the municipality (sq. mi.).

1.2.8 Economy

Guam's local economy may be classified as a small island tourist economy (SITE) (Bertram 2006), where the primary sector is tourism. According to the Guam Economic

Development Authority, tourism accounts for up to 60% of the government's annual revenues as well as provides 20,000 direct and indirect jobs (Guam Economic Development Authority 2015). According to Ruane (2013), approximately 1.278 million tourists visited Guam 2012, 12.8% more than 2011. The main tourist district of Guam is located at Tumon Bay (see Figure 13). The Gross Island Product (GIP), similar to Gross Domestic Product (GDP) is estimated at 4.052 billion USD (U.S. Department of Commerce-Bureau of Economic Analysis, 2010).



Figure 13: Photograph showing Tumon Bay, Guam. This developed tourist district of Guam features coastal hotels, high-end shops, and developments adjacent to a marine protected area. Photograph is courtesy of John Jocson.

Other drivers include federal government expenditures (including military spending) and local production of goods and services (Ruane 2014). Six key characteristics of the Guam economy include "(1) a small island economy that is relatively open that is (2) currently lacking economic diversification but (3) endowed with natural resources and a (4) multicultural society…(5) an unincorporated U.S. territory (6) located strategically in Asia-Pacific" (Ruane 2012). Ruane (2012) points out that these six characteristics are opportunities to increase economic development on Guam.

1.2.9 Natural Resources

A resource is any physical material on Earth that people use and value (Getis, Bjelland, and Getis, V. 2014). Natural materials (e.g., gold, timber, oil) become resources when humans value them (Getis, Bjelland, and Getis, V. 2014). Resources may be renewable (e.g., wind) at varying rates or non-renewable (e.g., oil). The uses and values of resources may change temporally, spatially, and culturally. The spatial distribution of natural resources vary in quality and quantity (Getis, Bjelland, and Getis, V. 2014). Some natural resources found on Guam include coral reefs, reef fish, native limestone forests, endemic birds and plants, solar insolation, wind, white-sand beaches, rivers, mangroves, lakes, caves, and an aquifer. These natural resources are managed by the local natural resource management agencies. These local agencies are subject to U.S. federal oversight and must comply with U.S. laws and regulations. A substantial portion of their budgets is financed by federal grants. Only the natural resources found in the Manell and Geus watersheds is of relevance to this dissertation and will be discussed in Chapter 6: Results – Geospatial Analysis of Manell and Geus Watersheds.

1.2.9.1 Threatened and endangered species

Currently, there are 12 animal species and 1 plant species in Guam on the Federal list of endangered and threatened species (USFWS 2008). Species listed have the full range of protection available under the Endangered Species Act of 1973, as amended (*The Endangered Species Act of 1973*).

Table 3: Federal list of threatened and endangered species on Guam (U.S. Fish and Wildlife Service 2011).

Fauna/Flora	Scientific Name (Genus Species)
FAUNA	
Endangered	
Bat, little Mariana fruit	*Pteropus tokudae*
Crow, Mariana	*Corvus kubaryi*
Kingfisher, Guam Micronesian	*Halcyon cinnamomina cinnamomina*
Moorhen, Mariana common	*Gallinula chloropus guami*
Rail, Guam	*Rallus owstoni*
Sea turtle, hawksbill	*Eretmochelys imbricata*
Sea turtle, leatherback	*Dermochelys coriacea*
Swiftlet, Mariana gray	*Aerodramus vanikorensis bartschi*
White-eye, bridled	*Zosterops conspicillatus conspicillatus*
Threatened	
Bat, Mariana fruit (i.e., Mariana flying fox)	*Pteropus mariannus mariannus*
Sea turtle, green	*Chelonia mydas*
Sea turtle, loggerhead	*Caretta caretta*
FLORA	
Endangered	
Iagu, Hayun	*Serianthes nelsonii*

1.2.10 Energy

According to the United States Energy Information Administration (2014), "Guam has no conventional energy resources and relies on petroleum products shipped in by tanker to meet almost all its energy needs." As of June 2013, Guam Power Authority prices averaged .29 USD per kilowatt hour (United States Energy Information Administration 2014). While the carbon emissions of Guam are negligible compared to larger more developed countries such as China and the U.S., it is important to decrease dependency on fossil fuels for energy security. Energy security is one aspect of sustainable development. For islands to be resilient, that must have self-sufficient, sustainable economies. Guam has worked to diversify its energy portfolio and the next section discusses the progress towards alternative energy.

1.2.10.1 Alternative Energy

Guam's renewable energy portfolio goal calls for 5% of net electricity sales to come from renewable energy resources by 2015, escalating to 25% by 2035 (United States Energy Information Administration 2014). In 2011, the Consolidated Commission on Utilities (CCU) approved two Guam Power Authority (GPA) contracts for the first commercial wind and solar projects, which are estimated to produce approximately 35 megawatts and due to begin operation in 2014-2015 (United States Energy Information Administration 2014). An additional 40 megawatts in renewable energy is planned for the second phase of this project. In addition to these local efforts, the U.S. Navy and Air Force bases on Guam are installing solar arrays and water heaters in military living quarters and linking electricity generation from solar energy to the main grid to reduce fuel use (United States Energy Information Administration 2014). GPA is investigating other fuel-reducing possibilities such as seawater air-conditioning, in which cold water drawn from offshore waters cools coastal building air-conditioning systems (United States Energy Information Administration 2014).

A Guam Strategic Energy Plan (Conrad and Esterly 2013) was coordinated by the current local government to explore renewable energy. Within this plan are two main policy recommendations that aim to promote investment in renewable energy and energy efficiency technology: (1) develop financial opportunities and mechanisms and (2) standardize the development process (Conrad and Esterly 2013). To further develop financial mechanisms and opportunities, Conrad & Esterly (2013) suggest the following:

1. Explore public-private partnerships in order to create local markets for renewable energy, energy conservation, and energy efficiency technology goods and services;
2. Pursue subsidies for renewable projects
3. Investigate third party financing;
4. Consider grants, subsidies, and peak pricing to reduce the overall cost of electricity.
5. Probe alternative financing models (e.g., performance savings' contracts and power purchase agreements).

Standardization of the development process refers to instituting a framework that addresses the request for proposal process. This would provide all available information in a transparent manner for potential investors in order to minimize risk, thus encouraging investment. Conrad & Esterly (2013) provide an example of such a framework that is endorsed by the National Renewable Energy Laboratory (NREL):

- "Site — Identify the physical location for the physical assets of a project, including property rights, length of tenure, terms and conditions, etc.
- Resource —Characterize and understand the renewable resource being considered.
- Off-take —Establish and secure by contract the buyer of both the energy and any other characteristics of output (e.g. renewable energy credits).
- Permits —Identify and obtain all permits necessary for project construction and operation.
- Technology —Invest in engineering design, equipment selection, and procurement activities of the chosen technology.
- Team —Assemble a fully qualified team that addresses all business, technical, financial, legal, and operational aspects.
- Capital —Attract financial resources necessary for final development, construction, commissioning, and initial operations."

However, despite the existence and investment in this plan, it appears that GPA (the sole power provider in Guam) is switching to liquefied natural gas (LNG) from diesel, after a feasibility study is completed in 2015 (Hong 2013). This future switch to LNG is based on an August 2012 projection. Oil was projected to increase from 79 USD/barrel in 2010 to 92USD/barrel in 2015, and thereafter grow at a rate of 1.1%, while LNG is indexed at 11% of Japanese Crude Oil prices (Cruz and Sablan 2013). There is heavy criticism and local opposition regarding this decision. First, the switch from diesel fuel to LNG would require a hefty financial investment of 800 million USD (Losinio 2014) in order to build the necessary infrastructure (i.e., a fuel import terminal at Apra Harbor or a floating storage unit that would take delivery from ocean tankers and pump onto land) (Conerly 2014). Secondly, all activity within Apra Harbor would have to cease during the transport of LNG to shore (Conerly 2014).

Simon Sanchez, chairman of the CCU, defended GPA's decision by arguing that LNG was a cleaner option (than diesel) for the interim it would take GPA to convert to 100%

renewable energy source (Losinio 2014). Furthermore, Sanchez mentioned it would cost approximately 400 million USD to upgrade the Cabras Power Plant to comply with the US EPA smokestack emissions rule (Losinio 2014). However, according to Guam Power Authority (2013), the "…cost for the scrubbers is estimated at 220,000,000 USD for wet scrubbers or 362,000,000 USD for dry scrubbers," and "quarterly testing is estimated to cost 200,000 USD per year for all four steam units." There seems to be some discrepancy regarding the actual costs of compliance and must be verified. GPA's reasoning is that LNG is projected to cost much less than oil in the future, so despite the hefty initial investment in LNG facilities & capabilities, GPA would save money on lower-priced LNG and more efficient plants in the long term (Cruz and Sablan 2013). However, this cost benefit analysis should be open to public review and scrutiny.

Sanchez further argues that the current renewable energy technology is not at the level to support a 100% conversion to renewables, but that will change (Losinio 2014). But, GPA will also be producing 25 megawatts of solar energy in Dandan, the site of the new municipal solid waste landfill, by the end of 2014 (Losinio 2014).

Waste to energy is another technology option for Guam. Politically, it is a highly contentious issue—the main concern is that it is not cost-effective for the government of Guam. There is some local support for waste to energy in Guam under certain circumstances (King and Baza 2014) . Waste to energy technology has improved since it was first introduced to Guam in the 1990s. With new biomass technology, there are low emissions and waste is converted to a fine ash. This would have dual benefits of reducing waste, and creating energy, while also drastically extending the life of the Layon municipal landfill (located in Dandan). The Navy has also expressed support of waste to energy in Guam, and because of the amount of waste needed to support a waste to energy plant, they advocate for an island-wide effort to support waste to energy on island that is co-financed and co-managed by the Department of Defense and the Government of Guam. However, more research into the waste composition produced in Guam and the feasibility of a waste to energy plant is needed.

Solar and wind energy are both viable renewable energy options for Guam. The main challenges with solar energy are that power can only be generated during the day; and without affordable battery storage technology, electricity could not be provided at night or on cloudy days. Another challenge is that the ability of solar panels to withstand typhoons still has yet to be tested. Wind is another viable energy source and the

Department of Defense has conducted wind studies in Guam that concluded that there were a limited number of locations in Guam with the necessary wind speed to support efficient wind farms. Thus, wind remains viable on a limited basis and has been included in GPA's renewable energy program.

1.2.11 Food Security

Food security refers to the availability of affordable, nutritious food. Most of the food on Guam is imported. The informal estimate of Guam's food supply is 4-7 days of available inventory at any given time (University of Guam and Agricultural Development in the American Pacific 2014). In 2009-2010, Guam imported 415 million USD in commodities, 51 million USD of which consisted of net food imports (United Nations Conference on Trade and Development 2012). In 2010, Guam only exported 8 million USD worth of commodities, which mainly comprised of fishery products, followed by ferrous waste, scrape; remelted ingots, iron, steel (United Nations Conference on Trade and Development 2012). More specific information, such as the amount and type of produce that is imported and sold, would assist farmers in identifying the market demands and adjust their crop schedule accordingly.

Local food production is a strategy to increase the food supply, decrease the amount of imported food, and eventually become a viable export. In recent years, there is a surge in locally grown, organically farmed produce. For example, there is a Farmers Cooperative Association of Guam, an organization of local farmers that promotes the consumption of local produce, fish and livestock, to support the production of value-added products, and to create a sustainable export industry (Farmers Cooperative Association of Guam 2014).

There is a Farm to Table Corporation that aims to strengthen Guam's economy by expanding and diversifying Guam's farming industry; increasing job security through job creation related to farming and food processing; encouraging the consumption of fresh, nutritious, affordable, local produce; and becoming a primary supplier of locally grown produce to Guam's restaurants and residents' homes (Farm to Table Guam Corporation 2014). In terms of food waste, approximately 50 tons of produce goes unsold each year (Farm to Table Guam Corporation, n.d.).

In addition to the Farmers Cooperative and the Farm to Table Corporation, there is also Guam's sustainable agriculture Professional Development Program at UOG that provides educational opportunities to the community about local food production. The University of Guam is quite supportive of agricultural research. Dr. Mari Marutani, in collaboration with the Center for Island Sustainability, has been leading research to convert food waste using a fermentation and sterilization process to create plant and animal feed, which would not only reduce food waste, but also support local farmers. Dr. Marutani also researches uses of adaptive plants to reduce crop loss. More collaboration between researchers at UOG, the local food producers, legislators, and small businesses is needed to apply this research to stimulate the local agricultural industry. Other initiatives being pursued in Guam include community gardens, farmers' markets, and the One-Village-One-Product initiative (Schumann 2013).

The United States Department of Agriculture offers grants for organic farms that will reimburse 80-100% of the costs of running an organic farm; technical assistance on organic farming, water saving technologies, and the prevention of soil erosion. The owner of the organic farm is responsible for start-up costs and land.

1.3 Dissertation Structure

Now that a comprehensive background for the island of Guam has been given, the organization of this thesis needs to be mentioned. This dissertation begins with an introduction that states the aims, objectives, and research questions. Within this introductory chapter, a general background that discusses location, geology, pre-history, history, governance, population, economy, natural resources, energy, and food security, about the island of Guam is provided. As of 01 Dec 2014, over 1000 references have been summarized and analyzed for the literature review[5]. In an effort to effectively organize and present these references, the literature review is divided into three chapters. Chapter 2 examines the literature pertaining to the topic of climate change as it relates to small islands with an emphasis on SLR and freshwater. Chapter 3 discusses

[5] Initial database searches on Google scholar using the keywords "Guam"+ "climate" + "change" + "adaptation" + "water" + "resources" returned 3,480 results. These results were reduced to 1650 by restricting the time period to 2000-present. Results pertinent to this dissertation were documented using Zotero. Similar database searches using identical keywords were conducted on ScienceDirect, Elsevier. Additional database searches on Google scholar, ScienceDirect, Elsevier, and Google were conducted using key words such as "watershed"+ "small Pacific islands" + "Guam" + "coastal" + "zone"+ "management" + "climate" + "change" + "adaptive capacity"; "scenarios" + "climate" + "change". Aside from basic database searches, references of particularly insightful articles were collected and read. Also, if a particular reference kept appearing, it was collected, read, and documented.

social vulnerability and adaptation. Chapter 4 examines coastal zone management at a variety of levels. This section also appraises 'ecosystem-based management', the approach currently advocated for by local natural resource managers. These three chapters provide the academic context of this thesis. Chapter 5 discusses the methodology used to meet the objectives and answer the research questions. Chapter 6 provides the results of the geospatial analysis of the Manell and Geus watersheds. Chapter 7 and 8 objectively present the results of the household survey and the informal interviews. The dissertation concludes with Chapter 9, which examines the results of the household survey within the context of vulnerability and impacts of climate change on Guam. It also provides suggestions for future research and recommendations for coastal zone management.

1.4 Summary

This thesis argues that examining the attitudes, perceptions, behaviors, and knowledge of a community towards a specific watershed can reveal the social vulnerability to climate change. Understanding and incorporating these elements of the human dimension in coastal zone management will lead to efficient and effective strategies that safeguard the natural resources for the benefit of the community. By having healthy natural resources, ecological and community resilience to climate change will increase, thus decreasing vulnerability.

In addition to conveying the research questions and explicitly outlining the specific objectives, this introductory chapter establishes a sense of place for those unfamiliar with the territory of Guam. It provides a depiction of the general physical geography of this small Pacific island and a brief account of the pre-historical and historical setting. It characterizes the modern, centralized governance structures, highlighting key local agencies that play an important role in natural resource and coastal zone management. An overview of the island's population was presented in the form of chloropleth maps. The local economy is generally discussed and two sectors, energy and food security, are deliberated in greater depth. This chapter builds the foundation upon which the thesis rests. The next chapter presents the first section of the literature review and the impacts of climate change on small islands with a focus on Guam.

Chapter 2: Impacts of Climate Change on Small Island States and Guam

2.1 Introduction

One of the challenges Guam will face is climate change. Prior to examining the vulnerability or adaptation of the Manell and Geus watersheds, the general subject of climate change must be discussed. Chapter 2 reviews the projected impacts of climate change on the coastal zone, small island states, and finally Guam. It delves into the topics of SLR and freshwater and introduces water as the conduit to examine the vulnerability of the two southernmost river basins (i.e., watersheds) on Guam, from ridge to reef.

2.2 Climate change

2.2.1 Overview

Climate change may be defined as "any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC 2007; IPCC 2014). In contrast, the United Nations Framework Convention on Climate Change (United Nations 1992) defines climate change to be "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". There is a global scientific consensus that climate change is occurring and it may be attributed to the emission of greenhouse gases from anthropogenic activies (IPCC 2001, IPCC 2007, IPCC 2014).

According to *The State of the Climate 2014* (Blunden and Arndt 2015), an annual peer-reviewed supplement to the *Bulletin of the American Meteorological Society*, all the essential indicators of Earth's changing climate continue to reflect warming trends. Major greenhouse gas concentrations (i.e., carbon dioxide, methane, and nitrous oxide) continue to rise and have reached historic high values in 2014 (Blunden and Arndt 2015). Global average atmospheric CO_2 reached a record high of 397.2 ppm (Blunden and Arndt 2015). Four independent global datasets measuring average global surface temperature indicate that 2014 was the warmest year on record (Blunden and Arndt 2015). Most regions experienced above-average temperatures with the exception of Eastern North America (Blunden and Arndt 2015). Average global average sea surface temperature also rose to a record high (Blunden and Arndt 2015). Global upper ocean heat content was measured as the highest on record, reflecting the continuing accumulation of thermal energy in the upper layers of the seas (Blunden and Arndt

2015). Oceans are absorbing approximately 90% of the excess heat from anthropogenic climate forcing (IPCC 2014). Average global sea level for 2014 was the highest ever recorded (Blundent and Arndt 2015), keeping pace with the rising trend of 3.2± 0.4 mm per year observed from the last two decades (IPCC 2014).

The Arctic continues to warm, as indicated by early snowmelt in 2014 and low sea ice extent (Blunden and Arndt 2015). Permafrost has started to melt (Blunden and Arndt 2015), since it was formed 11000 years ago (Christopherson and Birkeland 2014). Record and near-record high permafrost temperatures were observed in 2014 at a 20 m depth at 7 stations in the continuous permafrost region of Alaska (Blunden at Arndt 2015). The melting of the permafrost has the potential to release vast quantities of methane. Methane is 21 times more potent a greenhouse gas than carbon dioxide (Christopherson and Birkeland 2014) and its release could increase the rate of global warming (Schuur et al. 2015). It is conservatively estimated that the frozen peat bogs are storing billions of tons of methane and two trillion tons of carbon dioxide (Romanovsky et al. 2015). Glaciers are continuing to melt and there was negative glacier ice loss in 2014 (Blunden and Arndt 2015).

While Arctic sea ice is declining, the opposite is happening in Antarctica. Sea ice extent was the highest on record (Blunden and Arndt 2015). The Antarctic had seasonal variability with patterns of warmer-than-normal and cooler-than-normal conditions, which resulted in near-average conditions for 2014 (Blunden and Arndt 2015).

In 2014, there were 91 tropical cyclones, well above the average of 82 (derived from 1981 – 2010 data) (Blunden and Arndt 2015). Blunden and Arndt (2015) also note the increase in tropical cyclone activity in the Eastern/Central Pacific Ocean, the most that occurred since 1992. The tropical Pacific Ocean began exhibiting El Niño conditions (Blunden and Arndt 2015) and 2015 has been declared an El Niño year (Becker 2015).

The state of the climate in 2014, as reported by Blunden and Arndt (2015) are in line with the most current IPCC report (Stocker et al. 2014). The scientific consensus is that global warming is happening and it is primarily caused by human activities that inject greenhouses into Earth's atmosphere (IPCC 2001, IPCC 2007, IPCC 2014). The physical evidence indicates that Earth is warming and it is the responsibility of humankind to help reverse it while simultaneously cope with the impacts.

2.2.2 International Responses to Global Climate Change

The United Nations Framework convention on Climate Change (UNFCCC) serves as the primary mechanism to coordinate an international response to climate change. Its financial mechanism, the Global Environment Facility (GEF) provides financial resources to developing countries, particularly to the least developed countries and small-island developing states for adaptation planning, assessment, and pilot projects. The UNFCCC organized the Convention of Parties (COP 15) United Nations Climate Change Summit 2009 in Copenhagen, Denmark, during which 110 of the world leaders gathered to address one issue – climate change. The meeting essentially resulted in a non-binding resolution, formally regarded as the "Copenhagen Accord"[6]. One notable point of this summit is that "green growth" may be the prevailing economic model in making low-carbon emissions profitable. This positive theme, that addressing climate change could be an economic opportunity as opposed to a total financial burden, was continued at the most recent United Change Climate Summit 2014, which occurred in New York. While this meeting also resulted in several positive expressions of collective calls for action, these declarations are also non-binding. It is hoped that these non-binding resolutions may become steadfast commitments in the next meeting, scheduled for Paris 2015.

Representing the islands of the Pacific was the Alliance of Small Island States (AOSIS), an intergovernmental organization of low-lying coastal and small island countries. Established in 1990, the main purpose of the alliance is to consolidate the voices of Small Island Developing States (SIDS) to address global climate change. AOSIS has 42 members and observers from all around the world, of which 37 are members of the United Nations. Of the 42 members, 13 are located in the Pacific Ocean[7]. Guam is part of AOSIS, as a non-voting observer. Other observer countries include American Samoa, the Netherlands Antilles, and the US Virgin Islands.

For Pacific SIDS, the South Pacific Regional Environment Programme (SPREP) is the focal point for technical support for climate change issues. SPREP's mission focuses on strengthening meteorological services; understanding climate change, variability and SLR; understanding vulnerability, adaptation and mitigation; and supporting policy development on climate change. The South Pacific Islands Applied Geoscience Commission (SOPAC) also contributes to climate change knowledge by producing maps for SLR for several Pacific SIDS. The East-West Center in Honolulu Hawai'i (e.g. Shea, 2001, 2003) and the International Global Change Institute (IGCI) in

[6] The Copenhagen Accord is a deal that recognizes the need to restrict warming to 2 °C and outlines financing to help the world's poor cope with climate change, offering US$30 billion from rich nations in the period 2010-2012 and US$100 billion per year from 2020. The accord provides guidance on how nations can verify that their emissions are, in fact, falling, and in doing so it irons out a thorny issue that plagued two weeks of talks between almost 200 countries. Importantly, the deal also commits to implementing REDD, the mechanism that will protect forests, keeping their carbon locked up and out of the atmosphere

[7] Thirteen member countries of AOSIS located in the Pacific Ocean include Cook Islands, Fiji, Kiribati, Republic of the Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, Singapore, Solomon Islands, Tonga, and Tuvalu.

Hamilton, New Zealand (e.g. Feresi et al., 2000; Kouwenhoven and Cheatham, 2006) have long been involved in all aspects of Pacific SIDS and climate change.

Currently, there are many efforts underway in the development of adaptation strategies. For example, from 2002-2005, Canadian International Development Assistance funded a 2.2 million CDN project officially called Capacity Building for the Development of Adaptation Measures in PICs (CBDAMPIC) for the Cook Islands, Fiji, Samoa, and Vanuatu to develop and implement a capacity building program to increase the capability of local communities and national governments to reduce climate-related risks at the national and community level (South Pacific Regional Environment Programme 2003). The two main outcomes of CBDAMPIC are incorporating adaptation to climate change in current national and sector planning and budgeting processes (referred to as "mainstreaming"); and secondly, to increase the capacity of communities to adapt to climate-related stresses (South Pacific Regional Environment Programme 2003). Another example of an on-going effort aimed at decreasing vulnerability is the Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP) (South Pacific Regional Environment Programme 2008). PIGGAREP commenced in 2007 and is a joint venture between GEF and the United Nations Development Program (UNDP) that aims to reduce the growth rate of greenhouse gas emissions from fossil fuel use in the PICs through the removal of barriers and the promotion of cost-effective feasible renewable energy technologies (South Pacific Regional Environment Programme 2008). The ultimate objective of PIGGAREP is to reduce CO_2 emissions by 30% by 2015 (South Pacific Regional Environment Programme 2008). While these are progressive examples of proactive initiatives responding to climate change, they geographically focus on PICs located south of the equator, outside of U.S. jurisdiction.

Of relevance to Guam, one adaptation strategy that addresses adverse effects of climate change through conservation, is the Micronesia Challenge (United Nations Framework Convention on Climate Change 2008). The Micronesia Challenge officially commenced in 2006 and is a formal commitment by the Chief Executives of the Republic of Palau, RMI, FSM, the U.S. Territory of Guam, and the CNMI to "effectively conserve at least 30% of the near-shore marine and 20% of the terrestrial resources across Micronesia by the year 2020" (United Nations Environment Programme 2006). While Kiribati and Nauru were not represented during the original declaration, they participate unofficially and there are efforts underway to formalize their involvement. Jurisdictions participating in the Micronesia Challenge encompass approximately 6.7 million square kilometers of ocean, representing more than 20% of the Pacific Island region or alternatively, 5% of the largest ocean in the world. The Micronesia Challenge aims to protect at least 66 currently identified threatened species, 10% of the global total reef area and 462

corals which represents 59% of all known corals (United Nations Environment Programme 2008).

This formal commitment has expanded to include a regional framework that tackles climate change via conservation. Mainstreaming climate change into current conservation efforts, such as marine protected areas, may be a realistic way to increase resiliency of the natural ecosystems islanders depend upon (McLeod et al. 2009). The Micronesia Challenge sponsored a Climate Change Workshop in Majuro, Republic of the Marshall Islands, from 14-17 April 2009 to concentrate on climate change and adaptation for the islands of Micronesia (Adams 2009). Currently, there is much work to be done at the regional, national, and community level. This adaptation work is expected to occur simultaneously and collaboratively with the original, pre-existing plans currently underway.

2.2.3 Climate Change and the Coastal Zone

While Guam is a small island, the entire island is within the coastal zone (NOAA 2004). Thus, the entire territory is managed as a coastal zone. The coastal zone may be broadly defined as the interface between land and sea (Woodroffe 2002), or a transition area where terrestrial and marine environments influence each other (R. W. G. Carter 1988). However, while it is difficult to define precise seaward and landward boundaries of this interface (Woodroffe 2002), it is necessary for legislative, administrative, and planning purposes. According to U.S. law, the seaward boundary of the coastal zone is the "outer limit of the United States territorial sea" (15 CFR 923.32), which is the "three geographic mile line" (43 CFR 3301.1). While inland coastal zone boundaries differ for each state (see NOAA 2004), Guam's coastal zone is clearly and legally defined. Chapter 4 discusses CZM and Guam in greater depth.

Michel and Pandya (2010) provide a comprehensive overview of the impacts of climate change to the coastal zone. There is some overlap in comparison to impacts of climate change to small islands. While all small, tropical islands have a distinct coastal zone, not all coastal zones are located in tropical areas (e.g., Alaska, Greenland). Hence, some of these impacts to the coastal zone described by Michel and Pandya (2010), the IPCC (2014), and IPCC (2007a) may not apply to Guam. Instead, the discussion will focus on impacts to small islands, taking into account the relevant effects of climate change that coastal zones will experience.

2.2.4 Climate Change and Small Island States

Small islands have long been recognized as some of the places most vulnerable to the impacts of climate change (e.g., SLR) (Heffernan 2009; Engelen, Uljee, and White 1993; Vellinga and Klein 1993; Briguglio 1995; Nicholls and Mimura 1998; Mimura 1999; L. M. Carter et al. 2001; J. Hay

et al. 2001; J. J. McCarthy 2001; Nurse et al. 2001; Pelling and Uitto 2001; Tol et al. 2004; J. Hay and Mimura 2005; IPCC 2007b; Mimura et al. 2007). According to the (IPCC 2014; IPCC 2007a) some of the primary impacts of global climate change that may threaten small islands include:

1. The projected SLR for the next hundred years would cause enhanced soil erosion, loss of land, poverty, dislocation of people, increased risk from storm surges, reduced resilience of coastal ecosystems, saltwater intrusion into the freshwater aquifer, and high resource costs needed in responding and adapting to changes.
2. Coral reefs would be negatively affected by warming sea surface temperatures and decreases in ocean pH. There would be an increased number of bleaching events and reduced calcification rates. Other coastal ecosystems (e.g., mangroves, wetlands, seagrass beds) and the associated biodiversity would be adversely affected by rising temperatures and accelerated SLR.
3. Anticipated erosion of beaches and increased number coral bleaching events (leading to lower resilience of coral to disease which may increase coral mortality), is expected to affect sectors of the local economy such as fisheries and tourism.
4. SLR is expected to exacerbate inundation, storm surge, erosion, and other coastal hazards, thus threatening vital infrastructure (e.g., homes, water lines, hotels).
5. Higher-than-average temperatures are expected to contribute to an increase in the number of invasive, non-native species particularly on mid- and high latitude islands.
6. Water resources in many small islands in the Caribbean and the Pacific are expected to dwindle by mid-century, to the point of becoming insufficient to meet people's demand during periods of low precipitation.

Small islands are usually fairly isolated, have relatively small populations, have limited land and freshwater resources (Briguglio 1995; Dahl 1997; Mimura 1999; Barnett 2001; J. Hay et al. 2001). These factors alone already pose environmental and social challenges and will be exacerbated by climate change (Briguglio 1995; Dahl 1997; Mimura 1999; Barnett 2001; J. Hay et al. 2001). Owing to factors of limited size, availability, geology, and topography, water resources in small islands are extremely vulnerable to changes and variations in climate, especially to rainfall (Adger et al. 2007). Islands also have to deal with other issues such as migration, the potential loss of languages and cultures through emigration, gender inequities, pollution, and illegal resource extraction (Kelman 2006). For these reasons, small islands are generally perceived to have low adaptive capacity (Adger et al. 2007).

This vulnerability of small islands, specifically atoll countries, to climate change coupled with low adaptive capacity may put their sovereignty at risk (Barnett and Adger 2003). If a nation's

physical land mass disappears, they are no longer a nation-state. Ironically, the loss of sovereignty is not an issue for Guam because Guam is a colonial possession. Despite these issues and factors, small islands can utilize some of their unique characteristics to improve their adaptive capacity and reduce their vulnerability to the adverse effects climate change. Characteristics such as tight kinship networks, unique heritage, a strong sense of identity and community, creativity for sustainable livelihoods, remittances from off-island relatives, and traditional knowledge and experience of dealing with environmental and social changes, can work to the advantage of small islands.

2.2.5 Sea-Level Rise

According to Kelman and West, (2009), "…SLR is arguably the most certain and potentially devastating climate change impact [to small islands]." According to Meehl et al. (2007), it is anticipated that during the 21st century, sea level will rise at least 0.18 m and perhaps as much as 0.59 m. However, Meehl et al. (2007) explicitly do not provide an upper bound to the maximum possible SLR, stating that the final maximum rise by 2100 might exceed these projections, partly because of inputs from ice sheet break up in Greenland and Antarctica (events that were not included in the forecast). But, if the West Antarctic Ice Sheet collapses, global mean sea level is estimated to rise by approximately five meters (J. H. Mercer 1978; Vaughn and Sponge 2002), which would result in the total inundation of the coastal zones of most small islands. Figure 14 provides a clear overview of the various SL estimates calculated by different groups (Wenzel and Schröter 2014; Wenzel and Schröter 2010; Ray and Douglas 2011; C. C. Hay et al. 2015; Church and White 2011; Church and White 2006). While the details of each group's calculation vary, the overall trend indicates a rise is sea level (see Figure 14). C. C. Hay et al. (2015) found that rate of SLR is far greater than previously estimated, which may affect the accuracy of the projections.

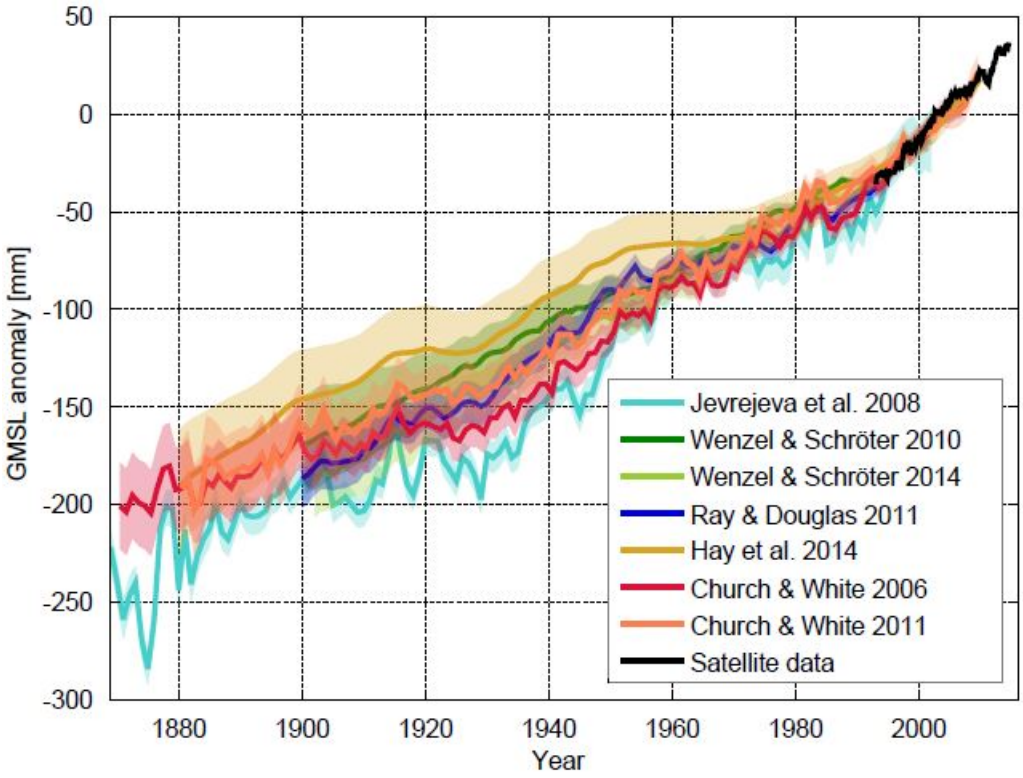


Figure 14: Sea level calculated by different research groups using various methods. Plots show sea level relative to satellite data (since 1992). Graph was created by Klaus Bittermann and reprinted from Schmidt et al. (2015).

SLR is a substantial concern, not only for the low-lying atoll islands, but also for many high islands where settlements, infrastructure and facilities are concentrated in the coastal zone (Mimura et al. 2007). Again, projected globally averaged SLR at the end of the 21st century (2090 to 2099), relative to 1980 to 1999 for the six SRES scenarios, ranges from 0.19 to 0.58 m (Meehl et al. 2007). But this estimate is called into question based on the findings of C. C. Hay et al. (2015) and could be far greater. Climate models also indicate a geographical variation of SLR due to non-uniform distribution of temperature and salinity and changes in ocean circulation (Meehl et al. 2007). Furthermore, regional variations and local differences depend on several factors, including non-climate related factors such as island tectonic setting and postglacial isostatic adjustment (Meehl et al. 2007).

Between 1993-2010, global mean sea level rose, with the highest rise in the Western Pacific Ocean (Merrifield 2011) (see Figure 15). Increases in sea level in the western tropical Pacific Ocean, have been observed over the past two decades, with rates approximately three times the global average (Merrifield and Maltrud 2011). Merrifield & Maltrud (2011) explain this anomaly by using a general circulation model to show that the high rates are caused by a gradual intensification of Pacific trade winds since the early 1990s. The modeled sea-level change captures the spatial trend pattern in satellite altimeter sea surface heights and the temporal trend shift in tide gauge observations. In addition to the sea level response, the model

also shows how other aspects of the ocean circulation have also increased in amplitude as a consequence of the trade wind intensification, including tropical surface currents, the shallow meridional over-turning circulation, the Equatorial Undercurrent, and the Indonesian Throughflow (Merrifield and Maltrud 2011). These results highlight an ongoing shift in the state of the tropical Pacific Ocean that will continue as long as the trade wind trend persists (Merrifield and Maltrud 2011). Trade winds are linked to ENSO.

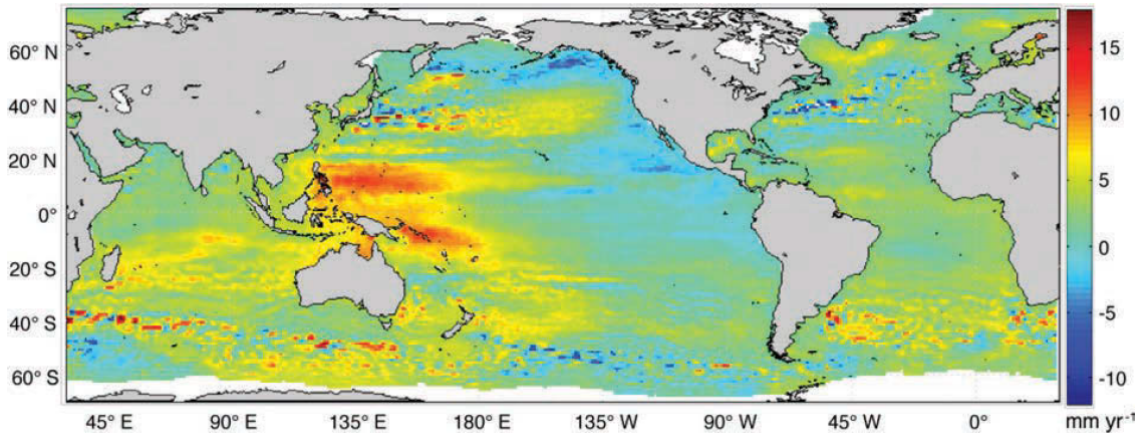


Figure 15: Sea-level trend for 1993–2010 from Aviso altimeter product, produced by Ssalto/Duacs with support from the Centre National d'Etudes Spatiales. (From Merrifield [2011] by permission of American Meteorological Society.) Reprinted with permission from Keener et al. (2013).

SLR coupled with seasonal high tides and storm surges can result in coastal inundation. SLR is a major factor contributing to recent and projected future reductions in coastal habitats, such as mangroves, tidal wetlands, coral reefs, beaches, and sea grass beds. This will ultimately affect ecosystem services, leading to an increased threat to resident wildlife and human populations. In a world without humans, the natural coastal ecosystem response to SLR would be a landward migration of tidal wetlands and beaches. However, this is not the case; humans are part of the coastal ecosystem and have impeded this natural response through the construction of seawalls, coastal roads, and various shoreline development. Enhancing natural ecosystems can increase resilience to climate change (Tompkins and Adger 2004).

2.2.5.1 Effects of SLR on Freshwater Resources

Hay & Mimura (2005) have summarized that the direct influences of SLR on water resources come principally from the following: new or accelerated coastal erosion; more extensive coastal inundation and higher levels of sea flooding; increases in the landward reach of sea waves and storm surges; seawater intrusion into surface waters and coastal aquifers; and further encroachment of tidal waters into estuaries and coastal river systems. Changes to the nature of freshwater may occur through precipitation changes and seawater intrusion into freshwater lenses and aquifers. Over the long-term, some islands receive up to 25% of their annual

freshwater supply during tropical cyclones (Kelman and West 2009). Thus, if the cyclone regimes change as a result of a warmer world, that may also affect the recharge rate of island aquifers.

Recent research on islands' freshwater lenses indicates that a rise in sea-level of 40–50 centimeters would have virtually no effect on groundwater supplies, or might even raise their volume, because the top of the freshwater lens would rise while its base would remain relatively unaffected (Falkland 1999). A small rise in sea levels may be an issue, if it raises freshwater lenses to more permeable layers on some islands (Falkland 1999), assuming that land mass remains the same (no erosion or inundation). Burns (2000) points out that one danger of water tables climbing close to or above the land surface is full evaporation of the freshwater resource. If sea level did rise, and land mass decreased, it is possible that groundwater lenses could shrink in the case of larger islands and "disappear" in the case of smaller islands (atolls) (Roy and Connell 1991).

One study pertaining to impacts on freshwater lenses, conducted in Tarawa Atoll, Kiribati, found that a concomitant rise of sea level (50 cm) and reduction of rainfall (25%) could reduce Tarawa Atoll's freshwater lens by 65% (White et al. 1999). However, the reduction of the lens was more attributable to a decrease in precipitation rather than the SLR (White et al. 1999). Future changes in seasonal and annual precipitation indicate a slight increase during June, July, and August in the Northern Pacific Ocean and during December, January, and February in the Southern Pacific Ocean (Christensen et al. 2007).

Furthermore, another aspect to consider with SLR is intrusion of saltwater into the freshwater lens, which would not only compromise the potable groundwater but result in negative consequences to agriculture as well as lowland forests (South Pacific Regional Environment Programme 1999). International assistance is especially needed to carry out appropriate adaptation strategies for climate change (Hay et al. 2003) especially for water resources (Hay and Mimura 2005).

2.2.5.2 SLR and Guam

For Guam, the mean sea level (MSL) trend is 8.60 millimeters/year with a 95% confidence interval of +/- 4.88 mm/yr (NOAA CO-OPS 2014b), which is equivalent to a change of .88 meters (2.82 ft) in 100 years (See Figure 16). This trend is based on monthly MSL data from Apra Harbor, Guam from 1993 to 2013 (NOAA CO-OPS 2014b). MSL is the highest in July (see Figure 17). Ninety year projections for Guam range from .13 m - .71 m (see Table 4).

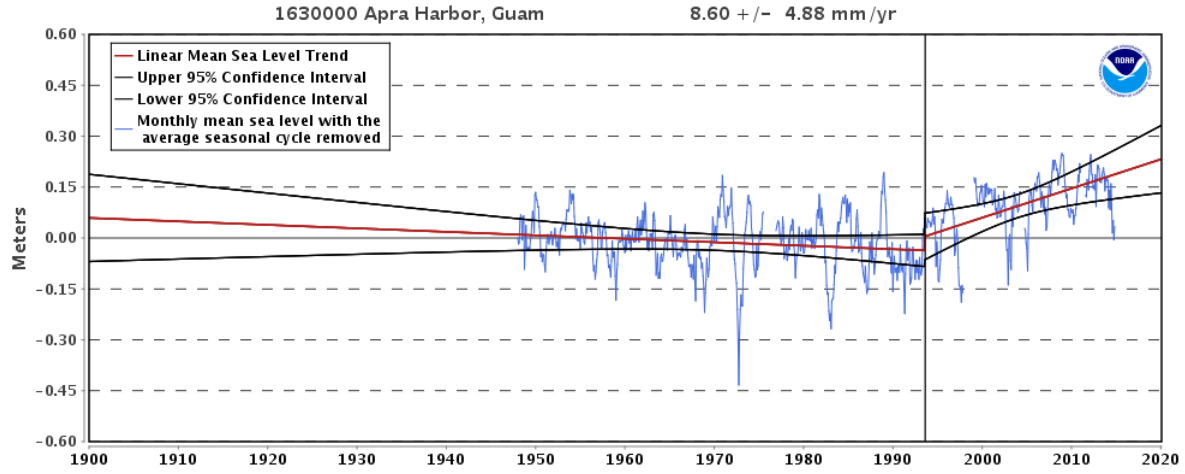


Figure 16: Plot showing the monthly mean sea level without the regular seasonal fluctuations caused by coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend (in red) is shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by NOAA CO-OPS. Solid vertical lines indicate times of major earthquakes in the vicinity of the station. Plot is reprinted with permission from (NOAA CO-OPS 2014b).

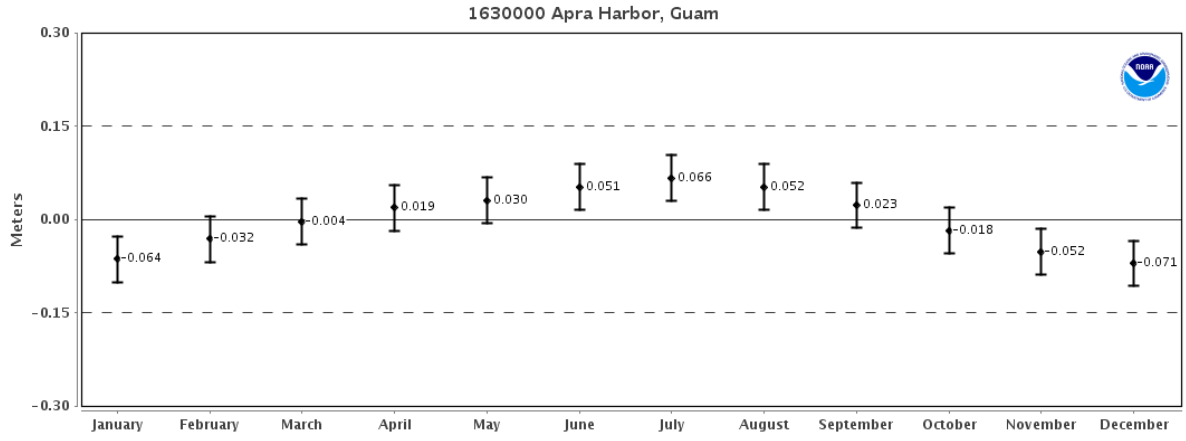


Figure 17: Plot showing the average seasonal cycle of mean sea level, caused by regular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents, for each calendar month's 95% confidence interval. Plot is reprinted with permission from (NOAA CO-OPS 2014a).

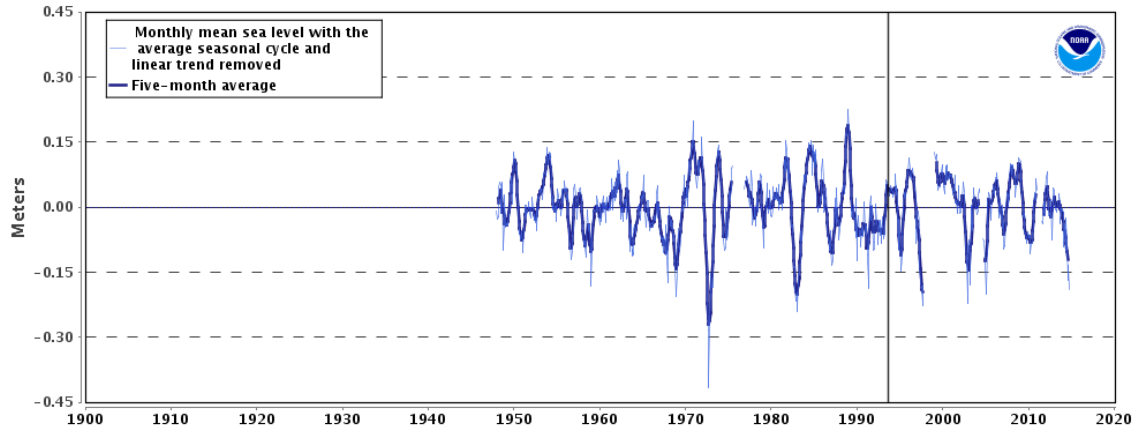


Figure 18: Plot showing the interannual variation of monthly mean sea level and the 5-month running average at Apra Harbor, Guam from 1948-2014. The average seasonal cycle and linear sea level trend have been removed. Inter-annual variation is caused by irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The interannual variation for many Pacific stations is closely related to the ENSO. Plot is reprinted with permission from NOAA CO-OPS (2014).

Table 4: Ninety-year projections (2010-2100) of relative SLR for Guam, together with measurements of local vertical crustal motion (VM) and uncertainty ($\pm S_{vm}$) on crustal motion (meters/90 years). $B1_{min}$ and $A1FI_{max}$ are the minimum and maximum projections from the IPCC (2007) and $A1FI_{max}$+ is the upper limit for the A1FI SRES scenario augmented to account for accelerated drawdown of ice sheets (Meehl et al. 2007). RG_{max} and RG_{min} are the maximum and minimum values for a range of source attribution and fingerprinting scenarios for a semi-empirical projection of 1.15 m GMSL rise over 90 years. GMSL (90 years): $B1_{min}$ = 0.15 m; $A1FI_{max}$ = .51 m: $A1FI_{max}$+ = .69 m; RG = 1.15m. Data for table is reprinted from (Forbes et al. 2013).

Location	$B1_{min}$ (m)	$A1F1_{max}$ (m)	$A1FI_{max}$+ (m)	Rg_{max} (m)	Rg_{min} (m)	VM (m)	$\pm s_{vm}$ (m)
Guam	0.13	0.5	0.71	1.25	1.21	0.01	0.08

2.2.6 Small Islands and Freshwater

"Water is gold" (Shea et al. 2001). Water sustains human lives and supports ecosystem services that society relies upon. Freshwater is a scarce resource for most Pacific islands. It requires special consideration for management and development in "normal" climate variability, natural disasters, contamination from human settlements, over-pumping of groundwater, and agricultural (and in some cases industrial/mining) activities. Many Pacific islands have limited surface water resources and obtain groundwater from a thin freshwater lens. Falkland (1999) provides an excellent overview regarding the main challenges and issues related to freshwater resources of small islands in addition to a succinct general explanation of a freshwater lens. Climate change or protracted anomalous climatic conditions can have extreme effects on water supply (Shea et al. 2001; IPCC 2007a; IPCC 2014).

Shea et al. (2001) summarize the key findings and recommendations of the Pacific Islands Regional Assessment of the Consequences of Climate Variability and Change. The Pacific

Assessment was conducted as a regional contribution to the first U.S. National Assessment of the Consequences of Climate Variability and Change. It aimed to nurture necessary critical partnerships to develop and use climate information to better understand and respond to the challenges and opportunities presented by climate variability and change for the Pacific Islands. The Pacific Assessment sought to develop a more holistic understanding of the regional consequences of climate variability for island jurisdictions while considering economic, social and other environmental stresses. It also provides support for a dialogue among scientists, governments, businesses and communities in the Pacific Region to promote the use of climate information to support decision-making. Based on input from over 200 participants through small discussion groups and two larger keystone workshops, one of the findings pertained to freshwater.

Discussions during the Pacific Islands Assessment reinforced the importance of addressing the adequacy and long-term stability of island water resources. There was emphasis on ascertaining the effects on freshwater resources as a consequence of climate change (Shea et al. 2001). More importantly, recommendations to enhance resilience with regard to freshwater are as follows:

1. Protect and restore watersheds
2. Conserve, recover and reuse water
3. Integrate water- and land-use management
4. Evaluate existing assets (from all systems) and develop unused/ alternative sources
5. Improve infrastructure
6. Explore traditional and customary practices for water resource management to supplement/adjust existing management regimes (e.g., Ahupua'a Resource Management System in Hawaii)
7. Plan for the long-term emphasizing self-sufficiency
8. Recover, treat and reuse wastewater
9. Promote water conservation
10. Review and revise permit regulatory regimes to enhance resilience and reduce vulnerability to climate variability and change
11. Use climate forecasts and information in decision-making— establish targeted climate information systems building on examples like PEAC
12. Improve climate and water resource monitoring (including socioeconomic data)
13. Address population and demographic issues
14. Promote education and awareness
15. Provide economic incentives for water conservation, recovery and reuse

16. Plan for extremes (particularly droughts)
17. Develop public/private partnerships especially among large-scale users (including the military)
18. Develop businesses targeted at water resource management systems climate forecasts and information in decision making
19. Promote public awareness and conservation in hotels, restaurants and other gathering places
20. Promote information exchange and dialogue" (Shea et al. 2001).

In addition to these recommendations, Burns (2002) suggests a comprehensive assessment of current water demand and projections of future demand; a sustainable research program monitoring use of freshwater, natural stresses and anthropogenic stresses; a stringent review of impacts of future development projects (e.g., tourism infrastructure) on coastal freshwater resources; and a substantial improvement in leak control of existing water infrastructure. Leaks can result in the loss of as much as 70% of the freshwater resources in some delivery systems (Burns 2002).

2.2.6.1 Reports and Documents Pertaining to Water that are Specific to Guam

Islands that have been subjected to substantial human modification are inherently more vulnerable to the impacts of climate change and SLR than islands that are uninhabited (Mimura et al. 2007). Considering that Guam is the most populated island of Micronesia and has been heavily modified, a case can be made that it is particularly vulnerable and should be studied.

Groundwater makes up 80% of Guam's potable water (Jocson, Jenson, and Contractor 2002). The majority of Guam's water comes from the Northern Guam Lens (Guam Waterworks Authority 2007). The Northern Guam Lens is a carbonate island karst aquifer composed of uplifting limestone units covering the northern half of Guam (Mylroie et al. 1999). Much research has been conducted on the Northern Guam Lens (e.g., Ayers and Clayshulte, 1984; Camp Dresser and McKee Inc (CDM), 1982; Jocson et al., 2002; Mink, 1976; Mylroie et al., 1999).

In order to provide evidence of the pressing local issues regarding water on Guam, a search of the Pacific Daily News archives was conducted using the following keywords: "Guam Water Authority" and "water outages". Unfortunately, the online archives only extend to 1999. The archives of the Pacific Daily News, the main newspaper of Guam, have approximately 234 articles and editorials with regard to the Guam Water Authority and water outages. Some of the major themes include water shortages, bill rates increases, school closures (due to water outages or poor water quality), water leaks/breaks, sewage issues, water outages, water quality,

and most recently, moratoriums on development and concerns for the impending military build-up.

Climate change is indirectly addressed through the military build-up. For more information about this build-up, see Chapter 9: section 9.2.1.4.1 Military Build-up and population growth. Admiral J. Samuel Locklear III, the current Naval Commander of the United States Pacific Command (USPACOM) views climate change as the largest security threat in the world (Bender 2013). These climate and non-climate issues surrounding the military build-up are summarized in a television broadcast produced by S. McCarthy (2009). In summary,

> "Guam's water, power and sewer systems will need to be upgraded to accommodate the population increase. CUC [8][sic] 's goal is to protect existing rate payers from these costs. For the CUC [sic] to succeed in building a "Unified" utilities system, DOD [Department of Defense] must absorb the cost of these infrastructure upgrades. If funding is not identified by DOD, the upgrades to infrastructure required for the buildup will not be made. • Sea level rise may impact how much water can be pumped from the Lens without destroying it as a fresh water source. The DEIS [draft Environmental Impact Statement] does not mention of how sea level rise due to climate change may impact the Northern Guam Lens" (Guam Coastal Management Program, Office of the Governor, and PBS Guam 2010).

2.3 Summary

This chapter is the second section of the literature review and discusses the impacts of climate change to small islands with an emphasis on SLR and freshwater resources. For Guam, it is anticipated to receive less precipitation than average (Lander, personal communication, 2014). The MSL trend is 8.60 millimeters/year with a 95% confidence interval of +/- 4.88 mm/yr (NOAA CO-OPS 2014b), which is equivalent to a change of .88 meters (2.82 ft) in 100 years (see Figure 16). Having this information is crucial for coastal zone and natural resource managers. The next chapter addresses vulnerability and adaptation, the social science side of climate change.

[8] CUC should be "CCU", an acronym for Consolidated Commission on Utilities (CCU), created by Guam Public Law 26-76. It is made up of five members elected at large to oversee the Guam Power Authority and the Guam Waterworks Authority. The CCU retains contracting authority for both utilities as well as the responsibility for selecting a qualified General Manager and Chief Financial Officer.

Chapter 3: Vulnerability and Adaptation

3.1 Introduction

There are several key concepts, specifically 'vulnerability' and 'adaptation' central to this dissertation. This chapter is devoted to exploring and assessing these concepts and the associated terminology in order to provide meaningful contextual definitions and their application to Guam and watersheds.

3.2 Vulnerability

While the discourse regarding vulnerability is rich (IPCC 2007, IPCC 2014, Adger, 2006), social or human vulnerability may be summarized as the "product of physical exposure to natural hazards, as well as a product of access to economic, political, social, environmental, and geographical assets"(Moser 2009). Adger (1999) provides an early framework for analyzing social vulnerability. Adger (2006) traces the working definitions of "vulnerability" and ultimately defines it as "the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt." IPCC (2007) echoes Adger (2006) about the need to develop robust and credible measures of vulnerability, develop diverse methods that include perceptions of risk and vulnerability, and incorporate governance research on the mechanisms that mediate vulnerability and promote adaptive action and resilience. Kelman (2014) argues that when it comes to small islands, climate change tends to focus on the physical aspects (e.g., SLR and changes in rainfall distribution and frequency), as opposed to community vulnerabilities.

3.2.1 Conceptual framework of vulnerability

The concept of vulnerability differs according to the context in which it is applied. There are generally three areas of vulnerability research – hazard-risk (e.g., Cutter, Boruff, and Shirley 2003; Cutter et al. 2009), food security (e.g., Løvendal and Knowles 2007), and impacts from climate change (e.g., Füssel 2007; Füssel and Klein 2006). The latter is of primary concern to this thesis. Vulnerability, within the climate change context, consists of three elements: exposure, sensitivity, and resilience (IPCC 2007, IPCC 2014). Each of these three elements will be discussed in the subsequent sections.

3.2.1.1 Exposure

Exposure is defined as a degree of climate stress upon a particular unit of analysis. It may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC, 2001, IPCC 2007, IPCC 2014). The two main elements to consider in exposure are things that can be affected by climate change (e.g., populations, resources, property) and the actual change in climate itself (e.g., SLR, precipitation and temperature changes). In the instance of Guam, houses in the Manell and Geus watersheds located near the coastline or in the flood plain would have high exposure to inundation or floods. Some of the pertinent questions surrounding exposure are:

- Who, within the community, is most exposed to impacts of climate change? Where do they reside?
- Which natural resources are the most exposed to impacts of climate change? Where are those resources located?

3.2.1.2 Sensitivity

Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al., 2001). Essentially, sensitivity is the biophysical effect of climate change. The sensitivity of a community may be determined by the relationship of the community to a resource or resources impacted by climate events and by the degree of dependency on that resource or resources (Wongbusarakum and Loper 2011). However, sensitivity may be altered by social and economic changes. Some of the pertinent questions regarding sensitivity within the Manell and Geus watersheds are as follows:

- Who is dependent on impacted natural resources (terrestrial or marine) for livelihood, and to what extent?
- What is the current health of the natural resources?
- Are the natural resources experiencing additional stress aside from climate change that would make them more vulnerable to climate change?

3.2.1.3 Resilience

The term 'resilience' was introduced by Holling (1973) to describe how dynamic systems (e.g., ecosystem, community, society) behave when stressed and move from their 'normal' state of equilibrium. Resilience, generally, is the ability of a system to recover after an event and adapt to future conditions (Folke 2006). Resilience may be defined as the "amount of change a system can undergo without changing state"(IPCC 2007b, IPCC 2014). Well-prepared communities are more resilient (NOAA Coastal Services Center 2009). However, one barrier communities face with respect to climate change is how the predicted global scenarios will manifest relatively, or rather, on a local scale. To study the effects of climate change on local socio-economic systems

requires formal instruments that produce realistic local representations based on the global emission scenarios of Nakicenovic et al. (2000). Framing this definition within a socio-ecological context, Adger et al. (2005) elaborate that the capacity of coastal ecosystems to regenerate after disasters and to continue to produce resources and services for human livelihoods must be understood at broader scales and actively managed and nurtured.

In an effort to address this barrier, work is being conducted to downscale the coarse-resolution model projections (see section 3.3.3 Barriers to Adaptive Capacity, for a discourse on downscaling). For example, the USGS Pacific Islands Climate Science Center has recently funded Wang and Annamalai (unpublished) for 21st century high-resolution climate projections for Guam and American Samoa. These forecasts will provide the necessary information to create realistic visualizations and localized scenarios.

In the case of small Pacific islands, the entire island is usually regarded as a coastal zone (see Chapter 4). Given the trends in the increasing human settlement of coastal areas, resource use, and the global climate change, building resilience in coastal communities is urgent (Adger et al. 2005). Already, the resilience of many social-ecological systems has eroded, particularly in vulnerable, marginalized societies (Adger et al. 2005).

3.2.2 Measuring vulnerability

Measuring vulnerability encompasses both quantitative and qualitative methods to describe vulnerability (Birkmann and Wisner 2006). Identifying the most vulnerable of the coastal community will require an analysis of the population and an analysis of the environment in which they reside. See Chapter 5: Methodology for a more thorough discussion on various ways to measure social vulnerability.

3.2.3 Scale

An important consideration when studying vulnerability is the concept of scale, particularly analysis scale. Geographers recognize three domains of scales: spatial, temporal, and thematic (Montell 2001). Within these domains, there are three meanings of scale: cartographic[9], analysis[10], and phenomenon[11] (Montell 2001). When discussing climate change models and scale, it is in reference to the analysis scale. Small islands in the Pacific cannot use the global

[9] Cartographic scale refers to the depiction of earth's surface on a map and may be represented as representative fraction, a verbal scale, or a graphic scale bar (Montell 2001).
[10] Analysis scale refers to the scale for understanding geographic phenomenon and is often used with digital representations of the earth (Montell 2001).
[11] Phenomenon scale refers to the true scale at which a geographic process or geographic structure exists in the real world and are usually summarized as 'micro-', 'meso-', or 'macro' (Montell 2001).

models because they are too-coarse scaled. McLaughlin, Andrew, and Cooper (2010) demonstrate that large-scale variations (e.g., village or local scale) of vulnerability may not be detected at smaller scales (e.g., national scale). Some indices that measure disaster-risk may not be appropriate measures at specific scales (Birkmann and Wisner 2006). This thesis is conducting a large-scale analysis of vulnerability (i.e., watershed scale). The maps and geospatial data are using a cartographic scale of 1:40,000 or greater.

3.2.4 Indicators

Identifying the most vulnerable groups within the coastal community to a specific threat such as climate change or even more distinctively, SLR, may be done by examining key indicators. Indicators are further discussed in the 5.3.2.4 Indicators. For example, N. Brooks, Adger, and Kelly (2005) found that the key indicators (which can be categorized as health status, governance, and education) of social vulnerability are:

- population with access to sanitation, (health status)
- literacy rate
- maternal mortality
- calorific intake (health status)
- voice and accountability
- civil liberties
- political rights
- government effectiveness
- literacy ratio (female to male)
- life expectancy at birth.

Notably, N. Brooks, Adger, and Kelly (2005) ignore economic indicators such as GDP and indicators of income inequality. Based on these 11 key indicators, N. Brooks, Adger, and Kelly (2005) constructed a list of the most vulnerable countries–five of the 59 countries/territories listed are small island states. However, N. Brooks, Adger, and Kelly (2005) note that the vulnerability of small island states maybe under-represented as they constitute a minority "special case". The particular factors that lead to large negative outcomes in islands (e.g., small size, low elevation, isolation) are not characteristics of the majority of the countries assessed and their effects will, therefore, not lead to a significant statistical signal in the analysis (N. Brooks, Adger, and Kelly 2005). While N. Brooks, Adger, and Kelly (2005) use these key indicators to identify the most socially vulnerable countries, it may also be feasible to use some of these indicators to identify the most vulnerable of a population.

In contrast to N. Brooks, Adger, and Kelly (2005), Pelling and Uitto (2001) focus on small islands and use the following indicators: human development index, debt service ratio, public expenditure on health as % of GDP, adult literacy and GDP/capita. Using these indicators, it is feasible to use United States Census data to see how Guam compares to other small islands. The Community-Based Risk Index (Bollin and Hidajat 2007) identifies and quantifies elements of the vulnerability conceptual framework (exposure, risk, and capacity). The index is comprised of 47 indicators that are arranged according to four thematic categories: physical/demographic; social; environmental; and economic vulnerability (see Table 5).

Table 5: Indicators used for Community-based Risk Index. Reprinted from Bollins and Hidajat (2007).

Main Factor and Factor Component	Indicator Name	Indicator
HAZARD		
Probability	(H1) Occurrence (experienced hazards	Frequency of events in the past 30 years
	(H2) possible hazards)	Probability of possible events. Chances per year
Severity	(H3) Intensity (experienced hazards)	Intensity of the worst event in the past 30 years
	(H4) Intensity (possible hazards)	Expected intensity of possible events
EXPOSURE		
Structures	(E1) Number of housing units	Number of housing units (living quarters)
	(E2) Lifelines	% of homes with piped drinking water
Population	(E3) Total resident population	Total resident population
Economy	(E4) Local gross domestic product (GDP)	Total GDP in constant currency
VULNERABILITY		
Physical/demographic	(V1) Density	People per km
	(V2) Demographic presure	Population growth rate
	(V3) Unsafe settlements	Homes in hazard prone areas (ravines, river banks, etc)
Social	(V4) Access to basic services	% of homes with piped drinking water
	(V5) Poverty level	% of population below poverty level
	(V6) Literacy rate	% of population that can read and write
	(V7) Attitude	Priority of population to protect against hazard
	(V8) Decentralisation	Portion of self-generated revenues of the total budget
	(V9) Community participation	% voter turnout at last communal elections
Economic	(V10) Local resource base	Total available local budget in USD
	(V11) Diversification	Economic sector mix for employment
	(V12) Small businesses	% of businesses with fewer than 20 employees

(V13) Accessibility	Number of interruption of road access in last 30 years

3.2.5 Uncertainty

Uncertainty is inherent and avoidable when considering future impacts of climate change and this is also true for vulnerability assessments that depend on scenarios. Patt, Klein, and Vega-Leinert (2005) argue that serious consideration of uncertainty in climate change vulnerability assessments is lacking; uncertainty is much higher than people, especially policy-makers, expect. Patt, Klein, and Vega-Leinert(2005) suggest that the great complexity of a human-environment system, the difficulty of obtaining data to test interactions between the different drivers of vulnerability over long time periods are the main causes for uncertainty.

Leach, Scoones, and Stirling (2010) and Leach et al. (2010) point out that in the face of significant change and uncertainty, the tendency has often been to "close down" too rapidly to a small set of decision alternatives by reconfiguring uncertainty into more manageable, but inappropriately narrow, calculations of risk and cost-benefit equations. The concept of development pathways has recently gained traction as one solution to address uncertainty. Development 'pathways' are defined as the "alternative possible trajectories for knowledge, intervention and change, which prioritize different goals, values and functions" (Leach et al 2010).

3.3 Adaptation

Adaptation, as defined by the (IPCC 2007a; IPCC 2014) is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". The ability of a society to adapt, whether to changing climate or other new circumstances, is in part a function of a society's level of wealth, education, institutional strength and access to technology (Smit et al. 2001). Human adaptive capacity may be defined as "the ability to cope with (prepare for, mitigate, or recover) any negative impacts of disaster" (Folke, Colding, and Berkes 2003). Adaptation, like vulnerability is inherently variable temporally (IPCC 2007; IPCC 2014). It may vary on a daily, monthly, yearly, or a decadal basis.

Adaptation may be classified as "reactive" (aims to alleviate impacts once they have occurred) or "proactive" (aims to reduce exposure to future risks) (Burton, Diringer, and Smith 2006). For example, ceasing development in areas with high erosion potential is an example of a proactive

approach, whereas providing emergency rapid response services to evacuate victims of landslide is a "reactive" approach. Proactive and reactive approaches must not only be considered, but also balanced when developing an adaptation strategy. Proactive adaptation measures usually require a greater initial investment but are more effective at reducing future risk and cost (Committee on Science, Engineering, and Public Policy et al. 1992). While the UNFCC established mitigation and adaptation both as priorities, international climate efforts have predominantly focused on mitigation, particularly the reduction of greenhouse gases. The climate benefits of mitigation are global (thus driven by international agreements such as Kyoto and consequential national policies), while its costs and ancillary benefits are experienced locally (Klein et al. 2007). While these mitigation efforts can lessen climate change, climate change is still inevitable (IPCC 2007a). Thus, the international effort has expanded to deal with adaptation and coping with a changing climate, which is well-suited for small islands who emit relatively insignificant amounts of carbon.

Adaptation, in contrast to mitigation, has benefits and costs that accrue on a more localized scale; it will mean different things for different people based on their immediate environment and socioeconomic situation (Klein et al. 2007). Because adaptation is locally focused, it is imperative to identify the geographic boundaries of the site in question. Using watersheds as a spatial unit of analysis is ideal for this situation. It is also important to construct a socioeconomic profile of the community that resides in the study site, which can be done through an examination of census data, preliminary interviews with key stakeholders, and social surveys of the local population. Initially, as a UNFCCC effort to address adaptation, a framework consisting of three stages was established (United Nations Framework Convention on Climate Change 1995). Stage 1, identifying the most vulnerable countries and regions and adaptation options was to be carried out in the short-term; the second and third stages were to be implemented over the medium and long terms. The second stage entailed the development of measures (e.g., capacity building) to prepare for adaptation while the third stage focused on implementing these measures (United Nations Framework Convention on Climate Change 1995). There has been considerable work done in stage 1 and stage 2 activities, resulting in information, resources, and capacity building but these outcomes have yet to facilitate on-the-ground implementation, technology development or access, or the establishment of robust national institutions to carry this international agenda forward (Burton, Diringer, and Smith 2006). It may be argued that Guam is still in the first and second stages of this framework. There is no known overarching vulnerability assessment for Guam. Without this, identifying adaptation options cannot be done.

Burton et al. (2006) have proposed three broad approaches in advancing the adaptation framework—

1. "Adaptation under the UNFCCC (proactive approach) - Committing reliable funding for high-priority implementation projects and facilitating comprehensive national strategies;
2. Integration with development (proactive approach)-Implementing measures such as mandatory climate risk assessments for projects financed by multi-lateral and bilateral funds;
3. Climate insurance (reactive approach)-Committing funds to support climate relief or insurance type approaches in vulnerable countries for losses resulting from climate change and climate variability. "

These suggestions by Burton et al. (2006) are quite sensible and would benefit small islands immensely.

Interest in exploring interrelationships between adaptation and mitigation is fairly recent phenomena (Klein et al. 2007). Klein et al. (2007) have found that effective climate policy should involve a diverse portfolio of mitigation and adaptation strategies. However, for small islands, the focus should be primarily on adaptation. Small islands are responsible for a modicum of global carbon emissions compared to large, coal burning countries (e.g., China).

3.3.1 Adaptive Capacity

The term 'adaptive capacity' is difficult to define and contested, and has been described as "an intellectual quagmire" (Patt, Dazé, and Suarez 2009). Adaptive capacity represents the available resources (e.g., natural, financial, institutional, or human), or access to resources (e.g., information, social networks, familial networks, expertise) within a specific system that may be used for coping with or recovering from negative impacts caused by climate change and the efficacy of using those resources (IPCC 2007a; IPCC 2014). In other words, adaptive capacity is the potential capability of a natural or human system to adjust to impacts of climate change while minimizing potential damage and cost. Adaptive capacity is uneven across and within societies (IPCC 2007a; IPCC 2014). Adaptive capacity varies significantly from system to system, sector to sector and region to region (IPCC 2007a; IPCC 2014). High adaptive capacity would increase the resilience of a system.

The demographic and economic profiles of a society, in addition to how developed that society is, play a factor in its capacity to adapt. There are individuals and groups within a society that have a very low capacity to adapt to climate change. For this case study, "capacity" may be defined as "a society's ability to adapt to changing climatic conditions, whether by reducing harm, exploiting beneficial new opportunities, or both" (Burton, Diringer, and Smith 2006).

Identifying and maximizing the benefits of such opportunities will perhaps be a key to sustainable development. Like resilience, the capacity to adapt is dynamic and influenced by factors such as socioeconomics, condition of natural resources, social networks, institutions, governance, and technology (IPCC 2007a; IPCC 2014).

In addition to opportunities, there are limits and barriers to adaptation such as the inability of natural systems to adapt to the rate and magnitude of climate change; technological restraints, financial restraints; and behavioral, social, and cultural constraints (IPCC 2007a; IPCC 2014). Another limit that must be addressed are knowledge gaps and impeded flows of information relevant to adaptation planning (IPCC 2007a; IPCC 2014).

Again, adaptive capacity will differ spatially and temporally. In this case-study of the Manell and Geus watersheds, some of the questions concerning adaptive capacity are as follows:

- What, if any, opportunities exist for the residents residing to deal with impacts on their natural resources?
- What, if any, barriers exist that could prevent residents from adapting to events of climate change?
- What, if any, challenges exist with regard to adaptation?

