US Army Corps of Engineers ®
Honolulu District

American Samoa
Final Post Disaster Watershed Plan

July 2022

Pago Pago Harbor and Matafao Mountain

DISCLAIMER: The information presented in this report is to provide a strategic framework of potential options to address problems within American Samoa watersheds. Options identified will follow normal authorization and budgetary processes of the appropriate agencies. Any costs presented in this document are rough order magnitude estimates used for screening purposes only.

Cover photo courtesy of Mark Schmaedick.

Table of Contents

List of Figures

List of Tables

Appendices

Acronyms

Acronym	**Definition**
ASDHS	American Samoa Department of Homeland Security
ASDOC	American Samoa Department of Commerce
ASEPA	American Samoa-Environmental Protection Agency
ASHPO	American Samoa Historic Preservation Office
ASPA	American Samoa Power Authority
AS THMC	American Samoa Territory Hazard Mitigation Council
BCR	Benefit-cost ratio
BMPs	Best Management Practices
BRIC	Building Resilient Infrastructure and Communities

CFR	Code of Federal Regulation
CO_2	Carbon Dioxide
CoRIS	Coral Reef Information System
CRAG	Coral Reef Advisory Group
CZMA	Coast Zone Management Act
DOI	Department of the Interior
DOT	Department of Transportation
DPW	Department of Public Works
EC	Engineering Circular
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ER	Engineering Regulation
ESA	Endangered Species Act
EWN	Engineering with Nature
FCC	Federal Communication Commission
FEMA	Federal Emergency Management Agency
FPMS	Floodplain Management Services
GHG	Greenhouse Gasses
GSFC	Goddard Space Flight Center
H&H	Hydraulics & Hydrology
HMP	Hazard Mitigation Plan
HPO	Historic Preservation Office
IBC	International Building Code
IPCC	Intergovernmental Panel on Climate Change
IPRC	International Pacific Research Center
IWR	Institute for Water Resources
LBJ	Lyndon Baines Johnson
LiDAR	Light Detection and Ranging
M	Million
MEOW	Maximum Envelope of Water
NASA	National Aeronautics and Space Administration
NCEI	National Center for Environmental Information
NDPTC	National Disaster Preparedness Training Center
NEMAC	National Environmental Modeling and Analysis Center
NFRMP	National Flood Risk Management Services Program
NFWF	National Fish and Wildlife Foundation

NMFS	National Marine Fisheries Service
NNBF	Nature and Nature-Based Features
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination Systems
NPS	National Park Service
NRCS	National Resources Conservation Service
NWS	National Weather Service
OCM	Office of Coastal Management
ODAPM	Office of Disaster and Petroleum Management
PAR	Population Attributable Risk
PB	Planning Bulletin
PIRCA	Pacific Islands Regional Climate Assessment
PI-CASC	Pacific Islands Climate Adaptation Science Center
PNRS	Project Notification and Review System
RISA	Regional Integrated Sciences and Assessments
SHPO	State Historic Preservation Office
SLC	Sea Level Change
SME	Subject Matter Experts
SST	Sea Surface Temperature
STEAM	Science, Technology, Engineering, Arts, Math
UH	University of Hawaii
UH-WRRC	University of Hawaii-Water Resources Research Center
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	US Department of Agriculture
USFWS	United States Fish and Wildlife Survey
USGS	United States Geological Service
WA	Watershed Assessment
WACSA	Watershed Assessment Cost Share Agreement
WRDA	Water Resources Development Act
WSO	Weather Service Office

Executive Summary

Study Authority

Authority for this Watershed Assessment (WA) is provided by Section 729 of the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662), as amended.

This study is funded by the Additional Supplemental Appropriations Disaster Relief Act, 2019 (P.L. 116-20), which fully federally funded the WA; therefore, a cost share agreement was not required.

Federal Interest

There is federal interest in conducting a WA to investigate strategies to increase community resilience from post-disaster effects in the territory of American Samoa (hereafter referred to as American Samoa).

Purpose and Scope

Funding for this WA was provided in response to Tropical Cyclone Gita, which impacted American Samoa in February 2018. Gita generated destructive wind and torrential rainfall causing widespread power outages. Approximately 1,000 people were evacuated to 12 shelters. Multiple mudslides occurred, uprooting many trees, and the intense rainfall caused flash flooding in low lying areas and near small streams.

This assessment recognizes and builds on the inherent resilience of Pacific Islands' cultures developed over thousands of years of oceanic living, and *fa'asamoa*, the traditional way of governance. The intent of this WA is to provide recommendations both within and outside of United States Army Corps of Engineers (USACE) authorities that will help to rehabilitate and improve the resiliency of damaged infrastructure and natural resources, reducing risks to human life and property from future natural hazards in American Samoa. The WA assessed the drivers of economic, social, and environmental risks through engagement with the public and other federal and territorial agencies, subject matter expert consultation, and research with the most recent reports available.

Shared Vision Statement

Natural hazards including tropical cyclones, flooding, shoreline erosion, landslides, and tsunamis negatively impact communities, the environment, and the economy in American Samoa. Many of these hazards are expected to intensify with climate change. A collaborative systems approach between stakeholders is needed to address these interrelated issues, improve watershed management, and support community resilience.

Collaborative Partner and Stakeholder Engagement

The USACE is working in collaboration with local and federal agencies to develop the WA. Table ES-0-1 below lists agency partners participating in the WA.

In accordance with Section 729 of the WRDA of 1986, as amended, cooperation letters were sent to the United States (U.S.) Environmental Protection Agency (EPA), United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Natural Resources Conservation Service (NRCS), the State Historic Preservation Officer (SHPO) who works within the American Samoa Historic Preservation Office (HPO), and National Park Service (NPS). In many cases local agencies were the more appropriate points of contacts and were engaged along with federal agencies.

Table ES-0-1. American Samoa Watershed Assessment Partners

Organization	Focus Area			
	Rainfall	Coastal	Water Quality/Supply	Tsunami
Local Agencies				
Coral Reef Advisory Group (CRAG)	X	X	X	–
Office of Disaster and Petroleum Management (ODAPM)	X	X	–	X
American Samoa Environmental Protection Agency (ASEPA)	X	X	X	–
American Samoa Power Authority (ASPA)	X	X	X	–
American Samoa Department of Commerce (ASDOC)	X	X	–	X
American Samoa Department of Public Works (DPW)	X	X	–	–
American Samoa Historic Preservation Office (HPO)	X	X	–	X
American Samoa Department of Port Administration	–	X	–	–
American Samoa Department of Homeland Security (AS DHS)	–	X	–	X
American Samoa Community College	–	X	X	–
National Park of American Samoa	X	X	–	–
University of Hawaii (UH)	X	X	X	X
University of Hawaii Sea Grant College Program	–	X	X	–
Federal Agencies				
USACE	X	X	X	X
U.S. Environmental Protection Agency (EPA)*	X	X	X	–
U.S. Geological Survey (USGS)	X	X	X	X
Dept of Interior* (DOI) [USFWS/NPS/Office of Insular Affairs/U.S. Geological Survey/	X	X	X	X

Organization	Focus Area			
	Rainfall	Coastal	Water Quality/Supply	Tsunami
Pacific Islands Climate Adaptation Science Center (PI-CASC)]				
Dept of Agriculture* (NRCS)	X	X	X	–
Dept of Commerce* [National Oceanic and Atmospheric Administration (NOAA) NMFS/Office for Coastal Management/National Weather Service]	X	X	X	X
Federal Emergency Management Agency (FEMA) (Region IX/Pacific Area Office)	X	X	–	X
Dept of Transportation (Federal Highways Admin.)	X	X	–	–
National Fish and Wildlife Foundation (NFWF)	X	X	X	–
National Aeronautics and Space Administration (NASA)	–	X	–	–

* Coordination required by Section 729 of the WRDA of 1986, as amended

USACE may investigate each of these four focus areas under various programs (see section 6.3), however the ability to implement projects will vary depending on alignment with USACE primary mission areas of flood risk management, coastal storm risk management, ecosystem restoration, and navigation.

Meetings with project partners were held throughout the duration of the WA. Appendix A – Interagency Alignment documents all meetings held to-date. Partner meetings were used to achieve the following:

- Determine study scope
- Develop shared vision statement
- Validate problem categories
- Preliminarily assess risk associated with problem categories and stressors
- Develop an initial array of measures and recommendations
- Seek input from subject matter experts (SME) in American Samoa
- Provide opportunity for stakeholder feedback and input

Study Location and Background

American Samoa is an unincorporated territory of the United States located in the mid-South Pacific Ocean, a part of the Samoan Islands archipelago in Polynesia (see Figure ES-0-1).

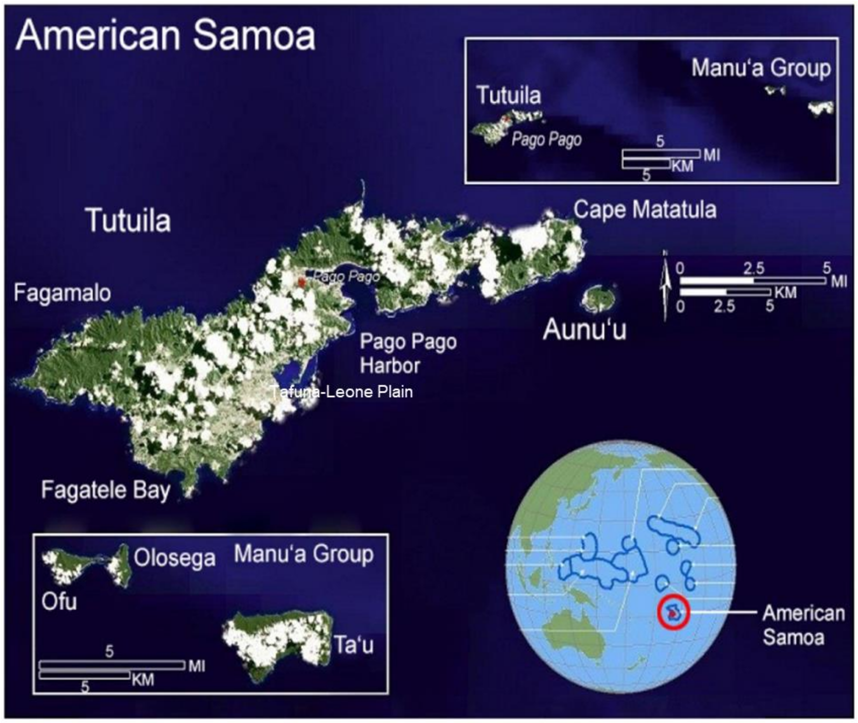


Figure ES-0-1. American Samoa Islands (Source: Pacific RISA)

American Samoa is represented by Congresswoman Aumua Amata (R), a delegate to the U.S. House of Representatives.

Due to the steep terrain of the islands, most development, including critical infrastructure such as the Lyndon B. Johnson (LBJ) Tropical Medical Center, the primary petroleum tank farm and roads are located along narrow areas between the mountains and the shoreline. Even Pago Pago harbor which is central to the economy of American Samoa is built within very limited space between steep slopes and the coast. The Tafuna-Leone plain on the southwestern area of Tutuila is the largest area of development and is the largest relatively flat area of all the islands.

Planning Process

This WA intends to provide a suite of recommendations to enhance community resiliency and improve watershed management. It incorporates available information from existing reports and on-going efforts from local and federal agencies.

The six-step watershed planning process includes:

- Identify Problems and Opportunities
- Inventory and Forecast
- Identify and Screen Measures
- Formulate Initial Array of Strategies
- Refine Initial Array and Evaluate Focused Array of Strategies
- Strategy Comparison and Selection

Problems

The problems were identified by focusing on natural hazards, including past extreme events, local needs, local government interests, and affected communities. The problem statements were developed collaboratively with stakeholders, through synthesis of existing reports, and through subject matter experts on the project team. The four problem statements and their corresponding stressors are listed below in Tables ES-0-2 through ES-0-5. For the purposes of this WA, stressors are conditions or events that occur as a result of the driving problem category.

Table ES-0-2. Rainfall and Storms Problem Statement and Stressors

Problem: Rainfall and Storms: Heavy rainfall, including tropical storms, cause high winds and riverine and overland flooding that cause public health and safety risks; impede evacuation routes; convey sediment and pollutants; damage homes, businesses and critical infrastructure; and increases environmental degradation.
Stressors
Landslides/Mudslides – Erodible soils and steep topography pose a risk of landslides/mudslides, especially after a storm event. Landslides/mudslides endanger life safety and threaten critical infrastructure, including the hospital and main roads.
Inland Habitat Degradation – Terrestrial and aquatic habitats are at risk of biodiversity and ecosystem loss from anthropogenic activities and storm events. This risk stems from water quality issues, invasive species, land use practices, and landslides.
Overland/Riverine Flooding – Flooding from tropical cyclone activity or more frequent rainfall events pose a risk to human health and safety, water quality, and critical infrastructure.
Power Outages – Power outages often result from tropical cyclone events and can continue for weeks.
Erosion – The presence of highly erodible volcanic soils can affect utilities, property, and the environment. Erosion may also lead to loss of developable land.
Flash Floods – Flash floods are exacerbated by the presence of steep slopes and impervious development and can cause landslides, damage to infrastructure, and life loss.
High Winds – High winds that typically accompany tropical storm events can reach up to 155 miles per hour with gusts exceeding 224 miles per hour. High winds pose a life loss threat and cause damage to agriculture, vegetation, infrastructure, homes, and power and water supply systems.

Table ES-0-3. Coastal Flooding and Erosion Problem Statement and Stressors

Problem: Coastal Flooding and Erosion: High surf, storm surge and coastal erosion, especially in low-lying coastal areas, threaten life safety; affect evacuation routes; damage homes, critical infrastructure, cultural sites, and businesses; and increase environmental degradation.
Stressors
Coastal Flooding – Coastal flooding and storm surge can cause inundation of coastal infrastructure including ports, roadways, and fuel storage.
Coastal Erosion – Coastal inundation and storm surge contribute to coastal erosion, damage to infrastructure, and possible loss of developable land.
Sea Level Change/Subsidence – Climate change and subsidence have exacerbated relative sea level rise, contributing to American Samoa having one of the highest recorded relative rates of SLC in the world.
Coastal Habitat Degradation – Coastal erosion, SLC, water quality issues, warming temperatures, and invasive species all contribute to the degradation of important coastal habitats like coral reefs and mangroves.

Table ES-0-4. Water Quality and Supply Problem Statement and Stressors

Problem: Water Quality and Supply: Water quality and the supply system throughout American Samoa are vulnerable to naturally occurring and anthropogenic stressors.
Stressors
Nutrient Loading – Pollution in waterways coupled with agricultural practices (pesticide and piggery waste runoff) harm water quality which reduces potable water supply for people and threatens vulnerable aquatic and coastal habitats.
Sedimentation – Due to the presence of erodible soils and steep slopes, sedimentation can clog water supply pumps leading to a decrease in potable water availability.
Drought – Drought may worsen with climate change and poses a risk to food availability and economic security.
Stormwater Management – Absence of stormwater management contributes to degradation in water quality and supply. Often there are prolonged boil water notices and, as a result, a reliance on single use plastic bottles or water refill stations with varying degrees of water quality.
Saltwater Intrusion – Subsidence, SLC, and aquifer withdraw increase saltwater intrusion, which threatens water quality and supply and could result in serious threats to food and economic security.

Water-borne Pathogens – Leptospirosis and *E. coli* cause public health and safety risks in American Samoa and result from pollution in waterways.

Table ES-0-5. Tsunami Problem Statement and Stressors

Problem: Tsunami: American Samoa is located in the Circum-Pacific earthquake belt and is particularly vulnerable to tsunamis. Locally generated tsunamis may provide only minutes to react and can cause extensive damage and loss of life.
Stressors
Tsunamis – Tsunamis, while infrequent, pose major threats to human health and safety.

Planning Goals and Objectives

The goal of this WA is to develop a framework to increase American Samoa's resilience to weather related hazards and reduce the effects of anthropogenic stressors through a focus on nature-based solutions where appropriate. This WA will provide a strategic roadmap to inform future investment decisions by multiple agencies (i.e., involvement by USACE, other federal agencies, or non-federal interests). Objectives identify planning outcomes that define successful resolutions of the problems and attainment of the opportunities identified. The **objectives** include:

Objective 1: Reduce life loss, injuries, and public health and safety risks from natural hazards in American Samoa.

Objective 2: Improve quantity and quality of inland and coastal ecosystems in American Samoa.

Objective 3: Reduce economic, environmental, and social impacts from natural hazards in American Samoa.

Objective 4: Improve territory-wide access to potable, municipal, and industrial water supply in American Samoa.

Risk and Uncertainty Assessment

To respond to water resources problems, a risk-based approach was utilized to identify the highest risks and inform near-term priorities of recommended actions. Risks within the study area are already occurring, with the potential for increased probability and consequences under future conditions. These risks were identified and evaluated through review of existing documentation as well as a series of partner and stakeholder collaborative engagement meetings with federal and territorial agencies. Risks fall within one or more of four categories: life loss, economic, social, and environmental. This largely aligns with benefit categories defined in the USACE Policy Memorandum "Policy Directive – Comprehensive Documentation of Benefits in Decision

Documents," dated January 5, 2021, which calls for *"equal consideration of economic, environmental, and social categories."* The principles of this policy directive were applied to inform the risk-based prioritization of identified problems.

A series of four scoping charrettes and a handful of one-on-one calls were held with partners to gain input and understanding on the problem categories, prioritize areas of risk, and curate an initial array of recommendations. Partner input at these meetings identified stressors and later validated the risk assessment. The qualitative risk assessment, conducted in collaboration with partners and stakeholders, identified and evaluated the following risk metrics for each detailed problem/stressor:

- Economic
- Life Loss
- Social Risk: *Social Connectedness, Health & Safety, Subsistence*
- Environmental: *Ecosystem Services Impacts, Species Loss, Habitat Loss, Cultural Resources*

The summary of the risk assessment results is shown below in Figure ES-0-2, and detailed plots and explanations of the risk assessment can be found in Section 5.2. Equal consideration was given to economic, life loss, social, and environmental risks. The highest relative risk rankings for each risk metric are categorized as "catastrophic" (and labeled with a red rectangle in Figure ES-0-2). As all identified problems and stressors pose high risk, the purpose of identifying this breakpoint is to identify the problems and stressors that carry the *highest* relative risk and should be urgently addressed. All other risks are categorized as "minor" or "major."

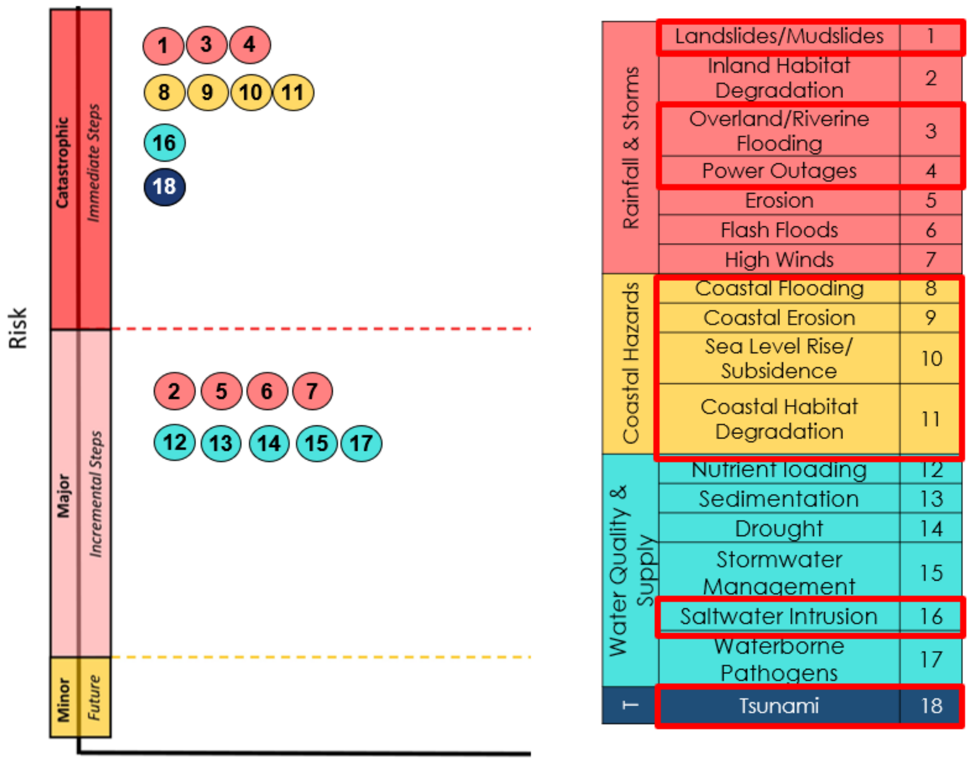


Figure ES-0-2. Risk Assessment Summary

A qualitative assessment of uncertainty was also performed to identify the level of consensus among stakeholders in implementing potential risk reduction measures for each stressor. The following categories of consensus were developed to frame risk reduction recommendations: actions, evaluate options/further study, and fill data gaps. For example, if there is a low level of uncertainty, and the activity can be completed now, the problem/stressor is categorized as an "Action." If we a stressor or activity needs further investigation before implementing an action, this is referred to as “Evaluate Options.” Finally, if more data is needed before evaluation and implementation, this is categorized as “Fill Data Gaps.” These uncertainty-based categories are defined as follows:

- ***Actions –*** Implementable solutions identified with a high level of consensus.
- ***Evaluate Options –*** Potential solutions could be defined with existing information.
- ***Fill Data Gaps –*** Additional data would be required to identify potential solutions better define the extent and consequences.

Each team member conducted discipline-specific research and assessed uncertainty based on their focused research and knowledge of possible solutions. For the final results, the team scores were averaged out and validated with partner input. Figure ES-0-3 shows the results of the collaborative uncertainty analysis.

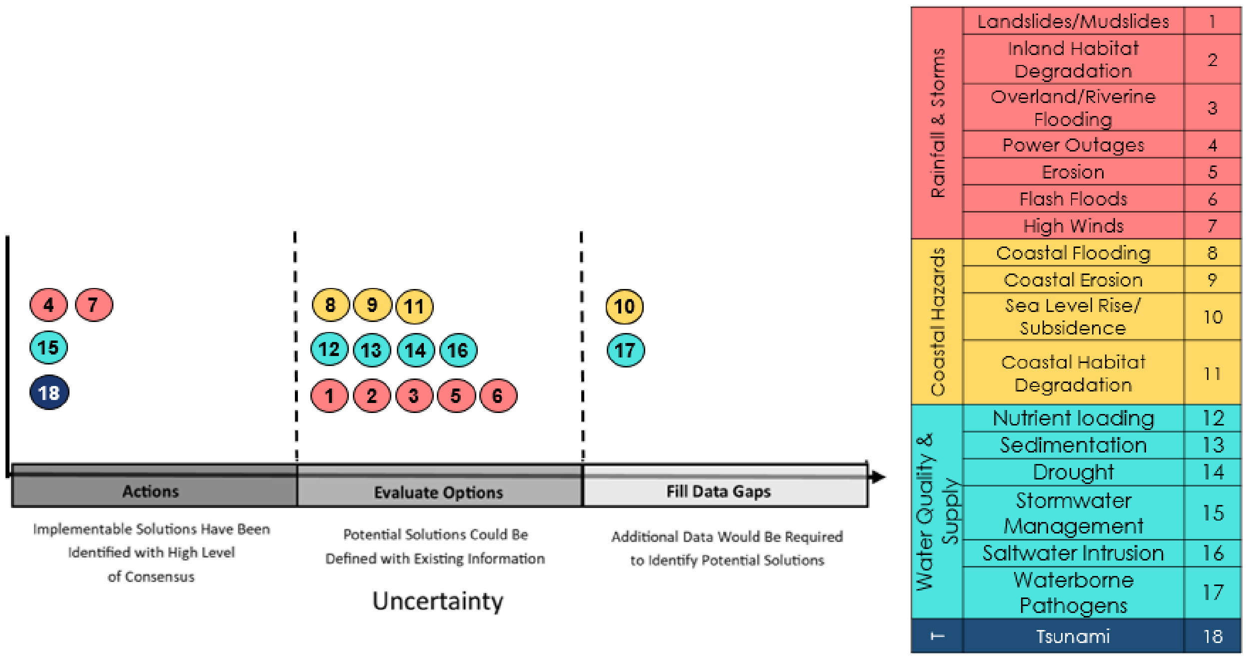


Figure ES-0-3. Uncertainty Analysis Results

Risk and uncertainty results were combined to develop a framework for the appropriate types (uncertainty-based) and timing (risk-based) for recommendations. For risks categorized as "catastrophic," immediate steps should be taken to reduce risks through direct actions, evaluate potential options for reducing risks, or fill data gaps. For problems categorized as "major," incremental steps should be taken (or continue) to reduce these significant risks. No stressors were found to rank as minor across economic, social, environmental, and life loss risk assessments. Although some stressors were ranked as minor in individual risk assessments, those stressors were not ranked as minor consistently throughout each risk metric, therefore there are no stressors ranked as minor in the overall risk summary. The risk- and uncertainty-based recommendations framework is shown below in Figure ES-0-4.