3.3.2 Measuring Adaptive Capacity

In addition to the difficulty in defining adaptive capacity, it happens to be one of the most challenging elements of resilience to measure, and despite its importance, it is an under-researched topic (Engle 2011). There are many determinants of adaptive capacity that vary according to theoretical framework (IPCC 2007a; IPCC 2014; Acosta et al. 2013; Tinch et al. 2015; Chen et al. 2014; Schneiderbauer et al. 2011; Pandey et al. 2011; Smit and Wandel 2006; Adger et al. 2004; Yohe and Tol 2002). Determinants may be measured by suggested indicators, which also depend on the associated theoretical framework. Basically, adaptive capacity is usually measured indirectly (Jacobs et al. 2015) through the use of proxy indicators that vary according to spatial scale (Folke et al. 2005) (e.g., regional scale (Hill 2012), national scale (N. Brooks, Adger, and Kelly 2005; Chen et al. 2014); or a watershed level scale (Pandey et al. 2011; Heikkila et al. 2013)).

Evaluating adaptive capacity depends upon defining a coping range and understanding how that range may be expanded by new and effective strategies (Smit et al. 2000). Yohe & Tol (2002) recognize the importance of scale and offer determinants for qualitatively evaluating adaptive

capacity, but do not provide specific indicators. Yohe and Tol (2002) identify eight determinants of adaptive capacity that are system-specific, sector-specific, and location specific:

1. The range of available technological options for adaptation
2. Availability of resources and distribution across the population
3. Structure of critical institutions; decision criteria
4. Stock of human capital (e.g., education, income, awareness)
5. Stock of social capital (including the definition of property rights
6. System's access to risk spreading processes
7. Ability of decision makers to process information, the credibility of decision makers
8. Public's perceived attribution of the source of stress and significance of exposure if that stress is locally manifested.

Dolan and Walker (2003) specify that the determinants of adaptive capacity at the local scale are access and distribution of resources, technology, information, wealth, risk perceptions, social capital, community structure, and institutional frameworks addressing climate change hazards. Furthermore, perceptions and experiences with climate extremes can identify inherent characteristics that enable or constrain a community to respond, recover and adapt. Local knowledge is key to climate change research and should be incorporated into research design and implementation (Birkmann and Wisner 2006).

According to the IPCC (2007) and IPCC (2014), adaptation to climate change is occurring but on a limited basis and adaptation measures are seldom undertaken to address climate change alone. Communities have been adapting to the impacts of weather and climate through a range of practices that include, but are not limited to crop diversification, irrigation, water management, disaster risk management, and insurance (IPCC 2007a; IPCC 2014). However, climate change may result in events that are outside the range of experience. In the case of small tropical islands, examples of such events include, but are not limited to drought, typhoon intensity, typhoon frequency, increased precipitation and increased storm surges attributed to SLR.

Often, adaptation measures are not implemented as stand-alone measures, but are embedded within broader initiatives such as water resource planning, natural resource management, coastal zone management, and disaster management planning (IPCC 2007a; IPCC 2014). In the case of Guam, there has been encouragement to incorporate impacts of climate change within existing planning procedures. For example, within the Guam Coastal Management Program

(GCMP), the creation of watershed management plans as guidance documents is the standard. Now, for the first time, the GCMP is incorporating potential impacts of climate change within such guidance documents that need to be considered from a planning perspective. Parry et al. (2007) also point out that adaptation measures may be implemented at low costs, but comprehensive cost-benefit analyses of such measures are lacking. There are limited cost-benefit estimates for global adaptation costs with regard to SLR, and energy conservation (IPCC 2007a; IPCC 2014).

3.3.3 Barriers to Adaptive Capacity

There are several barriers or challenges in maximizing adaptive capacity. These barriers may be financial, cultural, social, legal, political, technological, natural, or data-based in nature (Nurse et al. 2014). These barriers may be overcome at the local, regional, national, and international levels (IPCC 2007a; IPCC 2014). Identifying the barriers to adaptive capacity, pertinent to the scale of analysis, is the first step in overcoming them.

One barrier identified by Barnett, Lambert, and Fry (2008) is the very limited amount of climate impacts research that reflects local concerns and contexts. Even within small islands, "local" concerns and contexts can vary. For example, Southern Guam is geologically different (Tracey et al. 1964) and much more rural (U.S. Census Bureau 2011a) than Northern Guam. The different natural and social environments within one island may give rise to different 'local' concerns. The second barrier Barnett, Lambert, and Fry (2008) call attention to is that global models still do not provide an accurate, detailed picture of future climate scenarios at the scale of small islands. Current climate-change projections from Global Circulation Models (GCMs), as summarized in IPCC (2007), have limited application to the Pacific Islands, including Guam. Most long-term climate forecasts are specific to large horizontal spatial grid resolutions of 200 to 300 km (Barnett, Lambert, and Fry 2008). Thus, predictions from GCMs are not useful as the basis for planning adaptation measures at the regional and island scale. One solution is downscaling.

Downscaling climate data is a procedure for generating locally relevant data from the GCMs. Downscaling processes information known at global scales to make predictions at local scales in order to generate regionally specific forecasts. The two main approaches to downscaling climate information are dynamical and statistical. Dynamical downscaling runs high-resolution climate models on a regional sub-domain, using observational data or lower-resolution climate model output as a boundary condition. These models use physical principles to reproduce local climates, but are computationally intensive. Statistical downscaling is a two-step process. The

first step is the development of statistical relationships between local climate variables (e.g., sea surface temperature and precipitation) and large-scale predictors (e.g., pressure fields). The second step applies these statistical relationships to the GCM output in order to simulate local climate characteristics in the future. Currently, statistical downscaling efforts are underway specific to Guam and American Samoa (see Wang and Annamalai unpublished).

In addition to downscaling, there are several regional coordination efforts that facilitate data collection, analysis, and dissemination in order to support adaptation plans and polices (Keener et al. 2013). For example, the Pacific Islands Climate Science Center (PICSC), part of the USGS, was created in order to generate and translate science and knowledge co-developed with local island stakeholders to help prepare society to understand, anticipate, and adapt to a changing climate (U.S. Department of the Interior 2014).

Another major constraint is financial. Most Pacific Islands' economies may be classified as MIRAB (Bertram and Watters 1985; Bertram 2006), SITE (McElroy 2006) , or PROFIT (Baldacchino 2006). Bertram and Watters (1985) postulated a model describing how the majority of Pacific Islands' economies work—Migration, Remittances, Aid, and Bureaucracy (MIRAB). According to Bertram and Watters (1985), Pacific Islands' economies depend on two main funding streams: (1) remittances sent from migrants and (2) foreign aid and public bureaucracy. While the MIRAB characterizes most small island economics, there are several islands that did not fit the model (Hezel 2012; Bertram 2006). Thus, McElroy (2006) conceived SITE, or Small Island Tourist Economy, as an alternative model to MIRAB. SITE describes Pacific Islands' economies that largely depend on tourism. Baldacchino (2006) proposed PROFIT, or People considerations, Resource management, Overseas engagement, Finance, and Transportation, as another alternative to MIRAB. PROFIT economies focus on tax havens, offshore banking, and licensing for foreign governments and businesses (Baldacchino 2006). Bertram (2006) points out that most, if not all small islands' economies may be classified as one or a combination of these three models.

Guam is classified as a SITE (Bertram 2006). According to Ruane (2013), approximately 1.278 million tourists visited Guam 2012, 12.8% more than 2011. While tourism is a predominate sector of Guam's economy, other drivers include federal government expenditures (including military spending) and local production of goods and services (Ruane 2014). Guam's Gross Island Product (GIP) is estimated at 4.052 billion USD (U.S. Department of Commerce-Bureau of Economic Analysis, 2010). Six key characteristics of the Guam economy include "(1) a small island economy that is relatively open that is (2) currently lacking economic diversification but

(3) endowed with natural resources and a (4) multicultural society…(5) an unincorporated U.S. territory (6) located strategically in Asia-Pacific" (Ruane 2012). Ruane (2012) points out that these six characteristics are opportunities to increase economic development on Guam. This offers Guam the prospect of being able to overcome the financial barriers faced by other small islands in increasing adaptive capacity.

Aside from the aforementioned barriers, endogenous factors such as culture, ethics, knowledge, attitudes, and perceptions also have an effect on constraining adaptive capacity (Nurse et al. 2014). This thesis researches the knowledge, attitudes, and perceptions in an effort to identify barriers to adaptive capacity at the watershed level within a small island.

3.3.4 Community-based Adaptation

One heavily advocated type of adaptation to climate change is community-based (IIED 2009), which empowers and strengthens capacity building at local scales . It is argued that communities have a collective wealth of knowledge about the local environment and have been adapting to and coping with change for years (e.g., Lazrus 2005; J. Mercer 2005; J. Hay and Mimura 2006; Nakalevu 2006; Bridges and McClatchey 2009). Reid et al., (2009) provide an excellent overview of community based adaptation to climate change.

Loomis, (2000) contends that island communities are resistant to natural hazards because they relied on a number of successful adaptive traditions such as inter-island exchange, agricultural diversity, intra-community cooperation, food redistribution, and traditional building construction methods. Past-climate related changes in the Pacific Islands that demonstrate the possible effects of a documented sea-level fall on inland horticulture include water-table fall; the emergence of reef surfaces; the consequent reduction of nearshore water circulation; the emergence of reef islets and the conversion of tidal inlets to brackish lakes (Nunn 2000; Kumar et al. 2006; Nunn 2007b; Nunn et al. 2007). This alteration of the environment appeared to have forced Pacific Island cultures to change and adapt. Understanding these past modifications can help inform strategies for the present.

While traditional knowledge and past experiences are important, this does not mean that science or the present should be ignored. Moser (2009) contends that it is important to find out "…incentives and disincentives for learning, knowledge networks, and impediments to knowledge for adaptation decisions; the importance of leaders; and processes of diffusion of adaptation innovations (technologies and practices)" to successfully implement effective

adaptation strategies. Community based adaptation seem to offer techniques and approaches to retrieve such information.

On a note of caution, community-based approaches should not be regarded as a panacea, rather as an important and essential component to developing and implementing adaptive strategies (J. Mercer et al. 2007). For example, sometimes, local knowledge is not accurate (Tibby, Lane, and Gell 2008), or there may be a lack of cohesiveness within a community. Ideally, a combined or eclectic approach would increase resilience to natural hazards and reduce sensitivity by enabling indigenous communities to preserve their most effective indigenous practices, which form an important part of their cultural heritage (J. Mercer 2005).

3.3.4.1 Tools for Community-based Adaptation

Some case studies that utilize community based-adaptation-centered tools (e.g., Haynes, Barclay, and Pidgeon 2007; Maceda et al. 2009) involve visualization and usually aim to minimize risk from natural disasters. Furthermore, many first-hand accounts of community-based adaptation experiences may be found through informative forums and programs sponsored by non-government organizations (e.g., UNESCO 2009; World Wildlife Fund 2005). This sharing of information can provide communities that are beginning to 'formally' adapt, valuable lessons.

Expanding on the theme of visualization, Pacific Islanders in general, are visual people. Ideally, generating scientific local-scale narratives from data models that predict how global emission scenarios[12] produced by (Nakicenovic et al. 2000) would manifest on a local scale (i.e., Guam) could potentially assist in the development of effective proactive and reactive adaptive strategies. Outputs of a model are usually unattractive and unintuitive (Sorensen 1997). Thus, scenarios should be "re-drawn" to illustrate their meaning at a non-scientific level, perhaps in the form of a narrative. Designing and managing the social processes of localized climate scenario generation and usage is as important and difficult as managing the technical aspects of

[12] Special Report on Emissions Scenarios (SRES 2000) SRES scenarios are emission scenarios developed by Nakicenovic and Swart (2000) and used, among others, as a basis for some of the climate projections used in the IPCC Fourth Assessment Report. Illustrative scenarios are scenarios that demonstrate each of the six scenario groups reflected in Nakicenovic et al. (2000). They include four revised scenario markers for the A1B, A2, B1, B2 and two additional scenarios (A1F & A1T). A storyline is a narrative description of a scenario (or family of scenarios), that highlights the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution. The four scenario families (scenario families are scenarios that have a similar demographic, societal, economic and technical-change storyline) are referred to as: A1, A2, B1, B2. "A1" assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies and is divided into three groups describing alternative directions of technological change: A1F – Fossil intensive A1T- non-fossil energy resources A1B- Balance across all sources. "A2" describes a very heterogeneous world with high population growth, slow economic development and los technological change. "B1" describes a convergent world with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. "B2" describes a world with intermediate population and economic growth, emphasizing local solutions to economic, social, and environmental sustainability.

climate scenario construction (Hulme and Dessai 2008). It is important to remember that localized climate scenarios are relative to a specific time and context and will most likely be replaced with later scenarios due to the availability of better data, technology, and changes in people's understanding and relationship to climate change (Hulme and Dessai 2008).

Narratives (see Reitsma 2010 for a definition of narrative) could be a starting point to gather attitudes, perceptions and values of communities, policy makers, natural resource managers and planners toward climate change toward a tangible, plausible future scenario. Furthermore, narratives can help communities, policy makers, planners, and private developers by creating a mental image that depicts critical spatial environmental linkages within an area such as a watershed, and foster understanding how decisions (e.g., proposed developments or adaptation strategies) can environmentally and aesthetically impact a community especially with regard to an abstract concept, such as SLR or ecosystem-based management. Finally, narratives can assist in the conceptual development of ideas, the evaluation of a design or management option, the assessment of visual impacts, and the illustration ideas and alternatives for users and decision-makers.

Scenarios were initially utilized by the Shell Corporation in the 1960s and were meant to conceptualize multiple possible futures, in a structured and coherent way in order to facilitate decision-making in the present (Wack 1985). Scenarios are not predictions, which describe what will happen, but rather "predicative judgments" which describe what could happen (Shearer 2005). Hulme and Dessai, (2008) postulate that scenarios may be understood as processes or final products, which will in turn, determine the appropriate performance measures for evaluation.

There are a plethora of tools that vary in price and function (NOAA Coastal Services Center 2009) and could assist in the construction of narratives. Research into such tools and techniques in order to determine the optimum, cost-effective ones to develop narratives to assist in community based adaptation for Guam is outside the scope of this dissertation. Ideally, the research conducted coupled with the downscaled simulations can be the foundation for building local scenarios specific to the Manell and Geus watersheds. For example, O'Neill and Hulme (2009) use an iconic approach to harnesses the emotive and visual power of climate icons in order to help overcome some of the cognitive barriers that impede action towards lifestyle changes. While they focus on decarbonization, it can be applied to implementation of adaptive strategies.

In March 2014, a climate change adaptation outreach and planning workshop (Gombos, Atkinson, and Wongbusarakum 2013) was conducted by the Nature Conservancy on behalf of the Government of Guam in order to not only provide participants from various sectors with an understanding of climate change and its potential impacts to Guam, but to train the participants with skills to facilitate participatory community activities. To date, there have been no formal or informal participatory community-based activities on Guam that directly address adaptation planning.

3.3.5 Challenges of Adaptation

Some of the challenges small island communities face with respect to climate change projections involve the availability of specific data, at suitable scales. Access to appropriate imagery may pose problems. The resolution of data sets is generally too coarse (Kelman and West 2009). The financial resources to purchase high-resolution data, much less provide storage and maintenance for these data, is lacking, as is access to the technical expertise to model current conditions (e.g., the freshwater lens), or forecast future scenarios. (Kelman and West 2009). Other than published, peer-reviewed literature, there is no formal process to track information such as indigenous knowledge, local understanding, specialized reports that are unique to a specific island. Kelman & West (2009) also argue that bottom-up approaches should be encouraged to obtain local knowledge and gain an understanding of the needs of the community; while continuing the prevailing top-down approaches.

Adaptation requires significant financial resources (J. Hay and Mimura 2006; Mimura et al. 2007). Stern (2007) concludes that the benefits of strong, early action on climate change considerably outweigh the costs associated with the consequences and proposes several economic solutions (e.g., environmental taxes) to offset the initial investment. Stern (2008) estimates it will cost approximately 2% of the global gross domestic product to avoid the worst effects of climate change and that failure to do so could risk a global GDP being 20% lower than forecasted. Anticipatory and precautionary adaptation is more effective and less costly than forced last minute emergency fixes (e.g., 2005 Hurricane Katrina, New Orleans, 2013 Hurricane Sandy, New Jersey/New York). Adaptation and mitigation strategies have benefits and will most likely require communities to adopt new behaviors or change existing ones; it is important to quantify what those benefits are and what are the necessary behaviors needed to achieve such benefits.

Another challenge of adaptation is the lack of willingness to change behaviors. Nisbet & Myers (2007) analyzed approximately 70 public opinion surveys conducted over the past 20 years and found relationships between the following:

- public awareness and global warming;
- public understanding of the causes of global warming and specifics of the policy debate;
- public perceptions of the certainty of science and 'expert' opinion;
- public concern regarding the impacts;
- public support for policy action with regard to economic costs and public support for the Kyoto Protocol.

The governments and citizens of many countries show little concern about climate change and its consequences (Nisbet and Myers 2007). A possible explanation for the lack of interest in climate change is that the time-delayed, abstract, and statistical nature of the risks does not evoke strong reactions. Weber (2006) argues that in order to successfully induce visceral reactions towards global warming, the negative consequences of global warming must clearly relate to people's present reality. This will be effective in changing public opinion and promoting adaptive behaviors.

One final challenge is to bridge the gap between science and non-scientists (Moser and Dilling 2007). Translating climate science and knowledge into a language and format that is readily accessible, easy to comprehend, and culturally acceptable to stakeholders and local decision-makers is essential for community-based adaptation.

3.4 Summary

Social vulnerability may be viewed as a function of exposure, sensitivity, and adaptive capacity. To minimize social vulnerability, one could minimize exposure, sensitivity, or increase adaptive capacity or resilience. Adaptation is an essential part of the climate agenda, especially for those who will suffer the brunt of climate impacts (such as small islands). Increasing the resiliency of vulnerable societies to damaging climate events is currently ongoing, regardless of efforts to mitigate carbon emissions (Pielke Jr, Prins, and Rayner 2007). While small Pacific Island nations have very little impact in reducing overall global carbon emissions, they may take steps to decrease their vulnerability to ocean acidification, SLR, and increased ocean temperatures. For example, with regard to water scarcity issues, implementing innovative, inexpensive technologies such as rainwater catchments to diversify sources of drinking water would be a proactive measure that decreases vulnerability. Furthermore, empowering small communities

to control local resources and supporting traditional, legal, political, and financial frameworks that enhance social and ecological resilience, may help the islands be less vulnerable.

Within Guam, climate risks and vulnerabilities must be identified and quantified. Climate adaptation options need to be outlined and prioritized while current efforts should be inventoried according to sector. Each society has a coping range, a range of acceptable weather conditions conducive for its continued existence. Determining the coping range of Guam is essential to developing and implementing adaptive strategies and a review of the prehistorical evidence could give managers an idea of past climatic conditions for early human settlers.

Chapter 4: Coastal Zone Management

Addressing the anticipated impacts of climate change and decreasing vulnerability requires a discussion about governance, specifically, coastal governance. The entire island of Guam falls within the coastal zone (NOAA 2004). Climate change, in addition to on-going human activities, imposes additional stress on coastal environments. The interactions of multiple stressors result in complex unexpected ecological changes. Coastal communities need strategies that enable them to manage existing stressors and address the impacts of climate change in order to conserve, protect, and restore coastal habitats (Burkett and Davidson 2012).

Coastal zone management is the conservation and administration of natural ecosystems within the coastal zone, and their protection from anthropogenic impacts such as development, over-harvesting, and pollution (Beatley, Brower, and Schwab 2002). Ultimately, coastal zone management involves a delicate balance between the economy, the environment, and coastal communities. It is about managing people, in addition to actual resources (e.g., fisheries, mangroves, beaches, rivers, forests, coral reefs, watersheds). Presently, coastal managers are confronting climate change head-on (IPCC 2007a; IPCC 2014). Thus, coastal managers "…need to plan and implement adaptation measures to cope with these impacts in order to continue to protect the economic, social and environmental security of the state and of local communities"(Tribbia and Moser 2008).

Coastal zone management is practiced throughout the world (see Sorensen (1997), IPCC (2001), and IPCC (2014)). Cooper and Cummins (2009) offer a comprehensive perspective of the CZM in Northwest Europe. Shipman and Stojanovic (2007) provide a critique of implementation of CZM in Europe. For a wider and more generic overview, see Gray et al. (2014). These studies examine nations struggling to establish effective CZM programs. They are at a different stage of development than other CZM programs (i.e., the United States). So, while appreciating coastal governance is an international practice that varies spatially, the geographical focus of this thesis is on Guam, a territory of the United States. Thus, it is necessary to provide a succinct background of coastal zone management from a United States perspective and how that applies to coastal zone management in Guam and its watersheds.

4.1 CZM from a Federal Perspective (United States)

The federal Coastal Zone Management Act (CZMA) of 1972 (United States Congress 1972) is the backbone of the coastal zone management in the United States. It was passed in recognition of the importance of the coastal zone to the United States government and economy. Potentially adverse effects of intense development were placing pressures on this national resource. The CZMA asserts, "there is a national interest in the effective management, beneficial use, protection, and development of the coastal zone" (United States Congress 1972). Furthermore, Congressional findings supporting this Act describe how competition for the utilization of coastal resources, brought on by the increased demands of population growth and economic expansion, has led to the degradation of the coastal environment, including the "loss of living marine resources, wildlife, nutrient-rich areas, permanent and adverse changes to ecological systems, decreasing open space for public use, and shoreline erosion" (United States Congress 1972). With regard to whether who (state or federal government) is responsible for the governance of the coastal zone, the CZMA distinguishes,

> "the key to more effective protection and use of the land and water resources of the coastal zone is to encourage states to exercise their full authority over the land and waters in the coastal zone by assisting states... in developing land and water use programs... for dealing with coastal land and water use decisions of more than local significance." (United States Congress 1972).

The Act of 1972 was amended in 1990, increasing the power of states' rights. The 1990 amendments to the CZMA broadened the authority of state CZM programs by requiring that any federal activity that might reasonably be expected to affect the land, water resources, or uses of a state's coastal zone must be in compliance with the current state coastal policy before that federal action can proceed. This is a huge boon for coastal states…essentially this amendment gives them a powerful tool to enforce their state's vision of how coastal resources should be appropriately managed.

In short, the CZMA authorized a voluntary program of financial assistance for states to manage their coasts[13]. Officially, this voluntary program was to be administered by the

[13] States and territories participating in the US Coastal Zone Management Program include Alabama, Alaska, American Samoa, California, Connecticut, Delaware, Florida, Georgia, Guam, Hawaii, Illinois, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Northern

Secretary of Commerce. However, this responsibility was delegated to the National Oceanic and Atmospheric Administration (NOAA), specifically the Office of Coast and Ocean Resource Management (OCRM), within the Department of Commerce. States and territories along the coasts of the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Great Lakes are eligible to participate. While participation in the CZM program by states and territories is voluntary, it would be in the states' and territories' financial best interest to participate (it is additional federal money in state coffers). In order to participate in the coastal zone management program, a state is required to prepare a program management plan that must be approved by NOAA OCRM. The core of an approved program plan is a suite of enforceable program policies, based on existing state environmental statutes and regulations, which articulate the participating state or territory's vision for implementing the Congressional intent of the Coastal Zone Management Act. Once the program management plan is approved, a state program gains "federal consistency", as enforced by the amendment of 1990 to the CZMA. Again, this means that any federal action, including development activities, federally-issued licenses or permits, outer continental shelf oil and gas exploration, and federally funded projects, that takes place within a state's coastal zone must be found to be consistent with state coastal policies before the federal action can take place.

In general, the statewide seaward coastal zone boundary is the "outer limit of the United States territorial sea" (15 CFR 923.32), which is the "three geographic mile line" (43 CFR 3301.1). Inland coastal zone boundaries differ for each state (NOAA 2004). Again, the entire island of Guam is within the coastal zone (NOAA 2004). Using a watershed approach like Guam's coastal zone management program, the boundaries of the watershed would be from "Ridge to Reef" and in some instances beyond the reef.

4.2 CZM from a Local Perspective (Guam)

Guam is part of the voluntary program designated by the CZMA, overseen by NOAA OCRM. The Guam Coastal Management Program Plan was approved in 1979. Overseen by the Bureau of Statistics and Plans, the Guam Coastal Management Program (GCMP) guides the use, protection, and development of land and ocean resources within Guam's coastal zone. The entire island of Guam is regarded as a coastal zone, both locally and

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Mariana Islands, Ohio, Oregon, Pennsylvania, Puerto Rico, Rhode Island, South Carolina, Texas, U.S. Virgin Islands, Virginia, Washington, and Wisconsin.

federally (NOAA 2004). The Guam Coastal Management Program provides overall coordination and direction to a network of government agencies to ensure a balanced approach to coastal management. This program sits within the Bureau of Statistics and Plans and consists of one administrator, one geographic information systems (GIS) manager, six land-use planners, one program coordinator, one natural resource management specialist, one administrative assistant and one NOAA coral reef management fellow (see Figure 19). This is a well-rounded CZM team with strong skill sets.



Figure 19: Photograph of the staff of the Guam Coastal Management Program posing for an annual Christmas card.

It is expected, but not legally formalized, that the Guam Coastal Management Program works closely with a network of local government agencies. The agencies include Guam Environmental Protection Agency, the Department of Agriculture – Division of Aquatics and Wildlife Resources, the Office of the Governor, University of Guam Marine Laboratory and Water Energy Resources Institute, Guam Water Authority, Department of Land-Use and Planning, Department of Education, Department of Parks and Recreation, and Guam Visitors Bureau. Guam's Comprehensive Planning Enabling legislation, Seashore Protection Act, and several Executive Orders are among the key legislation for the GCMP. The GCMP is 100% federally funded and is responsible for locally administering the Coastal Zone Management grant and the Coral Reef Initiative Management and Monitoring grants, both from NOAA.

4.3 CZM and the Human Dimension

One challenge of managing resources associated within the coastal zone is a diverse population that may or may not share the same fundamental resource management values of the governing bodies, as reflected in governing polices. A fundamental problem for coastal zone managers is to recognize and consider these differing stakeholder interests and values in their management and policy decision-making processes (Himes 2007). Stakeholders ultimately will be affected by and will affect the future of natural resource management. Thus, to effectively manage coastal zone resources, managers will need to make complementary use of biological and social science while seeking more extensive input and involvement from stakeholders (Riley et al. 2002; Moser 2008; Tribbia and Moser 2008; Richmond et al. 2007). Himes (2007) argues that the inclusion of information pertaining to the human context is essential for effective conservation because it provides the foundation necessary to build stakeholder support, increase stakeholder compliance, and assess potential threats. Understanding socioeconomic factors may provide insights as to why stakeholders have resource-degrading behaviors (Cinner 2000) and inspire strategies on how such behavior can be changed. For natural resource managers, that is the ultimate challenge: striking a balance between natural resource conservation and conflicting stakeholder behaviors. Essentially, understanding differences in stakeholder attitudes, perceptions, behaviors, and knowledge toward the coastal zone and coastal resource management is crucial for successful implementation of adaptation strategies (Moser 2009).

Tribbia & Moser (2008) examined the challenges CZM managers face, information they use to perform their responsibilities, and other knowledge resources they may need to begin planning for climate change. They conducted 18 semi-structured interviews (between 60 – 90 minutes) with key informants exploring:

- Current coastal management challenges and management challenges and management responsibilities of interviewees
- Levels of awareness and understanding of climate change impacts on coastal zones
- Information use and constraints that affect coastal decision-making
- Historic actions taken by coastal managers to cope with adverse coastal conditions and perceived changes in the state's coping capacity

- Information needs related to climate change impacts
- Other perceived barriers to adapt to climate change.

Their findings indicate that CZM managers prefer certain types of information, particularly social science information. Tribbia & Moser (2008) also highlight the disconnect between scientists and managers; many management decisions continue to be made without scientific input (Sarewitz and Pielke 2007). Richmond et al. (2007) echo these sentiments and further suggest, "formal training designed to improve communications among policy makers, social scientists, natural scientists, and stakeholders is critical to sound policy development and implementation and should be added to curricula across disciplines".

Current writings champion the role of community in the context of natural resource management through meaningful participation (Bunce et al. 2000). There are a number of studies (Pomeroy et al. 1997; Sultana & Abeyasekera 2008) that provide statistical evidence indicating that community-based management is more successful, in terms of fewer stakeholder conflicts, compliance, and achievement of conservation goals, compared to management that does not consider the community. But despite its recent popularity, research into community attitudes and perceptions with regard to coastal resource management (let alone, climate change) is limited (Moser 2009), especially on Guam.

For Guam, understanding differences in the attitudes, perceptions, values, behaviors, and knowledge of the local community toward water and watersheds, is crucial for successful implementation of adaptation strategies. Information about the human dimension illustrates the vulnerability of a society. CZM managers can use this data to custom-tailor location-specific adaptation strategies that are supported by the community. Acceptance of these strategies could be measured by positive stakeholder behavioral changes (e.g., number of human-induced wildfires per month and change in annual landcover vegetation).

4.3.1 Understanding Community Attitudes Perceptions and Knowledge

Gifford & Sussman (2012) define an attitude as "…a latent construct mentally attached to a concrete or abstract object (otherwise known as an "attitude object"—a person, place, entity, or idea)". Traditionally, attitudes have three components: cognitive

(thoughts about the object, usually including an evaluation), affective (feelings about the object), and conative (behavioral intentions and actions regarding the object) (Pratkanis, Breckler, and Greenwald 1989). Attitudes can be confused with other constructs, such as values, beliefs (sometimes considered the cognitive component of attitudes), opinions, personality dispositions, and personal norms. Although all of these concepts relate to the three attitude components to some extent, they also differ in subtle but important ways. For example, according to Shrigley, Koballa, and Simpson (1988), "…beliefs list toward the cognitive; values are broader than attitudes and more culturally bound. Opinions, historically in competition with attitudes, are more cognitive." Personality traits differ from attitudes in that, like values, they are not focused on a particular object, are not necessarily evaluative, and are not easily changeable (Ajzen 2005). Another construct that has recently gained favor in environmental psychology research is "personal norm", originally proposed by Schwartz (1977). Wiidegren (1998) uses research from Schwartz (1977) to construct "The New Environmental Paradigm" (NEP) scale as an effort to determine factors that predict the willingness to pay for environmentally friendly food in Sweden. Unlike attitudes, pro-environmental personal norms are internalized social norms that directly influence behavior through feelings of guilt (Bamberg and Möser 2007).

Unlike attitudes, perceptions are the sensory experiences of the world and involve both the recognition of environmental stimuli and actions in response to these stimuli. Having perceptions allow humans to gain information about elements of the environment that are critical to survival and also allows humans to act within that perceived environment (Vishton 2011). Perception includes the five senses: taste, touch, sight, scent, and sound.

The perception of the condition of natural resources is related to *sensitivity* (see Chapter 3: Vulnerability and Adaptation-3.2.1.2 Sensitivity) because it provides information about an individual's impression of the state of their surrounding resources. Monitoring these perceived conditions of natural resources over time can alert natural resource managers, specifically coastal zone managers, of trends or changes that must be considered for planning purposes. Also, by understanding community perceptions of different types of climate events, coastal zone managers are provided with information that may influence the choice of adaptation strategies to increase success.

4.3.2 CZM and Traditional Knowledge

While Guam has an official Westernized democratic government, the traditional polity of Micronesian cultures usually centered around the power of chiefs and was the foundation of land and marine tenure (Haglelgam 2004; Hezel 2001; Petersen 2009). The literature on traditional land and marine tenure systems in Micronesia suggests that customary marine tenure varies slightly from island to island because of differences in the power of the chiefs and changes in modern constitutions. However, insights into the traditional polity may assist in facilitating community-based adaptation. For example, in more traditional Micronesian islands, such as Pohnpei, there is still direct reef tenure, or ownership, and hence individuals take responsibility for the state of their coral reefs and fisheries (Petersen 2009; Hezel 2001). This avoids a "tragedy of the commons" (Hardin 1968). Many Pacific island cultures treat the land-sea interface as a continuum rather than a boundary, and this "ridge-to reef" stewardship recognizes that upslope activities affect people and resources farther down a watershed and in the ocean (Petersen 2009). Traditionally based management systems and efforts may not necessarily be the ultimate and final solution, but they can offer ideas for potential adaptation. One advantage that the islands with intact traditional leadership and ownership of resources have is that they lack "red-tape" and can quickly and effectively apply scientific data and generate immediate dialogue and action (Richmond et al. 2007).

While traditional knowledge and past experiences are important, this does not mean that science should be ignored. On a note of caution, community-based approaches should not be regarded as a panacea, rather as an important and essential component to developing and implementing adaptive strategies (J. Mercer et al. 2007). For example, sometimes, local knowledge is not accurate (Tibby, Lane, and Gell 2008), or there may be a lack of cohesiveness within a community. Ideally, a combined or eclectic approach would increase resilience to natural hazards and reduce sensitivity by enabling indigenous communities to preserve their most effective indigenous practices, which form an important part of their cultural heritage (Mercer 2005).

4.4 CZM and the ecosystem-based approach

4.4.1 Ecosystem-based approach

The term ecosystem, initially coined by Tansley (1935) is "the basic functional unit of ecology" (Odum and Barrett 2005). An ecosystem is short for 'ecological system' and refers to a complex set of relationships between biological, chemical, and physical components within a specific area. Essentially, it is the interaction between living organisms, physical features, biochemical processes, natural phenomena, and human activities. Ecosystems provide a wealth of services for humans. An ecosystem-based approach uses a location-based approach to natural resource management that aims to protect the health, function, and resilience of an entire ecosystem for the benefit of all organisms. It is often referred to as ecosystem-based management (EBM).

EBM is a place-based framework for developing management plans at various scales, based on a set of guiding principles. These management plans should take into consideration the health of the whole ecosystem above all else; integrate the concerns of the environment, society, and the economy; and be focused on a specific place with scientifically discrete boundaries (e.g., watershed). Granek et al. (2010) point out that coastal ecosystems illustrate the logistic and political challenges of EBM.

4.4.2 Ecosystem-based approach, watersheds, CZM and Guam

The Guam Coastal Zone Management Program has adopted ecosystem-based management as its framework for natural resource management and they use watersheds as the spatial units of analyses. As opposed to managing various parts of the ecosystem separately, this is a holistic approach. They have commissioned several watershed management plans in order of priority. The most recent plan (see King 2014), is the first to incorporate statistically significant societal concerns about the condition of their resources and climate change.

4.5 Summary

In this instance, one important aspect of successful adaptation to climate change is coastal governance. The entire island of Guam is located within the coastal zone (NOAA 2004) and how this area is managed is directly related to how the U.S. federal government functions. The U.S. has a very specific framework for coastal zone

management that involves a voluntary program in which states and territories manage their coastal zones and are financially compensated. Guam is an active participant of this program and the GCMP is completely federally funded. The Guam Coastal Zone Management Program has chosen to subdivide their coastal zone into watersheds and approach CZM with ecosystem-based management. This concludes the literature review. The next chapter will presents the methodology used to answer the original research questions.

Chapter 5: Methodology

5.1 Introduction

There are a multitude of ways to measure social vulnerability. This chapter discusses some of the methodologies that seemed the most appropriate and relevant to this case study.

5.2 Methodologies Measuring Vulnerability

There are various ways to measure vulnerability. Downing et al. (2004) provide a loose methodology that seems open to interpretation, and aims to determine the vulnerability of a community in approximately four steps:

1. Clarify the conceptual framework
2. Define vulnerability
3. Review existing regional or national assessments that relate to vulnerability (e.g., Poverty Reduction Strategy Papers, environmental sustainability plans, natural hazards assessments)
4. Identify vulnerable groups
    a. Who is vulnerable, to what, in what way, and where

This is a desktop analysis and a very hands-off approach.

In contrast, Schröter et al. (2005) also provide a very thorough eight-step methodology to assess social vulnerability to climate change. This methodology is very community-orientated and community-driven. It would be extremely time-consuming to execute this and may not be realistic for Ph.D work, which is constrained to limited time, labor, and funding.

1. Define study area together with stakeholders
    a. Choose spatial and temporal scale.
2. Get to know the place over time
    a. Review literature
    b. Contact researchers
    c. Spend time in the field with stakeholders
    d. Explore nearby areas

3. Hypothesize who is vulnerable to what
    a. Refine focus on stakeholder sub-groups
    b. Identify drivers
4. Develop a causal model of vulnerability
    a. Examine exposure, sensitivity and adaptive capacity
    b. Formalize into models
5. Find indicators for the elements of vulnerability
    a. Exposure indicators
    b. Sensitivity indicators
    c. Adaptive capacity indicators
6. Operationalize models of vulnerability
    a. Apply models to weight and combine indicators
    b. Validate results
7. Project future vulnerability
    a. Choose scenarios with stakeholders
    b. Apply models
8. Communicate vulnerability creatively
    a. Be clear about uncertainty
    b. Trust stakeholders
    c. Use multiple interactive media

SEM-Pasifika provides a clean, adaptable methodology for coastal zone managers of Pacific Islands to conduct social and economic vulnerability assessments and monitoring (Wongbusarakum and Pomeroy 2008). This flexible methodology has the latitude to include stakeholders at any step, at the discretion of the researcher. Wongbusarakum and Pomeroy (2008) propose these main steps:

1. Define objectives
2. Identify sites and indicators
3. Consult with stakeholders
4. Prepare assessment
5. Collect data
6. Analyze data
7. Communicate results
8. Use results for adaptive management

An addendum to *SEM-Pasifika* was added to specifically address community-level social vulnerability to climate change (see Wongbusarakum and Loper, 2011). For example, one aspect of social vulnerability is *exposure* (see Chapter 3: Vulnerability and Adaptation -3.2.1.1 Exposure). Wongsbusarakum & Loper (2011) recommend using household surveys, secondary data sources (e.g., Census data), and information from key informants in order to identify demographically vulnerable groups. Some of the recommended indicators are as follows:

- household size and structure
- age
- gender
- level of education attained
- literacy
- occupation
- average annual income
- migration status
- home location and proximity to hazard areas
- health status and special needs
- affiliation with certain demographic groups, such as religious, ethnic , and language
- access to lifelines (e.g., drinking water, electricity, health care, transportation, and telecommunications) (Wongbusarakum and Loper 2011).

The household survey conducted for this dissertation collected data on age, gender, level of education attained, average annual income, migration status, occupation, proximity to hazard areas, religion, ethnicity, languages spoken at home, and access to lifelines. Drinking water was the only 'access to lifeline' indicator.

To measure *sensitivity* (see Chapter 3: Vulnerability and Adaptation - 3.2.1.2 Sensitivity), Wongbusarakum & Loper (2011) recommend using a household survey, biological monitoring, mapping, information from key informants through the creation of a seasonal calendar[14], and secondary data sources in order to determine perceived conditions of natural resources and the community's dependence on

[14] A seasonal calendar is a visual timeline about weather patterns (e.g., rainy season, dry season, typhoon season), seasonal events (e.g., spawning aggregations, fruiting season, tourism season) associated with specific times of the year (Wongbusarakum and Loper 2011).

resources and services vulnerable to climate events. Households or individuals that depend on a single economic sector (e.g., fishing, farming) are more vulnerable to impacts of climate change because degraded resources would make it more difficult to recover from a specific impact. Households or individuals that are diversified and rely on more than one economic sector are less vulnerable. Determining perceived conditions of natural resources is discussed thoroughly in Wongbusarakum and Pomeroy (2008) and some of the indicators are as follows:

- perceived community problems,
- perceived resource conditions,
- perceived threats to coastal and marine resources, and
- perceived coastal management problems.

Nakalevu (2006) also offers a bottom-up, systematic methodology to assess communities' vulnerability and adaptive capacity that involves local island communities analyzing their relative situations and making decisions that utilizes the best available data and traditional knowledge. Nakalevu, (2006b) helpfully offers user-friendly guidelines outlining the various steps to identify, analyze, and develop community adaptation strategies and opportunities related to climate change. The guidelines suggest a collection of activities to measure a specific indicator. Conducting these activities is a learning process designed to empower local communities to increase their local adaptive capacity to current and future challenges (Nakalevu 2006). Specifically, Nakalevu (2006) provides a clear, easy to interpret box that outlines the essential research questions and suggested participatory tools that can be used to answer such questions (see Table 6).

Table 6: Summary Table of Naklevu. Reprinted from Nakalevu (2006), pg. 27

Research Questions	Participatory Tools
What are the natural occurrences experienced by the community that reflect climate variabliity and extremes over the last 50 years or so?	Historical Timeline Household Interviews Focus Group Discussion
What are the impacts of these natural occurrences on the socio-economic well-being of local communities (e.g., housing, income, food, education, health, potable water)?	Impact Ranking Matrix Transect Walk Focus Group Discussion
What are the different socio-economic groups and institutions or agencies in the area that are affected by climate variability and extremes?	Semi-structured interviews Social/Wealth ranking matrix Focus Group Discussion
What are the vulnerable sectors in the community? Geographical location Transportation Communication Shelter Health Water and sanitation Education Livelihood Disaster frequency and intensity	Stakeholder analysis of different socio-economic groups Questionnaire
What makes the different socio-economic groups vulnerable to climate variability/change/events?	Stakeholder analysis of different socio-economic groups, may also include the role of governments (local and national), NGOs, churches, etc Cause and effect diagram
Do men and women give different weights or importance to climate change-related vulnerabilities?	semi-structured interviews questionnaire Focus group discussion
Do different occupational groups (e.g., fishermen, day labourers, farmers) rank climate change-related vulnerabilities differently?	Attitude ranking matrix Semi-structured interview Focus group discussion
Identify the types of 'social capital' that exists in communities (i.e., social organizations, networks, trading systems, etc.) in order to surmise their adaptive capacity under current oceanic and climatic conditions.	Semi-structured interviews Questionnaire Focus group discussion

5.3 Methodology Used for this Research

Ideally, all the aforementioned methodologies should be implemented with a committed team. The methodology used to answer the research questions is modeled after Wongbusarakum and Pomeroy (2011) and Nakalevu (2006). These approaches are straight-forward, user-friendly, flexible, and attainable in reasonable amount of time. Both are sensitive to island cultures and are appropriate for the geographical scale of this dissertation. These are the specific steps taken with regard to this dissertation:

5.3.1 Determination of objectives

The objectives (see 1.1.2 Objectives and Research Questions) were defined, reviewed, and amended based on a literature review and assessment of available data.

5.3.2 Identification of Sites and Indicators

GCMP subdivides the coastal zone into watersheds and conducts CZM using an EBM approach. Choosing a priority watershed as the case study was a logical decision. Now is an appropriate time to discuss the merits of using the watershed as a spatial unit of analysis, particularly if employing EBM.

5.3.2.1 Watersheds

According to (Sheehan 2009), the origins of the term "watershed" stem from *wasserscheide*, a German word in use since the 14th century which means 'water parting'. The Oxford English Dictionary defines watershed as, "the line separating the waters flowing into different rivers or river basins; a narrow elevated tract of ground between two drainage areas" (Oxford English Dictionary 2013). Europe continues to use this definition of the term watershed.

However, in the United States, the term 'watershed' evolved. Instead of referring to the specific boundary line between two drainage areas, the term grew to encompass the entire drainage area. Powell (N.D.) an American scientist geographer and the first director of the United States Geological Survey, defined a watershed as,

> "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."

Powell argued that communities in the West (America) needed to control their own water and land resources, following the precedents of Hispanic pueblo communities and the Mormons. One can make a similar argument for Guam. Powell pushed for the abandonment of proposals for a federal water reclamation program and the rejection of federally controlled appropriation system. He felt that by adopting these actions, communities will lose control over water and the environment will suffer. Finally, Powell proposed that the communities and stakeholders residing in the West organize themselves along "hydrographic" districts (i.e., watersheds and river basins), as opposed to political boundaries that are in conflict with these natural boundaries. While the individual watersheds in Guam have been identified, they are all managed under the Government of Guam (GovGuam), except for the parcels of land that are federally owned. Because Guam is a U.S. territory, the Government of Guam must comply with U.S. federal law. Guam does not have full control over their watersheds. The limited authority that Guam does have is restricted to the government and the communities that reside in the watersheds have no official control.

K. N. Brooks, Ffolliott, and Magner (2013) offer a more formal definition of the term 'watershed':

> "Watersheds are biophysical systems that define the land surface that drains water and waterborne sediments, nutrients, and chemical constituents to a point in a stream or a river defined by topographic boundaries. Watersheds are the surface landscape systems that transform precipitation into water flows to streams and rivers, most of which reach the oceans."

This definition provided by Brooks, Ffolliott, & Magner (2013) is more technical than the one provided by Powell (n.d.). However, it fails to mention humans directly; the emphasis is on physical geography.

For this thesis, a watershed is defined as a topographically delineated area that is drained by a river system. The watershed is a hydrologic unit, as well as, a physical-biological unit, as well as a socioeconomic and sociopolitical unit.

Integrated watershed management (IWM) is a process of governance that involves natural and human resources of a watershed to achieve specific objectives (K. N. Brooks, Ffolliott, and Magner 2013). Aspects of this process include, but are not limited to, the establishment of watershed management objectives, the formulation and evaluation of resource management actions, the use of tools to determine and implement specific

courses of action, and the development of pertinent monitoring strategies. Using an IWM approach links areas of upper elevation with areas of lower elevation, biologically, socially, and economically.

The use of a watershed as a spatial unit is extremely useful for natural resource management (Easter, Hufschmidt, and McCauley 1985). The watershed management movement is also an administrative strategy since watershed management involves breaking down some of the fundamental intergovernmental barriers that can impede the achievement of ecological or economic objectives for a specific area (Kenney 1997). For this thesis, the watershed is used as a spatial unit to examine the vulnerability of a specific community at a specific time.

5.3.2.2 Delineation of Watersheds on Guam

In 1998, the Government of Guam, in response to a federal Clean Water Initiative, conducted a unified watershed assessment (Government of Guam 1998) in order to classify the various watersheds of Guam according to water quality. According to Government of Guam (1998), the Natural Resource Conservation Service (NRCS) under the United States Department of Agriculture (USDA), delineated a watershed map for Guam and assigned each watershed with a unique hydrologic code. The hydrologic codes were originally developed by the United States Geologic Survey (USGS) and expanded by NRCS to include for smaller-sized drainage areas. The hydrologic code for the Manell watershed is 20100003-000-019 and the hydrologic code for the Geus watershed is 20100003-000-020 (Government of Guam 1998). Nineteen watersheds have been delineated on Guam (Watershed Professionals Network 2010).

5.3.2.3 Site Selection

The Manell and Geus watersheds were selected as the study site for this thesis. This decision was based on consultations with the Guam Coastal Management Program. They were in receipt of funding from NOAA's coral reef conservation program and the Manell and Geus watersheds were thought to be the most likely place for Guam to realistically and successfully conserve coral reefs. This is in part due to the low population, little development, variety of ecosystems, traditional close-knit community, diverse benthic habitat, the presence of a marine preserve, and the existence of terrestrial conservation areas.

5.3.2.4 Indicators

Indicators may be defined as "quantitative measures intended to represent a characteristic or a parameter of a system of interest" (Cutter et al. 2008). The use of indicators has been quite popular in sustainability and vulnerability studies (Parris and Kates 2003; Birkmann and Wisner 2006; Birkmann 2007). This push for employing empirical measures is driven by the great need for scientifically derived evidence to justify policies aimed at increasing resilience to climate change.

However, there are some concerns with using strictly indicators to measure vulnerability. Vulnerability indices are limited in the scale of analysis (Cutter et al. 2009), making it difficult to compare studies across space and time. Other limitations include the lack of comparability between various indices because each index may use different variables or was constructed differently, or place more emphasis on specific indicators (Cutter et al. 2009). Furthermore, some data is difficult to measure quantitatively and using qualitative techniques may be a better choice. Cutter et al. (2009) assert that indices are best used as descriptions of existing and anticipated conditions, and not as predictive tools.

Sustainability indices at a national level provide a one-dimensional metric to evaluate country-specific information on the three dimensions of sustainable development: economic, environmental, and social conditions. Some popular indices include the Environmental Sustainability Index (Esty et al. 2005), the Environmental Vulnerability Index (Kaly et al. 1999), Human Development Index (Malik 2014), the Wellbeing Index (Prescott-Allen 2001), Ecological Footprint (Wackernagel and Rees 1998), the Community-Based Risk Index (Bollin and Hidajat 2007). Alarmingly, Böhringer and Jochem (2007) demonstrate that a good portion of sustainability indices fail to fulfill fundamental scientific requirements rendering them inadequate to guide policy decisions.

It is not the intent to create a new index, but rather select indicators that are sensitive to this village and its watersheds. For this research, indicators were chosen from Wongbusarakum and Loper (2011). Indicators may be classified into the following groups: demographic, behaviors, perceptions, values, attitudes, and knowledge.

5.3.3 Consultation with stakeholders

The initial list of stakeholders was developed in consultation with Evangeline Lujan, administrator of the Guam Coastal Management Program and Ernest Chargalauf, Mayor of Merizo. A meeting with Ernest Chargalauf, the Mayor of Merizo, was organized for 19 July 2010 to discuss the project and obtain permission and support. Mr. Chargalauf provided two volunteers to assist with any research work – Jermaine Cruz and Tricia Quinata. After two weeks, Ms. Quinata quit due to familial obligations and was replaced by Benny Quinata.

Ms. Lujan helped identify local partners in coastal governance (see Appendix 4 – Attendance list of the Conservation Action Plan Workshop 2010). In order to gather information about the attitudes, perceptions, and knowledge of local and federal natural resource agency employees about the Manell and Geus watersheds, a two-day Conservation Action Planning (CAP) workshop, funded and facilitated by the Nature Conservancy (TNC) was organized in early September 2010 (see Appendix 3 - Conservation Action Plan Invitation Letter 2010). Steven Victor and Umiich Sengebau from The Nature Conservancy (TNC) facilitated the workshop on behalf of the GCMP. CAP is a process that assists communities, local governments, and natural resource management agencies to determine and prioritize the biological, social, and economic factors necessary for effective management within a specific geographical location. Based on the results of this workshop, strategic conservation action plans are developed, assessed, and incorporated into the watershed management plan for the specified area. The objectives of the CAP workshop are as follows:

- Identify actions that produce long-term measurable results of conservation efforts, at the local level;
- Establish partnerships to support and implement management interventions; and
- Quantitatively and qualitatively measure conservation impact in the area over time.

Because a household survey was conducted prior to the CAP to obtain the perceptions, attitudes, knowledge, and values of the community residing in the Manell and Geus watershed, this CAP workshop targeted stakeholders from the local and federal natural resource agencies (see Appendix 4 – Attendance list of the Conservation Action Plan Workshop 2010). One of the main outputs from was a threat matrix (see Figure 20) that reflects the perceptions of local and federal officials.

	Coral Reef Ecosystem	Forest ecosystem	Freshwater Ecosystem	Healthy & safe human communities	Native wildlife	Reef fish& edible inverts	Seagrass Ecosystem	Turtles	Summary Threat Rating
Over-harvesting	Medium				Medium	High		Very High	High
Sedimentation	High		High				Medium		High
Invasive species		High	Low	Medium	Very High				High
Fire		High		Medium					Medium
Flooding				High					Medium
PCB				Medium					Low
Crown of thorns starfish	Medium								Low
Physical damage	Low						Low		Low
Summary Target Ratings:	Medium	High	Medium	Medium	High	Medium	Low	High	High

Figure 20: Threat matrix summarizing local and federal government official's perceived threat level of various agents on the individual parts of the watersheds. Threat levels are low, medium, high, and very high and color-coded for visualization purposes. Guidance for assessing the health of key ecological attributes (KEAs) is from The Nature Conservancy (2007).

5.3.4 Assessment Preparation

5.3.4.1 Survey Design

For this thesis, a household survey was designed to measure the perceptions, attitudes, knowledge, and behaviors of the community at the selected study site. Questions for the household survey were formulated with guidance from a pre-released draft version of Wongbusarakum and Loper (2011) and Wongbusarakum and Pomeroy (2008). The majority of questions were close-ended questions. Because GCMP commissioned this work, they had to approve the survey questions and added additional ones (see Q.14, Q.27, Q.31, Q34, in Appendix 1 – Household Survey) that were of interest to them. These additional questions were not analyzed and not included in this work. The initial draft of the household survey was tested on a focus group consisting of four employees of the Bureau of Statistics and Plans who reside in the village of Merizo. Constructive feedback from this group led to a revision of the survey. The major concerns pertained to how

questions were worded. Suggestions for revision included alternative phrasing that is reflective of the local jargon.

Upon final approval of the survey, the two assistants from the Merizo Mayor's Office, Jermaine Cruz and Benny Quinata, helped with the distribution, administration, and collection of household surveys. GCMP provided free t-shirts, bags, and bottles that promoted watersheds. Respondents were given one promotional item of their choice if they completed a survey. This provided an excellent incentive for residents to participate in the study. There was great eagerness to obtain a promotional item. Data collection was completed in approximately 1.5 months and occurred during June-July 2010.

5.3.4.2 Power Analysis

In order to calculate the minimum sample size required for a representative sample of the population, power analysis[15] was used. The original population of Merizo used to calculate the sample size was 2163 (U.S. Census 2001) because during the time of the survey (2010), it was the best available data. The power analysis was determined using an online calculator (http://www.surveysystem.com/sscalc.htm). According to the online calculator, for a population of 2163, a minimum of 326 respondents were needed to achieve a representative sample of the population at a 95% confidence level, with a confidence interval of ±5%. However, the power analysis was recently recalculated with data from the 2010 Census, which was released in 2011. The 2010 population of Merizo was approximately 1850 (U.S. Census Bureau 2011a). For a population of 1850, a minimum of 318 respondents were needed to achieve a representative sample of the population at a 95% confidence level, with a confidence interval of ±5%. For this research, n = 350, greater than the minimum number needed for a representative sample.

5.3.4.3 Sampling

To identify participants in the household survey, non-random sampling was used. Specifically, snowball sampling and convenience sampling were the primary methods

[15] Statistical power analysis is an important technique in the design of experiments that helps determine how big a sample size should be selected for that experiment. If it is calculated before the experiment takes place, it is called as *a priori* power analysis. When it is calculated after data collection, it is referred to as a *post hoc* power analysis. In general, the larger the sample size, the higher statistical power in the analysis. By using a statistical power analysis, it is possible to compute an optimal sample size that would ensure that the statistical analysis is powerful and keep the sample size as small as possible. Technically, statistical power is the probability that a statistical analysis will be able to catch false null hypotheses. This is another way of saying that the analysis will not make a Type-II error.

used to obtain participants. To identify subjects for informal interviews, convenience sampling was used. Subjects for the informal interviews were found at the Merizo Senior Citizens' Center.

5.3.5 Data Collection

This section describes the collection of the various data used in this dissertation. In addition to the survey design and power analysis, additional datasets (e.g., geospatial data, census data) were identified.

5.3.5.1 Geospatial Data

GIS data for Guam were compiled and reviewed. Raw data were provided by the Bureau of Statistics and Plans Guam Coastal Management Program. Victor Torres, GIS Manager, provided a link to all the geospatial data stored on the Government of Guam servers. Some GIS data were obtained from the Water and Environmental Research Institute (WERI) at the University of Guam.

5.3.5.2 Secondary Data (U.S. Census)

The U.S. Census conducts an official census every decade. The last one for Guam occurred in 2010. These data were not available until 2011. Originally, 2000 U.S. Census data were used to conduct the power analysis. Upon availability of the 2010 data (U.S. Census Bureau 2011a), the power analysis was redone. Since population of Merizo decreased from 2000 to 2010, the results from the initial power analysis are valid. The demographic data collected by the household survey was compared to the 2010 census as verification that the sample was representative of the village of Merizo.

5.3.5.3 Household Survey

To measure the perceptions, attitudes, knowledge, and behaviors of the community, a household survey (see Appendix 1 – Household Survey) was administered from July through August 2010. Of the 400 hundred surveys administered, 354 were returned. Of the 354 returned, 350 were viable. Jermaine Cruz and Benny Quinata, employees from the Merizo Mayor's Office assisted in data collection. Convenience sampling and snowball sampling was used. Mr. Cruz and Mr. Quinata identified initial households that they personally knew, and in turn, participants recommended additional households that would be interested. The GCMP provided free education and outreach material (e.g., bags, t-shirts, and water bottles) to be distributed among the village. As an

incentive, when a participant completed a survey, he or she was given a t-shirt, bag, or water bottle.

Mr. Cruz and Mr. Quinata were compensated for their time. They were each given 200 USD for approximately 40 hours of part-time work over the course of two months. They wanted to do the work *pro bono* (they were receiving full-time salaries as employees of the Mayor's Office and merely wanted to help out with the project). However, the access to community they helped facilitate was invaluable and in order to demonstrate some gratitude, 200 USD was taken from personal funds and given to the two assistants after data collection.

5.3.5.4 Informal Interviews

In an effort to supplement the quantitative data generated from the household surveys, informal interviews with the elderly residents of Merizo were conducted with the hope of obtaining traditional ecological knowledge (TEK). The Merizo Senior Citizens' Center is located next to the Merizo Mayor's Office. Non-random, convenience sampling was employed at the Senior Citizens' Center to select participants. Arrangements with the Center's manager were made a week in advance. The manager informed elders about this project and participation was strictly voluntary. Six elders agreed to participate in an informal interview and have their responses recorded and used for this thesis. Two elders declined; they wanted no involvement. Another two elders wanted to be interviewed but did not want their responses recorded (their answers are not included in this thesis). All recorded informal interviews were conducted in English with the exception of one. One participant wanted the interview questions in Chamorro. The Center's manager served as a translator. Interviews were recorded and transcribed. Ideally, this TEK would been used to generate a seasonal calendar or narrative timeline (Nakalevu 2006).

5.3.6 Data Analysis

5.3.6.1 Geospatial Data

GIS data were analyzed using ESRI ArcInfo 10.0, 10.1, and 10.2. Maps were generated from GIS data and objectively presented in Section 6.1 Manell and Geus Watersheds.

5.3.6.2 Census Data

US Census data for 2000 and 2010 were downloaded from the United States Census Bureau, American FactFinder (U.S. Census Bureau 2014). Calvin Saruwatari from the Bureau of Statistics and Plans reviewed all available U.S. Census data for Guam and provided guidance to facilitate future accessibility.

5.3.6.3 Household Survey

A codebook was constructed in order to translate the responses from the household survey into 'numbers' that could be entered into IBM SPSS, software designed for the computation and display of statistical data. Every viable, completed household survey was examined and coded according the codebook. The coded data was then entered into an MS Excel database, taking approximately one year. The resulting MS Excel database was cleaned and imported into SPSS for statistical analysis. Within SPSS, syntax was used to categorize variables and values; group multiple response sets; generate descriptive statistics; and calculate inferential statistics. Consultations with Kathleen O'Brien[16] occurred to discuss potential analyses that may be used on the dataset. These tables and graphs were generated and a verbal description of the data was written (see Chapter 7: Results-Household Survey and Analysis). SigmaPlot and GraphPad were used to create graphs.

Analysis of variables 25 – 36 was omitted (see Appendix 2 – Household Survey Codebook) because the focus of the dissertation is freshwater. The omitted variables focused on the Marine Preserve. Only one general question about support for the marine preserves was included (variable 24 – see Appendix 2 – Household Survey Codebook). While it would be interesting to gain some in-depth insight in to how the community of Merizo feels about the marine preserves, it is outside the focus of the dissertation.

Analysis of variables 14 - 14d (see Appendix 2 – Household Survey Codebook) was omitted. These questions were incorporated because the Guam Coastal Management Program was concerned with marine debris and the number one item they collected during their annual International Coastal Cleanups is cigarette butts. Question 14 – 14d pertained how smokers disposed of their cigarette butts. It could be argued that 14d would provide additional insight with regard to resource-degrading behaviors; however

[16] Kathleen O'Brien is a lecturer and director of The Statistical Consultancy Unit, located in the School of Mathematical Sciences at University College Cork.

the benefit of analyzing the question was extremely low and would not add to or detract from the findings of this dissertation.

Analysis of variables 42a-42ac (see Appendix 2 – Household Survey Codebook) was omitted. These open-ended questions pertained to the types of crops farmers grew and required respondents to write their answers. The handwriting on some of the surveys was illegible. Rather than not include the surveys with unreadable hand written responses, analysis of the question was omitted.

Analysis of the results to questions 47 – 48 (see Appendix 1 – Household Survey) was omitted. These were open-ended questions seeking a general sense of the individual completing the survey. They were a closing opportunity for respondents to include anything they felt was not covered by the questionnaire. If responses to 47-48 were analyzed, over 50 variables would have been generated. Since most of the handwritten responses to question 47-48 were covered by previous close-ended questions, omission of these data seemed prudent.

5.3.7 Communication of Results

Unpublished results were communicated to the community in a follow-up village Conservation Action Planning Meeting that occurred on 27 August 2013 at the Merizo Mayor's Office. In addition to the community, the results were communicated to the National Oceanic Atmospheric Administration as part of a presentation supporting the Manell and Geus watersheds as the featured watershed in Habitat Blueprint. Results were recently shared at the 2015 Island Sustainability Conference, held in Tumon, Guam on 15 April 2015.

5.3.8 Incorporation into Adaptive Management

The results of the GIS analysis and household survey were included in a watershed management plan for the Manell and Geus watersheds (see King 2014). The watershed plan was completed in March 2014 and submitted to the GCMP for review. The plan has been approved and is currently being implemented.

5.4 Ethical Considerations

Any social science research conducted on Guam must notify the Institutional Review Board (IRB) housed at the University of Guam, regardless if the research is affiliated

with the University. Details for the application process may be found at the following site: http://www.uog.edu/administration/graduate-studies-sponsored-programs-and-research/institutional-review-board.http://www.uog.edu/administration/graduate-studies-sponsored-programs-and-research/institutional-review-board. Approval was granted for this project. A letter signed by the Director of the Bureau of Statistics and Plans accompanied every survey and clearly explained the purpose of the study, use of the results, and benefits of participation (see Appendix 1 – Household Survey). Participation was strictly voluntary. Participants were selected based on their location of residence (only people from the village of Merizo were invited to participate). Furthermore, participants were notified on the first page of the survey that information provided would be kept confidential (see Appendix 1 – Household Survey). Names of individual participants were not recorded to ensure anonymity of responses. No physical or mental harm came to any of the participants.

For the informal interviews, questions were pre-approved by the IRB and the Bureau of Statistics and Plans. Participation was also strictly voluntary. Participants were selected due to their advanced age, from the Merizo Senior Citizen Center. Participants gave verbal consent to have their responses recorded. For those that did not want their responses recorded and only wanted to chat, their interviews were not recorded or included in this research. Recorded responses were kept anonymous. Within the thesis, participants were referred to as "Person" and assigned a random number. No physical or mental harm came to any of the participants.

5.5 Limitations

The household survey was subject to approval by the Bureau of Statistics and Plans Guam Coastal Management Program. Several questions important to the BSP were incorporated into the household survey that were awkwardly worded and unnecessary. Those questions were not analyzed for this thesis. The time it took to enter and analyze data was lengthy due to a personal, medically excused leave of absence from the UCC Ph.D program. This research is limited to a specific location (Manell and Geus watersheds on Guam) and to a specific time (2010). Applying these results to all the watersheds on Guam would be foolish.

Chapter 6: Results – Geospatial Analysis of Manell and Geus Watersheds

Geographic Information Science/Systems (GIS) was used to conduct a geospatial analysis of the physical characteristics of the Manell and Geus watershed and provide visualizations of the study site. Raw geospatial data were collected from the Bureau of Statistics and Plans and analyzed using ArcGIS 10.1. This section objectively presents the results in the form of maps and tables. Discussion of these results is reserved for Chapter 9: Discussion and Conclusion).

6.1 Manell and Geus Watersheds

The Manell watershed is located Southern Guam (see Figure 21). It has an approximate drainage area of 4.55 mi^2 or 11.784 km^2 (Water and Environmental Research Institute of the Western Pacific 2014). The Geus Watershed is adjacent to the Manell Watershed and has a drainage area of 1.73 mi^2 or 4.480 km^2 (Water and Environmental Research Institute of the Western Pacific 2014). Both watersheds drain into Cocos Lagoon. On the western side of Cocos Lagoon is the Philippine Sea and on the eastern side is the Pacific Ocean. However, it appears that water draining from the Geus watershed into Cocos Lagoon exits out through the western channel (see Figure 21). Water draining from the Manell watershed into Cocos Lagoon exits out the eastern channels into the Pacific Ocean (see Figure 21). Cocos Lagoon may be identified by the light blue water in Figure 21. Table 7 presents an overview of the main characteristics of the Manell and Geus watersheds. Vector datasets (i.e., rivers, municipal boundaries, basin divides, and the boundaries of the marine protected area) are overlayed on satellite imagery (see Figure 21).

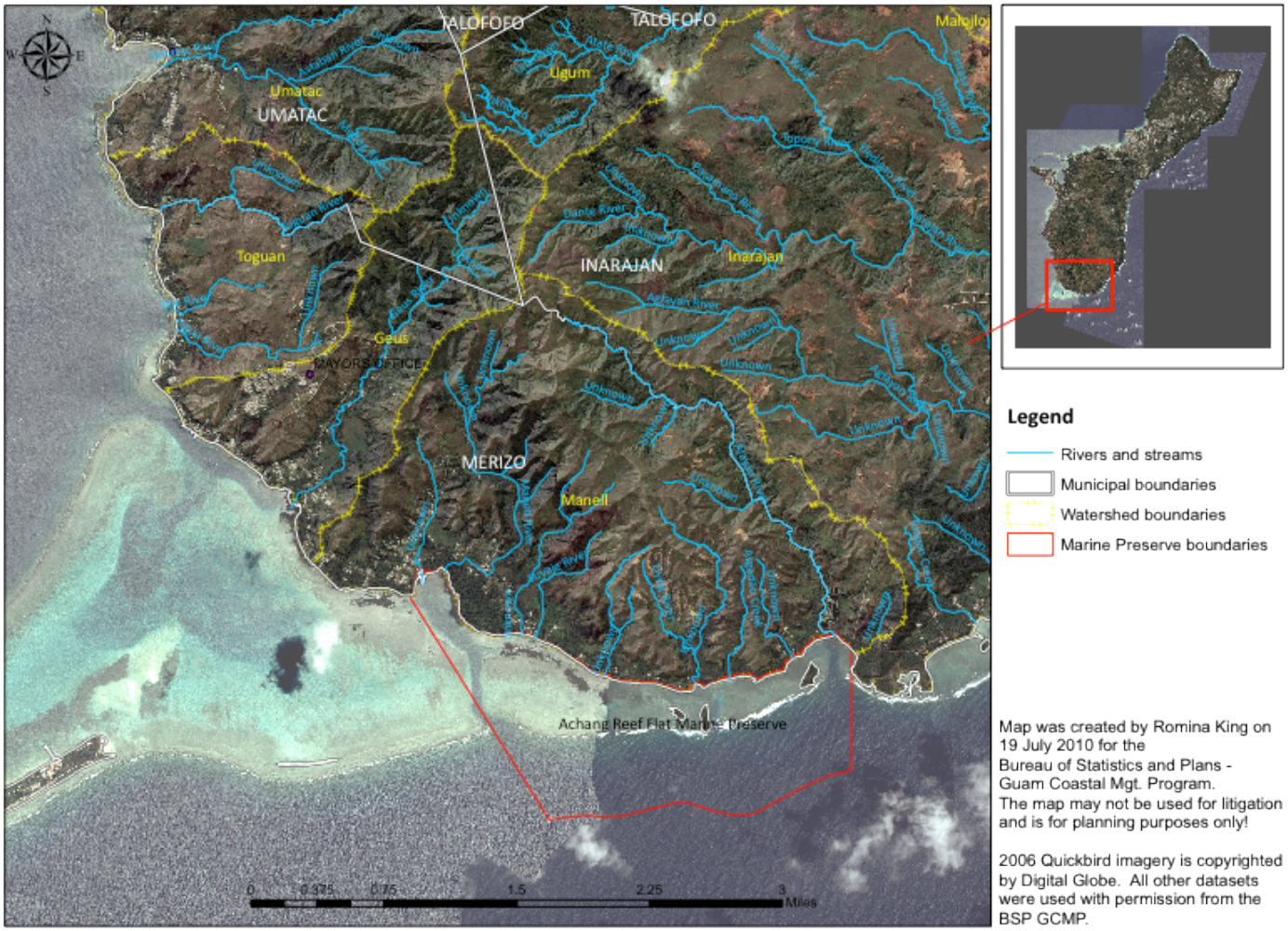


Figure 21. Site Map of the Manell and Geus Watersheds, located in Southern Guam.

Table 7. Characteristics of the Manell and Geus Watersheds, located in Guam. Area, mean elevation, maximum elevation, mean slope, landcover distribution, and forested areas were calculated using 2007 LIDAR data. Mean annual precipitation was calculated using data from local rain gauges. High priority area for fuels treatment and highest priority treatment areas were calculated using GIS overlays of the vegetation map (derived from the LIDAR). The highest priority treatment areas identifies the acres where one would get the most benefit for the cost of treatment – the highest priority areas that will meet multiple objectives. These acres combine risks to meet multiple objectives by being within 300 ft of a forest edge, delivering sediment to streams, and having moderate - extreme fire behavior risk. Ownership was calculated from a land ownership distribution data provided by the Government of Guam. Estimated delivered sediment yield, delivered sediment yield (tons/acre/year) were calculated using the N-SPECT model All data was compiled from the Guam Statewide Forest Resource Assessment and Resource Strategy 2010 – 2015.

Watershed	Area			Mean Elevation		Maximum elevation		Mean slope	Mean annual precipitation		Land cover distribution					Ownership		Estimated Delivered Sediment Yield (average tons/year)	Delivered Sediment Yield (tons/acre /year)	Forested Acres/Total Acres	High Priority area for Fuels Treatment to Protect Forests (Fire Risk rated Moderate to Extreme) in Acres	Highest Priority Treatment Areas - Multiple Objectives (acres)
	acres	sqmi	sqkm	ft	m	ft	m	%	in	cm	Bare Ground	Developed	Forest	Non-Forest	Other	GovGuam	Private					
Manell	3,107	4.9	12.6	226	69	1106	337	27	96	244	14%	3%	32%	51%	0%	43%	57%	63,147	20.3	988/3,107	977	689
Geus	1,120	1.7	4.5	331	101	1122	342	33	100	253	5%	10%	44%	41%	0%	75%	25%	8,822	7.9	493/1,120	341	206

Table 8: Freshwater resources of the Manell and Geus watershed. Data was compiled from the Guam Statewide Forest Resource Assessment and Resource Strategy 2010 – 2015.

	Length of Streams					
Watershed	**Perennial**		**Intermittent**		**Total**	
	mi	km	mi	km	mi	km
Manell	12.7	20.5	3.6	5.8	16.3	26.3
Geus	3.3	5.3	0	0	3.3	5.3

6.1.1 Physical Geography characteristics

The following sections present the geology, topography, climate, soils, landcover, benthic habitat, water resources, and flood zones within the Manell and Geus watersheds.

6.1.1.1 Geology

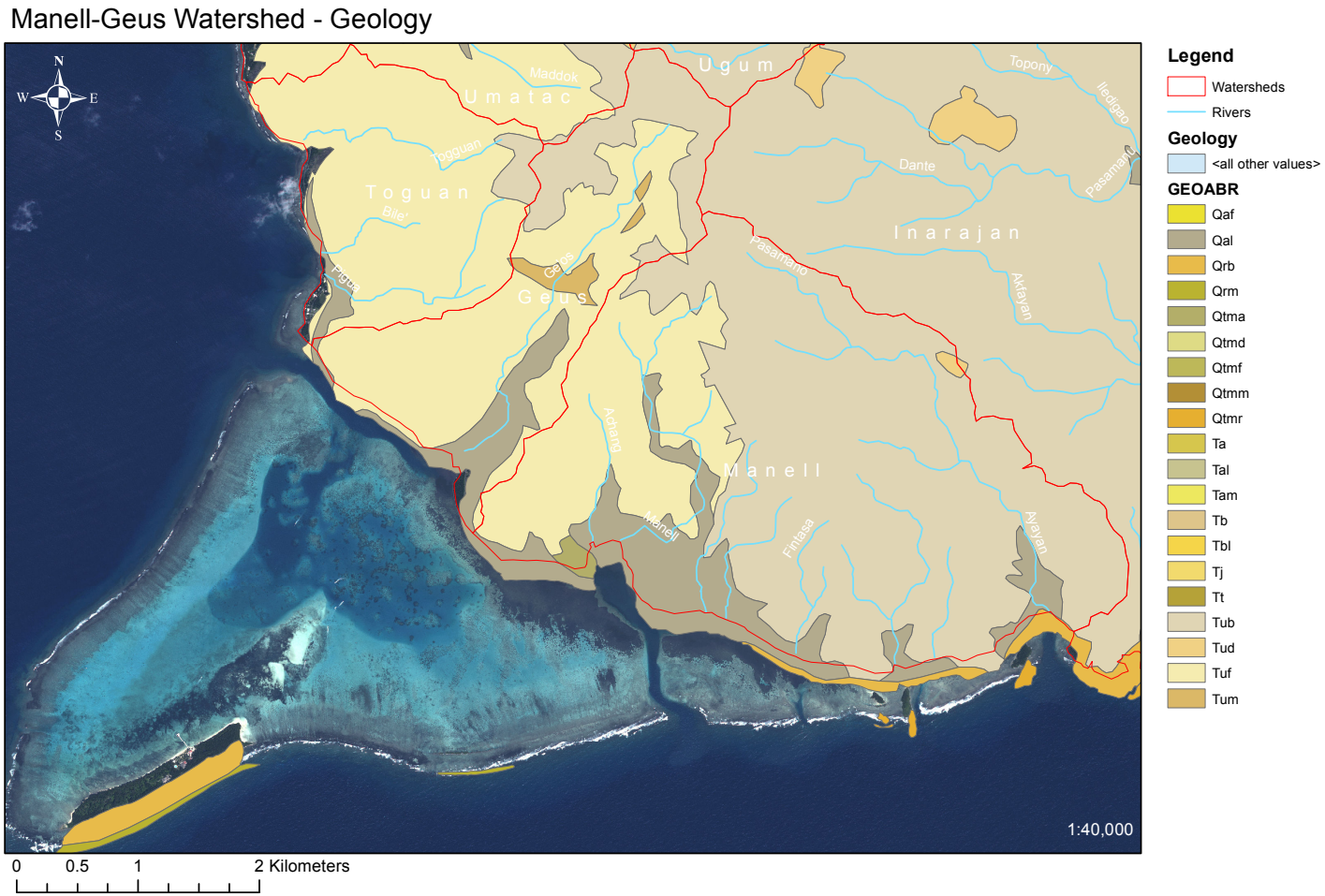
The Geus watershed is composed primarily of Tuf, Tub, and Qal (see Figure 22 and Table 9). The Manell watershed is similar to the Geus watershed with regard to geology and primarily composed of Tub, Tuf, and Qal (see Figure 22 and Table 10). Qal is Alluvium (Quaternary) – Alluvial clay deposits, mostly 30-100 feet thick, muck and clay in marshy estuarine deposits on the west coast, scattered sand and gravel bars within deposits near southeast river mouths, and clay fill in large sinks in limestone areas. Tub is Bolanos pyroclastic member (Miocene) and consists of breccia, conglomerates, and sandstones consisting largely of fragmented andesite. These andesites typically have prominent euhedral augite phenocrysts up to one centimeter in length and millimeter-scale plagioclase phenocrysts. Limestone clasts are conspicuous in some breccias and conglomerates. Estimated thickness of the Bolanos pyroclastic member ranges from 750-1000 feet. In order to calculate the area of the various types of geology present within in each watershed, the intersect tool was used in ArcGIS to compute a geometric intersection of the Geus river basin and the general geology of Guam dataset. The resulting shapefile provided geological information strictly within the Geus watershed. An additional field was added to the attribute table and the area for each type of geology was calculated, using the 'calculate geometry' feature. The same method was used to determine the area of the various type of geology within the Manell watershed.

Table 9: Geology of Geus Watershed.

GEOABR	Area (sq km)
Qal	0.488568239
Tub	1.032196509
Tuf	2.788845784
Tum	0.158486961

Table 10: Geology of the Manell watershed.

GEOABR	Area (sq.km.)
Qal	1.389458944
Qrb	0.005318242
Qtma	0.048168068
Tub	7.733863839
Tud	0.025946949
Tuf	2.579821798



2011 WorldView-2 imagery is copyrighted by DigitalGlobe and provided by the Bureau of Statistics and Plans Guam Coastal Management Program. All other datasets were provided by the University of Guam (UoG) Water Energy Research Institute (WERI) and Island Research & Education Initiative (IREI) and downloaded via www.hydroguam.net.

Map was created by Romina King on 11 March 2014 for her doctoral dissertation.

Figure 22: Geology of the Manell and Geus watersheds.

6.1.1.2 Topography

The 2007 Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX). LiDAR data were collected using the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system for the Government of Guam Department of Public Works and the Office of Homeland Security from February 18 through May 20, 2007. Because Guam did not have the necessary computing power, the raw LAS datasets were processed by the U.S. Army Corps of Engineers in Honolulu, HI in order to produce this 2007 LiDAR dataset. LiDAR data were originally collected to produce 2-foot (.6096 m) contours (see Figure 5 and Figure 23) and derive a digital elevation map (see Figure 24).

Figure 23 provides 30-meter elevation contours for the Manell and Geus watersheds. Data for 6-meter elevation contours is also available. It is recommended for use for in a large-scale elevation contour map of the Manell and Geus watersheds, to help determine best areas for re-vegetation (in conjuction with Figure 30 and Figure 31) and best possible access routes to those areas.

The highest elevation is approximately 1122 feet (342 meters) in the northern most point of Manell Watershed (Water and Environmental Research Institute of the Western Pacific 2014). Within the Geus watershed, the highest elevation is approximately 833 feet (254 meters) (Water and Environmental Research Institute of the Western Pacific 2014). These elevation figures correspond with Figure 24. With a digital elevation model (DEM), it is possible to calculate the slopes using the spatial analyst extension in ArcGIS. Guam's DEM is derived from the LiDAR dataset mentioned above. Slopes were calculated using DEM in ArcGIS. Figure 25 shows the slopes within the Manell and Geus watersheds; the steepest slopes are depicted in red.

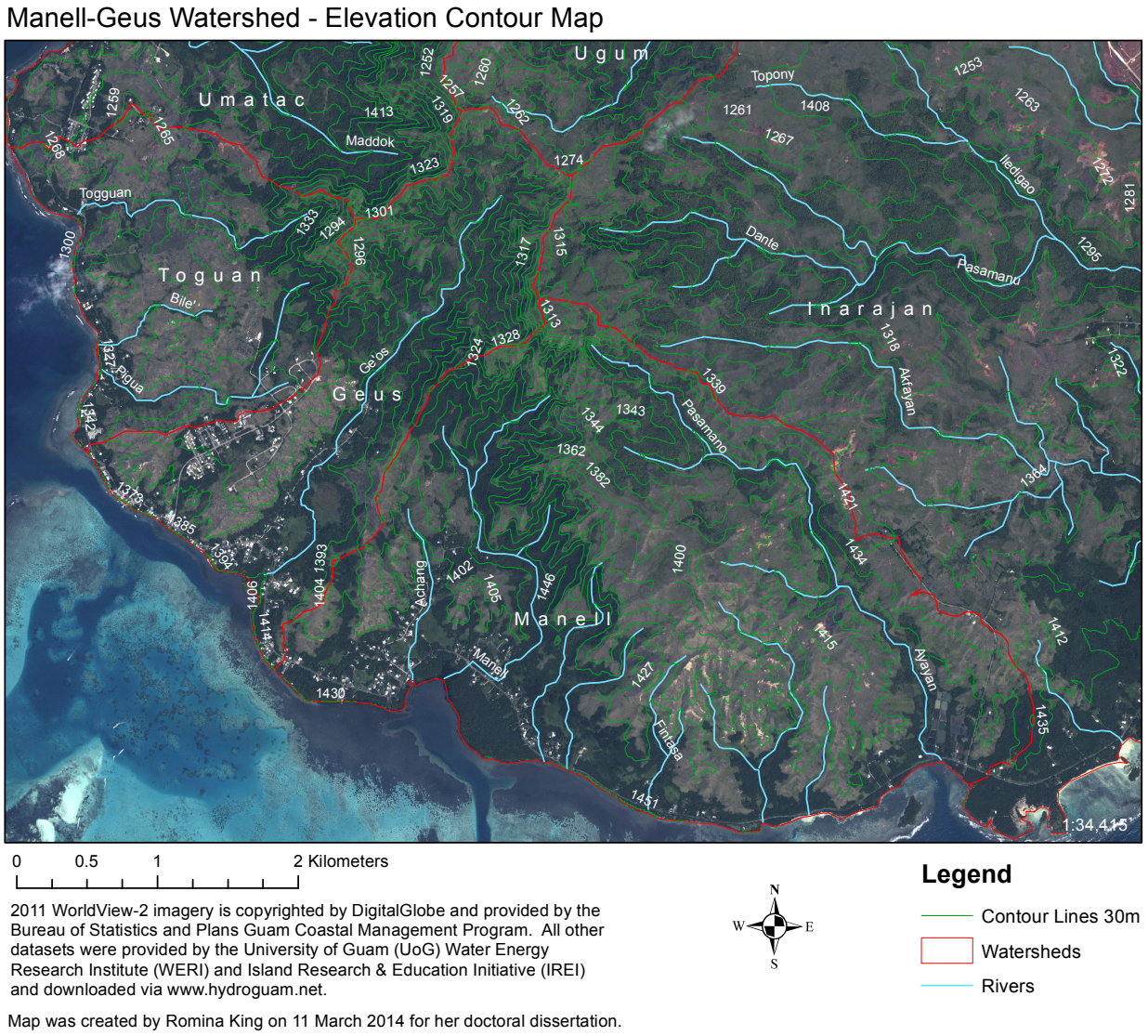


Figure 23: Elevation contour (30 m) map of the Manell and Geus watersheds.

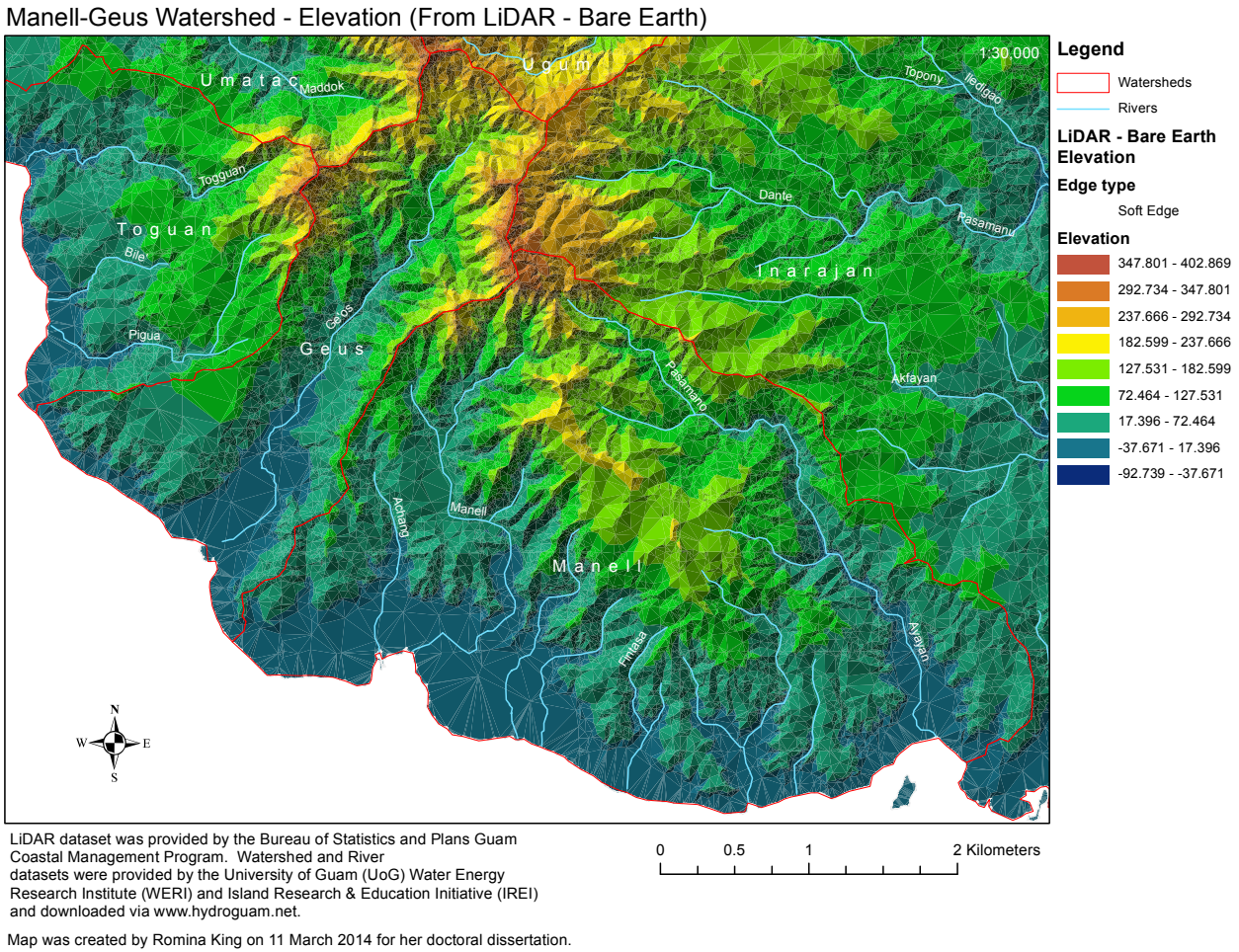


Figure 24: Digital Elevation Model of the Manell and Geus watersheds derived from 2007 LiDAR (Bare Earth).

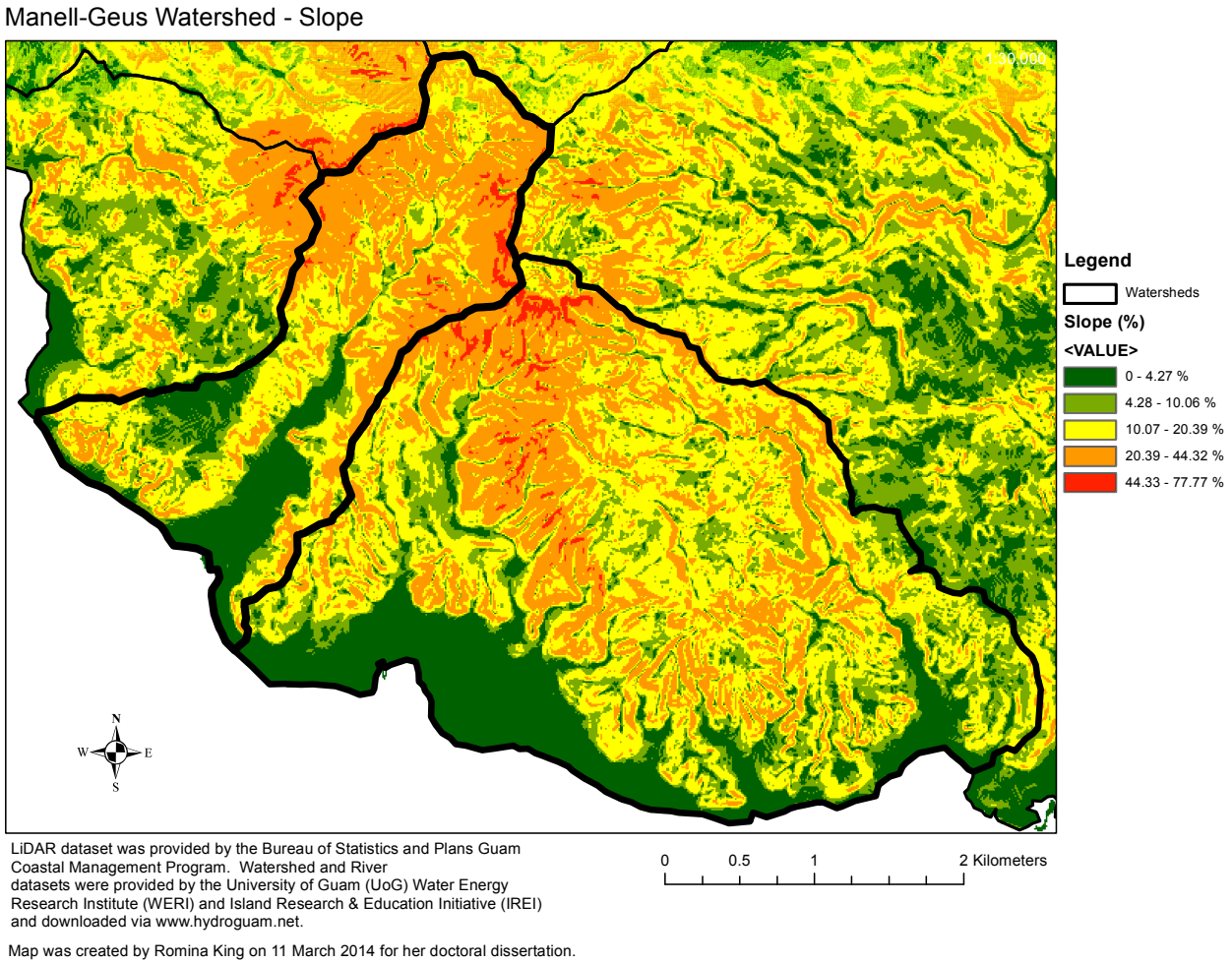


Figure 25: Slopes (derived from 2007 LiDAR data) of the Manell and Geus watersheds.

6.1.1.3 Climate

The climate of Guam is characterized by a dry season that runs from December through June, and a wet season from July through November. Annual rainfall is high, averaging 90 to 110 inches (228.6 – 279.4 cm) of precipitation (see Figure 7). Temperatures average 81 °F (27.2 °C) annually, with the coolest and least humid period being December through February.

6.1.1.4 Soils

Within the Geus watershed, the two most abundant general soil types found include Akina-Agfayan and Inarajan-Inarajan Variant (see Figure 26 and Table 11). Within the Manell watershed, the three most abundant general soils found include Akina-Agfayan, Akina-Togcha-Ylig, and Inarajan-Inarajan Variant (Water and Environmental Research Institute of the Western Pacific 2014) (see Figure 26 and Table 12). These soils are predominantly clays and can absorb a little amount of water (Young 1988). In order to calculate the area of the various soils present within in each watershed, the intersect tool was used in ArcGIS to compute a geometric intersection of the Geus river basin and the general soils of Guam dataset. The resulting shapefile provided information on soils strictly within the Geus watershed. An additional field was added to the attribute table and the area for each type of soil was calculated, using the 'calculate geometry' feature. The same method was used to determine the area of the various soils within the Manell watershed.

Table 11: General Soil types found within the Geus watershed

Soils General	Location	Depth	Area (km^2)
Akina-Agfayan	Volcanic Upland	very shallow to very deep	4
Akina-Atate	Volcanic Upland	shallow to very deep and Badlands	0
Akina-Togcha-Ylig	Volcanic Upland	very deep	0
Inarajan-Inarajan Variant	Bottomland	deep and very deep	1
Urban land	Limestone Upland	very shallow and shallow	0

Table 12: Soils found within the Manell watershed.

Name	Location	Depth	Area (km^2)
Akina-Agfayan	Volcanic Upland	very shallow to very deep	9
Akina-Atate	Volcanic Upland	shallow to very deep and Badlands	0
Akina-Togcha-Ylig	Volcanic Upland	very deep	1
Inarajan-Inarajan Variant	Bottomland	deep and very deep	2
Pulantat-Kagman-Chacha	Limestone Upland	shallow to very deep	0
Ritidian-Rock outcrop	Limestone Upland	very shallow	0
Shioya	Coastal land	deep and very deep	0

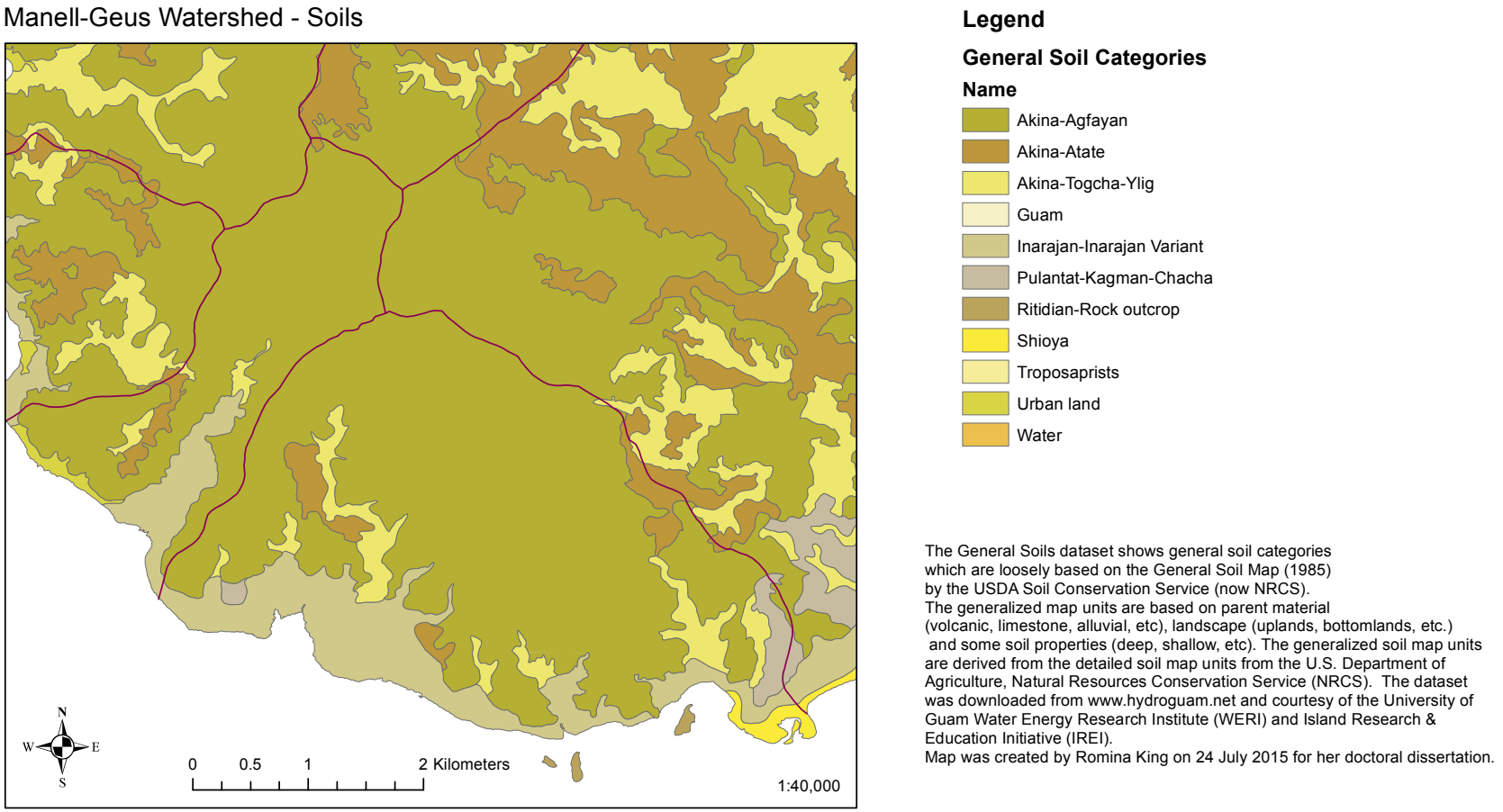


Figure 26: Soils found within the Manell and Geus Watersheds.

6.1.1.5 Land Cover

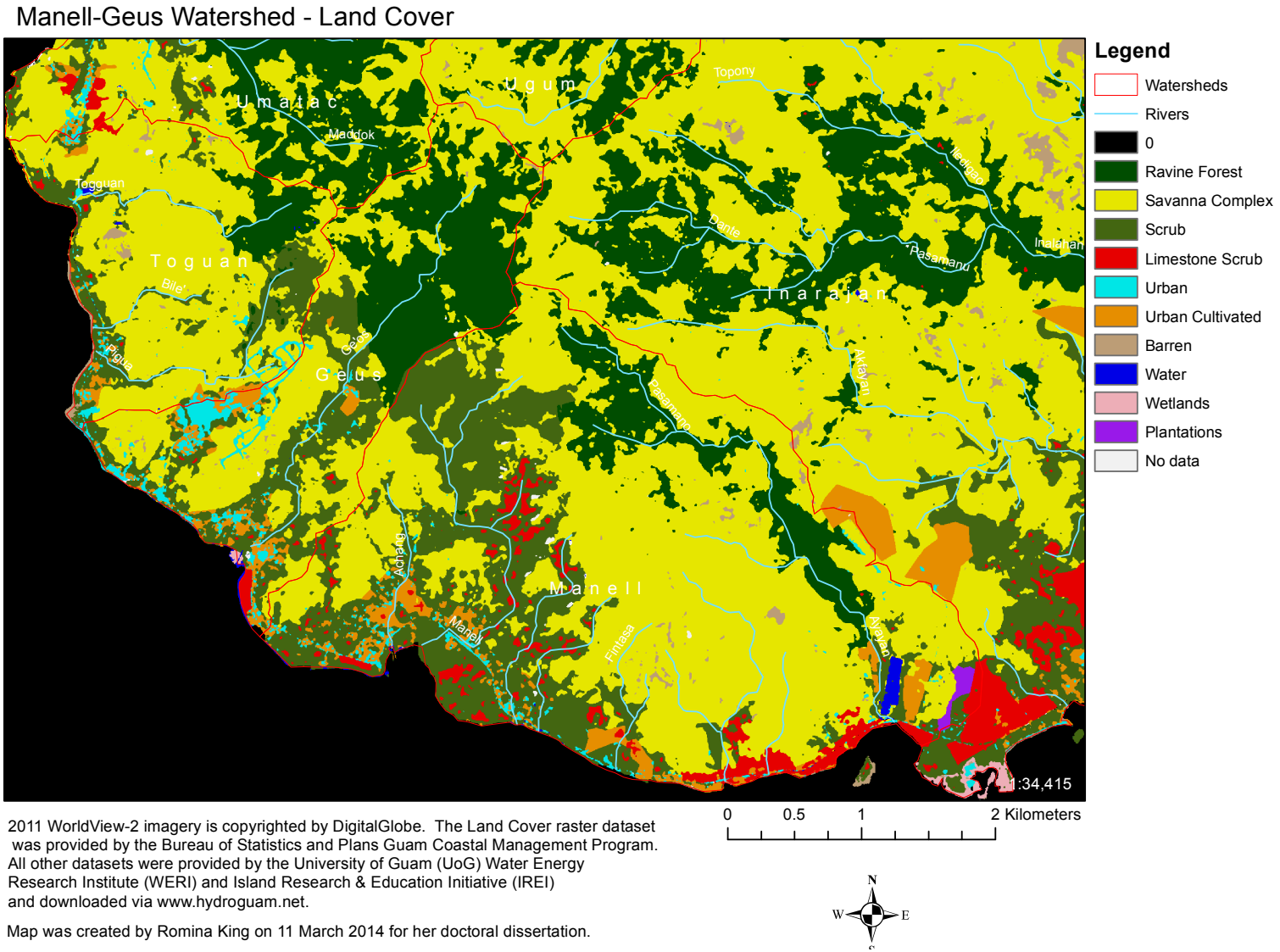
There is very little urban area within either the Manell or Geus watershed and the majority of both watersheds appear to be vegetated (see Figure 28). The vegetation within the Manell watershed is primarily dominated by Savanna complex (see Figure 28). This is one of the dominant vegetation types in Southern Guam due to the presence of volcanic soils (Taborosi 2013). There is ravine forest found along the Ajayen River (the eastern-most river of the Manell Watershed); scrub forest found along the Manell River; and intermittent patches of limestone scrub (see Figure 28). Ravine forests are mixed broadleaf forests that tend to develop in topographic depressions and consist of vegetation that grow well in volcanic soil and in the vicinity of surface water (Taborosi 2013). Most native ravine forests found on Guam are fairly degraded due to the damage from ungulates, fire, and introduced plant species (Taborosi 2013). Scrub forests are diverse brush-type forests that develop after the removal of primary forests or the degradation of secondary forects (Taborosi 2013). Figure 28 shows that the northern half of the Geus Watershed is composed of ravine forest, surrounded by savanna complex. The southern half of the Geus Watershed appears to be predominantly savanna complex with the exception of scrub forest surrounding the Geus River (see Figure 28).

6.1.1.5.1 Grasslands

Grasslands, (i.e., savanna complex), is a secondary vegetation community, dominated by grasses, found on volcanic soils (Taborosi 2013). The presence of grasslands is often evidence of human disturbance. In Guam's case, grasslands most likely developed as a consequence of land clearing techniques (i.e., repeated fires) by early human settlers (Athens and Ward 2004; Donnelly 2010). Figure 30 shows the location of grassland in the Manell and Geus watersheds. There is substantive amount of grasslands in both watersheds.



Figure 27: Photograph of grasslands in Southern Guam.



2011 WorldView-2 imagery is copyrighted by DigitalGlobe. The Land Cover raster dataset was provided by the Bureau of Statistics and Plans Guam Coastal Management Program. All other datasets were provided by the University of Guam (UoG) Water Energy Research Institute (WERI) and Island Research & Education Initiative (IREI) and downloaded via www.hydroguam.net.

Map was created by Romina King on 11 March 2014 for her doctoral dissertation.

Figure 28: Land cover of the Manell and Geus Watersheds.

6.1.1.5.2 Badlands

Badlands are areas of bare, nutrient poor soil and characterized by their distinct rusty-brown color (commonly known as "red dirt"). Ziemer (1987) noticed that repeated fires have led to the alteration of soil to saprolite (chemically weathered rock that is nutrient poor). The bare areas (badlands) often appear first on the ridges, then expand downward, but can also occur mid-slope and are prone to extreme erosion especially after heavy rains. Ziemer (1987) proposed the planting of vegetation with woody roots that could penetrate the soil and arrest erosion, after controlling or lessening the consistent periodic fires. Currently, in an effort to reclaim the badlands, one approach taken by the Department of Agriculture is to plant *Accacia spp.*, a fire-resistant and nitrogen-fixing tree. Another approach was to plant vetiver (Minton 2006). Ziemer (1987) also speculated that the natural forest margins retreat and grassland expands with continued burnings and proposed an analysis of historical aerial photographs to verify this hypothesis. Figure 31 depicts the location of badlands within the Manell and Geus watersheds.



Figure 29: Photograph showing a badland in the Manell watershed. Photo is courtesy of Maria Kottemaier.

The volcanic soils of southern Guam are associated with extensive erosion problems (Ziemer 1987), due to the presence of badlands. Badlands are extremely susceptible to erosion through wind and slope failure caused by oversaturation or earthquakes. Increased sedimentation associated with increased soil erosion and surface water runoff is a growing universal threat to coral reefs. Terrestrial runoff from landscape altering or clearing activities, such as the construction of houses, hotels, resorts, golf courses, marinas, recreational facilities, piers, roads, bridges, and waste treatment plants

negatively impact near-shore coral reefs (Fabricius 2005). Sediment from runoff may settle on coral reefs, smothering them or increasing the turbidity of the water, which reduces both the amount of light reaching corals and the level of photosynthetic activity by corals' zooxanthellae (Fabricius 2005). This, in turn, can cause diminished coral productivity and growth, enhanced macroalgal growth, and, ultimately, a communal shift on the reef from corals to macroalgae.

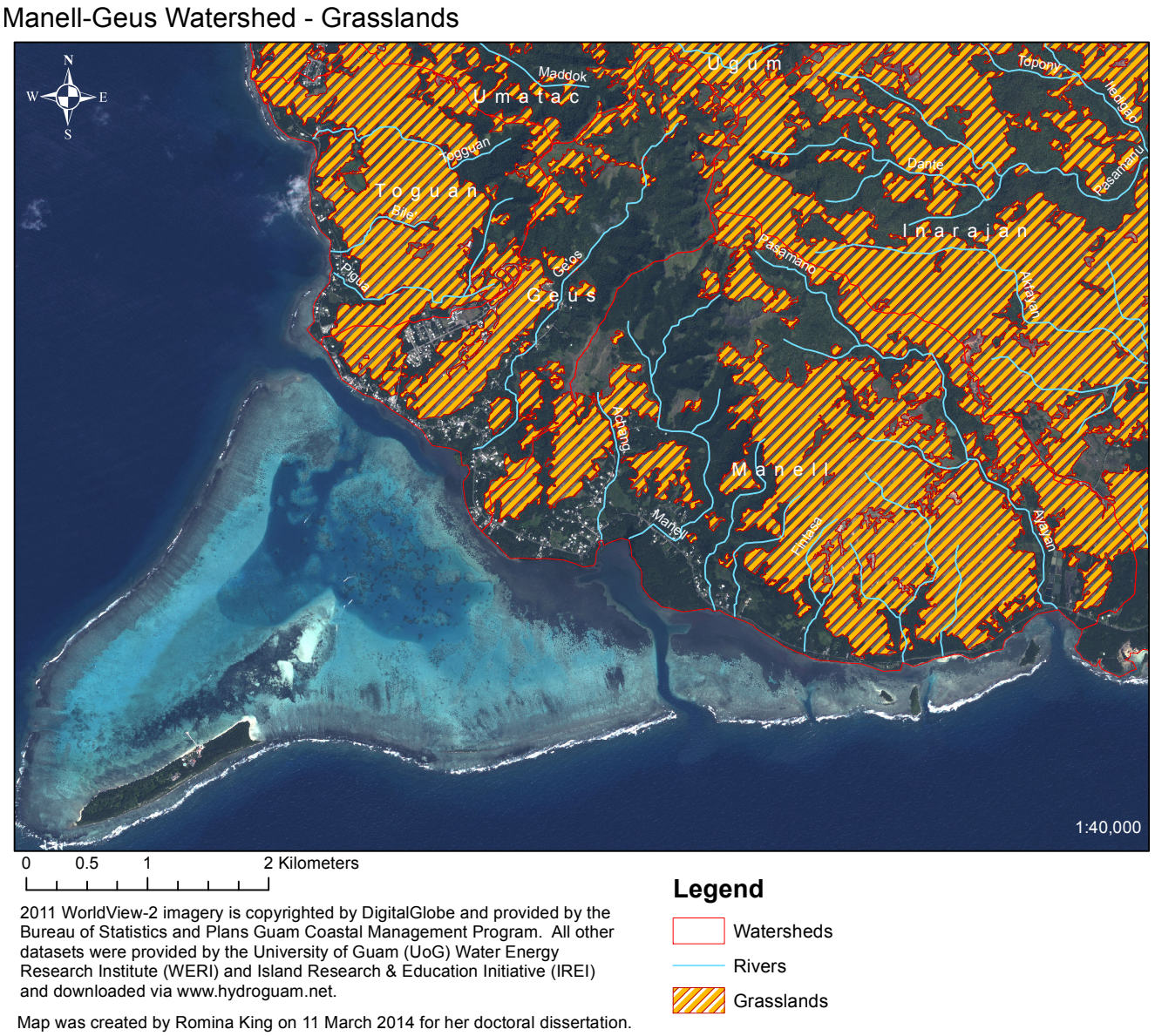


Figure 30: Location of grasslands (savanna complex) within the Manell and Geus watersheds

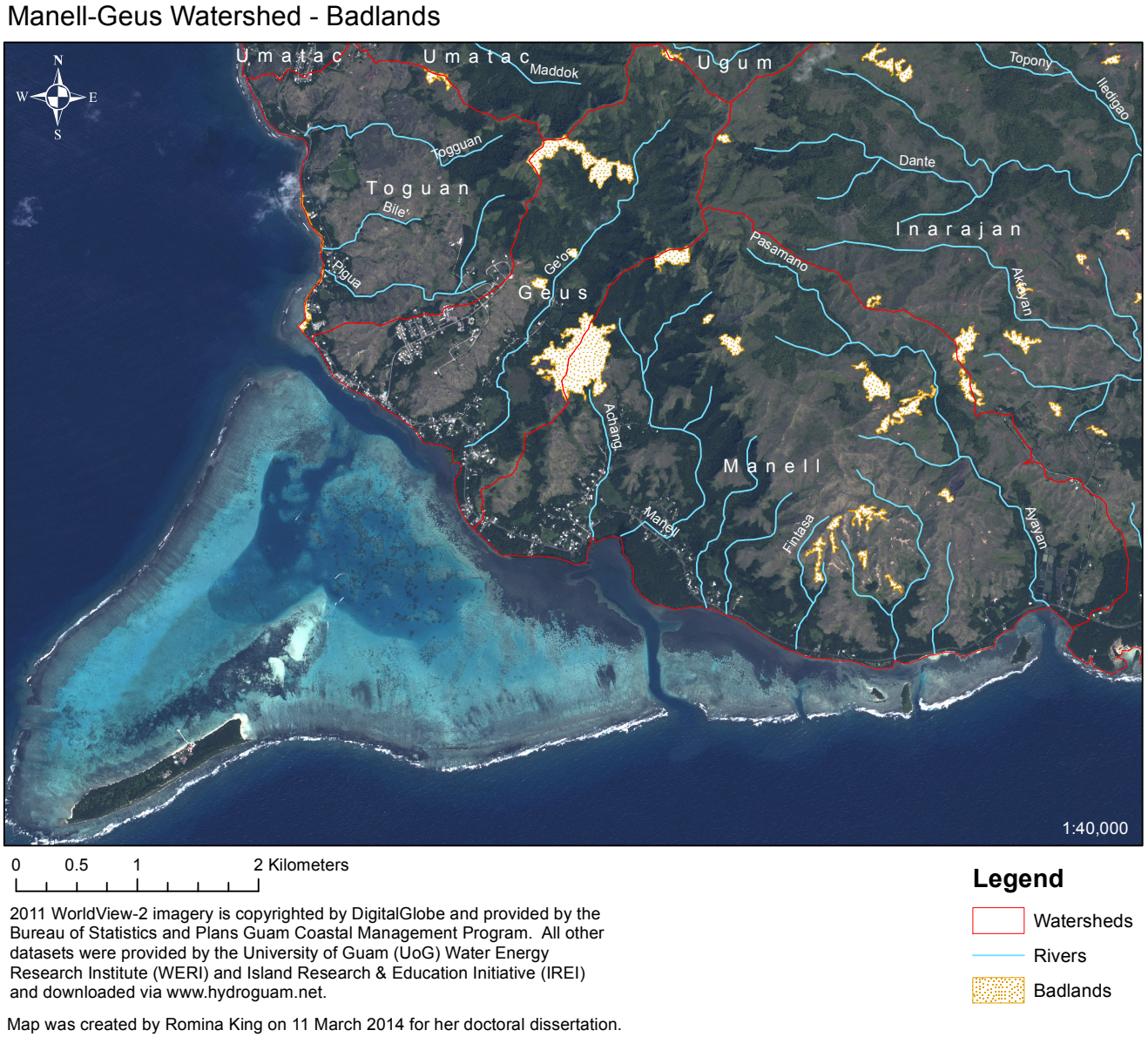


Figure 31: Location of badlands within the Manell and Geus watersheds

6.1.1.6 Benthic habitat

Guam is surrounded by offshore banks and fringing, patch, submerged, and barrier reefs. The coral reef lagoon area encompasses approximately 108 km^2 in nearshore waters (between 0 and 3 nautical miles) (Burdick et al. 2008). There are currently more than 1000 species of reef fish and more than 400 species of corals (Porter et al. 2005, Burdick et al. 2008). Some models and emission scenarios suggest that coral reefs located in Micronesia, may be particularly vulnerable to climate change (Donner et al. 2005).

The benthic habitat dataset (Burdick 2005) provides additional information such as structure. Benthic cover would be the most appropriate data for natural resource and coastal zone managers (Burdick, personal communication, 2014). Cocos Lagoon is surrounded by a fringing reef (see Figure 32). Coral reefs provide natural shoreline protection; provide a habitat for a variety of fish, crustaceans, and sea cucumbers; and offer potentially useful pharmaceutical substances to deal with cancer, inflammation, and bacteria (Moberg and Folke 1999).

6.1.1.6.1 Seagrass

There are substantive seagrass beds along the coast of the Manell watershed and north of Cocos Island (see Figure 32). Only three species of seagrasses occur in Guam waters: *Enhalus acoroides*, *Halophila minor*, and *Halodule uninervis*. The largest species, *Enhalus acoroides*, inhabits the sandy-silt areas near the mouths of rivers in the southern half of Guam. *Halodule uninervis* is abundant in Cocos Lagoon; a few patches can also be found on the shallow sandy reef flats near shore in the southern bays. *Halophila minor* can be found in shallow sandy reef flats and deeper lagoon environments.

6.1.1.7 Achang Marine Preserve

The Manell watershed drains into the Achang Reef Flat Marine Preserve (See Figure 32). No fishing, collecting, or harvesting of organisms is permitted in this preserve. However, fishing for seasonal fish (i.e., *manahak, atulai*, and *achemson*) is authorized by special permit from the Department of Agriculture Division of Aquatics and Wildlife Resources. This marine preserve is not actively enforced by DAWR, which can be irksome for law-abiding residents as they watch others violate the rules.

The Achang Reef Flat Preserve (4.8 km^2) is adjacent to the Manell Watershed. It includes a wide variety of habitats including mangroves (see Figure 33), seagrass (see Figure 32),

sand (see Figure 32), coral (see Figure 32), and channels (see Figure 32). The seagrass, mangrove, and estuarine areas of this preserve are important nursery areas for a number of fish species. Manell Channel, the largest channel included in the preserve, is an important congregation site for green sea turtles as the surrounding areas include rich foraging habitat including dense sea grass beds (Brown 2013, personal communication). There seems to be great support for the Achang Marine Preserve. Approximately, 41% of respondents (all residents of Manell and Geus watershed) support Achang Marine Preserve; 19% oppose it; and 30% do not know whether they support or oppose the preserve (see Figure 32).

The Cocos Lagoon, adjacent to Manell and Geus watersheds, has a predominantly sandy bottom with numerous small patch reefs scattered throughout (see Figure 32). This sheltered area has delicate staghorn coral communities that provide safe refuge for Convention of International Trade of Endangered Species (CITES) listed juvenile humphead wrasse (*Cheilinus undulatus*) and other reef fish species of concern. The lagoon is also home to soft coral stands that provide unique habitat found in few locations.

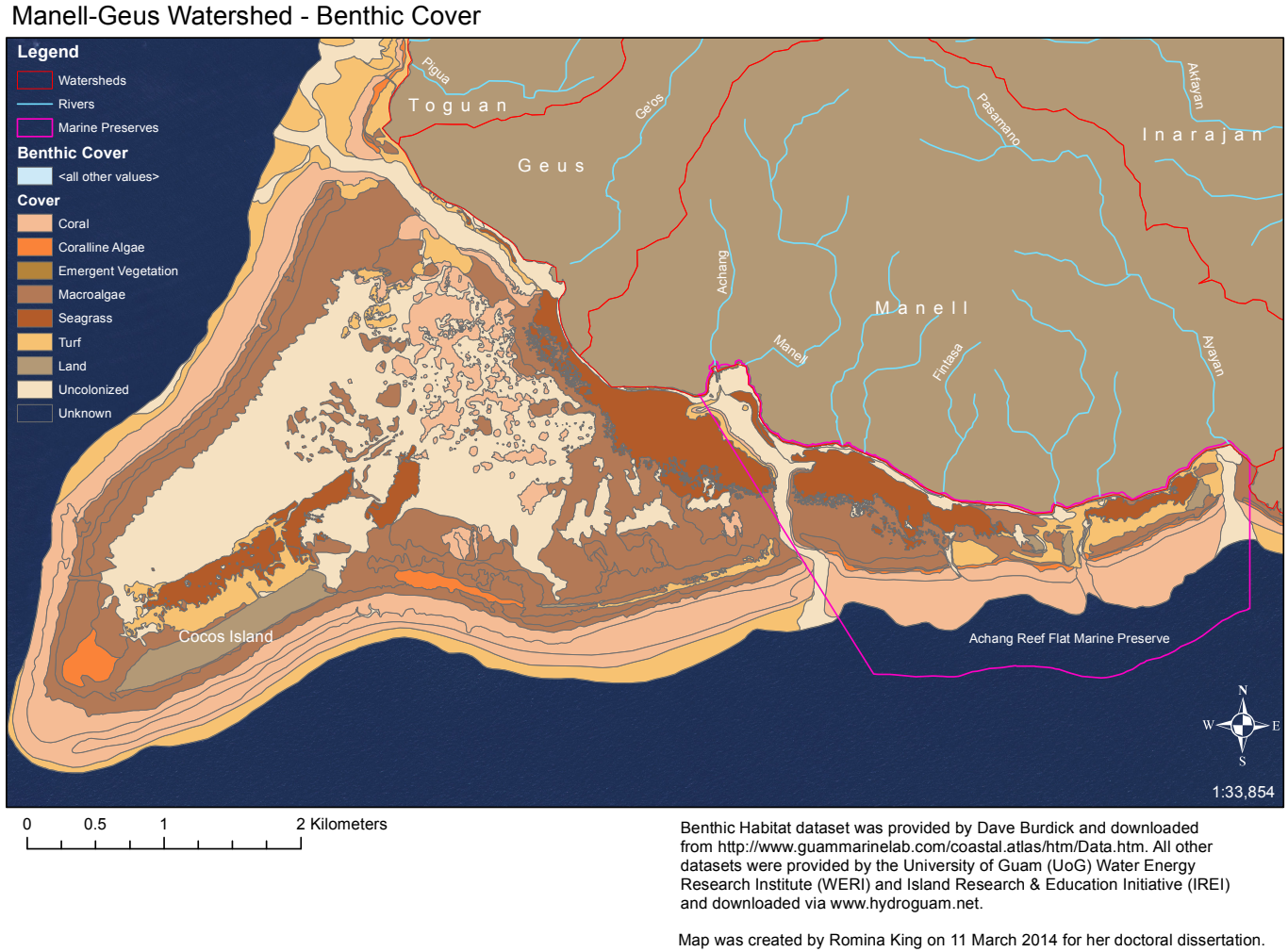


Figure 32: Benthic cover of marine areas surrounding the Manell and Geus watersheds.

6.1.1.8 Reef Fish, Edible Invertebrates, and Turtles

Of the fisheries catch in the coastal waters, crustaceans make up a large portion of non-finfish catch. There are several hundred species of crustaceans on Guam's coral reefs, but only about nine species of crab are targeted, including land and marine crabs. *Carpilius maculatus* and *Etisus splendidus* (the splendid pebble crab) are well fished. Spiny lobsters (*Panulirus pencillatus* and other species) and slipper lobsters (*Scyllarides squamosus* and *Parribacus antarcticus*) catches are also highly prized. Mantis shrimp and freshwater shrimp (*Macrobrachium rosenbergii*) are also harvested.

Echinoderms harvested include two species of sea urchins, the priest-hat urchin or hairy pincushion urchin (*Tripneustes gratilla*) and the Rock boring or math sea urchin (*Echinometra mathaei*), as well as two species of sea cucumbers, the warty Selenka's sea cucumber (*Stichopus horrens*) and the black sea cucumber or lolly fish (*Holothuria atra*). The introduced marine gastropod, Trochus or top shell (*Trochus niloticus*), is one of the larger edible shellfish that can be found on Guam's fringing reefs and reef flats. Species of octopus, including the common reef octopus (*Octopus cyanea*) and the Hawaiian night octopus (*Octopus ornatus*) are also popular mollusk food items.

Shore-based finfish harvesting is by cast nets, surround nets, spear-fishing, hook and line, hooks and gaffs, and gill netting. The principal fishes caught by these methods are surgeonfishes, jacks, rabbitfishes, goatfishes, snappers, emperors, and rudderfshes. Barracudas and mackerels are caught via boat.

Three of the seven species of the world's marine turtles have been reported from the coral reefs of the Mariana Archipelago: the green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricate*), and leatherback turtle (*Dermochelys coriacea*). Harvesting of sea turtles for food was legal on Guam until 1976. However, sea turtle populations decreased to the point that the government intervened and placed a ban on sea turtle harvest. Yet, even with a ban in place, poaching remains a significant problem in Guam and continues to contribute to the decline of turtle populations in this region.

6.1.1.9 Mangroves and Wetlands

Mangroves are trees and shrubs that grow in the coastal intertidal zone. Mangroves are the most carbon-rich forests in the tropics (Donato et al. 2011) and are threatened by climate change (Gilman et al. 2008). Gilman et al. (2008); Gilman et al. (2006); and Gilman (2004) provide an excellent literature review detailing the effects of SLR on

mangrove forests. Ellison and Stoddart (1991) estimate that "mangroves of high islands (deltaic and estuarine mangroves)…which have relatively large supplies of terrigenous inorganic and organic sediment from rivers…can keep pace with a 4.5mm/year relative SLR."

Mangroves are important because they help protect shorelines from erosion by stabilizing sediments with their intricate tangled root systems (Nunn 2009). It is commonly recommended to plant or restore them to increase shoreline protection (Nunn 2009). They assist in maintaining water quality by filtering pollutants and trapping sediments coming from the land. In addition to protection, mangroves also serve as nursery areas for coral-reef fish (Nagelkerken et al. 2002), shrimp (Sasekumar et al. 1992), and mollusks because they provide a sheltered refuge from predators as well as a source of food. Mangrove forests are regarded as renewable resources. Their durable, water-resistant wood may be used for the construction of houses, boats, and furniture (Bandaranayake 1998). Mangrove leaves have been used in medicine, tea, and tobacco substitutes (Bandaranayake 1998). Guam's mangrove forests are the most extensive and diverse in the Mariana Islands(P. Moore et al. 1975).

Guam's mangrove species include *Rhizophora mucronata, R. apiculata, Bruguiera gymnorrhiza, Avicennia marina, Lumnitzera littorea, N. fruticans, Xylocarpus moluccensis, Heritiera littoralis, H. tiliaceus* and *Acrostichum aureum* (Fosberg 1960; P. Moore et al. 1977; P. Moore and McMakin 1979). Guam's mangroves are managed under the 1978 Guam Executive Order No. 78-21, also known as "The Wetland Rules and Regulations". This established procedural guidelines and performance standards for the development and the conservation of wetland areas. It is in compliance with U.S. Federal Executive Order No. 11990, also known as "Protection of Wetlands", which prohibits development on federally owned wetlands.

Manell-Geus Watershed - Mangroves and Wetlands



Legend

- Watersheds
- Rivers

Wetlands and Mangroves

- <all other values>

WETLAND_TY

- Estuarine Wetland
- Mangroves

2011 WorldView-2 imagery is copyrighted by DigitalGlobe and provided by the Bureau of Statistics and Plans Guam Coastal Management Program. All other datasets were provided by the University of Guam (UoG) Water Energy Research Institute (WERI) and Island Research & Education Initiative (IREI) and downloaded via www.hydroguam.net.

Map was created by Romina King on 11 March 2014 for her doctoral dissertation.

Figure 33: Location of mangroves and wetlands within the Manell and Geus watersheds.

6.1.1.10 Water Resources

Water resources may be defined as sources of water available for use by humans, fauna, or flora and includes surface water, groundwater, nearshore waters, and wetlands. The following sections will discuss surface water and groundwater within the Manell and Geus watersheds.

6.1.1.10.1 Surface Water

Surface water is water on the surface of the planet (e.g., stream, river, lake, ocean). Freshwater surface waters include waters that flow continuously over land surfaces (e.g., river or stream), standing water in basins (e.g., lakes, ponds, reservoirs), and water flowing over the land as runoff. Surface waters on Guam are classified into three categories: S-1, S-2, and S-3[17]. The main rivers in the Manell watershed include Ajayan River (2.91 mi), Nelansa River (2.01 mi.), Laolao River (.98 mi), Fintasa River (.77 mi.), Liyog River (.72 mi.) and Asgalao Creek (0.5 mi) (Water and Environmental Research Institute of the Western Pacific 2014). The main river in the Geus watershed is the Geus River (2.71 mi) (Water and Environmental Research Institute of the Western Pacific 2014). It is regarded as one of the most pristine river ecosystems on Guam (Tibbatts, personal communication, 2013). The rivers geospatial dataset is currently being updated by USGS and WERI.

Table 13: Total length of perennial and intermittent streams located within the Manell and Geus watershed. Data was compiled from Table 7 of the Guam Statewide Forest Resource Assessment and Resource Strategy 2010 – 2015.

	Length of Streams					
Watershed	**Perennial**		**Intermittent**		**Total**	
	mi	km	mi	km	mi	km
Manell	12.7	20.5	3.6	5.8	16.3	26.3
Geus	3.3	5.3	0	0	3.3	5.3

[17] According to (Guam Environmental Protection Agency 2001), the category descriptions are as follows: Category S-1 (High) – Surface waters in this category are used for drinking water resources, conservation of wilderness areas. Waters designated as S-1 must be free from substances or pollutants. Category S-2 (Medium)—Surface waters in this category are used for recreation and a potable water supply that may have been treated. S-3 (Low)—Surface waters in this category are primarily used for commercial, agricultural, and industrial activities. All discharges within this zone are not required to have permits.

6.1.1.10.2 Groundwater

Groundwater is defined as any source of water beneath the ground surface. Groundwater makes up 80% of Guam's potable water (Jocson, Jenson, and Contractor 2002). The majority of Guam's water comes from the Northern Guam Lens (Guam Waterworks Authority 2007). The Northern Guam Lens is a carbonate island karst aquifer composed of uplifting limestone units covering the northern half of Guam (Mylroie et al. 1999). Much research has been conducted on the Northern Guam Lens (e.g., Ayers and Clayshulte, 1984; Camp Dresser and McKee Inc (CDM), 1982; Jocson et al., 2002; Mink, 1976; Mylroie et al., 1999). There is little to no groundwater in the Manell and Geus watersheds due to the geologic make-up of Southern Guam. Groundwater resources are predominantly found in Northern Guam.

6.1.1.10.3 Flood zones

Floodplains are areas of low elevation most prone to water inundation. The most recent Flood Insurance Rate Map (FIRM) update for Guam became effective September 28, 2007. Of importance to this watershed, the updated FIRM modified several transects along the southern coast as part of the revised typhoon analysis and decreased the effective floodway along the Geus River (Federal Emergency Management Agency 2012). Figure 35 was created using the 2007 FIRM dataset. The coastal floodplains in red (Zone VE in Figure 35) are located within the 100-year flood zone that are subject to additional hazards, such as storm surge. Zones A, AE, AH, and AO are all areas within the 100-year flood zone; they differ based on base flood elevations (see Figure 35). Areas in green, or Zone X, are outside the 100-year flood zone (see Figure 35). A 100-year flood is not a flood that occurs every century. The 100-year flood has 26% chance of occurring during a 30-year period (Federal Emergency Management Agency 2003). It appears that the transparent Zone A, AE, AH, AO, and VE, overlay quite a number of houses (white specks) on the WorldView-2 imagery (see Figure 35). Essentially, if a home is located in the 100-year flood zone, it is mandatory to purchase flood insurance.

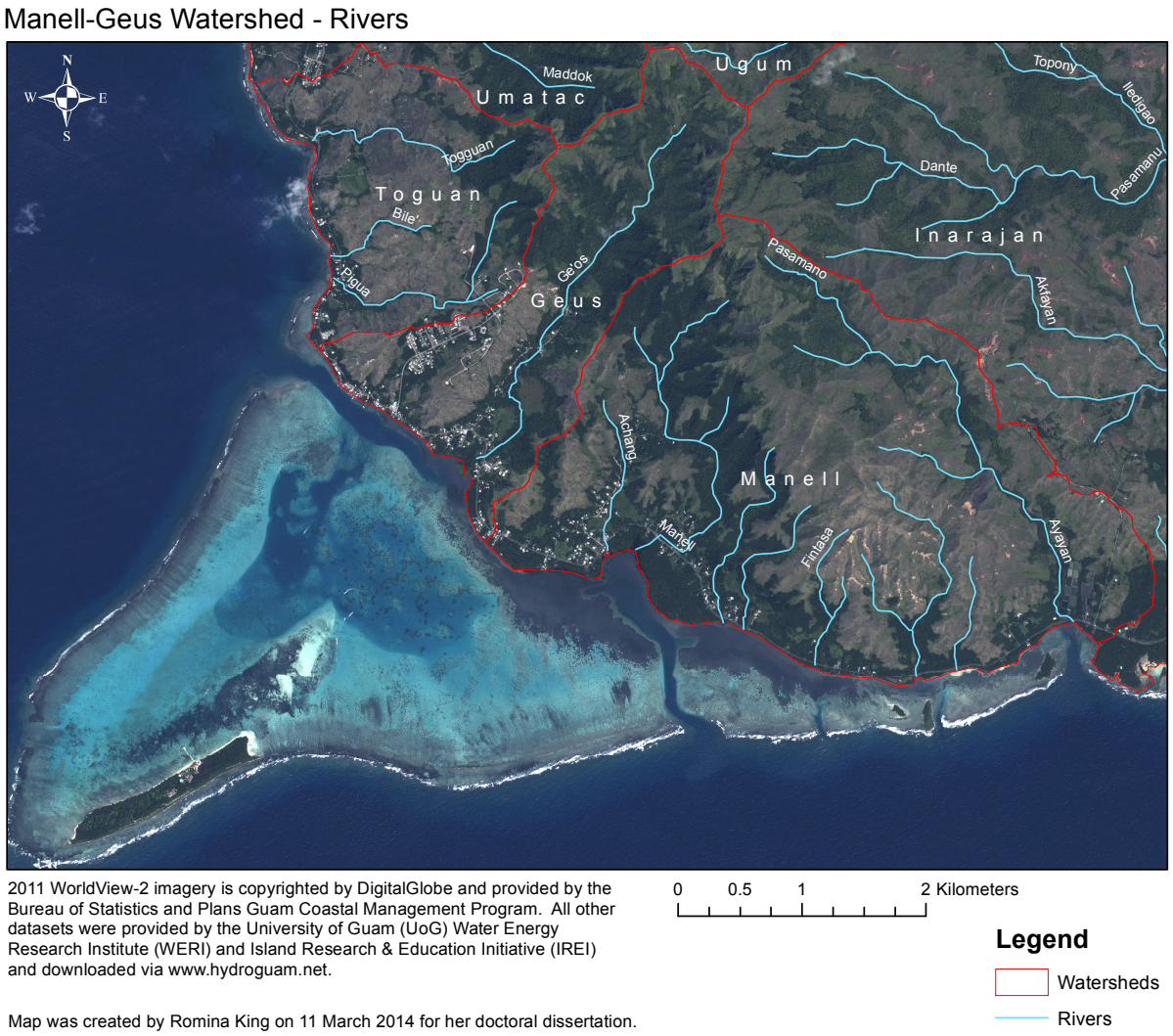


Figure 34: Map depicting the rivers of Manell and Geus watersheds. This river dataset is in the process of being updated by WERI in conjuction with USGS. The version used in this geospatial analysis lacked river names.

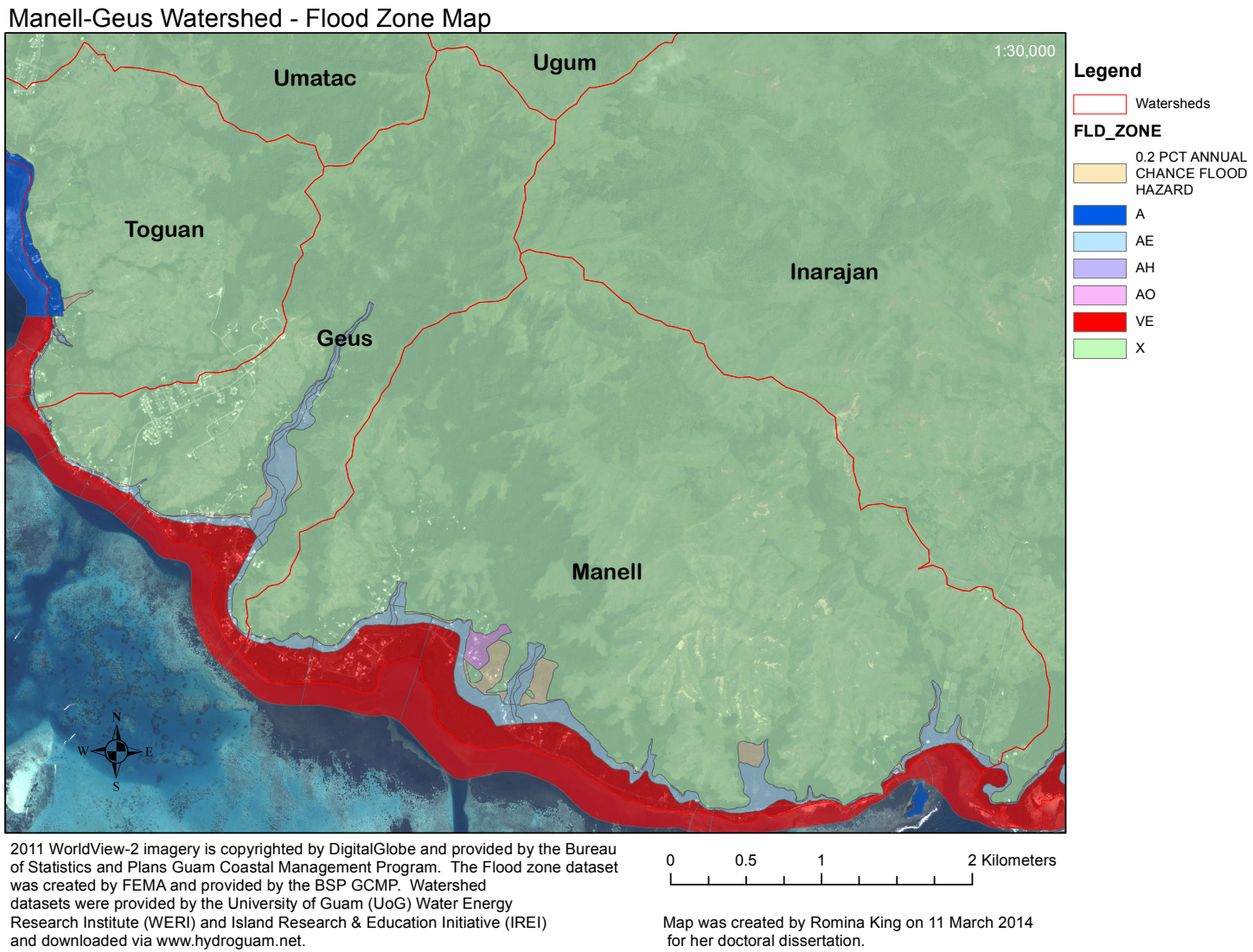


Figure 35: Flood zone map of the Manell and Geus watersheds. Reprinted from King 2014 and used with permission.

6.1.2 Human Geography Characteristics

The main village located within the Manell and Geus watersheds is Merizo. The original Chamorro name of the village, *Malesso'*, comes from the Chamorro word *lesso'*, a stage of growth for *mañåhak*, juvenile rabbit fish. The village is regarded as a traditional fishing village and the harvest of *mañåhak* is an annual cultural tradition. The mayor of Merizo from 2009 – the present is Ernest Chargaulauf.

6.1.2.1 Demographic Profile

The village of Merizo is a homogenous community. The majority of people identify themselves as Chamorro, Catholic, and speak Chamorro within their homes (U.S. Census Bureau 2011a). According to the 2000 U.S. Census, under half of the population (approximately 44% of the population) has attained a high school diploma. Also, the mean family income, according to the 2000 Census, was approximately 49,187 USD (Bureau of Statistics and Plans 2002). Currently, there are approximately 1850 people residing in the village of Merizo (U.S. Census Bureau 2011a), a decrease from the 2,163 people counted in the 2000 Census (U.S. Census Bureau 2001).

6.1.2.2 Prehistory and history

Literature specific to the Manell and Geus watersheds is sparse. See Chapter 1: Section 1.2.4 Pre-history section, for an overarching background for Guam. Archaeological evidence is limited to salvage archaeology reports associated with development. See Section 6.1.2.4 Historical Sites and Figure 37, for a list of sites within the two watersheds. These sites are administered by the State Historical Preservation Office (SHPO). Plate (2009) provides a brief synopsis of the history of Merizo or *Malesso*, the traditional Chamorro name, as it parallels the history of Guam (see 1.2.5 History).

6.1.2.3 Land ownership

While Guam has an official Westernized democratic government, the traditional polity of Micronesian cultures usually centered around the power of chiefs and was the foundation of land and marine tenure (Haglelgam 2004; Hezel 2001; Petersen 2009). The literature on traditional land and marine tenure systems in Micronesia suggests that customary marine tenure varies slightly from island to island because of differences in the power of the chiefs and changes in modern constitutions. However, insights into the traditional polity may assist in facilitating community-based adaptation. For example, in more traditional Micronesian islands, such as Pohnpei, there is still direct reef tenure, or ownership, and hence individuals take responsibility for the state of their coral reefs

and the fisheries they support (Petersen 2009; Hezel 2001). This avoids a "tragedy of the commons" (Hardin 1968). Many Pacific island cultures treat the land-sea interface as a continuum rather than a boundary, and this "ridge-to reef" stewardship recognizes that upslope activities affect people and resources farther down a watershed and in the ocean (Petersen 2009). Traditionally based management systems and efforts may not necessarily be the ultimate and final solution, but they can offer ideas for potential adaptation. One advantage that the islands with intact traditional leadership and ownership of resources have is that they lack "red-tape" and can quickly and effectively apply scientific data and generate immediate dialogue and action (Richmond et al. 2007).

However, in Guam, this traditional polity has been replaced by a Western government. Land holdings are legally bound. The Department of Land Management (DLM) is responsible for updating the cadastral geodata for Guam. Currently, DLM contracted an outside party to update the cadastral geodataset and the dataset is currently waiting for approval.

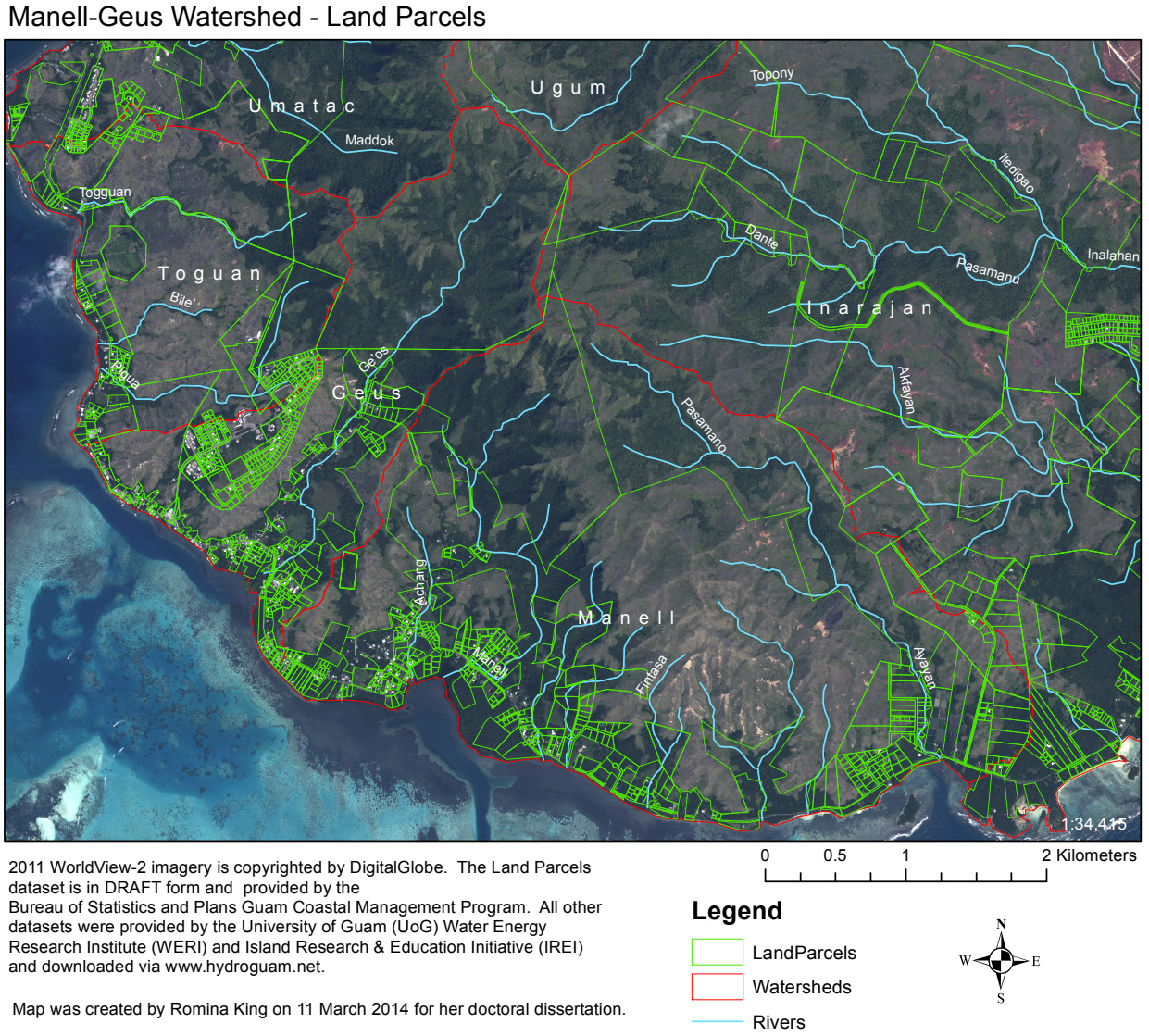


Figure 36: Land parcels within the Manell and Geus watersheds

6.1.2.4 Historical Sites

A historical site is an official location, identified by the Guam State Historic Preservation Office, where cultural, military, political, or social history has been preserved in the form of a building, landscape, site, or structure. There are approximately six historical sites located within the Manell watershed and there are twelve historical sites located within the Geus watershed (see Figure 37). The State Historical Preservation Office (SHPO) does not approve of disclosing specific locations of sites in fear of looting.

Historical and cultural sites located along the coastline are in danger from coastal erosion and flooding. Coastal erosion and flooding may increase with a warming climate, further threatening these cultural and historic sites. By knowing where these sites are, the GCMP may work with SHPO to take measures in safeguarding these locations and incorporating protective action of these locations in local management plans.

Restoring the natural habitat can increase natural resilience to coastal disasters (Adger et al. 2005) . Restoring the natural environment in order to minimize flooding and decrease upland erosion in the Manell and Geus watersheds would entail re-vegetation projects (see Figure 30 and Figure 31). Re-vegetation work requires approval from SHPO to avoid disturbing prehistorical and historical sites. In some instances, this would involve a full-time archaeologist to be present during the removal of invasive species and the planting of native trees.