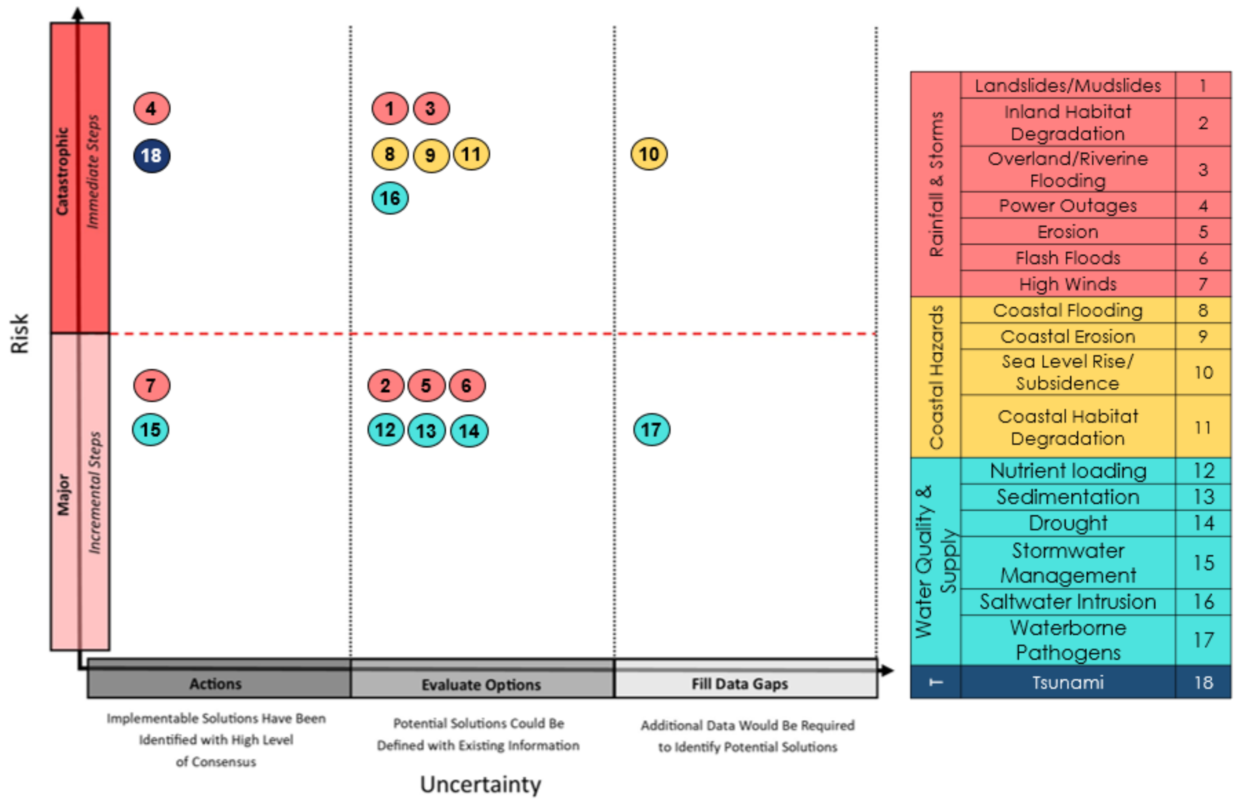


Figure ES-0-4. Risk and Uncertainty Summary

Recommendations and Implementation

The risk and uncertainty assessments framed recommendations that would be appropriate for the level of risk and existing knowledge and resources. Figure ES-0-5 below shows the broad types of recommendations the team and partners evaluated as part of this WA.

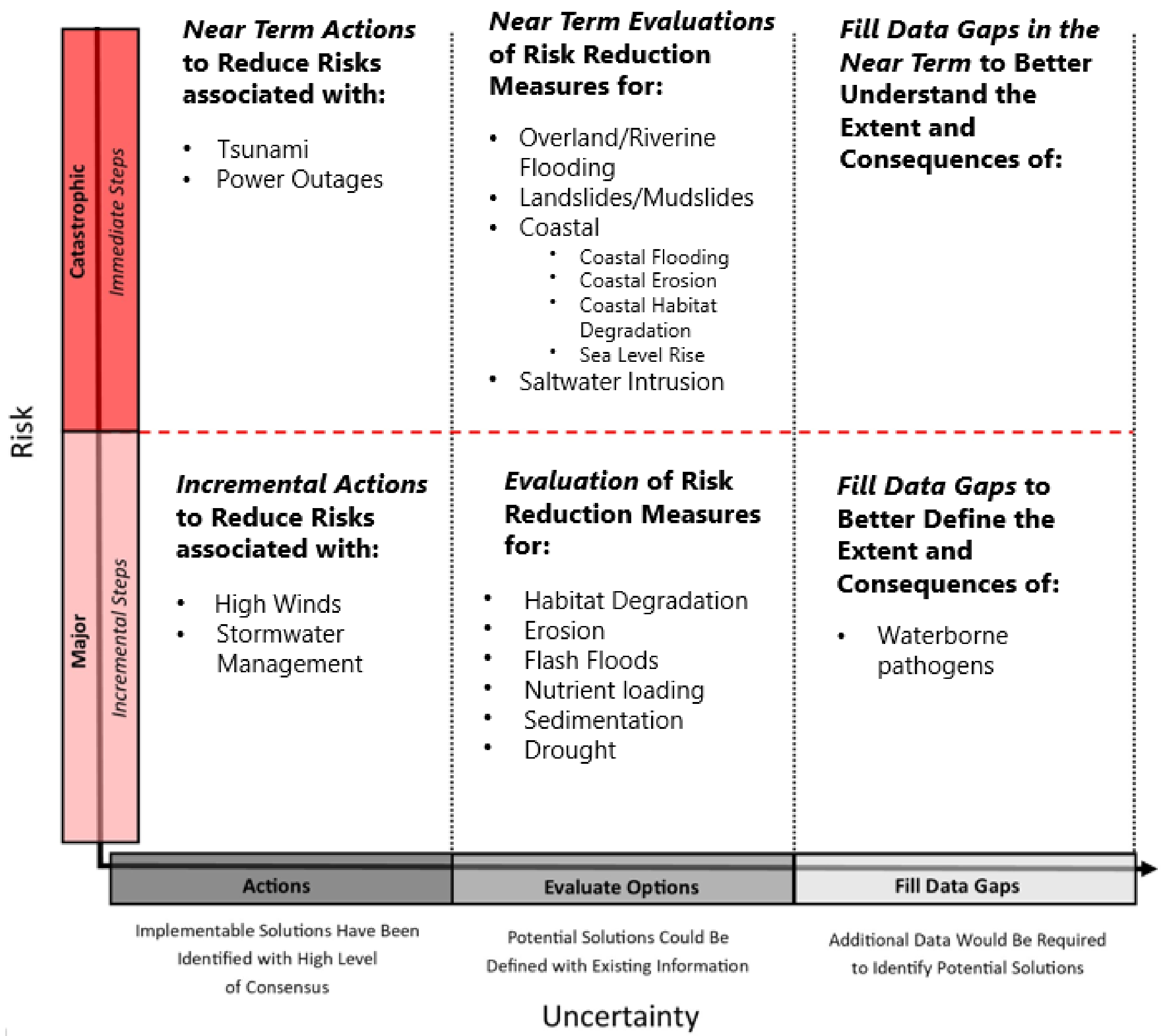


Figure ES-0-5. Framing Recommendations

SLC was moved from the catastrophic risk/fill data gaps column to catastrophic risk/evaluate options to be considered alongside other coastal stressors in preliminary recommendations.

The recommendations were developed by combining management measures, pulling recommendations from existing reports and project requests, partner input, and USACE expertise.

Partners expressed the desire for green solutions in American Samoa in several meetings and phone calls. With this consideration, the team developed a set of nature-based and non-structural solutions to complement other structural solutions and provide a breadth of options.

Potential agencies that could champion the implementation of recommendations are noted in the following recommendation tables. Letters of support from these key agencies are included in Appendix A.

Recommendations for catastrophic risks are shown below. The full suite of recommendations for both catastrophic and major risks are found in Section 6 of the report. Costs are rough estimates and are denoted by the following scale:

- $ $0-$1Million (M)
- $$ $1M-$5M
- $$$ $5M+

Near-term Actions

Recommendations framed as near-term actions address stressors with high risk and low implementation uncertainty. These should be pursued as soon as possible; ideally within five years. Stressors with solutions categorized as near-term actions include:

- **Tsunamis** (Table ES-0-6)
- **Power Outages** (Table ES-0-7)

Table ES-0-6. Tsunami Recommendations

	Focus	Recommendation	Potential Partners and Funding
Tsunami	Improve Existing Warning System	Assess the need to update, modernize, and expand American Samoa's tsunami warning system. Ensure updates to the tsunami warning system consider various needs and are accessible to all.	**Estimated Cost: $$$** **Potential Funding:** ASDHS, FEMA **Champion Agency:** FEMA, ASDHS **Other Potential Partners/Stakeholders:** , ODAPM
	Emergency Action Planning	Identify gaps in Emergency Action Plan coverage, including inclusive and accessible response planning and plans for private centers of commerce. Coordinate policy requiring development and maintenance of Emergency Action Plans.	**Estimated Cost: $** **Potential Funding:** ASDHS, FEMA, FPMS-Silver Jackets **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** FEMA, ASDHS, Governor's Office, NDPTC, NOAA, ODAPM, UH
	Power and Communication Redundancies	Supplement and improve communication and power redundancies to utilize during an emergency such as alternative backup power, ultra-high frequency radio, or additional cell towers.	**Estimated Cost: $$** **Potential Funding**: DOI Office of Insular Affairs **Champion Agency:** FEMA, ASDHS **Other Potential Partners/Stakeholders**: ASDOC, FCC, NOAA, NWS, ODAPM

Table ES-0-7. Power Outages Recommendations

	Focus	Recommendation	Potential Partners and Funding
Loss of Power	Emergency Preparedness	Ensure that evacuation shelters and other critical infrastructure like water wells, booster stations, and sewer lift stations have backup generators and fuel, and water storage tanks (as applicable).	**Estimated Cost: $$** **Potential Funding**: FEMA, DOI Office of Insular Affairs **Champion Agency:** FEMA **Other Potential Partners/Stakeholders**: ASDHS, ASDOC, FCC, NOAA, NWS, ODAPM
	Alternative Energy	Invest in equitable alternative, green energy sources (solar, wind, etc.) to lessen the reliance on imported fuel and increase resiliency to often long-lasting power outages.	**Estimated Cost: $** **Potential Funding**: DOE, USDA (REAP) **Champion Agency:** ODAPM **Other Potential Partners/Stakeholders**: FEMA, ASDHS, ASDOC, ASEPA, ASPA, FCC, NOAA, NWS

Near-term Evaluate Options

Stressors that fall into the category of "Evaluate Options" in the near-term are those with catastrophic risk and moderate levels of implementation uncertainty. Near-term means responsible parties should initiate studies within 0-5 years and target implementation within 5-10 years.

Stressors in this category include:

- **Overland/Riverine Flooding** (Table ES-0-8)
- **Coastal Flooding** (Table ES-0-10)
- **Coastal Erosion** (Table ES-0-10)
- **Sea Level Rise/Subsidence** (Table ES-0-10)
- **Coastal Habitat Degradation** (Table ES-0-10)
- **Saltwater Intrusion** (Table ES-0-11)

Table ES-0-8. Overland/Riverine Flooding Recommendations

	Focus	Recommendation	Potential Partners and Funding
Overland/ Riverine Flooding	Stream Gauge Monitoring	Implement the National Water Model, a real-time hydrologic model. The gauge network will allow monitoring of real time weather and river flow conditions. This will contribute to NWS warnings, archive data for future studies, and assist ASPA with runoff and well volume calculations.	**Estimated Cost: $** **Potential Funding:** FPMS-Silver Jackets, USGS, NOAA OCM, UH, FEMA **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** USACE, ASPA, NWS, ODAPM, USGS
	Hydrologic & Hydraulic Analysis	Develop precipitation projections and conduct hydraulic analyses to consider the adequacy and/or needs to upgrade drainage way and culvert capacity in areas vulnerable to precipitation flooding.	**Estimated Cost: $** **Potential Funding:** USACE FMPS/PAS, FPMS-Silver Jackets, NFWF **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** NOAA OCM, ASPA, NWS, ODAPM, AS EPA, DPW
	Data Portal and Information Sharing	Set up geoportal database to collect and share interagency data on floods and water quality.	**Estimated Cost: $** **Potential Funding:** USACE FMPS/PAS, FPMS-Silver Jackets, UH, PI-CASC **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** USACE, ASPA, NWS, ODAPM, PI-CASC, ASDOC
	Critical Infrastructure Protection	Protect key infrastructure and transportation assets, including small boat harbors and airports, from future anticipated storm events, flooding, landslides, and SLC impacts.	**Estimated Cost: $$-$$$** **Potential Funding:** USACE CAP Section 103/205, AS DOT **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ODAPM, AS DPW, AS Port Administration, DOI Office of Insular Affairs, AS DOT

Table ES-0-9. Landslide/Mudslide Recommendations

	Focus	Recommendation	Potential Partners and Funding
Landslides/ Mudslides	Detailed Landslide Mapping	Create database of past landslide/ mudslide information including location, cause, runout lengths, volumes, weather associated data, and potential hazards. Identify areas with slopes over 60% and/or new construction in these hazard areas.	**Estimated Cost: $** **Potential Funding:** ODAPM, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASDOC, FEMA, ODAPM, USGS, ASDPW, ASDHS, NWS

Table ES-0-10. Coastal Flooding and Erosion Recommendations

	Focus	Recommendation	Potential Partners and Funding
Coastal Hazards	Green Infrastructure Assessment and Education	Inform decision makers on benefits of green infrastructure and nature-based solutions. Evaluate potential natural and nature-based features (NNBF) that would provide enhanced flood and landslide protection, beach access and/or ecosystem services.	**Estimated Cost: $** **Potential Funding:** ASCMP 309, FPMS-Silver Jackets, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders**: FEMA, NOAA OCM, ODAPM, ASEPA
	Ecosystem Restoration	Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) including restoring mangrove habitat in high priority areas (e.g., Pala Lagoon, Pago Pago Harbor, etc.), permeable greenspaces, and areas suitable for submerged/ artificial reef pilot projects.	**Estimated Cost: $** **Potential Funding:** ASCMP 309, NFWF, UH Sea Grant, USACE CAP Section 206, GI **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASEPA, AS Port Administration, CRAG, NFWF, NOAA OCM, NPS, UH Sea Grant
	Shoreline Protection	Develop solutions to protect high priority areas vulnerable to coastal flooding and erosion (e.g., Nua-Seetaga, Matafao, Asili, Aua, Laulii, and Vatia).	**Estimated Cost: $$-$$$** **Potential Funding:** USACE CAP Section 14 or 103, USACE RSM, DOT, PI-CASC, RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** DOI Office of Insular Affairs, NOAA OCM, ODAPM, ASDPW, USGS, DOT
	Strengthen and Enforce Regulation	Strengthen the Project Notification and Review System (PNRS) to enforce zoning restrictions and limit new development in highly vulnerable areas.	**Estimated Cost: $** **Potential Funding:** ASDOC, FEMA, FPMS-Silver Jackets **Champion Agency:** ODAPM

	Focus	Recommendation	Potential Partners and Funding
			Other Potential Partners/Stakeholders: ASEPA, ASDOC, ASDPW, FEMA, Governor's Office, NOAA OCM, USACE
	Wave Exposure Analysis	Complete a wave exposure analysis to identify areas where ecosystem enhancement/green infrastructure solutions are feasible and/or where more durable structures are required.	**Estimated Cost: $** **Potential Funding**: USACE CAP/FPMS/ PAS/RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders**: FEMA, NOAA OCM, ODAPM, USGS
	Resilience Planning	Engage residents of vulnerable areas in long range village adaptation/recovery co-planning effort to combat the effects of climate change and SLC.	**Estimated Cost: $** **Potential Funding:** NOAA OCM, USACE FPMS/Silver Jackets,/PAS, PI-CASC **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** CRAG, ASDHS, ODAPM**,** UH Sea Grant, USACE, USGS
	Coastal Erosion Analysis	Complete a coastal erosion historical rate analysis and update the shoreline condition inventory to highlight high risk areas with rising sea levels and rapid subsidence levels.	**Estimated Cost: $** **Potential Funding:** USACE CAP/FPMS/ PAS/RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ODAPM, FEMA, USGS
	Expand Coastal Hazards System	Fund and implement expansion of the Coastal Hazards System, a probabilistic model for quantifying coastal hazards, to American Samoa.	**Estimated Cost: $$-$$$** **Potential Funding:** USACE, NOAA, FEMA **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ERDC/CHL, FEMA

Table ES-0-11. Saltwater Intrusion Recommendations

	Focus	Recommendation	Potential Partners and Funding
Saltwater Intrusion	Subsidence Study	Conduct study to identify areas affected by subsidence hotspots and promote LiDAR use to monitor subsidence zones.	**Estimated Cost: $-$$** **Potential Funding:** FPMS-Silver Jackets, USGS, FPMS, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** NASA, USGS
	Well Sampling Program	Develop a well sampling program to monitor key wells in the Tafuna-Leone Plain.	**Estimated Cost: $** **Potential Funding:** USACE PAS, USGS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** AS Community College, ASPA, UH

This page is intentionally blank. Main Report begins on next page.

1 Introduction

1.1 Study Authority

Authority for this Watershed Assessment (WA) is provided by Section 729 of the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662, title VII, Section 729), as amended, which authorizes the U.S. Army Corps of Engineers (USACE) to:

> *"Assess the water resources needs of river basins and watersheds of the United States including needs related to –*
> *(1) ecosystem protection and restoration;*
> *(2) flood damage reduction;*
> *(3) navigation and ports;*
> *(4) watershed protection;*
> *(5) water supply; and,*
> *(6) drought preparedness."*

This study is funded by the Additional Supplemental Appropriations Disaster Relief Act, 2019 (P.L. 116-20), which fully federally funded the WA, therefore a cost share agreement was not required.

1.2 Federal Interest

There is federal interest in conducting a WA to investigate strategies to increase community resilience from post-disaster effects in the territory of American Samoa (hereafter referred to as American Samoa).

1.3 Background, Purpose and Scope

Funding for this WA was provided in response to Tropical Cyclone Gita, which impacted American Samoa in February 2018. Gita generated destructive wind and torrential rainfall causing infrastructure damage and widespread power outages (Figure 1-1). Approximately 1,000 people were evacuated to 12 shelters. Multiple mudslides occurred, uprooting many trees, and the intense rainfall caused flash flooding in low lying areas and near small streams. The anticipated impacts of climate change are likely to exacerbate these and other threats to the resilience of American Samoa and its people.

Figure 1-1. Damage from Cyclone Gita in American Samoa (Source: Radio New Zealand, 2018)

This assessment recognizes and builds on the inherent resilience of Pacific Islanders' cultures developed over thousands of years of oceanic living, and *fa'asamoa*, the traditional way of governance. The intent of this WA is to provide recommendations both within and outside of USACE authorities that will help to improve the resiliency to future natural hazards in American Samoa.

The WA assessed economic, social, and environmental risks through engagement with federal and territorial agencies, subject matter expert consultation, and research with the most recent reports available. The following steps were used to develop the WA: assess the watershed characteristics; identify problems and data gaps; develop, evaluate, and prioritize an array of strategies that respond to the problems. Recommendations include structural and non-structural measures; include actions to be taken, implementation strategies, and potential funding opportunities for federal and territorial agencies to support the selected strategy.

1.4 Study Location and Background

American Samoa is an unincorporated territory of the United States located in the mid-South Pacific Ocean, a part of the Samoan Islands archipelago in Polynesia (see Figure 1-2) American Samoa consists of 70 villages across five main islands (Tutuila, Aunuu, Ofu, Olosega, and Tau), a smaller privately owned island (Swains Island), and one coral atoll (Rose Atoll) (Figure 1-3). Tutuila is the largest and most populous island, with a 58 square mile land area and approximately 48,000 residents. Aunu'u Island is 0.59 square miles and located one mile southeast of Tutuila, with less than 450 residents. The islands of Ofu, Olosega, and Tau are collectively referred to as the Manu'a Islands and are 2.8 square miles, 2.0 square miles, and 6.5 square miles respectively. They have a combined population of 850 and are located approximately 70 miles east of Tutuila.

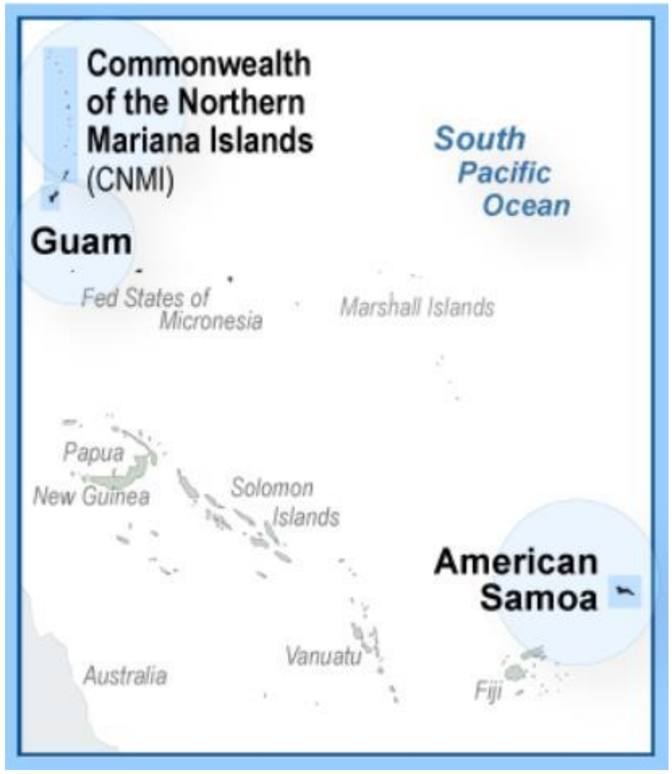


Figure 1-2. American Samoa in the South Pacific Ocean (Source: U.S. Government Accountability Office)

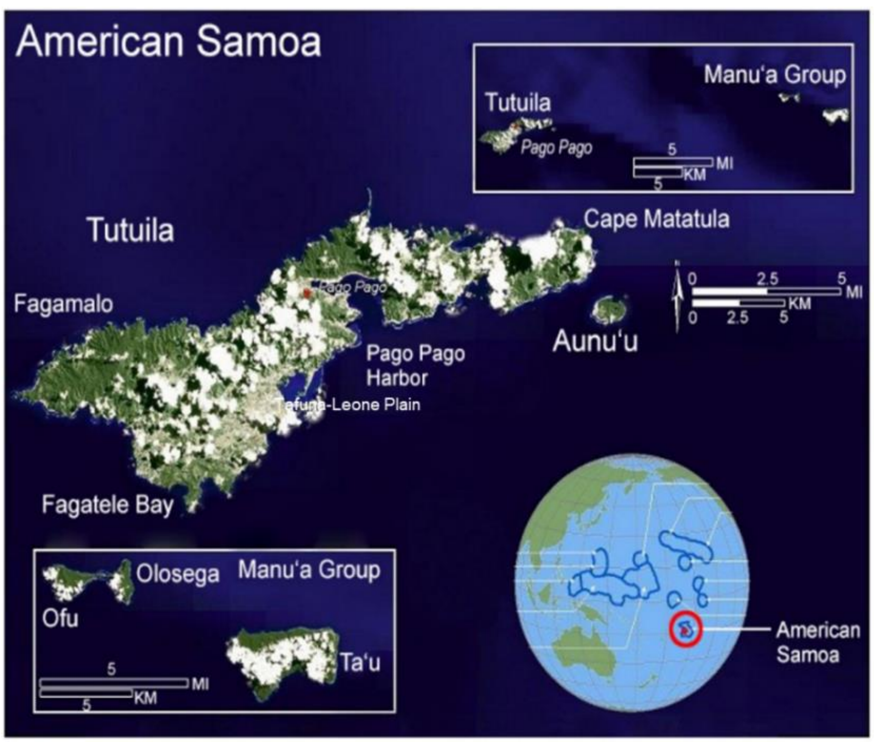


Figure 1-3. American Samoa Islands (Source: Pacific RISA)

American Samoa is represented by Congresswoman Aumua Amata Coleman Radewagen (R), a delegate to the U.S. House of Representatives.

Due to the steep terrain of the islands, most development, including critical infrastructure such as the Lyndon B. Johnson (LBJ) Tropical Medical Center, the primary petroleum tank farm, and the primary roads are located along narrow areas between the mountains and the shoreline. Even Pago Pago harbor, which is central to the economy of American Samoa, is built within very limited space between steep slopes and the coast. The Tafuna-Leone Plain on the southwestern area of Tutuila is the largest relatively flat area of all the islands and subsequently is the largest area of development.

1.5 Shared Vision

Per Engineer Regulation 1105-2-102 this WA aims to bring "stakeholders together in a collaborative approach that should result in a shared vision of possible future conditions." The shared vision statement, shown below, encompasses the perspectives of study stakeholders and was used as the basis for the development of planning objectives.

Shared Vision Statement
Natural hazards including tropical cyclones, flooding, shoreline erosion, landslides, and tsunamis negatively impact communities, the environment, and the economy in American Samoa. Many of these hazards are expected to intensify with climate change. A collaborative systems approach between stakeholders is needed to address these interrelated issues, improve watershed management, and support community resilience.

2 Interagency Alignment

The entire study process for the American Samoa Post Disaster WA involved broad stakeholder engagement with representation from federal, state, and local agencies and organizations. This interagency collaboration between partners working in and managing the watersheds in American Samoa is a critical aspect of the study, and the interactions played a crucial role in shaping the assessment.

Two months after this study was initiated, the COVID-19 pandemic struck the world and redefined how interagency partners engage and collaborate with each other. As a result, the study team relied almost entirely on virtual interactions across four time zones. Unable to go on a site visit early in the project, the study team communicated regularly with local partners and used existing data, reports, satellite imagery and photographs to better understand the study area. As the study progressed, interagency alignment and concurrence was obtained throughout the study process, from scoping the study to prioritizing actions.

2.1 Partners and Stakeholders

In accordance with Section 729 of the WRDA of 1986, as amended, cooperation letters were sent to the United States Environmental Protection Agency (EPA), United States Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS), Natural Resources Conservation Service (NRCS), American Samoa Historic Preservation Office, and National Park Service (NPS).