6.1.2.5 Land Use Zones

Land use zoning classifies the type of development that is allowed on a specific parcel of land. Currently, there is a Draft North and Central Guam Land Use Plan (ICF International, Plan Rite, and Sablan Environmental, Inc. 2009). However, the Manell and Geus watersheds are outside the scope of this plan. The Guam Land Use Commission under the Department of Land Management is empowered to grant subdivision approvals, zone changes, conditional uses and variances. The majority of the Manell and Geus watersheds are zoned “agriculture” (see Figure 38). The areas depicting ‘one-family and multiple dwelling zones make up the village of Merizo (see Figure 38). There are few commercially zoned areas (see Figure 38).

6.1.2.6 Conservation Areas

A conservation area is a tract of land or designated area of water that is protected under law in order safeguard natural features, cultural heritage, or specific biota. Conservations areas are one way to protect and in some instances, increase healthy natural systems. Healthy natural systems can increase natural resilience to coastal storms and flooding. Increase natural resilience can reduce social vulnerability (Adger et al. 2005)

According to (Sablan Environmental, Inc. 2008), approximately 22% of Guam's land has been designated as local or federal conservation lands. The Bolanos Conservation Area is one of the three terrestrial conservation areas (Anao and Cotal are the other two) under the administrative oversight of the Department of Agriculture (Sablan Environmental, Inc. 2008). These conservation areas contain habitats that are critical to native species (Guam Department of Agriculture Division of Aquatics and Wildlife Resources 2005). A portion of the Bolanos Conservation Area is within the northern part of the Geus watershed (see Figure 39). There are no terrestrial conservation areas within the Manell watershed or along the coastline (see Figure 39).

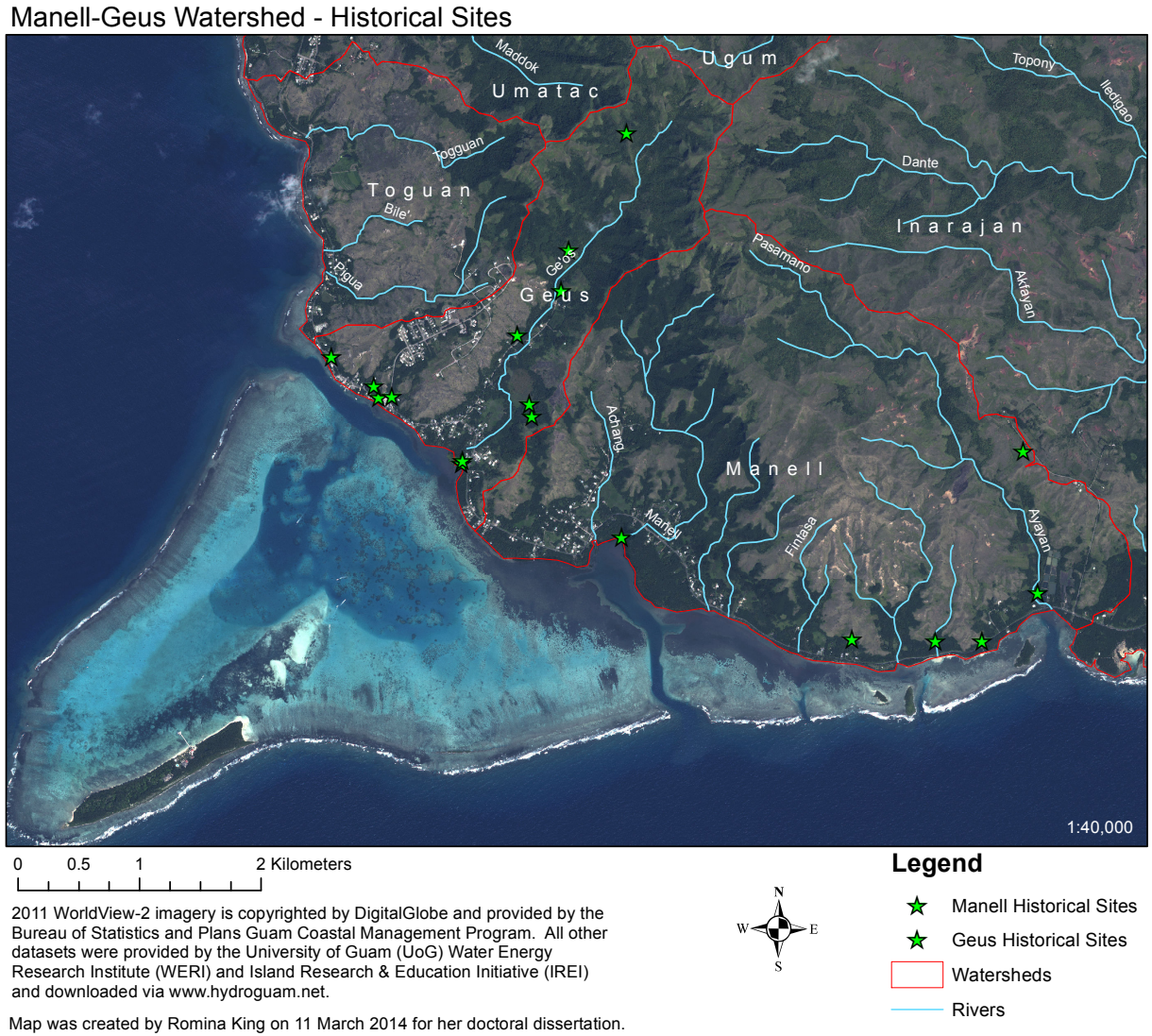


Figure 37: Location of historical sites within the Manell and Geus watershed.

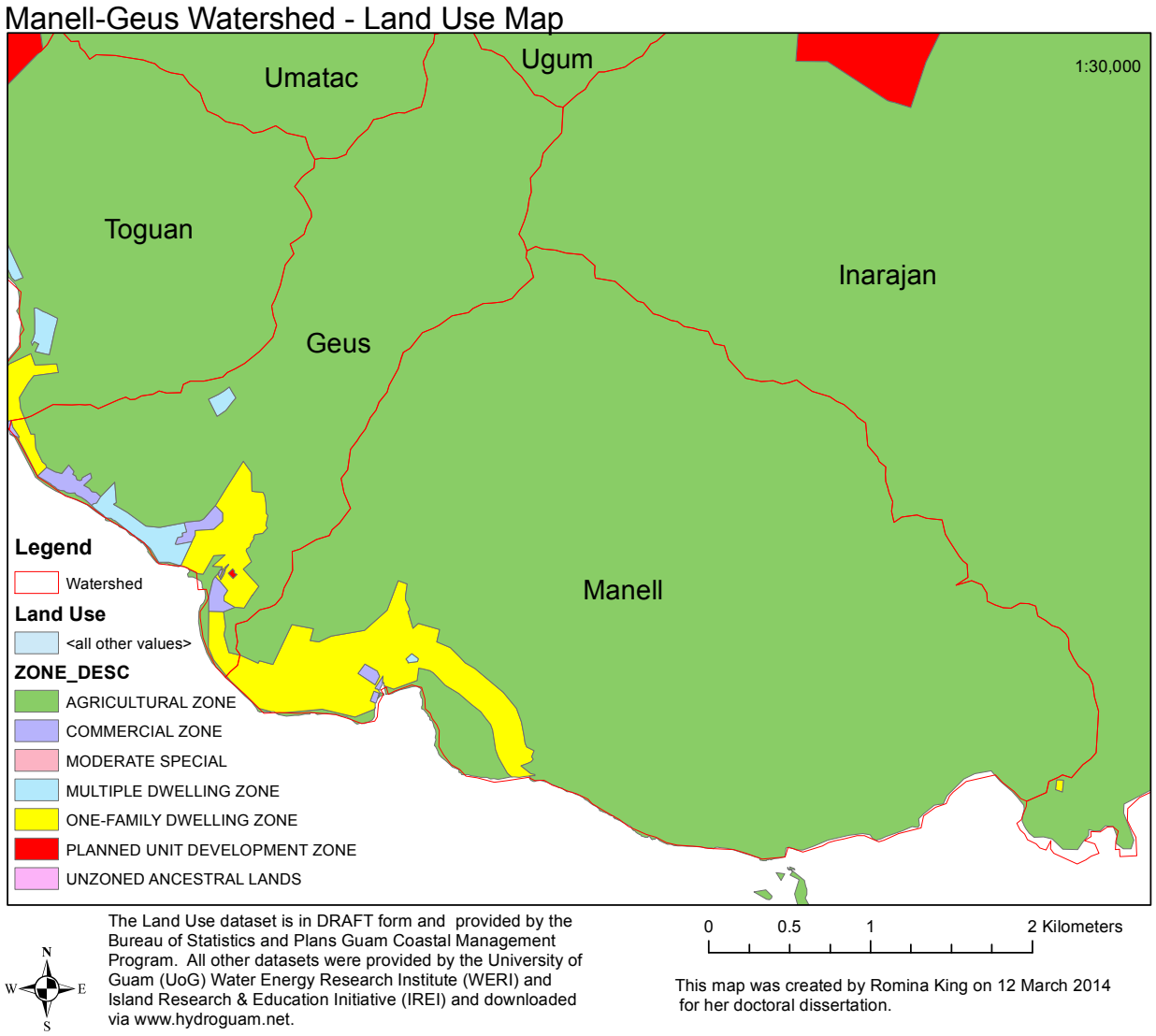


Figure 38: Land Use Map of the Manell and Geus watershed.

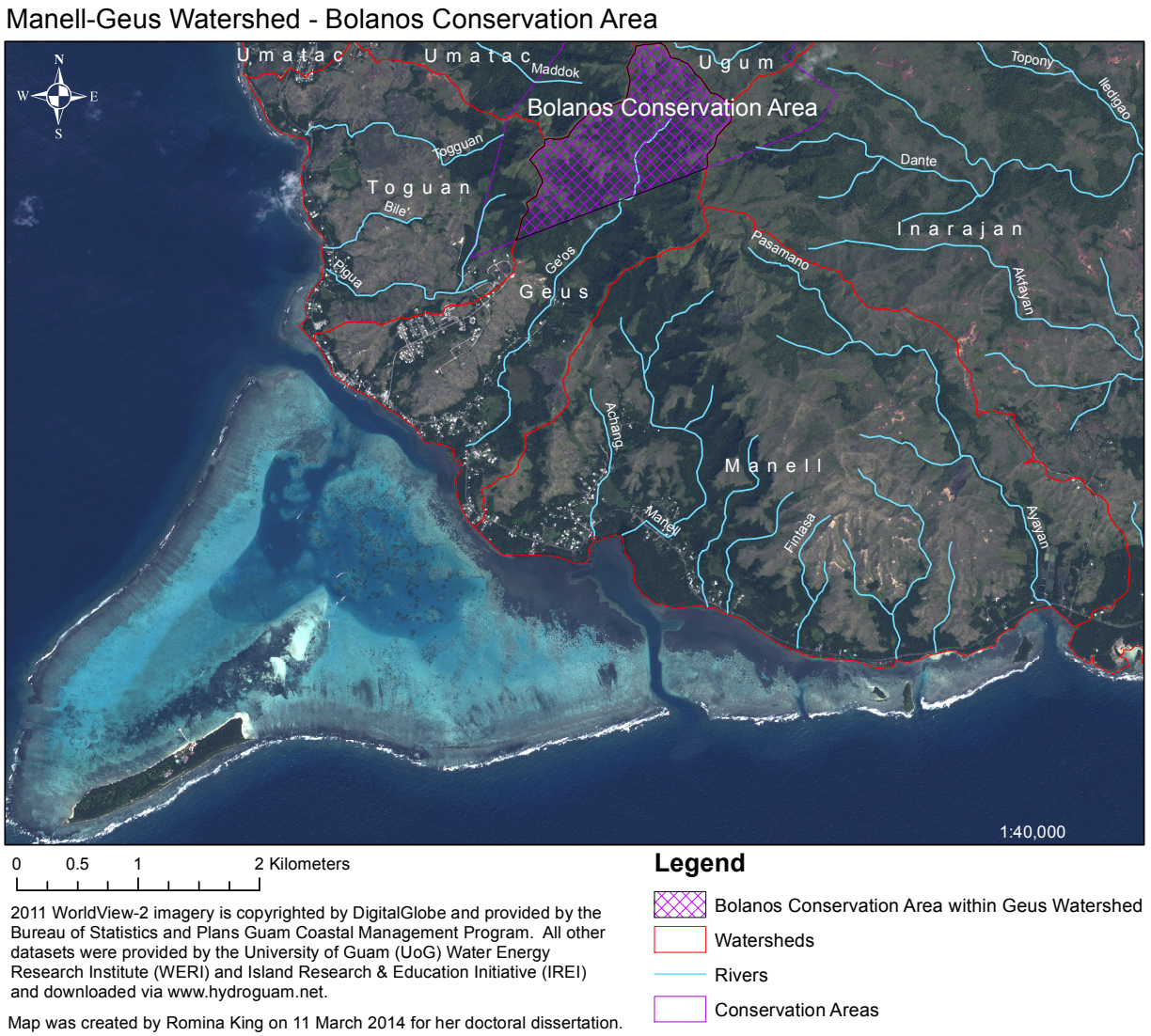


Figure 39: Terrestrial conservation areas within the Manell and Geus watershed.

6.1.2.7 Water Utilities Infrastructure

Approximately 72% of the population disposes of their sewage via public sewer, while 25% have a septic tank or cesspool (Bureau of Statistics and Plans 2002). The Guam Waterworks Authority is responsible for water and wastewater utilities. During flooding events, the sewers in the Manell and Geus watersheds get backed up. This becomes a public health concern.

"In the water sector, climate-induced water scarcity could be felt quite differently by communities supplied by large water utilities compared to communities not currently connected to these larger water suppliers. Some social science research thus distinguishes weather –related water scarcity for human induced scarcity, raising important questions about access, political power and traditional water rights"(Moser 2009).

"Many water-based systems are heavily managed, with extensive infrastructure, multiple laws and regulations, and a complex set of institutions to govern these systems. Prior to intensive development, these systems were at one time characterized by dynamic ecosystems—riverine, riparian, wetland and terrestrial—that supported complex biodiversity. For millennia, humans have modified ecosystems to procure water that sustains human and ecological systems. Governance and management of regional water systems are complex in both form and function." (Cosens et al. 2014)

6.3 Summary

This chapter presents the results of a geospatial analysis on the Manell and Geus watersheds. It provides a detailed environmental geography of the Manell and Geus watersheds at a large scale (1:40,000) using geospatial data and U.S. Census data. Understanding the physical characteristics of the Manell and Geus watersheds is the first step in determining ecological resilience. Understanding the social and economic characteristics of human community is a necessary step in determining social vulnerability. The next chapter will examine impacts of climate change on small islands and more specifically, Guam.

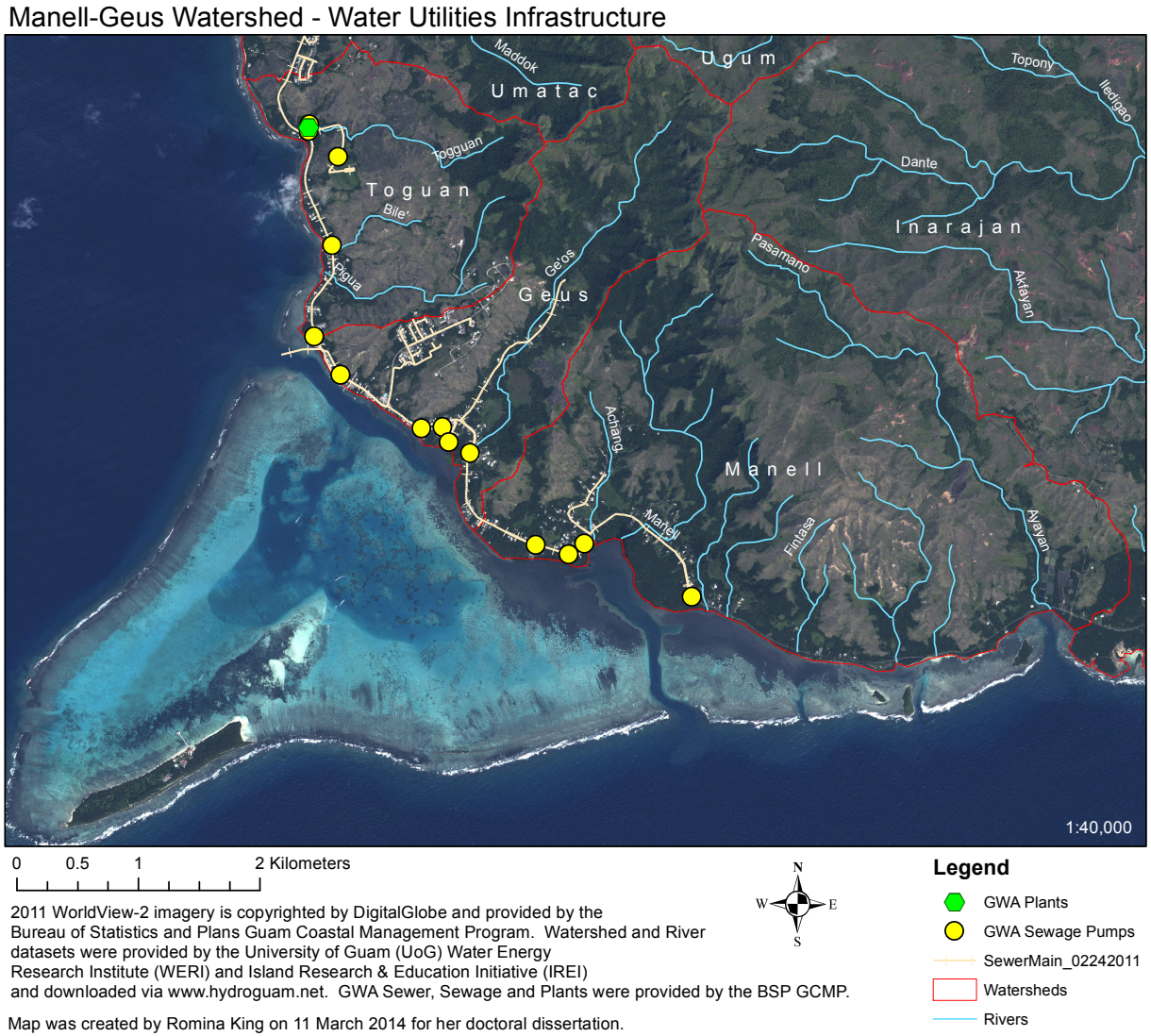


Figure 40: Water Utilities Infrastructure with the Manell and Geus watershed.

Chapter 7: Results-Household Survey and Analysis

In an effort to measure the perceptions, attitudes, knowledge, and behaviors of the community, a household survey was administered from July through August 2010. Of the 400 hundred surveys administered, 354 were returned. Of the 354 surveys returned, 350 were viable. Variables and corresponding values were coded and a master codebook was created (see Appendix 2 – Household Survey Codebook). Completed surveys were coded by hand and data was entered into an Excel database. Data entry took approximately one year. The final database was imported into SPSS. Data were cleaned and analyzed in SPSS. Graph Pad Prism 6 was used to generate graphs.

The variables from the household survey may be classified into six categories – Demographic Information, Values, Behaviors, Attitudes, Perceptions, and Knowledge. There are 15 variables that examine demographic characteristics of the residents of the Manell and Geus watersheds (V1-V8; 9a-9d; V10, V11; 11a -11e – see Appendix 2 – Household Survey Codebook and Chapter 7: Demographic Information). There are approximately 23 variables examining the values of the residents of the Manell and Geus watersheds (16a-16w - see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.4 Values There are approximately 22 variables examining the behaviors of the residents of the Manell and Geus watersheds (12a-12q; V17; V41; V42; V43; V44 – see Appendix 2 – Household Survey Codebook and Chapter 7: There are approximately 15 variables examining attitudes of the residents of the Manell and Geus watersheds (23a-23n; V24 – See Appendix 2 – Household Survey Codebook and Chapter 7: Attitudes). There are approximately 34 variables examining perceptions of the residents of the Manell and Geus watersheds (15b-15p; 17a – 17i; V19, V20, V22; 45a-45h – see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.3 Perceptions). There are approximately four variables examining knowledge (with regard to watersheds and spatial awareness of the environment) of the residents of the Manell and Geus watersheds (V37-V40 – see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.6 Knowledge).

This chapter objectively presents the results of the household survey in two major sections – Descriptive Statistics and Inferential Statistics. Analysis and discussion of these results is reserved for Chapter 9: Discussion and Conclusion.

7.1 Descriptive Statistics

7.1.1 Demographic Information

There are approximately 15 variables that examine demographic characteristics of the residents of the Manell and Geus watersheds (V1-V8; 9a-9d; V10, V11; 11a -11e – see Appendix 2 – Household Survey Codebook).

7.1.1.1 Residence

Of the 350 respondents, approximately 26% resided in the Manell watershed; 32% resided in the Geus; 36% did not know; 6% left the question blank (see Table 14). Approximately 13% of respondents believed they resided in a watershed other than Manell or Geus. Those 13% were wrong (the surveys were filled out in their place of residence which was physically located in the Manell or Geus watershed). Thus, those 13% have been added to those that "do not know" which watershed they live in.

Table 14: Percentage of respondents residing in the Manell or Geus watersheds. N=350.

Watershed	Percent
Manell	25.7
Geus	32.0
Do not know	36.0
No response	6.3

7.1.1.2 Duration of Residency

Originally, there were 12 categories of this categorical variable. Twelve categories were collapsed into three: short-term residency (0-5 years), medium-term residency (6-10 years), and long-term residency (greater than 10 years). Of the 350 respondents, approximately 4% are short-term residents, 5% are medium-term residents, 89% are long-term residents, and 3% declined to answer (see Table 15). The majority of respondents (89%) are long-term residents of the Manell-Geus watershed (see Table 15).

Table 15: Percentage of respondents residing in the Manell or Geus watersheds for a short-term, medium-term, and long term. N=350.

Residency	Percent (%)
short-term residency (0-5 years)	4.0
medium-term residency (6-10 years)	5.1
long-term residency (greater than 10 years)	89.1
No response	1.7

7.1.1.3 Home Ownership

Of the 350 respondents, approximately 35% owned their homes; 17% rented; 36% responded with other; and 12% left the question blank. See Table 16.

Table 16: Percentage of respondents who own or rent their homes within the Manell and Geus watersheds. N=350.

Ownership	Percent
own	34.9
rent	17.4
other	35.7
No response	12

7.1.1.4 Age

Of the 350 respondents, approximately 25% were adolescents (15-19 years of age); 24% were young adults (20-34 years of age); 39% were middle-aged (35-60 years of age); and 11% were elderly (over 60 years of age). See Table 17. In the original survey, respondents were given 13 choices offering various age ranges (e.g., 15-19; 45-49) and asked to check the answer that best defines their age. Responses were aggregated into four different categories: adolescents, young adults, middle-aged, and elderly. There are several varying definitions for 'middle-age'. For example, according to Collins Dictionary, middle age is "... usually considered to occur approximately between the ages of 40 and 60" ("Middle Age" 2014). The US Census defines middle age as including both the age categories 35 to 44 and 45 to 54 (U.S. Census Bureau 2011b). The Diagnostic and Statistical Manual of Mental Disorders, the standard diagnostic manual of the American Psychiatric Association, used to define middle age as 40–60, but as of Edition IV (1994) revised the definition upwards to 45–65. For purposes of this dissertation, middle-aged is classified as a person who is 35-60 years of age.

Table 17: Percentage of respondents who are adolescents, young adults, middle-aged, or elderly. N=350.

Age	Percent (%)
adolescent	24.9
young adult	24
middle age	38.6
elderly	10.9
No response	1.7

7.1.1.5 Gender

Of the 350 respondents, approximately 48 % were male; 50 % were female; and 2% left the question blank. See Table 18.

Table 18: Percentage of respondents who are male or female. N=350.

Gender	Percent (%)
male	48.3
female	49.7
No response	2.0

7.1.1.6 Level of Education Attained

Of the 350 respondents, approximately 38% did not complete high school; 48% attained a high school diploma or General Education Diploma (GED); 2% attained an associate's degree; 2% attained a bachelor's degree; 1% attained a graduate or professional degree; and 2% of respondents declined to answer the question. See Table 19.

Table 19: Highest level of education obtained by respondents. N=350.

Level of Education Attained	Percent (%)
Did not complete high school	38.3
High school diploma or G.E.D	47.7
Completed a degree higher than a high school diploma (i.e., A.D; BA or Bsc, MA or MSc, Ph.D)	11.7
No Response	2.3

7.1.1.7 Ethnicity

Of the 350 respondents, 90% identified themselves as Chamorro. The remaining 10% identified themselves as Filipino, Caucasian, Chuukese, Marshallese, Palauan, Pohnpeian, or Chinese. See Table 20.

Table 20: Ethnicity of respondents. N=350.

Ethnicity	Percent (%)
Chamorro	90.3
Filipino	0.6
Caucasian/white	0.6
Chuukese	0.3
Marshallese	0.3
Palauan	0.6
Pohnpeian	0.3
Chinese	0.6
No response	6.6

7.1.1.8 Language

This was a multiple response question; respondents were instructed to check off the languages spoken at home. Of the 350 respondents, approximately, 95% speak English at home (see Table

21). Approximately 69% also speak Chamorro (see Table 22). Approximately 2% speak Tagalog (see Table 23). The most commonly spoken languages at home are English and Chamorro.

Table 21: Percentage of respondents who can speak English. N=350.

Can speak English	Percent
no	4
yes	95.1
No Response	0.9

Table 22: Percentage of respondents who can speak Chamorro. N=350.

Can speak Chamorro	Percent (%)
no	30.6
yes	68.6
No Response	0.9

Table 23: Percentage of respondents who can speak Tagalog. N=350.

Can speak Tagalog	Percent (%)
no	97.4
yes	1.7
No Response	0.9

7.1.1.9 Religion

Of the 350 respondents, 95% regarded themselves as Catholics. See Table 24.

Table 24: Religions of the respondents. N=350.

Religion	Percent
Catholic	95.1
Buddhist	0.3
Seventh Day Adventist	0.3
Lutheran	0.3
Baptist	1.1
local/traditional	0.3
No response	1.7
other	0.9

7.1.1.10 Employment

Of the 350 respondents, 31% worked for wages full-time; 6% worked for wages part-time; 14% were unemployed, but collected public assistance; 9% were unemployed but did not collect public assistance; 11% were retired; 8% were homemakers; 18% were students; 3% declined to answer. See Table 25.

Table 25: Employment status of respondents. N=350.

Employment Status	Percent (%)
Work for wages (full-time)	30.9
Work for wages (part-time)	6.3
Student (full-time)	16.6
Student (part-time)	1.7
Retired	11.1
Home-maker	8.0
Unemployed (collect public assistance)	14.0
Unemployed (do not collect public assistance)	8.6
No response	2.9

7.1.1.10.1 Nature of employment

Of the 350 respondents, 37% (approximately 130) were employed. Of the 130 employed respondents, 49% worked for private companies, 24% were employed by the Government of Guam; 2% worked for the U.S. Military; 5% worked for the U.S. Government; 4% worked for a non-governmental organization; and 2% worked as 'other'. See Table 26.

Table 26: Occupations of the respondents. N=130.

Occupation	Percent
self-employed (unspecified)	3.3
fisherman	1.6
other	8.1
private company or business	48.8
Government of Guam	24.4
U.S. government (military)	2.4
U.S. Government (non-military)	4.9
non-governmental organization	4.1
other	2.4
No Response	0

7.1.1.10.2 Location of employment

Of the 130 employed respondents, only 125 provided a response. Approximately 3% work in Agana Heights; 4% work in Agat; 1% work in Asan-Maina; 4% work in Barrigada; 10% work in Hagatna; 4% worked in Inarajan; 2% work in Mangilao; 36% work in Merizo; 2 % work in

Mongmong-Toto-Maite; 12% work in Piti; 8% work in Santa Rita; 1% Talofofo, 11% work in Tamuning-Tumon; and 1% work in Yigo. Approximately 62% percent of employed respondents work outside of Merizo.

Table 27: Locations of work of employed respondents. N=125.

Location of Employment	Frequency	Percentage
Agana Heights	4	3.2
Agat	5	4.0
Asan-Maina	1	.8
Barrigada	5	4.0
Hagatna	13	10.4
Inarajan	5	4.0
Mangilao	3	2.4
Merizo	45	36.0
Mongmong-Toto-Maite	3	2.4
Piti	15	12.0
Santa Rita	10	8.0
Talofofo	1	.8
Tamuning-Tumon	14	11.2
Yigo	1	.8

7.1.1.11 Average Annual Income

Of the 130 employed respondents, only 89 answered this question. Of the 89 responses, approximately 38% make less than $25,000/year; 35% make between $25000 -$50000/year; 7% make between $50000 – 99,000; and 20% preferred not to answer the question. The island annual mean salary for all occupations is $33,280/year (Bureau of Labor Statistics 2015). According to this study, the majority of people that chose to answer this question make that much or below.

Table 28: Average annual income of employed respondents. N=89.

Average Annual Income	Percentage of Employed Respondents
Less than $2500	6.7
$2,500 - $4,900	2.2
$5,000 - $9,999	5.6
$10,000 - $14,999	11.2
$15,000 - $24,999	12.4
$25,000 - $34,999	18
$35,000 - $49,999	16.9
$50,000 - $74,999	5.6
$75,000 - $99,000	1.1
Preferred not answer	20.2

7.1.2 Behaviors

There are approximately 22 variables exploring the behaviors of the residents of the Manell and Geus watersheds (12a-12q; V17; V41; V42; V43; V44 – see Appendix 2 – Household Survey Codebook). In an effort to profile respondents with regard to behavior, respondents were asked a series of questions that examined behaviors pertaining to environmental concerns and lifestyle behaviors.

7.1.2.1 Recycling

Of the 350 respondents, approximately 16% recycle all the time; 46% recycle some of the time; 15% rarely recycle; 9% never recycle; and 13% declined to answer. See Figure 41.

7.1.2.2 Burning garbage

Of the 350 respondents, approximately 13% burn garbage all the time; 35% burn garbage some of the time; 19% rarely burn garbage, 22% never burn garbage; and 10% declined to answer. See Figure 41.

7.1.2.3 Burning vegetation

Of the 350 respondents, approximately 49% never burn vegetation; 17% rarely burn vegetation; 12% burn vegetation sometimes; 8% burn vegetation all the time; and 14% declined to answer. See Figure 41.

7.1.2.4 Throw vegetation in the jungle

Of the 350 respondents, approximately 39% never dispose of their vegetative debris in the jungle; 17% rarely dispose of their vegetative debris is in the jungle; 20% dispose of the vegetative debris some of the time; 9% dispose of the vegetative debris all the time; and 16% declined to answer. See Figure 41.

7.1.2.5 Smoke trees

Of the 350 respondents, approximately 36% never smoke their trees; 13% rarely smoke their trees; 22% smoke their trees some of the time; 16% smoke their trees all the time; and 13% declined to answer. See Figure 41.

7.1.2.6 Compost

Of the 350 respondents, approximately 49% never compost, 15% rarely compost; 13% compost some of the time; 7% compost all the time; and 17% declined to answer. See Figure 41.

7.1.2.7 Take garbage to Ordot Dump

Of the 350 respondents, approximately 59% never take their garbage to Ordot Dump; 13% rarely take their garbage to Ordot Dump; 7% take their garbage to Ordot Dump some of the

time; 4% take their garbage to Ordot Dump all the time; and 16% declined to answer. See Figure 41.

7.1.2.8 Take garbage to Mayor's dumpster

Of the 350 respondents, approximately 62% never take their garbage to the mayor's dumpster; 17% rarely take their garbage there; 6% take their garbage to the dumpster some of the time; 2% take their garbage there all the time; and 12% declined to answer. See Figure 41.

7.1.2.9 Curbside garbage collection

Of the 350 respondents, approximately 32% never participated in curbside collection; 16% rarely participated in curbside collection; 14% participated in curbside collection some of the time; and 25% participated in curbside collection all of the time; and 13% declined to answer the question. See Figure 41.

7.1.2.10 Hike/Run

Of the 350 respondents, approximately 24% never hike or run; 19% rarely hike or run; 33% hike or run sometimes; and 10% hike or run all the time; 14% declined to answer the question. See Figure 42.

7.1.2.11 Hunt coconut crabs

Of the 350 respondents, approximately 57% never hunt for coconut crabs; 15% rarely hunt for coconut crabs; 11% hunt for coconut crabs sometimes; 3% hunt for coconut crabs all the time; and 14% declined to answer. See Figure 42.

7.1.2.12 Off-road

Of the 350 respondents, approximately 58% never go off-roading; 12% rarely go off-roading; 10% go off-roading some of the time; 3% go off-roading all the time; and 16% declined to answer the question. See Figure 42.

7.1.2.13 Swimming

Of the 350 respondents, approximately 13% never swim; 11% rarely swim; 41% swim sometimes; 23% swim all the time; and 12% declined to answer. See Figure 42.

7.1.2.14 Fishing

Of the 350 respondents, approximately 29% never fish; 19% rarely fish; 29% fish some of the time; and 10% fish all the time; and 13% declined to answer. See Figure 42.

7.1.2.15 Hunt

Of the 350 respondents, approximately 58% never hunt; 13% rarely hunt; 9% hunt sometimes; and 5% hunt all the time; and 15% declined to answer. See Figure 42.

7.1.2.15.1 Hunting

Due to hunting's association with arson, which is extremely destructive to vegetation, several follow-up questions were added in an effort to obtain more knowledge, particularly, where they hunt. Approximately 15% of the 350 respondents hunt (see Table 29). Of those 52 hunters, approximately 54% indicate they hunt within the Manell and Geus watersheds (see Table 30).

Table 29: Respondents who hunt. N=350.

Hunt	Percent
yes	14.9
no	8.2
No response	3.1

Table 30: Respondents who hunt within the Manell and Geus watersheds. N=52.

Do you hunt in Merizo	Percent
yes	53.8
no	23.1
No response	23.1

7.1.2.15.2 Prey

Of the 350 respondents, 52 were hunters. Of those 52 hunters, 28 people hunted within the Manell and Geus watersheds . Of the 28 people, they were given a multiple response question regarding the prey they hunt. Of the 28 hunters, approximately 41% hunt deer; 31% hunt wild boar; 1% hunt bats; 20% hunt or trap coconut crabs; 2.5% hunt turtles; and 4% hunt other creatures.

Table 31: Prey hunted by respondents who hunted in the Manell and Geus watersheds. N=28.

Prey	Percent
deer	41.2
wild boar	31.2
bats	1.2
coconut crabs	20
turtles	2.5
other	3.8

7.1.2.16 Farm

Of the 350 respondents, approximately 45% never farm; 18% rarely farm; 13% farm some of the time; 10% farm all the time; and 13% declined to answer. See Figure 42.

7.1.2.17 Community participation

Of the 350 respondents, approximately 20% participated in a watershed restoration project in the past year (2009-2010); 75% did not participate in a watershed restoration project; and 5% did not respond. See Table 32.

Table 32: Respondents who participated in watershed restoration projects (2009-2010). N=350.

Participation in a watershed project in the last year (2009-2010)	Percent (%)
yes	20.3
no	74.9
No response	4.9

Of the 350 respondents, approximately 71 respondents (20%) participated in a watershed project. Of those 71 respondents, they were asked a multiple response question asking what types of watershed restoration projects they participated in the past year. Of those 71 respondents, approximately 21% planted trees; 4% monitored water quality; 35% participated in beach clean-ups; 36% participated in village clean-ups; and 2% implemented good watershed practices at home. See Table 33.

Table 33: Types of watershed restoration projects respondents participated in (2009-2010). N=71.

Type of watershed project	Percent (%)
tree planting	21.4%
water monitoring	4.3%
beach clean-ups	35.0%
village clean-ups	36.4%
implemented watershed practices at home	2.1%
other	0.7%

7.1.2.17.1 Potential interest in future watershed projects

Of the 350 respondents, approximately 57% expressed interest in future watershed projects; 38% did not express any interest in future watershed projects; 5% declined to answer. See Table 34.

Table 34: Percentage of respondents interested in participating in future watershed projects. N=350.

Interest in future watershed projects	Percent (%)
yes	57.1
no	37.7
No response	5.1

The 200 respondents who expressed interest in participating in a future watershed project were given a follow up multiple- response question in order to see what types of project would be of the most interest. Of the 200 respondents, approximately 21% would plant trees; 8% would monitor water quality; 26% would participate in beach clean-ups; 27% would participate in village clean-ups; 8% would implement good watershed practices at home; 5% would be interested in a hunting clinic that demonstrates good hunting practices; 3% were not sure what type of project that would be of interest to them; 2% indicated 'other'. See Table 35.

Table 35: Types of future watershed projects respondents expressed interest in participating. N=200.

Future watershed projects of Interest	Percent (%)
tree planting	21.3
water monitoring	7.8
beach clean-ups	26.0
village clean-ups	27.1
implemented watershed practices at home	7.8
hunting clinic demonstrating ways to hunt without setting fires	5.1
do not know/unsure	3.3
other	1.6

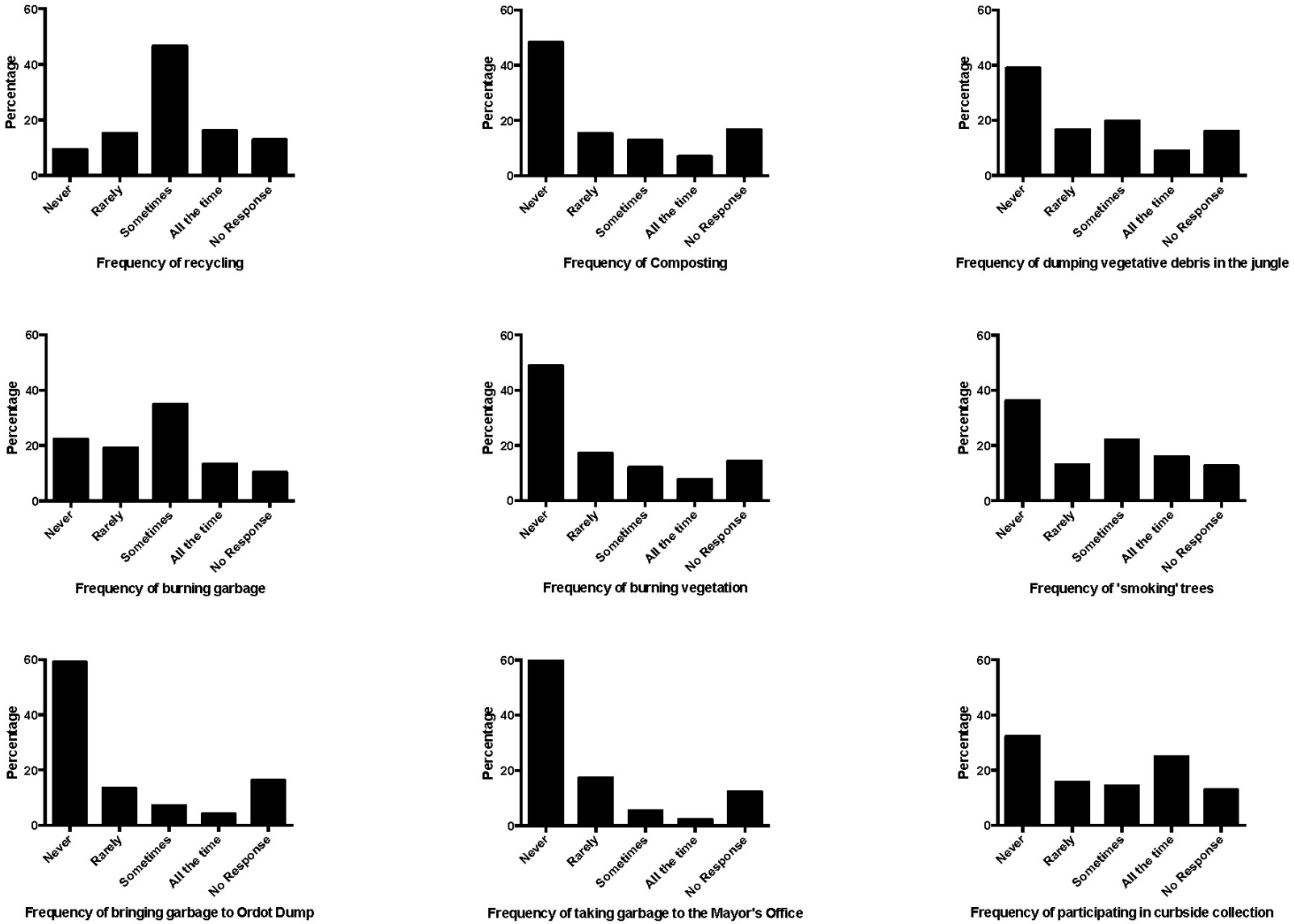


Figure 41: Nine bar graphs depicting the frequency of specific behaviors of respondents such as recycling, composting, dumping vegetative debris in the jungle, 'smoking' trees, burning garbage, burning vegetation, participating in curbside collection, bringing garbage to Ordot Dump, taking the garbage to the Merizo Mayor's Office.

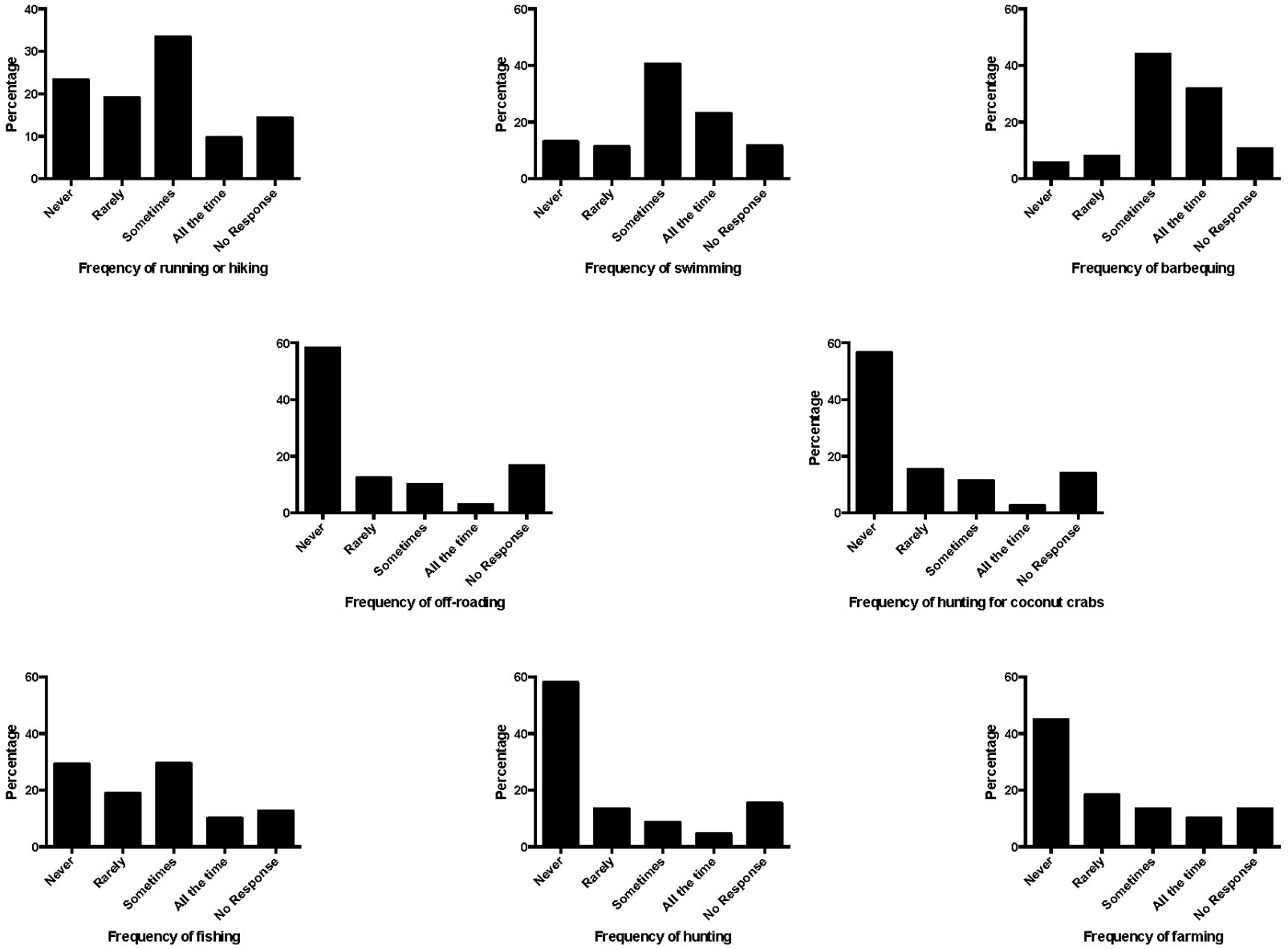


Figure 42: Eight bar graphs depicting the frequency of behaviors among residents within the Manell and Geus watersheds. Behaviors include running or hiking; swimming, barbequing, off-roading, hunting for coconut crabs, fishing, hunting, and farming. N=350.

7.1.3 Perceptions

7.1.3.1 Are solid waste fees too high?

Of the 350 respondents, approximately 70% believed solid waste fees were too high; 27% believed solid waste fees were not too high; and 3% declined to answer.

7.1.3.2 Perceived threats to the Manell/Geus Watershed

Of the 350 respondents, approximately 58% perceived threats to the watershed; 38% did not think there were any threats to the watershed; and 4% declined to answer. See Table 36.

Table 36: Percentage of respondents who perceive 'threats' to the Manell and Geus watersheds. N=350.

Are there 'threats' to the Manell and Geus watersheds?	Percent (%)
Yes	58
No	38
No response	4

A subset of the dataset was created. Cases of the respondents who perceived threats to the watershed were selected (n=203). The results are as follows:

7.1.3.2.1 Pollution

Respondents were asked whether pollution was a threat to the watershed. Of the 203 respondents who perceived threats to the watershed, approximately 7% did not know; 2% strongly disagreed; 1% disagreed; 28% agreed; and 49% strongly agreed. Approximately 11% declined to answer. See Figure 43.

7.1.3.2.2 Development

Respondents were asked whether development was a threat to the watershed. Of the 203 respondents who perceived threats to the watershed, approximately 14% did not know; 2% strongly disagreed; 3% disagreed; 3% did not care; and 26% agreed; and 33% strongly agreed. Approximately 18% declined to answer. See Figure 43.

7.1.3.2.3 Wildland fires

Respondents were asked whether wildland fires were a threat to the watershed. Of the 203 respondents, approximately 13% did not know; 3% strongly disagreed; 3% did not care; 30% agreed; and 30% strongly agreed. Approximately 15% declined to answer. See Figure 43.

7.1.3.2.4 Off-roading

Respondents were asked whether off-roading was a threat to the watershed. Of the 203 respondents, 17% did not know; 3% strongly disagreed; 7% disagreed; 5% did not care; 29% agreed; and 21% strongly agreed. Approximately 17% declined to answer. See Figure 43.

7.1.3.2.5 Invasive Species

Respondents were asked whether invasive species were a threat to the watershed. Of the 203 respondents, 19% did not know; 2% strongly disagreed; 5% disagreed; 3% did not care; 30% agreed; and 23% strongly agreed. Approximately 16% declined to answer. See Figure 43.

7.1.3.2.6 Lack of awareness

Respondents were asked whether lack of awareness was a threat to the watershed. Of the 203 respondents, approximately 15% did not know; 2% strongly disagreed; 7% disagreed; 2% did not care; 28% agreed; and 30% strongly agreed. Approximately 16% declined to answer. See Figure 43.

7.1.3.2.7 Lack of rainfall

Respondents were asked whether lack of rainfall was a threat to the watershed. Of the 203 respondents, approximately 18% did not know, 4% strongly disagreed; 19% disagreed; 3% did not care; 19% agreed; and 20% strongly agreed. Approximately 18% declined to answer. See Figure 44.

7.1.3.2.8 Overfishing

Respondents were asked whether overfishing was a threat to the watershed. Of the 203 respondents, approximately 23% did not know; 7% strongly disagreed; 12% disagreed; 4% did not care; 19% agreed; and 16% strongly agreed. Approximately 18% declined to answer. See Figure 44.

7.1.3.2.9 Land clearing

Respondents were asked whether land clearing was a threat to the watershed. Of the 203 respondents, approximately 16% did not know; 2% strongly disagreed; 4% disagreed; 2% did not care; 27% agreed; and 40% strongly agreed. Approximately 9% declined to answer. See Figure 44.

7.1.3.2.10 Coastal erosion

Respondents were asked whether coastal erosion was a threat to the watershed. Of the 203 respondents, approximately 14% did not know; 1% strongly disagreed; 2% disagreed; 1% did

not care; 25% agreed; and 49% strongly agreed. Approximately 9% declined to answer. See Figure 44.

7.1.3.2.11 Military build-up

Residents were asked whether the impending military build-up was a threat to the watershed. Of the 203 respondents, approximately 23% did not know; 4% strongly disagreed; 7% disagreed; 3% did not care; 22% agreed; and 28% strongly agreed. Approximately 13% declined to answer. See Figure 44.

7.1.3.2.12 Overpopulation

Respondents were asked whether overpopulation was a threat to the watershed. Of the 203 respondents, approximately 19% did not know; 5% strongly disagreed; 10% disagreed; 3% did not care; 27% agreed; and 25% strongly agreed. Approximately 11% declined to answer. See Figure 44.

7.1.3.2.13 Climate change

Respondents were asked whether climate change was a threat to the watershed. Of the 203 respondents, approximately 21% did not know; 4% strongly disagreed; 6% disagreed; 3% did not care; 27% agreed; and 27% strongly agreed. Approximately 12% declined to answer. See Figure 45.

7.1.3.2.14 Poor infrastructure

Residents were asked whether poor infrastructure was a threat to the watershed. Of the 203 respondents, approximately 17% did not know; 2% strongly disagreed; 3% disagreed; 2% did not care; 27% agreed; and 40% strongly agreed. Approximately 9% declined to answer. See Figure 45.

7.1.3.2.15 Flooding

Residents were asked whether flooding was a threat to the watershed. Of the 203 respondents, approximately 12% did not know; 2% strongly disagreed; 22% agreed; and 57% strongly agreed. Approximately 6.4% declined to answer. See Figure 45.

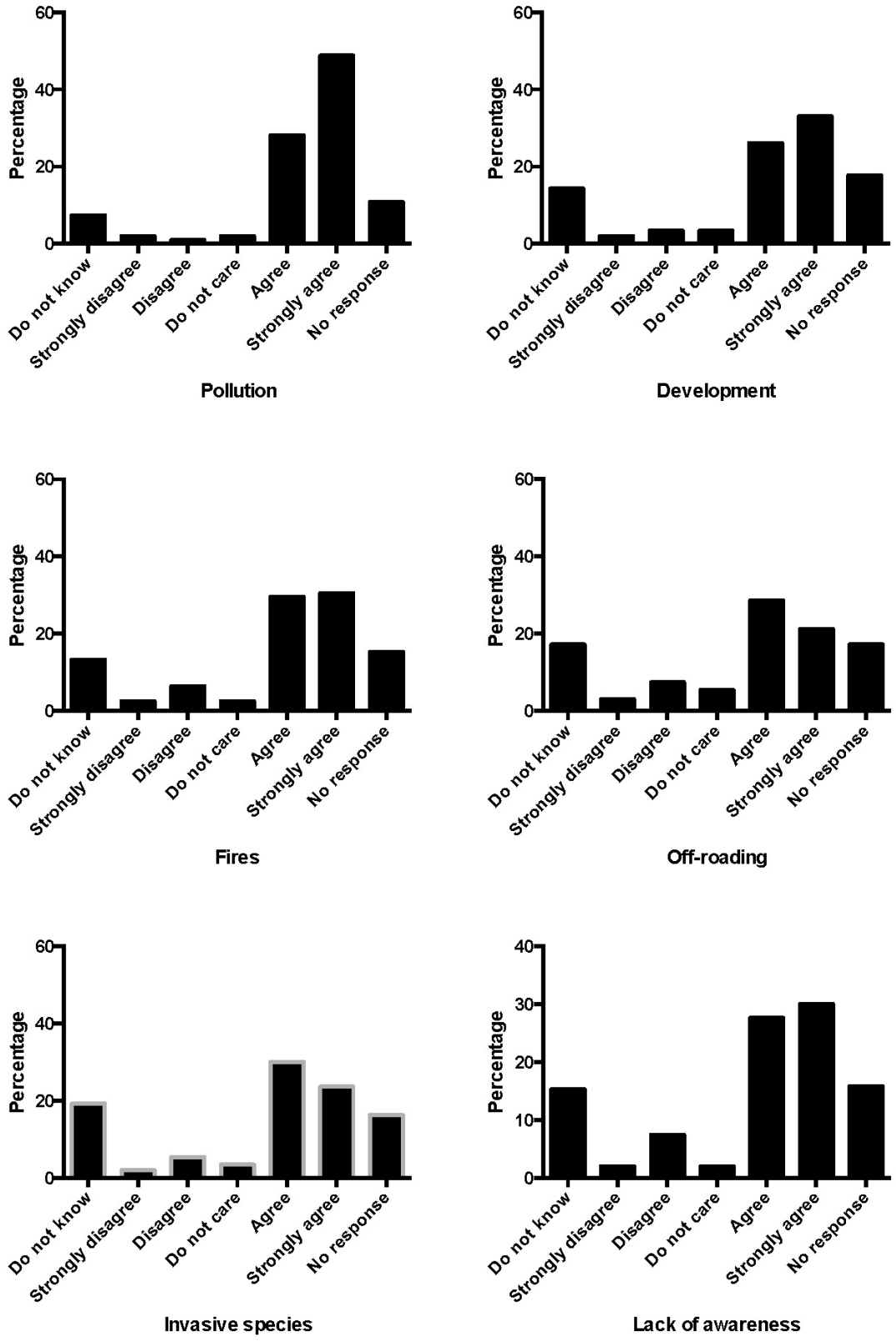


Figure 43: Six bar graphs depicting perceived threats to the Manell and Geus watersheds. Threats include pollution, development, fires, off-roading, invasive species, and lack of awareness. N=203 for each graph.

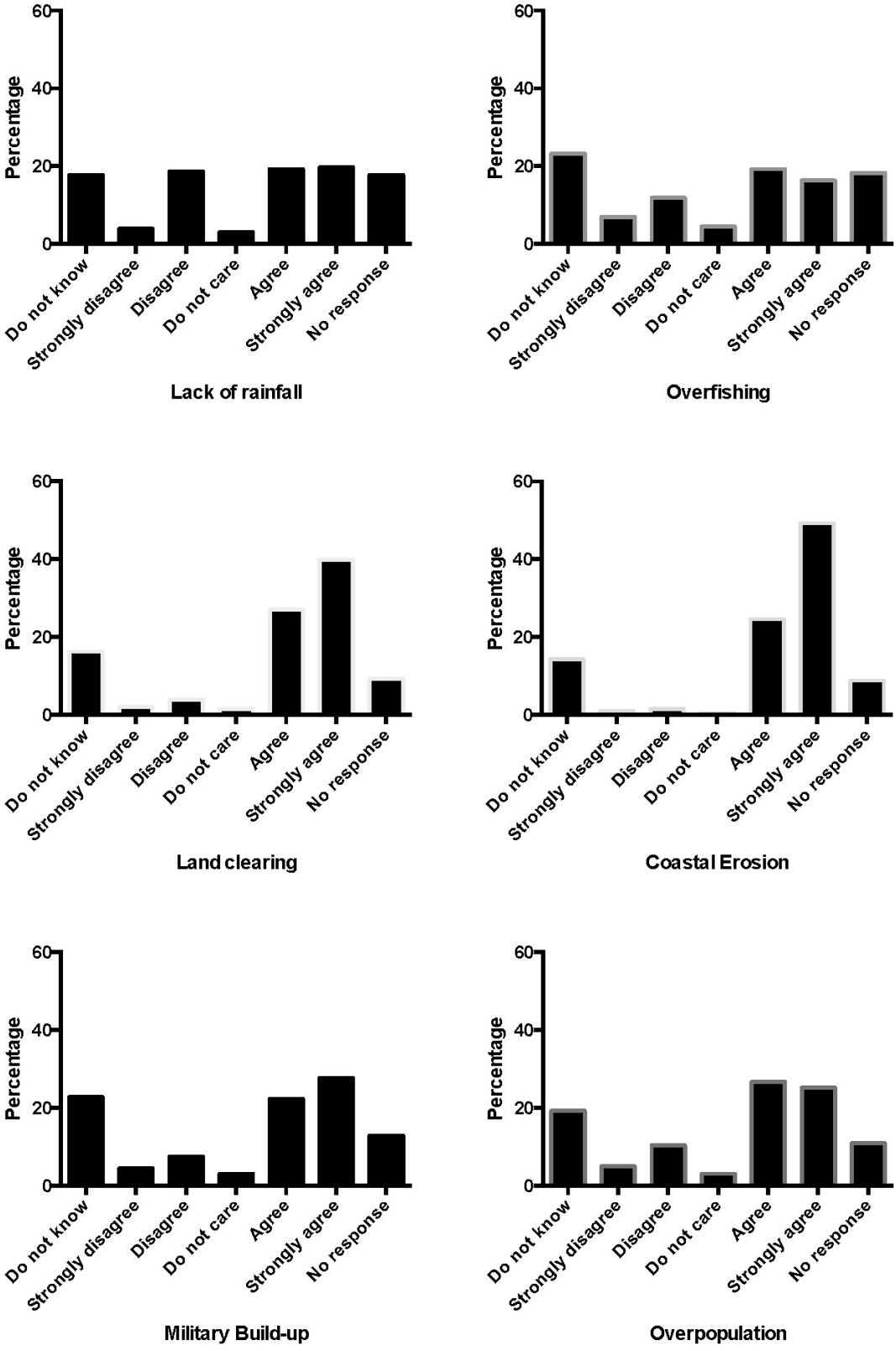
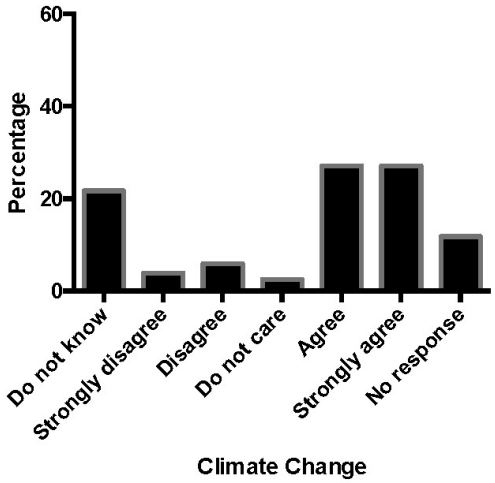
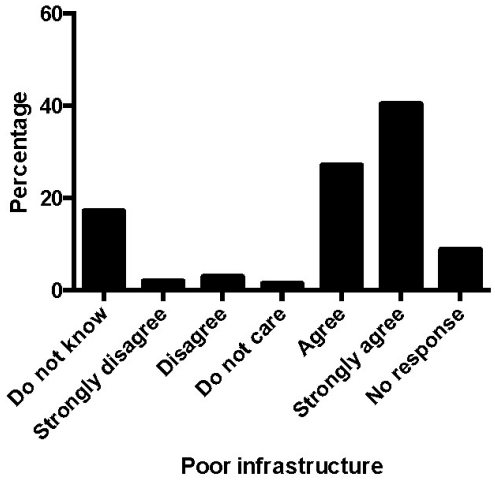


Figure 44: Six bar graphs depicting perceived threats to the Manell and Geus watersheds. Threats include lack of rainfall, overfishing, land clearing, coastal erosion, military buildup, and over population. N=203 for each graph.





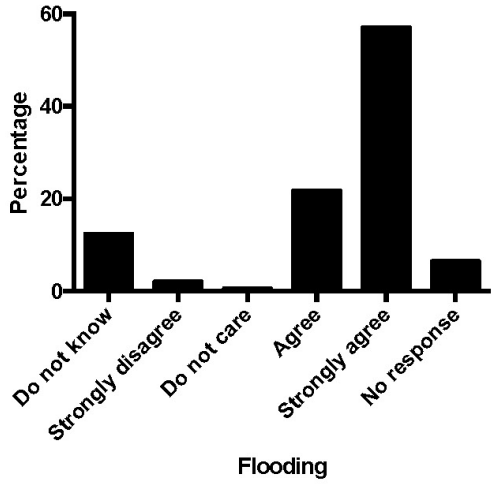


Figure 45: Three bar graphs depicting perceived threats to the Manell and Geus watersheds. Threats include climate change, poor infrastructure, and flooding. N=203 for each graph.

7.1.3.3 Perceptions of the Manell and Geus watersheds

In an effort to determine whether residents had an ecologically favorable view of the Manell and Geus watersheds, they were asked to 'strongly disagree', 'disagree', 'do not care', 'agree', 'strongly agree', or 'do not know' with eight specific statements.

7.1.3.3.1 "The forests are filled with native vegetation."

The first statement sought to examine to whether respondents perceived the forests within the Manell and Geus watersheds to be filled with native vegetation. Of the 350 respondents, approximately 29% did not know whether the forests are filled with native vegetation; 2% strongly disagreed with the statement; 13% disagreed with the statement; 2% did not care; 28% agreed with the statement; and 16% strongly agreed with the statement. Approximately 10% of respondents left the question blank. See Figure 46.

7.1.3.3.2 "Native animals are abundant."

The second statement pertained to whether respondents perceived an abundance of native animals within the Manell and Geus watersheds. Of the 350 respondents, approximately 29% did not know if native animals were abundant; 3% strongly disagreed with the statement; 18% disagreed with the statement; 2% did not care; 26% agreed with the statement; and 10% strongly agreed with the statement. Approximately 13% of respondents left the question blank. See Figure 46.

7.1.3.3.3 "There is erosion."

The third statement pertained to whether respondents perceived erosion occurring within the Manell and Geus watersheds. Of the 350 respondents, approximately 20% did not know whether erosion was occurring; 1% strongly disagreed with the statement; 4% disagreed with the statement; 1% did not care; 27% agreed with the statement; and 33% strongly agreed with the statement. Approximately 14% of respondents left the question blank. See Figure 46.

7.1.3.3.4 "The rivers are clean."

The fourth statement pertained to whether respondents perceived the rivers within the Manell and Geus watersheds to be clean. Of the 350 respondents, approximately 20% did not know whether the rivers were clean; 17% strongly disagreed with the statement; 29% disagreed with the statement; 2% did not care; 16% agreed with the statement; and 3% strongly agreed with the statement. Approximately 13% of respondents left the question blank. See Figure 46.

7.1.3.3.5 "There are many wildland fires."

The fifth statement pertained to whether respondents perceived that there were many wildland fires within the Manell and Geus watersheds. Of the 350 respondents, approximately 19% did not know whether there are many wildand fires; 5% strongly disagreed with the statement;

16% disagreed with the statement; 2% did not care; 29% agreed with the statement; and 15% strongly agreed with the statement. Approximately 14% of respondents left the question blank. See Figure 46.

7.1.3.3.6 "It floods often."

The sixth statement pertains to whether residents perceived frequent flooding events. Of the 350 respondents, approximately 12% did not know whether it floods often; 2% strongly disagreed with the statement; 4% disagreed with the statement; 1% did not care; 27% agreed with the statement; and 41% strongly agreed with the statement. Approximately 11% of respondents left the question blank. See Figure 46.

7.1.3.3.7 "There should be more forest clearing."

The seventh statement pertains to whether residents perceived an overabundance of forest within the Manell and Geus watersheds. Of the 350 respondents, approximately 20% did not know whether there should be more forest clearing; 16% strongly disagreed with the statement; 14% disagreed with the statement; 2% did not care; 19% agreed with the statement; and 15% strongly agreed with the statement. Approximately 14% of respondents left the question blank. See Figure 46.

7.1.3.3.8 "There are more non-native animals than native animals."

The eighth statement pertains to whether residents perceived more non-native animals than native animals within the Manell and Geus watersheds. Of the 350 respondents, approximately 25% did not know whether there are more non-native animals than native animals; 2% strongly disagreed with the statement; 3% disagreed with the statement; 2% did not care; 26% agreed with the statement; and 30% strongly agreed with the statement. Approximately 12% of respondents left the question blank. See Figure 46.

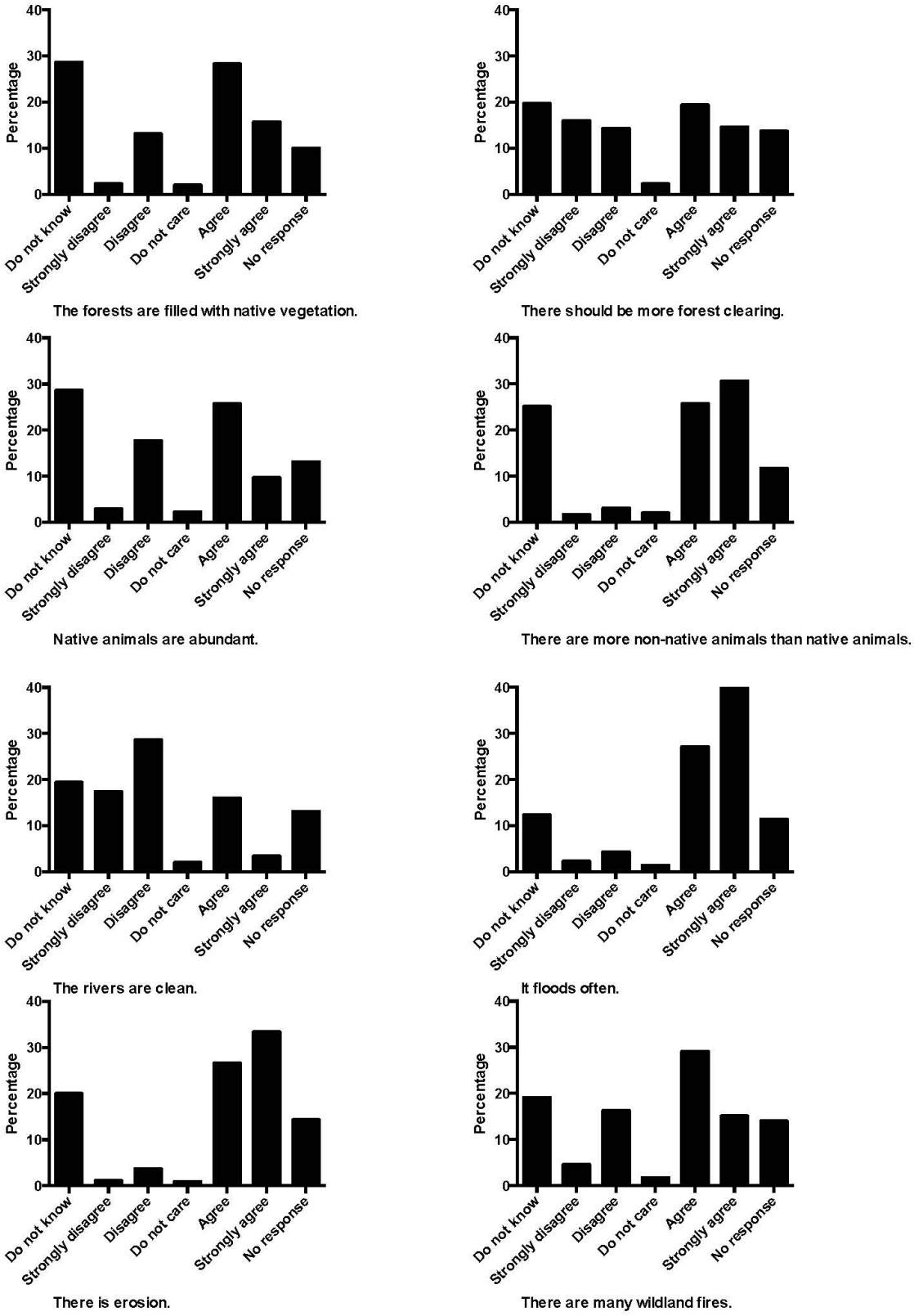


Figure 46: Eight bar graphs depicting perceptions of the respondents regarding the Manell and Geus watershed. N=350 for each graph.

7.1.3.4 Community Water Perceptions and Knowledge

A series of questions were used to measure the respondents' perceptions and knowledge specific to the water they consume.

7.1.3.4.1 Frequency of Tap Water Consumption

Of the 350 respondents, approximately 15% never drink tap water; 16% rarely drink tap water; 25% sometimes drink tap water; 13% often drink tap water; and 29% drink tap water all the time. Approximately 3% declined to answer. See Figure 47.

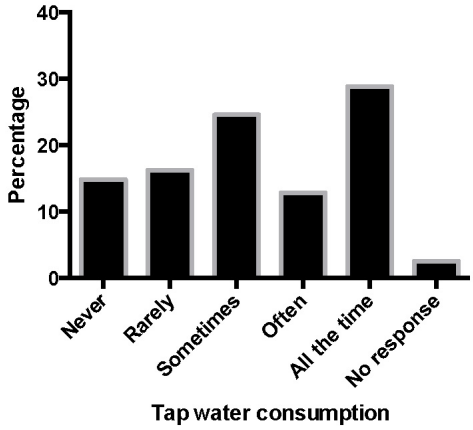


Figure 47: Bar graph depicting the frequency of tap water consumption according to a Likert scale. N=350.

7.1.3.4.2 Reasons for not drinking tap water

Of the 350 respondents, approximately 108 people (31%) either "rarely" or "never" drank tap water. Thus, a subset of the 350 respondents was created that consists of these 108 people. The perceptions this subset had are as follows. This was a multiple response question and respondents allowed to check off one or more reasons. Of the 108 respondents within the subset, approximately 11% perceived tap water to be dirty; 8% perceived tap water to contain bacteria; 11% perceived tap water tasted bad; 16% perceived tap water to contain too much chlorine; 2% perceived tap water to taste salty; 14% perceived tap water as too cloudy; 7% perceived tap water as not safe to drink; 10% did not drink tap water for health reasons; 9% do not drink water; 12% listed 'other' as a reason. See Figure 48. On Survey No. 60, a respondent added an option that was not included on the survey question – "buy water". This option should have been available on the original household survey because the purchase of bottled water is quite common on Guam.

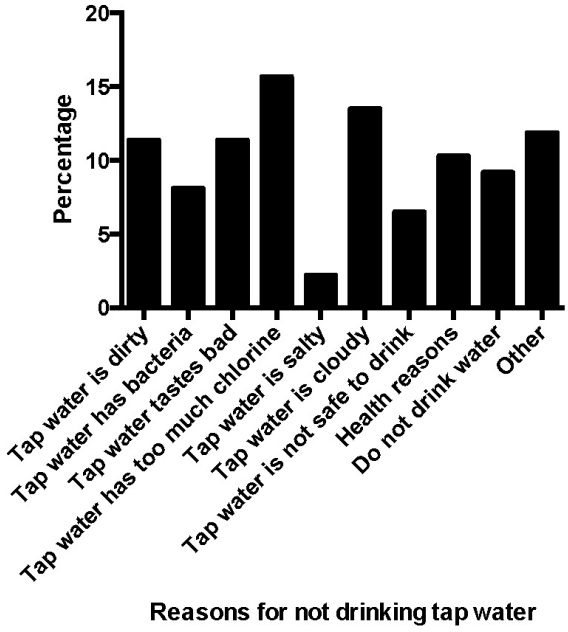


Figure 48: Bar graph depicting reasons why respondents 'never' or 'rarely' consumed tap water. N=108.

7.1.3.4.3 Knowledge of tap water origin

Respondents were asked if they knew the origin of their tap water. Of the 350 respondents, approximately 20% did know; 72% believed their tap water came from Ugum Water Treatment Plant; 2% believed their tap water came from Fena Reservoir; 1% believed their tap water came from Santa Rita Springs; and no one believed their water came from the Northern Guam Lens. See Figure 49.