The USACE worked in collaboration with federal and territorial agencies, partners, and stakeholders to develop the WA, shown below in Table 2-1. For the purpose of this WA, a stakeholder is defined as any interested party, to include federal, territorial, and local agencies. The American Samoa Office of Disaster and Petroleum Management served as the primary study partner and was instrumental in ensuring collaboration with appropriate territorial and local agencies, partners, and stakeholders.

Table 2-1. American Samoa Watershed Assessment Partners

Organization	Focus Area			
	Rainfall	Coastal	Water Quality/Supply	Tsunami
Local Agencies				
Coral Reef Advisory Group (CRAG)	X	X	X	–
Office of Disaster and Petroleum Management (ODAPM)	X	X	–	X
American Samoa Environmental Protection Agency (ASEPA)	X	X	X	–
American Samoa Power Authority (ASPA)	X	X	X	–
American Samoa Department of Commerce (ASDOC)	X	X	–	X

Organization	Focus Area			
	Rainfall	Coastal	Water Quality/Supply	Tsunami
American Samoa Department of Public Works (DPW)	X	X	–	–
American Samoa Historic Preservation Office (HPO)	X	X	–	X
American Samoa Department of Port Administration	–	X	–	–
American Samoa Department of Homeland Security (AS DHS)	–	X	–	X
American Samoa Community College	–	X	X	–
National Park of American Samoa	X	X	–	–
University of Hawaii (UH)	X	X	X	X
University of Hawaii Sea Grant College Program	–	X	X	–
Federal Agencies				
USACE	X	X	X	X
U.S. Environmental Protection Agency (EPA)*	X	X	X	–
U.S. Geological Survey (USGS)	X	X	X	X
Dept of Interior* (DOI) [USFWS/NPS/Office of Insular Affairs/U.S. Geological Survey/ Pacific Islands Climate Adaptation Science Center (PI-CASC)]	X	X	X	X
Dept of Agriculture* (NRCS)	X	X	X	–
Dept of Commerce* [National Oceanic and Atmospheric Administration (NOAA) NMFS/Office for Coastal Management/National Weather Service]	X	X	X	X
Federal Emergency Management Agency (FEMA) (Region IX/Pacific Area Office)	X	X	–	X
Dept of Transportation (Federal Highways Admin.)	X	X	–	–
National Fish and Wildlife Foundation (NFWF)	X	X	X	–
National Aeronautics and Space Administration (NASA)	–	X	–	–

* Coordination required by Section 729 of the WRDA of 1986, as amended

USACE may investigate each of these four focus areas under various programs (see section 6.3), however the ability to implement projects will vary depending on alignment with USACE primary mission areas of flood risk management, coastal storm risk management, ecosystem restoration, and navigation.

2.2 Stakeholder Engagement

Partner involvement was a cornerstone for the development of the American Samoa WA. A wide breadth of partners was invited and encouraged to participate throughout all stages of the planning process and report development.

Most of the report development process coincided with the COVID-19 pandemic, which limited in-person meetings. As such, stakeholder engagement was conducted virtually over Cisco WebEx. Partners unable to join for plenary calls were invited to provide input through online forms.

Partner meetings were used to achieve the following:

- Determine study scope
- Develop shared vision statement
- Validate problem categories
- Preliminarily assess risk associated with problem categories and stressors
- Develop an initial array of measures and recommendations
- Seek input from subject matter experts in American Samoa
- Provide opportunity for stakeholder feedback and input

During the kickoff and scoping phase of the project, two plenary stakeholder engagement meetings (July and October 2020) and several one-on-one conversations were held to discuss the scope of the study and draft the Shared Vision Statement.

In November 2020, USACE hosted an all-partners call where interested parties were encouraged to comment on the Shared Vision Statement and assessment of problems, opportunities, objectives, and constraints. The team received positive feedback from partners on the Shared Vision Statement, problem categories, and planning goals. Additionally, partners shared their agency's priorities and existing tools to aid in the WA.

One-on-one meetings and a series of four targeted charettes were held with partners to gather information on stressors and problem categories. The team met one-on-one with partners from ODAPM, CRAG, UH, FEMA, and American Samoa Sea Grant. These discussions helped inform the inventory and forecasting process. Furthermore, the conversations discussed areas of high concern and possible implementation barriers including physical, political, technical, or fiscal constraints.

Major discussion points from these valuable one-on-one calls include the following:

- There is desire for green infrastructure and nature-based solutions from some agencies, but not all.
- Funding that requires a benefit-cost ratio (BCR) greater than unity tends to be harder for American Samoa to secure. Often the BCR is low due to the cost to transport materials and evaluation of benefits.
- The WA could inform the 2025 Hazard Mitigation Plan (HMP) update.

- FEMA is increasing funding opportunities for green infrastructure through programs like Building Resilient Infrastructure and Communities (BRIC).
- There is desire for hydrologic monitoring and data sharing program; potential to build interagency partnerships.
- Wells on the east side of Tafuna are shallow and yielding salty water. As a result, locals rely on bottled water. To move away from reliance on single-use plastics, the water quality must be improved.

The USACE team conducted a series of four virtual charrettes during June and July 2021, focused on each of the identified problem categories, listed below in Table 2-2. All WA partners were invited to participate in the charrette series. Each used online polling websites to solicit interactive feedback. Participants were asked to provide input on the problem statements, stressors, effects, potential recommendations, and potential implementation roadblocks. Several questions were focused on assessing the likelihood and consequence of problem categories and stressors. These inputs were used to inform the risk assessment. Additionally, participants curated an initial array of measures and recommendations to address the stressors. All questions asked during the virtual WebEx charrettes were also provided to participants as a Google Form to allow for additional input from partners unable to join the calls. Table 2-2 documents the attendance for the four charrettes.

Table 2-2. Charrette Meeting Schedule

Date	Topic/Problem Area	Participants
June 22, 2021	Rainfall	NOAA Office for Coastal Management; National Park of American Samoa; NASA; USFWS; CRAG; NRCS; American Samoa Department of Port Administration; American Samoa DPW
June 28, 2021	Coastal Flooding & Erosion	NOAA Office for Coastal Management; NASA; USFWS; NRCS; American Samoa EPA; ODAPM; American Samoa DPW; National Park of American Samoa; FEMA Region IX; CRAG
July 13, 2021	Landslides & Tsunamis	CRAG; FEMA Region IX; USFWS; American Samoa EPA; NASA; American Samoa Coastal Management Program
July 20, 2021	Water Quality & Supply	ODAPM; UH; NOAA Office for Coastal Management; Jamie Caplan Consulting; NASA; American Samoa EPA; USFWS

Figure 2-1. Preliminary Partner Risk Assessment and Figure 2-2 below illustrate the preliminary qualitative risk assessments performed in the charrette series. The preliminary risk assessments from the partner calls informed the USACE risk assessment (documented in Section 5). However, USACE considered additional details that led to differences in the two assessments. Measures and recommendations presented in partner calls are incorporated in the list of measures found in Section 6.2.

The preliminary risk assessment graph (Figure 2-1) represents that coastal flooding and erosion are the greatest risk relative to other stressors, as shown with the yellow dot in the upper right-hand quadrant. Conversely, tsunami risk poses the most severe consequences, yet it has the lowest likelihood of occurrence and the lowest risk relative to the other stressors, as shown with the dark blue dot in the lower right-hand quadrant. Rainfall poses the second greatest risk due to its high likelihood of occurrence, as depicted by a red dot in uppermost left-hand quadrant. The third greatest risk, water quality and supply, is represented by the green dot nearest the center of the graph. Landslides, shown with a light blue dot, have a lower likelihood of occurrence than the other two risks in the left-hand side and pose the fourth greatest risk. The preliminary prioritization graph below reflects the risk prioritization.

Figure 2-2 displays the initial hazard prioritization conducted with input from partners. The chart shows that coastal flooding and erosion along with rainfall and storms are the highest priorities to address. Later discussions in the WA explain the rationale and the inclusion of tsunamis as a catastrophic risk (Section 5).

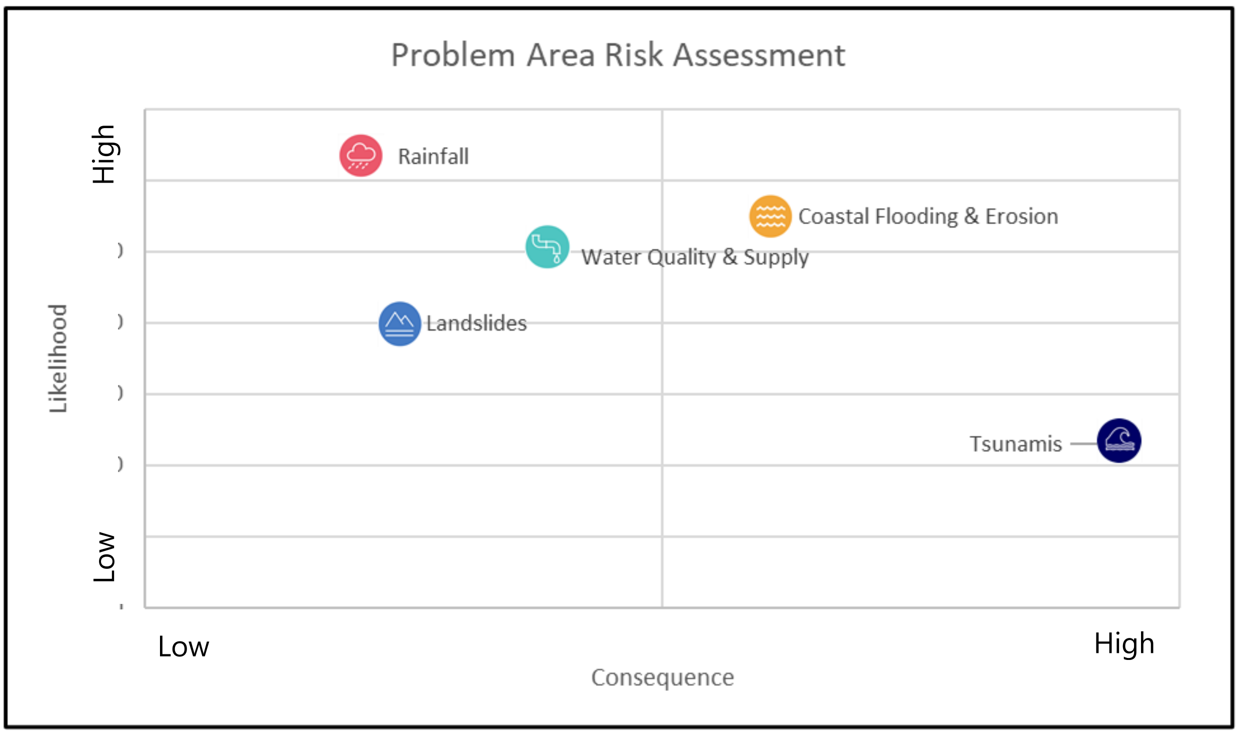


Figure 2-1. Preliminary Partner Risk Assessment

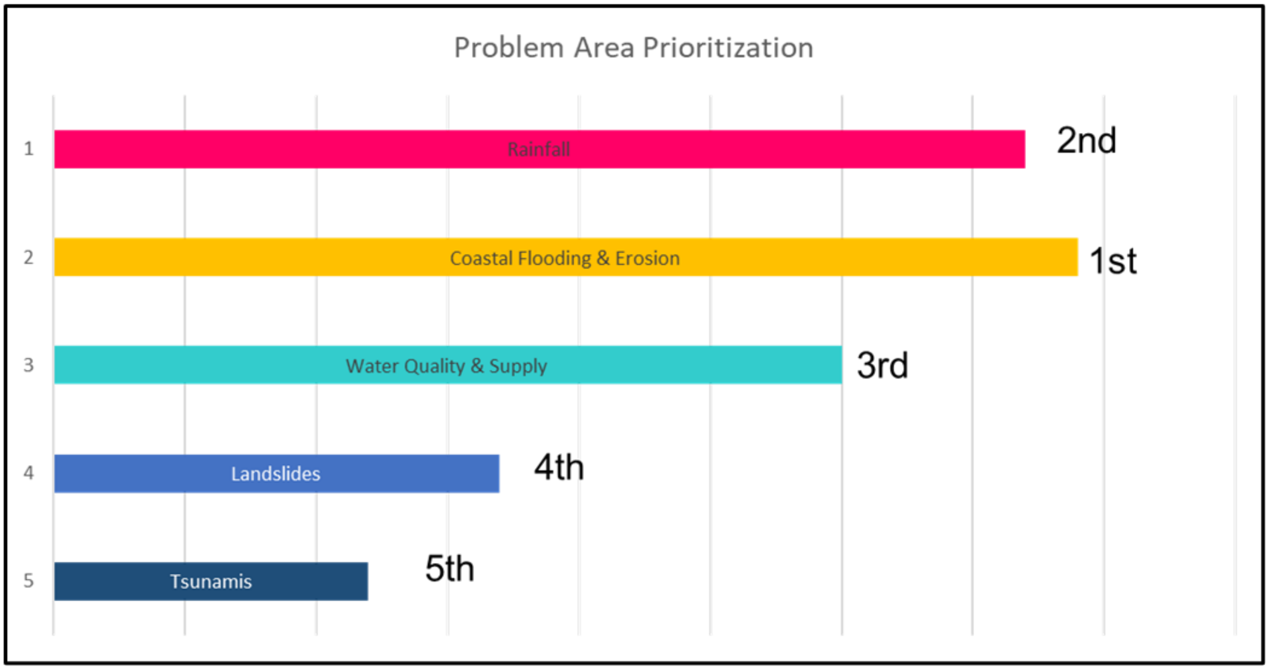


Figure 2-2. Preliminary Prioritization

Several partners were invited to attend the Shared Vision Milestone Meeting in January 2021 and Recommendations Milestone Meeting in October 2021, both focused on presenting project status and planned next steps to USACE senior leaders and project reviewers. The team received support from both partners and USACE leadership for the Shared Vision Statement and continuation of the WA at the Shared Vision Milestone and Recommendation Milestone. The ODAPM American Samoa Territorial Hazard Mitigation Officer provided opening remarks at both milestone meetings, emphasizing the importance of collaboration in her words.

2.3 Existing Reports and Initiatives

The following reports and initiatives were identified through the scoping process as either a key recent report, or a forthcoming initiative with a nexus to the goals of the WA that either inspired the development of this WA or will integrate with this effort in the future.

Area of Concern: Rainfall & Storms **Status:** On-going

Agencies: U.S. National Weather Service (NWS); Weather Service Office (WSO) Pago Pago; ASPA; and University of Hawaii Water Resources Research Center (UH-WRRC)

Improving Hydrological Data Collection to Support Flood and Weather Mitigation on Multiple Timescales in American Samoa (WSO Pago Pago, 2020): Supports warning systems and planning capacity by improving data capture and transmission at existing streamflow and data management sites maintained by ASPA and UH-WRRC. These data will provide additional information for NWS forecasts, nowcasts, and emergency alerts.

Areas of Concern: Rainfall & Storms **Status:** Completed
Agencies: Pacific PIRCA
Climate Change in American Samoa (PIRCA, 2021): Assessment of climate change indicators, impacts and adaptive capacity in American Samoa. Gauged more extreme rainfall and flooding, increasing air temperatures, and coral reef bleaching and loss.

Area of Concern: Rainfall & Storms **Status:** Forthcoming
Agencies: UH-WRRC
Daily Streamflow Forecasting in American Samoa by Machine Learning Approaches (UH-WRRC, n.d.): Uses artificial intelligence to accurately forecast short-term streamflow. It will help water resources managers, stakeholders, and decision makers to mitigate the risk of upcoming floods.

Areas of Concern: Rainfall & Storms **Status:** Completed
Agencies: USACE, Honolulu District; USACE, Huntsville Engineering Center; and US Army Health Facilities Planning Agency
Assessment of Health Care Infrastructure and Services Lyndon Baines Johnson Tropical Medical Center Pago Pago, American Samoa (USACE, HNC, & USAHFPA, 2019): This assessment addressed the declining and vulnerable condition of the Lyndon Baines Johnson (LBJ) Hospital in Pago Pago and evaluated five options to improve hospital conditions. The report calls for improvements to be made to the hospital, including options for relocation and/or renovation.

Area of Concern: Rainfall & Storms **Status:** Completed
Agencies: AS CRAG; NOAA Coral Reef Conservation Program
Promoting the Use of Green Stormwater Infrastructure in American Samoa, Prepared by Horsely Written Group Inc for AS Coral Reef Advisory Group (CRAG, 2019): Report presents recommendations on strategies to improve stormwater management and increase the implementation of green infrastructure practices in American Samoa.

Area of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: USACE, Honolulu District
Climate Related Vulnerability Assessment for Transportation Infrastructure: American Samoa – Final (USACE, POH, 2020): The study assessed the vulnerability of American Samoa's transportation assets to climate related hazards. In addition to infrastructure vulnerabilities associated with environmental factors, social characteristics that influence community resilience to climate related hazards were analyzed to inform mitigation project considerations.

Area of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: NASA Goddard Space Flight Center (GSFC)

Coastal Land Change due to Earthquakes and Implications for Sea-Level Rise in the Samoan Islands (NASA GSFC, 2019): Response to NASA research proposal to continue and expand geodesy measurements to help forecast sea-level rise.

Area of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: NOAA; UH
Sea Level Rise and Inundation Risks in American Samoa (NOAA & UH, n.d.): Compilation of working papers related to sea level rise or inundation risk in American Samoa. Intended to help American Samoan community understand and plan for risk related to sea level rise.

Area of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: NFWF; NOAA; and University of North Carolina Asheville, National Environmental Modeling and Analysis Center (NEMAC)
American Samoa Coastal Resilience Assessment: Stakeholder Engagement Read Ahead Materials (NFWF, NOAA, & NEMAC, 2021): Assessment identified community assets exposed to flooding threats, important fish and wildlife resources, and resilience hubs.

Areas of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: ODAPM
Updated Building Codes: ODAPM applied for FY22 FEMA grant funding to update American Samoa building codes to the 2018 International Building Code (IBC) standards from the 1964 IBCs. The application also included efforts for training and building code enforcement.

Areas of Concern: Coastal Flooding & Erosion **Status:** On-going
Agencies: USACE, Honolulu District
Tafuna Flood Risk Management Study (USACE, POH, 2022): Evaluated flooding problems and identified potential flood risk reduction alternatives along the Taumata, Leaveave and Vaitele streams. Evaluated site-specific flood risk management alternatives and developed (one/two-dimensional combination) HEC-RAS model (unsteady flow analysis) for the study area.

Areas of Concern: Coastal Flooding & Erosion **Status:** Completed
Agencies: NFWF; NOAA
American Samoa Coastal Resilience Assessment (NFWF & NOAA, 2021): Identified coastal areas that are ideal for the implementation of nature-based solutions that build both human community resilience and fish and wildlife habitat. Shares goal to help communities reduce adverse impacts to infrastructure and communities and improve habitats of fish and wildlife species.

Areas of Concern: Water Quality & Supply **Status:** Completed
Agencies: UH

Various scientific publications (Schuler et al., UH)*: Identification of effluent and nitrogen loading sources territory-wide. Identified water quality impacts, sources, and solutions. *Refer to the References section for full list of Schuler et al., papers used in the development of the Watershed Assessment.

Area of Concern: Water Quality & Supply **Status:** Completed
Agencies: ASEPA
American Samoa Integrated Water Quality Report (ASEPA, 2018): Evaluated water quality against standards, and the progress ASEPA made in maintaining and restoring water quality.

Area of Concern: Water Quality & Supply **Status:** Completed
Agencies: ASEPA
American Samoa Reef Flats Project Report (prepared by Nimbus Environmental Services for ASEPA, 2016): Recurring, 5-year national coastal condition "snapshot" assessment of reef flat water quality conditions in American Samoa.

Area of Concern: Water Quality & Supply **Status:** Completed
Agencies: UH
Stream Water Chemical Parameters for Tutuila Island, American Samoa (Bardi et al., 2005): Study that monitored chemical parameters of stream conditions. Results used toward establishing multi-metric indices of biological integrity for streams in American Samoa, allowing for rapid and accurate assessment of watershed health and a more complete understanding of processes driving freshwater ecosystems.

Areas of Concern: Tsunami **Status:** Completed
Agencies: USACE, Honolulu District
American Samoa Tsunami Study (USACE, 2012): Study that holistically evaluated tsunami risk in American Samoa following the destructive 2009 tsunami and offered a suite of recommendations to increase coastal resilience. The study process involved broad stakeholder engagement and collaborative development of a multi-year implementation plan.

Areas of Concern: Tsunami **Status:** On-going
Agencies: ASDHS; NOAA
Tsunami Education and Outreach: ASDHS conducts regular outreach and training for tsunami safety on a quarterly basis. The initiative is funded through a DHS and NOAA grant. Trainings have been provided across the territory, including in less populous villages.

Area of Concern: Multiple **Status:** Completed
Agencies: NOAA Pacific Regional Integrated Sciences and Assessments (RISA) Team and the East-West Center
Climate Change in American Samoa: Indicators and Considerations for Key Sectors Report for the PIRCA (PIRCA, 2021): Report summarized the observed changes and future projections in key climate indicators in American Samoa. It also described climate-related issues affecting families and households; extreme weather and climate change risks and considerations for managers and decision-makers; and needs for information and research.

Areas of Concern: Multiple **Status:** Completed
Agencies: USACE, Honolulu District
Climate Related Vulnerability Assessment for Transportation Infrastructure (USACE, POH, 2020): Vulnerability assessment of American Samoa's transportation assets to climate related hazards. Vulnerability indices created for transportation assets as well as for social vulnerability. Identified data gaps and future studies.

Areas of Concern: Multiple **Status:** Completed
Agencies: AS Governor's Office; AS Territory Hazard Mitigation Council (THMC)
American Samoa Hazard Mitigation Plan (AS THMC, 2020): Defined risks and vulnerabilities in a systematic manner and analyzed the vulnerability of critical structures with respect to mapped known natural hazard areas. Defined responsibilities and analyzed local capacities and capabilities. Included hazard mitigation strategy with hazard-specific actions.

Areas of Concern: Multiple **Status:** Completed
Agencies: AS CRAG
American Samoa Healthy Coral Reef Local Action Strategy (CRAG, 2020): Outlined a strategy to protect the health and resilience of American Samoa's coral reef ecosystems using scientific research and community engagement. Identified stressors to coral reef ecosystems. Included strategies for education and outreach, research, monitoring, and management (both village-based and territory-wide).

Areas of Concern: Multiple **Status:** On-going
Agencies: ASPA
Science, Technology, Engineering, Arts, Math (STEAM) Academy: The STEAM initiative provides mitigation education to high school students in American Samoa. Problem categories covered in this WA are included in the curriculum taught in STEAM. The program aims to develop a knowledgeable future workforce.

3 Watershed Planning Process

The USACE watershed planning process aims to provide a comprehensive and strategic evaluation and analysis that includes diverse political, geographic, physical, institutional, technical, and stakeholder considerations. To increase resilience to future tropical cyclone activity, a full range of water resources needs must be considered. Ecological impairments such as habitat loss can increase consequences of a typhoon. For example, loss of coral reef habitat may directly correlate to a reduction in the natural barrier to reduce storm surge. Likewise, upland deforestation can contribute to stream erosion and result in sedimentation in estuaries, increasing coastal storm risks to infrastructure. Unique water supply challenges and vulnerabilities may exist within a remote island environment, which, when further challenged by a tropical cyclone, could leave people without potable water for extensive periods of time.

In order to identify the full range of drivers and stressors that may contribute to increased risks associated with tropical cyclone activity, this WA considers all water resources needs, regardless of agency responsibilities, and develops a strategic roadmap to inform future investment decisions by multiple agencies, in coordination with local, territorial, and federal agencies.

This WA provides a suite of recommendations to enhance community resiliency and improve watershed management in American Samoa. It builds on the Pacific Islanders' inherent resilience from living on the land for thousands of years. The WA also incorporates available information from existing reports and on-going efforts from local and federal agencies. The goal of this process is to improve the economic, environmental, and social outcomes of water management decisions through facilitation of a common understanding of the natural resources system, allowing stakeholders to identify tradeoffs and management options.

USACE follows a six-step structured and iterative planning process as outlined in Engineer Regulation (ER) 1105-2-100, the "USACE Planning Guidance Notebook," and ER 1105-2-102 "Watershed Studies."

The six-step watershed planning process is:

1. Identify Problems and Opportunities
2. Inventory and Forecast
3. Identify and Screen Measures
4. Formulate Initial Array of Strategies
5. Refine Initial Array and Evaluate Focused Array of Strategies
6. Strategy Comparison and Selection

The American Samoa WA is following the Watershed Studies Guidance outlined in ER 1105-2-102 "Watershed Studies." This study process combines USACE traditional water resources planning, structured public participation, and collaborative systems modelling to work towards comprehensive and strategic evaluations and analyses. Figure 3-1 below illustrates the planning process for this WA and how the six-step planning process was used to formulate recommendations.