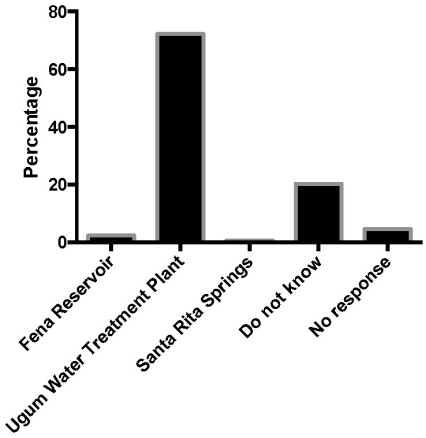


Figure 49: Bar graph depicting respondents' perceptions regarding where tap water in Manell and Geus watershed orginates. N=350.

7.1.3.4.4 Perception of Water Outage Frequency and Duration

Respondents were asked about the frequency of water outages they experienced. Approximately 4% did not know; 3% replied “never”; 48% replied “rarely”; 30% replied

"sometimes"; 12% replied "often"; and 1% replied "all the time". Approximately 2% declined to answer. See Figure 50. Respondents were asked about the duration of the water outages they experienced. Approximately 61% of respondents responded "one day"; 30% believed "a few days"; 1% believed the outage to last a week; 1% believed the outage to last several weeks; and 1% believed the outage to last several months. See Figure 51.

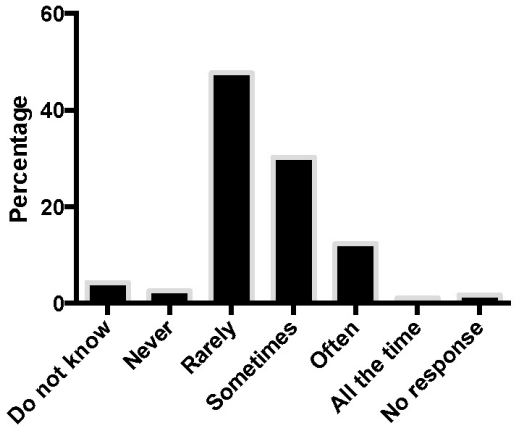


Figure 50: Bar graph depicting the perceived frequency of water outages, using a Likert scale. N=350.

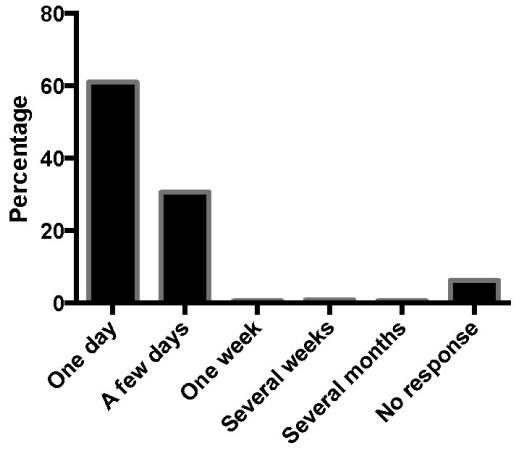


Figure 51: Bar graph depicting the perceived duration of water outages. N=350.

7.1.3.4.5 Alternative sources of water during outages

This was a multiple response set; respondents could choose more than one response. Of the 350 respondents, approximately 28% of respondents obtain their water from a water truck (provided by the Government of Guam, Guam Water Authority); 31% obtain their water at the Office of the Merizo Mayor (where the water truck is usually parked); 23% obtain their water from a friend or relative in North who had water; 7% obtain water from a beach with a public tap or shower; and 12% had a personal rainwater catchment. See Figure 52.

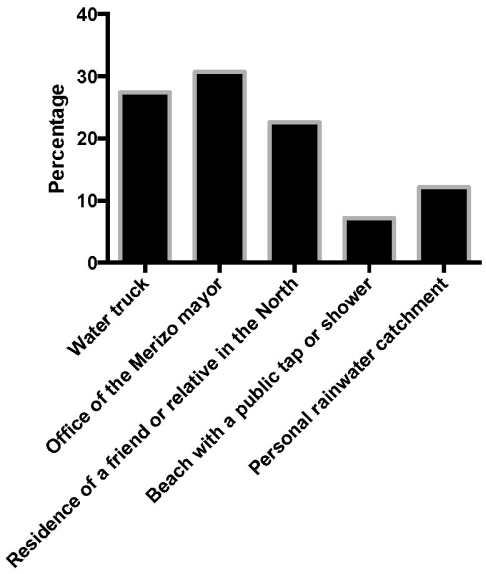


Figure 52: Bar graph depicting alternative locations respondents obtain water during a water outage.

7.1.3.4.6 Perception of frequency of boil water notices

Of the 350 respondents, approximately 22% felt they never received boil water notices; 47% felt they rarely received boil water notices; 17% felt they sometimes receive boil water notices; 4% felt they receive boil water notices often; and 1% felt they never receive boil water notices; and 9% choose not to answer the question. See Figure 53.

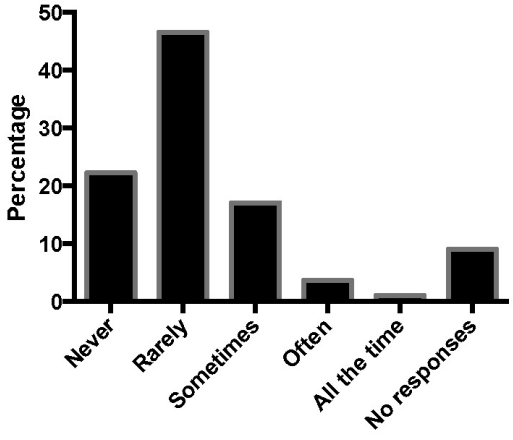


Figure 53: Bar graph depicting perceived frequency of boil water notices. N=350.

7.1.4 Values

There are approximately 23 variables examining the values of the residents of the Manell and Geus watersheds (16a-16w - see Appendix 2 – Household Survey Codebook). Respondents were asked to check off the top five things they valued most within the watershed from a list of twenty-four items. Humans have a difficult time ranking. They can keep at most, seven 'chunks'

of information within their immediate short-term memory (Miller 1956). Sala (2007) provides a detailed discussion of this 'magical' seven as it pertains to memory. There may have been too many options for respondents to choose from and it may be likely they were overwhelmed. Alas, this salient point was not known prior to constructing of the survey questions. In summary, the options prioritized by the respondents collectively as follows:

1. The cessation of flooding
2. Improving the roads
3. Improving the waterlines
4. Improving the schools
5. Having clean rivers
6. Having lots of fish
7. Having clean drinking water
8. Having clean oceans
9. Fish diversity
10. Reduced water outages
11. Having healthy coral reefs
12. Improving the sewer lines
13. Repopulating native species
14. Improving the local economy
15. Having healthy native forests
16. Increasing development
17. Reducing solid waste fees
18. Increasing the number of parks
19. Amending the rules for Achang Marine Preserve
20. Increasing local tourism
21. Having a designated place of garbage disposal
22. Increasing the number of boat ramps

See Figure 54, Figure 55, and Figure 56.

7.1.4.1 Having lots of fish

Approximately 25% of respondents listed having an abundant amount of fish as one of the top five things they valued most. See Figure 54.

7.1.4.2 Fish diversity

Approximately 18% of respondents listed "having many kinds of fish" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.3 Native species

Approximately 12% of respondents listed "repopulating native species" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.4 Improving the roads

Approximately 50% of respondents listed road improvement as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.5 Improving the schools

Approximately 31% of respondents listed improvement of schools as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.6 Improving the waterlines

Approximately 33% of respondents listed improving the waterlines as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.7 Improving the sewer lines

Approximately 13% of respondents listed improving the sewer lines as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.8 Stop the flooding of the roads

Approximately 53% of respondents listed "stop the flooding of the roads" as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.9 Having healthy native forests

Approximately 7% of respondents listed "healthy native forests" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.10 Having healthy coral reefs

Approximately 17% of respondents listed "healthy coral reefs" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.11 Having clean rivers

Approximately 26% of respondents listed "clean rivers" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.12 Having clean oceans

Approximately 20% of respondents listed "clean oceans" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.13 Having clean drinking water

Approximately 25% of respondents listed "clean tap water" as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.14 Reduced water outages

Approximately 18% of respondents listed a reduction in of water outages as one of the top five things they valued most in the watershed. See Figure 56.

7.1.4.15 Improving the local economy

Approximately 11% of respondents listed an improvement to the local economy as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.16 Parks

Approximately 6% of respondents listed a desire for more parks as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.17 Place for Garbage disposal

Approximately 3% of respondents listed a designated place for garbage disposal as one of the top five things they valued most in the watershed. See Figure 56.

7.1.4.18 Reduction of solid waste fees

Approximately 6% of respondents listed a reduction of solid waste fees as one of the top five things they valued most in the watershed. See Figure 56.

7.1.4.19 Boat ramps

Approximately 1% of respondents listed boat ramps as one of the top five things they valued most in the watershed. See Figure 56.

7.1.4.20 Amending the rules and regulations to the Achang Marine Preserve

Approximately 6% of respondents listed a desire to amend the rules and regulations of the Achang Marine Preserve as one of the top five things they valued most in the watershed. See Figure 54.

7.1.4.21 Tourism

Approximately 5% of respondents listed a desire to increase the number of tourists who come to Merizo as one of the top five things they valued most in the watershed. See Figure 55.

7.1.4.22 Development

Approximately 7% of respondents listed a desire for more development as one of the top five things they valued most in the watershed. Approximately 8% of respondents listed a desire to

restrict development as one of the top five things they valued most in the watershed. See Figure 55.

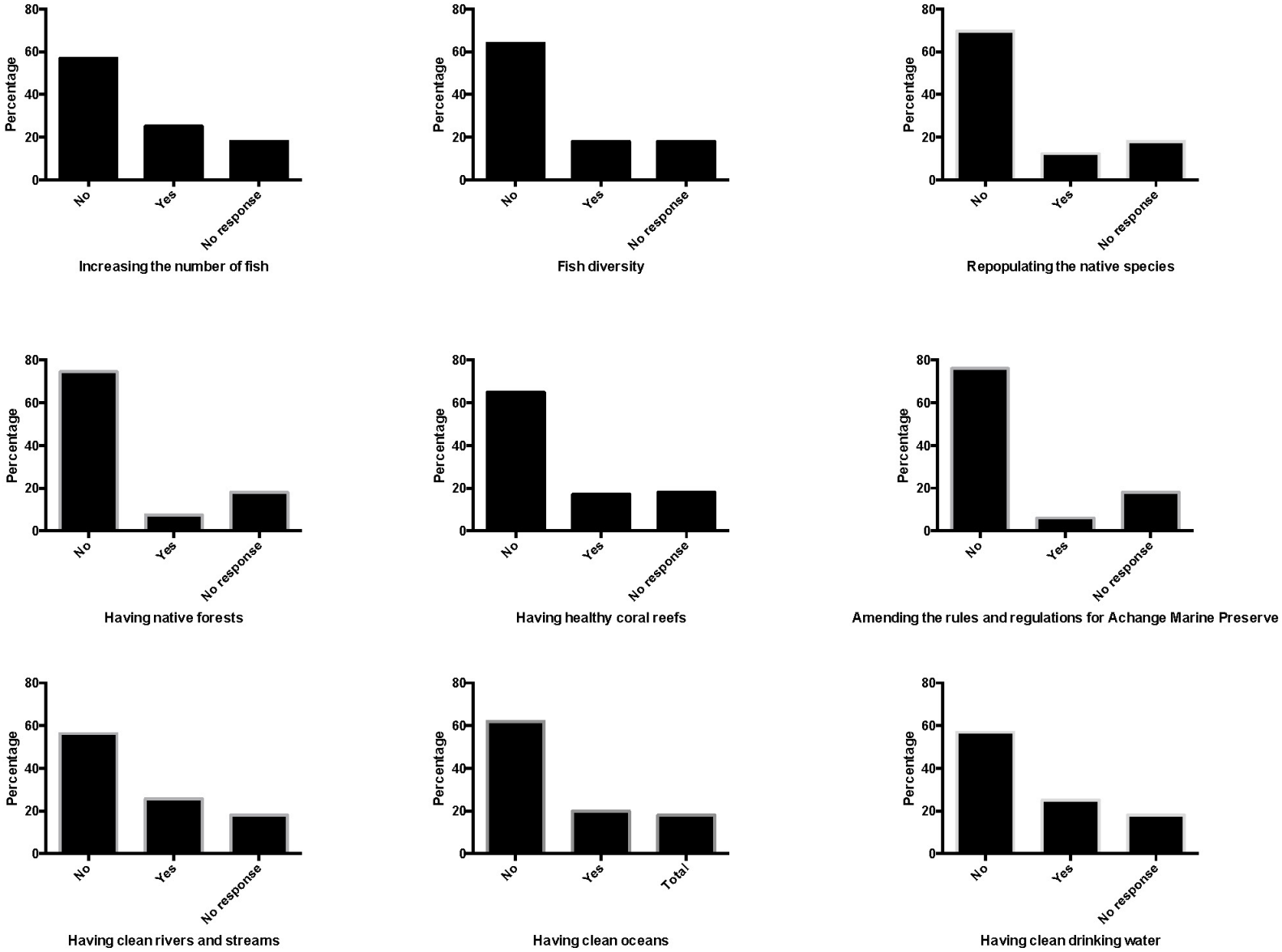


Figure 54: Bar graphs depicting values of respondents. Respondents were asked to select 5 of 22 options of the most personal importance. Results for the following are presented here: number of fish; fish diversity; native species; native forests; healthy coral reefs; clean rivers; clean oceans; clean drinking water; and amending the rules and regulations of the Achang Marine Preserve. N=350.

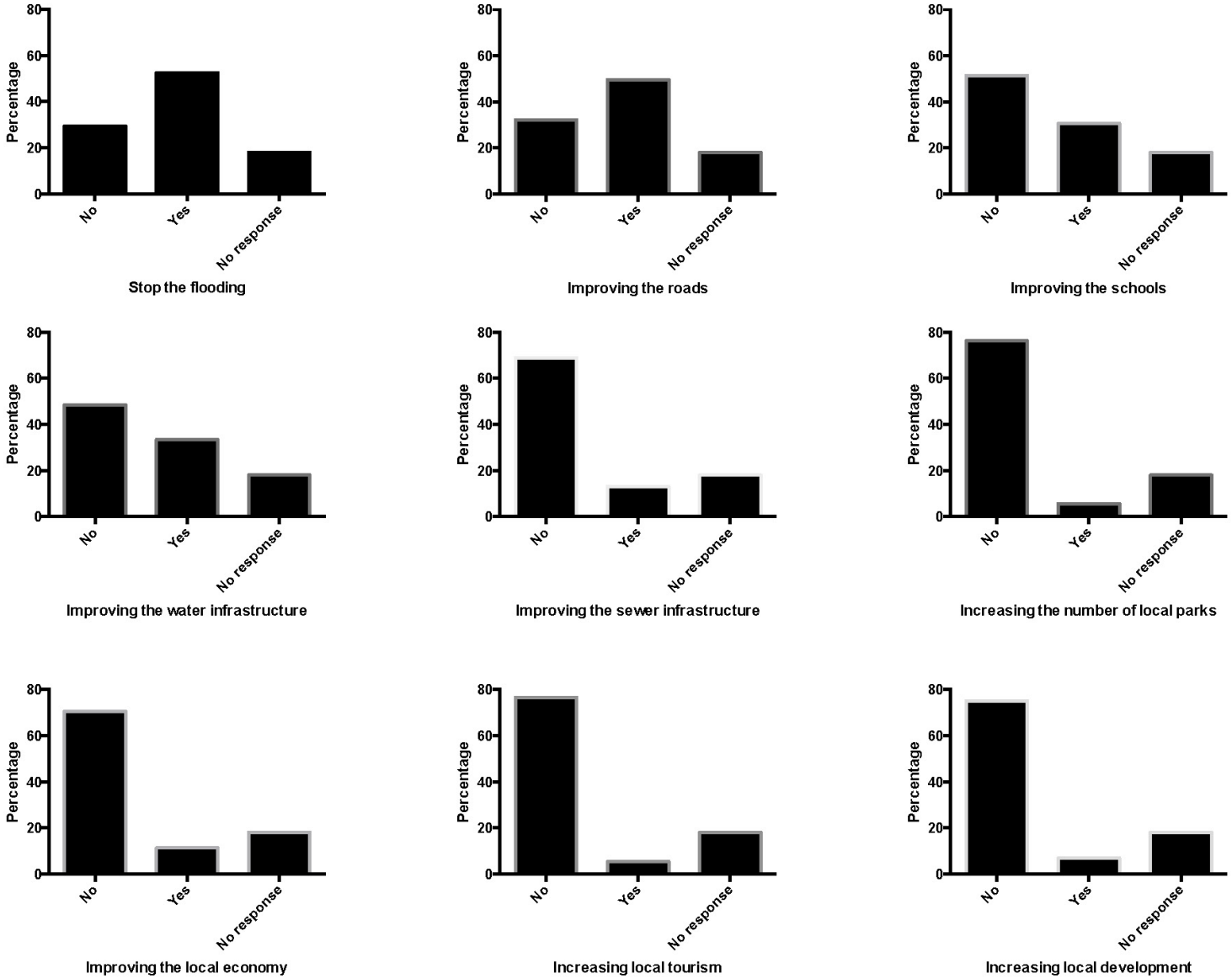


Figure 55: Bar graphs depicting values of respondents. Respondents were asked to select 5 of 22 options of the most personal importance. Results for the following are presented here: cessation of flooding events; local roads; schools; water infrastructure; sewer infrastructure; number of local parks; local economies; local tourism; and development. N=350.

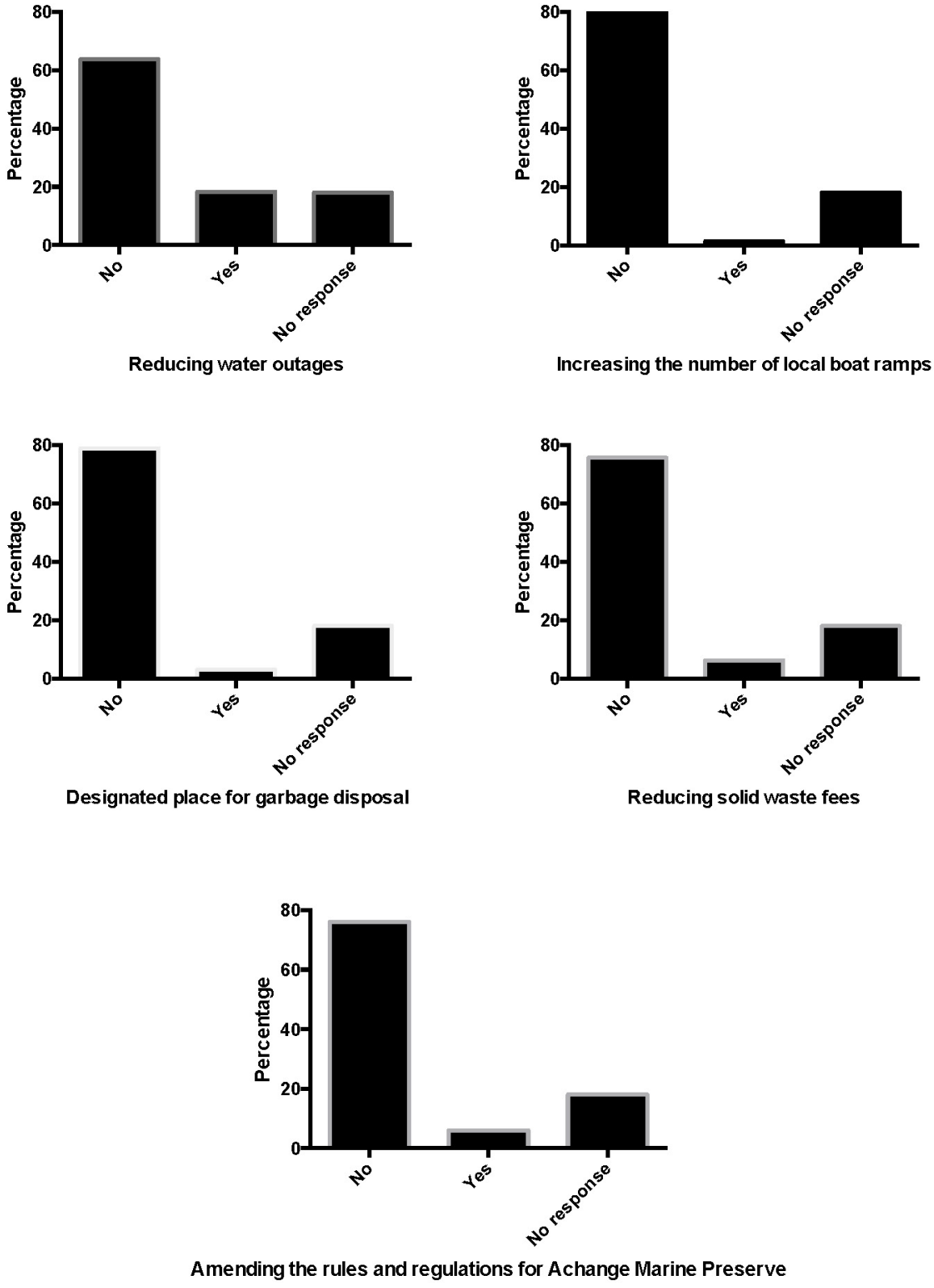


Figure 56: Bar graphs depicting values of respondents. Respondents were asked to select 5 of 22 options of the most personal importance. Results for the following options are presented here: reduction of water outages; increase in the number of local boat ramps; reduction in solid waste fees; and a designated place for garbage disposal; amending the rules for Achang Marine Preserve. N=350.

7.1.5 Attitudes

There are approximately 15 variables examining attitudes of the residents of the Manell and Geus watersheds (23a-23n; V24 – See Appendix 2 – Household Survey Codebook).

7.1.5.1 Trust in Governance

In an effort to gauge community trust for government agencies, respondents were asked how much they trust local government agencies responsible for the natural resources, infrastructure, and studies within the Manell and Geus watersheds. See Figure 57, Figure 58, and Figure 59.

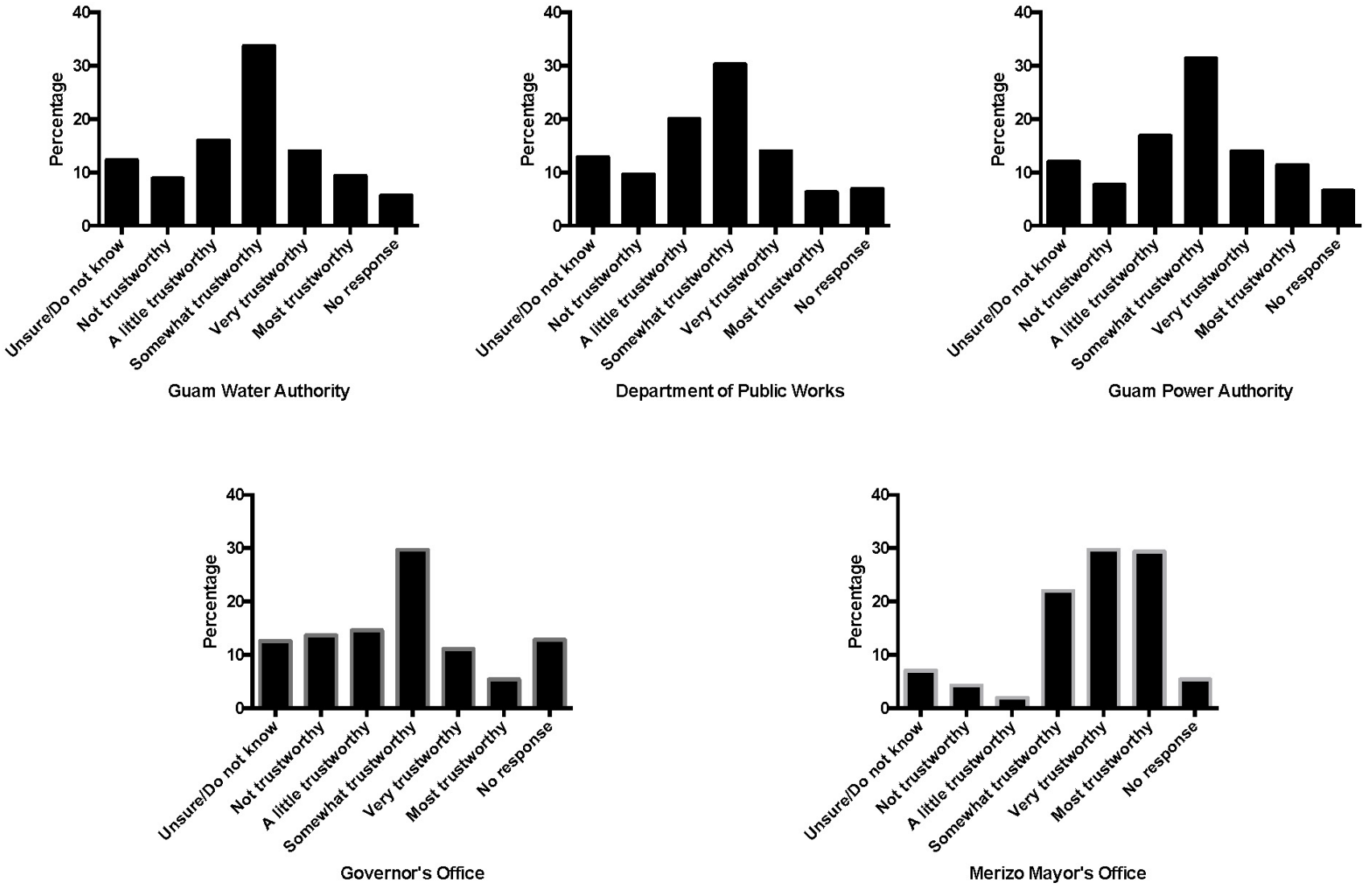


Figure 57: Five bar graphs depicting levels of trust for the Guam Water Authority, Department of Public Works, Guam Power Authority, Governor's Office and Merizo Mayor's Office. N=350 for each graph.

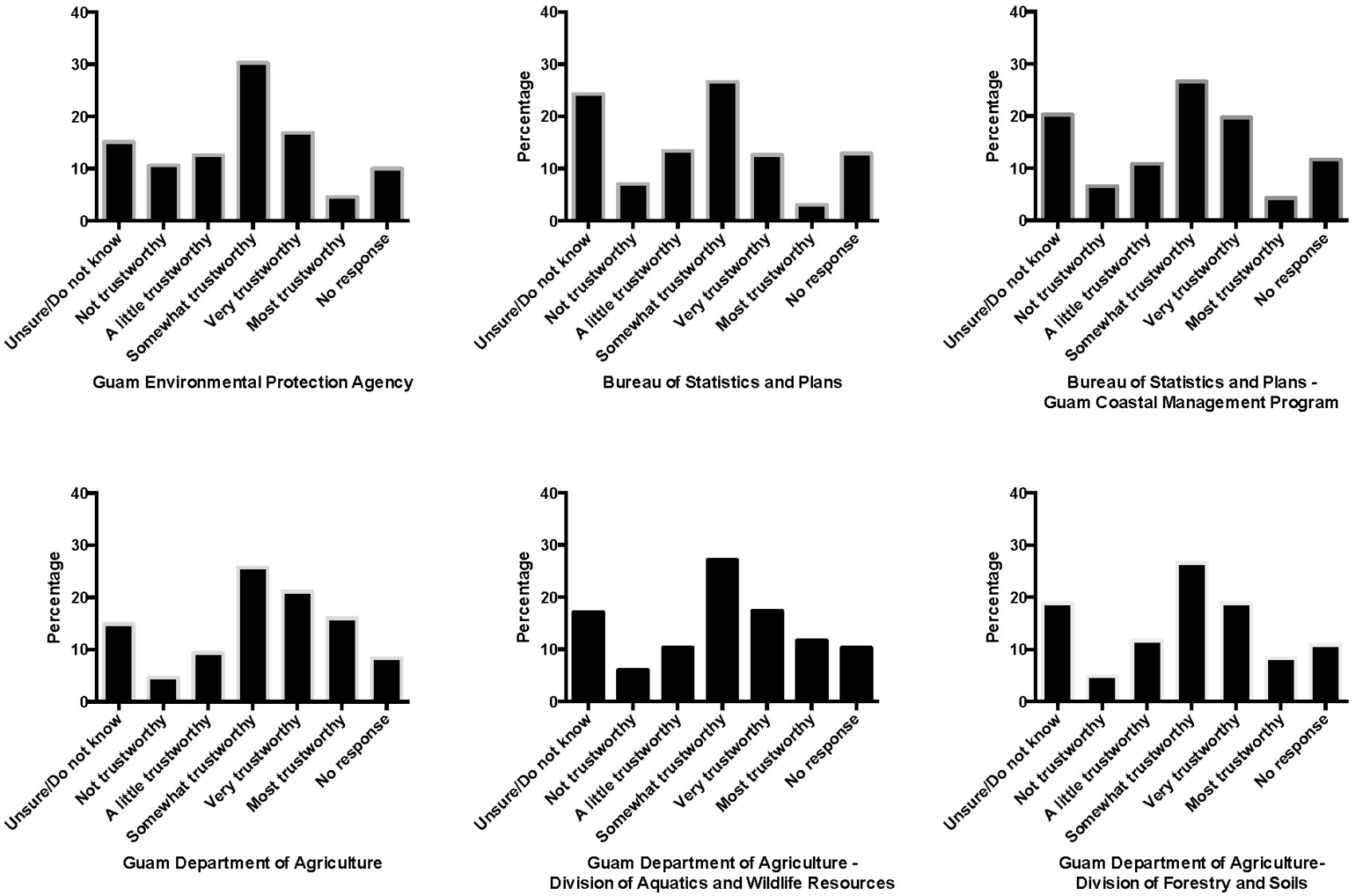
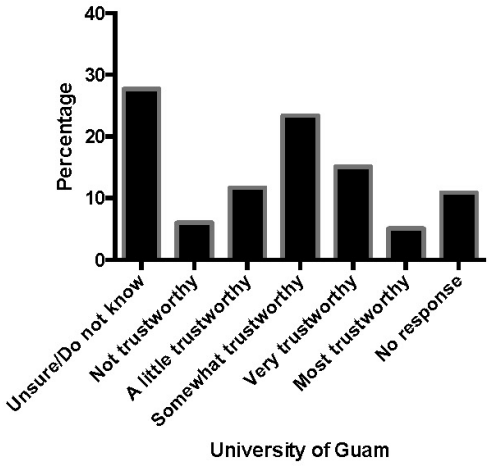
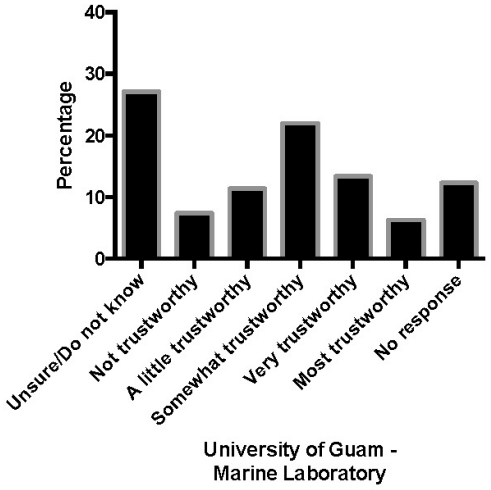


Figure 58: Six bar graphs depicting levels of trust for the Guam Environmental Protection Agency, the Bureau of Statistics and Plans, the BSP Guam Coastal Management Program, the Department of Agriculture, the DoAg Division of Aquatics and Wildlife Resources, and the DoAg-Division of Forestry and Soils. N=350 for each graph.





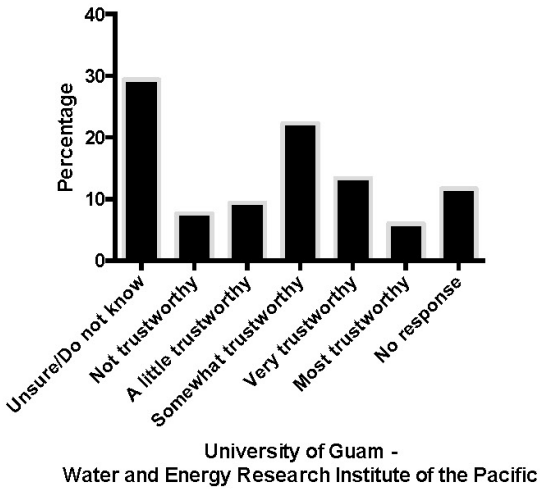


Figure 59: Three bar graphs depicting levels of trust for the University of Guam, UOG Marine Laboratory, and the UOG Water Energy Research Institute of the Western Pacific. N=350 for each graph.

7.1.5.2 Support for Achang Marine Preserve

Of the 350 respondents, approximately 30% did not know whether they supported Achang Marine Preserve (see Figure 32); 14% opposed the preserve; 5% strongly opposed the preserve; 6% do not care; 18% support the preserve; and 23% strongly support the preserve. Approximately 5% of respondents declined to answer. See Figure 60.

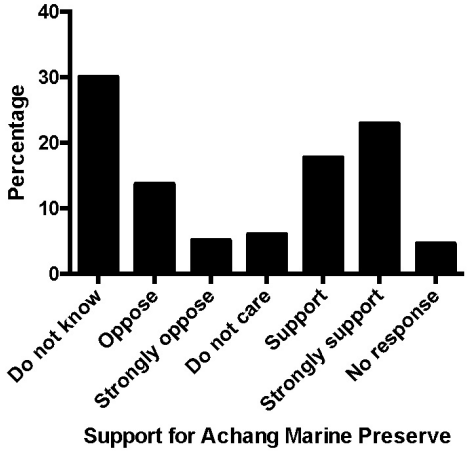


Figure 60: Bar graph showing levels of opposition and support for the Achang Marine Preserve. N=350.

7.1.6 Knowledge

There are approximately four variables examining knowledge (with regard to watersheds and spatial awareness of the environment) of the residents of the Manell and Geus watersheds (V37-V40 – see Appendix 2 – Household Survey Codebook). Local and federal natural resource agencies have been moving towards managing resources from a 'watershed' perspective and encouraging communities to regard their watershed with a 'ridge to reef' ethos. However, the community being managed may or may not be familiar, let alone define the term 'watershed' or the term 'ridge to reef'.

7.1.6.1 Familiarity with the term 'watershed'

Of the 350 respondents, approximately 52% were not familiar with the term "watershed"; 27% were familiar with the term watershed; and 17% did not know whether they were familiar with the term or not. Approximately 3% declined to answer.

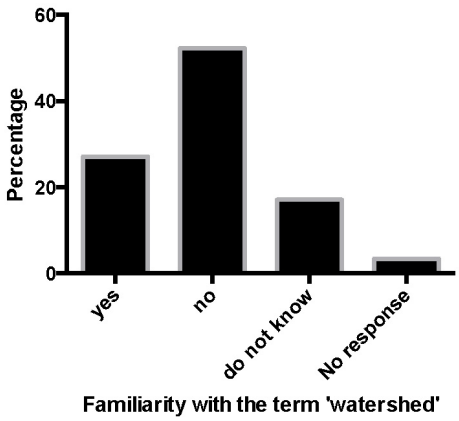


Figure 61: Bar graph showing whether respondents were familiar with the term 'watershed'. N=350.

7.1.6.2 Ability to define the term 'watershed'

Of the 350 respondents, approximately 26% felt they could define a watershed; 40% felt they could not define the term 'watershed'; 29% did not know whether they could define the term 'watershed'. Approximately 29% did not know if they could define the term. Approximately 5% declined to answer.

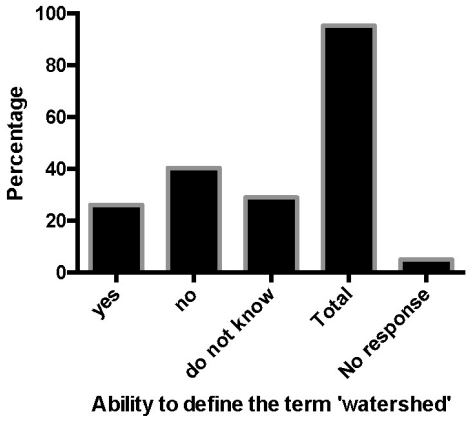


Figure 62: Bar graph depicting the ability of respondents to define the term 'watershed'. N=350.

7.1.6.3 Familiarity with the term 'Ridge to Reef'

Of the 350 respondents, approximately 27% felt they were familiar with the term "Ridge to Reef"; 46% did not know the term "Ridge to Reef"; and 24% did not know if they were familiar with the term "Ridge to Reef". Approximately 3% declined to answer. See Figure 63.

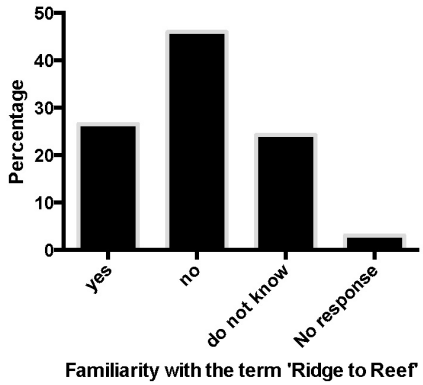


Figure 63: Bar graph depicting how familiar respondents were with the term 'Ridge to Reef'. N=350.

7.1.6.4 Spatial awareness – Proximity to a river

Of the 350 respondents, approximately 49% felt they lived relatively close to a river; 42% did not feel they lived near a river; and 6% did not know if they lived near a river. Approximately 2% declined to answer the question. See Figure 64.

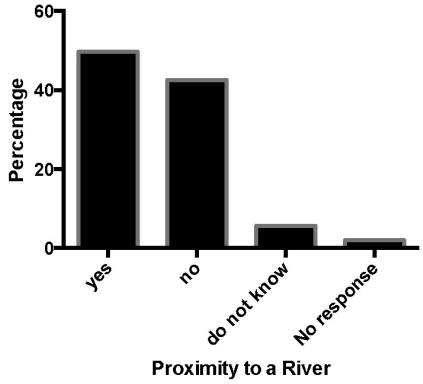


Figure 64: Bar graph depicting whether respondents knew if they resided close to a river. N=350.

7.1.7 Summary of descriptive statistics

The variables from the Household survey were classified into six categories – Demographic Information, Values, Behaviors, Attitudes, Perceptions, and Knowledge. There are 15 variables that examine demographic characteristics of the residents of the Manell and Geus watersheds (V1-V8; 9a-9d; V10, V11; 11a -11e – see Appendix 2 – Household Survey Codebook and Chapter 7: Demographic Information). There are approximately 23 variables examining the values of the residents of the Manell and Geus watersheds (16a-16w - see Appendix 2 – Household Survey Codebook and Chapter 7:7.1.4 Values . There are approximately 22 variables examining the behaviors of the residents of the Manell and Geus watersheds (12a-12q; V17; V41; V42; V43; V44 – see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.2 Behaviors).

There are approximately 15 variables examining attitudes of the residents of the Manell and Geus watersheds (23a-23n; V24 – See Appendix 2 – Household Survey Codebook and Chapter 7: Attitudes). There are approximately 34 variables examining perceptions of the residents of the Manell and Geus watersheds (15b-15p; 17a – 17i; V19, V20, V22; 45a-45h – see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.3 Perceptions). There are approximately four variables examining knowledge (with regard to watersheds and spatial awareness of the environment) of the residents of the Manell and Geus watersheds (V37-V40 – see Appendix 2 – Household Survey Codebook and Chapter 7: 7.1.6 Knowledge). These results will be discussed in Chapter 9: Discussion and Conclusion.

7.2 Inferential Statistics

Inferential statistics involves analyzing the strength of what a specific subset indicates about the rest of the population. Essentially, the results of an analysis using a representative sample may be generalized and applied to the larger population. There are several statistical tests of significance to determine the probability that the results are representative of the population or if they occurred by chance.

7.2.1 Correlations

Correlation is a statistical technique to determine whether or not a relationship exists between variables, the strength of that relationship, and the statistical significance of that relationship (Hayslett 1968). Previous research indicates that factors such as age, gender, level of education attained, and average annual income may influence attitudes, perceptions, and behaviors towards natural resources and environmental conservation (Kollmuss and Agyeman 2002). For relationships that could be tested, a bivariate correlation using a Spearman's rank coefficient were conducted for the following demographic variables: age, gender, level of education attained, and average annual income; and 20 variables associated with behaviors; 23 variables associated with values; 15 variables associated with attitudes; 4 variables associated with knowledge; and 34 variables associated with perceptions. A grand total of 384 correlations were conducted and the resulting correlation coefficients (p-values) were analyzed.

Significant correlation coefficients greater than or equal to 0.8 and less than or equal to -0.8 were examined carefully, because variables with such a strong relationships should not be used in a model together (University of Leeds 2008). Such high significant correlation coefficients are usually indicative of autocorrelation and when placed together in a model, the results may be difficult to interpret due to collinearity (University of Leeds 2008). In the following sections,

statistically significant correlations are presented for each variable: gender, level of education attained, age, and average annual income.

7.2.2 Gender

A bivariate correlation using a Spearman's rank coefficient were conducted for the variable of gender with regard to 20 variables associated with behaviors; the 23 variables associated with values; the 15 variables associated with attitudes; the 4 variables associated with knowledge; and the 34 variables associated with perceptions. A total of 96 bivariate correlations using a Spearman's rank coefficient were conducted.

Gender and values

With regard to gender and values, a total of 23 bivariate correlations using a Spearman's rank coefficient were conducted. Of the results, three were statistically significant at the .05 level (2-tailed). There is a positive, weak relationship between gender and valuing clean tap water (see Table 37). There is a positive, weak relationship between gender and valuing an amendment to the rules and regulations of the Achang Marine Preserve (see Table 38). There is a negative, weak relationship between gender and valuing the jungles (see Table 39).

Table 37: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and having clean tap water. Correlation is significant at the 0.05 level (2-tailed); N = 283.

Correlation Coefficient (P-Value)	.151
Sig. (2-tailed)	.011
N	283

Table 38: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and amending the rules and regulations of the Achang Marine Preserve. Correlation is significant at the 0.05 level (2-tailed); N = 283.

Correlation Coefficient (P-Value)	.120
Sig. (2-tailed)	.043
N	283

Table 39: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and jungles. Correlation is significant at the 0.05 level (2-tailed); N = 323.

Correlation Coefficient (P-Value)	-.119
Sig. (2-tailed)	.033
N	323

Gender and knowledge

With regard to gender and knowledge, a total of four bivariate correlations using a Spearman's rank coefficient were conducted. Of the results, none were statistically significant at the .01 level (2-tailed) or the .05 level (2-tailed).

Gender and attitudes

With regard to gender and attitudes, a total of 15 bivariate correlations using a Spearman's rank coefficient were conducted. Of the results, two were statistically significant at the .05 level (2-tailed). There is a positive, weak relationship between gender and trust toward the Guam Department of Public Works (Table 40). There is a positive, weak relationship between gender and trust for the Guam Environmental Protection Agency (see Table 41).

Table 40: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and trust for the Guam Department of Public Works. Correlation is significant at the 0.05 level (2-tailed); N = 321.

Correlation Coefficient (P-Value)	.116
Sig. (2-tailed)	.037
N	321

Table 41: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and trust for the Guam Environmental Protection Agency. Correlation is significant at the 0.05 level (2-tailed); N = 310.

Correlation Coefficient (P-Value)	.133
Sig. (2-tailed)	.020
N	310

Gender and behaviors

With regard to gender and behaviors, a total of 20 bivariate correlations using a Spearman's rank coefficient were conducted. Of the results, eight were statistically significant at the .01 level (2-tailed) and five were statistically significant at the .05 level (2-tailed). There is a negative, weak relationship between gender and the burning of vegetation (see Table 42). In an effort to visualize this correlation, a clustered bar graph was generated (see Figure 5). It appears that men burn vegetative debris more than women. There is a negative, weak relationship between gender and the disposal of vegetation in the jungle (see Table 43). To better visualize this relationship, a clustered bar graph was generated (see Figure **66**). It appears that males are disposing vegetative debris in the jungle, more so than females. There is a negative, weak relationship between gender and the smoking of trees (see Table 44). In an effort to better visualize this relationship, a clustered bar graph was generated (see Figure 67). There is a negative, weak relationship between gender and off-roading (see Table 45). There is a negative, weak relationship between gender and fishing (see Table 46). There is a negative, weak relationship between gender and hunting (see Table 47). There is a negative, weak relationship between gender and farming (see Table 48). There is a negative, weak relationship between gender and taking the garbage to Ordot Dump (see Table 52). To better visualize this relationship, a clustered bar graph was generated (see Figure 68). It appears that male respondents tend to transport garbage to the Ordot Dump more than females. There is a

negative, weak relationship between gender and hiking or running (see Table 53). In order to better visualize this relationship, a clustered bar graph was generated (see Figure 69). There is a negative, weak relationship between gender and hunting for crabs (see Table 49). There is a negative, weak relationship between gender and swimming (see Table 50). There is a negative, weak relationship between gender and having barbeques (see Table 51).

Table 42: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the burning of vegetation. Correlation is significant at the 0.01 level (2-tailed); N = 295.

Correlation Coefficient (P-Value)	-.153
Sig. (2-tailed)	.009
N	295

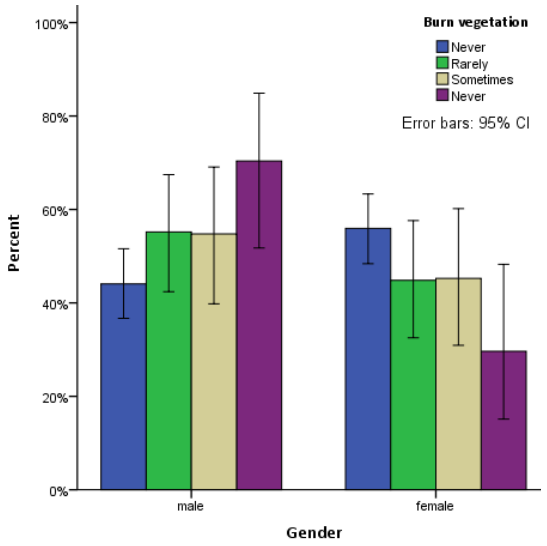


Figure 65: Clustered bar graph showing the percentage of males and females who never, rarely, sometimes, or never burn vegetation. N=295.

Table 43: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the disposal of vegetation in the jungle. Correlation is significant at the 0.01 level (2-tailed); N = 289.

Correlation Coefficient (P-Value)	-.172
Sig. (2-tailed)	.003
N	289

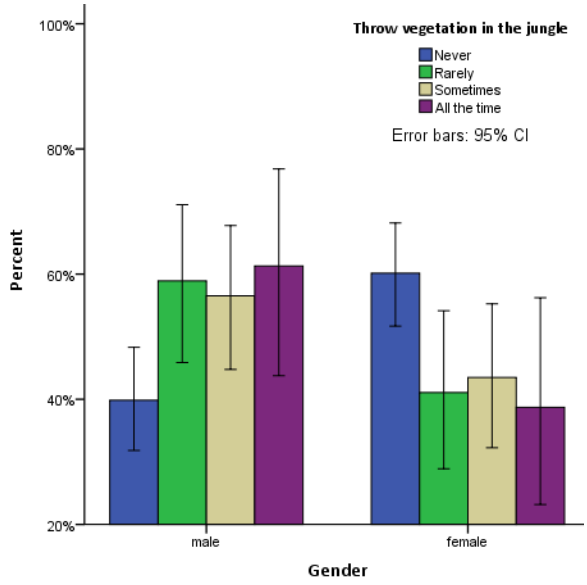


Figure 66: Clustered bar graph showing the percentage of males and females who never, rarely, sometimes, or never dispose of their vegetation in the jungle. N=289

Table 44: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the 'smoking of trees'. Correlation is significant at the 0.01 level (2-tailed); N = 301.

Correlation Coefficient (P-Value)	-.158
Sig. (2-tailed)	.006
N	301

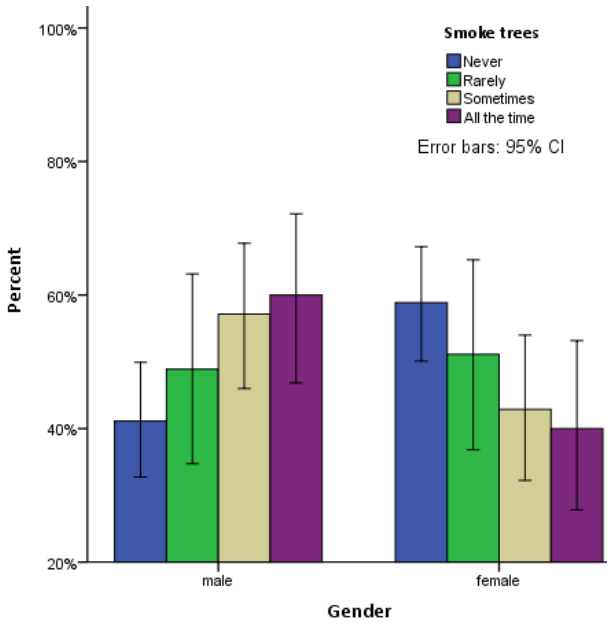


Figure 67: Clustered bar graph showing the percentage of males and females who never, rarely, sometimes, or never 'smoke' trees. N=301.

Table 45: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and off-roading. Correlation is significant at the 0.01 level (2-tailed); N = 287.

Correlation Coefficient (P-Value)	-.218
Sig. (2-tailed)	.000
N	287

Table 46: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and fishing. Correlation is significant at the 0.01 level (2-tailed); N = 301.

Correlation Coefficient (P-Value)	-.313
Sig. (2-tailed)	.000
N	301

Table 47: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the hunting. Correlation is significant at the 0.01 level (2-tailed); N = 293.

Correlation Coefficient (P-Value)	-.277
Sig. (2-tailed)	.000
N	293

Table 48: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and farming. Correlation is significant at the 0.01 level (2-tailed); N = 298.

Correlation Coefficient (P-Value)	-.248
Sig. (2-tailed)	.000
N	298

Table 49: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and hunting for crabs. Correlation is significant at the 0.05 level (2-tailed); N = 296.

Correlation Coefficient (P-Value)	-.127
Sig. (2-tailed)	.029
N	296

Table 50: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and swimming. Correlation is significant at the 0.05 level (2-tailed); N = 305.

Correlation Coefficient (P-Value)	-.118
Sig. (2-tailed)	.039
N	305

Table 51: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and having barbeques. Correlation is significant at the 0.05 level (2-tailed); N = 308.

Correlation Coefficient (P-Value)	-.112
Sig. (2-tailed)	.049
N	308

Table 52: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and taking garbage to the Ordot Dump. Correlation is significant at the 0.05 level (2-tailed); N = 289.

Correlation Coefficient (P-Value)	-.121
Sig. (2-tailed)	.039
N	289

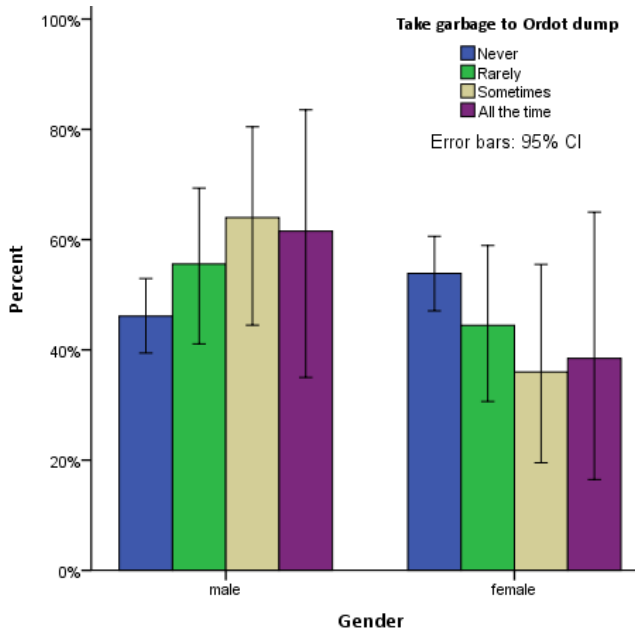


Figure 68: Clustered bar graph showing the percentage of males and females who never, rarely, sometimes, or never take their garbage to Ordot Dump. N=289.

Table 53: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and hiking or running. Correlation is significant at the 0.05 level (2-tailed); N = 296.

Correlation Coefficient (P-Value)	-.117
Sig. (2-tailed)	.044
N	296

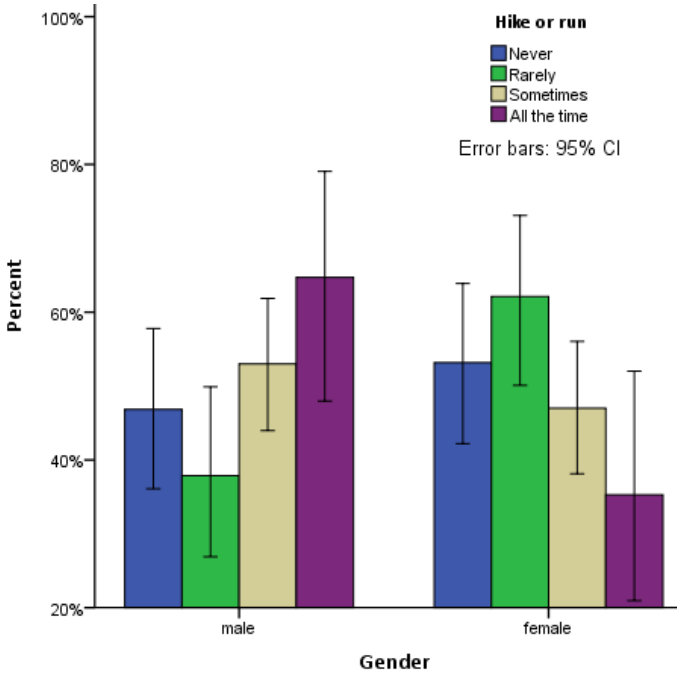


Figure 69: Clustered bar graph the percentage of males and females who never, rarely, sometimes, or never hike or run. N=289.

Gender and perceptions

With regard to gender and perceptions, a total of 34 bivariate correlations using a Spearman's rank coefficient were conducted. Of the results, three were statistically significant at the .05 level (2-tailed). There is a positive, weak relationship between gender and the perception that tap water tastes 'bad' (see Table 54). There is a negative, weak relationship between gender and the perception that the forests are filled with native vegetation (see Table 55). There is a negative, weak relationship between gender and the perception that there is erosion in the Manell and Geus watersheds (see Table 56).

Table 54: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the perception that tap water tastes 'bad'. Correlation is significant at the 0.05 level (2-tailed); N = 91.

Correlation Coefficient (P-Value)	.213
Sig. (2-tailed)	.043
N	91

Table 55: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the perception that the forests are filled with native vegetation. Correlation is significant at the 0.05 level (2-tailed); N = 312.

Correlation Coefficient (P-Value)	-.115
Sig. (2-tailed)	.042
N	312

Table 56: Correlation coefficient, significance, and number of cases (N) for the following variables: gender and the perception that there is erosion. Correlation is significant at the 0.05 level (2-tailed); N = 297.

Correlation Coefficient (P-Value)	-.127
Sig. (2-tailed)	.028
N	297

7.2.3 Age

A bivariate correlation using a Spearman's rank coefficient were conducted for the variable of age with regard to 20 variables associated with behaviors; the 23 variables associated with values; the 15 variables associated with attitudes; the 4 variables associated with knowledge; and the 34 variables associated with perceptions. A total of 96 bivariate correlations using a Spearman's rank coefficient were conducted.

Age and values

A bivariate correlation using a Spearman's rank coefficient were conducted for the variable of age with regard to 23 variables associated with values. Of the results, one was significant at the .01 level (2-tailed) and two were significant at the .05 level (2-tailed). There is a negative, weak relationship between age and valuing the improvement of schools (see Table 57). There is a positive, weak relationship between age and having healthy forests (see Table 58). There is a negative, weak relationship between age and valuing family (see Table 59).

Table 57: Correlation coefficient, significance, and number of cases (N) for the following variables: age and valuing the improvement of schools. Correlation is significant at the 0.01 level (2-tailed); N = 284.

Correlation Coefficient (P-Value)	-.241
Sig. (2-tailed)	.000
N	284

Table 58: Correlation coefficient, significance, and number of cases (N) for the following variables: age and having healthy native forests. Correlation is significant at the 0.05 level (2-tailed); N = 284.

Correlation Coefficient (P-Value)	.133
Sig. (2-tailed)	.025
N	284

Table 59: Correlation coefficient, significance, and number of cases (N) for the following variables: age and valuing family. Correlation is significant at the 0.05 level (2-tailed); N = 324.

Correlation Coefficient (P-Value)	-.109
Sig. (2-tailed)	.050
N	324

Age and knowledge

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of age with 4 variables associated with knowledge. Of the results, one was significant at the .05 level (2-tailed). There is a negative, weak relationship between age and familiarity with the term watershed (see Table 60).

Table 60: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the familiarity with the term 'watershed'. Correlation is significant at the 0.05 level (2-tailed); N = 334.

Correlation Coefficient (P-Value)	-.126
Sig. (2-tailed)	.021
N	334

Age and attitudes

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of age with regard to 15 variables associated with attitudes. Of the results, one was significant at .01 level (2-tailed) and one was significant at the .05 level (2-tailed). There is a positive, weak relationship between age and an attitude toward the Achang Reef Marine Preserve (see Table 61). There is a negative, weak relationship between age and trust toward the Department of Agriculture (see Table 62).

Table 61: Correlation coefficient, significance, and number of cases (N) for the following variables: age and attitude toward the Achang Reef Marine Preserve. Correlation is significant at the 0.01 level (2-tailed); N = 330.

Correlation Coefficient (P-Value)	.173
Sig. (2-tailed)	.002
N	330

Table 62: Correlation coefficient, significance, and number of cases (N) for the following variables: age and attitude toward the Department of Agriculture. Correlation is significant at the 0.05 level (2-tailed); N = 317.

Correlation Coefficient (P-Value)	-.119
Sig. (2-tailed)	.034
N	317

Age and behaviors

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of age with regard to 20 variables associated with behaviors. Of the results, six were significant at the .01 level (2-tailed) and four were significant at the .05 level (2-tailed). There is a positive, weak relationship between age and burning vegetation (see Table 63). There is a positive, weak relationship between age and composting (see Table 64). There is a negative, weak relationship between age and hiking and running (see Table 65). There is a negative, weak relationship between age and off-roading (see Table 66). There is negative, modest relationship between age and swimming (see Table 67). There is a negative, weak relationship between age and having barbeques (see Table 68). There is a negative, weak relationship between age and recycling (see Table 69). There is a positive, weak relationship between age and participation in curbside pickup of garbage (see Table 70). There is a positive, weak relationship between age and farming (see Table 71). There is a negative, weak relationship between age and the frequency of tap water consumption (see Table 72).

Table 63: Correlation coefficient, significance, and number of cases (N) for the following variables: age and burning vegetation. Correlation is significant at the 0.01 level (2-tailed); N = 297.

Correlation Coefficient (P-Value)	.194
Sig. (2-tailed)	.001
N	297

Table 64: Correlation coefficient, significance, and number of cases (N) for the following variables: age and composting. Correlation is significant at the 0.01 level (2-tailed); N = 288.

Correlation Coefficient (P-Value)	.141
Sig. (2-tailed)	.016
N	288

Table 65: Correlation coefficient, significance, and number of cases (N) for the following variables: age and hiking or running. Correlation is significant at the 0.01 level (2-tailed); N = 296.

Correlation Coefficient (P-Value)	-.333
Sig. (2-tailed)	.000
N	296

Table 66: Correlation coefficient, significance, and number of cases (N) for the following variables: age and off-roading. Correlation is significant at the 0.01 level (2-tailed); N = 288.

Correlation Coefficient (P-Value)	-.156
Sig. (2-tailed)	.008
N	288

Table 67: Correlation coefficient, significance, and number of cases (N) for the following variables: age and swimming. Correlation is significant at the 0.01 level (2-tailed); N = 297.

Correlation Coefficient (P-Value)	-.443
Sig. (2-tailed)	.000
N	305

Table 68: Correlation coefficient, significance, and number of cases (N) for the following variables: age and barbequeing. Correlation is significant at the 0.01 level (2-tailed); N = 309.

Correlation Coefficient (P-Value)	-.384
Sig. (2-tailed)	.000
N	309

Table 69: Correlation coefficient, significance, and number of cases (N) for the following variables: age and recycling. Correlation is significant at the 0.05 level (2-tailed); N = 301.

Correlation Coefficient (P-Value)	-.129
Sig. (2-tailed)	.026
N	301

Table 70: Correlation coefficient, significance, and number of cases (N) for the following variables: age and participating in the curbside collection of garbage. Correlation is significant at the 0.05 level (2-tailed); N = 301.

Correlation Coefficient (P-Value)	.140
Sig. (2-tailed)	.015
N	301

Table 71: Correlation coefficient, significance, and number of cases (N) for the following variables: age and farming. Correlation is significant at the 0.05 level (2-tailed); N = 299.

Correlation Coefficient (P-Value)	.123
Sig. (2-tailed)	.033
N	299

Table 72: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the frequency of tap water consumption. Correlation is significant at the 0.05 level (2-tailed); N = 337.

Correlation Coefficient (P-Value)	-.133
Sig. (2-tailed)	.015
N	337

Age and perceptions

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of age with regard to 34 variables associated with perceptions. Of the results, two were significant at the .01 level (2-tailed) and three were significant at the .05 level (2-tailed). There is a positive, weak relationship between age and the perception that tap water contains too much chlorine (see Table 73). There is a positive, weak relationship between age and the perception that there are frequent boil water notices (see Table 74). There is a positive, weak relationship between age and the perception that tap water is salty (see Table 75). There is a positive, weak relationship between age and the perception that there are frequent water outages (see Table 76). There is a negative, weak relationship between age and the perception that there is erosion within the Manell and Geus watersheds (see Table 77).

Table 73: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the perception that tap water has too much chlorine. Correlation is significant at the 0.01 level (2-tailed); N = 90.

Correlation Coefficient (P-Value)	.309
Sig. (2-tailed)	.003
N	90

Table 74: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the perception of frequent boil water notices. Correlation is significant at the 0.01 level (2-tailed); N = 314.

Correlation Coefficient (P-Value)	.229
Sig. (2-tailed)	.000
N	314

Table 75: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the perception that tap water is salty. Correlation is significant at the 0.05 level (2-tailed); N = 90.

Correlation Coefficient (P-Value)	.209
Sig. (2-tailed)	.048
N	90

Table 76: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the perception of water outage frequency. Correlation is significant at the 0.05 level (2-tailed); N = 340.

Correlation Coefficient (P-Value)	.111
Sig. (2-tailed)	.040
N	340

Table 77: Correlation coefficient, significance, and number of cases (N) for the following variables: age and the perception that there is erosion. Correlation is significant at the 0.01 level (2-tailed); N = 309.

Correlation Coefficient (P-Value)	-.140
Sig. (2-tailed)	.016
N	296

7.2.4 Education

A bivariate correlation using a Spearman's rank coefficient were conducted for the variable of education with regard to 20 variables associated with behaviors; the 23 variables associated with values; the 15 variables associated with attitudes; the 4 variables associated with knowledge; and the 34 variables associated with perceptions. A total of 96 bivariate correlations using a Spearman's rank coefficient were conducted.

Education and values

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of education with regard to 23 variables associated with values. Of the results, two were significant at the .01 level (2-tailed) and four were significant at the .05 level (2-tailed). There is a negative, weak relationship between education and valuing the improvement of schools (see Table 78). There is a weak, positive relationship between education and valuing a beautiful environment (see Table 79). There is a weak, positive relationship between education and valuing the proximity to the ocean (see Table 80). There is a weak, positive relationship between education and valuing the improvement of the water infrastructure (see Table 81). There is a weak, positive relationship between education and valuing the improvements to the sewage system (see Table 82). There is a negative, weak relationship between education and familiarity with the concept of 'ridge to reef' (see Table 85).

Table 78: Correlation coefficient, significance, and number of cases (N) for the following variables: education and improving the schools. Correlation is significant at the 0.01 level (2-tailed); N = 281.

Correlation Coefficient (P-Value)	-.200
Sig. (2-tailed)	.001
N	281

Table 79: Correlation coefficient, significance, and number of cases (N) for the following variables: education and valuing a beautiful environment. Correlation is significant at the 0.01 level (2-tailed); N = 322.

Correlation Coefficient (P-Value)	.171
Sig. (2-tailed)	.002
N	322

Table 80: Correlation coefficient, significance, and number of cases (N) for the following variables: education and valuing the proximity to the sea. Correlation is significant at the 0.05 level (2-tailed); N = 322.

Correlation Coefficient (P-Value)	.131
Sig. (2-tailed)	.018
N	322

Table 81: Correlation coefficient, significance, and number of cases (N) for the following variables: education and improving the waterlines. Correlation is significant at the 0.05 level (2-tailed); N = 281.

Correlation Coefficient (P-Value)	.138
Sig. (2-tailed)	.020
N	281

Table 82: Correlation coefficient, significance, and number of cases (N) for the following variables: education and valuing more parks. Correlation is significant at the 0.05 level (2-tailed); N = 281.

Correlation Coefficient (P-Value)	-.149
Sig. (2-tailed)	.013
N	281

Education and knowledge

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of education with regard to four variables associated with knowledge. Of the four results, three were significant at the .01 level (2-tailed). There is a negative, weak relationship between education and familiarity with the term 'watershed' (see Table 83). There is a negative, weak relationship between education and the ability to define the term 'watershed' (see Table 84).

Table 83: Correlation coefficient, significance, and number of cases (N) for the following variables: education and familiarity with the term 'watershed'. Correlation is significant at the 0.01 level (2-tailed); N = 332.

Correlation Coefficient (P-Value)	-.223
Sig. (2-tailed)	.000
N	332

Table 84: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the ability to define the term 'watershed'. Correlation is significant at the 0.01 level (2-tailed); N = 328.

Correlation Coefficient (P-Value)	-.234
Sig. (2-tailed)	.000
N	328

Table 85: Correlation coefficient, significance, and number of cases (N) for the following variables: education and familiarity with the concept of 'ridge to reef'. Correlation is significant at the 0.01 level (2-tailed); N = 333.

Correlation Coefficient (P-Value)	-.167
Sig. (2-tailed)	.002
N	333

Education and attitudes

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of education with regard to 15 variables associated with attitudes. Of the 15 results, 1 was significant at the .01 level (2-tailed) and 1 was significant at the .05 level (2-tailed). There is a

positive, weak relationship between education and attitude toward the Achang Marine Preserve (see Table 86). There is a positive, weak relationship between education and attitude toward the Department of Agriculture (see Table 87).

Table 86: Correlation coefficient, significance, and number of cases (N) for the following variables: education and attitude towards the Achang Marine Preserve. Correlation is significant at the 0.01 level (2-tailed); N = 330.

Correlation Coefficient (P-Value)	.182
Sig. (2-tailed)	.001
N	328

Table 87: Correlation coefficient, significance, and number of cases (N) for the following variables: education and attitude towards the Department of Agriculture Division of Forestry and Soils Resources. Correlation is significant at the 0.05 level (2-tailed); N = 307.

Correlation Coefficient (P-Value)	.129
Sig. (2-tailed)	.024
N	307

Education and behaviors

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of education with regard to 20 variables associated with behaviors. Of the 20 results, 3 were significant at the .01 level (2-tailed) and 6 were significant at the .05 level (2-tailed). There are positive, weak relationships between education and

- burning vegetation (see Table 88),
- composting (see Table 89),
- recycling (see Table 91).

There are negative, weak relationships between education and

- having a barbeque (see Table 90),
- burning garbage (see Table 92),
- hunting for crabs (see Table 93),
- swimming (see Table 94),
- frequency of tap water consumption (see Table 95),
- participation in past watershed projects (see Table 96).

Table 88: Correlation coefficient, significance, and number of cases (N) for the following variables: education and burning vegetation. Correlation is significant at the 0.01 level (2-tailed); N = 296.

Correlation Coefficient (P-Value)	.150
Sig. (2-tailed)	.010
N	296

Table 89: Correlation coefficient, significance, and number of cases (N) for the following variables: education and composting. Correlation is significant at the 0.01 level (2-tailed); N = 287.

Correlation Coefficient (P-Value)	.170
Sig. (2-tailed)	.004
N	287

Table 90: Correlation coefficient, significance, and number of cases (N) for the following variables: education and having a barbeque. Correlation is significant at the 0.01 level (2-tailed); N = 308.

Correlation Coefficient (P-Value)	-.170
Sig. (2-tailed)	.003
N	308

Table 91: Correlation coefficient, significance, and number of cases (N) for the following variables: education and recycling. Correlation is significant at the 0.05 level (2-tailed); N = 300.

Correlation Coefficient (P-Value)	.113
Sig. (2-tailed)	.050
N	300

Table 92: Correlation coefficient, significance, and number of cases (N) for the following variables: education and burning garbage. Correlation is significant at the 0.05 level (2-tailed); N = 309.

Correlation Coefficient (P-Value)	-.113
Sig. (2-tailed)	.019
N	309

Table 93: Correlation coefficient, significance, and number of cases (N) for the following variables: education and hunting for crabs. Correlation is significant at the 0.05 level (2-tailed); N = 296.

Correlation Coefficient (P-Value)	-.132
Sig. (2-tailed)	.023
N	296

Table 94: Correlation coefficient, significance, and number of cases (N) for the following variables: education and swimming. Correlation is significant at the 0.05 level (2-tailed); N = 304.

Correlation Coefficient (P-Value)	-.116
Sig. (2-tailed)	.043
N	304

Table 95: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the frequency of tap water consumption. Correlation is significant at the 0.05 level (2-tailed); N = 335.

Correlation Coefficient (P-Value)	-.136
Sig. (2-tailed)	.013
N	335

Table 96: Correlation coefficient, significance, and number of cases (N) for the following variables: education and participation in past watershed projects. Correlation is significant at the 0.05 level (2-tailed); N = 327.

Correlation Coefficient (P-Value)	-.118
Sig. (2-tailed)	.033
N	327

Education and perceptions

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of education with regard to 34 variables associated with perceptions. Of the 34 variables, 6 of the results were significant at the .01 level (2-tailed) and 9 of the results were significant at the .05 level (2-tailed). There are positive, weak relationships between education and the following perceptions:

- wildland fires are a threat to the Manell and Geus watersheds (see Table 97),
- invasive species are a threat to the watershed (see Table 98),
- lack of awareness is a threat to the watershed (see Table 99),
- overfishing is a threat to the watershed (see Table 100),
- poor infrastructure is a threat to the watershed (see Table 101),
- there are frequent water outages (see Table 102),
- off-roading is a threat to the watershed (see Table 103),
- lack of rainfall is a threat to the watershed (see Table 104),
- coastal erosion is a threat to the Manell and Geus watersheds (see Table 105),
- climate change is a threat to the watershed (see Table 106),
- overpopulation is a threat to the watershed (see Table 107),
- the military build-up is a threat to the watershed (see Table 108),
- the forests are filled with native vegetation (see Table 109),
- there is erosion in the Manell and Geus watersheds (see Table 110),
- there are more non-native animals than native animals (see Table 111).

Table 97: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that wildland fires are a threat to the watershed. Correlation is significant at the 0.01 level (2-tailed); N = 172.

Correlation Coefficient (P-Value)	.220
Sig. (2-tailed)	.004
N	172

Table 98: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that invasive species are a threat to the watershed. Correlation is significant at the 0.01 level (2-tailed); N = 170.

Correlation Coefficient (P-Value)	.210
Sig. (2-tailed)	.006
N	170

Table 99: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that lack of awareness is a threat to the watershed. Correlation is significant at the 0.01 level (2-tailed); N = 171.

Correlation Coefficient (P-Value)	.213
Sig. (2-tailed)	.005
N	171

Table 100: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that overfishing is a threat to the watershed. Correlation is significant at the 0.01 level (2-tailed); N = 166.

Correlation Coefficient (P-Value)	.210
Sig. (2-tailed)	.007
N	166

Table 101: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that poor infrastructure is a threat to the watershed. Correlation is significant at the 0.01 level (2-tailed); N = 187.

Correlation Coefficient (P-Value)	.287
Sig. (2-tailed)	.000
N	187

Table 102: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that there are frequent water outages. Correlation is significant at the 0.01 level (2-tailed); N = 338.

Correlation Coefficient (P-Value)	.168
Sig. (2-tailed)	.002
N	338

Table 103: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that off-roading is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 168.

Correlation Coefficient (P-Value)	.183
Sig. (2-tailed)	.018
N	168

Table 104: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that lack of rainfall is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 167.

Correlation Coefficient (P-Value)	.194
Sig. (2-tailed)	.012
N	167

Table 105: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that coastal erosion is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 187.

Correlation Coefficient (P-Value)	.158
Sig. (2-tailed)	.031
N	187

Table 106: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that climate change is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 181.

Correlation Coefficient (P-Value)	.162
Sig. (2-tailed)	.029
N	181

Table 107: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that overpopulation is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 183.

Correlation Coefficient (P-Value)	.183
Sig. (2-tailed)	.013
N	183

Table 108: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that the military build-up is a threat to the watershed. Correlation is significant at the 0.05 level (2-tailed); N = 179.

Correlation Coefficient (P-Value)	.169
Sig. (2-tailed)	.024
N	179

Table 109: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that forests are filled with native vegetation. Correlation is significant at the 0.05 level (2-tailed); N = 309.

Correlation Coefficient (P-Value)	.113
Sig. (2-tailed)	.047
N	309

Table 110: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that there is erosion. Correlation is significant at the 0.05 level (2-tailed); N = 295.

Correlation Coefficient (P-Value)	.117
Sig. (2-tailed)	.044
N	295

Table 111: Correlation coefficient, significance, and number of cases (N) for the following variables: education and the perception that there are more non-native animals than native animals. Correlation is significant at the 0.05 level (2-tailed); N = 304.

Correlation Coefficient (P-Value)	.146
Sig. (2-tailed)	.011
N	304

7.2.5 Income

A bivariate correlation using a Spearman's rank coefficient were conducted for the variable of income with regard to 20 variables associated with behaviors; the 23 variables associated with values; the 15 variables associated with attitudes; the 4 variables associated with knowledge;

and the 34 variables associated with perceptions. A total of 96 bivariate correlations using a Spearman's rank coefficient were conducted.

Income and values

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of income with regard to 23 variables associated with values. Of the 23 results, there were 2 significant results at the .05 level (2-tailed). There is negative, weak relationship between income and valuing more parks (see Table 112). There is a positive, weak relationship between income and valuing Cocos Island (Table 113).

Table 112: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and valuing having more parks. Correlation is significant at the 0.05 level (2-tailed); N = 71.

Correlation Coefficient (P-Value)	-.286
Sig. (2-tailed)	.016
N	71

Table 113: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and valuing Cocos Island. Correlation is significant at the 0.05 level (2-tailed); N = 85.

Correlation Coefficient (P-Value)	.225
Sig. (2-tailed)	.038
N	85

Income and knowledge

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of income with regard to 4 variables associated with knowledge. Of the 4 results, 1 was significant at the .05 level (2-tailed). There is a negative, weak relationship between income and familiarity with the term 'watershed' (see Table 114).

Table 114: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and familiarity with the term 'watershed'. Correlation is significant at the 0.05 level (2-tailed); N = 87.

Correlation Coefficient (P-Value)	-.231
Sig. (2-tailed)	.031
N	87

Income and attitudes

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of income with regard to 15 variables associated with attitudes. Of the 15 results, there was 1 significant result at the .05 level (2-tailed). There is a negative, weak relationship between income and attitude towards the Merizo Mayor's Office (Table 115).

Table 115: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and attitude towards the Office of the Merizo Mayor. Correlation is significant at the 0.05 level (2-tailed); N = 85.

Correlation Coefficient (P-Value)	-.224
Sig. (2-tailed)	.039
N	85

Income and behaviors

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of income with regard to 20 variables associated with behaviors. Of the 20 results, there were 2 significant results at the .05 level (2-tailed). There is a negative, weak relationship between income and disposing vegetative debris in the jungle (see Table 116). There is negative, weak relationship between income and hiking or running (see Table 117).

Table 116: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and throwing vegetation in the jungle. Correlation is significant at the 0.05 level (2-tailed); N = 85.

Correlation Coefficient (P-Value)	-.220
Sig. (2-tailed)	.049
N	81

Table 117: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and hiking or running. Correlation is significant at the 0.05 level (2-tailed); N = 83.

Correlation Coefficient (P-Value)	.240
Sig. (2-tailed)	.029
N	83

Income and perceptions

A bivariate correlation using a Spearman's rank coefficient was conducted for the variable of income with regard to 34 variables associated with perceptions. Of the 34 results, there were 2 significant results at the .05 level (2-tailed). There is positive, modest relationship between income and the perception that drinking tap water is associated with negative health (see Table 118). There is a negative, weak relationship between income and the perception that it floods often (see Table 119).

Table 118: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and not drinking tap water for health reasons. Correlation is significant at the 0.05 level (2-tailed); N = 32.

Correlation Coefficient (P-Value)	.444
Sig. (2-tailed)	.011
N	32

Table 119: Correlation coefficient, significance, and number of cases (N) for the following variables: average annual income and perceiving that it floods often. Correlation is significant at the 0.05 level (2-tailed); N = 77.

Correlation Coefficient (P-Value)	-.236
Sig. (2-tailed)	.038
N	77

7.3 Summary

This chapter objectively presents the descriptive and inferential statistical results from the household survey. The analysis and discussion of these findings is reserved for Chapter 9: Discussion and Conclusion. The next chapter presents the results of informal interviews conducted for this dissertation.

Chapter 8: Results-Informal Interviews and Analysis

Convenience sampling was used to identify respondents. Approximately six informal interviews were conducted mid-September in 2010. Interviews were conducted at the Merizo Senior Citizens' Center, located next to the Merizo Mayor's Office. There are approximately ten senior citizens who regularly frequent the center. Only six agreed to be interviewed and have their responses recorded. Two declined. Two wanted to be interviewed but did not want their responses recorded (their answers were not included in this thesis). A general set of questions was used to guide the interview (see Appendix 3). All interviews were conducted in English except for one, which was conducted in Chamorro. The manager of the Senior Citizen's Center served as a translator.

Elders are highly respected in Chamorro culture. They are referred to as the *manhamko*. In an effort to obtain a narrative timeline of observed change to the Manell and Geus watersheds, elders were interviewed. Elderly people are characterized by the U.S. Census Bureau as people who are over 59 years of age.

Statistically, these informal interviews are not a representative sample of the elderly population in the Manell and Geus watersheds. These informal interviews supplement the quantitative results from the household survey. Responses obtained from these interviews give insight into the natural occurrences experienced by the residents of the Manell and Geus watersheds that reflect climate variability and extremes over the last 50 years.

8.1 Demographic characteristics

The oldest person to be interviewed was 84 years of age and the youngest person interviewed was 60 years of age. The range is 24 years. Of the six participants, four were male and two were female. Because this was an informal interview, a chance to 'talk story'[18], no formal socioeconomic information was requested from the interviewees. Direct questions about income are often regarded as invasive. All

[18] 'Talk story' is a commonly used phrase in Hawaii. It is also used in Guam and refers to an 'informal chat'.

interviewees were retired, and no longer in the workforce. Each person was assigned a number and will be referred to as a number in order to maintain anonymity.

8.2 Responses to questions from the informal interview

Is the climate different today than it was 30 years ago? How is it different?

Person 2, 3, 5, and 6 of the six participants felt that the climate was the same now as it was 30 years ago. Person 4 felt it was colder now than it was 60 years ago. Person 1 felt that the rainy season and windy season are 'off'. Person 1 also felt that it is much 'hotter' now than in the past.

Were there more floods in the past? How did you deal with floods in the past?

The next two questions related to flooding. Preliminary results from the household survey indicated that flooding was a major concern to the residents of the Manell and Geus watersheds (see Chapter 7, Values: 7.1.4.8 Stop the flooding of the roads). Person 1 felt that there was more flooding now. Person 2, 4, 5, and 6 felt that there was less flooding now than there was in the past. Person 5 elaborated on the flooding events in the past; the water was cleaner in the past and people would go out and have more fun in the floods. Person 5 observed that, "people used to go into the jungle and remove debris" in order to alleviate flooding. A common observation was that in the past, there was less bamboo (the major vegetation that gets washed down the rivers and forms 'dams' that block the water into Cocos Lagoon and redirect the water onto the roads or people's yards) and the river water was cleaner. Person 6 and 2 mentioned that they would 'dig a place for the flood water to go'. Clearly, physical alteration of the flooded environment to redirect flood water has always been a coping mechanism. This physical alteration continues in the present. Employees from the Mayor's Office were personally observed deepening the channel with a backhoe, on the lagoon side of the road in an effort to increase drainage of the nearby properties.

Was it rainier?

Most of the interviewees declined to discuss this question except for Person 4 and Person 5. Person 4 perceived that there was more rain before than now. Person 5 directly addressed the rainy and dry seasons and mentioned that the rainy season now was 'spottier', but basically the same.

Did you have more typhoons? What did you do to deal with the typhoons?

Person 5 described the time period between 1980 and 1990 as the worst decade with regard to typhoons and mentioned there were three during this time. Person 5 felt there were more typhoons in the past than the present. Person 2 and 6 both mentioned Typhoon Karen as the worst typhoon in their collective memory. Person 2 and 6 both stated that there were more typhoons in the past but it was much easier to recover from typhoons now than in the past. This could be because of the presence of the Federal Emergency Management Agency (FEMA) or because as Person 2 and 6 noted that the 'community is much closer now than before'. This is the opposite of what Person 1 and 3 perceives, with regard to community. Person 1, 3, and 5 strongly emphasized that community was much closer in the past; people were more willing to help out in past more so than the present. Person 1 observed that one does not know their neighbors now, and there were very few to no fences. The demarcation of property with physical walls may indicate more boundaries between residents. Person 1 also mentioned Typhoon Karen, but was not sure if there were more typhoons today than in the past. However Person 1 is in agreement with Person 6 and 2 with regard to recovery from typhoon damage; it is much easier to recover from typhoons now than in the past. But unlike Person 6 and 2 (who both feel that recovery time is quicker now because of increased community cohesion), Person 1 reasons that the quicker recovery time is attributed to technology. Person 5 felt the recovery time is the same as the past and was rather critical of the use of FEMA money; Person 5 felt that FEMA money was misspent. Person 1 also suggested that planting more 'durable' coconut trees, beetlenut trees, orange trees, and breadfruit trees would decrease recover time, because heartier trees would be able to withstand typhoon winds.

Were there more fish?

Person 6, 2, and 1 both deemed that there were more reef fish in the past than the present; however the average size of fish was the same. Person 3 also deemed that there were more fish in the past than the present but was not sure about average size. Also, Person 6 and 2 perceived that the fish present today were quicker. Person 2 fished a little bit. Person 1 attributes the present day decline of the number of reef fish to land-based sources of pollution (e.g., chemicals, increased sedimentation smothering reef fish habitats) Person 1 is not an advocate of opening the Achang Marine Preserve because 'the younger generation does not want the ocean, so why bother preserving it?'. Person 1 also mentioned that with the creation of the Achang Marine Preserve, Person 1 had to purchase a boat and with the costs of gasoline, fishing has become more expensive and time consuming. Person 1 reasoned that this impacts fishermen's

livelihoods, coupled with the opening of the fish farm, located near the mouth of the Ayaysen River (see Figure 34). Person 1 also boasted that Merizo is the best fishing ground in all of Guam. Person 5 was also rather critical of the opening of the Achang Marine Preserve; Person 5 felt there was no warning and that the Division of Aquatics and Wildlife Resources (DAWR) were too far away to effectively enforce the rules and regulations. Person 5 strongly distrusts the DAWR.

While on the topic of fish, Person 1 mentioned crabs and how there were more crabs in the past. Person 1 shared that in the past, it would take five minutes to fill a bucket with crabs whereas now, it would take an hour to fill that same bucket. Person 1 also mentioned that people are selling crabs to supplement their income; in the past, one would expect to receive 15 cents per crab, but now the average price would be 25 cents per crab. On a side note, one of the recently introduced festivals Merizo celebrates is the *Malesso Gupot* (Merizo Crab Festival) which began in 2008 and is usually held at the end of March.

Was the water in the rivers cleaner?

Person 6, 2, 4, and 3 felt that the rivers are cleaner now than in the past especially with the introduction of sewer systems. Person 6 and 2 mentioned that prior to sewers, people who resided near rivers would dispose of their waste in the river. Person 1 also mentioned that people would wash their clothes in the river. Person 1 possessed the same sentiment as Person 6 and 2 with regard to the cleanliness of the rivers; rivers were cleaner in the past than they were in the present. However, Person 1 noted that people only drank from the rivers when they were flowing. This indicates that while the rivers were 'cleaner' in the past, they were only 'clean enough' to drink from with an increased flow rate. Person 1 also mentioned that people would clean vegetative debris from the river by setting bamboo traps. The bamboo traps would act as a filter, allowing water to flow through, but not large vegetation.

Was the jungle different? Different trees?

With regard to variety of tree species, Person 6 and 2 did not notice a difference in the composition of the jungle. Person 1 felt the trees were the same now as they were in the past. Person 4 perceived the jungles to be different now compared to the past but could not verbally describe the difference. Person 5 mentioned that the trees were basically the same as they were in the past and noted that there is more bamboo now than there was in the past.

Was there more jungle? Or less jungle?

Person 6, 2, and 3 felt the jungle was thicker in the past; there were more trees. Person 1 felt there was less jungle in the past; it was passable whereas now it is so thick that one would need a machete to get through. Person 5 described the jungle in the past to be less overgrown. Person 5 elaborated and mentioned that people used to go into the jungle and remove 'debris'.

Were there more birds? What kind?

Person 6, 5, 4, 2, and 3 felt that there were more birds but couldn't identify the birds specifically. Person 1 and 3 noticed that there were more birds as well as fruit bats. Person 6, 5, 2, and 1 attribute the demise of the birds to the brown tree snake.

Did you have a problem getting drinking water?

Person 6, 2, 3, and 1 used rainwater catchments in the past as their primary source of water. Person 1 elaborated that the water from rainwater catchments tasted better than water from tap; water from the tap was chlorinated. Person 1 mentioned that these rain water catchments allowed for independence; people would secure drinking water in 55 gallon tanks. However, now Person 6, 3, and 2 obtain their water from the tap. Person 1 and 5 use the tap, but do not depend on it; Person 1 and still maintains a rainwater catchment and store water in a 55 gallon storage container. When the water goes out, Person 6 and Person 2 acquire their water from the water truck provided by the Guam Water Authority stationed at the Merizo Mayor's Office.

Have you heard of climate change?

All people interviewed have heard of climate change. Person 6, 3, and 2 felt that climate change is not real. Person 3 strongly felt the climate was the same as it was in the past and that 'there was plenty sunshine'. Person 6 and 2 associated climate change with typhoon severity and mentioned 'Typhoon Karen'[19]. Person 6 and 2 felt that there has not been a typhoon to match the destructive nature of Typhoon Karen and concluded that if climate change was real, there would be more 'Typhoon Karens". Person 1 referred to climate change as 'global warming' and felt that it was real and senior citizens are especially endangered. Person 1 was very forthcoming with his opinions and thoughts about global warming. Person 1 has observed that the culture is 'wearing

[19] Typhoon Karen was a Category Five super typhoon that struck Guam in November 1962. It is regarded as one of the most destructive events in Guam's history.

out'; Guam is modernizing and not in the best interest of the people; Guam's politicians are corrupt and embodying American law which may conflict with the 'old ways'. Person 1 is adamant about passing the knowledge of the past to today's youth because time is limited for the senior citizens. Person 4, who perceived it to be colder now than in past, felt that climate change was good.

8.3 Analysis

Results from the informal interviews provide valuable insights in to the elderly population's understanding of climate change. The most noteworthy observation is that the responses were inconsistent. Thus, a coherent narrative timeline was not possible. The collective wisdom of the elders is often hailed as invaluable and reverential, but in this case, it must be taken with a necessary degree of caution.

Responses to the interview questions revealed evidence of adaptive capacity with respect to freshwater. Water storage catchments are being presently utilized, although not as much as in the past. Also, some of the interviewees avail of the water buffalo parked at the mayor's office during times of extenuating water outages. With the development of public water infrastructure, there is clearly a change in where people obtain their water. Stephenson (1979) notes that people from Merizo used local river water prior to the development of public water infrastructure. Bamboo was often used to transport water from the river to houses as pipes or on the back of carabao (Stephenson 1979). None of the interviewees mentioned or discussed this particular usage of bamboo, but Person 5 did mention the abundance of bamboo now compared to the past. Once public water became readily available, it seems the use of bamboo decreased and without the continuous harvest it would subsequently lead to an overgrowth (see Figure 70).

Harvesting rainwater is a low-cost, low-technology solution to increase access to safe drinking water in rural, low-income areas (Abbasi and Abbasi 2011). While it is a concern that rainwater harvested from rooftop catchments may have contaminants (Abbasi and Abbasi 2011), several atolls in Micronesia obtain their drinking water from rainwater catchments and the water is generally within the acceptable thresholds (e.g., total fecal coliform) associated with potable water . By understanding the pollutant pathways, it is possible to purify the water within acceptable water quality standards with simple and inexpensive devices (Abbasi and Abbasi 2011).



Figure 70: Photograph of the overgrowth of bamboo in the Manell River. Hikers are walking through a dry riverbed. Photo is courtesy of Maria Kottemaier.

Some interviewees were more forthcoming than others. Person 1 and 5 spoke far more than the rest. Person 6 and Person 2 were husband and wife and insisted upon being interviewed together. Person 2 was in agreement with his wife's responses for the most part; the exception being with regard to fish. Person 2 had more to say about fish than Person 6.

Chapter 9: Discussion and Conclusion

This thesis argues that examining the attitudes, perceptions, behaviors, and knowledge of a community towards their specific watershed can reveal their social vulnerability to climate change. Understanding and incorporating these elements of the human dimension in coastal zone management will lead to efficient and effective strategies that safeguard the natural resources for the benefit of the community. By having healthy natural resources, ecological and community resilience to climate change will increase, thus decreasing vulnerability. This chapter discusses the results that were objectively presented in the previous three chapters, with a highlight on the major findings. It revisits the original research questions presented in Chapter 1 and conveys the contribution to environmental geography, coastal zone management, and the people of Guam. It concludes with recommendations for coastal zone management and future research.

9.1 Major findings

Based on the results from the geospatial analysis and the household survey, more than a majority of residents of the Manell and Geus watershed perceive that they are vulnerable to **flooding** (see 7.1.3.3.6 "It floods often.", 7.1.3.2.15 Flooding, and 7.1.4.8 Stop the flooding of the roads). A good portion of the community resides within the 100-year floodplain (see Figure 35). Whether they associate flooding with climate change is unclear. However, 54% of residents perceive climate change to be a threat to the watershed (see 7.1.3.2.13 Climate change). "Changes in annual rainfall in the Western North Pacific sub-region from 1950-2010 show that the islands in the west are getting slightly more rainfall than in the past, while islands in the east are getting much less" (Keener et al. 2013). If this trend continues, Guam should be experiencing more precipitation, which would mean increased risk for flooding. Ironically, 39% of the community feels that a 'lack of rainfall' is a current threat to the watershed (see Figure 44). Generally, there is still a relatively low level of awareness and understanding at the community level about what climate change is, let alone, the threats it pose (Nunn 2009) and this appears to be true for Merizo. The residents may not fully understand the details of climate science, but 68% of respondents believe it floods often (see 7.1.3.3.6 "It floods often.") and 78% believe flooding is a threat to the watershed (see Figure 45). Comprehending the relationship between climate change and flooding would be ideal,

but the Merizo residents can adapt to increased flooding events, regardless if they understand climate science or accept climate change.

However, while residents may not fully understand or accept climate change, they can grasp the concept of a watershed, precipitation, and the immediate relationship to flooding. Approximately 52% of residents were not familiar with the term 'watershed' (see Figure 61). Of the 27% that did recognize the term watershed (see Figure 61), only 26% felt they could define it, while 40% could not (see Figure 62). Another question posed to the residents concerned whether they were familiar with the term "Ridge to Reef". "Ridge to Reef" is the catch-phrase used by Guam Coastal Management Program (GCMP) to describe their management strategy for watersheds. Knowing the term would imply a basic understanding of watershed functions and its geographical boundaries. Only 27% of respondents indicated they knew what "Ridge to Reef" meant, while 46% did not know the term (see Figure 63). Close to half of the respondents did not know what "Ridge to Reef" meant and this is the slogan GCMP uses to describe its EBM, watershed approach. This is a serious concern when it comes to evaluating GCMP's environmental education and outreach. It means the message about watersheds is not getting through to people. The term becomes jargon that is constantly used but does not resonate. This lack of knowledge is a challenge for GCMP, because it would be difficult to get public support for a watershed management plan promoting restoration if the constituents do not know what a watershed is. The residents recognize this as environmental education/communication issue. Approximately 39% of residents agree that lack of awareness is a threat to the watersheds (see Figure 43).

This lack of knowledge about watersheds could be partially the fault of GCMP. Levels of trust in the GCMP varied. Approximately 28% of residents found the GCMP to be somewhat trustworthy, 21% found the agency to be very trustworthy, and less than 5% found GCMP to be most trustworthy (see Figure 58). Taking this into consideration, perhaps it is time to change the messenger. It may be more appropriate to educate, empower, and entrust the Merizo's mayor's office with the task of teaching the community about a watershed and the relationship to flooding because the mayor's office is the most trusted local governing body (see Figure 57).

In addition to precipitation, there are other factors that affect flooding, such as the presence of healthy forests. Water collection is an ecosystem function of a healthy forest. When the native forests of a watershed are degraded, this service becomes

compromised. Forest canopies serve as a shield bearing the force of rain, thus diminishing the erosive effects of precipitation on the soil. Rain falling on bare earth causes erosion and washes away the moisture retaining topsoil. Soil is also a factor. The predominant soils in the Manell and Geus watersheds are of the *Akina* complex, which are clays (see Table 11, Table 12, and Figure 26). Clays are less permeable; they have poor water absorption and retention (Christopherson and Birkeland 2014). Once these soils are saturated during rainfall events, additional water will lead to run-off.

Approximately 60% of residents agreed that there was erosion (see Figure 46). A healthy forest can reduce the amount of surface run-off, thus reducing flooding events. However, only 7% of respondents listed 'healthy native forests' as one of their top five priorities (see Figure 54). A healthy forest can also improve soil quality by providing constant organic material. Improving the soil quality can increase water retention and decrease run-off. While 44% of residents believed the forests that exist in both watersheds were filled with native vegetation, 29% did not know if this was actually the case (see Figure 46). The forests that are found in the watersheds are primarily ravine (see Figure 28) and contain some native trees and plants (Taborosi 2013). However, the majority of landcover consists of grasslands, which is not native (see Figure 28). Approximately 53% of residents perceived invasive species as a threat (see 7.1.3.2.5 Invasive Species and Figure 43). Invasive species is a broad term that could include fauna and flora. It should have been clarified as to whether it was in reference to animals or plants. Most of the ravine forests in southern Guam are degraded; their quality and quantity have been negatively impacted by introduced, invasive plant species, feral ungulates, and fire (Taborosi 2013).

The residents were divided when questioned about whether there should be more forest clearing (of already diminished and degraded forests). Approximately 34% of residents agreed that there should be more clearing, while 30% disagreed (see 7.1.3.3.7 "There should be more forest clearing." and Figure 46). There are substantial portions of the Manell and Geus watersheds that consist of grasslands (see Figure 30) and badlands (see Figure 31 and Figure 71). Badlands on Guam have erosion rates six times higher than vegetated savanna (Minton 2006). Clearing forested areas would add to the erosion.



Figure 71: Photograph of a badland in the Manell watershed.

Grasslands (i.e., savanna complex) constitute the majority of landcover in both watersheds (see Figure 28). This savanna complex consists of fire-prone species, a readily available fuel source for fires. Pollen analyses of sediment cores indicate the demise of the upland forests in southern Guam and the development of the present-day savanna complex occurred approximately 2900 years before the present (Athens and Ward 2004). This is most likely due to the adoption of slash-burn agriculture practices by prehistoric human settlers (Athens and Ward 2004). The replacement of native forests with pyrophytic grasslands is one of the most negative ecological impacts of fire (Nasi et al. 2002).

Fires in tropical forests are usually human-induced (Nasi et al. 2002). The current savanna complex is evidence of this (Athens and Ward 2004), and burning continues in the present-day (Minton 2006). Between 1979-2000, there were an average of 730 fires per year, that burned approximately 4800 acres (19.4249 km^2) (Neill and Rea 2004). The majority of the fires occur in southern Guam (Neill and Rea 2004). Hunters routinely set wildfires to attract prey to a particular site. Deer and pigs are drawn to the young plant shoots that sprout in recently burned areas. About 15% of residents in Merizo hunt (see Table 29) and of those hunters, roughly 54% hunt in the Manell and Geus watersheds (see Table 30). The most popular prey, in ascending order, are deer, pigs, crabs, turtles, and bats (see Table 31). Approximately 60% of the residents agreed that wildland fires are a threat to the watershed (see Figure 43). Fires are not only destructive to the natural ecosystem, they are dangerous to areas of human settlement.

In an effort to eradicate hunter-induced fires through the promotion of environmentally friendly hunting methods, a two-year RARE Pride[20] island-wide campaign was financed by the GCMP, from 2010-2012. The campaign did not appear to be successful, because arson as a hunting method continues to be practiced. But there was small interest in participating in future clinics that demonstrate ways to hunt without using arson (see Table 34).

Fires are not only caused by hunters. Some residents engage in activities such as burning garbage (see 7.1.2.2 Burning garbage), burning vegetation (see 7.1.2.3 Burning vegetation), and smoking trees[21] (see 7.1.2.5 Smoke trees) (see Figure 41). These are considered acts of arson or negligent burning and are illegal (9 GCA § 34.30 (2001)). High solid waste fees[22] could be one factor influencing these practices. Approximately 70% of residents felt solid waste fees were too high (see 7.1.3.1 Are solid waste fees too high?) and 32% have never participated in curbside garbage collection (see 7.1.2.9 Curbside garbage collection and Figure 41). Nor do they use alternative means of disposal, such as bringing rubbish to the dumpster located at the Mayor's office (see 7.1.2.8 Take garbage to Mayor's dumpster and Figure 41).

In addition to wildland fires, half of residents perceive off-roading to be a threat to the watershed (see 7.1.3.2.4 Off-roading and Figure 43). Off-roading is the activity of driving a four-wheel drive vehicle over rough terrain. It is a rather contentious issue in the United States (Cordell et al. 2005). The increased number of off-road vehicles is seen as a threat to protected public lands (Cordell et al. 2005). Off-roading is a popular recreational activity enjoyed by many on Guam. There are no known environmental impact assessments that specifically study the consequences of off-roading on Guam's lands. GCMP operates under the assumption that off-roading activities denude the terrain of vegetation and contribute to the creation of badlands (Lujan, personal communication, 2010). To summarize, the fires, the number of badlands and grasslands, a degraded forest, low quality soil, and amount of precipitation affect the amount of surface water runoff and erosion, and thus flooding.

[20] RARE pride campaigns are social marketing campaigns that utilize a specific methodology in order to change detrimental human behaviors for the betterment of the environment.
[21] Smoking trees is the practice of burning vegetation under the tree and fanning the smoke up into the tree in order to get of insects and pests.
[22] Solid waste fees are 30 USD/month and include the costs of curbside garbage collection and recycling.

Sea level is rising (Wenzel and Schröter 2014; Wenzel and Schröter 2010; Ray and Douglas 2011; C. C. Hay et al. 2015; Church and White 2011; Church and White 2006) and the Western Pacific Ocean has risen three times the global average (see Figure 15) (Merrifield and Maltrud 2011). For Guam, the mean sea level (MSL) trend is 8.60 mm/year with a 95% confidence interval of +/- 4.88 mm/yr (NOAA CO-OPS 2014b), which is equivalent to a change of .88 meters (2.82 ft) in 100 years (see Figure 16). SLR can heavily contribute to future reductions in coastal habitats, such as mangroves, tidal wetlands, coral reefs, beaches, and sea grass beds. Mangroves, coral reefs, beaches, and sea grass beds are all present in the Manell and Geus watersheds (see Figure 33 and Figure 32). Having healthy coral reefs is ranked 11th out of 22 physical attributes of the watershed that residents value (see Chapter 7: Section 7.1.4 Values). In 2007, the Total Economic Value (TEV) for Guam's reefs was estimated at 127.3 million USD per year (van Beukering et al. 2007). Tourism accounted for approximately 75% of TEV (94.6 million USD per year), diving and snorkeling for 8.7 million USD per year, fisheries for 4.0 million USD per year, biodiversity for 2.0 million USD per year, and coastal protection for 8.4 USD million per year (van Beukering et al. 2007). The coastal floodplains (Zone VE in Figure 35) are located within the 100-year flood zone and are subject to additional hazards, such as storm surge. SLR is associated with an increase in storm surges (Tebaldi, Strauss, and Zervas 2012) and could pose a threat to people residing in the coastal floodplains. Approximately 74% of residents agree that coastal erosion is threat to the watershed (see 7.1.3.2.10 Coastal erosion and Figure 44). Whether the community understands the relationship between coastal erosion and increased storm surges and the association with SLR is unclear.

9.1.1 Demographic Profile

The rural village of Merizo straddles the Manell and Geus watersheds. The community is predominantly Chamorro (see Table 20) and Catholic (see Table 24). The languages spoken are English and Chamorro (see Table 21 and Table 22). Most are long-term residents (see Table 15) and usually own their homes or stay in familial compounds (see Table 16). Only 17% rent (see Table 16). Almost 50% of residents have achieved a high school diploma and there are very few (11%) who have attained a higher degree (see Table 19). About 38% of the residents did not complete high school (see Table 19). This is an extremely tight-knit, working class, homogenous community. This demographic data is in line with the U.S. Census data (2000, 2010). Consideration for the demographic profile of Merizo is the beginning to creating custom-tailored CZM

strategies. If these strategies are designed for Manell and Geus watersheds, with the village of Merizo in mind, successful implementation is more likely, as opposed to strategies that do not consider the community.

For a management strategy to be truly effective, understanding the demographic profile is not enough. Having a firm grasp on the community's attitudes, perceptions, and knowledge is a must (Ryan and Brown 2000; Moser 2009; Mobley 2015). Several relationships between demographic variables and behaviors, attitudes, perceptions, and knowledge were tested using a bivariate correlation (see 7.2 Inferential Statistics). The demographic variables of interest are gender, age, education, and income.

9.1.2 Behaviors

This thesis looked at 22 variables exploring the behaviors of the residents of the Manell and Geus watersheds (12a-12q; V17; V41; V42; V43; V44 – see Appendix 2 – Household Survey Codebook). These behaviors may be classified as pro-environmental, not pro-environmental, and neutral. Pro-environmental behaviors would include recycling, composting, taking garbage to Ordot Dump, taking garbage to the Mayor's dumpster, curbside garbage collection, and participating in watershed restoration projects. Non-environmentally friendly behaviors include burning garbage, burning vegetation, 'smoking' trees, off-roading. Neutral behaviors include hiking/running, swimming, crabbing, hunting, fishing, and farming.

Hunting, fishing, and farming may be viewed as positive, negative, or neutral depending on how these activities are specifically conducted. For instance, hunting may be viewed as a resource-degrading behavior if poor hunting practices are used (e.g., arson). But, hunters target feral ungulates (e.g., deer and pig). The grazing and rooting habits of these introduced species wreak considerable damage to the watershed and contribute to soil erosion (Beschta et al. 2013; Dixon 2011; Worthington et al. 2001). Restoration of native forests will require control of the feral ungulate population, as observed in Hawaii (Hawaii Conservation Alliance 2005). According to the HCA (2005), effective methods of controlling ungulate populations are as follows:

- create and maintain ungulate barriers such as exclusionary fences around pristine habitat,
- remove, sterilize, or kill animals faster than their rate of reproduction, and
- consistently monitor the ungulate population and barriers.

On Guam, NRCS is using exclusionary fencing at Anderson Air Force Base (located in Northern Guam) to protect native limestone forest from deer and pig. Hunting on Guam is regulated by the Department of Agriculture-Division of Aquatics and Wildlife Resources (see Department of Agriculture Division of Aquatics and Wildlife Resources 1997). If hunting is conducted in an environmentally conscientious manner (e.g., not using arson), its role in in the removal of ungulates would make it a pro-environmental behavior.

Similar arguments may be made for fishing. Destructive fishing practices such as SCUBA spearfishing, which can eliminate depth as a natural refuge for large fish (Lindfield, McIlwain, and Harvey 2014) or 'blast' fishing, which can devastate fish habitat (Pet-Soede, Cesar, and Pet 1999), would make fishing a non-environmentally friendly behavior . Destructive fishing practices can decimate fisheries and sometimes fish habitat (Richmond 1993). However, fishing is not solely characterized by one technique, let alone a damaging method, but rather a multitude of methods that range from sustainable to destructive. Since respondents of the household survey who indicated they fish were not further questioned as to the type of methods they employed, it is difficult to judge whether 'fishing' should be a neutral behavior or a resource-degrading one.

As with hunting and fishing, a case may be made for farming. Farming, too, may be viewed as a positive, negative, or neutral activity toward the environment. Poor agriculture practices, such as the overuse of pesticides or herbicides may be detrimental to water quality and increase non-point source pollution within the watershed. Sustainable small organic farms, personal garden plots that do not use pesticides or herbicides, or rain gardens[23] may be seen as pro-environmental.

This thesis shows that there are quite a number of behaviors that damage the watershed (e.g., burning, off-roading) being practiced alongside pro-environmental behaviors (e.g., recycling, composting). By examining studies conducted in the fields of psychology and sociology, it may be possible to explain why some residents have resource-degrading behaviors and others do not. Kollmuss and Agyeman (2002) have found the following factors to be associated with pro-environmental behavior:

[23] A *rain garden* is a shallow depression that usually consists of native plants and grasses. It should be positioned near a runoff source like a downspout, driveway or sump pump to capture rainwater runoff and stop the water from reaching the sewer system. Runoff will be captured in the garden.

- Demographic
    - Gender
    - Education
- External
    - Institutional factors
    - Economic factors
    - Social and cultural factors
- Internal
    - Motivation
    - Environmental knowledge
    - Values
    - Attitudes
    - Awareness
    - Emotional involvement
    - Locus of control
    - Responsibility

In the following sections, the relationship between some of these factors and pro-environmental behaviors as it relates to this thesis are examined.

9.1.2.1 Gender and behaviors

One demographic factor found to influence environmental behaviors is gender (Zelezny, Chua, and Aldrich 2000; Kollmuss and Agyeman 2002; Tindall, Davies, and Mauboulés 2003). A multi-national study conducted by Hunter, Hatch, and Johnson (2004) showed that females tend to engage in more environmental behaviors than men, particularly private ones (e.g., recycling, composting). The findings in this thesis are inconsistent with the studies that demonstrate women care more about the environment (Zelezny, Chua, and Aldrich 2000), or are more likely than men to have environmentally friendly household behaviors (Tindall, Davies, and Mauboulés 2003). This study did not find statistically significant relationships between women and recycling, composting, curbside garbage collection. However, weak relationships were found between males and other pro-environmental behaviors. Specifically, males are more likely to dispose of vegetative debris in the jungle (see Table 43 and Figure **66**) and haul garbage to Ordot Dump (see Table 52 and Figure 68). This is more in line with the work conducted by Mobley (2015), who found that males were more likely to participate in activities that improve water quality within a watershed located in South Carolina.

Furthermore, weak relationships were found between males and poor environmental practices. It appears that men are more likely to burn vegetative debris (see Table 42 and Figure 5) and are more likely to 'smoke' trees (see Table 44 and Figure 67). Males are also more likely to partake in off-roading activities (see Table 45). This study also found that males were more likely to engage in outdoor activities such as fishing (see Table 46), hunting (see Table 47), farming (see Table 48), hiking or running (see Table 53), hunting for crabs (see Figure 42), swimming (see Figure 42), and having barbeques (see Figure 42). This may indicate a slightly stronger connection to the watershed than females.

9.1.2.2 Education and behaviors

With regard to education, this study also found weak relationships between education and pro-environmental behaviors. People who had attained higher levels of education were more likely to compost (see Table 89), and recycle (see Table 91), both pro-environmental behaviors. Surprisingly, better-educated residents were also more likely to burn vegetation (see Table 88), not a pro-environmental activity.

Residents who attained lesser levels of education are more likely to burn garbage (see Table 92), an environmentally irresponsible behavior. However, people with lesser education most likely have participated in past watershed projects (see Table 96). They are also more likely to have barbeques (see Table 90), hunt for crabs (see Table 93), swim (see Table 94), and consume tap water (see Table 95), environmentally neutral behavior.

9.1.2.3 Age and behaviors

In addition to the demographic factors of gender and education, age was also a factor in this study. Weak correlations were found between age and the following pro-environmental behaviors: composting (Table 64) and participating in curbside garbage collection (Table 70). This implies that older people were more likely to compost and participate in curbside garbage collection. However, older people were also more likely to burn vegetation (Table 63). As previously discussed, burning vegetation is not the best option for the disposal of vegetative debris. Aside from releasing carbon dioxide into the atmosphere, this could lead to accidental wildland fires. It is more beneficial to compost or dispose of vegetation in the jungles. A weak relationship was found between

an increase in age and farming (Table 71). This is supported by responses from the informal interviews with the village elders (see Chapter 8: Section 8.2 Responses to questions from the informal interview). It seems that the older generations have a connection to the land and engage in outdoor activities that provide direct benefit (e.g., farming). Prior to westernization, the inhabitants of Guam were able to sustainably support themselves through fishing and agriculture (Freycinet 1943; Thompson 1945). It is logical that older people will have retained vestiges of that traditional knowledge that relates to surviving off the land and sea.

Weak relationships were found between younger people and recycling (Table 69). This could be due to initiatives such as iRecycle, a school-based aluminum can recycling program created by the Guam Business Partners for Recycling (GBPR). GBPR is comprised of eight businesses that have joined forces to implement aluminum recycling in 40 schools on Guam. They have hired a program administrator to coordinate the implementation of this program in the schools and provide education/outreach presentations and training to all participants. This public-private partnership received a substantial amount of publicity and support. Ideally, this environmental education of the younger generation could have positive lasting consequences, such as continuing to recycle long after graduation.

Weak correlations were found between younger people and the following environmentally neutral behaviors: hiking and running (Table 65), off-roading (Table 66), swimming (Table 67), and barbeques (Table 68). Younger people were more likely to partake in these activities. These outdoor activities are purely recreational, in contrast to an activity such as farming, which requires a consistent amount of work.

9.1.2.4 Income and behaviors

Aside from demographic factors such as education and gender, Kollmuss and Agyeman (2002), also found external factors, such as economics to affect pro-environmental behaviors. In this study, a decrease in income was correlated with the disposal of vegetative debris in the jungle (see Table 111), as well as the environmentally neutral behaviors of hiking or running (see Table 112). The disposal of vegetative debris in the jungle may be viewed as a positive environmental activity. As vegetative debris decomposes, it adds nutrients to the soil. The physical, chemical, and biological characteristics of healthy forest soils play a tremendous role in delivering high quality water to streams, moderating stream hydrology, and providing diverse aquatic habitat

(Neary, Ice, and Jackson 2009). While this overview of Neary, Ice, and Jackson (2009) is focused on North America, the same premise is applicable to soils in tropical forests.

9.1.3 Perceptions

Experiential variables (e.g., discernment and assessment of threats) probe into the community's lived experiences and their observations of threats to the watershed (Mobley 2015). Approximately 89% of respondents are long-term residents of Merizo (see Table 15). Fifty-eight percent of respondents believe there are threats to the watershed (see Table 36). Those that perceived threats assessed a list of potential hazards and asked whether they agreed, strongly agreed, disagreed, strongly disagreed, or did not know about each individual listed risk (see 7.1.3.2 Perceived threats to the Manell/Geus Watershed). Threats such as climate change, flooding, off-roading, lack of awareness, lack of rainfall, land clearing, and coastal erosion are justly perceived as threats to the watershed ((see 7.1.3.2 Perceived threats to the Manell/Geus Watershed). The community seemed divided over whether overpopulation and the impending military build-up were threats (see 7.1.3.2.11 Military build-up, 7.1.3.2.12 Overpopulation, and Figure 44).

9.1.3.1 Protection Motivation Theory

Protection Motivation Theory (PMT) was originally developed by R. W. Rogers (1975) in order to explain the relationship between fear and changes in attitudes. Individuals are motivated to act in order to protect themselves from a threat (R. W. Rogers 1975). Essentially, two cognitive processes are activated when an individual learns about a threat: threat appraisal and coping appraisal. Threat appraisal and coping appraisal are measured by a number of cognitive variables. Theoretically, threat appraisal and coping appraisal would be the motivation to changing one's behavior accordingly (such as ceasing threatening behavior or adopting a positive behavior). Doing nothing would imply that hazard is non-threatening and there is no benefit for a behavior change. Traditionally, PMT has been applied to various issues within the health sector (e.g., Helmes 2002; Plotnikoff et al. 2010), as discussed by Koerth et al. (2013). Of particular interest to this thesis, Koerth et al. (2013) point out, PMT has been applied in climate change adaptation studies (e.g.,Cismaru et al. 2011; Grothmann and Patt 2005). Koerth et al. (2013) apply PMT to coastal adaptation to SLR and flood risk by examining what motivates coastal dwellers residing in Denmark and Germany to adapt proactively to SLR and associated flooding. Their findings indicate that variables related to the

cognitive process of coping appraisal are better predictors than demographic ones for protective behavior (Koerth et al. 2013).

McKenzie-Mohr (2000b) and McKenzie-Mohr (2000a) discuss the value in using PMT principles to elicit behavior change, shape environmental education, and formulate effective management strategies. PMT theory postulates that people will act to protect themselves from a threat, based on their perceived severity of the threat and their perceived vulnerability to the threat (R. W. Rogers 1975). In the Manell and Geus watersheds, 58% of the respondents surveyed are aware of the threats to their watersheds, such as flooding, coastal erosion, land clearing, pollution, poor infrastructure, and to a lesser degree, fires, development, and lack of awareness (see 7.1.3.2 Perceived threats to the Manell/Geus Watershed). Threat appraisal is clearly activated as demonstrated by the results, as is coping appraisal. Flooding has been identified as a threat and the residents of Merizo have developed reactive coping mechanisms. For example, during intense rainfall events, residents who reside close to a river created makeshift dams out of limestone backfill that they had stockpiled in their yards for this very purpose (see Figure 72). The dams serve to reroute the water away from their homes. In addition to dams, some residents would use backfill to build up the riverbanks in order to prevent the river from spilling over and inundating houses. Residents purchase this limestone directly out-of-pocket. Insurance or government grants do not cover these expenses.

Another coping mechanism adopted by residents is the voluntary physical monitoring of culverts (see Figure 73). In an attempt to prevent bamboo dams (see Figure 74), which build up and block the culverts, resulting in a backpile of water that overflows onto the road and neighboring homes, residents have voluntarily policed the culvert during high rain events. Despite their best efforts, they have never been able to prevent a bamboo dam from forming. They just manage to prolong the inevitable.

For Merizo, using the residents' desire to limit flooding could be the motivation needed to cease resource-degrading behaviors, especially if the linkages between these behaviors, a compromised ecosystem, and reduced natural protection from inundation are clear. The desire to mitigate flooding is an immediate motive that revolves around an individual's need. It is not altruistic and just may be the incentive that encourages residents to cease detrimental behaviors and adopt positive practices. People can act

pro-environmentally without having any concern for the environment, so long as the action is self-benefitting (Kollmuss and Agyeman 2002).

Flooding is extremely costly. If the roads are flooded to the point of being impassable, residents are not able to commute to work, costing them a day's wages. According to Chapter 7: section 7.1.1.10.2 Location of employment, the majority of employed respondents commute to a workplace outside of Merizo. Estimated drive time to Hagatna (the capital of Guam) is approximately 50 minutes, a fairly lengthy time to spend in the car for a small island. Also, damage to private property is costly, especially if this is a recurring expense.



Figure 72: Photograph showing a stockpile of limestone in a Merizo resident's backyard.



Figure 73: Photograph of "Joe", a Merizo resident who voluntarily monitors the Manell River culvert during high rain events. Joe uses a long hook to guide bamboo through the culverts to avoid a pile-up.



Figure 74: Photograph showing bamboo stuck at the drainage culvert creating a dam. This will block the water from flowing freely from the Manell River and cause an overflow onto the road and people's homes.

9.1.3.2 Gender and Perceptions

Males were slightly more likely to positively perceive that the forests are filled with native vegetation (see Table 55). This is clearly not the case. Figure 28 shows the overwhelming abundance of savanna complex in both watersheds. Perhaps, the

residents believe that grasslands are 'native'. This would be a symptom of the 'shifting baselines' syndrome (Pauly 1995) or environmental generational amnesia (Kahn and Kellert 2002). Males were also slightly more likely to perceive that there is erosion in the Manell and Geus watersheds (see Table 56).

9.1.3.3 Education and Perceptions

From this research, there are weak positive correlations between education and the following perceptions of threats to the watershed:

- Wildland fires (Table 97)
- Invasive species (Table 98)
- Lack of awareness (Table 99)
- Overfishing (Table 100)
- Poor infrastructure (Table 101)
- Off-roading (Table 103)
- Lack of rainfall (Table 104)
- Coastal erosion (Table 105)
- Climate change (Table 106)
- Overpopulation (Table 107)
- Military build-up (Table 108)

Basically, an increase in level of education seemed to be related to perceiving the aforementioned threats. PMT theory posits that people will act in self-interest to protect themselves from a threat, based on their perceived severity of the threat and their perceived vulnerability to the threat (R. W. Rogers 1975). Knowing that there is a relationship between level of education and threat perception, can inform coastal zone managers that there is a segment of the population (38%, see Table 36) that does not perceive *any* threats to the watershed and most of the 58% (see Table 36) that do perceive threats are more likely to be better educated.

There are also positive weak correlations between education and the following perceived condition of the resource:

- Forests were filled with native vegetation (Table 109)
- More non-native animals than native animals (Table 111)

Individuals who have attained higher levels of education are more likely to perceive the forests to be filled with native vegetation, and be filled with more non-native animals than native. Again, this is not the case and may be explained as symptoms of the 'shifting baselines' syndrome (Pauly 1995) or environmental generational amnesia (Kahn and Kellert 2002). The individuals have grown up thinking the savanna grasslands are 'normal' and part of the original 'native' forest. They have also grown up with the notion that deer, and pig are native species, because these ungulates have been present on Guam for a long period of time and are culturally important food items.

9.1.3.4 Age and perceptions

In this thesis, relationships between age and perception were found. The majority of those perceptions concerned tap water. Of the 350 respondents, approximately 15% never drink tap water; 16% rarely drink tap water; 25% sometimes drink tap water; 13% often drink tap water; and 29% drink tap water all the time. Approximately 3% declined to answer (see Figure 47). The respondents who 'never' or 'rarely' drank tap water were given follow-up questions to determine the reason for their aversion. This study showed that older residents that do not drink tap water were more likely to perceive that tap water contains too much chlorine (see Table 73) or that tap water is salty (see Table 75). Bottled water consumption is a reflection of modernization; it is a tradition that originated in Europe and spread globally (Ferrier 2001). Bottled water is the alternative to tap water and people generally choose it for taste (e.g., no chlorine taste) or for safety (i.e., it is perceived as safer and of better quality) (Ferrier 2001). Even in areas where tap water is safe to drink, the demand for bottled water is increasing (Arnold 2006). The production of bottled water produces unnecessary garbage (i.e., packaging) and requires vast quantities of energy to transport to markets (Arnold 2006). Drinking water on Guam must comply with the federal regulations stipulated in the Safe Drinking Water Act. Yet, there are many people on Guam that regularly consume bottled water. On the island, there are at least 17 dedicated water stations where people may bring empty bottles (usually 5-gallon containers) to refill at a price (Yellow Pages Ink 2015). This does not include the numerous, small mom and pop shops that have water dispensers for purified water where one can refill their water bottles for a small fee. Perhaps, preference for bottled water has a basis. Older people were more likely to perceive that there are frequent boil water notices (see Table 74) and frequent water outages (see Table 76). Boil water notices are issued by Guam EPA when a water sample from a public drinking water source is tested and found to have

contaminants over the legal threshold of the Safe Drinking Water Act. As mentioned in Chapter 2, Section 2.2.6.1 Reports and Documents Pertaining to Water that are Specific to Guam, there are issues with the current system for centralized water. Those issues are reflected in the perceptions residents (especially older ones) have about tap water.

The one perception that seemed to be affected by the age of an individual was unrelated to tap water. It had to do with a threat to the watershed—erosion. Younger people are more likely to perceive that there is erosion within the Manell and Geus watersheds (see Table 77). This could be related to the relationship found between younger people and their likelihood to engage in outdoor, recreational, environmentally neutral behaviors such as hiking and running (Table 65), off-roading (Table 66), swimming (Table 67). If younger people are constantly outdoors, playing in the watershed, they are in the ideal position to observe physical change, such as erosion, over time.

9.1.3.5 Income and perceptions

There is a positive, modest relationship between income and the perception that drinking tap water is associated with negative health (see Table 118). The arguments made in Chapter 9: Section 9.1.3.4 Age and perceptions about bottled water are applicable here. Residents with higher incomes have more disposable money that can be spent on luxuries like bottled water.

There is a weak correlation between a decrease in income and the perception that it floods often (see Table 119). People who make less money tend to perceive that it floods frequently. Their lower income may restrict them from living in better, more secure accommodations away from flooding zones. One way to visualize this would be to map U.S. Census income data according to census block, the smallest spatial unit offered by the U.S. census and overlay it with the flood map. This would give an approximation of the relationship between lower income and high-risk inundation areas. Under 13 USC § 9, the Census Bureau is required to make certain that individual identities cannot be "reasonably deduced", or re-identified. Re-identification is the practice of linking anonymous data to the actual identity of an individual. Sweeney (2000) has demonstrated that anonymous data sets, such as ones collected by the U.S. census can often be readily re-identified. Re-identification is legal in the United States. Despite the best intentions, to map the income census data, according to census block,

for such a small village where everyone has a fairly good idea of where everyone lives, seems rather intrusive, albeit legal. In Merizo people are somewhat sensitive about divulging income. In this study, 20% of employed respondents preferred not to disclose their average annual income (see Table 28). The creation of this map was not pursued out of respect.

9.1.4 Values

In the social sciences, the term 'value' generally refers to an individual's principles or standards of behavior; an individual's judgment of what is important in life (Rokeach 1973). Rokeach (1973) argues that the concept of values is the main dependent variable in the study of culture, society, and personality, and the main independent variable in the study of social attitudes and behavior. Intrinsic motivation is largely shaped by values (Kollmuss and Agyeman 2002). Fuhrer et al. (1995), as cited by Kollmuss and Agyeman (2002) proposed that values are most influenced by immediate social surroundings (i.e., family, peers, neighbors). To a lesser extent, values are shaped by the media and politics, and only slightly by cultural surroundings (Fuhrer et al. 1995). Merizo is one of the most traditional Chamorro villages; 90% of respondents identified as being Chamorro (see Table 20) and are still actively speaking the language (see Table 22).

Chamorro culture revolves around the most central value of *inafa'maolek*, or interdependence, and it depends on the spirit of cooperation (Cunningham 1992). Literally translated, the phrase means 'to make' (*inafa'*) 'good' (*maolek*). It is about restoring or keeping concord, above all else. There is a marked emphasis on collectivism rather than individualism, or the whole is more important than one part. All other Chamorro values are based on *inafa'maolek*. According to Cunningham (1992), the main Chamorro values are as follows:

- *Respetu* is respect given to the elderly and significant individuals within the family and community. Respect is shown various ways.
    - *Manginge* is an expression of respect given to elders and persons of authority. It usually comes in the form of a kiss on the cheek or the touch of the nose to the elder's right hand.
    - *Chenchule* means giving help (usually in the form of money or services needed) to family (nuclear or extended) during times of need.

  - *Mamahlao* means to be ashamed. This is to be avoided at all costs; bringing shame to one's family is a grave transgression. The concept of shame in Chamorro culture ensures that every individual, regardless of social rank, will act accordingly to avoid shame and maintain *inafa'maolek*.

- *Ayuda Familia* refers to the duty of assisting one's nuclear or extended family without fail.
  - *Che'lu* refers to relationships with siblings. Traditional Chamorro cultures were matrilineal (Cunningham 1992). Thus, siblings strongly relied upon each other to protect family property, raise the children of the family, and generate assets to keep the family well endowed (Hattori 2014). The brother-sister relationship was considered absolutely permanent and completely reliable (Hattori 2014). .
  - *Påtgon* denotes the concept that children are valued and raising them is everyone's responsibility.

Family is an integral part Chamorro culture, so in this instance, the hypothesis postulated by Fuhrer et al. (1995) only partially applies. Family values are very strong. Social capital is very high. P. C. Stern (1992) found values have a significant influence on environmental behaviors.

9.1.4.1 Gender and values

Stern, Dietz, and Kalof (1993) found no relationship between gender and environmental values. In this study, there were three statistically significant, but weak correlations found between gender and values pertaining to tap water consumption. This study found that that men are more likely to value clean tap water (Table 37). If there was a local push to become more sustainable and environmentally friendly, one of the behaviors that should be discouraged is the consumption of bottled water. Understanding why females are less likely than males to value tap water could provide insights to strategies that encourage drinking tap water.

It appears that men are more likely to value an amendment to the rules and regulations of the Achang Marine Preserve (Table 38). Approximately 39% of the population indicated they fish (see Figure 42 and 7.1.2.14 Fishing) and more males than females identify themselves as fishermen (Table 48). This may explain why males are more

likely to desire a change in the rules of the local preserve. In the past, activities such as warfare, canoe building, navigation, and fishing, were practiced by males (Cunningham 1992). Women on the other hand, were responsible for taking care of the young children, maintaining the household and working in the garden (Cunningham 1992). In this study, it was found that females are slightly more likely to value the jungles more so than males (Table 39).

9.1.4.2 Education and values

In this thesis, weak positive correlations were found between education and the following:

- Valuing a beautiful environment
- Valuing the proximity to the ocean
- Valuing the improvement of freshwater
- Valuing improvements to the water infrastructure
- Valuing improvements to the sewage system

In other words, it appears the higher the level of education attained, a person tended to value the aforementioned assets of Merizo. Values are generally taught and this particular set may have been acquired in school. Bolstering education in the village and encouraging residents to finish high school and enter college would not only improve human capital, but perhaps also make valuing the environment more widespread and common. Values, just like culture, evolve and change over time. Seeing an elevation of environment to the same status as family could perhaps be a path to an increase in pro-environmental behaviors for this predominantly Chamorro village. Individuals with lesser education were more likely to value the improvement of the schools. Again, investment in education will increase human capital (one determinant of adaptive capacity).

9.1.4.3 Age and values

This study found that younger people were more likely to value the improvement of schools (Table 57) and family (Table 59). It is fantastic that younger generations are espousing the traditional values of family. It is indicative that the cultural values of family are being transmitted. The desire to improve the schools may also indicate the appreciation of education. Older people were more likely to value having a healthy forest (Table 58). The informal interviews support this finding. Almost all elderly interviewees all admitted that they spent far more time in the forest in the past than in

the present. They all observed that children today spend more time indoors than children in the past.

9.1.4.4 Income and values

People with smaller incomes are slightly more likely to value additional parks (see Table 112). Parks on Guam are free to use and can provide much needed sanctuaries where people can relax and enjoy nature. Research on the benefits of contact with the natural environment show significant positive psychological effects on people (Maller et al. 2009). Parks are places that can serve to reduce stress, anger, frustration and aggression; provide opportunities for social bonding; and offer inspiration and mental stimulation (Maller et al. 2009).

People with greater incomes are slightly more likely to value Cocos Island (Table 113). Cocos Island is an island 1.5 km off the southern tip of Merizo that sits on the southwestern end of Cocos Lagoon (see Figure 21). The island is uninhabited, 1,600 meters and has an area of approximately 386,303 m^2 (see Figure 21). The western half of Cocos Island is a day resort that caters to tourists. The eastern half of the island is public land, owned by the Government of Guam and part of the Territorial Park. Cocos Island is accessed via boat—passenger ferries make daily trips to Cocos for a small fee. Cocos Island was the former site of a U.S. Coast Guard long-range navigation station that operated from 1944-1963. Cocos Island Resort is a major employer of local in Merizo. Since Guam is classified as a SITE (Bertram 2006) and tourism is the major sector, perhaps people with higher incomes recognize the economic importance of Cocos Island. Or perhaps, the residents with more wealth have higher disposable incomes and more time for leisure activities. Thus, they could avail of Cocos Island during free time.

9.1.5 Attitudes

In addition to values, attitudes also have a significant effect on environmental behavior (P. C. Stern 1992; P. C. Stern, Dietz, and Kalof 1993). Attitudes may be defined as positive or negative feelings about an object or person and environmental attitudes (Kollmuss and Agyeman 2002). Kollmus and Agyeman (2002) found that attitudes have little to no influence on pro-environmental behavior. Zaller (1992) contends, "Individuals do not possess integrated true attitudes on most issues that are relatively peripheral to their everyday concerns. Instead, they tend to respond to survey questions based on the most recent information that they have been presented on that issue." Thus, cues from political elites play an important role in these responses. Zaller

(1992) has shown that the higher the individuals' level of education, the more aware they are of elite cues and the more likely they will respond in accordance with those cues. While the attainment of tertiary education is low (see Table 19), residents of Merizo would be sensitive to elite, political cues. Residents readily phone the mayor's office looking for general information about anything. According to one of the mayor's receptionists, people call with a variety of inquiries that should be directed elsewhere. For example, during power or water outages, residents will call the mayor's office notifying personnel of an outage or request an estimated time frame for the restoration of those services. Questions like these are better directed at the GWA, if it is water related, or GPA, if it is power related. People also call in inquiring about outsiders in the village and request for the mayor to investigate. There is a large amount of trust in the mayor, an elected official, (see Figure 57) and any messages coming from his office would carry more weight than from another source. Prior to doing any fieldwork in Merizo, it is courtesy to notify the mayor, either by phone or in person.

9.1.5.1 Gender and attitudes

In this study, women were slightly more likely to trust the Guam Department of Public Works (Table 40), as well as the Guam Environmental Protection Agency (see Table 41).

9.1.5.2 Education and Attitudes

The results indicate that residents who have received more schooling are more likely to support the Achang Marine Preserve (see Table 86), as well as trust the Department of Agriculture (see Table 87). This is most likely due to the education that they are receiving in school. The Department of Agriculture regularly conducts outreach to all the schools and makes its employees readily available to give presentations upon request.

9.1.5.3 Age and attitudes

When examining linkages between age and attitudes, there is a positive, weak relationship between age and an attitude toward the Achang Reef Marine Preserve (see Table 61). Older people are more likely to support the marine protected area. Prior to the establishment of the marine preserves, there were a number of public meetings to gain trust, obtain input, and provide information about the importance of the protected

areas. Older people may remember this work. This study found that younger people seem more likely to trust Guam DAg, more than older people (see Table 62). Again, this is probably due to the exposure Dag receives from doing regular outreach to the schools. DAg is officially in charge of enforcing the rules and regulations of all marine preserves on Guam, including Achang.

9.1.5.4 Income and attitudes

Looking at relationships between income and attitudes, the results indicate that people who receive less income are more likely to be supportive of the Merizo Mayor's Office (Table 115). According to Mayor Chargalauf, "People call here [the mayor's office] for everything." Some of the general sentiments of the village are, "Down here, we are on our own. Adelup [location of the Governor's Office] doesn't care about us," and "We are always the last to receive assistance after a typhoon." Mayor Chargalauf is a long-term resident of Merizo and is physically present to deal with village matters readily. People are more likely to act on information presented by a person whom they trust than just facts alone (Kahan, Jenkins-Smith, and Braman 2011). Research on Micronesia suggests that a key element to successful conservation is when conservation managers and scientists devise an adaptable communication strategy specific to their audience for the duration of the project and revise that communication strategy accordingly (Montambault et al. 2015). Such a communication strategy should be developed for Manell and Geus and should include the Mayor's Office.

9.1.6 Knowledge

Lack of exposure to and understanding of scientific information about climate change could explain failure to cease resource-degrading behaviors (Kellstedt, Zahran, and Vedlitz 2008). This is doubtful. The oldest and simplest models, such as the Information Deficit Model (Burgess, Harrison, and Filius 1998) assumed that simply educating people about environmental issues (e.g., climate change), would result in more pro-environmental behavior (Kollmuss and Agyeman 2002). Research has proven these models as inaccurate (Kempton, Boster, and Hartley 1995). Changing behavior is complex and will require more than additional knowledge or increased awareness. So while the residents Merizo view 'lack of awareness' as a threat to the watershed (see 7.1.3.2.6 Lack of awareness) and a good portion are not familiar with the term 'watershed' (see Figure 61), much less able to define it (see Figure 62), increasing environmental education alone most likely will not change resource-degrading behaviors. That is not to say that environmental education should be ceased. On the

contrary, it should be continued and strengthened. Hines, Hungerford, and Tomera (1987) argue that for an individual to even consider changing their behavior, they need to have a sufficient amount of knowledge surrounding the environmental problem and its causes. Educating the residents of Merizo about how the health of their watershed is related to natural flood protection is the first step in changing behavior. For Protection Motivation Theory (PMT) (R. W. Rogers 1975) to apply, people will need some knowledge to properly assess a threat. Again, 38% of all respondents did not think there were any threats to the watershed (see Table 36). Could it be that they did not know what constituted a threat? Perhaps it was because they did not know what a watershed was, fundamental knowledge prior to doing a threat assessment.

9.1.6.1 Gender and knowledge

In this study, there were no significant correlations found between gender and knowledge.

9.1.6.2 Education and knowledge

Kollmus and Agyeman (2002) find that the more education an individual has attained correlates with more knowledge about environmental issues. In this study, there were negative, weak correlations between education and the following: the ability to define the term watershed (Table 84) and familiarity with the concept of 'ridge to reef' (Table 85). This means that the less education an individual had, the less likely he or she would be able to give a working definition of a watershed or describe the boundaries of a watershed.

9.1.6.3 Age and knowledge

With respect to relationships between age and knowledge, there is a negative, weak relationship between age and familiarity with the term watershed (Table 60). It seems that younger people are more familiar with the 'term' watershed. This is most likely due to recent exposure in middle school and high school. This seems to contradict the previous correlation between lack of education and inability to define the term 'watershed'. Perhaps, school curricula have changed and older people with lesser education were not exposed to the current curricula that have a heavy emphasis on science, technology, engineering, and mathematics (STEM).

9.1.6.4 Income and knowledge

With respect to income and knowledge, there is a weak relationship between a decrease in income and familiarity with the term 'watershed' (see Table 114). Individuals with lower incomes are slightly less likely to be familiar with the term 'watershed'. Higher incomes and financially advantageous decision-making is generally correlated with higher levels of education (Cole, Paulson, and Shastry 2014). As opposed to income, the indirect explaination for this could be the lack of education.

9.2 Discussion

Now that the results from the last three chapters on results have been discussed holistically, the main research questions can now be revisited. The main research questions have been grouped according to topic.

9.2.1 Climate Change and Freshwater Resources in the Manell and Geus Watersheds

The focus of this thesis is community vulnerability of the southernmost watersheds in Guam to impacts of climate change on freshwater resources.

9.2.1.1 Global Emission Scenarios, Freshwater, and Guam

The original research question is as follows:
How will the global emission scenarios manifest locally and how will that affect freshwater resources?

One of the first steps in assessing the nature of community vulnerability to climate change is understand how the outputs of the Global Circulation Models (GCMs) would manifest at the scale of small islands. This would be extremely useful for small islands to adequately plan for impacts of climate change. Not having this information would not necessarily prohibit planning, but the strategies developed may not be sufficient. Currently, statistical downscaling efforts are underway specific to Guam and American Samoa (see Wang and Annamalai unpublished). When these results have been made public, it should provide predictions of regional precipitation patterns in the Pacific.

9.2.1.2 Flooding

The original research question is as follows:

How will climate change affect freshwater resources on the Manell and Geus watershed?

Unlike the eastern Pacific, the western Pacific is expected to receive more precipitation (Keener et al. 2013) as the result of a changing climate. The residents of the Manell and Geus watersheds perceive flooding as the greatest threat (see 7.1.3.2.15 Flooding). From 2002 - 2012, the average annual rainfall for Guam has been slightly below average, primarily because of the dominance of La Niña (personal communication, Lander 2012). Now that El Niño conditions have been declared for 2015 (Becker 2015), the frequency and intensity of flooding events will most likely increase, as well as tropical cyclone activity. This will be compounded with a changing climate. Increased precipitation, a degraded watershed, and environmentally damaging behaviors can exacerbate inundation. This community has a high exposure to flooding events and a high sensitivity to the impacts of flooding (see Figure 75, Figure 76, and Figure 78).



Figure 75: Photograph of a flooded private lot during a high rain event in Merizo.



Figure 76: Photograph of a private residence in Merizo. The driveway has transformed into a flowing stream.



Figure 77: Photograph of a residence in Merizo. The entire front yard is slowly transforming into a pond as the homeowners watch.

9.2.1.3 Drinking Water

As for other freshwater resources, such as drinking water, it is less clear. The village of Merizo gets its drinking water from Ugum Reservoir (see Figure 78), located in the Talofofo watershed and outside the geographical scope of this research. Water is piped

in from the Ugum Water Treatment Station. Water has been known to shut down in Merizo, due to high turbidity or low water levels at Ugum. It is expected that precipitation will increase in the future as a result of climate change (Keener et al. 2013). If the Talofofo watershed, where Ugum is located, experiences high erosion rates, increased rainfall may increase the turbidity, thus leading to increased water outages for the Guam's southern villages, including Merizo.

Respondents were asked about the frequency of water outages they experienced. According to Figure 50, the majority of participants perceived that water outages occurred (48%) "rarely"; 30% replied "sometimes"; and only 12 % replied "often"; and 1% replied "all the time". Respondents were also asked about the duration of the water outages they experienced. The majority of respondents (61%) estimated that most outages last for "one day" and 30% believed the outages lasted "a few days" (see Figure 51). There is evidence of reactive adaptation to water outages as a result of post-typhoon damage or increased turbidity. Elders revealed during the informal interviews that they still employ water catchments and use that during water outages.



Figure 78: Photograph of Ugum River and dam, near the intake pipe to the Ugum Water Treatment Plant.

9.2.1.4 External Stressors on Guam

The original research questions is as follows:

How much consideration must be given to changes (e.g., population increase, negative economic forecasts, political change) other than anticipated climate change?

Studies, such as McCubbin, Smit, and Pearce (2015); Birk (2014); Lauer et al. (2013); Lata and Nunn (2011), point out that in addition to physical climate stressors (e.g., SLR, changes in precipitation, SST warming, ocean acidification), non-climate stressors also play a significant role in vulnerability for small islands. For Simbo, Solomon Islands, Lauer et al. (2013) identified a number of challenges and opportunities presented by globalization that nurtured and suppressed community resilience to a large-scale disaster by examining the island's recovery to a tsunami. McCubbin, Smit, and Pearce (2015) find that vulnerability in Funafuti, Tuvalu is a result of a "synergy of climate and non-climate stressors", such as economic hardship, food insecurity, cultural forces, and overcrowding. Lata and Nunn (2011) examined the Rewa River Delta in Fiji and found cultural values and beliefs were a barrier to adaptation. In the Reef Islands, Solomon Islands, the findings of Birk (2014) suggest that some of non-climatic stressors, such as population change, are currently – and in the short term – more important determinants of local vulnerability than climate change and sea-level rise. The growing number of studies indicates that non-climatic stressors appear to be significant determinants of vulnerability in the Pacific Islands. This thesis, too, finds that demographic, political, economic, and cultural changes play a substantial role in the vulnerability of the Manell and Geus watersheds. These changes will be discussed in the subsequent sections.

9.2.1.4.1 Military Build-up and population growth

The impacts of climate change may be exacerbated by existing stressors (McCubbin, Smit, and Pearce 2015) such as population growth (McCubbin, Smit, and Pearce 2015; Birk 2014). The U.S. Department of Defense (DOD) plans to develop and construct facilities and infrastructure to support the relocation of 8600 Marines and their 9000 dependents from Okinawa, Japan to Guam (Joint Guam Program Office, Naval Facilities Engineering Command, Pacific 2010). In addition to the marines, DOD will also be building facilities and infrastructure to support the relocation of approximately 600 U.S. Army personnel and their 900 dependents to operate an Air and Missile Defense Task Force (AMDTF) to combat the threat of ballistic missiles (Joint Guam Program Office,

Naval Facilities Engineering Command, Pacific 2010). In total, this would add approximately 19000 additional people on the island. This figure does not include the migrant laborers that will move to Guam to the do the actual construction work.

The proposed build-up will have significant social, economic, and environmental impacts. Perez (2009) discusses in- depth, the hard truths that may come with this buildup. The increase in consumption, recreational, and housing demands will increase as a result of additional humans. The incoming people and the several construction projects needed to support military capability associated with this expansion will directly or indirectly impact Guam's natural resources. Owen (2010) found in general, Guamanians perceive that the military build-up would be good for the economy, but unhealthy for the island's culture. While it is doubtful that the new arrivals will settle in the Manell and Geus watersheds, due to the distance from the U.S. Navy base and U.S. Airforce base, the effects of this build-up may still be felt in Merizo. For example, 62% of the employed residents commute (see 7.1.1.10.2 Location of employment). These commute times may increase with additional traffic caused by an increase in motor vehicles. The cost of living would also increase. Military personnel stationed abroad receive hefty housing allowances. Depending on their rank and number of dependents, military personnel residing overseas may receive as much as 2205-2450 USD/month (Military Advantage 2015). The entire overseas housing allowance (OHA) must be spent; otherwise, any remainder that is not used will be lost income. This will drive the cost of rent up, making it very difficult for middle-income, non-military personnel to find affordable housing. With the knowledge that military personnel can afford higher rents and pay on a timely basis, landlords will most likely prefer military renters to non-military ones. The mean annual salary for all occupations on Guam is 33,280 USD (Bureau of Labor Statistics 2015). Being able to afford to pay 2200 USD/month for rent with that income would be extremely difficult. But, in terms of seeing an influx of military personnel in Merizo, that is most unlikely because there are closer villages with more amenities that may be more appealing in terms of convenience and comfort.

The military build-up could also provide job opportunities for the unemployed residents of Merizo. Approximately 22.6% of respondents stated they were unemployed (either collecting public assistance or not collecting public assistance) (see Table 22). Ideally, if the construction work could be locally sourced, it might drive the unemployment rate down, not just for Merizo, but for the entire island. It could also reduce the number of

migrant workers anticipated to move to Guam for work, thus decreasing the total new additions, and reducing the footprint of this build-up.