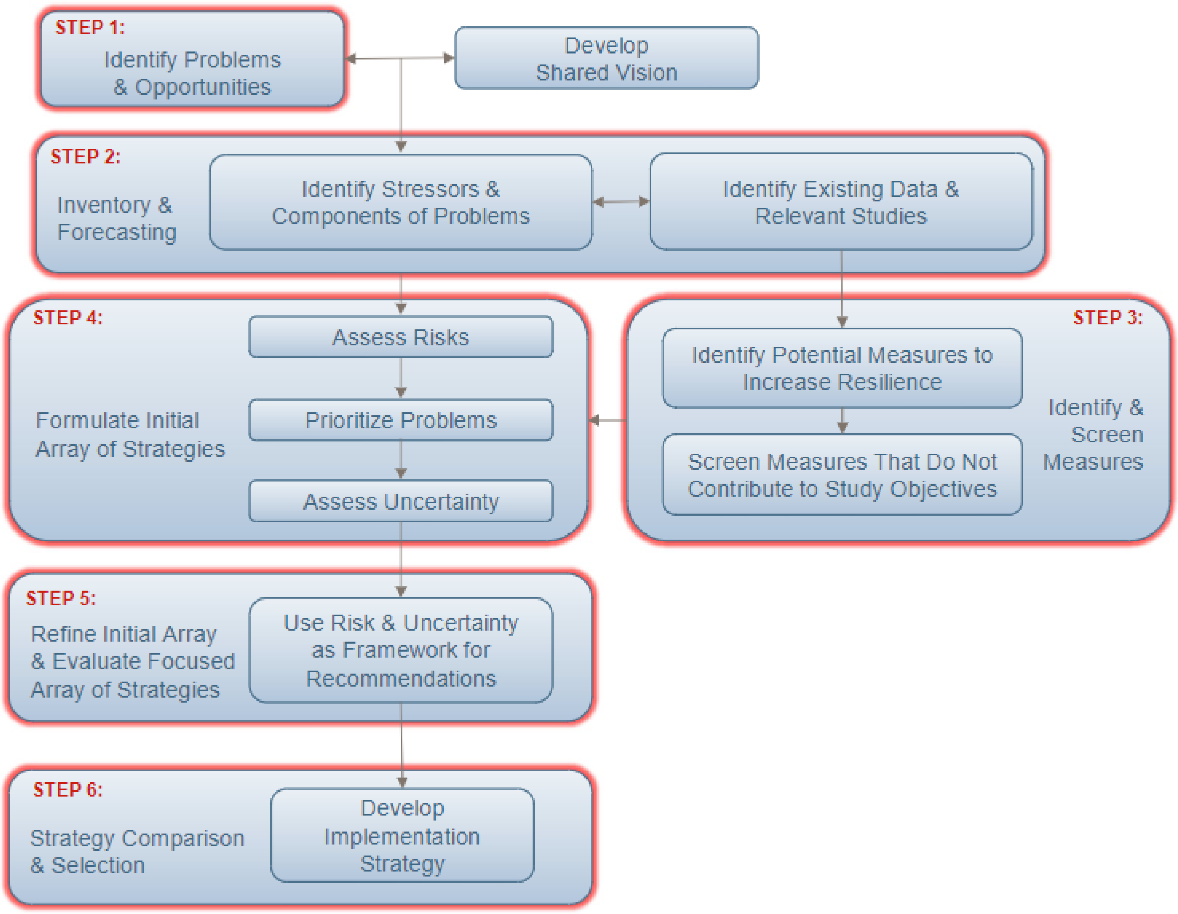
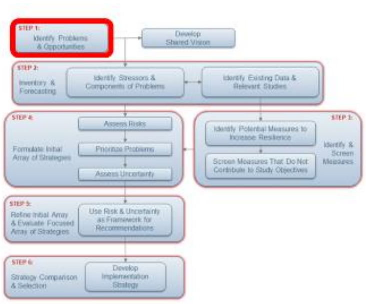


Figure 3-1. American Samoa WA Planning Process

3.1 Risk and Vulnerabilities/Problems



The problems were identified by focusing on natural hazards, past extreme events, community needs, local government interests, and the affected public. The problem statements were developed collaboratively with inputs from stakeholders and team subject matter experts and through extensive research and synthesis of existing reports. The colors of the problem statements are used throughout the document to denote what problem category the report is discussing.

Rainfall & Storms: Heavy rainfall, including tropical storms, cause high winds and riverine and overland flooding that impedes evacuation routes; conveys sediment and pollutants; damages homes, businesses, and critical infrastructure; causes public health and safety risks; and increases environmental degradation.

Coastal Flooding and Erosion: High surf, storm surge and coastal erosion, especially in low-lying coastal areas, threaten life safety; affect evacuation routes; damage homes, critical infrastructure, cultural sites, and businesses; and increase environmental degradation.

Water Quality and Supply: Water quality and the supply system throughout American Samoa are vulnerable to naturally occurring and anthropogenic stressors.

Tsunami: American Samoa is located in the Circum-Pacific earthquake belt and is particularly vulnerable to tsunamis. Locally generated tsunamis may provide only minutes to react and can cause extensive damage and loss of life.

3.2 Opportunities

Opportunities are future desirable conditions that may coincide with the solutions to the identified problems in the study area. The project team identified the following opportunities for this WA:

Opportunity 1: Improve surface and groundwater quality.

Opportunity 2: Improve the form, function, and natural processes of aquatic and riparian/shoreline ecosystems.

Opportunity 3: Increase sustainable and renewable energy sources that support an equitable and universal access to energy and a net-zero emission world.

Opportunity 4: Increase use of nature-based and nonstructural solutions to reduce the risk of storm impacts.

Opportunity 5: Leverage and develop collaborative interagency partnerships to address priorities and reduce data gaps for multi-hazard risk management.

3.3 Planning Goals and Objectives

The **goal** of this WA is to develop a framework to increase American Samoa's resilience to weather related hazards and reduce the effects of anthropogenic stressors through a focus on nature-based solutions, where appropriate. This WA will provide a strategic roadmap to inform future investment decisions by multiple agencies (i.e., involvement by USACE, other federal agencies, or non-federal interests). Presidential Executive Order 13653, "Preparing the U.S. for Impacts of Climate Change" (78 FR 66817) defines resilience as, "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover from disruptions." Objectives identify planning outcomes that define successful resolutions of the problems and attainment of the opportunities identified.

RESILIENCE means "the ability to **anticipate, prepare for,** and **adapt** to **changing conditions** and **withstand**, respond to, and **recover** from **disruptions**."
(Presidential Executive Order 13653)

Figure 3-2. USACE Principles of Resilience

Figure 3-2 shows the **USACE Principles of Resilience** which include prepare, absorb, recover, and adapt. Definitions for these terms come from Engineering and Construction Bulletin 2020-6.

Prepare: Considers the needs of a community or system to better withstand future disruptions.

Absorb: Enhances the ability of a community or system to endure a disruption and limit subsequent damage. This principle can also be used as an opportunity to consider adding system component robustness, redundancy, and increased reliability.

Recover: Stresses wise and rapid repair or functional restoration of a community or system following a disruption.

Adapt: Considers modifications to a project component or system that maintains or improves future performance based on lessons learned from previous events.

These definitions are used throughout the report to demonstrate how proposed measures and recommendations contribute to increasing resilience to weather related hazards and achieving the planning goal.

The project team identified the following study **objectives**:

Objective 1: Reduce life loss, injuries, and public health and safety risks from natural hazards in American Samoa.

Objective 2: Improve quantity and quality of inland and coastal ecosystems in American Samoa.

Objective 3: Reduce economic, social, and environmental impacts from natural hazards in American Samoa.

Objective 4: Improve territory-wide access to potable, municipal, and industrial water supply in American Samoa.

3.4 Constraints and Consideration

No specific planning constraints were identified for this WA.

Planning considerations represent key elements for the project team to keep in mind as the WA evolves; however, these elements will not necessarily limit the plan formulation process.

Consideration 1: American Samoa has a communal land system where some land is held by families. The *ability of families to move because of climate related threats or infrastructure relocation initiatives is limited*. Protective measures, including hard and green infrastructure solutions or structural elevations, are preferred to relocation of homes and businesses, to the extent practicable.

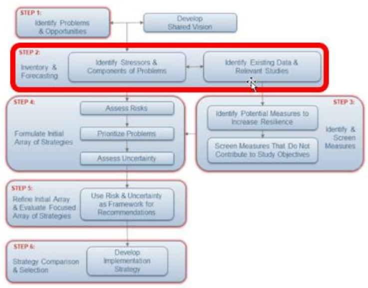
Consideration 2: *Relocation opportunities are limited* due to the steep topography and relatively small amount of developable land (e.g., with a 30% slope or less). Broadly, protection of existing land is a priority of local partners and stakeholders.

Consideration 3: *Climate change* is predicted to increase storm intensity and global sea levels, leading to exacerbated flooding. Climate change will be considered and integrated in all stages of the planning process.

Consideration 4: USACE will ensure collaboration and concurrence with partners on the recommendations set forth in the watershed assessment. However, *recommendations do not* *affect the administrative priorities of the American Samoa Government or federal and local agencies and carry no obligation to be implemented*.

Consideration 5: American Samoa has many undocumented cultural resources across the territory. Additionally, traditional cultural practices are an intangible cultural resource held village by village. *Recommendations need to consider cultural resources* and identify data gaps by considering cultural resource inventories or respectful engagement with villages prior to potential project implementation. The most successful plans will integrate traditional cultural practices and have community support.

4 Inventory and Forecasting



The second step of the USACE Watershed Planning Process is a thorough inventory and forecast of existing and future conditions. This section documents a hazard assessment of existing conditions with information drawn from partner input and the latest scientific literature. Understanding the underlying conditions is critical to formulating relevant and targeted recommendations to increase resiliency. This WA uses a 50-year forecast period of analysis for inventory and forecasting purposes. The 50-year forecast period of analysis for this assessment spans from 2022 to 2072. However, other agencies may have differing periods of analysis.

4.1 Existing Conditions and Risks

4.1.1 People, History, and Cultural Resources

Typical inventories for cultural resources focus on preserving tangible cultural resources such as a site, building, structure, object, or a district under state and federal historic preservation law. It is necessary for this WA to also consider the *intangible* cultural resources that play an important role for cultural identity across the territory today. The following sections summarize the human history of American Samoa to better understand the context of cultural resources.

Early settlement on the Samoan Islands occurred before the existence of written records. The earliest people to arrive in Samoa were Pacific seafarers known as the "Lapita" culture who sailed from the Bismarck Archipelago in Papua, New Guinea. Strong archaeological evidence of the Lapita people settling in Samoa comes from a site in the Mulifanua Village at Upolu Island, Samoa excavated during the 1960's. Many pieces of Lapita broken clay pots with a geometric design and dentate stamping were recorded and dated to around 3,000 years.

Artifacts and materials culturally associated with Samoa's early prehistory include pottery, stone tools like basalt adzes, volcanic glass, fishhooks, shell ornaments, and faunal remains. Other archaeological features to be encountered and listed respectfully in the Samoan language are fale (house foundations), lau mafola (terraces), pa (walls), foaga (grinding stones), and tia (platforms). The Lapita ancestors brought domesticated pigs, dogs, and chicken to Polynesia in addition to cultivation crops such as taro, yams, root crops, and breadfruit.

Researchers believe that pottery manufacture in Samoa ceased to exist around 1,500 years ago, beginning at around 300 A.D. (Clark and Michlovic, 1996) or even as late as 800 A.D. (Kirch, 1993). This period without pottery is known as the Samoan "Dark Ages" due to its poor representation in Samoan history and archaeology. Despite the uncertainty surrounding this period, these Dark Ages served an important role in the development of Samoan culture. The *matai* system that establishes the head of a descendant group and administers the family estates in a village or district's best interests (Stover, 1999) is believed to have developed during this time (Craig, 2009).

A majority of American Samoa's prehistoric sites are dated to the late prehistoric and early historic period. The material culture is dominated by large mounds, village settlements, quarry sites, raised pathways, agricultural terraces, and defensive fortifications. Structures like defensive walls, terraces, and mounds were built inland on high ridges of mountains while permanent village settlements were established along coastal areas where they were exposed to coastal hazards and storms. *Pa* (walls in Samoan) are a common feature built inland due to political warfare amongst the island's chiefs of Western Samoa and Tutuila. The *tia seu lupe* (star mounds in Samoan) are another significant structural site made from stone. Star mound platforms were built in the last 500 years and used to hunt pigeons as part of a traditional practice by chiefs.

American Samoa's prehistoric village complexes are identified by their central open space known as a *malae*. The malae is surrounded by village houses used for meetings, chief's houses, or simply dwelling places for village members. Certain village sites are still occupied and maintained by descendant Samoan communities and their *matai*s. Villages not occupied today were abandoned in the late prehistoric or early historic period and are either still visible on the surface or buried below the ground. The remnants of these abandoned village sites are viewed as cultural landscapes that play an important role in maintaining cultural identity (ASHPO, 2002).

Despite the influence of Christianity and European colonization, Samoan properties from the last two centuries still resemble their prehistoric remains including defensive fortifications, quarries, and star mound platforms. Village complexes today retain their traditional, cultural, and physical structures.

The first recorded contact with Europeans was in 1722 by Dutch explorer Jacob Roggeveen who took sight of the Samoan Islands during an expedition sponsored by the Dutch West India Company intending to establish a western trade route for the Maluku Islands. Soon after, French explorer Louis-Antoine de Bougainville sailed to Samoa in 1768 followed by French naval officer Jean François de Lapérouse in 1787. European missionaries began settling on the island and soon established Christian missionaries in 1830. For example, the Atauloma Girl's School and the Fagalele Boy's School in western Tutuila educated Samoan children and converted them from traditional religious practices to Christianity. Along with European traders and military personnel, Pacific Islanders from the Cook Islands who were associated with the London Missionary Society and Tongans missionaries working with the Methodists started settling on the Samoan Islands.

Historic properties associated with the Samoan Island's European encounters include those buildings that served as parochial schools and military facilities. A massacre monument at Aasu, Massacre Bay is dedicated to the killing of Lapérouse's 12 crewmembers who encountered 1,500 Samoans near the coast before a violent confrontation ensued.

By the late 19th century, the Samoan Islands were partitioned by the provisions set forth in the 1899 Treaty of Berlin. The treaty was established after rising tensions between the United States, Germany, and Great Britain, all saw strategic value in claiming Samoan lands to establish trading stops and naval stations (Tapu, 2020). The Tripartite Treaty of 1899 granted all rights of the eastern Samoan islands to the United States forming the unincorporated territory of the American Samoa today. Germany was granted the rights of the western islands Upolu and Savai'i, which today function as the Independent State of Samoa.

There are many Historic properties tied to the U.S. Navy's control of American Samoa from 1900 to 1951 that stand today. The territory was a coaling station during World War II and provided a strong Pacific defense location during the war. American Samoa's historic resources associated with World War II include military fortifications and districts, government buildings, medical or training facilities, air bases such as the Tafuna Airfield, gun emplacements, and pillboxes lined up along the coastline of American Samoa (ASHPO, 2002). Other historic resources include submerged maritime shipwrecks lost near the American Samoa waters that were linked to British colonization, the whaling industry, and World War II naval activities. Naval aircrafts were also reported as abandoned or having crashed into the Pacific Ocean near American Samoa between 1942 and 1944 (Van Tilburg, 2007).

Intangible cultural resources are also essential to consider for the recommendations proposed by this WA. The Samoan way of living known as *fa'asamoa* in Samoan remains deeply embedded in American Samoa's culture, government, and physical landscape. Samoan legends and traditions that surround the territory's natural features have become a part of *fa'asamoa*. Identifying and preserving these traditions are a unique yet challenging opportunity in this effort. The National Register Bulletin 38 has addressed this issue by defining a category of protected cultural resources known as Traditional Cultural Properties (TCP). This guidance defines a TCP as a historic property eligible for inclusion in the National Register of Historic Places because of cultural practices or beliefs for a living community's history and maintaining their cultural identity (Parker and King, 1990).

One example of an intangible cultural resource associated with a natural feature is the Samoan word *tupua*, which refers to special rocks or formations that represent ancient humans. This idea can also apply to water resources like freshwater springs or passages in a reef which have cultural associations with ancient Samoan folklore as non-human beings.

Past conservation strategies include outreach to villages to improve the documentation of intangible cultural resources. Village outreach can also help agencies understand how intangible heritage plays an important role for Samoan culture. Responses from villages and local residents indicated that intangible cultural resources have "…extraordinary significance to Samoan culture. Compared to all of the archaeological and historic sites that the Historic Preservation Office tries to protect, these sites are seen as the most significant to local residents." (Volk et al., 1992).

Additional information on history and cultural resources can be found in Appendix E – Cultural Resource Analysis.

4.1.2 Economy and Infrastructure

The location of American Samoa relative to the U.S. mainland has led to challenges for a diversified economy. The StarKist Tuna Cannery is vital and central to the economy of American Samoa. It is the last remaining cannery, and local opinion shows a low confidence that the cannery will remain open in the future (ASDOC, 2019). Eighty percent of the islands' exports are from canned and pouched tuna, leaving it susceptible to an economic shock. For example, a loss of StarKist could cause the loss of nearly 2,500 jobs and drop exports by approximately 80%.

Employees in American Samoa generally earn lower wages when compared to the continental US, averaging $16,415 annually (US Census Bureau, 2017). The main employment sectors are Manufacturing, Retail Trade, Health Care and Social Assistance, Accommodation and Food Services, and Construction (US Census Bureau, 2017). There is no defined federal poverty line for American Samoa, but in fiscal year 2021, 75% of the population was considered to be eligible for Medicaid and the Children's Health Insurance Program (CHIP).

According to the American Samoa Comprehensive Economic Development Strategy, the sector seen locally as having the most potential for growth is Information Communication and Technology. This confidence stems from large government investments in fiber optic cable infrastructure on the islands. The other sectors seen as being potentials for growth were capital investment projects leveraging new investors, eco and general tourism, and federal expenditures such as grant programs (ASDOC, 2019).

As previously mentioned, development within American Samoa is concentrated along the coastline due to the steep topography of the islands. Most structures are located within the Eastern and Western Districts on the Islands of Tutuila and Aunu'u, with additional structures within the Manu'a District islands of Ofu, Olosega, and Ta'u. Overall, there are approximately 11,805 structures in American Samoa, 11,152 of which are on the islands of Tutuila and Aunu'u. Figure 4-1 shows critical infrastructure on Tutuila.

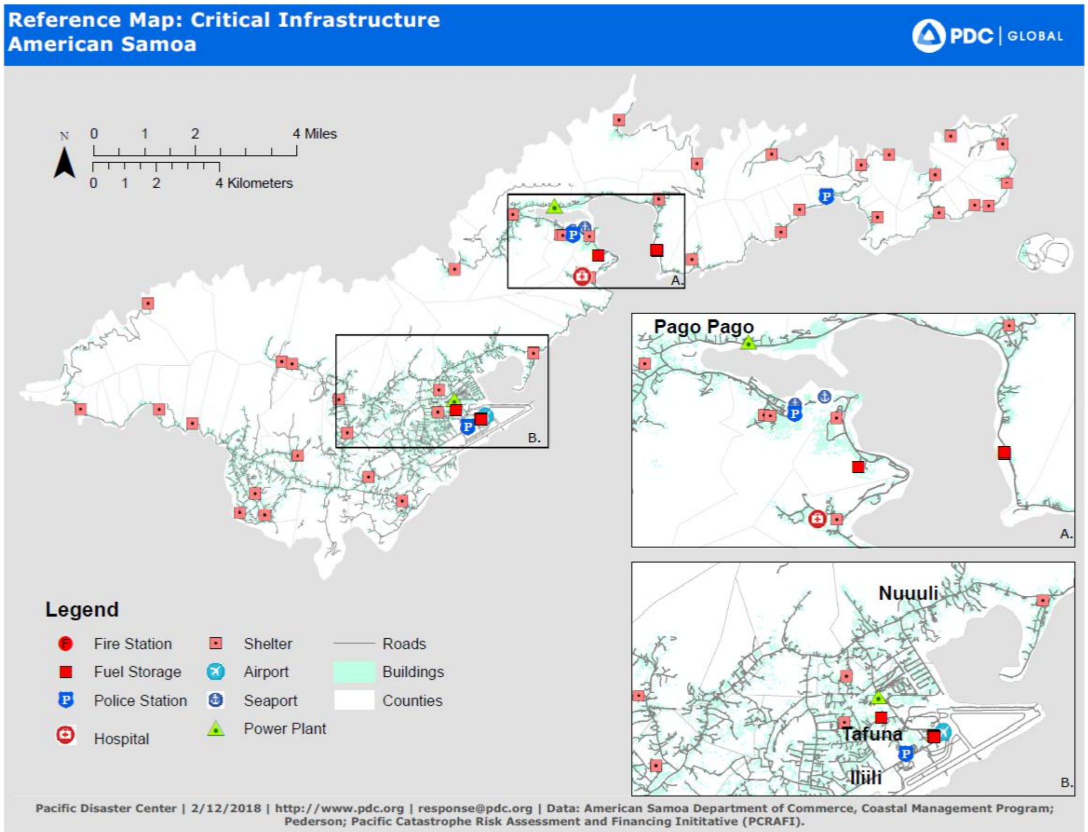


Figure 4-1. Tutuila Critical Infrastructure (Source: Pacific Disaster Center, 2018)

American Samoa produces 97% of their electricity using diesel generation, with the remaining 3% from solar power. The diesel generation plants for Tutuila are located near the airport on the Tafuna Plain, and on the northern coastline of Pago Pago harbor in areas that are at risk to coastal storms. Most of the solar generation is from the newly constructed Ta'u photovoltaic site, which supplies 100% of the island's generation and accounts for a total of 13% of the total generating capacity for the islands. However American Samoa only partially utilizes this capacity due to the photovoltaic site being on the island of Tau which has a small population and not having an effective method to transmit the generated solar power to Tutuila. Because of this, solar only accounts for 3% of the energy generation despite the additional capacity the photovoltaic site provides. The Ta'u site alone reduces American Samoa's dependency on imported diesel fuel by 100,00 gallons per year (EIA, 2022).

The Linden B. Johnson (LBJ) Medical Center is the sole hospital for American Samoa. Located in Faga'alu on Tutuila, the center was assessed by USACE in 2019 in response to Hurricane Gita. The USACE report found that the hospital was in a state of physical failure due to age, exposure, and lack of preventive maintenance. At the current rate of degradation, the hospital may be unable to provide sufficient space to properly support long-term patient care and risks the denial of accreditation in the future. The construction of a new facility near the airport on Tutuila was proposed in 2016; however, there were major concerns that the length of time needed to reach the hospital from the eastern villages would be too long during an emergency and was therefore considered prohibitive. The USACE report recommended instead to replace the existing facility, and complete interim repairs to deficient systems immediately (USACE, HNC, & USAHFPA, 2019).

Appendix B – Economics and LifeSim contains additional details on the economy and infrastructure of American Samoa.

4.1.3 Environmental and Land-Use Considerations

The natural vegetation of American Samoa is tropical rainforest, due to the warm climate and year-round rainfall. In American Samoa, native forests extend from the seashore up to the highest mountain peaks (Figure 4-2). Topographical variation, along with human and natural disturbances, have influenced the growth and distribution of various rainforest types across American Samoa's landscapes.

Figure 4-2. American Samoa Vegetation (Source: NOAA OCM)

The topography of American Samoa includes steep volcanic slopes and flat narrow coastal plains and constrains land use and development. To sustain American Samoa's increasing population, important forest habitats have been cleared and replaced by agriculture, residential, commercial, and business development. The combination of limited flat lands and high demand for lands suitable for growing crops, building roads, homes, and businesses have significantly increased pressure on the forests. The main island of Tutuila contains 34,082 acres of land, which is 70% of the total land area for American Samoa. Only 18,626 acres have less than a 45% slope, limiting areas for development and agriculture. Rainfall supplies the only freshwater source to the islands.

Most people in American Samoa live in Tutuila near the coast. Despite the limited agricultural land, there is a semi-commercial production of taro, bananas, tropical fruits, nuts, and vegetables. Traditional family gardens produce coconuts, breadfruit, and yams, and production nearly meets domestic needs (Pacific RISA, 2022). Fruits and nuts were the top commodity group in American Samoa in 2018, with a combined value of $20.5M in consumption and sales, followed by field crops, melons, and vegetables ($18.3M) (USDA, 2018). 4.6% of the employed population also participated in subsistence activities, like farming and fishing, per the 2010 US Census data (US Census Bureau, 2010).

The indigenous people of American Samoa have preserved their traditional lifeways, known as *fa'asamoa*, for thousands of years. The Samoan people take pride in incorporating their unique traditional practices into their system of governance from management of the land and its resources to land ownership (Tapu, 2020). For example, the two foundations of *fa'asamoa* within customary land ownership follows a system of communal land tenure passed on by families and the *matai* system. The *matai* title relates to the hierarchical position reflected in Samoan life from the *'aiga* (meaning "family" or a title holder's descendant group), to a village, district, or even an entire island. A specific plot of land is connected to a *matai* who is tasked with decisions for its land use by immediate family members and village members (Tapu, 2020) and arguably those outside of the village without Samoan ancestry.

The role of *matai* as leaders of their ancestral lands is traditionally led by men but can sometimes include women. The *matai* are assigned through a consensus vote by the *'aiga*. This bestows the title upon an individual for a lifetime unless removed by the Samoan judicial system.

The American Samoan Constitution, adopted in 1929 and revised in 1960, has merged United States mainland and Samoan concepts together, allowing the territory to create three branches of government like the United States. American Samoa Senators must be registered *matai* holders, and they must commit to protecting "lands, customs, culture, and the traditional Samoan family organization of persons of Samoan ancestry" (Tapu, 2020).

The American Samoa government upholds policies that limit land ownership to people of Samoan decent, and a significant portion of the island's land is owned under communal village governance. Land tenure includes five ownership types: communal lands (88.4% of land) owned by *aiga* (extended families) of a village, government lands owned by the American Samoa Government (3.4%), freehold lands and individually owned lands owned by private landowners (4.0%), and church lands owned by religious denominations (2.1%). The communal land ownership system may present challenges with implementation of some types of structural and non-structural recommendations. Many areas lack clear ownership and title records due to the land ownership system. Without the necessary data to determine property owner consensus, buyout or relocation analysis may be difficult, and it is likely more realistic and practical to elevate or flood proof structures.