9.2.1.4.2 COFA Impacts

In addition to the military build-up, another source contributing to population growth could be Micronesians migrating to Guam, due to the Compacts of Free Association[24] (COFA). COFAs are agreements between the United States and each of the following sovereign USAPI: Federated States of Micronesia (FSM), Republic of the Marshall Islands (RMI), and the Republic of Palau. The COFA's immigration provisions authorize unrestricted immigration into the United States, its territories and possessions, enabling citizens of the FSM, RMI, and Palau, to freely and legally enter, work, and establish residence as non-immigrant aliens. In addition to these visa waivers, the United States also provides economic assistance (including eligibility for certain U.S. federal programs), defense of the FSM, RMI, and Palau in exchange for exclusive U.S. military and operational rights within each of the island's territorial and marine jurisdiction. According to the Guam's Compact Impact Reconciliation Report, attested by an independent accounting firm, the un-reimbursed Compact Impact cost for the period 1987 to 2003 totaled 269 million USD[25] (Office of the Governor 2012). From 2004 – 2011, the Government of Guam claims the cost incurred from impacts of COFA were a total of 440.67 USD[26] (Office of the Governor 2012). This figure does not seem to take into consideration local taxes that employed Micronesian migrants pay or the educational grant awards that Micronesian migrants receive to attend college at the University of Guam.

Rubinstein and Levin (1992) posited that as a result of the COFAs, Guam has experienced many of the impacts associated with large-scale migration on the following: population growth, provision of services and the issue of ethnic assimilation. In the early 1990s, Rubinstein and Levin (1992) predicted that Micronesian migration to Guam would increase, resulting in nucleated ethnic communities, a sizeable working class, social costs, and potential ethnic conflict. Table 120 shows the number of Micronesians

[24] The Compact of Free Association Act of 1985 (P.L.99-239), implemented in 1986, established the relationship between the United States and the Federated States of Micronesia (FSM) and Republic of the Marshall Islands (RMI). The Compact of Free Association Act of 1985 (P.L.99-658), implemented in November 1994, establishes the relationship between the United States and the Republic of Palau. The Compact of Free Association Amendments Act of 2003 (P.L.108-188) renewed the original Compact of Free Association (P.L. 99-239) between the United States and the Federated States of Micronesia (FSM) and the Republic of the Marshall Islands (RMI).
[25] This total figure is divided as follows: $178 million for education, $48 million for health, welfare and labor, and $43 million for public safety (Office of the Governor 2012).
[26] This total figure has not been audited by an independent accounting firm (Office of the Governor 2012).

on Guam did increase until 2008. The latest figure shows the Micronesian population decreased from 2008-2012 (see Table 120).

Table 120: Micronesian Population of Guam from 1995 – 2012. U.S. Census and local census data compiled by Levin (2015).

Year	Micronesian Population
1995	5000
1997	5789
2000	8573
2003	9098
2008	16358
2012	13558

Most of the Micronesian migration to Guam has been attributed to COFA. Evidence of human migration as a response to climate change is scarce for small islands (Nurse et al. 2014). It would be interesting to see how many of the Micronesian migrants in Guam have moved due to climate change. This source of population growth is political in nature. Because Guam is a territory, it does not have control over who is allowed in and out of its borders. Until the political status of Guam is changed, this issue of immigration control may not be resolved.

9.2.1.4.3 Political Stressors

In addition to population growth, political change is a factor that must be considered. The current administration will be replaced in 2018 and there will most likely be a series of new political appointees, who may not be necessarily qualified, to lead the natural resource agencies. These new agency heads may change the policy that could negatively or positively affect how natural resources are managed.

The Governor of Guam recently signed Executive Order (E.O.) 2015-08, which establishes a Climate Change Task Force and a Climate Change Technical Advisory Committee (Office of the Governor 2015). E.O. 2015-08 mandates this Task Force to complete a comprehensive vulnerability assessment for the island of Guam (Office of the Governor 2015). This is a very top-down approach that will require generous financial assistance from the U.S. federal government. Fortunately, OIA[27] is anticipating

[27] The Office of Insular Affairs (OIA) is responsible for administering the U.S. Federal government's relationship with the territories of Guam, American Samoa, the United States Virgin Islands (USVI), and the Commonwealth of the Northern Mariana Islands (CNMI).

approximately seven million USD from Congress later this year to address resiliency and vulnerability in the USAPI[28] (Office of Congressional and Legislative Affairs 2015). Ideally, the government of Guam could receive some of this funding to accomplish the mandates set out in E.O. 2015-08.

From 04-05 June 2015, Assistant Secretary Kia'aina convened the U.S. Insular Areas Climate Change Stakeholder Meeting, with the Government of Guam as co-hosts, at the Hyatt Regency Hotel in Tumon, GU. The meeting brought together U.S. federal officials actively involved in addressing climate change adaptation and resilience strategies in the USAPI. USAPI representatives shared their efforts towards developing climate change action plans and discussed data, tools, resources, needs, and successful programs with US federal officials. Panel discussions included: Disaster Preparedness, Energy Needs and Planning, Role of Non-Governmental and Regional Organizations in Climate Change, Natural and Cultural Resources Management, and the Role of Insular Areas Higher Education Institutions in Capacity Building.

This was an upper-level closed-door, invitation-only meeting. Representing Guam was Wil Castro, Point of Contact for Climate Change for the Office of the Governor, and Robert Underwood, President of the University of Guam. Unfortunately, local government agencies were denied access and did not have an opportunity to observe the panels or network with high-ranking officials.

While the current administration is supporting climate change work, this is their last term in office. Their replacements could have opposing views on climate change and not support adaptation and vulnerability work and revoke E.O. 2015-08. There is research that elite cues (from trusted politicians and media) have a large effect on the level of public concern about climate change (Brulle, Carmichael, and Jenkins 2012). Currently, there is political will, but whether it will remain is not known. It is also unclear if this political motivation will translate into financial support for local initiatives at the village level.

Another potential political stressor to be aware of is a change in the office of the mayor. According to Figure 58, the residents of Merizo trust this office more so than other

[28] The United States Affiliated Pacific Islands (USAPI) region includes American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia (Chuuk, Kosrae, Pohnpei, and Yap), Guam, Hawaii, the Republic of the Marshall Islands, and the Republic of Palau.

government agency. It seems as though the modern day village mayors are the closest embodiment of a traditional chief. The replacement of Mr. Chargalauf, if he loses in the next mayoral election will set the political tone in Merizo and there could be less or greater emphasis on the environment and climate change.

The last political stressor has to do with the political status of Guam. Guam is a colony of the United States. The people (e.g., indigenous Chammorros) who inhabit non self-governing territories such as the five US territories and commonwealths (i.e., Guam) have a right to self-determination and self-governance under international law (Van Dyke, Amore-Siah, and Berkley-Coats 1996). The people of Guam, have petitioned the federal government to officially change their political status of territory to that of commonwealth status (Van Dyke, Amore-Siah, and Berkley-Coats 1996). Bills regarding Chamorro Self-Determination have been introduced to Congress four different instances and both the Bush and Clinton administrations were consistent in their opposition (Van Dyke, Amore-Siah, and Berkley-Coats 1996). Thus, the bills were never reported out of committee and a final agreement was never reached (Van Dyke, Amore-Siah, and Berkley-Coats 1996).

9.2.1.4.4 Economic stressors

In addition to elite cues (from trusted politicians), structural economic factors also have an effect on the level of public concern about climate change (Brulle, Carmichael, and Jenkins 2012). Thus, changes to the economy should also be considered. If the island economy takes a downturn, and negatively affects employment, it may place greater stress on natural resources. For example, people may fish more in order to supplement their diets and provide for their families, because they cannot afford the high cost of food. In this study, improving the local economy did not rank high among respondents (see Chapter 7: Section 7.1.4 Values).

9.2.1.4.5 Infrastructure

Infrastructure is an aspect of Merizo that respondents valued (see Chapter 7: Section 7.1.4 Values). Out of a list of 22 aspects of the watershed they cared about, improving the roads, waterlines, and schools, ranked second, third, and fourth, respectively (see Chapter 7: Section 7.1.4 Values). Residents recognize that the local infrastructure needs to be improved and repaired. The Department of Public Works prioritized a list of infrastructure projects for the entire island of Guam, including the village of Merizo (Parsons Transportation Group, Inc 2010). Some of these projects should help alleviate

the flooding (see Appendix 6 – Infrastructure Projects for the village of Merizo). U.S. federal Executive Order 11988, also known as "Flood Plain Management", mandates that the construction of structures and facilities on flood plains should incorporate measures of flood-proofing. Thus, if the infrastructure projects identified by Parson Transportation Group, Inc. (2010) are funded and completed, it should noticeably lessen the severity of inundation. Finding the funding for infrastructure projects for rural areas is challenging because it requires a hefty financial investment. It is difficult to justify such a large expense for so few people.

One example of poor infrastructure that needs to be addressed is the mouth to the Manell River. It is hardened with concrete walls and the river is re-directed away from its natural floodplain and forced to make an unnatural, 90° turn, run alongside the main road in a concrete channel, go through a culvert, and make another 90° before it empties into Cocos lagoon (see Figure 79 and Figure 80).



Figure 79: Photograph of the mouth of the Manell River facing north. The mouth has been hardened to divert the river from its natural floodplain.



Figure 80: Photograph of the mouth of the Manell River facing south. The mouth has been hardened and the river is forced to turn 90 degrees to the right.

9.2.2 Vulnerability and Resilience in the Manell and Geus Watersheds

The term 'vulnerability' does not translate well into most Pacific Island languages (Campbell 2009), including Chamorro. This is ironic, considering that the Pacific islands are generally viewed as some of the most vulnerable places on Earth with respect to climate change (IPCC 2001, IPCC 2007, IPCC 2014). They have high exposure to natural disasters such as typhoons, storm surges, earthquakes, flooding, volcanic explosions, and drought. However, Pacific Islanders have managed to survive and thrive for millennia, prior to the arrival of Europeans (Campbell 2009; Nunn 2007a). The antonym of vulnerability is resilience. In climate studies, one cannot discuss vulnerability without examining resilience and this is especially true for the Pacific islands, including Guam.

Recall Figure 2, and the wide expanse of ocean separating the small islands of Micronesia. The prehistoric systematic exploration and colonization of the Pacific Islands, including Micronesia, (Irwin 1994; Irwin 1989) is nothing short of amazing, but also a testament to resilience! The mere existence of these island cultures is an example

of resilience. Traditional practices that buoyed this resiliency such as inter-island exchange, ceremonial feasting, marine and land tenure, elevated living structures, chiefdoms, sustainable fishing, and agroforestry have eroded as a result of colonialism, modernization, and globalization. Elements of traditional, sustainable lifestyles that enabled Pacific Islanders to withstand the effects of environmental disasters are no longer present or have evolved in a manner that have rendered them less effective (Campbell 2009). This is the case for Guam.

9.2.2.1 Traditional Knowledge

Guam is the most modernized and least traditional of the islands within Micronesia. Guam has been occupied by the Spanish, the Americans, the Japanese (briefly), and the Americans (again). During the course of Spanish occupation, it has been estimated that the Chamorro population was decimated as a result of disease and warfare and the population was reduced from 200,000 to approximately 5,000 by 1741 (R. F. Rogers 1995). During the initial American occupation, English was mandated to be the official language for business, government, and education, and the use of Chamorro was discouraged. Despite this, according to Santos-Bamba (2013), the Chamorro language and traditions continued to be practiced, mostly because of the role women played as teachers to their children and grandchildren. As observed by Santos-Bamba (2013), it is "…through prayer and song, and in private and social spaces Chamorro language and literacy are present and Chamorro women on Guam continue to contribute as mothers and teachers of Chamorro language and culture." In the Manell and Geus watersheds, approximately 90% of respondents identified as Chamorro (see Table 20) and 67% of respondents can speak Chamorro (see Table 22). This provides strong evidence that Merizo is a stronghold for the Chamorro culture.

9.2.2.1.1 Religion

Additionally, approximately 95% of respondents are Catholics (see Table 24). The local church, San Dimas offers mass daily at 6:00 pm except for Sundays, when it is offered at 6:00 am and 11:00 am. Religion, particularly Catholicism, is an important part of Chamorro culture (Hezel 2005). One of the reasons that Chamorro culture has survived is because it amalgamated with Catholicism (Hezel 2005). As Santos-Bamba (2013) noted, prayers were spoken in Chamorro, allowing the perpetuation of a language that the locals were forbidden to speak in school, work, and places of business. Crumrine (1982) analyzes how the modern village *fiesta* that celebrates the patron saint of each

village is rooted in the ancient ritual of feasting (see Figure 81). Feasting is an important cultural practice in Micronesia (Hezel 2001). Competitive feasting was a way to redistribute food, in accordance with culture-specific rules of hierarchy and etiquette, to the entire clan.



Figure 81: Photograph of 2013 Merizo Fiesta. Note the abundance of traditional food, mixture of Catholic religious symbols (Jesus statue) with ancient Chamorro cultural symbols (*latte stone*). Courtesy of Guam Pacific Daily News.

With the recent encyclical (Francis 2015), Pope Francis addresses the severity of climate change in 246 individual points. Pope Francis (2015) writes about humanity's contribution to climate change, climate injustice, and the ability of humans to make things better with the political support. Pope Francis (2015) proposes that the solution to climate change, "entails profound changes in lifestyles, models of production and consumption, and the established structures of power which today govern societies." This has given CZM an unprecedented opportunity to partner with the Catholic Church to push strategies that build community resilience and improve ecosystem resilience to combat impacts of climate change.

9.2.2.1.2 Customary Practices

Some of the customary practices utilized in the past warrant a discussion because their revival could contribute to adaptive capacity. According to responses from the informal interviews, it seemed that prior to the installation of the public water infrastructure, the residents of Merizo obtained their water from the rivers and homemade rain-water catchments. Bamboo was regularly harvested and used to transport water from the river, either as pipes or carried by carabao (Stephenson 1979). The removal of the bamboo occurred much more frequently, preventing overgrowth, which is present today. The overgrowth of bamboo outcompetes native vegetation and is not the best for streambank stabilization. During heavy rain events, bamboo will snap and clog the

waterways (see Figure 74), re-diverting the water onto the road or peoples' homes. Another response from the informal interviews mentioned the regular clearing of vegetation in the past, which does not occur today. With modernization, this practice has ceased.

In terms of cultural practices, prehistoric Chamorro homes were elevated on *latte* stones (see Figure 8). Most of the houses in Merizo are not elevated and are single-level, detached concrete bungalows. It is perhaps time to consider reviving and modernizing this tradition. It is an opportunity for architects and structural engineers to collaborate on cost-effective renovations that elevate existing homes. It is also vital that the Government of Guam amend the building code for the coastal floodplains that require new developments to be elevated as a flooding precaution. J. Mercer et al. (2007) identify the need for a specific framework that guides how indigenous and western knowledge may be combined to minimize disaster risk to environmental hazards (e.g., typhoons, tsunamis) and therefore reduce the vulnerability of rural indigenous communities in small island developing states (SIDS).

9.2.2.2 Vulnerability

One of the original research questions asked, "***Who is the most vulnerable and who are the least vulnerable?"***

In the context of flooding, the most vulnerable people within these watersheds are those who reside in the coastal floodplains, followed by those who reside within the 100-year floodplain (see Figure 35). The least vulnerable are those who reside on elevated land, situated away from rivers, in elevated houses and are surrounded by healthy ravine forests. Guam is not as traditional as the other islands in Micronesia (e.g., Yap, Palau, Chuuk, Kosrae, Pohnpei, Marshall Islands, Rota). The residents of Manell and Geus do not rely on coastal resources as their primary source of food. Guam is quite modernized and most of the island's food supply is imported.

Of the 203 respondents who believed there were threats to the watersheds, approximately 54% agreed that climate change was a threat, while 21% did not know. In the residents' minds, it seems that there is no association between coastal erosion and flooding with climate change. The linkage between precipitation and flooding is very clear. Residents demonstrated this knowledge by calling the Guam Coastal

Management Program to videotape flooding they predicted would occur that very day (14 September 2013). As one resident described, "if the rain continues like this [steady], the river [Manell] will begin to flow and after a couple of hours, my backyard will flood and then the road". Whether the residents associate an increase in rainfall as an impact of climate change is not readily apparent. It may also be irrelevant. Residents will have to adapt to an increase in flooding events, regardless if they connect it with a warmer world. In addition to flooding, approximately 74% of residents agree that coastal erosion is a threat to the watershed (see 7.1.3.2.10 Coastal erosion). Whether the community understands the relationship between coastal erosion and increased storm surges and SLR is unclear.

9.2.2.2 Adaptive Capacity in the Manell and Geus watersheds

The original research question is as follows: ***What is the adaptive capacity of the community residing within the Manell and Geus watershed?***

The continued existence of small islands will depend on their capacity to adapt to change that cannot be avoided, even if carbon emissions were to cease. Adapting to climate change can manifest in a variety of ways. It can be reactive. It can be action to reduce the impacts of climate change as they happen. Or, it may be proactive. It can be action to avoid, manage, or capitalize on the future impacts of climate change. Adaptation can range from simple to complex. Some impacts may only require small changes, whereas greater impacts may require a novel innovation. Adaptive capacity includes the knowledge, skills, and resources required to identify and implement adaptation effectively to change (Jacobs et al. 2015).

For this case study, 'adaptive capacity' has been defined as "a society's ability to adapt to changing climatic conditions, whether by reducing harm, exploiting beneficial new opportunities, or both" (Burton, Diringer, and Smith 2006). This thesis sought to evaluate the ability of the Merizo community to adjust to a changing climate. In doing so, local solutions that intended to minimize harm were documented. In this instance, flooding, or an excess amount of freshwater, may be used as the context on which to evaluate the adaptive capacity of Merizo. Keener et al (2013) point out that islands in the western Pacific Ocean are receiving slightly more annual rainfall (based on precipitation data from 1950-2010). Currently, Merizo's main issue is flooding; 79% agreed or strongly agreed that flooding was a threat to the watershed (see 7.1.3.2.15

Flooding). Figure 76 and Figure 77 provide photographic evidence of the beginning of a flooding event.

The community is proactively and reactively adapting to this threat and have employed local solutions. Figure 82 is an example of a local reactive adaptation to the stress of flooding. Employees from the Merizo mayor's office respond to calls about the bamboo dam blocking the culvert. Residents have come to rely directly on the Merizo mayor's office, not the Governor's office or the Department of Public Works, during flood events. The Merizo mayor's office, in turn, depends on support from the Governor and local government agencies such as DPW, to help address the needs of its constituents. A backhoe is stationed at the Merizo mayor's office, on loan from DPW, to assist with recovery from heavy rain events. The backhoe is used to clear the bamboo from the culvert, dig new drainage paths from flooded residences, or deepen existing channels.

Another adaptation undertaken by residents is the stockpiling of limestone for construction of temporary barriers to block water from entering their homes (see Figure 72). This is a proactive measure; they are anticipating future flooding events. Another action to mitigate flooding is depicted in Figure 73: Photograph of "Joe", a Merizo resident who voluntarily monitors the Manell River culvert during high rain events. Joe uses a long hook to guide bamboo through the culverts to avoid a pile-up. All of these adaptations are local solutions. The residents are attempting to minimize the damage that flooding can inflict. These local solutions may not be enough, should flooding increase and become more severe as a result of projected increase rainfall for the region. Figure 74 shows the bamboo dam that comes with high rainfall events that "Joe" valiantly tried to prevent. Joe's actions only prolonged and not prevented the inevitable blockage.

In addition to these local solutions, more can be done. Community based long-term strategies need to be devised. To do so, community access to the modern-day financial and technological resources must be improved. GCMP has assigned a watershed coordinator to liaise with the village of Merizo and one of the responsibilities of this person is to share grant opportunities and information about local programs. There are also tools available to the community and GCMP for planning.

For example, NOAA Pacific Services Center (2013) developed a digital coast SLR and coastal flooding impacts viewer specifically for Guam and Saipan. This planning tool

may be used to assist CZM managers in visualizing the potential impacts of SLR. There are six different SLR scenarios (0-6 feet or 0-1.82 m) that may be viewed at different scales (NOAA Pacific Services Center 2013). Areas of potential inundation are color-coded according to levels of confidence. This is an example of how federal agencies are assisting local jurisdictions and increasing adaptive capacity. While this tool is freely available, it is not being used by GCMP, let alone the community.

Efforts need to be focused upstream. Long-term adaptive strategies should include a community watershed restoration plan that aims to re-vegetate the savannah grasslands with a healthy forest, reduce the number of bamboo stands, re-introduce native species of flora, and stabilize the streambanks. This may seem like a Herculean effort for a community of 1850 people (U.S. Census 2011), but there are available resources and support. For example, there are a number of federal grants from NOAA, USDA NRCS, and USGS that seek to fund community driven work. There are technological tools and expertise that is available from the university, non-governmental organizations, and local and federal agencies. Ideally, this watershed-wide restoration should be a coordinated effort with the local and federal natural resource agencies, the mayor's office, private landowners, the schools, the university, non-government organizations, and private businesses.

Adaptive capacity is one of the most challenging components of resilience to measure, and despite its importance, it is an under-researched topic (Engle 2011). It is usually measured indirectly (Jacobs et al. 2015) through the use of proxy indicators that vary according to spatial scale (Folke et al. 2005) (e.g., regional scale (Hill 2012), international scale (Milman et al. 2013); national scale (N. Brooks, Adger, and Kelly 2005; Chen et al. 2014); a watershed level scale (Pandey et al. 2011; Heikkila et al. 2013).

This thesis uses the following eight determinants of adaptive capacity defined by (Yohe and Tol 2002):

1. The range of available technological options for adaptation
2. Availability of resources and distribution across the population
3. Structure of critical institutions; decision criteria
4. Stock of human capital (e.g., education, income, awareness)
5. Stock of social capital (including the definition of property rights)

6. System's access to risk spreading processes
7. Ability of decision makers to process information, the credibility of decision makers
8. Public's perceived attribution of the source of stress and significance of exposure if that stress is locally manifested.

Each of these determinants will be discussed as they relate to the disseration in the subsequent sections.

9.2.2.2.1 Technological Capacity

There is no outright definition for technological capacity as it relates to climate change. It is often described as component of adaptive capacity and it, too, is difficult to quantify. For this thesis, technological capacity is interpreted as the specific ability of a group or an individual to apply scientific knowledge for practical purposes, measured in quantity and level of quality, over an extended period. In the context of climate change, technology can potentially play an important role in adaptation (IPCC 2007). For example, desalination plants, low-water toilets, photovoltaic panels, computers, and other engineering solutions can help humans cope better with impacts to climate change. Innovation refers to the development of new technologies or strategies, or the revival of old ones in response to new conditions (Bass, 2005). This is an important aspect of adaptation, particularly under uncertain future climate conditions (IPCC 2007).

In this household survey, the only question that applies to technological capacity is in relation to where people obtained water during outages (see Chapter 7: Section 7.1.3.4.5 Alternative sources of water during outages). Of particular interest was whether people used low-technology solutions, such as rainwater catchments, as a coping mechanism to water outages, which are mostly perceived to 'rarely' or 'sometimes' occur (see Figure 50). From the informal interviews, it was discovered that rainwater catchments were the primary source of water in the past. This allowed for water security and independence. People did not have to depend on the Government of Guam or GWA for their water; they were able to procure it for themselves, using low-cost technology.

It could be argued, using the definition of technical capacity specified by this thesis, that it is present in Merizo. People do apply knowledge to solve problems and it is readily

apparent in the local responses to flooding, which have been discussed at great length in Section 9.1.3.1 Protection Motivation Theory.

9.2.2.2.2 Availability and distribution of financial resources

Another determinant of adaptive capacity is the availability and distribution of financial resources. This is usually in reference as to whether there are available funds for adaptation and whether the institutions or private individuals that control these funds are prepared to spend them on adaptive strategies (Yohe and Tol 2002). As a territorial possession of the United States, Guam has access to federal financial and technical resources. All U.S. federal grants are available at www.grants.gov. This is a centralized repository with a functional search engine to research available grants from all U.S. government agencies for eligible applicants. A good portion of the local government budget is financed by U.S. federal aid. Applications, requirements, and performance metrics can vary from grant to grant. These applications may be very time-consuming, tedious, and in some instances, require a financial match.

Poorer people are found to be more vulnerable than richer people (Yohe and Tol 2002). People with higher incomes will have more money to protect themselves from impacts of climate change. This study found the majority of the residents of the Manell Geus have incomes (Table 28) below the island's mean annual salary of 33,280 USD (Bureau of Labor Statistics 2015). While personal incomes are low, it does not preclude people from applying for federal grants to pursue adaptation planning and implementation. It would be more challenging.

9.2.2.2.3 Institutional capacity

Effective institutions are an aspect of adaptive capacity to climate risks. Governments and other institutions at the island level, national level, and international level play a critical role in increasing society's capacity to adapt accordingly and timely as environmental conditions change and new climate change knowledge surfaces. Institutions can convey the risk and sensitivity to climate hazards, facilitate or impede individual and collective responses, and shape the outcomes of such responses (Agrawal 2010). Institutions affect how residents responded to environmental challenges in the past, and they will most likely remain the fundamental mediating mechanisms that translate the impact of external interventions to facilitate adaption to climate change in

the future (Agrawal 2010). For example, in Guam, after a disaster such as a major typhoon strikes, FEMA[29] arrives and provides disaster relief.

There is strong island leadership with the issue of climate change. The creation of E.O. 2015-08 – Relative to Addressing the Impact of Climate Change (Office of the Governor 2015), which calls for a Climate Change Task Force (CCTF) and Technical Advisory Committee to complete a comprehensive vulnerability assessment within one year demonstrates strong political will. The CCTF will consist of a representative from each local government agency. The Governor's office has appointed an official Point of Contact, Wil Castro, to head up the CCTF and oversee the execution of E.O. 2015-08. E.O. 2015-08 provides the beginning of a policy framework that provides institutional coordination across government sectors.

Coastal governance is centralized, well structured, clearly defined, and has a supporting legal framework. While local communities are not legally empowered to make their own decisions about their natural resources, they can find financial and technical support for local initiatives that align with local government priorities (which have to align with federal government priorities). The Humåtak Project, occurring in the adjacent Umatac Watershed is an excellent example of a local initiative where Umatac village is taking action to restore the watershed, coral reefs, and near-shore fisheries (see Shelton 2015). The residents of Umatac are planting trees, employing low-cost technology (i.e., sediment sock filter[30]), and monitoring the Umatac Bay for improvements in coral and fish. The Humåtak Project receives funding from local and federal agencies and provides a match with volunteer hours. The success of this project should inspire the residents of Merizo to start a similar initiative.

9.2.2.2.4 Competence, capability, and credibility of decision-makers

The main decision-maker for the island of Guam is the Governor and is elected by the people in a democratic process. The majority of residents find the Governor's Office 'somewhat trustworthy' (see Figure 57). This may have changed because during the

[29] The Federal Emergency Management Agency (FEMA) is an agency within the U.S. Department of Homeland Security, established by a federal executive order (E.O. 12127). The primary purpose of FEMA is to coordinate the response to a disaster that overwhelms the resources of local and state authorities. In the case of Guam, the disaster would have to only overwhelm the island authorities.

[30] Sediment sock filters are mesh stockings filled with mulch that are installed perpendicular to an eroding hillside to decrease erosion and promote vegetation.

time of fieldwork (2010), the Governor was Felix Camacho and it is now Ed Calvo. Governor Calvo won the last election by an overwhelming majority, which indicates popular support. However, since Guam is a territorial possession of the United States, one could argue that the actual main decision maker is the President of the United States (POTUS). POTUS is an elected leader but the residents of Guam are not allowed to vote in federal elections. While Barack Obama (current POTUS) hails from Hawaii, a small Pacific island that happens to be a U.S. state, and would be more sensitive to the issues of small island states, the people of Guam did not, or rather could not vote for him. Alas, POTUS does not directly manage the affairs of the island, but can overrule any local actions that are not in line with the U.S. interests.

The Department of the Interior (DOI) Office of Insular Affairs (OIA) manages the relationship between Guam and the United States. The following points cannot be emphasized enough. Due to its political status, Guam does not have full control of its natural resources or control over immigration. Until the political status of Guam is changed from a territory to a sovereign nation, it will not have the latitude to make decisions that could affect its adaptive capacity. As it stands, CZM managers have the ability to make decisions about the coastal zone, so long as those decisions comply with local and federal laws and are somewhat trusted by the community (see Figure 58).

In terms of credibility, Leeson and Sobel (2010) point out the local public corruption that is associated with FEMA funds. For example, when Super Typhoon Paka devastated Guam in 1997, FEMA provided 1.2 million USD to the government of Guam for the replacement of bus shelters (Leeson and Sobel 2010). This money was illegally awarded to the primary business rival of the governor at the time in return for financial and public endorsement of the 1998 gubernatorial campaign (Leeson and Sobel 2010). According to the household survey, the majority of residents do not find the Governor's office to be 'most trustworthy' or 'very trustworthy' (see Figure 57). Is is probably indicative of the residents' awareness of local public corruption and their hesitance to completely trust the Governor's office.

9.2.2.2.5 Human Capital

Human capital includes the skills, health, experience, knowledge, and education of individuals that contribute to the productivity of labor and capacity to manage land (Jacobs et al. 2015). There is no one, straightforward way of measuring human capital because there are many variables that affect it. One method of measuring it is using the

Human Capital Index (World Economic Forum 2015). Results from this thesis would not be able to give a quantified measurement of the human capital within the Manell and Geus watersheds. At best, information from the demographic profile may provide a very broad overview of some aspects of the stock of human capital in Merizo. This would not even be close to a quantitative metric that has a strict methodology and many indicators, such as the Human Capital Index (World Economic Forum 2015).

In terms of education, one aspect of human capital, (see Chapter 7: Section 7.1.1.6 Level of Education Attained), 38% of respondents did not complete high school; 48% attained a high school diploma or General Education Diploma (GED) (see Table 19). Only five % of respondents completed tertiary education (see Table 19). In terms of knowledge, questions in the household survey were specific to knowledge pertaining to the environmental characteristics of the Manell and Geus watersheds. Using these variables is not enough to confidently contribute a statement about the entire knowledge base of the residents. Other factors such as skills, health, and experience were not examined.

9.2.2.2.6 Social Capital

Social capital describes the patterns and intensity of networks among humans and the shared values, which arise from those networks. Its application in natural resource management suggests that social bonds and norms are critical for shaping individual action to achieve positive biodiversity outcomes (Pretty 2003). Pretty (2003) and Pretty and Smith (2004) find that social capital is a vital, fundamental component of capacity for successful natural resource management. Relationships of trust, reciprocity and exchange, common rules, norms and sanctions, and connectedness in groups (i.e., components of social capital), are crucial in shaping pro-environmental behavior. When social capital is high (i.e., there is an existence of formalized groups) people have the confidence to invest in collective pro-environmental activities, knowing that others in the group will also participate (Pretty and Smith 2004). Social and familial pressure can strongly influence the behavior of groups (Armitage 2005). In particular, inclusive forms of social capital support the actions of individuals through the sharing of knowledge, labor (human capital), equipment (physical capital) and finances (financial capital) (e.g. Pelling and High 2005). When there is high social capital, new ideas can spread more rapidly which can allow for social learning of ecosystem concepts (Pretty and Smith 2004). Valuing and fostering strong social relations, in the form of trust,

reciprocity, locally developed rules, cultural norms and taboos, has been shown to deliver favorable biodiversity outcomes (Pretty and Smith 2004).

Macias and Williams (2014) examine three types of social capital—relational social capital, generalized trust, and community social capital, and the relationships with pro-environmental behavior, environmental activism, and willingness to sacrifice for the environment. Macias and Williams (2014) found that time spent with neighbors was positively correlated with both environmental lifestyle and willingness to sacrifice variables, whereas time spent with relatives was negatively correlated.

Armitage (2005) examines the relationship among adaptive capacity, community-based resource management performance, and the socio-institutional determinants of collective action (e.g., technical, financial, and legal constraints) in the context of politics, scale, knowledge, community and culture in Southeast Asia and northern Canada. Armitage (2005) analyzes exogenous and endogenous variables that influence how individuals act collectively and the ways that they respond to changing circumstances, learning, in order to build adaptive capacity for natural resource management.

Social capital in Merizo is high. See Section 9.1.4 Values, for the discussion of the main values of Chamorro culture. This is a tight-knit community that values family. Social capital may be the key to fostering pro-environmental behavior and the component that strengthens adaptive capacity in Merizo. It needs to be further explored, for the entire island of Guam.

9.2.2.2.7 Community perceptions about the source of stress and significance of exposure

The threat perceptions this study has examined have been discussed at great length in Section 9.1.3 Perceptions. The community perceives flooding as a local stress, but may not see the connection with a changing climate. This may make them more open to develop and incorporate adaptive strategies that focus on minimizing their exposure to this particular threat and the process increase their knowledge by actively using familial social networks.



Figure 82: Photograph of employees from the Merizo mayor's office sent to assist in the clearing of the accumulated bamboo blocking water drainage from the overflowing Manell River.

9.2.2.3 Community Resilience and Guam

The original research question is as follows:

How resilient are coastal communities, particularly small Micronesian Island-states such as Guam, in the face of global climate change?

Adger (2000) defines social resilience as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change. There is a link between ecological and social resilience, particularly for social groups or communities that are dependent on ecological and environmental resources for their livelihoods (Adger 2000). Merizo is not entirely dependent on the local environment, except for those that work in the tourism sector. Ecological resilience could be higher and that would provide added social benefits, especially in terms of flood protection.

Small islands have been and are continuing to adapt to environmental, social, economic, and political change (Campbell 2009). As previously discussed in Section 9.2.2.2 Adaptive Capacity in the Manell and Geus watersheds, it may be argued that the adaptive capacity for Guam is high, despite its small size, remote location, low population.

However, Guam is not typical of all Micronesian island-states. Guam is a high island, with an abundant freshwater lens. Guam is the most modernized and least traditional of all this islands in Micronesia. It is a melting pot of different nationalities. Traditional chiefdoms have eroded. Despite this, determinants of adaptive capacity, particularly social capital, technological capability, and financial opportunity are present, in at least two watersheds. Guam is far more resilient than people would expect. However, to bolster this resilience, it is crucial to address the non climate-related stressors and the current critical social, economic, and environmental issues. It is important to strengthen the natural environment in a socially and culturally acceptable manner in order to cope with future impacts of climate change (Adger et al. 2005). Raising awareness and communicating future risks to local communities will likely increase human and environmental resilience to the larger term impacts of climate change (Nurse et al. 2014).

9.2.2.4 Economic Feasibility of Proactive and Resilient Strategies to Climate Change on Guam

One of the original research questions posed is as follows:
What types of proactive and reactive resilient strategies are economically feasible?
Two main strategies to consider are ecosystem restoration and sustainable development. These are discussed in the following sections.

9.2.2.4.1 Ecosystem Restoration

Ecosystems provide a host of services that benefit humans. The Millennium Ecosystem Assessment (2005) groups ecosystem services into four broad categories: provisioning (e.g., production of food and water), regulation (e.g., control of climate and hydrology), supporting (e.g., nutrient cycles), and cultural (e.g., recreational). One proactive strategy would be to improve the ecosystem service of water regulation. This would involve a revegetation strategy that replaces the grassland-dominated watershed with a healthy forest that has a strong canopy and filled with native species. Increased organic matter from the healthy forest can provide nutrients to enrich the soil, allowing it to absorb more water. In addition to upland reforestation, restoring the natural floodplain may also mitigate the current flood risk. Jacobson, Lindner, and Bitner (2015) examine the possibility of reestablishing the original floodplain to decrease flood risk for the lower Missouri River. Undertaking a similar quantitative study for the Manell and Geus could shed more light on this possible solution. This would increase natural flood protection

and increase natural resiliency. Restoring the coastal floodplains of the rivers located in the Manell and Geus watershed could alleviate the issue of flooding. However, the original floodplains are currently inhabited. People have built homes in these vulnerable areas and the restoration of the natural floodplain could be met with hostility. Since there are a number of existing residences in the coastal floodplain, one adaptation option could be to retrofit existing houses and elevate them. Amending the building code to ensure new structures are elevated to withstand flooding events is also a logical strategy.

9.2.2.4.2 Sustainable Development

In addition to ecosystem restoration, another strategy to increase resilience is sustainable development. 'Sustainable development' is commonly defined as, "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1987). It is economic development without over-exploiting or depleting natural resources. In this case, sustainable development requires the perspective of viewing the island of Guam as a connected ecosystem that is part of the world system, across space and time (King and Baza 2014). Past decisions affect present generations, just as current decisions will affect future generations. Embracing sustainable development today can help safeguard the natural resources for future generations.

To increase self-reliance, without sacrificing development, involves the promotion of community-based businesses; the mainstreaming of current industries to be more sustainable; the encouragement of locally grown sustainable agriculture; the decrease of the dependency on fossil fuels; and the creation of a legal and political framework that endorses these ideas. The main goal of sustainable island development for Guam is to enable residents to satisfy their basic needs and strive toward a better quality of life in the present, without compromising natural resources for future generations. Sustainable island development is relative; what this specifically means for one island may or may not be appropriate for another island and how this is implemented in one island may or may not be suitable for another island. Currently there is no official overarching, all-encompassing sustainable development policy for the island of Guam and this needs to change.

9.3 Policy Implications

Local policy should seek to enable transition pathways to a sustainable, resilient island-economy and promote sustainable development. It is time to consider an overarching, island-wide sustainable development policy set forth by King and Baza (2014). This will require inter-agency cooperation, in addition to forging new partnerships with private businesses, non-governmental organizations. It will entail stakeholder engagement and popular support for it to succeed.

Another pathway local policy should support would be the enhancement of natural ecosystem functions to increase resilience to climate change (Tompkins and Adger 2004). Dealing with climate change via environmental restoration and conservation is one realistic way to increase natural resiliency, which would decrease social vulnerability. In the case of the Manell and Geus watersheds, restoring the watersheds to healthy native forests from predominant grasslands would improve the quality of the soil. This can increase the amount of water the watersheds could absorb, thus decreasing the amount of run-off into the rivers. This would in turn, alleviate flooding, reduce sedimentation, and limit erosion. Additionally, serious consideration for the restoration of the original floodplain should be given. Ultimately, it could make the village of Merizo more resilient to projected increases in precipitation (one predicted impact of climate change).

To successfully achieve this ecosystem restoration, several steps must occur simultaneously. First, the issue of wildland fires must be addressed. The engagement of fire-related behaviors such as arson as a hunting technique, burning vegetation, 'smoking' of the trees, and burning rubbish need to be at the very least managed, if not altogether ceased. It is recommended that a fire management plan be co-developed with the community, the Guam Fire Department, the Department of Agriculture, the Guam Coastal Management Program, and the Natural Resource Conservation Service. This fire plan should address best-practice, safe burning methods. The current arson laws need to be enforced. This may be an opportunity for the community to engage in a 'neighborhood watch' that polices and reports arson.

In addition to eradicating wildland fires, large-scale re-vegetation needs to occur. A massive, coordinated tree planting involving the community needs to be planned over a specific period of time. It cannot be stressed enough, that for these new trees to survive, wildland fire must be under control. One major burn can devastate months of painstaking effort. This was the case with the Cetti Bay watershed, a neighboring

watershed on Guam. The U.S. Navy was mandated to perform compensatory mitigation as required by the National Environmental Policy Act, for the dredging of benthic habitat impacted by the Kilo Wharf extension, located in Apra Harbor, Guam. The U.S. Navy gave 8 million USD to the Government of Guam to reforest 500 acres of the degraded Cetti Bay watershed as off-site mitigation for the coral damage in Apra Harbor. Unfortunately, Cetti Bay Watershed was burned, destroying a good portion of the newly planted trees.

Furthermore, the question of what species of flora constitute a native forest on Guam must be answered prior to watershed restoration. This is a research question that has yet to be fully answered. There is some idea of what the forests were composed of prior to human settlement, based on the pollen cores from Athens and Ward (2004) and Donnelly (2010). Prior to re-establishing native forests, Guam Forestry has been widely planting *Acacia confusa*, a fire-resistant introduced species, in the grasslands to prevent soil erosion (Liu and Fischer 2006). In the Umatac watershed (a watershed adjacent to the Geus), a community-based reforestation project (Humåtak Project) is alternately planting *Acacia confusa* and a native tree, *Intsia bijuga* (commonly known as *ifit)* to stabilize the soils.

Participating in initiatives such as the Micronesia Challenge is an excellent way to fortify natural ecosystems. Mainstreaming climate change into current conservation efforts, such as marine protected areas or protected terrestrial areas, may be a realistic way to increase resiliency of the natural ecosystems islanders depend upon (McLeod et al. 2009). The Manell and Geus watersheds were selected as a 'Habitat Focus Area' for NOAA Habitat Blueprint (NOAA 2015). There are federal resources directed to addressing the recommendations set forth in the Manell and Geus watershed management plan (see King 2014). Ideally, through Habitat Blueprint, coastal and marine habitats may be restored in order to increase resiliency to climate change and sustain the economic, cultural, and environmental benefits the community enjoys.

In addition to increasing natural resilience, another option is to safeguard existing developments and roads in the Manell and Geus watersheds. The Department of Public Works prioritized a list of infrastructure projects for the village of Merizo (Parsons Transportation Group, Inc 2010) that should help alleviate the flooding (see Appendix 6 – Infrastructure Projects for the village of Merizo). U.S. federal Executive Order 11988, also known as "Flood Plain Management", mandates that the construction of structures

and facilities on flood plains should incorporate measures of flood-proofing. Thus, if the infrastructure projects identified by Parson Transportation Group, Inc. (2010) are funded and completed, it should noticeably lessen the severity of inundation.



Figure 83: Small *Acacia confusa*



Figure 84: *Ifit* tree located in the University of Guam

On an island scale, the Governor of Guam signed Executive Order (E.O.) 2015-08, which establishes a Climate Change Task Force and a Climate Change Technical Advisory

Committee (Office of the Governor 2015). E.O. 2015-08 mandates this Task Force to complete a comprehensive vulnerability assessment for the island of Guam (Office of the Governor 2015). This is a top-down approach that needs to be supplemented with a bottom-up approach. This policy provides enabling legislation that supports adaptation on Guam and it is important that it is executed.

9.4 Theoretical Contribution

Research from this thesis has contributed to the fields of environmental geography and coastal zone management.

9.4.1 Contribution to Environmental Geography

Environmental geography is often referred to as the bridge between human and physical geography. Understanding the spatial aspects of human-environment interactions has never been more crucial, especially with regard to climate change (Castree et al. 2009). It requires a comprehension of climatology, hydrology, biogeography, geology, geomorphology as well as having a firm grasp on the humanities particularly in the realms of cultural anthropology, psychology, and political science (Castree et al. 2009). It is not simply possible to understand environmental problems without examining the physical processes and the cultural, economic, and political systems that accompany issues such as resource management and climate change.

This research is a synthesis of environmental and human knowledge for a very specific portion of the Earth that may be unjustly impacted by climate change. For this small part of the world (Manell and Geus watersheds), it attempts to answer a question that is fundamental to the survival of the human species: how vulnerable are humans to impacts of climate change? The results provide an excellent case study and example to future environmental geographers interested in interdisciplinary vulnerability assessments and natural resource management planning. The results also demonstrate the importance and use of tools (GIS and SPSS) in the field of environmental geography.

9.4.2 Contribution to CZM

This research is incorporated into a watershed management plan for the Manell and Geus watersheds (see King 2014) for the GCMP. It is also an example of bridging the gap between academia and management. In addition to the vital, continuous long-term monitoring of climate variables (e.g., rain and flooding), CZM managers also need

constant social data about the community that reside in the very areas they manage. Inclusion of the attitudes, perceptions, behaviors, and knowledge of the residents can direct a watershed management plan and frame it in a manner that garners the support of the community. Incorporating this social science data ensures this plan is a reflection of Merizo residents' values. As a result, they now have a vested interest in its successful implementation. The community wants to cease flooding. While eradicating inundation may be out of the realm of CZM managers, minimizing the severity of flooding events through watershed restoration is quite feasible.

9.4.3 Contribution to Guam

This thesis offers a compilation of studies conducted specific to the Manell and Geus watersheds. Ideally, the people of Guam may use this work as a model for future watershed management plans and realize that their input is a valuable part of natural resource management and should be included in planning processes. While the Guamanians do not have full control over their natural resources, participation in the planning process allows them to have a voice in how their watershed is managed, until the time their political status is resolved.

9.5 Recommendations for Future Research

There are five key recommendations for future research which include:

- Detailed GIS mapping for southern Guam
- Undertaking longitudinal studies
- Undertaking additional case studies for replication
- Examining motivations and incentives for adaptation
- Scenario-building
- Focused investigations on each of the determinants of adaptive capacity for all of Guam
- Coupled ecological and social monitoring of conservation and watershed restoration

The first recommendation is to undertake detailed GIS mapping for the southern watersheds in order to delineate micro-drainages. This is a data gap that must be filled for degraded land restoration. Information can be used to strategically restore grasslands and badlands back to native forests. Micro-drainages will identify sediment transport pathways, access corridors for restoration teams, and potential redirections of

rainwater for maximum absorption. This could also provide visual guides and the basis for models that could predict wildfire behavior and thus direct fire suppression and post-burn protocols.

In addition to the micro-drainages, bamboo stands need to be mapped and identified. During high rain events, the bamboo is broken and washes down the river resulting in the creation of dams. There is high-resolution imagery available for Guam but the classification schemes do not isolate bamboo, it is grouped within 'ravine forest' (see Figure 28). It is necessary to quantify and locate the amount of bamboo present in both watersheds and devise a management strategy that is specific to bamboo. Bamboo is an extremely difficult plant to manage. Eradication involves shoveling the bamboo out at the roots. Put prior to managing it, it is important to know the location and quantity of bamboo.

Secondly, this study is snapshot in time. It is relevant to the Manell and Geus watersheds for 2010. It would be prudent to continue long-term monitoring of the community to observe any changes in attitudes, perceptions, behaviors, and knowledge especially toward their watershed and flooding. It is also an opportunity to see if the watershed restoration efforts that will be exerted will actually reduce the severity of flooding events. It would be very interesting to see if the community perceives the severity of flooding to be less and associates it with successful ecosystem recovery.

Thirdly, it is also recommended that watershed plans for the remaining watersheds on Guam incorporate impacts of climate change and consider the vulnerability of the community. It would be ideal if they used a similar method and questionnaire. Once research for those watersheds is complete, it would be interesting to compare vulnerability across watersheds in Guam, and perhaps other watersheds located in other tropical islands.

Fourthly, the premise of this thesis calls for a change in resource-degrading behaviors in conjunction with watershed restoration. In order to change those behaviors, more research should be conducted on incentives and disincentives. What will motivate a person to stop burning, whether it is for hunting, for garbage, or for smoking the trees? What will motivate an individual adopt environmentally friendly behaviors that protect the watershed? While this in the realm in psychology or sociology, discovering the impetus for change would be incredibly useful to CZM managers.

Fifth, more research should be done on each of the determinants of adaptive capacity. A dedicated investigation with robust methodology on each determinant can offer a more holistic and quantified measurement of adaptive capacity. Ideally, that could be used to not only obtain baseline data, but also to measure the direct impact new adaptation interventions have on adaptive capacity.

Sixth, should the Government of Guam invest in ecosystem restoration and conservation, monitoring not only the physical systems but also the social systems should occur. This would provide evidence that those inteventions do or do not provide direct and indirect benefits to the local community. This would be a crucial component for adaptive management. Based on the monitoring results, CZM managers can adjust their strategy by adding an intervention or removing one accordingly.

One last recommendation calls for the development of narratives. Narratives could initiate the dialogue between the community and the CZM managers. Ideally, the narratives would be based on the downscaled simulations and could be specific to the Manell and Geus watersheds. Attitudes, perceptions and values of communities, policy makers, natural resource managers and planners about climate change could be collected after viewing a tangible, plausible future scenario. These mental images could depict critical spatial environmental linkages within an area such as a watershed, and foster understanding how decisions (e.g., continued burning) can environmentally and aesthetically impact a community, especially with regard to an abstract concept, such as watershed restoration.

9.6 Recommendations for CZM

This is a place-based study that provides valuable information for CZM managers about the Manell and Geus watersheds and the people that reside there. Armed with information about the human dimension, CZM managers can now create watershed management plans that increase adaptive capacity to climate change. CZM managers should take advantage of the high social capital present in Merizo. The traditional knowledge, values, and kinship of local island communities should be acknowledged as valuable for ecosystem-based, natural resource management. While social capital is one component of adaptive capacity (Yohe and Tol 2002), it is a crucial one (Pretty 2003, Pretty and Smith 2004).

In addition to the watershed management plan, GCMP should devise a general educational strategy that initially informs Merizo residents the definition of a watershed, the physical boundaries of the Manell and Geus watersheds, ecosystem threats within the watershed, and personal activities people can do to minimize those threats. The strategy should be uncomplicated, culturally sensitive, and location specific. It could be implemented by a number of organizations in Merizo, so long as the message is the same. Organizations could include the Mayor's Office, the most trusted agency (see Figure 57), the Catholic Church, or a local champion, such as the one used to promote the Humåtak Project in the neighboring Umatac watershed (see Shelton 2015). The strategy could also be financially supported by local government agencies, including GCMP.

It is strongly recommended that GCMP engage the Mayor's Office and the Church. Religion plays an important part of Chamorro culture (Santos-Bamba 2013; Crumrine 1982). Restoration of the Manell and Geus native forest will be most effective when conducted as an inclusive partnership, especially considering the scale of the endeavor. Private and public landowners, residents, community organizations, special interest groups, local, state and federal agencies are stakeholders. Partnerships that engage all of these groups in a local watershed planning process have an authentic opportunity to develop a strategy that balances management needs and community objectives with the availability of technical and financial assistance from a variety of sources.

There is a lack of empirical studies with robust methods that identify and measure effects of drivers (e.g., climate change) of migration. Impacts of COFA on Guam are of great concern to long-term residents (Smith 1993). OIA also recognizes this and has provided 15 million USD annually to the island of Guam since 1986, the year the first COFAs took effect to offset impacts (Cagurangan 2014). While Micronesian migration does not seem to be a significant issue in Merizo, this should be investigated further for the island of Guam, especially with respect to climate change. Assessing the nature of Micronesians migrating to Guam as a result of impacts of climate change to their respective islands would shed light on the regional issue of migration and climate.

Improving risk knowledge and island resource management while strengthening socioeconomic systems and livelihoods (Hay 2013) are all goals GCMP should incorporate into their strategic planning.

9.7 Conclusion

Ultimately, for the Manell and Geus watersheds, the vulnerability to climate change is the result of a combination of climate and non-climate stressors. Despite these multiple stressors, some determinants of the adaptive capacity are arguably high, particularly social capital and the community perceptions about the source of stress and exposure. Understanding the differences in the attitudes, perceptions, values, behaviors, and knowledge of the local community toward water and watersheds, is crucial for successful implementation of adaptation strategies in a range of environmental change settings, not just that of climate responses. Information about the human dimension illustrates the vulnerability of a society. CZM managers can use this data to custom-tailor location-specific adaptation strategies that are supported by the community. Acceptance of these strategies could be measured by positive stakeholder behavioral changes (e.g., number of human-induced wildfires per month) and physical changes (e.g., change in annual land cover vegetation).

Islands are globally connected in ways that defy the accepted perception that comes with being small, isolated, and impoverished . Guam may be small and geographically isolated, but it is by no means destitute. The village of Merizo, like Guam, is wealthy in social capital. As a territorial possession of the US, it has access to funding and federal government support. Guam has financial resources that are not as readily available for other small islands. They are eligible for technical and financial assistance from U.S. federal agencies, such as NOAA, EPA, USDA, and FEMA in pursuing adaptation strategies.

However, being a colony also has disadvantages. Different levels of political sovereignty for decision-making and the availability of resources affect an island's ability to implement responses to climate change in a timely manner (Kelman 2010). The residents of Merizo do not have local control over the natural resources in the Manell and Geus watershed. For that matter, Guamanians do not have full control over their island's natural resources and immigration. Any formal adaptation strategies Merizo, or Guam decide to implement will have to be approved by the local government and must comply with U.S. federal laws.

Island environments are dynamic. "Contemporary climate change is not the first or only force of change buffeting islands, and it will accelerate and exacerbate existing social, economic, political, and especially, environmental trends" (Lazrus 2012). It is hoped

that this research assists the residents of Merizo and inspires them to restore and protect their watersheds for present and future generations.

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Appendices

Appendix 1 – Household Survey

Please help Merizo by taking this 15 minute community survey!

You will get a FREE bag, water bottle or t-shirt for your help!

This survey is 100% confidential.
Please contact the Bureau of Statistics and Plans for more information.
Phone: 472-4201

BUREAU OF STATISTICS AND PLANS

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Hafa Adai!

The Bureau of Statistics and Plans-Guam Coastal Management Program is developing a watershed management plan for the **Manell-Geus watershed** (see attached map). The village of Merizo lies within this watershed.

A **watershed** is an area of land, bounded by ridges of high ground, where water drains from high points to low points. The water moves through a network of drainage pathways, both underground and on the surface and eventually merges into streams and rivers, continuing to move until it reaches a wetland (in some cases) and into the ocean.

A **watershed management plan** is a guide, or a blueprint, on how best to protect and improve the water quality and other natural resources, such as forests, wetlands, and animals for the benefit of the people living within the watershed. Rainwater, as it moves over land can carry pollutants and loose soil into the ocean, and could cause the reefs to be smothered and the fish to starve. A damaged watershed can contribute to flooding during intense, high rainfall events such as typhoons and tropical storms. A well-researched watershed management plan can help identify and address the issues affecting the environment from ridge to reef.

We need your help! While there are many things to consider in developing a watershed plan, community input is the most important. Please take 15 minutes of your day to complete the attached survey. As a token of our appreciation, each person who completes a survey will receive a gift! The results of this survey will give us a general idea of the attitudes, beliefs, and behaviors of the communities that reside in the Manell/Geus watershed with regard to their land and ocean environment.

Romina King, a post-graduate student, is conducting this survey on behalf of the Bureau of Statistics and Plans Guam Coastal Management Program. If you have any questions or concerns, please contact her by email at rominaking@gmail.com or by telephone at 929.6714. You may also contact the Bureau at 472-4201.

Sincerely,

Alberto A. Lamorena V
Director

HOUSEHOLD SURVEY

Measuring Attitudes; Perceptions; Beliefs; Land and Marine Use Patterns in the Manell/Geus Watershed

NOTE: *Your responses are important to us! Whatever information you provide will be kept strictly confidential and individual surveys will not be shared or shown to people not directly working on the project. All responses will be counted and added together in order to represent the viewpoint of the entire community. You must be 16 years of age or older to participate in this survey!*

SECTION 1 – Background Information ***(Please check only one answer for each question unless indicated otherwise.)***

1. Do you live in Merizo?
   ☐ yes ☐ no

   *If you checked "no", **please stop**. You are not eligible to take this survey unless you are a resident of Merizo.*

2. Which watershed do you live in? *Please refer to the map.*
   ☐ Manell ☐ Geus ☐ Other ☐ Don't know

3. How many years have you lived in Merizo?
   ☐ all your life
   ☐ 0-5 years
   ☐ 6-10 years
   ☐ 11-15 years
   ☐ 16-20 years
   ☐ 21-25 years
   ☐ 26-30 years
   ☐ 31-35 years
   ☐ 36-40 years
   ☐ 41-45 years
   ☐ 46-50 years
   ☐ more than 50 years

4. Do you own or rent your house or apartment?
   ☐ own ☐ rent ☐ other:

5. How old are you?
   ☐ 15-19 years
   ☐ 20-24 years
   ☐ 25-29 years
   ☐ 30-34 years
   ☐ 35-39 years
   ☐ 40-44 years
   ☐ 45-49 years
   ☐ 50-54 years
   ☐ 55-60 years
   ☐ 60-69 years
   ☐ 70-79 years
   ☐ 80-89 years
   ☐ 90 years and over

6. What is your gender?
   ☐ male ☐ female

7. What is your level of education?
   ☐ Did not complete high school
   ☐ High school diploma or GED
   ☐ Associate's degree
   ☐ Some college
   ☐ Bachelor's degree
   ☐ Some graduate school
   ☐ Graduate or professional degree
   ☐ Ph.D

8. Which best describes your ethnic background? *If you are a combination of ethnicities, please check the one box the you feel best represents you.*
   ☐ Chamorro
   ☐ Filipino
   ☐ Carolinian
   ☐ White/Caucasian
   ☐ Black/African American
   ☐ Chuukese
   ☐ Marshallese
   ☐ Kosraean
   ☐ Palauan
   ☐ Pohnpeian
   ☐ Yapese
   ☐ Japanese
   ☐ Chinese
   ☐ Korean
   ☐ Thai

   ☐ Other Pacific Islander: *(please specify)*
   ☐ Other Asian: *(please specify)*
   ☐ Other: *(please specify)*

9. What is/are the languages spoken at your house in Guam? *(Please check all that apply.)*
   ☐ English ☐ Chamorro ☐ Tagalog ☐ Other:

10. What is your religion?

- ☐ Catholic
- ☐ Buddhist
- ☐ Muslim
- ☐ SDA
- ☐ Methodist
- ☐ Lutheran
- ☐ Baptist
- ☐ Presbyterian
- ☐ Jewish
- ☐ Local/traditional
- ☐ None
- ☐ Decline to answer
- ☐ Other: *(please specify)*

11. What is your main employment? ***Please check only one****.*

- ☐ Work for wages (full-time) ***(Go to question 11a-11d)***
- ☐ Work for wages (part-time) ***(Go to question 11a-11d)***
- ☐ Student (full-time) ***(Go to question 11e.)***
- ☐ Student (part-time) ***(Go to question 11e.)***
- ☐ Retired
- ☐ Home-maker
- ☐ Unemployed-collect public assistance
- ☐ Unemployed-do not collect public assistance

(a) If you checked "work for wages" full-time or part-time, what best describes who you work for?

- ☐ self-employed *(if you check this box, please specify below)*
  - ☐ *Farmer*
  - ☐ *Fisherman*
  - ☐ *Hunter*
  - ☐ *Other:*
- ☐ private company or business
- ☐ Government of Guam
- ☐ U.S. Government (military)
- ☐ U.S. Government (non-military)
- ☐ Non-governmental organization
- ☐ Other:

(b) Where is your work? ***Please check only one.***

- ☐ Agana Heights
- ☐ Agat
- ☐ Asan-Maina
- ☐ Barrigada
- ☐ Chalan Pago-Ordot
- ☐ Dededo
- ☐ Hagatna
- ☐ Inarajan
- ☐ Mangilao
- ☐ Merizo
- ☐ Mongmong-Toto-Maite
- ☐ Piti
- ☐ Santa Rita
- ☐ Sinajana
- ☐ Talofofo
- ☐ Tamuning-Tumon
- ☐ Umatac
- ☐ Yigo
- ☐ Yona

(c) On average, how often do you commute in to work?

- ☐ More than five days a week
- ☐ Five days a week
- ☐ Four days a week
- ☐ Three days a week
- ☐ Two days a week
- ☐ One day a week
- ☐ Never

(d) What is your annual average income? ***(If you feel uncomfortable with this question, you don't have to answer it. Remember, answers are confidential and will be used to construct a socioeconomic profile of Merizo, which will give GCMP a better understanding of the community. But, again, you don't have to answer this question if you don't want to.****)*

- ☐ Less than $2,500
- ☐ $2,500 - $4,999
- ☐ $5,000 - $ 9,999
- ☐ $10,000 - $14,999
- ☐ $15,000 - $24,999
- ☐ $25,000 - $34,999
- ☐ $35,000 - $49,999
- ☐ $50,000 - $74,999
- ☐ $75,000 - $99,000
- ☐ $100,000 or more
- ☐ Prefer not answer

(e) If you checked "student", full-time or part-time, what school are you attending?

- ☐ University of Guam
- ☐ Guam Community College
- ☐ High School: *(please specify)*
- ☐ Other (e.g., homeschool, technical college, online university): *(please specify):*

Section II – Lifestyle

12. In Merizo, do you…

	All the time	Sometimes	Rarely	Never
Recycle				
Burn garbage				
Burn vegetation				
Throw vegetation in the jungle				
Smoke your trees				
Compost				
Take your garbage to Ordot dump				
Take your garbage the Mayor's dumpster				
Participate in curbside pickup of your garbage				
Hike or run				
Go coconut crabbing				
Off-roading				
Swim				
Barbeque				
Fish				
Hunt				
Farm				
Other: *Please specify all*				

13. Do you think solid waste fees are too high?
☐Yes ☐No

14. Do you smoke?
☐Yes ☐No

(a) If yes, in general, what do you do with the cigarette butts?
☐Put it into an ashtray
☐Put it into the garbage
☐Throw it on the ground
☐Other:

15. Do you think there are threats to the Manell/Geus watershed?
☐Yes ☐No

(a) If yes, do you think the following currently threaten the Manell/Geus watershed and the people that live in it? *(This continues on the next page.)*

	Strongly Agree	Agree	Don't Care	Disagree	Strongly disagree	Don't know
Disease (diabetes, cancer, gout)						
Pollution						
Development						
Wildland fires						
Off-roading						
Invasive species						
Lack of Awareness						
Lack of Rainfall						
Overfishing						

Question 15 continued from the previous page… If yes, do you think the following currently threaten the Manell/Geus watershed and the people that live in it?

	Strongly Agree	Agree	Don't Care	Disagree	Strongly disagree	Don't know
Land clearing						
Coastal erosion						
Climate change						
Overpopulation						
Military Buildup						
Poor infrastructure						
Flooding						

☐ Other:

16. What do you value the most in the Manell/Geus watershed? From the following list, please check the **TOP 5** things you would like to see happen in your watershed:

Having lots of fish	
Having many different kinds of fish	
Having native species (e.g., Kingfisher, Fahini) back in the forests	
Improving the roads	
Improving the schools	
Improving the waterlines	
Improving the sewer lines	
Stop the flooding of the roads	
Having healthy native forests	
Having healthy coral reefs	
Having clean water (rivers)	
Having clean water (oceans)	
Having clean water (tap)	
Reducing water outages	
Improving the local economy	
Having more parks	
Having a place to drop garbage	
Reducing garbage fees	
Having more boat ramps	
Amending the rules and regulations for Achang Marine Preserve	
Increasing the number of tourists that come to Merizo	
Having more development in Merizo	
Restricting development in Merizo	

☐ Other:

17. Do you drink tap water?

☐ All the time ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

(a) If you rarely, or never drink tap water, what is the reason? *Please check all that apply*

☐ tap water is dirty
☐ tap water is cloudy
☐ tap water has lots of bacteria
☐ it is not safe to drink tap water
☐ tap water tastes bad
☐ health reasons
☐ tap water has too much chlorine
☐ don't drink water
☐ tap water is salty
☐ other

18. Where do you get your tap water?

☐ Fena Reservoir
☐ Santa Rita Springs
☐ Northern Guam Lens
☐ Don't know
☐ Ugum Water Treatment Plant

19. How often do you have water outages?

☐ All the time ☐ Often ☐ Sometimes ☐ Rarely ☐ Never ☐ Don't know

20. On average, how long do the water outages last?

☐ One day ☐ A week ☐ A month
☐ A few days ☐ A couple of weeks ☐ Several months

21. When the water goes out, where do you get your water?

☐ Water-truck
☐ Mayor's Office
☐ Go to a relative or friend's house up in the North
☐ Go to a beach that has water (e.g., Talofofo, Ipan)
☐ Use water from rainwater catchment and boil the water

22. How often do you receive boil water notices?

☐ All the time ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

23. How much do you trust Government of Guam agencies?

	Most trustworthy	Very trustworthy	Somewhat trustworthy	A little trustworthy	Not trustworthy	Unsure/don't know
Guam Water Authority						
Guam Department of Public Works						
Guam Environmental Protection Agency						
Office of the Governor						
Merizo Mayor's Office						
Bureau of Statistics and Plans						
Guam Coastal Management Program						
University of Guam						
Marine Laboratory						
Water Energy Research Institute						
Department of Agriculture						
Division of Aquatics and Wildlife Resources						
Division of Forestry and Soils Resources						
Guam Power Authority						

Section III – Marine Environment- ***The Manell Watershed drains directly into the Achang Reef flat preserve and is considered part of the Manell Watershed. (Please refer to the map.) Below are some questions regarding this part of the Manell Watershed.***

24. How do you feel about having the Achang Reef Flat Marine Preserve in your village?

☐ Strongly support ☐ Support ☐ Don't Care
☐ Strongly oppose ☐ Oppose ☐ Don't Know

25. How do you identify the boundaries of the Achang Reef Flat Marine Preserve?

☐ Signs
☐ GPS
☐ Land-based markers (such as trees, buildings, houses)
☐ Range markers
☐ Buoys
☐ Friends or family have told you
☐ Other:

26. Do you think that the Achang Reef Flat Marine Preserve…

	Strongly Agree	Agree	Don't Care	Disagree	Strongly disagree	Don't Know
Harms the local economy						
Protects habitats such as coral reefs						
Increases the number of fish and other animals inside the preserve						
Increases the number of fish and other animals outside the preserve						
Is well-enforced						
Is a waste of government resources						
Protects cultural resources						
Educates students and the public						
Provides recreational opportunities such as diving, snorkeling (activities other than fishing)						
Helps increase tourism						
Provides no benefits at all						
Has fair and just rules and regulations.						
Is clearly marked						

27. In **general**, how often do you go to the Achang Reef Flat Marine Preserve? ***Please check only one box in section (a) and one box in section (b).***

(a) ☐ Every day (Monday – Sunday)
☐ Once a week (Monday – Friday)
☐ Twice a week (Monday – Friday)
☐ Three times a week (Monday-Friday)
☐ Four times a week (Monday-Friday)
☐ Five times a week (Monday-Friday)
☐ Every day

(b) ☐ Only on the weekends
☐ Only on the holidays
☐ Only on special occasions

28. What activities you like to do within the Achang Reef Flat Marine Preserve? *(Check all that apply.)*

☐ Dive
☐ Snorkel
☐ Swim
☐ Fish
☐ Collect seashells
☐ Collect *balåte* (sea-cucumbers)
☐ Other:

29. What government agency is in charge of the Achang Reef Flat Marine Preserve? *(Check one or all that you think apply.)*

☐ Guam Environmental Protection Agency
☐ Office of the Governor
☐ U.S. Fish and Wildlife
☐ National Oceanic Atmospheric Administration
☐ Bureau of Statistics and Plans Guam Coastal Management Program
☐ Department of Agriculture Division of Aquatics and Wildlife Resources
☐ Guam Visitors' Bureau
☐ Guam Police Department
☐ Other:

30. Have you ever witnessed a violation in the Achang Reef Flat Marine Preserve?
☐Yes ☐No ☐Not sure

(a) If you checked "yes" to Question 30 did you report the violation?
☐Yes ☐No

(b) If you checked "no" to Question 30a, why did you not report the violation?
☐The person committing the violation was your friend or relative.
☐You did not know who to report the violation to.
☐You did not know what number to call.
☐Too tired.
☐Too busy.
☐You forgot.
☐No telephone.
☐It didn't seem that big a deal.
☐Other:

31. How often do you visit the beach? ***Please check only one box for section (a) and one box for section (b).***

(a)
☐Every day (Mon – Sun)
☐Once a week (Mon -Fri)
☐Twice a week (Mon -Fri)
☐Three times a week (Mon-Fri)
☐Four times a week (Mon-Fri)
☐Five times a week (Mon-Fri)

(b)
☐On the weekends
☐On special occasions

32. Do you fish?
☐Yes ☐No

(a) If yes, do you fish in
☐saltwater ☐freshwater ☐both

(b) If yes, what kinds of fish do you usually catch? *Please list all:*

33. Check all the activities you like to do at the beach.
☐Barbeque
☐Swimming
☐Reef walking
☐Collecting seashells
☐Walking
☐Surfing/bodyboarding
☐Kiteboarding
☐Kayaking
☐Spearfishing
☐SCUBA spearfishing
☐Hook and line fishing
☐Fishing with a net
☐Bird watching
☐Hanging out with friends and family
☐Drinking (alcohol)
☐Other:

34. When it is time to leave the beach, what do you do with your garbage?
☐Bag it up and leave there.
☐Bag it up and put it in the garbage cans or dumpster.
☐Bag it up and take it with you, to throw away later.
☐Separate the garbage and recycle all the materials that can be recycled.
☐Throw it in the water.
☐Other:

35. How often are there beach closures in Merizo?
☐All the time ☐Often ☐Sometimes ☐Rarely ☐Never ☐Don't know

36. What beach or beaches do you visit the most? Please use the following map and **circle** the all the ones you have visited the last year and please **star** the one you go to the most often.



Section IV: Terrestrial

37. Prior to this survey, have you ever heard the term "watershed"?
☐Yes ☐No ☐Don't know

38. If you were asked to define a watershed, would you be able to?
☐Yes ☐No ☐Don't know

39. Are you familiar with the term "Ridge to Reef"?
☐Yes ☐No ☐Don't know

40. Do you live near a river?
☐Yes ☐No ☐Don't know

41. Do you hunt?
☐Yes ☐No

(a) If you answered "yes" to the last question, do you hunt in Merizo?
☐Yes ☐No

(b) What kind of animals do you hunt? Please check all that apply.
☐deer ☐birds ☐turtles
☐wild boar ☐bats ☐does not apply
☐goats ☐coconut crabs ☐other:

42. Do you farm?
☐Yes ☐No

(a) If yes, what crops do you grow? Please list all:

43. In the last year, have you participated in any watershed restoration projects?
☐Yes ☐No

(a) If yes, what activities did you participate in?
☐tree planting ☐implemented watershed practices at home
☐water monitoring ☐don't know/unsure
☐beach clean-ups ☐other:
☐village clean-ups

44. Would you be interested in participating in watershed restoration projects for Merizo?
☐Yes ☐No

(a) If yes, what activities would you participate in?
☐tree planting
☐water monitoring
☐beach clean-ups
☐village clean-ups
☐implemented watershed practices at home
☐hunting clinic demonstrating ways to hunt without setting fires
☐don't know/unsure
☐other:

45. Do you agree with the following statements? In Merizo…

	Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree	Don't know
the forests are filled with native vegetation.						
native animals are abundant.						
there is erosion.						
the rivers are super clean.						
there are many wildland fires.						
it floods often.						
there should be more forest clearing.						
there are more non-native animals (e.g., deer, pig) than native animals (e.g., fanihi, kingfisher, Koko).						

46. What is your favorite thing about living in Merizo?

- ☐ Family
- ☐ Beautiful environment
- ☐ Close to the sea
- ☐ Cocos Island
- ☐ Jungles
- ☐ Rivers
- ☐ Animals
- ☐ School
- ☐ Other:
- ☐ Don't like anything about Merizo

47. What is the most frustrating thing about living in Merizo?

48. What is the number one thing you would like to see changed in Merizo?

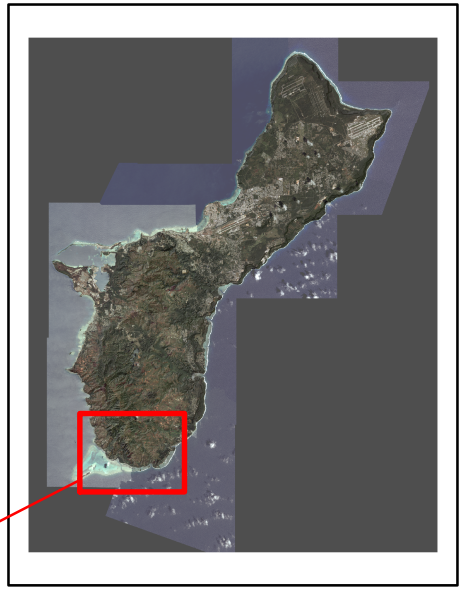
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Thank you for completing the survey! This will be of great help to us! Please hand your completed to survey to one of our volunteers in order to receive your free gift (t-shirt, water bottle, or bag), while supplies last.