4.1.4 Ecosystems and Resource Management

Eight natural plant communities can be recognized in American Samoa: (1) Littoral Strand, (2) Marsh, (3) Freshwater Forest, (4) Mangrove Forest, (5) Lowland Lava Flow Rainforest, (6) Montane Forest, (7) Montane Scrub, and (8) Summit Scrub, shown in Figure 4-3 (Whistler, 2002). Littoral Strand comprises the forest, scrub, and herbaceous zones influenced directly by the surrounding coastline. Littoral forests provide habitat for several wildlife species including flying foxes, seabirds, and nesting sea turtles.

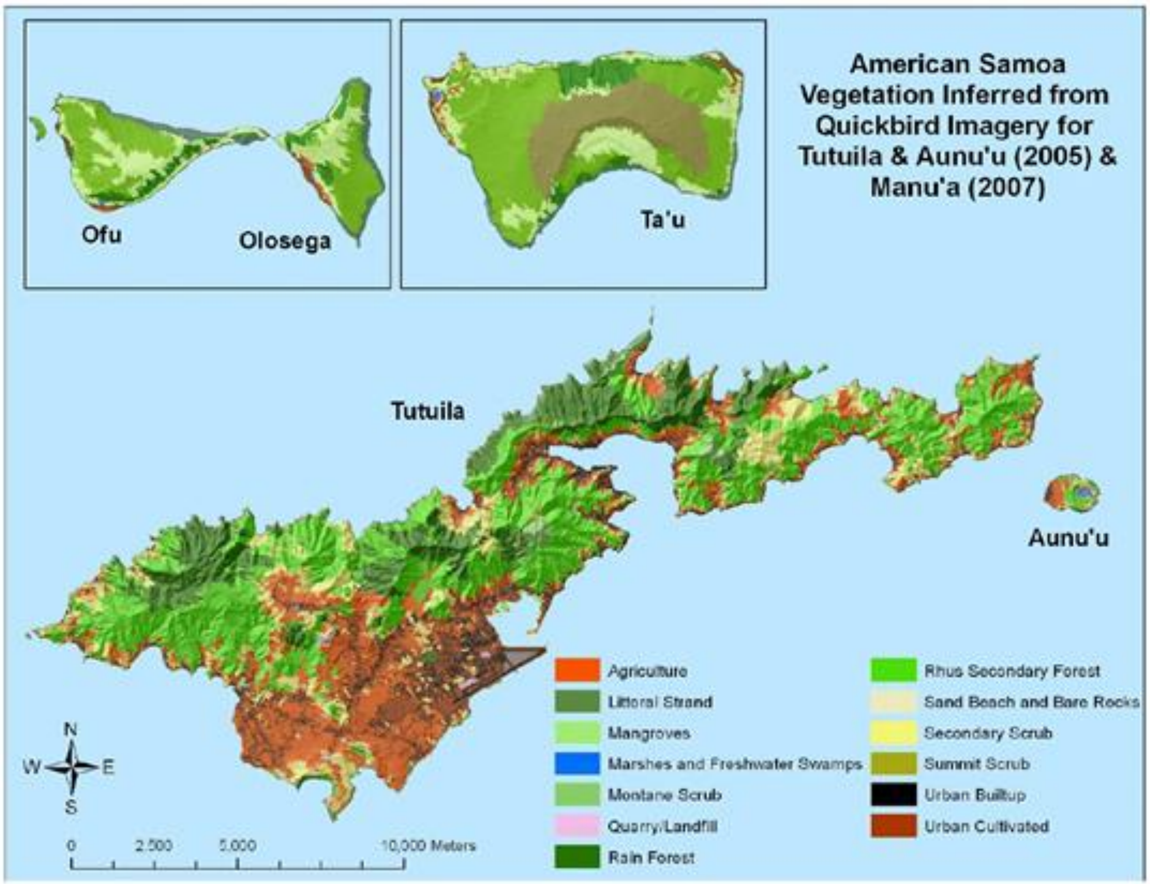


Figure 4-3. Vegetation Types in American Samoa (Source: Forestry Program, 2010)

Marsh, Freshwater Forest, and Mangrove Forest are classified as "wetlands," but they comprise only a small percentage of the overall land area of American Samoa. Less than 400 acres of wetland remain and 48% have been degraded or lost (Forestry Action Plan, 2020). American Samoa's wetlands and mangroves are jurisdictional waters of the United States and thus protected under Rule 8-80 (Ex. Ord. 03-80); ASCMP Reg. (Ex. Ord. 07-88); Rule 2-97, effective 4 Aug 97. Out of the seven islands that comprise American Samoa, mangroves occur on only two, Tutuila and Aunu'u. Lowland lava flow rainforest occurs on the Tafuna Plain in Tutuila and has been lost to human development. This threatened forest community sits directly above important aquifers from which the community receives most of its drinking water. Most of the rainforest between the coastal areas and the mountain peaks are *Rhus taitensis* (tavai or sumac) secondary forest, and they grow in areas once disturbed by humans or natural hazards, such as cyclones. Much rainforest remains, especially on the north side of Tutuila and in scattered patches on the Manu'a Islands. Additional information on terrestrial habitats can be found in Appendix D – Environmental Analysis.

The unique coral reef habitat that characterizes the fringing reefs of American Samoa merits special concern. Generally, coral reefs are threatened by poor water quality, climate change, over-fishing, and other anthropogenic activities. They are particularly vulnerable to climate change and are harmed by coral bleaching, ocean acidification, increased storm occurrence and SLC. Coral bleaching can occur from prolonged exposure of the corals to increased sea surface temperature (SST). Bleaching then leads to coral mortality and has lasting effects on coral ecosystem community structure. Scleractinian corals are the primary habitat builders in American Samoa and are already living close to their thermal threshold (Hoegh-Guldberg, 1999). This means that modest changes in temperature affect their ability to survive.

Of the 70 villages in American Samoa, 20% have resource management plans in place, 7% of coral reef area is under no-take designation, and 25% of coral reef area is designated under management. Management actions such as regulating SCUBA spearfishing, protecting large reef species, and relocation of tuna cannery outfall pipes have worked to mitigate some of the impacts from these activities and protect the coral ecosystem (NOAA CoRIS, n.d.).

4.1.5 Climate

Climate preparedness and resilience activities are considered and recognized in all USACE studies to ensure reliable project performance due to changing future climatic conditions. Changing climatic conditions could result in changes to storm intensity, frequency, and duration which may potentially have wide ranging effects to USACE projects. Coastal effects include increased shoreline erosion and the associated increased coastal storm risk, and increased frequency of overtopping for coastal levees. Increased rainfall intensity and duration could lead to inland hydrologic effects such as altered channel sedimentation that can increase flood elevations, increased reservoir sedimentation that reduces storage for flood control and water supply, further leading to an inability to provide necessary water pumping capacity.

The engineering analyses, consistent with ER 1100-2-8162 (Incorporating Sea Level Changes in Civil Works Programs) and Engineering and Construction Bulletin 2018-14 (Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects), incorporate existing climatic conditions, and expected future changes to specific coastal and hydrologic baselines. These changes in baseline conditions are based on published information and are not determined in this study and are included for reference only. However, since no specific projects are recommended in this report due to the intent and focus of watershed assessments, no specific and direct effects due to climate change are determined. More information about the existing and future climate can be found in the Engineering Appendix (Appendix C).

American Samoa is south of the equator with coordinates at roughly 14 degrees south and 170 degrees west. It is east of the Pacific date line in the Central South Pacific. Given its tropical location, relatively small seasonal variations in annual air temperature occur in American Samoa. Only 2 to 6 degrees Fahrenheit difference exists between the warmest and coolest months.

The wet season in American Samoa is generally December through March; however, trace precipitation is recorded about 300 days of the year. Rainfall averages between 125 and 250 inches per year and are seasonally and locality dependent. Humidity ranges between 73% to 84% (NOAA, 2013). Annual temperature averages have increased by 3 degrees Fahrenheit since 1957 (USACE, POH, 2020). Annual maximum temperatures have changed by roughly 0.5 degrees Fahrenheit from 29-year normals, based on data from 1991-2020, (NOAA NCEI, 2020) and are illustrated by the diagonal dotted blue line in Figure 4-4.

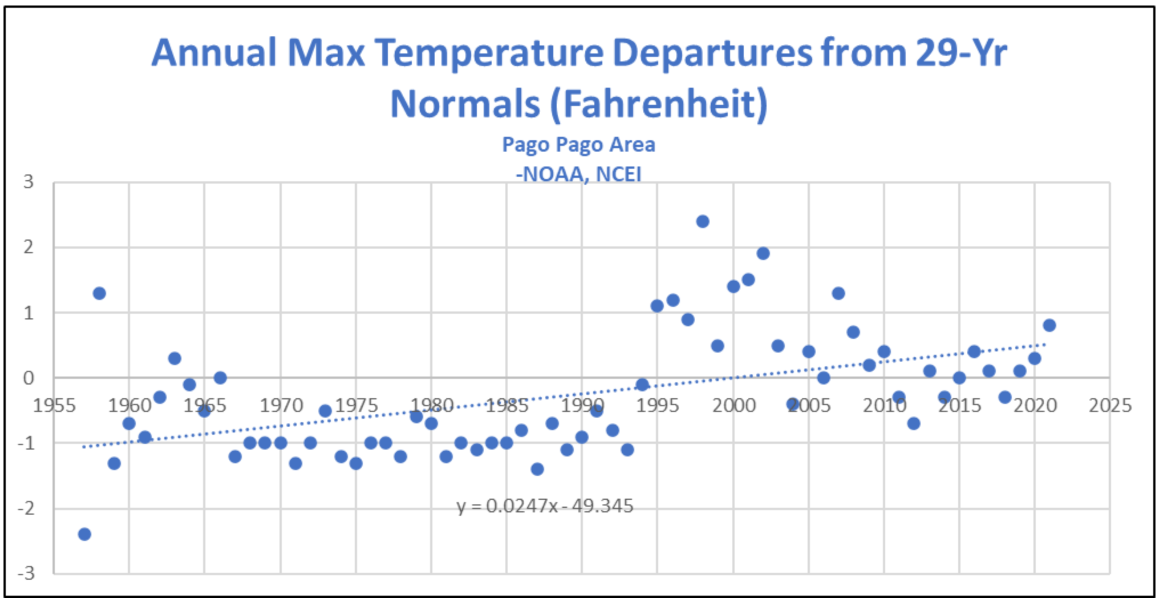


Figure 4-4. Pago Pago Annual Maximum Temperature Departures from Normals (Source: NWS Weather Data)

Annual precipitation has also slightly increased by roughly 8 inches from 29-year precipitation normal (1991-2020) and are illustrated in Figure 4-5.

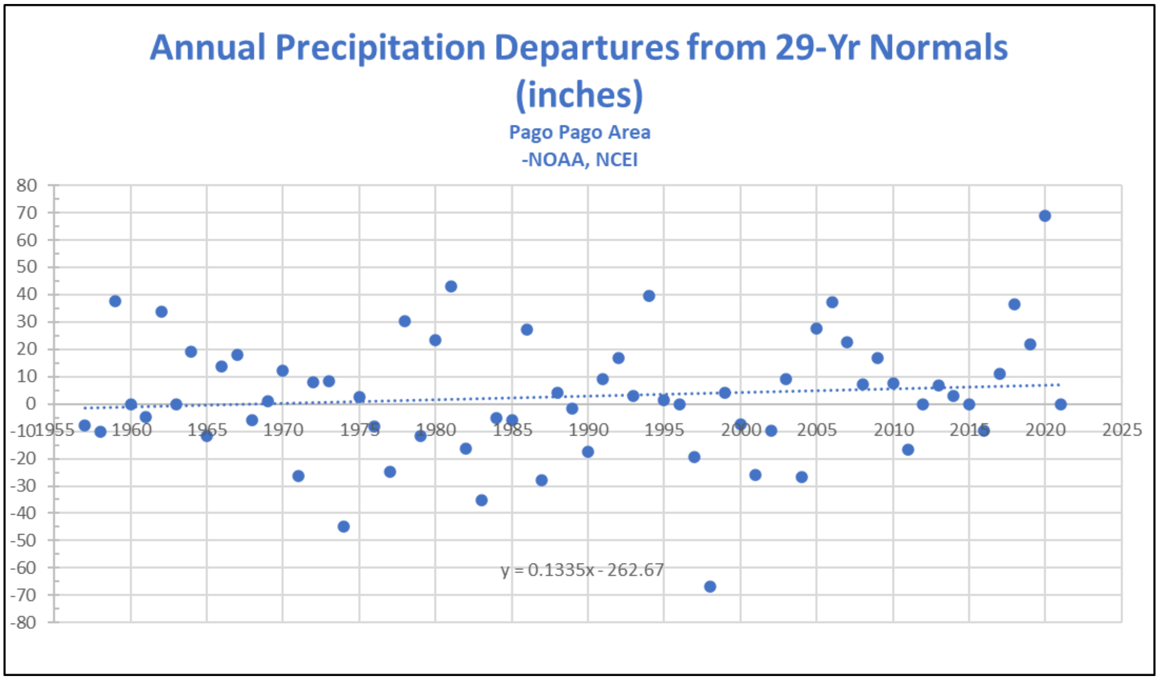


Figure 4-5. Pago Pago Annual Precipitation Departures from Normals (Source: NWS Weather Data)

Climate impacts sea level, coastal storm surge, tropical cyclone intensity, agriculture, transportation, power, cultural practices, and the economy and is significantly tied to El Niño Southern Oscillation (ENSO) fluctuations. ENSO consists of three phases, Neutral, El Niño and La Niña, with average durations between 9 and18 months.

The relationship between El Niño and La Niña cycles and the Southern Oscillation is a relationship between oceanic SST and the atmospheric pressure gradient, respectively. In neutral conditions the Pacific trade winds are driven westward owing to changes in the atmospheric pressure gradient across the Pacific, where lower atmospheric pressures in the western Pacific and higher pressure to the east drive trade winds and warmer SST westward. Consequently, cooler SSTs observed in the eastern Pacific. Higher SSTs transfer heat to the atmosphere, which, in turn, change the pressure gradient. In other words, the pressure gradient affects the SST and the SST affects the pressure gradient. This circulation is referred to as the Walker Circulation.

Under El Niño conditions, trade winds weaken, allowing warmer western Pacific waters to migrate eastward. This results in lower sea levels and SST in the western Pacific and higher sea levels and SST in the eastern Pacific. Sea surface elevations can fluctuate from El Niño and La Niña events by as much as 0.7 to 1.0 feet (IPRC, 2014). During El Niño the western Pacific experiences reduced rainfall and drought conditions, while the eastern Pacific experiences wetter conditions. Under La Niña conditions, trade winds increase, resulting in significant pooling of warm water and higher SST in the western Pacific, increased sea levels, and increased convection. Correspondingly, lower

SST, lower sea levels, and reduced convection occurs in the eastern Pacific (NOAA, 2021). See Figure 4-6 below for an illustration of ENSO cycles.

Tropical cyclones thrive off warm ocean waters. El Niño effectively discharges heat into the ocean, leading to intensified tropical cyclones (Rupic et al., 2018). ENSO affects climate and weather patterns which impact precipitation, cyclones, and sea levels, saltwater intrusion, aquatic life, and reef mortality.

Increasing surface water temperatures and SLC are presently observed on American Samoa and are expected to increase with climate change. SLC creates higher water surface elevation profiles that increase backwater in estuaries. Flooding along coastal infrastructure currently impacts commerce and egress; therefore, SLC will further exacerbate the situation. NOAA (2021) estimates that Tutuila will experience 8.9 millimeters per year of SLC. SLC is expected to also affect water supply adversely by increasing saltwater intrusion in freshwater sources. Appendix C – Engineering Analysis provides additional details on American Samoa climate considerations.

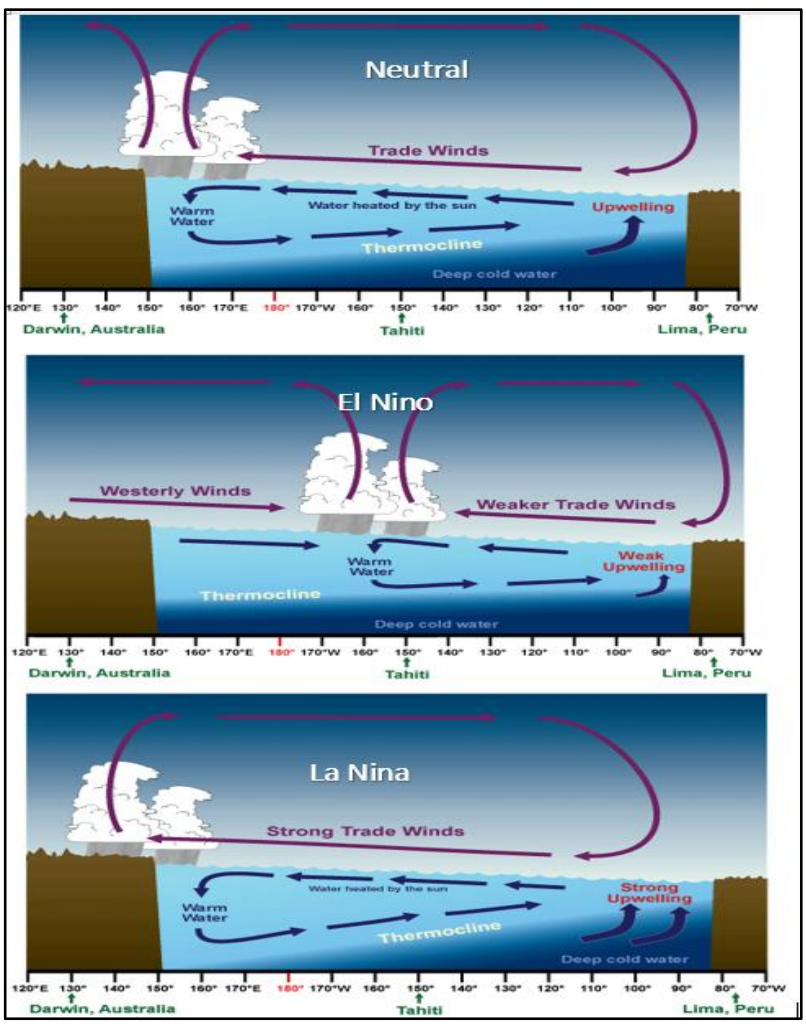


Figure 4-6. ENSO Fluctuations in the Pacific: Neutral, El Niño, and La Niña (Source: NOAA)

4.1.6 Rainfall, Storms, and Flooding

American Samoa has suffered substantial damages from tropical storms and rainfall events. Rainfall and high winds have contributed to property damage, and landslides from rainfall and flash floods have led to life loss. Some of the most significant storm events in American Samoa include flash floods in 2003, Hurricane Heta in 2004, Tropical Cyclone Olaf in 2005, a tsunami in September 2009, severe storms and flooding in 2014, and Tropical Cyclone Gita in 2018. Constant heavy rain during hurricane season and severe landslides have caused considerable damages such as life loss, damages to homes, businesses, government buildings, and infrastructure. Population growth and development continue to increase the vulnerability of American Samoa to natural hazards.

American Samoa's proximity to the most active tropical cyclone belt in the southwest Pacific Ocean renders the islands and their inhabitants exposed to tropical storms. Over the last 50 years, American Samoa was impacted by nine major hurricanes, with combined losses greater than $300M. Additionally, smaller, more frequent rainfall events have the potential to cause damage to infrastructure, the economy, and the environment.

Monsoon and tropical cyclones saturate the soil and prevent infiltration, so even small rain events that occur after these storms can result in significant stormwater runoff onto streets and into waterways. American Samoa's steep topography also contributes to shallow soils and increases stormwater runoff. The Tafuna Leone Plain, which has more porous soils good for infiltration, is the exception as most of the island contains thin erodible soils on steep slopes, which limits infiltration and contributes to significant runoff (USDA, 1984).

Tropical storms also cause high winds that can reach speeds of up to 155 miles per hour with gusts exceeding 224 miles per hour. High winds have resulted in severe damage to property, power distribution systems, and water and sewage systems. Downed power lines from high winds have significantly hindered intra-island communication. High winds during Tropical Cyclone Val in 1991 defoliated over 90% of primary forest on Tutuila and caused $50-$80M of damage to the Port of Pago Pago. Tropical Cyclone Heta (2004) brought high winds that destroyed 600 homes and damaged more than 4,000 others. Tropical Cyclone Gita passed through the main Island of Tutuila in February 2018 causing damages to homes that displaced more than 800 people (USACE, 2020). Tropical cyclones Vicki and Wasi caused damages in the American Samoa Islands in January to February 2020. Strong winds, flash floods, coastal flooding and landslides resulted in power outages and significant damage to public and private properties.

American Samoa also experiences frequent flood damages from heavy rains and tropical storms. Five FEMA declared disasters have occurred since 2005 due to severe storms and cyclones. Eighty-six percent (86%) of disaster declarations in American Samoa involved flood impacts. These floods caused water quality degradation, flooded roads, business closures, and landslides. The territory has recorded over 200 riverine and flash flood events since 1967. As previously described, steep terrain and the limited shoreline constrain development to areas along the coast, often in alluvial flats. These concentrated developments are prone to riverine flooding, and impervious roadways and infrastructure exacerbate flash flooding from intense rain.

Figure 4-7 reflects FEMA coastal and estuarine flood zones for a 1% annual chance of exceedance (ACE). FEMA flood hazard areas are zones that FEMA has defined according to varying characteristics of flooding in a given location. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area. Coastal and riverine areas that are a likely to flood are described in Table 4-1 below.

Table 4-1. FEMA Flood Zones

Zone	Description
A	Riverine areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.
AE	Riverine areas in the base floodplain where base flood elevations are provided. AE Zones are now used on new format Flood Insurance Rate Maps instead of A1-A30 Zones.
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Additional inundation maps can be found in the Engineering Appendix (Appendix C). Gauges indicated in the figures are monitoring wells (utilized by ASPA), NWS wind gauges, and several stream gauges recently installed under a land grant to the UH-WRRC but are in need of further funding for telemeters to enable live data feeds for water quality research. The highlighted gauge at the Pago Pago airport is the NWS's only real time rain gauge (although the NPS may collect manual data similar to the Ito gauges). Gauges marked "Ito" are named for a past volunteer, named Ito, that manually read and recorded daily data for the NWS.

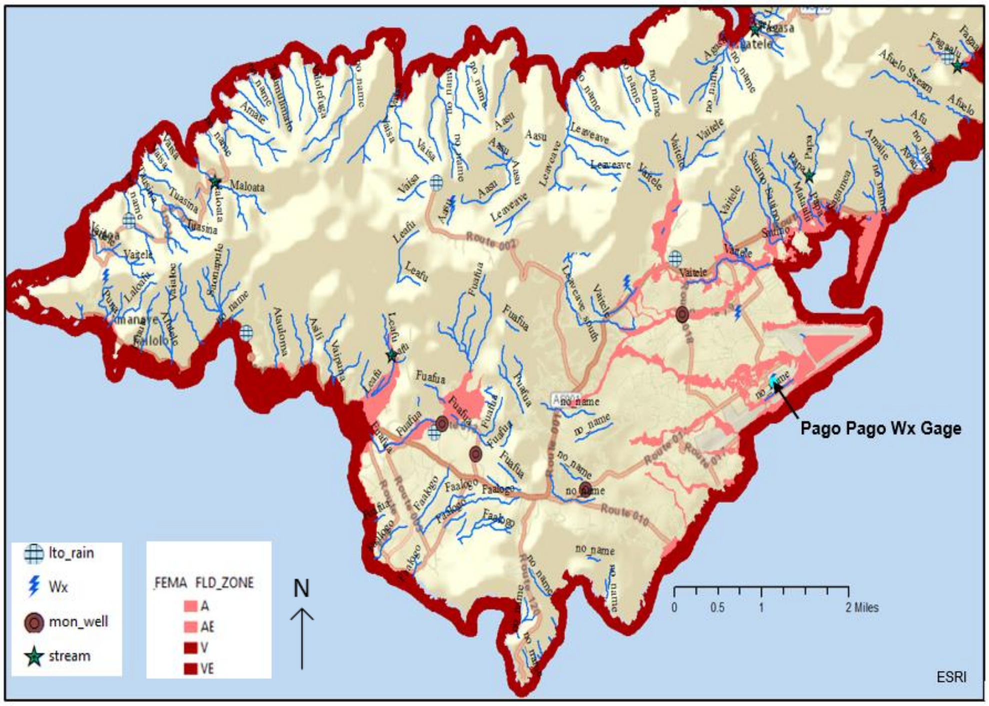


Figure 4-7. Western Tutuila, FEMA Riverine and Coastal 1% Annual Exceedance Probability Flooding (Source: NOAA NHC, 2021)

Storms, typhoons, high wave events, and the flooding of critical infrastructure in low-lying areas commonly result in power outages across American Samoa. Currently, 100% of American Samoa's fuel is imported. Diesel fuel is crucial to the generation of power and electricity in American Samoa. The fuel is stored within the Pago Pago harbor, a particularly vulnerable location for susceptibility to storm and tsunami events. Damage to storage and treatment tanks could result in waterway pollution and disruption of fuel supply across American Samoa.

Soil conditions and steep slopes also pose a significant risk for landslides and mudflows during floods. Landslides and mudflows often occur along riverine reaches and at the base of steep slopes during flash flooding. There are over 100 recorded landslides or mudflows, some of which have caused fatalities (AS THMC, 2020). In 1979, storm-induced landslides caused four fatalities in Se'etaga, Tutuila, and a flash flood-induced landslide in 2003 caused five fatalities. In December of 2007 a flash flood and riverine flooding from Faganeanea to Pago Pago caused debris flows through the LBJ Tropical Medical Center parking lot and into the surgical room. Flooding and debris flow also pose a risk to surface and sub-surface cultural resources like burial sites, artifacts, and remnants of past villages. Figure 4-8 depicts landslide risk in Tutuila.