Remember, all answers are strictly confidential! Once all the surveys are counted and analyzed, the results from the survey will be available at the Merizo's mayor office by September. Please feel free to contact Romina King at 929-6714 or the Bureau of Statistics and Plans at 472-4201.

Manell-Geus Watershed Map





Legend

- Rivers and streams
- Municipal boundaries
- Watershed boundaries
- Marine Preserve boundaries

Map was created by Romina King on 19 July 2010 for the Bureau of Statistics and Plans - Guam Coastal Mgt. Program.
The map may not be used for litigation and is for planning purposes only!

2006 Quickbird imagery is copyrighted by Digital Globe. All other datasets were used with permission from the BSP GCMP.

Appendix 2 – Household Survey Codebook

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Codebook

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[DataSet1] C:\Users\109119094\Dropbox\DISSERTATION\UCCMain2013_King_CLEAN.sav

ID

		Value
Standard Attributes	Position	1
	Label	<none>
	Type	Numeric
	Format	F11
	Measurement	Scale
	Role	Input
N	Valid	350
	Missing	0
Central Tendency and Dispersion	Mean	175.50
	Standard Deviation	101.181
	Percentile 25	88.00
	Percentile 50	175.50
	Percentile 75	263.00

V2

		Value	Count	Percent
Standard Attributes	Position	2		
	Label	Watershed		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Manell	90	25.7%
	2	Geus	112	32.0%
	3	Other	47	13.4%
	4	Do not know	79	22.6%
Missing Values	99		22	6.3%

V3

		Value	Count	Percent
Standard Attributes	Position	3		
	Label	Duration of Residency		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Entire existence	126	36.0%
	2	0-5 years	14	4.0%
	3	6-10 years	18	5.1%
	4	11-15 years	19	5.4%
	5	16-20 years	42	12.0%
	6	21-25 years	16	4.6%
	7	26-30 years	20	5.7%
	8	31-35 years	24	6.9%
	9	36-40 years	18	5.1%
	10	41-45 years	6	1.7%
	11	46-50 years	9	2.6%
	12	more than 50 years	32	9.1%
Missing Values	98		1	0.3%
	99		5	1.4%

V4

		Value	Count	Percent
Standard Attributes	Position	4		
	Label	Home Ownership		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	own	122	34.9%
	2	rent	61	17.4%
	3	other	125	35.7%
Missing Values	99		42	12.0%

V5

		Value	Count	Percent
Standard Attributes	Position	5		
	Label	Age		
	Type	Numeric		
	Format	F11		
	Measurement	Scale		
	Role	Input		
N	Valid	344		
	Missing	6		
Central Tendency and Dispersion	Mean	4.63		
	Standard Deviation	3.194		
	Percentile 25	1.00		
	Percentile 50	5.00		
	Percentile 75	7.00		
Labeled Values	1	15-19	87	24.9%
	2	20-24	39	11.1%
	3	25-29	20	5.7%
	4	30-34	25	7.1%
	5	35-39	46	13.1%
	6	40-44	33	9.4%
	7	45-49	21	6.0%
	8	50-54	21	6.0%
	9	55-59	14	4.0%
	10	60-69	22	6.3%
	11	70-79	14	4.0%
	12	80-89	1	0.3%
	13	90 years or more	1	0.3%

V6

		Value	Count	Percent
Standard Attributes	Position	6		
	Label	Gender		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	male	169	48.3%
	2	female	174	49.7%
Missing Values	99		7	2.0%

V7

		Value	Count	Percent
Standard Attributes	Position	7		
	Label	Highest level of education attained		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	did not complete high school	134	38.3%
	2	high school diploma or GED	167	47.7%
	3	associate's degree	8	2.3%
	4	some college	21	6.0%
	5	Bachelor's degree	6	1.7%
	6	some graduate school	1	0.3%
	7	graduate or professional degree	5	1.4%
	8	doctorate of philosophy	0	0.0%
Missing Values	99		8	2.3%

V8

		Value	Count	Percent
Standard Attributes	Position	8		
	Label	Ethnicity		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Chamorro	316	90.3%
	2	Filipino	2	0.6%
	3	Carolinian	0	0.0%
	4	Caucasian/white	2	0.6%
	5	African American/black	0	0.0%
	6	Chuukese	1	0.3%
	7	Marshallese	1	0.3%
	8	Kosraean	0	0.0%
	9	Palauan	2	0.6%
	10	Pohnpeian	1	0.3%
	11	Yapese	0	0.0%
	12	Japanese	0	0.0%
	13	Chinese	2	0.6%
	14	Korean	0	0.0%
	15	Thai	0	0.0%
	16	Other Pacific Islander	0	0.0%
	17	Other Asian	0	0.0%
	18	Other	0	0.0%
Missing Values	98		19	5.4%
	99		4	1.1%

@9a

		Value	Count	Percent
Standard Attributes	Position	9		
	Label	Can speak English		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	14	4.0%
	1	yes	333	95.1%
Missing Values	99		3	0.9%

@9b

		Value	Count	Percent
Standard Attributes	Position	10		
	Label	Can speak Chamorro		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	107	30.6%
	1	yes	240	68.6%
Missing Values	99		3	0.9%

@9c

		Value	Count	Percent
Standard Attributes	Position	11		
	Label	Can speak Tagalog		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	341	97.4%
	1	yes	6	1.7%
Missing Values	99		3	0.9%

@9d

		Value	Count	Percent
Standard Attributes	Position	12		
	Label	Can speak a language other than English, Chamorro, or Tagalog		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	345	98.6%
	1	yes	2	0.6%
Missing Values	99		3	0.9%

V10

		Value	Count	Percent
Standard Attributes	Position	13		
	Label	Religion		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Catholic	333	95.1%
	2	Buddhist	1	0.3%
	3	Muslim	0	0.0%
	4	Seventh Day Adventist	1	0.3%
	5	Methodist	0	0.0%
	6	Lutheran	1	0.3%
	7	Baptist	4	1.1%
	8	Presbyterian	0	0.0%
	9	Jewish	0	0.0%
	10	local/traditional	1	0.3%
	11	none	0	0.0%
	12	decline to answer	4	1.1%
	13	other	3	0.9%
Missing Values	99		2	0.6%

V11

		Value	Count	Percent
Standard Attributes	Position	14		
	Label	Employment		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Work for wages (full-time)	108	30.9%
	2	Work for wages (part-time)	22	6.3%
	3	Student (full-time)	58	16.6%
	4	Student (part-time)	6	1.7%
	5	Retired	39	11.1%
	6	Home-maker	28	8.0%
	7	Unemployed (collect public assistance)	49	14.0%
	8	Unemployed (do not collect public assistance)	30	8.6%
Missing Values	98		1	0.3%
	99		9	2.6%

@11a

		Value	Count	Percent
Standard Attributes	Position	15		
	Label	Nature of employment		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	self-employed (unspecified)	4	1.1%
	2	farmer	0	0.0%
	3	fisherman	2	0.6%
	4	hunter	0	0.0%
	5	other	10	2.9%
	6	private company or business	60	17.1%
	7	Government of Guam	30	8.6%
	8	U.S. government (military)	3	0.9%
	9	U.S. Government (non-military)	6	1.7%
	10	non-governmental organization	5	1.4%
	11	other	3	0.9%
Missing Values	97		207	59.1%
	98		4	1.1%
	99		16	4.6%

@11b

		Value	Count	Percent
Standard Attributes	Position	16		
	Label	Location of employment		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Agana Heights	4	1.1%
	2	Agat	5	1.4%
	3	Asan-Maina	1	0.3%
	4	Barrigada	5	1.4%
	5	Chalan Pago-Ordot	0	0.0%
	6	Dededo	0	0.0%
	7	Hagatna	13	3.7%
	8	Inarajan	5	1.4%
	9	Mangilao	3	0.9%
	10	Merizo	45	12.9%
	11	Mongmong-Toto-Maite	3	0.9%
	12	Piti	15	4.3%
	13	Santa Rita	10	2.9%
	14	Sinajana	0	0.0%
	15	Talofofo	1	0.3%
	16	Tamuning-Tumon	14	4.0%
	17	Umatac	0	0.0%
	18	Yigo	1	0.3%
	19	Yona	0	0.0%
Missing Values	97		207	59.1%
	98		1	0.3%
	99		17	4.9%

@11c

		Value	Count	Percent
Standard Attributes	Position	17		
	Label	Frequency of commute to work		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	More than five days a week	43	12.3%
	2	Five days a week	66	18.9%
	3	Four days a week	5	1.4%
	4	Three days a week	4	1.1%
	5	Two days a week	2	0.6%
	6	One day a week	1	0.3%
	7	Never	1	0.3%
Missing Values	97		207	59.1%
	99		21	6.0%

@11d

		Value	Count	Percent
Standard Attributes	Position	18		
	Label	Average annual income		
	Type	Numeric		
	Format	F11		
	Measurement	Scale		
	Role	Input		
N	Valid	89		
	Missing	261		
Central Tendency and Dispersion	Mean	6.38		
	Standard Deviation	2.937		
	Percentile 25	4.00		
	Percentile 50	6.00		
	Percentile 75	8.00		
Labeled Values	1	Less than $2,500	6	1.7%
	2	$2,500-$4,999	2	0.6%
	3	$5,000-$9,999	5	1.4%
	4	$10,000-$14,999	10	2.9%
	5	$15,000-$24,999	11	3.1%
	6	$25,000-$34,999	16	4.6%
	7	$35,000-$49,999	15	4.3%
	8	$50,000-$74,999	5	1.4%
	9	$75,000-$99,999	1	0.3%
	10	$100,000 or more	0	0.0%
	11	Prefer not to answer	18	5.1%

@11e

		Value	Count	Percent
Standard Attributes	Position	19		
	Label	School currently attending		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	University of Guam	5	1.4%
	2	Other	4	1.1%
	3	High school	41	11.7%
	4	Other	2	0.6%
	9		1	0.3%
Missing Values	97		274	78.3%
	98		1	0.3%
	99		22	6.3%

@12a

		Value	Count	Percent
Standard Attributes	Position	20		
	Label	Recycle		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	33	9.4%
	1	Rarely	53	15.1%
	2	Sometimes	163	46.6%
	3	All the time	56	16.0%
Missing Values	98		3	0.9%
	99		42	12.0%

@12b

		Value	Count	Percent
Standard Attributes	Position	21		
	Label	Burn garbage		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	78	22.3%
	1	Rarely	67	19.1%
	2	Sometimes	122	34.9%
	3	All the time	47	13.4%
Missing Values	98		1	0.3%
	99		35	10.0%

@12c

		Value	Count	Percent
Standard Attributes	Position	22		
	Label	Burn vegetation		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	171	48.9%
	1	Rarely	60	17.1%
	2	Sometimes	42	12.0%
	3	Never	27	7.7%
Missing Values	98		3	0.9%
	99		47	13.4%

@12d

		Value	Count	Percent
Standard Attributes	Position	23		
	Label	Throw vegetation in the jungle		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	136	38.9%
	1	Rarely	58	16.6%
	2	Sometimes	69	19.7%
	3	All the time	31	8.9%
Missing Values	98		3	0.9%
	99		53	15.1%

@12e

		Value	Count	Percent
Standard Attributes	Position	24		
	Label	Smoke trees		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	127	36.3%
	1	Rarely	46	13.1%
	2	Sometimes	77	22.0%
	3	All the time	56	16.0%
Missing Values	98		1	0.3%
	99		43	12.3%

@12f

		Value	Count	Percent
Standard Attributes	Position	25		
	Label	Compost		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	169	48.3%
	1	Rarely	54	15.4%
	2	Sometimes	45	12.9%
	3	All the time	24	6.9%
Missing Values	98		1	0.3%
	99		57	16.3%

@12g

		Value	Count	Percent
Standard Attributes	Position	26		
	Label	Take garbage to Ordot dump		
	Type	Numeric		
	Format	F1		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	207	59.1%
	1	Rarely	47	13.4%
	2	Sometimes	25	7.1%
	3	All the time	14	4.0%
Missing Values	99		56	16.0%
	System		1	0.3%

@12h

		Value	Count	Percent
Standard Attributes	Position	27		
	Label	Take garbage to Mayor's dumpster		
	Type	Numeric		
	Format	F1		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	219	62.6%
	1	Rarely	61	17.4%
	2	Sometimes	19	5.4%
	3	All the time	8	2.3%
Missing Values	99		42	12.0%
	System		1	0.3%

@12i

		Value	Count	Percent
Standard Attributes	Position	28		
	Label	Participate in curbside pickup of garbage		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	113	32.3%
	1	Rarely	55	15.7%
	2	Sometimes	50	14.3%
	3	All the time	87	24.9%
Missing Values	98		2	0.6%
	99		43	12.3%

@12j

		Value	Count	Percent
Standard Attributes	Position	29		
	Label	Hike or run		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	82	23.4%
	1	Rarely	67	19.1%
	2	Sometimes	117	33.4%
	3	All the time	34	9.7%
Missing Values	98		2	0.6%
	99		48	13.7%

@12k

		Value	Count	Percent
Standard Attributes	Position	30		
	Label	Go coconut crabbing		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	198	56.6%
	1	Rarely	54	15.4%
	2	Sometimes	40	11.4%
	3	All the time	9	2.6%
Missing Values	98		2	0.6%
	99		47	13.4%

@12l

		Value	Count	Percent
Standard Attributes	Position	31		
	Label	Off-road		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	204	58.3%
	1	Rarely	43	12.3%
	2	Sometimes	35	10.0%
	3	All the time	10	2.9%
Missing Values	98		3	0.9%
	99		54	15.4%
	System		1	0.3%

@12m

		Value	Count	Percent
Standard Attributes	Position	32		
	Label	Swim		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	46	13.1%
	1	Rarely	40	11.4%
	2	Sometimes	142	40.6%
	3	All the time	81	23.1%
Missing Values	98		3	0.9%
	99		38	10.9%

@12n

		Value	Count	Percent
Standard Attributes	Position	33		
	Label	Barbeque		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	20	5.7%
	1	Rarely	28	8.0%
	2	Sometimes	154	44.0%
	3	All the time	111	31.7%
Missing Values	97		1	0.3%
	98		1	0.3%
	99		35	10.0%

@12o

		Value	Count	Percent
Standard Attributes	Position	34		
	Label	Fish		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	102	29.1%
	1	Rarely	66	18.9%
	2	Sometimes	103	29.4%
	3	All the time	35	10.0%
Missing Values	98		1	0.3%
	99		43	12.3%

@12p

		Value	Count	Percent
Standard Attributes	Position	35		
	Label	Hunt		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	203	58.0%
	1	Rarely	47	13.4%
	2	Sometimes	30	8.6%
	3	All the time	16	4.6%
Missing Values	98		1	0.3%
	99		53	15.1%

@12q

		Value	Count	Percent
Standard Attributes	Position	36		
	Label	Farm		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	157	44.9%
	1	Rarely	64	18.3%
	2	Sometimes	47	13.4%
	3	All the time	35	10.0%
Missing Values	98		2	0.6%
	99		45	12.9%

@12r

		Value	Count	Percent
Standard Attributes	Position	37		
	Label	Other		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	53	15.1%
	1	Rarely	16	4.6%
	2	Sometimes	8	2.3%
	3	All the time	6	1.7%
Missing Values	98		2	0.6%
	99		265	75.7%

V13

		Value	Count	Percent
Standard Attributes	Position	38		
	Label	Are solid waste fees too high?		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Yes	246	70.3%
	2	No	93	26.6%
Missing Values	99		11	3.1%

V15

		Value	Count	Percent
Standard Attributes	Position	39		
	Label	Do you perceive any threats to the Manell/Geus watershed		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Yes	203	58.0%
	2	No	133	38.0%
Missing Values	99		14	4.0%

@15a

		Value	Count	Percent
Standard Attributes	Position	40		
	Label	Disease		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	41	11.7%
	1	Strongly disagree	9	2.6%
	2	Disagree	13	3.7%
	3	Do not care	3	0.9%
	4	Agree	49	14.0%
	5	Strongly agree	57	16.3%
Missing Values	97		133	38.0%
	98		2	0.6%
	99		43	12.3%

@15b

		Value	Count	Percent
Standard Attributes	Position	41		
	Label	Pollution		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	17	4.9%
	1	Strongly disagree	4	1.1%
	2	Disagree	3	0.9%
	3	Do not care	4	1.1%
	4	Agree	57	16.3%
	5	Strongly agree	99	28.3%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		31	8.9%

@15c

		Value	Count	Percent
Standard Attributes	Position	42		
	Label	Development		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	31	8.9%
	1	Strongly disagree	4	1.1%
	2	Disagree	7	2.0%
	3	Do not care	7	2.0%
	4	Agree	54	15.4%
	5	Strongly agree	67	19.1%
Missing Values	97		134	38.3%
	98		3	0.9%
	99		43	12.3%

@15d

		Value	Count	Percent
Standard Attributes	Position	43		
	Label	Wildland fires		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	30	8.6%
	1	Strongly disagree	5	1.4%
	2	Disagree	13	3.7%
	3	Do not care	5	1.4%
	4	Agree	60	17.1%
	5	Strongly agree	62	17.7%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		40	11.4%

@15e

		Value	Count	Percent
Standard Attributes	Position	44		
	Label	Off-roading		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	38	10.9%
	1	Strongly disagree	6	1.7%
	2	Disagree	15	4.3%
	3	Do not care	11	3.1%
	4	Agree	58	16.6%
	5	Strongly agree	43	12.3%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		44	12.6%

@15f

		Value	Count	Percent
Standard Attributes	Position	45		
	Label	Invasive species		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	42	12.0%
	1	Strongly disagree	4	1.1%
	2	Disagree	11	3.1%
	3	Do not care	7	2.0%
	4	Agree	61	17.4%
	5	Strongly agree	48	13.7%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		42	12.0%

@15g

		Value	Count	Percent
Standard Attributes	Position	46		
	Label	Lack of awareness		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	33	9.4%
	1	Strongly disagree	4	1.1%
	2	Disagree	15	4.3%
	3	Do not care	4	1.1%
	4	Agree	57	16.3%
	5	Strongly agree	61	17.4%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		41	11.7%

@15h

		Value	Count	Percent
Standard Attributes	Position	47		
	Label	Lack of rainfall		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	38	10.9%
	1	Strongly disagree	8	2.3%
	2	Disagree	39	11.1%
	3	Do not care	6	1.7%
	4	Agree	39	11.1%
	5	Strongly agree	40	11.4%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		45	12.9%

@15i

		Value	Count	Percent
Standard Attributes	Position	48		
	Label	Overfishing		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	49	14.0%
	1	Strongly disagree	14	4.0%
	2	Disagree	25	7.1%
	3	Do not care	9	2.6%
	4	Agree	39	11.1%
	5	Strongly agree	33	9.4%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		46	13.1%

@15j

		Value	Count	Percent
Standard Attributes	Position	49		
	Label	Land clearing		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	35	10.0%
	1	Strongly disagree	4	1.1%
	2	Disagree	8	2.3%
	3	Do not care	4	1.1%
	4	Agree	56	16.0%
	5	Strongly agree	81	23.1%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		27	7.7%

@15k

		Value	Count	Percent
Standard Attributes	Position	50		
	Label	Coastal erosion		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	31	8.9%
	1	Strongly disagree	2	0.6%
	2	Disagree	3	0.9%
	3	Do not care	2	0.6%
	4	Agree	51	14.6%
	5	Strongly agree	100	28.6%
Missing Values	97		134	38.3%
	98		2	0.6%
	99		25	7.1%

@15l

		Value	Count	Percent
Standard Attributes	Position	51		
	Label	Climate change		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	47	13.4%
	1	Strongly disagree	8	2.3%
	2	Disagree	12	3.4%
	3	Do not care	6	1.7%
	4	Agree	55	15.7%
	5	Strongly agree	55	15.7%
Missing Values	97		134	38.3%
	98		2	0.6%
	99		31	8.9%

@15m

		Value	Count	Percent
Standard Attributes	Position	52		
	Label	Overpopulation		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	41	11.7%
	1	Strongly disagree	10	2.9%
	2	Disagree	22	6.3%
	3	Do not care	7	2.0%
	4	Agree	54	15.4%
	5	Strongly agree	51	14.6%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		30	8.6%

@15n

		Value	Count	Percent
Standard Attributes	Position	53		
	Label	Military build-up		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	47	13.4%
	1	Strongly disagree	9	2.6%
	2	Disagree	15	4.3%
	3	Do not care	7	2.0%
	4	Agree	46	13.1%
	5	Strongly agree	57	16.3%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		34	9.7%

@15o

		Value	Count	Percent
Standard Attributes	Position	54		
	Label	Poor infrastructure		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	37	10.6%
	1	Strongly disagree	4	1.1%
	2	Disagree	6	1.7%
	3	Do not care	4	1.1%
	4	Agree	56	16.0%
	5	Strongly agree	82	23.4%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		26	7.4%

@15p

		Value	Count	Percent
Standard Attributes	Position	55		
	Label	Flooding		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	27	7.7%
	1	Strongly disagree	4	1.1%
	2	Disagree	0	0.0%
	3	Do not care	2	0.6%
	4	Agree	45	12.9%
	5	Strongly agree	116	33.1%
Missing Values	97		134	38.3%
	98		1	0.3%
	99		21	6.0%

@15q

		Value	Count	Percent
Standard Attributes	Position	56		
	Label	Other		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	8	2.3%
	1	Strongly disagree	0	0.0%
	2	Disagree	0	0.0%
	3	Do not care	0	0.0%
	4	Agree	5	1.4%
	5	Strongly agree	18	5.1%
Missing Values	97		139	39.7%
	98		1	0.3%
	99		179	51.1%

@16a

		Value	Count	Percent
Standard Attributes	Position	57		
	Label	Having lots of fish		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	199	56.9%
	1	Yes	88	25.1%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16b

		Value	Count	Percent
Standard Attributes	Position	58		
	Label	Having many kinds of fish		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	224	64.0%
	1	Yes	63	18.0%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16c

		Value	Count	Percent
Standard Attributes	Position	59		
	Label	Repopulating native species		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	244	69.7%
	1	Yes	43	12.3%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16d

		Value	Count	Percent
Standard Attributes	Position	60		
	Label	Improving the roads		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	113	32.3%
	1	Yes	174	49.7%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16e

		Value	Count	Percent
Standard Attributes	Position	61		
	Label	Improving the schools		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	180	51.4%
	1	Yes	107	30.6%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16f

		Value	Count	Percent
Standard Attributes	Position	62		
	Label	Improving the waterlines		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	170	48.6%
	1	Yes	117	33.4%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16g

		Value	Count	Percent
Standard Attributes	Position	63		
	Label	Improving the sewer lines		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	241	68.9%
	1	Yes	46	13.1%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16h

		Value	Count	Percent
Standard Attributes	Position	64		
	Label	Stop the flooding of the roads		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	103	29.4%
	1	Yes	184	52.6%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16i

		Value	Count	Percent
Standard Attributes	Position	65		
	Label	Having healthy native forests		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	261	74.6%
	1	Yes	26	7.4%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16j

		Value	Count	Percent
Standard Attributes	Position	66		
	Label	Having healthy coral reefs		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	227	64.9%
	1	Yes	60	17.1%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16k

		Value	Count	Percent
Standard Attributes	Position	67		
	Label	Having clean water (rivers)		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	197	56.3%
	1	Yes	90	25.7%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16l

		Value	Count	Percent
Standard Attributes	Position	68		
	Label	Having clean water (oceans)		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	217	62.0%
	1	Yes	70	20.0%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16m

		Value	Count	Percent
Standard Attributes	Position	69		
	Label	Having clean water (tap)		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	199	56.9%
	1	Yes	88	25.1%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16n

		Value	Count	Percent
Standard Attributes	Position	70		
	Label	Reducing water outages		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	223	63.7%
	1	Yes	64	18.3%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16o

		Value	Count	Percent
Standard Attributes	Position	71		
	Label	Improving the local economy		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	247	70.6%
	1	Yes	40	11.4%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16p

		Value	Count	Percent
Standard Attributes	Position	72		
	Label	Having more parks		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	267	76.3%
	1	Yes	20	5.7%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16q

		Value	Count	Percent
Standard Attributes	Position	73		
	Label	Having a place to deposit garbage		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	276	78.9%
	1	Yes	11	3.1%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16r

		Value	Count	Percent
Standard Attributes	Position	74		
	Label	Reducing garbage fees		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	265	75.7%
	1	Yes	22	6.3%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16s

		Value	Count	Percent
Standard Attributes	Position	75		
	Label	Having more boat ramps		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	282	80.6%
	1	Yes	5	1.4%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16t

		Value	Count	Percent
Standard Attributes	Position	76		
	Label	Amending the rules and regulations for Achang Marine Preserve		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	266	76.0%
	1	Yes	21	6.0%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16u

		Value	Count	Percent
Standard Attributes	Position	77		
	Label	Increasing the number of tourists who come to Merizo		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	268	76.6%
	1	Yes	19	5.4%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16v

		Value	Count	Percent
Standard Attributes	Position	78		
	Label	Having more development in Merizo		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	263	75.1%
	1	Yes	24	6.9%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16w

		Value	Count	Percent
Standard Attributes	Position	79		
	Label	Restricting development in Merizo		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	259	74.0%
	1	Yes	28	8.0%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		32	9.1%

@16x

		Value	Count	Percent
Standard Attributes	Position	80		
	Label	Other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	No	279	79.7%
	1	Yes	0	0.0%
Missing Values	97		1	0.3%
	98		30	8.6%
	99		40	11.4%

V17

		Value	Count	Percent
Standard Attributes	Position	81		
	Label	Frequency of tap water consumption		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	52	14.9%
	1	Rarely	57	16.3%
	2	Sometimes	86	24.6%
	3	Often	45	12.9%
	4	All the time	101	28.9%
Missing Values	99		9	2.6%

@17a

		Value	Count	Percent
Standard Attributes	Position	82		
	Label	Tap water is dirty		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	71	20.3%
	1	yes	21	6.0%
Missing Values	97		240	68.6%
	99		18	5.1%

@17b

		Value	Count	Percent
Standard Attributes	Position	83		
	Label	Tap water has bacteria		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	77	22.0%
	1	yes	15	4.3%
Missing Values	97		240	68.6%
	99		18	5.1%

@17c

		Value	Count	Percent
Standard Attributes	Position	84		
	Label	Tap water tastes bad		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	71	20.3%
	1	yes	21	6.0%
Missing Values	97		240	68.6%
	99		18	5.1%

@17d

		Value	Count	Percent
Standard Attributes	Position	85		
	Label	Tap water has too much chlorine		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	63	18.0%
	1	yes	29	8.3%
Missing Values	97		240	68.6%
	99		18	5.1%

@17e

		Value	Count	Percent
Standard Attributes	Position	86		
	Label	Tap water is salty		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	88	25.1%
	1	yes	4	1.1%
Missing Values	97		240	68.6%
	99		18	5.1%

@17f

		Value	Count	Percent
Standard Attributes	Position	87		
	Label	Tap water is cloudy		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	67	19.1%
	1	yes	25	7.1%
Missing Values	97		240	68.6%
	99		18	5.1%

@17g

		Value	Count	Percent
Standard Attributes	Position	88		
	Label	Tap water is is not safe to drink		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	80	22.9%
	1	yes	12	3.4%
Missing Values	97		240	68.6%
	99		18	5.1%

@17h

		Value	Count	Percent
Standard Attributes	Position	89		
	Label	Health reasons		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	73	20.9%
	1	yes	19	5.4%
Missing Values	97		240	68.6%
	99		18	5.1%

@17i

		Value	Count	Percent
Standard Attributes	Position	90		
	Label	Do not drink tap water		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	75	21.4%
	1	yes	17	4.9%
Missing Values	97		240	68.6%
	99		18	5.1%

@17j

		Value	Count	Percent
Standard Attributes	Position	91		
	Label	Other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	69	19.7%
	1	yes	22	6.3%
Missing Values	97		241	68.9%
	99		18	5.1%

V18

		Value	Count	Percent
Standard Attributes	Position	92		
	Label	Awareness of origin of tap water		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	Fena Reservoir	8	2.3%
	2	Northern Guam Lens	0	0.0%
	3	Ugum Water Treatment Plant	253	72.3%
	4	Santa Rita Springs	2	0.6%
	5	Do not know	71	20.3%
Missing Values	99		16	4.6%

V19

		Value	Count	Percent
Standard Attributes	Position	93		
	Label	Perception of water outage frequency		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	15	4.3%
	1	Never	9	2.6%
	2	Rarely	167	47.7%
	3	Sometimes	106	30.3%
	4	Often	43	12.3%
	5	All the time	4	1.1%
Missing Values	98		1	0.3%
	99		5	1.4%

V20

		Value	Count	Percent
Standard Attributes	Position	94		
	Label	Perception of average water outage duration		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	One day	214	61.1%
	2	A few days	107	30.6%
	3	One week	2	0.6%
	4	Several weeks	3	0.9%
	5	One month	0	0.0%
	6	Several months	2	0.6%
Missing Values	98		3	0.9%
	99		19	5.4%

@21a

		Value	Count	Percent
Standard Attributes	Position	95		
	Label	Water truck		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	196	56.0%
	1	yes	126	36.0%
Missing Values	99		28	8.0%

@21b

		Value	Count	Percent
Standard Attributes	Position	96		
	Label	Office of the Merizo mayor		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	181	51.7%
	1	yes	141	40.3%
Missing Values	99		28	8.0%

@21c

		Value	Count	Percent
Standard Attributes	Position	97		
	Label	Residence of a friend or relative in the North		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	218	62.3%
	1	yes	104	29.7%
Missing Values	99		28	8.0%

@21d

		Value	Count	Percent
Standard Attributes	Position	98		
	Label	Beach with a public tap or shower		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	289	82.6%
	1	yes	33	9.4%
Missing Values	99		28	8.0%

@21e

		Value	Count	Percent
Standard Attributes	Position	99		
	Label	Personal rainwater catchment		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	266	76.0%
	1	yes	56	16.0%
Missing Values	99		28	8.0%

V22

		Value	Count	Percent
Standard Attributes	Position	100		
	Label	Perception of frequency of boil water notices		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Never	78	22.3%
	1	Rarely	163	46.6%
	2	Sometimes	60	17.1%
	3	Often	13	3.7%
	4	All the time	4	1.1%
Missing Values	98		3	0.9%
	99		29	8.3%

@23a

		Value	Count	Percent
Standard Attributes	Position	101		
	Label	Guam Water Authority		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	43	12.3%
	1	Not trustworthy	31	8.9%
	2	A little trustworthy	56	16.0%
	3	Somewhat trustworthy	118	33.7%
	4	Very trustworthy	49	14.0%
	5	Most trustworthy	33	9.4%
Missing Values	99		20	5.7%

@23b

		Value	Count	Percent
Standard Attributes	Position	102		
	Label	Guam Department of Public Works		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	45	12.9%
	1	Not trustworthy	34	9.7%
	2	A little trustworthy	70	20.0%
	3	Somewhat trustworthy	106	30.3%
	4	Very trustworthy	49	14.0%
	5	Most trustworthy	22	6.3%
Missing Values	99		24	6.9%

@23c

		Value	Count	Percent
Standard Attributes	Position	103		
	Label	Guam Environmental Protection Agency		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	53	15.1%
	1	Not trustworthy	37	10.6%
	2	A little trustworthy	44	12.6%
	3	Somewhat trustworthy	106	30.3%
	4	Very trustworthy	59	16.9%
	5	Most trustworthy	16	4.6%
Missing Values	98		2	0.6%
	99		33	9.4%

@23d

		Value	Count	Percent
Standard Attributes	Position	104		
	Label	Office of the Governor		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	44	12.6%
	1	Not trustworthy	48	13.7%
	2	A little trustworthy	51	14.6%
	3	Somewhat trustworthy	104	29.7%
	4	Very trustworthy	39	11.1%
	5	Most trustworthy	19	5.4%
Missing Values	98		2	0.6%
	99		43	12.3%

@23e

		Value	Count	Percent
Standard Attributes	Position	105		
	Label	Office of the Merizo Mayor		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	25	7.1%
	1	Not trustworthy	15	4.3%
	2	A little trustworthy	7	2.0%
	3	Somewhat trustworthy	77	22.0%
	4	Very trustworthy	104	29.7%
	5	Most trustworthy	103	29.4%
Missing Values	98		1	0.3%
	99		18	5.1%

@23f

		Value	Count	Percent
Standard Attributes	Position	106		
	Label	Bureau of Statistics and Plans		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	85	24.3%
	1	Not trustworthy	25	7.1%
	2	A little trustworthy	47	13.4%
	3	Somewhat trustworthy	93	26.6%
	4	Very trustworthy	44	12.6%
	5	Most trustworthy	11	3.1%
Missing Values	99		45	12.9%

@23g

		Value	Count	Percent
Standard Attributes	Position	107		
	Label	BSP Guam Coastal Management Program		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	71	20.3%
	1	Not trustworthy	23	6.6%
	2	A little trustworthy	38	10.9%
	3	Somewhat trustworthy	93	26.6%
	4	Very trustworthy	69	19.7%
	5	Most trustworthy	15	4.3%
Missing Values	98		1	0.3%
	99		40	11.4%

@23h

		Value	Count	Percent
Standard Attributes	Position	108		
	Label	University of Guam		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	97	27.7%
	1	Not trustworthy	21	6.0%
	2	A little trustworthy	41	11.7%
	3	Somewhat trustworthy	82	23.4%
	4	Very trustworthy	53	15.1%
	5	Most trustworthy	18	5.1%
Missing Values	99		38	10.9%

@23i

		Value	Count	Percent
Standard Attributes	Position	109		
	Label	UOG Marine Laboratory		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	95	27.1%
	1	Not trustworthy	26	7.4%
	2	A little trustworthy	40	11.4%
	3	Somewhat trustworthy	77	22.0%
	4	Very trustworthy	47	13.4%
	5	Most trustworthy	22	6.3%
Missing Values	98		1	0.3%
	99		42	12.0%

@23j

		Value	Count	Percent
Standard Attributes	Position	110		
	Label	UOG Water Energy Research Institute		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	103	29.4%
	1	Not trustworthy	27	7.7%
	2	A little trustworthy	33	9.4%
	3	Somewhat trustworthy	78	22.3%
	4	Very trustworthy	47	13.4%
	5	Most trustworthy	21	6.0%
Missing Values	99		41	11.7%

@23k

		Value	Count	Percent
Standard Attributes	Position	111		
	Label	Department of Agriculture		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	52	14.9%
	1	Not trustworthy	16	4.6%
	2	A little trustworthy	33	9.4%
	3	Somewhat trustworthy	90	25.7%
	4	Very trustworthy	74	21.1%
	5	Most trustworthy	56	16.0%
Missing Values	98		1	0.3%
	99		28	8.0%

@23l

		Value	Count	Percent
Standard Attributes	Position	112		
	Label	DoAg Division of Aquatics and Wildlife Resources		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	60	17.1%
	1	Not trustworthy	21	6.0%
	2	A little trustworthy	36	10.3%
	3	Somewhat trustworthy	95	27.1%
	4	Very trustworthy	61	17.4%
	5	Most trustworthy	41	11.7%
Missing Values	98		2	0.6%
	99		34	9.7%

@23m

		Value	Count	Percent
Standard Attributes	Position	113		
	Label	DoAg Division of Forestry and Soils Resources		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	66	18.9%
	1	Not trustworthy	17	4.9%
	2	A little trustworthy	41	11.7%
	3	Somewhat trustworthy	93	26.6%
	4	Very trustworthy	66	18.9%
	5	Most trustworthy	29	8.3%
Missing Values	99		38	10.9%

@23n

		Value	Count	Percent
Standard Attributes	Position	114		
	Label	Guam Power Authority		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Unsure/Do not know	42	12.0%
	1	Not trustworthy	27	7.7%
	2	A little trustworthy	59	16.9%
	3	Somewhat trustworthy	110	31.4%
	4	Very trustworthy	49	14.0%
	5	Most trustworthy	40	11.4%
Missing Values	99		23	6.6%

V24

		Value	Count	Percent
Standard Attributes	Position	115		
	Label	Attitude toward Achang Reef Marine Preserve		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	105	30.0%
	1	Oppose	48	13.7%
	2	Strongly oppose	18	5.1%
	3	Do not care	21	6.0%
	4	Support	62	17.7%
	5	Strongly support	80	22.9%
Missing Values	98		2	0.6%
	99		14	4.0%

V37

		Value	Count	Percent
Standard Attributes	Position	116		
	Label	Familiarity with definition of watershed		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	95	27.1%
	2	no	183	52.3%
	3	do not know	60	17.1%
Missing Values	99		12	3.4%

V38

		Value	Count	Percent
Standard Attributes	Position	117		
	Label	Ability to define watershed		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	91	26.0%
	2	no	141	40.3%
	3	do not know	101	28.9%
Missing Values	99		17	4.9%

V39

		Value	Count	Percent
Standard Attributes	Position	118		
	Label	Familiarity with Ridge to Reef		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	93	26.6%
	2	no	161	46.0%
	3	do not know	85	24.3%
Missing Values	99		11	3.1%

V40

		Value	Count	Percent
Standard Attributes	Position	119		
	Label	Proximity to a river		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	174	49.7%
	2	no	149	42.6%
	3	do not know	20	5.7%
Missing Values	99		7	2.0%

V41

		Value	Count	Percent
Standard Attributes	Position	120		
	Label	Do you hunt?		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	52	14.9%
	2	no	287	82.0%
Missing Values	98		1	0.3%
	99		10	2.9%

@41a

		Value	Count	Percent
Standard Attributes	Position	121		
	Label	Do you hunt in Merizo?		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	28	8.0%
	2	no	13	3.7%
Missing Values	97		289	82.6%
	98		2	0.6%
	99		18	5.1%

@41b

		Value	Count	Percent
Standard Attributes	Position	122		
	Label	deer		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	12	3.4%
	1	yes	33	9.4%
Missing Values	97		292	83.4%
	99		13	3.7%

@41c

		Value	Count	Percent
Standard Attributes	Position	123		
	Label	wild boar		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	20	5.7%
	1	yes	26	7.4%
Missing Values	97		292	83.4%
	99		12	3.4%

@41d

		Value	Count	Percent
Standard Attributes	Position	124		
	Label	goats		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	46	13.1%
	1	yes	0	0.0%
Missing Values	97		292	83.4%
	99		12	3.4%

@41e

		Value	Count	Percent
Standard Attributes	Position	125		
	Label	birds		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	46	13.1%
	1	yes	0	0.0%
Missing Values	97		292	83.4%
	99		12	3.4%

@41f

		Value	Count	Percent
Standard Attributes	Position	126		
	Label	bats		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	45	12.9%
	1	yes	1	0.3%
Missing Values	97		292	83.4%
	99		12	3.4%

@41g

		Value	Count	Percent
Standard Attributes	Position	127		
	Label	coconut crabs		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	30	8.6%
	1	yes	16	4.6%
Missing Values	97		292	83.4%
	99		12	3.4%

@41h

		Value	Count	Percent
Standard Attributes	Position	128		
	Label	turtles		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	44	12.6%
	1	yes	2	0.6%
Missing Values	97		292	83.4%
	99		12	3.4%

@41i

		Value	Count	Percent
Standard Attributes	Position	129		
	Label	does not apply		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	46	13.1%
	1	yes	0	0.0%
Missing Values	97		292	83.4%
	99		12	3.4%

@41j

		Value	Count	Percent
Standard Attributes	Position	130		
	Label	other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	43	12.3%
	1	yes	3	0.9%
Missing Values	97		292	83.4%
	99		12	3.4%

V42

		Value	Count	Percent
Standard Attributes	Position	131		
	Label	Do you farm?		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	79	22.6%
	2	no	255	72.9%
Missing Values	98		1	0.3%
	99		15	4.3%

V43

		Value	Count	Percent
Standard Attributes	Position	132		
	Label	Participation in watershed projects in the past year		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	71	20.3%
	2	no	262	74.9%
Missing Values	99		17	4.9%

@43a

		Value	Count	Percent
Standard Attributes	Position	133		
	Label	tree planting		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	41	11.7%
	1	yes	30	8.6%
Missing Values	97		263	75.1%
	99		16	4.6%

@43b

		Value	Count	Percent
Standard Attributes	Position	134		
	Label	water monitoring		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	63	18.0%
	1	yes	7	2.0%
Missing Values	97		264	75.4%
	99		16	4.6%

@43c

		Value	Count	Percent
Standard Attributes	Position	135		
	Label	beach clean-ups		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	21	6.0%
	1	yes	49	14.0%
Missing Values	97		264	75.4%
	99		16	4.6%

@43d

		Value	Count	Percent
Standard Attributes	Position	136		
	Label	village clean-ups		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	18	5.1%
	1	yes	52	14.9%
Missing Values	97		264	75.4%
	99		16	4.6%

@43e

		Value	Count	Percent
Standard Attributes	Position	137		
	Label	implemented watershed practices at home		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	67	19.1%
	1	yes	3	0.9%
Missing Values	97		264	75.4%
	99		16	4.6%

@43f

		Value	Count	Percent
Standard Attributes	Position	138		
	Label	do not know/unsure		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	70	20.0%
	1	yes	0	0.0%
Missing Values	97		264	75.4%
	99		16	4.6%

@43g

		Value	Count	Percent
Standard Attributes	Position	139		
	Label	other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	68	19.4%
	1	yes	2	0.6%
Missing Values	97		264	75.4%
	99		16	4.6%

V44

		Value	Count	Percent
Standard Attributes	Position	140		
	Label	Interest in future watershed projects		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	1	yes	200	57.1%
	2	no	132	37.7%
Missing Values	99		18	5.1%

@44a

		Value	Count	Percent
Standard Attributes	Position	141		
	Label	tree planting		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	79	22.6%
	1	yes	117	33.4%
Missing Values	97		134	38.3%
	99		20	5.7%

@44b

		Value	Count	Percent
Standard Attributes	Position	142		
	Label	water monitoring		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	153	43.7%
	1	yes	43	12.3%
Missing Values	97		134	38.3%
	99		20	5.7%

@44c

		Value	Count	Percent
Standard Attributes	Position	143		
	Label	beach clean-ups		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	53	15.1%
	1	yes	143	40.9%
Missing Values	97		134	38.3%
	99		20	5.7%

@44d

		Value	Count	Percent
Standard Attributes	Position	144		
	Label	village clean-ups		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	48	13.7%
	1	yes	149	42.6%
Missing Values	97		134	38.3%
	99		19	5.4%

@44e

		Value	Count	Percent
Standard Attributes	Position	145		
	Label	implemented watershed practices at home		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	153	43.7%
	1	yes	43	12.3%
Missing Values	97		134	38.3%
	99		20	5.7%

@44f

		Value	Count	Percent
Standard Attributes	Position	146		
	Label	hunting clinic demonstrating ways to hunt without setting fires		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	168	48.0%
	1	yes	28	8.0%
Missing Values	97		134	38.3%
	99		20	5.7%

@44g

		Value	Count	Percent
Standard Attributes	Position	147		
	Label	do not know/unsure		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	178	50.9%
	1	yes	18	5.1%
Missing Values	97		133	38.0%
	98		1	0.3%
	99		20	5.7%

@44h

		Value	Count	Percent
Standard Attributes	Position	148		
	Label	other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	187	53.4%
	1	yes	9	2.6%
Missing Values	97		134	38.3%
	99		20	5.7%

@45a

		Value	Count	Percent
Standard Attributes	Position	149		
	Label	The forests are filled with native vegetation.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	100	28.6%
	1	Strongly disagree	8	2.3%
	2	Disagree	46	13.1%
	3	Do not care	7	2.0%
	4	Agree	99	28.3%
	5	Strongly agree	55	15.7%
Missing Values	99		35	10.0%

@45b

		Value	Count	Percent
Standard Attributes	Position	150		
	Label	Native animals are abundant.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	100	28.6%
	1	Strongly disagree	10	2.9%
	2	Disagree	62	17.7%
	3	Do not care	8	2.3%
	4	Agree	90	25.7%
	5	Strongly agree	34	9.7%
Missing Values	99		46	13.1%

@45c

		Value	Count	Percent
Standard Attributes	Position	151		
	Label	There is erosion.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	70	20.0%
	1	Strongly disagree	4	1.1%
	2	Disagree	13	3.7%
	3	Do not care	3	0.9%
	4	Agree	93	26.6%
	5	Strongly agree	117	33.4%
Missing Values	98		1	0.3%
	99		49	14.0%

@45d

		Value	Count	Percent
Standard Attributes	Position	152		
	Label	The rivers are clean.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	68	19.4%
	1	Strongly disagree	61	17.4%
	2	Disagree	100	28.6%
	3	Do not care	7	2.0%
	4	Agree	56	16.0%
	5	Strongly agree	12	3.4%
Missing Values	98		1	0.3%
	99		45	12.9%

@45e

		Value	Count	Percent
Standard Attributes	Position	153		
	Label	There are many wildland fires.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	67	19.1%
	1	Strongly disagree	16	4.6%
	2	Disagree	57	16.3%
	3	Do not care	6	1.7%
	4	Agree	102	29.1%
	5	Strongly agree	53	15.1%
Missing Values	99		49	14.0%

@45f

		Value	Count	Percent
Standard Attributes	Position	154		
	Label	It floods often.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	43	12.3%
	1	Strongly disagree	8	2.3%
	2	Disagree	15	4.3%
	3	Do not care	5	1.4%
	4	Agree	95	27.1%
	5	Strongly agree	144	41.1%
Missing Values	99		40	11.4%

@45g

		Value	Count	Percent
Standard Attributes	Position	155		
	Label	There should be more forest clearing.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	69	19.7%
	1	Strongly disagree	56	16.0%
	2	Disagree	50	14.3%
	3	Do not care	8	2.3%
	4	Agree	68	19.4%
	5	Strongly agree	51	14.6%
Missing Values	98		1	0.3%
	99		46	13.1%
	System		1	0.3%

@45h

		Value	Count	Percent
Standard Attributes	Position	156		
	Label	There are more non-native animals than native animals.		
	Type	Numeric		
	Format	F11		
	Measurement	Ordinal		
	Role	Input		
Valid Values	0	Do not know	88	25.1%
	1	Strongly disagree	6	1.7%
	2	Disagree	11	3.1%
	3	Do not care	7	2.0%
	4	Agree	90	25.7%
	5	Strongly agree	107	30.6%
Missing Values	99		40	11.4%
	System		1	0.3%

@46a

		Value	Count	Percent
Standard Attributes	Position	157		
	Label	Family		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	42	12.0%
	1	yes	285	81.4%
Missing Values	98		11	3.1%
	99		12	3.4%

@46b

		Value	Count	Percent
Standard Attributes	Position	158		
	Label	Beautiful environment		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	104	29.7%
	1	yes	223	63.7%
Missing Values	98		11	3.1%
	99		12	3.4%

@46c

		Value	Count	Percent
Standard Attributes	Position	159		
	Label	Close to the sea		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	132	37.7%
	1	yes	195	55.7%
Missing Values	98		11	3.1%
	99		12	3.4%

@46d

		Value	Count	Percent
Standard Attributes	Position	160		
	Label	Cocos Island		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	187	53.4%
	1	yes	140	40.0%
Missing Values	98		11	3.1%
	99		12	3.4%

@46e

		Value	Count	Percent
Standard Attributes	Position	161		
	Label	Jungles		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	235	67.1%
	1	yes	92	26.3%
Missing Values	98		11	3.1%
	99		12	3.4%

@46f

		Value	Count	Percent
Standard Attributes	Position	162		
	Label	Rivers		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	228	65.1%
	1	yes	99	28.3%
Missing Values	98		11	3.1%
	99		12	3.4%

@46g

		Value	Count	Percent
Standard Attributes	Position	163		
	Label	Animals		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	229	65.4%
	1	yes	98	28.0%
Missing Values	98		11	3.1%
	99		12	3.4%

@46h

		Value	Count	Percent
Standard Attributes	Position	164		
	Label	School		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	199	56.9%
	1	yes	128	36.6%
Missing Values	98		11	3.1%
	99		12	3.4%

@46i

		Value	Count	Percent
Standard Attributes	Position	165		
	Label	Other		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	289	82.6%
	1	yes	38	10.9%
Missing Values	98		11	3.1%
	99		12	3.4%

@46j

		Value	Count	Percent
Standard Attributes	Position	166		
	Label	Do not like anything about Merizo		
	Type	Numeric		
	Format	F11		
	Measurement	Nominal		
	Role	Input		
Valid Values	0	no	325	92.9%
	1	yes	2	0.6%
Missing Values	98		11	3.1%
	99		12	3.4%

Appendix 3 - Conservation Action Plan Invitation Letter 2010

BUREAU OF STATISTICS AND PLANS

(Bureau of Planning)

Government of Guam

Felix P. Camacho
Governor of Guam

Michael W. Cruz, M.D.
Lieutenant Governor

P.O. Box 2950 Hagåtña, Guam 96932
Tel: (671) 472-4201/3
Fax: (671) 477-1812

Alberto "Tony" Lamorena V
Director

Memorandum

To: Director, Department of Agriculture
ATTN: Chief, Division of Aquatic and Wildlife Resources
Celestino Aguon, Division of Aquatic and Wildlife Resources
Jay Guiterrez, Division of Aquatic and Wildlife Resources
Brent Tibbatts, Division of Aquatic and Wildlife Resources
Jeff Quitugua, Division of Aquatic and Wildlife Resources
Diane Vice, Division of Aquatic and Wildlife Resources
Suzanne Medina, Division of Aquatic and Wildlife Resources
Chief, Division of Forestry and Soils Resources
Justin Santos, Division of Forestry and Soils Resources
Administrator, Guam Environmental Protection Agency
ATTN: Jesse Cruz, Monitoring and Analytical Services
Margaret Aguilar, Watershed Planning
Director, University of Guam Marine Laboratory
ATTN: Jenny McIlwain

From: Director, Bureau of Statistics and Plans

Subject: Manell/Geus Watershed Conservation Action Planning (CAP) Workshop

Hafa Adai! On behalf of the Bureau of Statistics and Plans Guam Coastal Management Program, we would like staff from your agency to participate in our upcoming Conservation Action Planning (CAP) Workshop scheduled on 31 August – 01 September 2010 at the Guam Marriott. The workshop will be for two days and will be facilitated by Steven Victor and Umiich Sengebau from The Nature Conservancy (TNC). This workshop will focus strictly on the Manell and Geus watersheds, which encompass the village of Merizo.

The CAP workshop is a process that will assist Government of Guam agencies in determining and prioritizing the biological, social, and economic factors necessary for effective management within a specific geographical location (in this case, the Manell and Geus watersheds). Based on the results of this workshop, strategic conservation action plans will be developed, assessed, and incorporated into the watershed management plan for the area. The objectives of the CAP workshop are as follows:

- Identify actions that produce long-term measurable results of conservation efforts, at the local level;
- Establish partnerships to support and implement management interventions; and
- Quantitatively and qualitatively measure conservation impact in the area over time.

This process was also used to develop a Conservation Action Plan for the village of Piti. Currently, there are several projects being implemented in Piti as a result of this plan such as rain gardens, bioswales, and public watershed hikes.

There are a limited number of spaces available for this free workshop and lunch will be provided. Please inform us whether or not you will be attending, no later than 25 August 2010. If there are any questions or concerns, please contact Romina King at rominaking@gmail.com or 929-6714.



ALBERTO A. LAMORENA V
Director

Appendix 4 – Attendance list of the Conservation Action Plan Workshop 2010

MANELL/GEUS - CONSERVATION ACTION PLAN INVIT

	Name	Agency	Telephone No.
	Alberto "Tony" Lamorena	BSP	
	Dave Burdick	BSP - GCMP	
	Elaina Todd	BSP - GCMP	
	Esther Taitague	BSP - GCMP	
	Evangeline Lujan	BSP - GCMP	
*	Tammy Jo Anderson	BSP - GCMP	
	Cheryl Calustro	DAWR	
*	Brent Tibbatts	Department of Ag.	
	Joe Torres	Department of Agriculture	
	Diane Vice	DeptAg	
	Suzanne Medina	DeptAg	
	Tino Aguon	DeptAg - DAWR	
	Joe Mafnas	DeptAg - Forestry	
*	Justin Santos	DeptAg - Forestry	
	Jay Gutierrez	DeptAg-DAWR	
	Benny Cruz	EPA	
	Jesse Cruz	EPA	
	Margaret Aguilar	EPA	
	Peggy Denny	iRecycle	
	Ernest Chargalauf	Merizo Mayor's Office	
*	Barbara Alberti	National Park Service	
	Val Brown	NOAA Fisheries	
	Mark Defley	NRCS	
	Trina Leberer	TNC	
	Jenny McIllwain	UOG ML	
	Laurie Raymundo	UOG ML	
	Romina King		

*Denotes letters notifying heads of agency about the CAP.

Appendix 5 - Informal interviews

What is your name?

What is your age?

How long have you resided in Merizo?

Is the climate different today than it was 30 years ago? How is it different?

Were there more floods in the past? How did you deal with floods in the past?

Was it rainier?

Did you have more typhoons? What did you do to deal with the typhoons?

Was there more fish?

Was the water in the rivers cleaner?

Was the jungle different? Different types of trees?

Was there more jungle? Less jungle?

Were there more birds? What kind?

Did you have a problem getting drinking water?

Have you heard of climate change?

Appendix 6 – Infrastructure Projects for the village of Merizo

Guam Stormwater Drainage Master Plan

Merizo Village

Site Evaluations

Site Rank	Site ID	Loc A	Loc B	Site Score	Type of Roadway	No. of Affected Properties	Within Flood Zone A	Public Safety Threat	Maintenance	Flooding Severity	Erosion Severity	Env Water Impact	ROW Needed	COST	Site Assessment	Mitigation Type	Mitigation Effort	Proposed Improvements	Cost
1	ME-102	RT 4	Asgado Creek	172	Highway	N/A	Yes	High	Medium	Medium	High	Coastal	No	Low	Two 36" RCP cross culverts with headwalls under Rt4 route Asgadao Creek to Asgadao Bay. Upstream culverts are clogged with sediment and debris, downstream they are about 2/3 covered with sediment. Road is been undermined in the proximity of the cross culverts. Need to remove debris/sediment/vegetation and add embankment stabilization for about 50' both upstream and downstream.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 200 SF Rip Rap, 1 headwall/wingwall	To prevent further clogging of culverts and further undermining of the road near the cross culverts, maintenance including 1/4 acre of debris removal followed by placement of a 10'x10' rip rap energy dissipater (both upstream and downstream) along with installation of a headwall/ wingwall structure at the culvert outlet is recommended.	$47,100
2	ME-119	RT 4	SO Benny Espinoza Ave	159	Highway	1	Yes	Medium	Medium	Medium	Low	Coastal	No	Low	A 3-36" RCP cross culvert under Rt4 south of Benny Espinoza Ave. At the upstream of these culverts a house has been built on top of the headwall. It needs debris/sediment removal, and embankment stabilization(riprap) both upstream and downstream channels.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	Maintenance and channel stabilization for the area adjacent to and upstream of the house is required. Remove one quarter acre of debris. Place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet upstream and 50 feet downstream of culvert.	$143,000
3	ME-128	RT 4	NO Bile river	158	Highway	N/A	Yes	Medium	Medium	Medium	Medium	Coastal	No	Low	A single 36" RCP cross culvert runs under Rt4 north of Bile river. This cross culvert should be replaced with a 5'x3' RCB with wingwalls, and the upstream and downstream channels need debris/vegetation removal and embankment stabilization(riprap).	Conveyance Maintenance/ Conveyance Improvement	2 headwall/wingwall, 200 SF Rip Rap, 1/4 AC Debris Removal, 20 CY Cut, 100'x5'x3' RCB	The cross culvert at this site needs to be replaced with 100 linear feet of 5'x3' RCB , a headwall/wingwall structure with 100 sq ft rip rap stabilization upstream and downstream of the culvert, excavation of approximately 20 cubic yards and maintenance including a quarter acre of debris removal.	$169,000
5	ME-103	RT 4	Liyog River	146	Highway	N/A	Yes	Low	Medium	N/A	High	Coastal	No	Low	Bridge along Rt4 over Lyog river. All four approach slabs corners are undermined, and both upstream and downstream of the river there is significant accumulation of sediment and debris. Both upstream and downstream need debris and sediment removal, and need to provide embankment stabilization upstream and downstream for about 50' .	Erosion Control/ Conveyance Maintenance	100 CY Cut; 1,000 SF Rip Rap; 1/4 AC Debris Removal	To prevent further undermining of all four approach slabs at the bridge along Route 4 over Lyog River, maintenance consisting of a quarter acre of debris removal along with 100 cubic yards of excavation and installation of 1,000 square feet rip rap channel stabilization for a distance of 50' upstream and 50' downstream of the bridge is recommended.	$147,000
5	ME-129	RT 4	Toguan river	146	Highway	N/A	Yes	Low	Medium	N/A	High	Coastal	No	Low	Bridge along Rt4 over Toguan river. The upstream river is routed along a trapezoidal concrete lined channel, this channel ends with the bridge. Portions of the upstream concrete embankment are broken and need to be fixed. Bottom of the concrete channel needs to extend under bridge and downstream to stop the undermining of the bridge abutments. Need to add embankment stabilization(riprap) along the approach slabs, and also need to add riprap downstream base of river to stop erosion.	Conveyance Maintenance/ Conveyance Improvement	1/4 AC Debris Removal; 200 SF Rip Rap; 10,000 SF Channel Lining	Embankment stabilization is needed along the approach slabs and to stop erosion downstream, the placement of rip rap is required. A quarter acre of debris removal is required for maintenance. Erosion control will require approximately 200 square feet of rip rap embankment stabilization (placed upstream and downstream) and the repair of the concrete trapezoidal channel approximated at 10,000 square feet of channel lining.	$196,000
7	ME-106	RT 4	Sumay River	142	Highway	N/A	Yes	Low	Medium	N/A	Medium	Coastal	No	Low	Bridge over Sumay river. Need erosion stabilization along approach slabs and also upstream and downstream along the river embankment. Also needs upstream and downstream debris/sediment/vegetation removal.	Erosion Control/ Conveyance Maintenance	1,000 SF Rip Rap; 1/4 AC Debris Removal	To prevent further erosion, maintenance including 1/4 acre of debris removal and erosion control including 1,000 square feet of rip rap channel stabilization for a distance of 50 feet upstream and 50 feet downstream of the bridge is required.	$143,000
7	ME-114	RT 4	Manell Channel	142	Highway	10	Yes	High	Medium	High	High	Coastal	Yes	High	A 20'x8'(estimated dimensions) rectangular concrete channel runs parallel to Rt4 along the east side, it carries the manell river flow. The channel is covered with sediment. Need to clean channel of sediment and stabilize upstream Manell river to prevent sediment to continue covering the channel. Probably upstream from the concrete lined channel a sediment basin needs to be built to capture all the sediment. Downstream from this channel there are two outlets that are completely covered with sediment that needs to be cleared of debris. Segments of the channel's east wall are collapsing, they need to be replaced with new walls.	Erosion Control/ Conveyance Maintenance/ Conveyance Improvement	4,000 CY Rock Removal; 1/4 AC Debris Removal; 5,000 SF Rip Rap; 20 CY Cut; 10,000 SF Retaining Wall	To prevent the continuation of sediment falling and covering the channel and to stabilize the Manell River, maintenance in the form of a quarter acre of debris removal, removal of 4,000 cubic yards of rock, placement of 5,000 square feet of rip rap channel stabilization (upstream of the concrete channel for an estimated 250 feet), 20 cubic yard of soil excavation, and replacement of portions of the existing concrete rectangular channel (approximately 2000 feet approximated by 10,000 sq ft of retaining wall) is recommended.	$7,630,000
9	ME-110	RT 4	Suyaje river	139	Highway	N/A	Yes	Low	Low	N/A	Medium	Coastal	No	Low	A double 6'x3' RCB cross culvert routes Suyaje river to Sumay Bay. It needs about 100' of embankments stabilization upstream, and about 50' downstream. Also needs roadway stabilization along the two headwalls, about 50' on both sides of headwalls to stop the undermining of Rt4. Need dredging of river bottom both upstream and downstream.	Erosion Control/ Conveyance Maintenance	1,000 SF Rip Rap; 1/4 AC Debris Removal	To prevent further erosion, maintenance including 1/4 acre of debris removal and erosion control including 1,000 square feet of rip rap channel stabilization for a distance of 100 feet upstream and 50 feet downstream of the culvert is required.	$143,000
10	ME-105	RT 4	SO Sumay river	138	Highway	N/A	Yes	N/A	Medium	Medium	Medium	Coastal	No	Low	South from Sumay river a 4'x4' RCB cross culvert runs under Rt4 and discharges to Sumay Bay. Needs erosion stabilization upstream and downstream for about 50', and also along RT4 next to the headwalls. Also needs debris and vegetation removal upstream and downstream.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris. Place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet upstream and 50 feet downstream of culvert.	$143,000
11	ME-125	RT 4	NO Merizo Catholic Cemetery	136	Highway	N/A	Yes	Low	Low	Low	N/A	Coastal	No	Low	North of Merizo Catholic cementary, there is a 36" RCP cross culvert runs under Rt4. The upstream end of the cross culvert has a catch basin that needs an apron and trash rack, the downstream end couldn't be located (it is possibly covered with sediment).	Storm Drain Improvement/ Conveyance Maintenance	1000 SF Rip Rap, 1/4 AC Debris Removal, 1 Apron	To prevent further erosion, maintenance including 1/4 acre of debris and sediment removal and erosion control including 1,000 square feet of rip rap channel stabilization for a distance of 50 feet downstream of the culvert is required. Add apron and trash rack to existing catch basin at the site.	$2,100
11	ME-130	RT 4	Ajayan river	136	Highway	N/A	Yes	Low	Low	N/A	Low	Coastal	No	Low	Bridge along Rt4 over Ajayan river. Approach slabs are been undermined, need to stabilize roadway embankment with riprap.	Erosion Control/ Conveyance Maintenance	1000 SF Rip Rap, 1/4 AC Debris Removal	To prevent further undermining of the approach slabs, maintenance consisting of a quarter acre of debris removal along with installation of 1,000 square feet rip rap channel stabilization is recommended.	$143,000
13	ME-126	RT 4	Pigua river	135	Highway	N/A	Yes	Low	Medium	Medium	Low	Coastal	No	Medium	A 6'x12' RCB under Rt4 routes Pigua River. This cross culvert RCB needs to be widenen and debris/vegetation removal and embankment stabilization(riprap or gabions) is needed on both upstream and downstream channels.	Conveyance Maintenance/ Conveyance Improvement/ Erosion Control	100 CY Cut; 100 SF Rip Rap; 800 SF Gabions; 100'x6'x12' RCB (Added Barrel)	The cross culvert at this site needs to be widened, and embankment stabilization is needed upstream and downstream. Recommended improvements include 100 cubic yard of excavation, placement of 100 square feet of rip rap stabilization along the base (10 feet upstream and 10 feet downstream of the culvert), 800 square feet of gabions placed along the embankments (400 sq ft upstream and 400 sq ft downstream of culvert), and placement of a 100'x6'x12' RCB.	$543,000
14	ME-101	RT 4	Asmaile Creek	132	Highway	N/A	Yes	Low	Medium	N/A	Medium	Coastal	No	Medium	Three cross culverts under Rt4 route Asmaile Creek to Ajayan Bay. 2-36" RCP and 1-24" cross culverts with straight headwalls. Both upstream and downstream need debris/vegetation removal, dredging of channel base and embankment stabilization with riprap for about 100' upstream and downstream.	Erosion Control/ Conveyance Maintenance	1/2 AC Debris Removal, 2000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one half acre of debris. Place 2,000 square feet of rip rap for channel stabilization for a distance of 100 feet upstream and 100 feet downstream of culvert.	$285,000
14	ME-108	RT 4	SO Suyafe River	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	Un-named tributary at this location. Standing water observed on the upstream side. Downstream side needs bank stabilization along the culvert and roadway. Along Route 4 there are 4 cross culverts with un-named tributaries that need bank stabilization on the upstream and downstream sides.	Erosion Control/ Conveyance Maintenance	1/2 AC Debris Removal, 2000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one half acre of debris and place 250 square feet rip rap for channel stabilization for a distance of 25 feet upstream and 25 feet downstream of 4 culverts (2,000 square feet total).	$145,000
14	ME-112	RT 4	SO Juan Babauta St	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	A 6'x4' RCB cross culvert under Rt4, just south of Juan Babauta St. The RCB is in good condition, there is erosion around the upstream headwall. Need to extend headwall (or add rip rap) upstream to include a 36" RCP that is discharging to the side of the headwall, and also need to add rirap for erosion control.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal; 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris and place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet upstream of existing culvert and around 36" RCP culvert outlet located immediately upstream of cross culvert.	$143,000
14	ME-113	RT 4	Juan Babauta St	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	Double 6'x3' RCB cross culvert. Upstream three grated inlets discharge to RCB, these inlets are adjacent to a home. There is also a lateral cross culvert discharging to RCB from the north. Downstream channel needs debris/trash/vegetation removal and embankment stabilization(riprap).	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal; 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris and place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet downstream of existing culvert.	$143,000

Site Rank	Site ID	Loc A	Loc B	Site Score	Type of Roadway	No. of Affected Properties	Within Flood Zone A	Public Safety Threat	Maintenance	Flooding Severity	Erosion Severity	Env Water Impact	ROW Needed	COST	Site Assessment	Mitigation Type	Mitigation Effort	Proposed Improvements	Cost
14	ME-115	RT 4	North of Manell Channel	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	North of Manell Channel along Rt4 three existing 5'x3' RCB cross culverts need improvements on the upstream and downstream channels. Need debris removal and embankment stabilization for about 20' upstream and downstream.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	Embankment stabilization and maintenance are needed at this site. Remove one quarter acre of debris and place 330 square feet of rip rap for a distance of approximately 20' both upstream and downstream of each culvert (totaling 2000 sq ft total for 3 culverts).	$11,000
14	ME-116	RT 4	Achang River	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	6'x3' RCB cross culvert under Rt4 carries Achang river flow to Achang Bay. Upstream and downstream need sediment and debris removal.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal; 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris. Place 1,000 square feet of rip rap for channel stabilization for a distance of 25 feet upstream and 25 feet downstream of culvert.	$16,000
14	ME-121	RT 4	NO Benny Espinoza Ave	132	Highway	N/A	No	Low	Medium	N/A	Medium	Coastal	No	Low	A 10'x5' RCB cross culvert under Rt4. This RCB needs sediment/debris/vegetation removal and embankment stabilization(riprap) both upstream and downstream. Along the downstream base also riprap need to be placed to stop the undermining of the RCB wingwalls.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	To prevent further erosion, maintenance including 1/4 acre of debris removal and erosion control including 1,000 square feet of rip rap channel stabilization for a distance of 50 feet upstream and 50 feet downstream of the culvert is required.	$143,000
14	ME-122	RT 4	Chalan Joseph A Cruz	132	Highway	N/A	Yes	N/A	Medium	N/A	Medium	Coastal	No	Low	10'x5' RCB cross culvert under Rt4, just south of Chalan Joseph A. Cruz. This RCB routes runoff from a channel along the south side of Chalan Joseph A. Cruz. The RCB is in good condition, upstream channel needs debris/sediment removal and embankment stabilization.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris and place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet upstream of existing culvert.	$143,000
22	ME-117	RT 4	NO Geus river	129	Highway	N/A	Yes	N/A	Medium	N/A	Low	Coastal	No	Low	A double 24" RCP cross culvert under Rt4 just south of Geus river. Upstream channel is in good condition except for vegetation clearing, downstream channel needs debris/sediment removal and embankment stabilization.	Erosion Control/ Conveyance Maintenance	1/4 AC Debris Removal, 1000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one quarter acre of debris and place 1,000 square feet of rip rap for channel stabilization for a distance of 50 feet downstream of existing culvert.	$143,000
22	ME-120	RT 4	Benny Espinoza Ave	129	Highway	N/A	Yes	N/A	Medium	N/A	Low	Coastal	No	Low	A concrete lined channel parallel to Rt4 needs sediment removal. It discharges to the 3-36" RCP cross culverts.	Conveyance Maintenance	1/4 AC Debris Removal	Maintenance is needed at this site. Remove one quarter acre of debris and sediment from channel.	$1,940
22	ME-124	RT 4	SO Merizo Catholic Cemetery	129	Highway	1	No	Low	Medium	Low	Medium	Coastal	No	Medium	A mixed of cross culverts cross Rt4 south of Merizo Catholic Cementary. The upstream side consits of 4-36" RCP and 4-24" RCP cross culverts, the 4-24" cross culverts sit on top of the 4-36" cross culverts. The upstream side is a RCB cross culvert. This system should be replaced with a 12'x6' RCB cross culvert with wingwalls on both ends. The upstream and downstream channels need debris/sediment/vegetation removal, and embankment stabilization(riprap) to stop the undermining of Rt4.	Erosion Control/ Conveyance Improvement	100'x12'x6' RCB, 2 headwalls/wingwalls, 1000 SF Rip Rap	To stop the undermining of Route 4, the placement of approximately 100 linear feet of 12'x6' RCB, with two headwall/wingwall structures (one upstream and one downstream), and 1,000 square feet of channel stabilization are required.	$677,000
25	ME-111	Emma Reyes St		123	Collector	1	Yes	Medium	Medium	High	N/A	Coastal	Yes	Low	Home 100' away from Rt4 floods. The Suyaje river floods property, need to add a berm to raise the Suyaje river embankment and prevent flooding of property.	Conveyance Maintenance/ Conveyance Improvement	1/4 AC Debris Removal; 1000 SF Rip Rap; 3000 CF Fill	To minimize flooding of the adjacent home, a 1.5-ft high berm (5 ft wide) is recommended along both embankments of the river on the upstream side of the culvert for a distance of approximately 200 feet. Remove one quarter acre of debris. Place 1,000 square feet of rip rap along inner side of berm and 3,000 cubic feet of fill.	$144,000
26	ME-104	RT 4	SO Sumay river	119	Highway	N/A	Yes	Medium	Medium	Low	High	Coastal	Yes	Medium	South from Sumay river the roadway has eroded next to the shoreline, it needs shoreline protection for about 500' from Sumay river.	Coastal Protection	1/2 AC Debris Removal; 5000 SF Rip Rap	To prevent further shoreline erosion as a result of high tides, maintenance including 1/2 acre of debris removal followed by installation of 5,000 square feet of rip rap coastal stabilization (approximately 10-ft in width along the shoreline) from Sumay River to 500 feet south of the river is recommended.	$707,000
26	ME-107	RT 4	NO Sumay river	119	Highway	N/A	Yes	Medium	Medium	Low	High	Coastal	Yes	Medium	North of Sumay river along the shoreline Rt4 needs erosion stabilization to prevent erosion during high tides for sand to cross roadway.	Coastal Protection	1/2 AC Debris Removal; 5000 SF Rip Rap	To prevent further shoreline erosion as a result of high tides, maintenance including 1/2 acre of debris removal followed by installation of 5,000 square feet of rip rap coastal stabilization (approximately 10-ft in width along the shoreline) from Sumay River to 500 feet north of the river is recommended.	$707,000
26	ME-118	RT 4	Geus river	119	Highway	N/A	Yes	N/A	Medium	N/A	Low	Coastal	No	Medium	A 4 cell 12'x8' RCB under Rt4 carries Geus river flow. Needs debris/sediment/vegetation removal and embankment stabilization both upstream and downstream.	Erosion Control/ Conveyance Maintenance	1/2 AC Debris Removal; 2,000 SF Rip Rap	Erosion control and maintenance is needed at this site. Remove one half acre of debris. Place 2,000 square feet of rip rap for channel stabilization for a distance of 50 feet upstream and 50 feet downstream of culvert.	$285,000
														TOTAL					**$13,168,000**