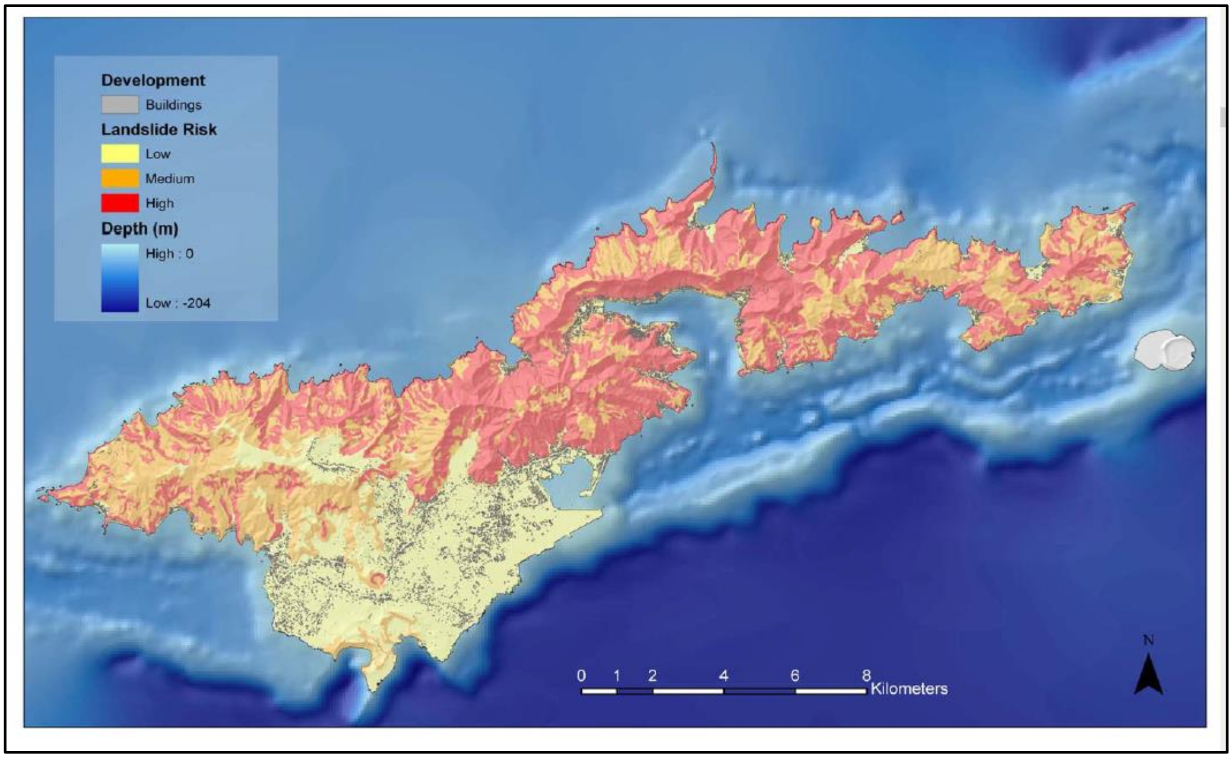


Figure 4-8. Landslide Risk Across Tutuila (Source: USGS, 2006)

Native habitat in American Samoa is also at risk from storm events and the subsequent transport of pollution and sediment into waterways. Terrestrial species also face challenges from the physical impacts of flooding and landslides/mudflows. Additionally, due to rapid population growth, the otherwise buffering effects of plant communities like mangroves, wetlands, and lowland forest have been nearly eliminated. Non-native plant and animal species also threaten to out-compete and reduce the abundance of some native species.

4.1.7 Coastal Erosion and Coastal Flooding

Most coastal flooding in American Samoa is tied to tropical storms and cyclones, and a recent survey found that 98% of Samoans believe their homes or businesses are at risk (AS THMC, 2020). Coastal inundation is controlled by the steep bounding mountain terrain. The limited flat terrain that accommodates development is coastal and is at high risk for inundation from high surf and storm surge. Storm surge results in the greatest damage to coastal infrastructure and cultural resources, while the highest number of fatalities are tied to high surf events. Since 1950, 92 high surf events have occurred and caused seven fatalities, compared to no fatalities from tropical storms or cyclones.

SLC is a driver of increased flood risk in American Samoa. SLC is exacerbated by climate change and warming temperatures. SLC is not uniform from region to region and is based on ocean circulation patterns, land subsidence, and tectonic movement. In American Samoa, tectonic activity and land subsidence from the 2009 earthquake/tsunami increased vulnerability to relative SLC by lowering the ground surface elevation. The relative SLC is accelerating more quickly than the global average in American Samoa and based on the high SLC curve is anticipated to reach 4.6 feet by 2070 and 7.5 feet by 2100 (USACE Sea Level Change Calculator, n.d.)

Coastal flooding and erosion impact American Samoa's coral reefs. Coral reefs are vulnerable from related stressors including runoff pollution, nutrient loading, and invasive species, especially the crown-of-thorns starfish. Coastal flooding and erosion may also pollute or damage important habitat for coral reefs.

4.1.7.1 People and Structures at Risk

As described in prior sections, floods and storms have caused significant damage in American Samoa and modeling results suggest an increase in life safety risks and flood damages are expected in the future.

The economic analysis for the WA evaluated the direct, event-based impacts from flooding in an existing and future scenario with SLC to quantify future risks. The USACE Institute of Water Resources, Risk Management Center's LifeSim 2.0.1 model (LifeSim) was the analytical tool used to estimate casualties and damages to structures and from road inundation. LifeSim analyzes areas with any number of people (population) at risk (PAR) of flooding, and exposed PAR (population that the model calculates to experience flood depths) casualties. The LifeSim model uses water depth and extent, paired with other inputs including structure values, heights, locations, and population to calculate what risk is likely to occur under storm conditions.

Two scenarios were modeled using LifeSim to estimate potential casualties from the existing conditions scenario and the future conditions scenario. The existing condition analysis assumed the current calendar year at the time modeling was completed, 2022. The future conditions analysis was conducted for the year 2072 to account for the 50-year projections of SLC in the Hydraulics and Hydrology (H&H) data.

The NOAA storm surge Maximum Envelope of Water (MEOW) is a composite product representing the maximum height of storm surge water in a given basin grid cell using hypothetical storms run with the same intensity, forward speed, storm trajectory and initial tidal level (NOAA, 2021). Data from the NOAA MEOW was used for the LifeSim assessment.

There are no comprehensive structure inventories available for American Samoa that could be used. Therefore, this project team developed a GIS-based generalized structure inventory. Typically, structure inventories contain information regarding attributes such as building type, value and location that can be used for many different purposes. The GIS process for this WA created standardized point shapefiles for use in LifeSim. Attributes were then populated based on the same distributions of the National Structure Inventory for the island of Maui, HI to create a representative generalized structure inventory that could then be used for modeling. The National Structure Inventory is a national database of all the structures within the United States and is often used by USACE in the modeling of risk. A more detailed description of the generalized structure inventory can be found in Appendix B – American Samoa Economics and LifeSim.

All modeling estimates represent very rough order of magnitude estimates of damages to inform planning and are not exact to the degree necessary for feasibility-level decisions. The results of the LifeSim analysis are also limited in level of detail due to the inability of the model to portray coastal dynamics of wave forces and severe velocities. In essence, the model will show what PAR, infrastructure, and depths exist in the current and future scenarios for coastal storms and storm surge based on existing and future sea level conditions. These results can be overlaid with other risk maps, such as landslides, and inland/flash flooding maps to highlight where compounding risks may occur today and in the future with SLC. This information can then be used to inform planning decisions or actions to ameliorate the risk.

In the existing conditions scenario, a total of 626 structures were estimated to experience inundation in American Samoa at an *average* depth of 2.4 feet and a *maximum* depth of 21.2 feet. Table 4-2 shows rough order potential PAR as well as the number of structures that were modeled to experience flooding and maximum depth. Figure 4-9 shows areas with exposure of the PAR to flooding on Tutuila for the existing conditions scenario. The areas with exposure of the PAR generally correspond with low elevation terrain and development. Figure 4-10 shows areas of future risk (shown as solid red), that do not appear until the presence of greater depths of coastal flooding due to SLC.

Table 4-2. Risk to American Samoa Islands Under Existing Scenarios of the NOAA MEOW Storm Surge Event (Source: USACE, 2021)

Island	Structures Inundated	Depth of Maximum Flood Inundation (ft)	Total PAR
Aunu'u	48	3.0	651*
Ofu & Olosega	42	21.2	124
Ta’u	100	14.7	754
Tutuila	436	6.0	6,769
All Islands	626	21.2	8,298

*Population in PAR larger than population of Aunu’u due to how PAR is calculated in structure inventory as a function of occupancy type and square footage.

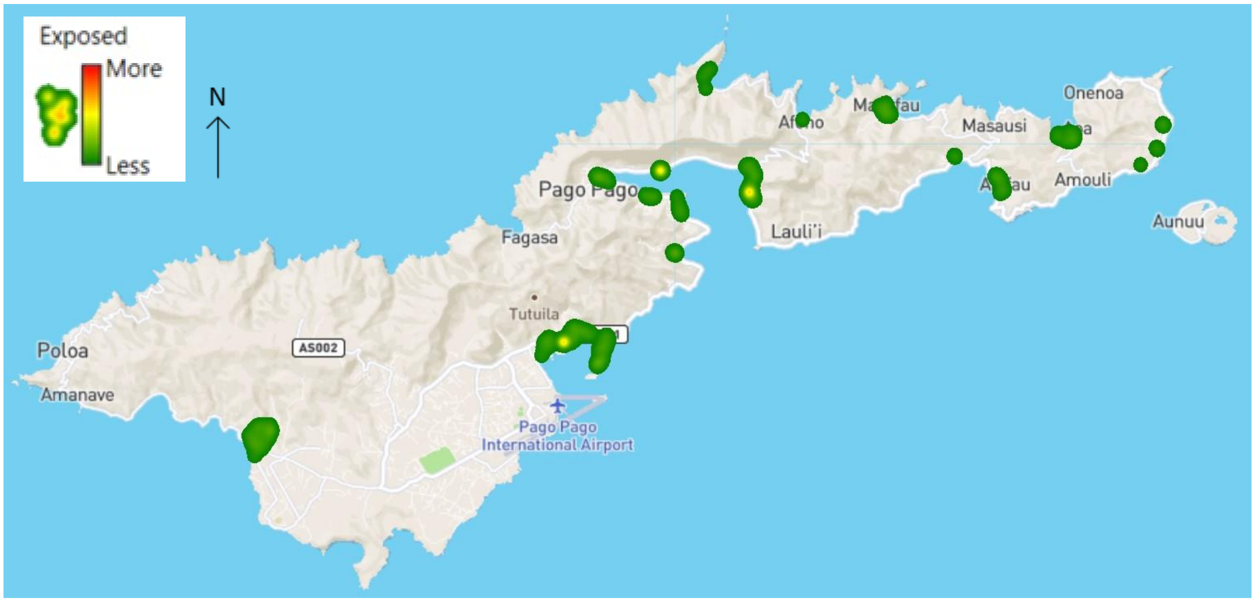


Figure 4-9. Heat Map of Areas with Exposure of the PAR to Flooding for the Island of Tutuila Under the NOAA MEOW Storm Surge Event (Source: USACE, 2021). Areas of more exposure appear as yellows and is due to higher concentration of people living or working within areas vulnerable to coastal flooding and storm surge.

To assist in the planning process, LifeSim was used to identify areas of risk within the coastal flooding areas under the future scenario. One village shown to have risk that was not in the existing scenario was Lauli'I on the island of Tutuila. Many of the villages that have PAR in the existing scenario see an increase in PAR moving towards the future scenario. In the existing scenario, approximately 17% of the entire population of American Samoa is considered to be at risk of coastal flooding. Overall, there was a PAR increase of 6% from the existing scenario, with the largest individual area increases occurring in the villages of Olosega (+81%), Pagai (+78%), and Aoa (+71%). Results of the future conditions scenario are shown in Figure 4-10, Table 4-3, and Table 4-4. Additional, more detailed maps are available in Appendix B - Economics and LifeSim.

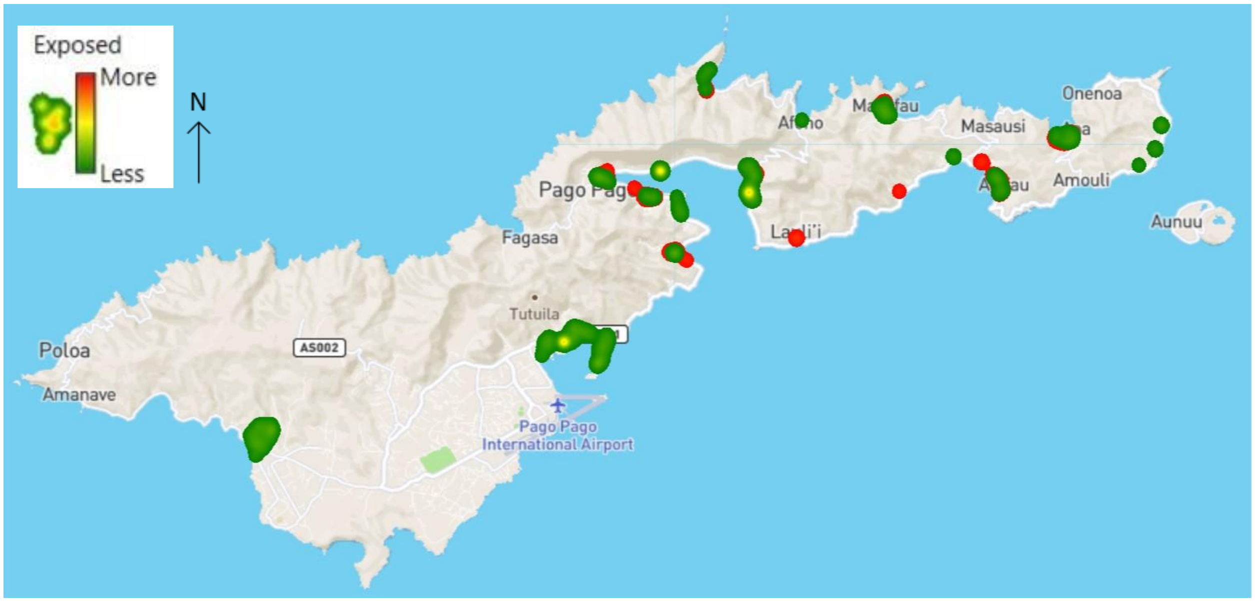


Figure 4-10. Heat Map of Risk Areas for the Islands of Tutuila Under the MEOW Storm Surge Event with Future Scenario SLC. Solid Red Indicates new exposure in the Future Scenarios that did not occur in Existing Scenarios and can be considered a result of SLC. (Source: USACE, 2021)

Table 4-3. Population at Risk for Existing and Future Conditions Scenarios

Location	PAR Total - Existing	PAR Total - Future	Percent Change in Future
Aunu'u	651	722	11%
Ofu & Olosega	124	150	21%
Ta'u	754	754	0%
Tutuila	6,769	7,164	6%
Grand Total	8,298	8,790	5.9%

Table 4-4. Structures Inundated from Coastal Flooding for Existing and Future Conditions Scenarios

Location	Structures Inundated - Existing	Structures Inundated - Future	Percent Change in Future
Aunu'u	48	80	67%
Ofu & Olosega	42	47	12%
Ta'u	100	100	0%
Tutuila	436	485	11%
Grand Total	626	712	13.7%

Of urgent attention to inform future planning, once Route 001 in Pago Pago is flooded, most standard vehicle traffic from the eastern half of Tutuila would be unable to reach the only hospital on the island. In addition, once Route 009 near Pala Lagoon is flooded, traffic from Poloa and the westernmost villages will be severely limited or cut off from the rest of the island, including the hospital.

Results for Aunu'u show the greatest changes from the existing to future scenario with an 11% increase in the number of people at risk and 67% increase in the number of structures inundated. Risk in Tutuila is also estimated to increase in the future scenario with an approximate additional 6% PAR, 11% of structures inundated, and overall damage increases of over 79%. Notably, in the future scenario, the village of Lauli'i shows PAR that was not present in the existing scenario. All increases to PAR are due to increases in flooding, and not from increases in the number of people expected to be exposed. The Manu'a islands of Ta'u, Ofu and Olosega also experience increases in PAR, structures inundated and damaged under the future scenario, and given their remoteness, even small shifts in risk can be relatively significant given the limited availability of emergency services and places to seek shelter. Additional LifeSim results and discussion can be found in Appendix B - Economics and LifeSim.

4.1.8 Water Quality and Supply

American Samoa is divided into 41 major watersheds, each roughly 1.5 square miles in size. Heavy rainfall flushes contaminants into the water systems. Drinking water is frequently under a boil water notice for the majority of American Samoa due to contamination of *Escherichia coli* and other bacteria from human and animal waste. Contaminants pose a threat to both ecological systems and public health. Sources of pollution include both human and natural processes, like sedimentation.

Twenty-six watersheds in American Samoa do not meet the American Samoa Water Quality Standards set by the EPA. Impairments are from nutrients, metals, pathogen indicators, waste collection system failures, intensive animal feeding operations and natural weathering of the volcanic soils. High levels of solid waste in streams block flows and also increase risk to human health by promoting standing water and flooding. For example, standing water increases mosquito breeding and associated risk of leptospirosis (Sauafea-Le'au, 2013; Welch et al., 2019).

Water quality in certain areas was also found to have a high bacteria load from feral animal and livestock waste. For example, piggery management led to contamination of Afuelo Stream (Matu'u Watershed) with high levels of bacteria, thus exposing water sources to leptospirosis and *E. coli*. Regular stream water monitoring, public education and outreach, facility inspections, and enforcement of environmental and public health regulations helped reduce the leptospirosis risk and led to declines in *E. coli* concentrations (EPA, 2006).

Currently there is no centralized wastewater infrastructure for many villages in American Samoa. Efforts at workable on-site wastewater management in these villages are impeded by population density, topography, soils characteristics, and complex land tenure among residents.

Agricultural practices, underlying geology (volcanic conduits), and storm events contribute to sedimentation, further decreasing water quality. The steep topography of American Samoa coupled with the naturally occurring high phosphate concentrations in the underlying volcanic rock increase the volume of phosphate-rich sediment that enters the downstream waterways. Agricultural practices and development of impermeable surfaces also lead to a degradation in water quality and have negative effects for coral reefs and mangroves. The degradation of these aquatic habitats also leads to a decline in aquatics species dependent on these habitats.

There are seven industrial operations regulated under the EPA National Pollution Discharge Elimination Systems (NPDES) program. These permittees include Starkist Samoa, Samoa Tuna Processors, Utulei Wastewater Treatment Facility (ASPA), Tafuna Wastewater Treatment Facility (ASPA), Pacific Energy (bulk fuel storage and transfer), Satala Power Plant (ASPA), and The American Samoa Shipyard Services Authority. Five of the NPDES permittees discharge to Pago Pago Harbor. Recent analysis of NPDES monitoring data showed that several of these facilities do not meet the requirements established by individual NPDES permits. Compliance by NPDES permittees would improve water quality in American Samoa (ASEPA, 2018).

There are seven wells in the Tafuna Leone well field providing most of the drinking and cannery water to Tutuila. One well produces 20% of that well field supply and is frequently closed (in addition to other nearby wells) due to sediment wash conveyed through lava conduits and fractures.

Droughts also affect water quality in American Samoa. Historically, droughts have caused closures in industries reliant on freshwater such as the StarKist tuna cannery and agriculture. Droughts have also led to saltwater intrusion into groundwater aquifers in some areas (AS THMC, 2020). Since rainfall is the primary source of all fresh water on the island, the effects of drought tend to be long lasting on the environment and the economy throughout American Samoa.

Four significant droughts have been documented since 1974 and resulted in heavily impacted groundwater sources, crop damages, and food shortages (in 1974); the closure of school for one week, and the closure of the StarKist cannery for 6 months (in 1983); Aunuu’s sole drinking water spring dried up completely (in 1998); and three months of less than normal rainfall triggered the U.S. Coast Guard to send a ship with a desalination plant to American Samoa (in 2011).

Drought also affects local cultivation of taro, coconut, yam, breadfruit, cocoa, and banana, which are main local staples grown for both subsistence farming and export. Drought also affects traditional practices of cultivation or gathering (fish, other sea life, and medicinal plants). Table 4-5 summarizes significant droughts and impacts in American Samoa (AS THMC, 2020).

Table 4-5. Record of Significant Droughts (Source: AS THMC, 2020)

Year of drought	Impacts
1974-1975	Underground water sources dried up and sediment made water undrinkable. Vegetation dried and many crops were damaged, causing food shortages. Drought broke with several days of heavy rainfall that caused devastating landslides. Additional effects included water rationing, closure of schools, curtailment of fish cannery operations, reduction of work hours for government employees, and subsequent economic recession.
1983-1984	Impacts included water rationing, school closure for one week, cannery closure for six months (concurrent with renovations), reduction of work hours for government employees, and economic recession.
1988	Wells in Tualauta District started to taste salty as groundwater levels were depleted. Only 10.11 inches of rain recorded by the weather bureau at Tutuila's airport from April to August as compared to between 125 and 250 inches per year on average. Several wells and rivers dried up, the Aunu'u natural spring evaporated, and the catchment area at Malaeloa completely dried up.
September 2011	This event was less severe than previous occurrences and was quenched by rainfall the following month. However, it did prompt a U.S. Coast Guard/New Zealand team to send a ship with a desalination plant on board.

Saltwater intrusion can degrade water quality and supply across the islands and is exacerbated by SLC. Seawater located beneath the freshwater lens limits the rate that groundwater can be used in island settings. Saltwater intrusion from over-pumping or wells drilled too deep near the lens currently affects water quality in several of Tutuila's wells and aquifers (US Climate Resilience Toolkit, 2019). Several wells on the western side of Tafuna are shallow and pulling salty water. As a result, residents and businesses rely on bottled water (ASEPA, 2018).

Topography and volcanic geology form high-level groundwater reservoirs and aquifers contained in rock above sea level. Low permeability of volcanic rocks limits the capacity of these reservoirs that supply base flow to streams rather than drinking water. In below sea-level aquifers, freshwater floats on a layer of subterranean saltwater. Rare dry periods of two- to three-months duration can result in critical drinking water shortages as saltwater intrudes into the depleted freshwater lens (ASEPA, 2014 and 2018).

Two primary factors contribute to saltwater intrusion into basal lens wells, which are the most common type of well in American Samoa: the elevation of the bottom of the well in relation to mean sea level and the rate of extraction of water from the aquifer. In Pago Pago and Aua, wells have been drilled more than 100 feet below sea level before hitting freshwater. Wells of this type must be monitored often for chloride content. If levels begin to rise, the pumping rate must be reduced (ASPA, 2014).

Most of the water supply system in American Samoa was built in the early 20th century by the US Navy, with additional construction undertaken by the Department of the Interior in the 1960's. Approximately 60% of the system's water is lost to leaks and unmetered withdrawals. Leak detection is a priority for ASPA and is done primarily through acoustic leak detection for the mainlines that are generally located beneath the road infrastructure. When combined with the terrain's ability to absorb water, these subsurface pipes can cause a challenge to leak detection due to no visible indication of a leak. Crews also conduct surveys within the villages to observe and repair meters and identify any unmetered withdrawals.

Additional details on water quality and supply can be found in Appendix C – Environmental Analysis.

4.1.9 Tsunami

American Samoa resides in the Circum-Pacific earthquake belt, making it vulnerable to earthquakes leading to tsunamis. While tsunami hazards are infrequent, their consequences are extremely high. Over the past 100 years, approximately 12 tsunamis have occurred with run up heights above one foot. The source of a tsunami may come from as far away as Chile (approximately 6,000 miles) to as close as the Tonga Trench (approximately 100 miles). Locals may or may not feel the earthquake, and their timing for egress can vary from minutes to hours.

The 2009 tsunami resulted from an 8.1 magnitude earthquake roughly 128 miles southwest of American Samoa within the Tonga Trench. The resulting tsunami produced wave heights from 6.5 to 39 feet, causing 35 fatalities and $910,000 in damages to water supply and wastewater systems alone. Property damage and crop damage were estimated at $81M and $20,000 respectively (NOAA NCEI, 2020). Additionally, one of two major employers (tuna cannery) was permanently closed, coastal roads were eroded, and multiple booster stations, treatment plants, and lift stations were damaged. Communication network capacities were overwhelmed and phone lines, power lines, power plants, television, and radio operations failed.

Tsunamis pose significant risk to health and safety, economics, critical infrastructure, and other social effects. Stakeholders indicate that the island does not currently have a functional siren system, which exacerbates the associated risk. Furthermore, 50% of designated emergency shelters in American Samoa are within the 2009 tsunami inundation zones.

Currently tsunami warning systems are not functioning, and the territory is seeking funding for a new warning system. Tsunami drills are practiced every six months. Radio stations, social media, and community alerts are the primary modes of emergency warnings for tsunamis.

4.2 Future Conditions

This WA uses a 50-year forecast period of analysis for inventory and forecasting purposes. The 50-year forecast period of analysis for this assessment spans from 2022 to 2072. However, other agencies may have differing periods of analysis.

Rising temperatures, sea level rise, and carbon dioxide (CO_2) levels are projected to continue globally. American Samoa is vulnerable to the effects of climate change as water quality, flooding, the economy, and water supply are inextricably tied, and remain under threat without action.

Climate change will affect a multitude of essential metrics including transportation, emergency egress, economic viability (ports and businesses at shoreline harder to relocate), residential flooding/typhoon/tsunami safety, and saltwater intrusion to freshwater aquifers and ecosystems. Climate change may also exacerbate the intensity of both flooding and droughts. Increased storm intensity will continue to cause widespread power outages and threaten the imported fuel supply, both through the lack of access to imports and the destruction of critical supply and storage infrastructure in flood-prone areas.

The future of climate variability and greenhouse gas (GHG) emission projections are based on human activity. The Intergovernmental Panel on Climate Change (IPCC) has high confidence that climate change will undermine food security by mid-21st Century and beyond. Marine species redistribution and reductions in global marine diversity and fishery productivity are likely.

Increases in earth's surface temperatures (land and sea) are causing large melt events to land-based glaciers as well as thermal expansion of ocean waters, both of which are contributing to global sea level rise. Relative SLC is a combination of this global change in sea level with subsidence, or sinking, of the tectonic plates. This phenomenon is occurring in American Samoa and was hastened by a powerful combination of near simultaneous fault and thrust earthquakes that occurred in the Tonga Trench in September 2009 (Scientific American, 2010; National Science Foundation, 2010). Based on Pago Harbor tide gauge data, this event caused Tutuila to initially rise about 2 to 3 inches at the time of the earthquake event, and then sink down about 7 to 9 inches over the next 2 to 3 years due to the more immediate "relaxation from the earthquake deformation." Since then, the ongoing subsidence is estimated to be occurring at a rate of about 0.5 inches per year and is expected to continue in addition to anticipated climate related SLC.

SLC curves reflect varying acceleration assumptions tied to differing human mitigation activities. A low acceleration rate depicts high mitigation efforts and higher acceleration (high curve) represents a business-as-usual response. SLC is not uniform from region to region and is based on ocean circulation patterns, land subsidence, and tectonic movement. In American Samoa, tectonic activity and land subsidence play a significant role in sea level change and acceleration.

Figure 4-11 illustrates the high, intermediate, and low relative SLC estimates at the Pago Pago NOAA gauge (ER 1100-2-8162). This study relies on the high curve (shown in red) which is in alignment with territory and other agency projections for SLC. The USACE SLC Calculator utilized provides a way to visualize USACE and other authoritative SLC scenarios for any tide gauge that is part of the NOAA National Water Level Observation Network. The calculator includes inputs on the unique local SLC rate that accounts for subsidence and estimates between 2.4 and 4.6 feet of relative sea level rise in American Samoa by 2070 and 3.1 to 7.5 feet by 2100 on the low and high curve, respectively (Figure 4-11).

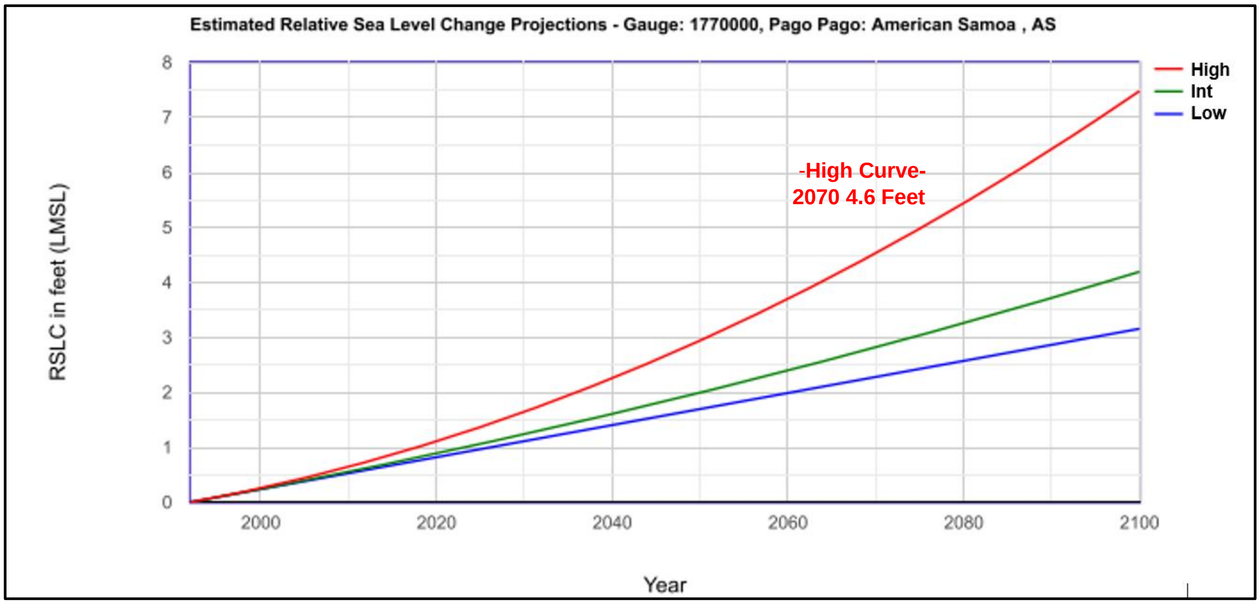


Figure 4-11. USACE Sea Level Change Calculator, Projected Relative Sea Level Change for American Samoa

Flooding along coastal infrastructure currently impacts commerce and egress; therefore, SLC will further exacerbate the situation. SLC is also expected to adversely affect water supply by increasing saltwater intrusion in freshwater sources.

Although future estimates of rainfall are difficult to quantify, increasing rainfall and temperature trends have been observed. A warming ocean and atmosphere increase precipitable water in the atmosphere and intensifies rainfall and tropical cyclones. There is a clear El Niño connection where tropical storm activity is increased in the South Pacific. Longer storm lifetimes and intensities are correlated with warm SST (IPCC, 2007). By 2035, cyclone intensities are projected to increase 133% relative to 1986-2005 (NOAA, 2018).

Nuisance flooding, characterized by low levels of inundation that do not significantly threaten public safety but can interrupt daily life, cause property damage, and impair the function of infrastructure such as roadways and sewers (Moftakhari et al., 2018). Nuisance flooding will continue to impact road access, divert transportation, harm infrastructure, cause power outages, and negatively impact water quality and ecosystems. Damage to major roadways and critical infrastructure from storm surge will be amplified with SLC and storm intensification. Broader scale flooding during large storms will impact emergency egress and shut down the economy for longer periods of time. With climate change and land clearing (which encourage invasive growth), the projections for intensified rainfall on steep and poorly managed land will result in further landslides and mudslides. As population changes and sea levels rise, development may be pressed to encroach further upslope. Therefore, landslides could become a greater problem for the future.

Although there is not yet consensus on predictions regarding future storm intensity, any potential future increases in storm intensity and wave run-up (coastal inundation and high surf) in American Samoa would exacerbate coastal erosion and worsen damage to communities and harbors along the shoreline. Warmer temperatures will tax habitat and native plant species, dry soils needed for agriculture, further acidify oceans, and stress corals. Warm waters are fuel for cyclone intensification, which will exacerbate wind damage and interrupt power generation. Water supply is inextricably tied to power (pumping of ground water) and is, therefore, a disruptor to water supply and economic dependencies to water and power.

Furthermore, when tropical storms and cyclones occur, the territory experiences disruptions to vital supplies of food and fuel. American Samoa is completely dependent on fuel imports, and Pago Pago harbor acts as a distributary supply base for its outer islands. Further power and supply disruptions are expected in the future without a departure from imported fuels.

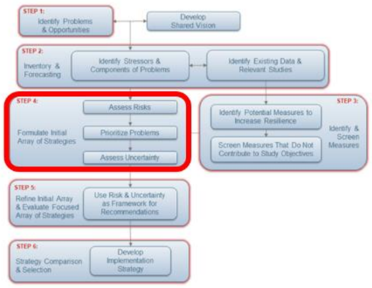
Declining water quality and supply will continue to pose issues to communities in future conditions. Historically, during moderate rainfall events, heavy sediment percolates through subsurface volcanic conduits. These groundwater pathways convey sediments that clog wells and can render them inoperable. This sediment wash during storms results in up to a 30% loss of available drinking water (drinking water wells are disabled for a period of time dependent on the storm duration and the necessary response time to clear sediment, typically a day or two). This loss will intensify when coupled with future expectations of drought and will reduce freshwater recharge and increase brackish water within the aquifer. These conditions are consequential to human health, natural resources, and the economy. One of the largest employers in American Samoa, the cannery operations, are dependent upon the pumped well water that is shut down during flooding.

Watershed pollution from local trash fill and dumping also pose a threat to water quality across American Samoa, with heavy metals and flame retardants being a major concern. Contaminations can also impact coral reef recovery. Without action to remove pollution sources and invasive species, water quality and aquatic habitats will continue to decline. Meanwhile, sedimentation stress on nearshore reefs will continue to increase.

Future economic conditions could differ significantly in American Samoa due to low public confidence in the long-term existence of the StarKist cannery which is responsible for much of the territory's economic activity. Legally mandated increases in wages, a declining global market for tuna products, large fines, disputes over access to fisheries, and the closure of the other canneries threaten the viability of StarKist remaining open in American Samoa in the future. While there likely would be significant economic impacts if the cannery shut down, no significant changes are expected to the overall population at risk on the island of Tutuila without major changes to the overall population.

In addition to environmental factors, anthropogenic stressors, like urbanization, are expected to increase. In 1986, 95% of American Samoan land was vegetated (93% forest) and 5% was urban. As of 2001, urban areas had increased to 7% of the land cover. On Tutuila, from 2005 to 2010, there was a net increase in both impervious surface area (7%) and developed area (6%). Further urbanization, at least on Tutuila, is expected.

5 Risk Assessment and Evaluation



To prioritize water resources problems and subsequent actions, a risk-based approach was utilized to identify the highest risks for which near-term efforts should focus. Risk conditions currently exist within the study area, with the potential for increased probability of risk event occurrence and associated consequences under future conditions. These risks, identified and evaluated through review of existing documentation as well as a series of partner engagement meetings with federal and territorial agencies, largely fall within one or more of four categories: life loss, economic, social, and environmental. This aligns with benefit categories defined in the USACE Policy Memorandum "Policy Directive – Comprehensive Documentation of Benefits in Decision Documents," dated January 5, 2021, which calls for *"equal consideration of economic, environmental, and social categories."* The principles of this policy directive were applied to inform the risk-based prioritization of identified problems.

A series of four virtual scoping charrettes and several one-on-one calls were held with partners to gain input on the problem categories, prioritize areas of risk, and curate an initial array of recommendations. Partner input at these meetings identified stressors and later validated the risk assessment. Additional details on partner engagement can be found in Section 2.2 and Appendix A – Interagency Alignment.

5.1 Stressors

The team, in conjunction with input from partners in the scoping charrettes, identified a set of stressors for each problem category. For the purposes of this WA, stressors are conditions or events that occur as a result of the driving problem category.

Table 5-1. Rainfall and Storms Problem Statement and Stressors

Rainfall and Storms: Heavy rainfall, including tropical storms, cause high winds and riverine and overland flooding that impede evacuation routes; convey sediment and pollutants; damage homes, businesses, and critical infrastructure; cause public health and safety risks; and increase environmental degradation.
Stressors
Landslides/Mudslides – Erodible soils and steep topography pose a risk of landslides/mudslides, especially after a storm event. Landslides/mudslides endanger life safety and threaten critical infrastructure, including the hospital and main roads.
Inland Habitat Degradation – Terrestrial and aquatic habitats are at risk of biodiversity and ecosystem loss from anthropogenic activities and storm events. This risk stems from water quality issues, invasive species, land use practices, and landslides.
Overland/Riverine Flooding – Flooding from tropical cyclone activity or more frequent rainfall events poses a risk to water quality, critical infrastructure, and human health and safety.
Power Outages – Power outages often result from tropical cyclone events and can continue for weeks.
Erosion – Due to the presence of highly erodible volcanic soils, erosion can result in impacts to utilities, property, and the environment. Erosion may also lead to loss of developable land.
Flash Floods – Flash floods are exacerbated by the presence of steep slopes and impervious development. Flash floods can cause landslides, damage to infrastructure, and life loss.
High Winds – High winds typically accompany tropical storm events and can reach speeds of up to 155 miles per hour with gusts exceeding 224 miles per hour. High winds pose a life loss threat and cause damage to agriculture, vegetation, infrastructure, homes, and power and water supply systems.

Table 5-2. Coastal Flooding and Erosion Problem Statement and Stressors

Coastal Flooding and Erosion: High surf, storm surge and coastal erosion, especially in low-lying coastal areas, threaten life safety; affect evacuation routes; damage homes, critical infrastructure, cultural sites, and businesses; and increase environmental degradation.
Stressors
Coastal Flooding – Coastal flooding and storm surge can cause inundation of coastal infrastructure, including ports, roadways, and fuel storage.
Coastal Erosion – Coastal inundation and storm surge contribute to coastal erosion, damage to infrastructure, and possible loss of developable land.
Sea Level Rise/Subsidence – Climate change and subsidence have exacerbated relative sea level rise, contributing to American Samoa having one of the highest recorded relative rates of SLC in the world.
Coastal Habitat Degradation – Coastal erosion, SLC, water quality issues, warming temperatures, and invasive species all contribute to the degradation of important coastal habitats like coral reefs and mangroves.

Table 5-3. Water Quality and Supply Problem Statement and Stressors

Water Quality and Supply: Water quality and the supply systems throughout American Samoa are vulnerable to naturally occurring and anthropogenic stressors.
Stressors
Nutrient Loading – Pollution in waterways coupled with agricultural practices (pesticide and piggery waste runoff) contribute to declining water quality, which affects access to potable water and threatens vulnerable aquatic and coastal habitats.
Sedimentation – Due to the presence of erodible soils and steep slopes, sedimentation can clog water supply pumps, leading to a decrease in potable water availability.
Drought – Drought may worsen with climate change and poses a risk to food availability and economic security.
Stormwater Management – Absence of stormwater management contributes to degradation in water quality and supply. Often there are prolonged boil water notices and, as a result, a reliance on single use plastic bottles or water refill stations that have varying degrees of water quality.
Saltwater Intrusion – Subsidence, SLC, and aquifer withdraw contribute to saltwater intrusion, which threatens water quality and supply. It may have serious consequences to food and economic security.
Water-borne Pathogens – Leptospirosis and *E. coli* cause public health and safety risks in American Samoa and result from pollution in waterways.

Table 5-4. Tsunami Problem Statement and Stressors

Tsunami: American Samoa is located in the Circum-Pacific earthquake belt and is particularly vulnerable to tsunamis. Locally generated tsunamis may provide only minutes to react and can cause extensive damage and loss of life.
Stressors
Tsunami – Tsunamis, while infrequent, pose major threats to human health and safety.

5.2 Risk Assessment Process and Evaluation

In collaboration with partners and stakeholders, stressors were qualitatively assessed on risks relating to economic damage, life loss, social vulnerability, and environmental degradation. The risk assessment accounted for both likelihood and consequence of stressors' contributions to the risk indices. Risk ratings were evaluated based on current circumstances but did include flexibility for risks that are expected to worsen with climate change or exacerbated environmental stress. The four risk metrics (economic, life loss, social, and environmental) were evaluated based on the following criteria in sections 5.2.1 through 5.2.3.

5.2.1 Economic Risk

Economic risk estimates the combination of likelihood and consequences of harm to property, to infrastructure, to other assets, as well as to economic systems (measured in monetary terms) and are assessed over a 50-year forecasting period of analysis, which spans from 2022 to 2072. The following ratings shown in Table 5-5 and Table 5-6 were applied to each of the stressors for economic risk:

Table 5-5. Qualitative Probability Metrics for Economic Impacts over a 50-year Planning Horizon

Economic Risk – Probability	
Probability	*Definition*
Not Likely	It is not anticipated a stressor will contribute to this risk.
Could Occur	It is possible a stressor could contribute to this risk.
Has Occurred	A stressor has contributed to this risk.
Has Occurred and Increasing	A stressor has contributed to this risk and is anticipated to do so again in the future.
Occurs Often	A stressor contributes to this risk frequently.
Occurs Often and Increasing	A stressor contributes to this risk frequently and is anticipated to continue to increase.

Table 5-6. Qualitative Consequence Metrics for Economic Impacts over a 50-year Planning Horizon

Economic Risk – Consequences	
Magnitude of Consequence	*Definition*
No Impact	No impacts are anticipated.
Household Impact	Impacts are anticipated to affect a single household.
Town/Village Impact	Impacts are anticipated to affect a community.
Watershed Impact	Impacts are anticipated to affect multiple communities.
Territory Impact	Impacts are anticipated to affect one or more islands in the territory.
National Impact	Impacts are anticipated to affect the mainland U.S. and other surrounding countries/territories.

5.2.2 Social and Environmental Risk

Social risk assessed three risk indices: social connectedness, health and safety, and subsistence. The definition for social connectedness was adapted from the USACE Institute for Water Resources (IWR) 2013 "Other Social Effects: A Primer" and refers to sustaining a sense of connection to the community and neighborliness. This can include the displacement of people, business, and farms, and refers to the loss of intangible cultural resources such as folklore, traditions, language, and cultural knowledge.

Health and Safety, as defined by the "Other Social Effects: A Primer," accounts for risks to human health and safety including effects on security, life, health, safety, and emergency preparedness. The third index used to assess the social risk is subsistence, which is the ability of individuals and communities to be self-sustaining, such as reliance on natural resources to support a community and livelihoods.

Environmental risk was assessed through four indices: ecosystem services impacts, habitat loss, species loss, and cultural resources loss. Ecosystem services refers to the various benefits provided by certain environmental and natural resources to communities. Cultural resource loss encompasses the damage or loss of tangible cultural resources.

For both social and environmental risk, stressors were evaluated for each risk index. The single highest ranking between indices in the environmental and social categories was carried through for the overall environmental or social risk assessment.

The following evaluation metrics, shown in Table 5-7 and Table 5-8, were used for both social and environmental risk:

Table 5-7. Probability Metrics for Social and Environmental Impacts

Social and Environmental Risk – Probability	
Probability	*Definition*
Not Likely	It is not anticipated a stressor will contribute to this risk.
Not Likely but Increasing	It is not likely but could happen.
Could Occur	It is likely possible a stressor will contribute to this risk.
Could Occur and Increasing	It is very likely or becoming more likely.
Has Occurred	A stressor has contributed to this risk.
Has Occurred and Increasing	A stressor has contributed to this risk and is more likely to do so in the future.

Table 5-8. Consequence Metrics for Social and Environmental Impacts

Social and Environmental Risk – Consequences	
Magnitude of Consequence	*Definition*
Temporary Impact	It is possible for a stressor to cause temporary impacts to community/cultural/environmental resources.
Temporary Impact and Increasing	It is possible for a stressor to cause temporary impacts to community/cultural/environmental resources, and they may become more severe.
Long-Term Impact	It is possible for a stressor to cause long-term impacts to community/cultural/environmental resources.
Long-Term Impact and Increasing	It is possible for a stressor to cause long-term impacts to community/cultural/environmental resources, and they may become more severe.

Permanent Impacts Possible	It is possible for a stressor to cause permanent, irreversible impacts to community/ cultural/ environmental resources.
Permanent Impacts and Increasing	It is possible for a stressor to cause permanent, irreversible impacts to community/ cultural/ environmental resources, and they may become more severe.

5.2.3 Life Loss Risk

Life loss risk evaluated the likelihood of the stressor occurring and the subsequent life loss consequences that may occur. Life loss risk applied the following scoring metrics (Table 5-9 and Table 5-10):

Table 5-9. Probability Metrics for Life Loss Impacts

Life Loss Risk – Probability	
Probability	*Definition*
Remote	It is very unlikely a stressor will occur in any given year.
Low	There is a low chance a stressor will occur in any given year.
Moderate	There is a moderate chance a stressor will occur in any given year.
Likely	It is likely a stressor will occur in any given year.
Very Likely	It is very likely a stressor will occur in any given year.

Table 5-10. Consequences Metrics for Life Loss Impacts

Life Loss Risk – Consequences	
Magnitude of Consequence	*Definition*
Unlikely Life Loss	It is not anticipated a stressor will result in any life loss.
Low Magnitude Life Loss	If a stressor occurs, it is anticipated a few lives will be lost.
Moderate Magnitude Life Loss	If a stressor occurs, it is anticipated more than a few lives will be lost.
High Magnitude Life Loss	If a stressor occurs, significant life loss is inevitable.

5.2.4 Risk Assessment Results

Equal consideration was given to economic, life loss, social, and environmental risks; therefore, the problems/stressors that were ranked as the highest relative risk (above the red dashed line on Figure 5-1 through Figure 5-11 below) from any metric were categorized as "catastrophic." Problems and stressors for which no relative risk ranking fell among the highest risks were categorized as "major" or "minor." The categories help prioritize resiliency strategy implementation for stressors USACE and partners agreed were imminent.

All stressors are high risk and important to address. USACE qualitatively placed the red dashed line shown in the figures below to designate the relative highest risk stressors and help prioritize potential future actions. For social and environmental metrics, these were risks where permanent impacts have occurred. The relative highest economic risks are those where widespread impacts occur with high frequency. Highest life loss risks consider the magnitude of potential life loss and frequency of the stressor occurring. The range for life loss highest risk spans from frequent events with low magnitude life loss to infrequent events with the potential for high magnitude life loss.

A yellow dashed line also designated a "minor risk" category to denote the relative lowest risk stressors for each risk metric. Stressors falling between minor and catastrophic are considered a major risk.

Figure 5-1 through Figure 5-11 below show the risk assessment results. To note, stressors located in the same square all have equal risk levels.

5.2.4.1 Economic Risk

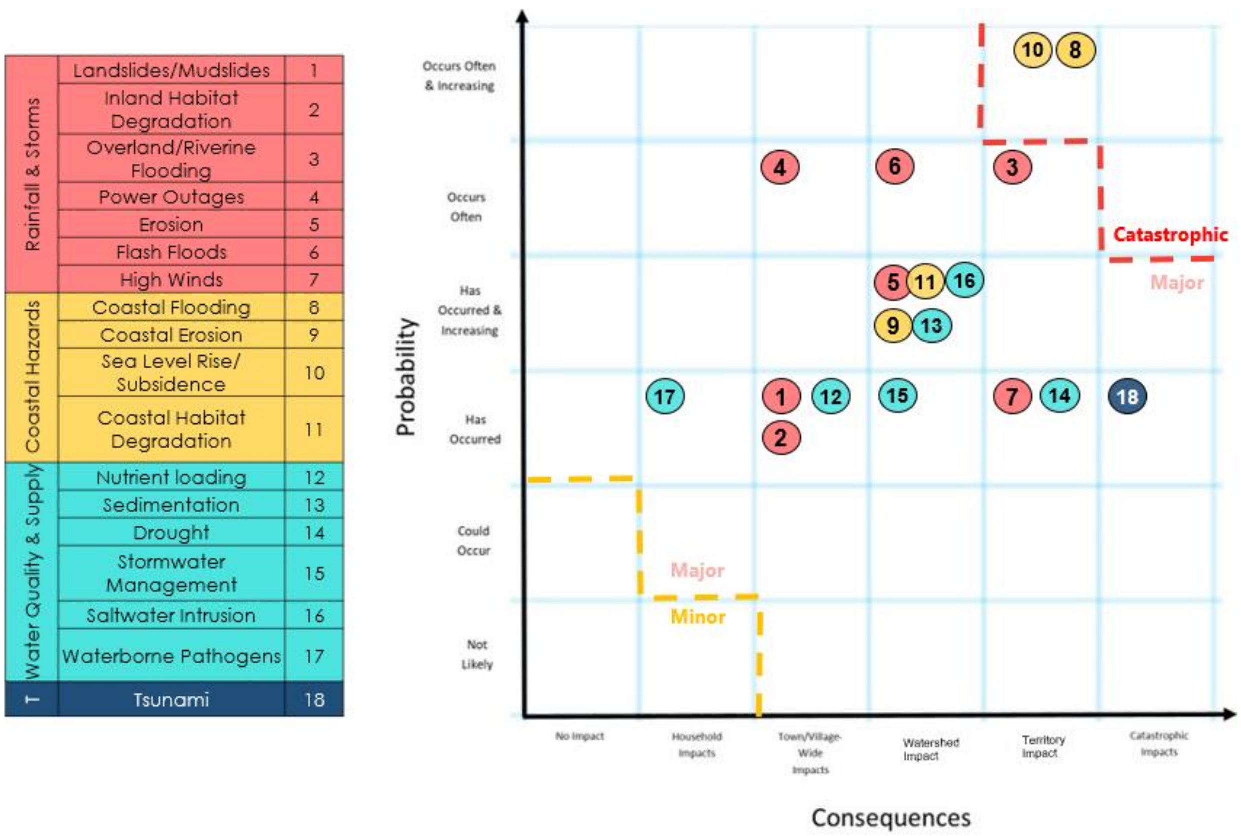


Figure 5-1. Economic Risk Assessment Results

Figure 5-1 above shows the results of the economic risk assessment. Coastal flooding and Sea Level Rise/Subsidence were rated as catastrophic risks. Both stressors are connected and could severely impact the economy in American Samoa. Climate change and rapid subsidence are expected to exacerbate local SLC creating conditions that increase the probability and intensity of flooding events. Coastal flooding occurs more often from storm events and affects critical infrastructure and facilities built in coastal flood zones. SLC has the potential to displace entire communities and industries. While the related stressors, coastal erosion and coastal habitat degradation, are not identified as catastrophic risks, they have occurred and are increasing. These stressors may cause impacts limited to the affected watershed area. Loss of coastal habitat may have an impact on tourism revenue.

Rainfall and storms include stressors like flash floods and overland/riverine flooding that occur often from storms and smaller rainfall events with antecedent conditions. These have varying consequences; however, none are forecasted to be catastrophic. Potential for economic impact stems from damage to infrastructure and businesses from storm events or long-term power outages that have been recorded to last up to six months. Landslides and terrestrial habitat degradation may cause economic impacts in affected areas due to inaccessibility to centers of commerce.

Water quality and supply have caused economic impacts with varying consequences. Industries reliant on freshwater such as the cannery or farms may be impacted from a lack of clean water supply. Saltwater intrusion and sedimentation directly affect access to clean water. As subsidence increases, so does the probability for saltwater intrusion. Water-borne pathogens may have economic consequences in the affected watershed due to missed work or school days from sickness, as this scenario is known to occur presently.

Tsunamis can cause widespread economic impacts due to the devastating consequences to infrastructure and life loss. Negative effects on mental and physical health and the loss of essential workers associated with tsunamis also may impact the economy. Due to the infrequency of tsunamis, this was not deemed to be a catastrophic risk warranting immediate action. While tsunamis are not a regular occurrence, future building decisions should consider the possibility of future tsunamis. An estimated $100M in accumulated losses have been associated with tsunamis.

5.2.4.2 Social Risk

The following sections describe the social risk assessment that evaluated metrics of social connectedness, health and safety, and subsistence. An overall social risk summary is provided in Section 5.2.4.2.4.

5.2.4.2.1 Social Connectedness

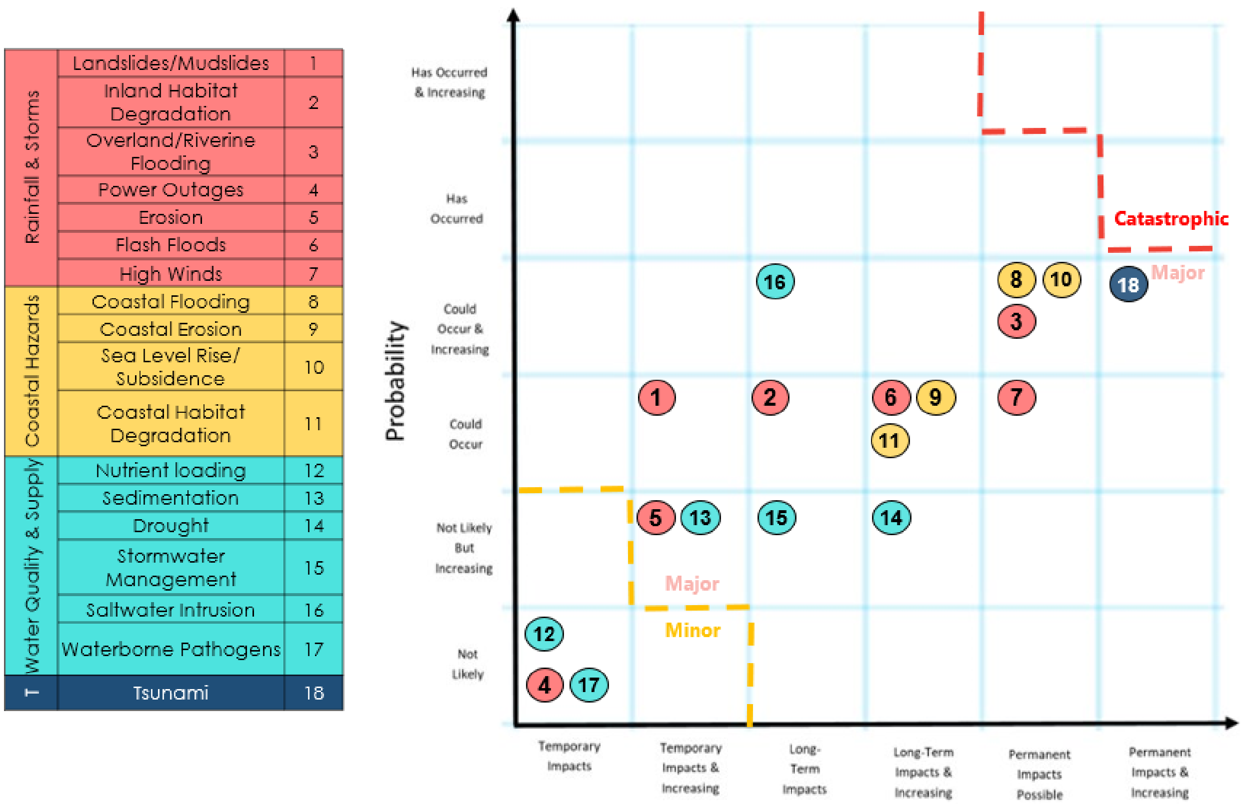


Figure 5-2. Social Connectedness Risk Assessment Results

Figure 5-2 displays the risk assessment for social connectedness. No stressors were considered catastrophic for social connectedness. Rainfall and storms pose a social connectedness risk primarily from flooding effects. Damages to homes, businesses, infrastructure, and property may cause displacement during repairs. Overland and riverine flooding poses the risk of permanent displacement as the effects of a serious flood may permanently damage homes or property such as farmland. Tropical Cyclone Tam destroyed 70% of local crops in 2006. The consequences for several stressors in rainfall and storms are increasing due to projections that tropical cyclones may intensify with climate change. In 1987, Hurricane Tusi left 98% of the 2,000 people in the islands temporarily homeless with an estimated loss of $5-$10M. In 2004, Tropical Cyclone Heta left 10% of inhabitants homeless and had an estimated loss of $50-$100M. In 2014, flooding across all islands destroyed 100 homes and resulted in one fatality. In 2018, Tropical Storm Gita damaged 1,000 houses after dropping 17 inches of rain over a five-day period. Power outages are not likely to cause a loss of social connectedness.

Coastal flooding and erosion may cause irreparable damage and/or loss to property in coastal areas. Minimal erosion could lead to great losses for coastal villages in American Samoa and in severe cases force populations to be relocated. SLC would permanently remove homes, property, and infrastructure in areas close to the shore; however, this has yet to occur. Some families own land on the coast, making them particularly susceptible to coastal hazards and loss of social connectedness. Coastal flooding is expected to increase in probability due to rapid SLC in American Samoa.

Water quality and supply are not expected to significantly contribute to displacement or loss of social connectedness. Saltwater intrusion may have other long-term consequences particularly for farmers reliant on freshwater for their livelihood. Other stressors to water quality and supply are unlikely to cause displacement; however, drought could have long-term impacts depending on length and severity. A serious drought would limit water availability, having more serious consequences for farmers. Nutrient loading and water-borne pathogens are unlikely to impact social connectedness because water may be sourced elsewhere if contaminated.

Tsunamis have the potential to have devastating consequences such as injury and loss of life and damage to buildings and infrastructure in coastal zones. Should this occur, there could be permanent impacts that are increasing with changes to PAR and building in coastal zones.

5.2.4.2.2 Health & Safety

Rainfall & Storms	Landslides/Mudslides	1
Rainfall & Storms	Inland Habitat Degradation	2
Rainfall & Storms	Overland/Riverine Flooding	3
Rainfall & Storms	Power Outages	4
Rainfall & Storms	Erosion	5
Rainfall & Storms	Flash Floods	6
Rainfall & Storms	High Winds	7
Coastal Hazards	Coastal Flooding	8
Coastal Hazards	Coastal Erosion	9
Coastal Hazards	Sea Level Rise/ Subsidence	10
Coastal Hazards	Coastal Habitat Degradation	11
Water Quality & Supply	Nutrient loading	12
Water Quality & Supply	Sedimentation	13
Water Quality & Supply	Drought	14
Water Quality & Supply	Stormwater Management	15
Water Quality & Supply	Saltwater Intrusion	16
Water Quality & Supply	Waterborne Pathogens	17
T	Tsunami	18

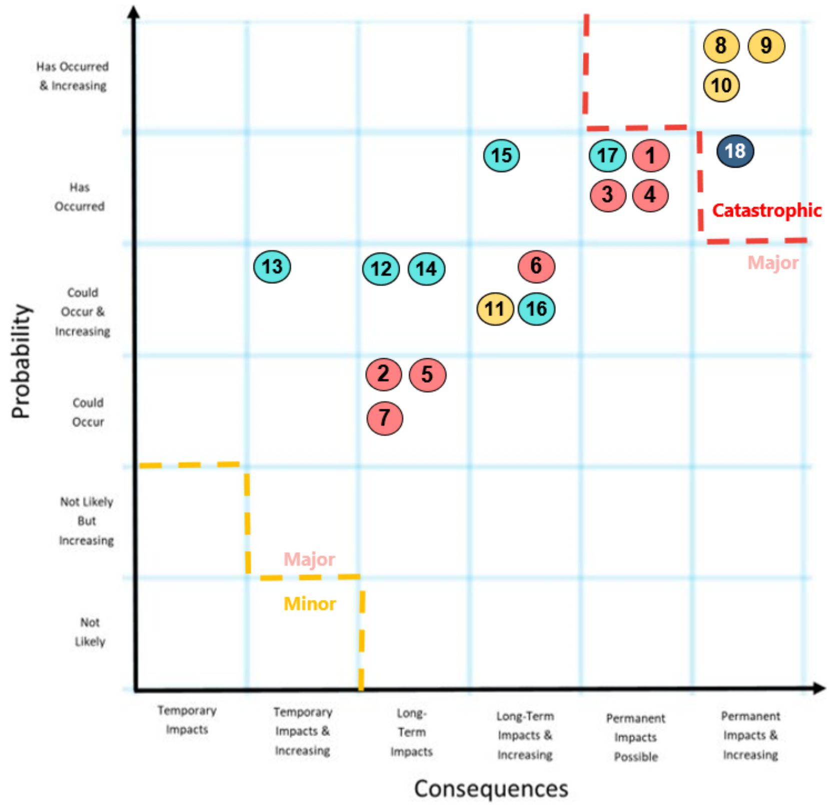


Figure 5-3. Health and Safety Risk Assessment Results

Figure 5-3 depicts the risk assessment results for health and safety. Coastal flooding, coastal erosion, and Sea Level Rise/Subsidence have catastrophic risks for health and safety impacts. These three stressors are linked together and pose a significant risk to health and safety due to the high likelihood for damage to critical roads, infrastructure, and facilities directly adjacent to the coast. Damage to these resources may directly harm people from impact damage or may indirectly pose a threat to health and safety through blocked roads to homes, the hospital, and other critical areas. When coastal flooding, tsunami or hurricane, and increased nuisance flooding during high tides are combined with SLC, more water will inundate the land further inland. Salinization of fresh groundwater aquifers is a concern as this may cause contamination to drinking water supplies.

Tsunamis have the highest reported injury and fatality statistics of any stressor evaluated in the WA. In 2009, American Samoa was impacted by the South Pacific Tsunami, which caused widespread destruction and over 100 injuries.

Power outages also have possible permanent impacts. Temporary or long-term power outages may prevent the hospital from providing critical care services and household power outages may also prevent essential functions like oxygen supply. Water supplies and sewage pumping are stalled during power outages if systems are not equipped with back-up generators.

Other stressors of rainfall and storms have potential for long-term impacts to health and safety. Flash floods and high winds both have potential for impact injuries from debris. Inland habitat degradation may have long-term health and safety impacts due to loss of resources and ecosystem services like natural water filtration and erosion control. Landslides and overland/riverine flooding both have reports of injuries and fatalities, making permanent impacts possible (and likely to increase in probability moving forward).

In addition to the catastrophic coastal risks, coastal habitat degradation has a risk for long-term impacts. Destruction of coastal ecosystems like corals, mangroves, and coastal wetlands, which provide wave attenuation services, increases the chances a community is impacted by coastal flooding and storm surge, which can cause direct impact injuries or mortality.

Waterborne pathogens have a direct linkage to illnesses and diseases such as leptospirosis and *E. coli*. Possible, albeit uncommon, effects from leptospirosis and *E. coli* includes kidney failure and respiratory complications. Water contaminated with human or animal waste, or pollution may cause shorter (digestive complications) or longer-term (leptospirosis and *E. coli)* health impacts. Saltwater intrusion currently impacts drinking water availability and parts of the territory are often on a boil water notice due to wells pulling very salty water. This may cause long-term impacts for households unable to purchase bottled water. Sedimentation can clog and subsequently close wells creating risk for temporary health and safety impacts from lack of water supply.

5.2.4.2.3 Subsistence

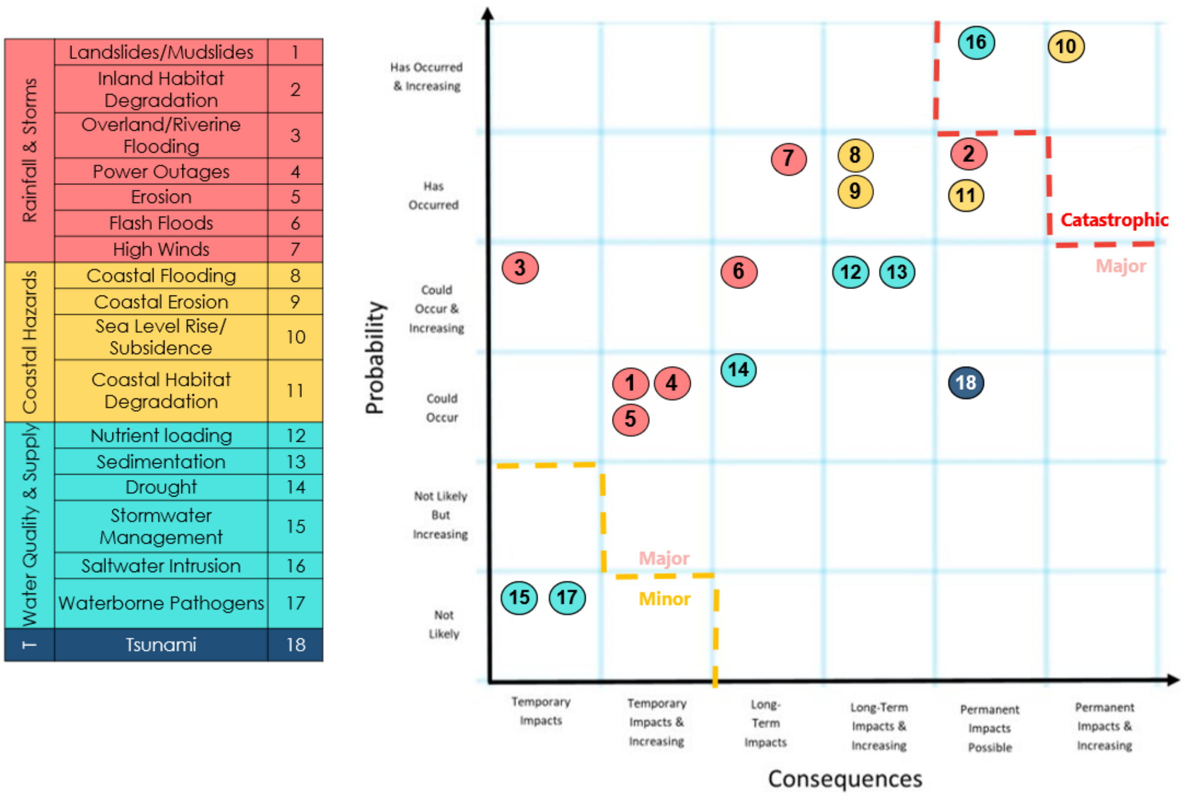


Figure 5-4. Subsistence Risk Assessment Results

Figure 5-4 shows the risk assessment results for subsistence. Sea Level Rise/Subsidence poses a catastrophic subsistence risk. SLC permanently alters and inundates coastal areas, rendering the land and habitat unusable. SLC is increasing due to climate change and high subsidence rates. Sea level rise is increasing due to global warming trends. Rising seas means areas further inland are being impacted by coastal flooding, nuisance flooding and King Tides. Such events threaten property, populations and cultural assets and may force relocation of populations in the future.

Saltwater intrusion is also a catastrophic subsistence risk due to possible permanent impacts to groundwater sources. Saltwater intrusion negatively affects groundwater quality leading to reductions in drinking, municipal, industrial, and agricultural water supply. Saltwater intrusion cannot be reversed, so its impacts are permanent. This issue has occurred, and its likelihood is increasing due to rapid subsidence rates.

High winds and inland habitat degradation pose major, albeit not catastrophic, risks for subsistence impacts. High winds have caused defoliation of over 90% of affected forests, which impairs access to natural resources used for island subsistence. Terrestrial habitat degradation may permanently lose or alter (from invasive species) critical natural resources. The velocity and volume of water moved in a flash flood have long-term impacts to critical resources necessary for subsistence such as farmland and natural resources. Other stressors of rainfall and storms are expected to have temporary consequences as ecosystems and land recovers from storm damages. The probability for flash floods and overland/riverine flooding are increasing due to expected intensification of tropical cyclones due to climate change.

Coastal hazards pose a risk for long-term or permanent impacts due to the irreparable nature of SLC and coastal habitat degradation (loss of corals, fish, etc.). Loss of coastal habitat that has sustained locals for centuries could have permanent impacts to subsistence. Coastal flooding and coastal erosion have long-term impacts from destruction of habitat from flooding or erosion.

Saltwater intrusion is a catastrophic risk for subsistence, and other water quality and supply stressors have varying subsistence consequences. Nutrient loading degrades water quality and subsequently aquatic habitat. It has the potential to cause harmful algal blooms. Because of this, long-term impacts could occur. Sedimentation also has potential for long-term risks as it clogs waterways and impedes access to fresh water necessary for farming and other subsistence activities. Long-lasting drought can reduce water supply, dry up aquatic habitats, and hinder agricultural practices. Stormwater management and water-borne pathogens are unlikely to cause subsistence impacts.

The force of a tsunami could result in permanent subsistence impacts such as loss of farmland and natural resources. However, tsunamis are relatively infrequent events, lowering the probability of subsistence impacts.

5.2.4.2.4 Social Risk Summary

For social risk, stressors were evaluated for each risk index: social connectedness, health and safety, and subsistence. The single highest ranking between indices in the social categories was carried through for the overall social risk assessment. Coastal flooding, coastal erosion, Sea Level Rise/Subsidence, saltwater intrusion, and tsunami were all catastrophic other social effects risks. The risk summary plot is shown in Figure 5-5.

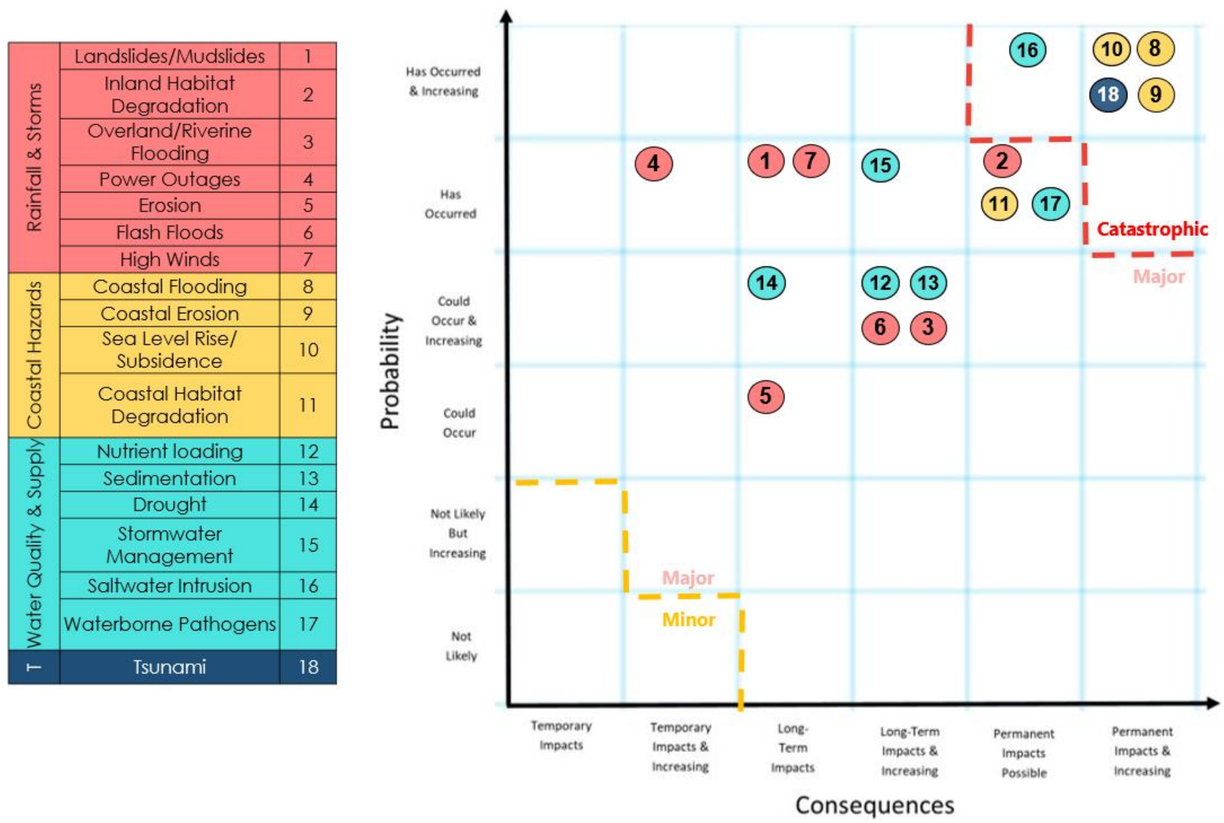


Figure 5-5. Other Social Effects Risk Summary

5.2.4.3 Environmental Risk

The sections below document the environmental risk assessment, which evaluated metrics of ecosystem services, species loss, habitat loss, and cultural resources. Section 5.2.4.3.5. provides an overall environmental risk summary.

5.2.4.3.1 Ecosystem Services Impacts

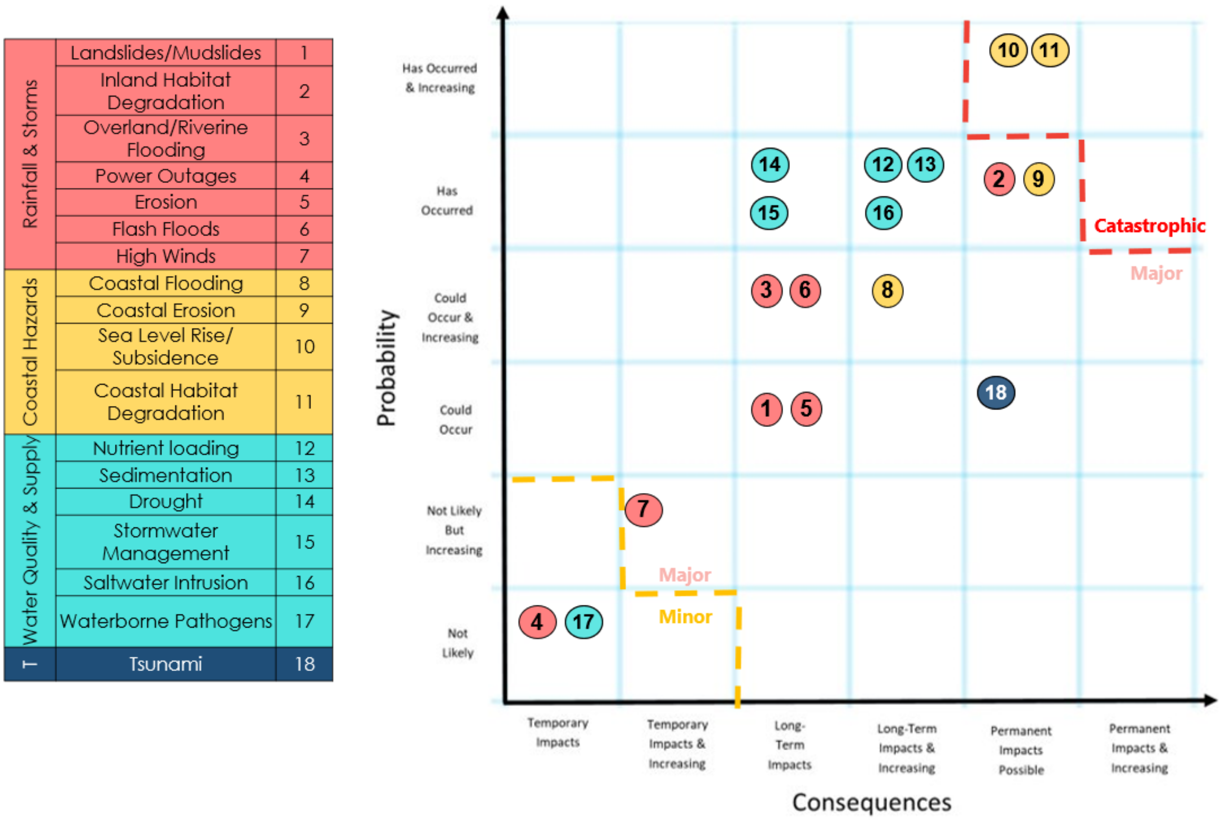


Figure 5-6. Ecosystem Services Risk Assessment Results

The risk results for ecosystem services are shown above in Figure 5-6. Sea Level Rise/Subsidence and coastal habitat degradation are catastrophic risks for ecosystem services. SLC exacerbates damages to vital coastal resources, like mangroves, which would otherwise reduce impacts of wave energy and storm surge. Furthermore, coastal ecosystems like corals also provide protection again storm surge by dissipating wave energy before it reaches the shore. Loss of these important coastal resources have permanent impacts to ecosystem services. Potential coastal habitat degradation is increasing in probability due to climate change exacerbating sea level rise, ocean acidification, and altering temperatures beyond what local ecosystems are adapted to withstand.

All coastal areas in American Samoa are subject to coastal erosion, a slow onset hazard that means very small changes over time may eventually result in large problems. Storm surge, hurricanes, human development, and climate change impacts may exacerbate the process. Human development may cause premature degradation of shoreline through disruption of vegetative materials holding the soils in place, or excessive runoff, which washes the shore away.

Terrestrial habitat degradation also has permanent impacts. For example, loss of wetlands reduces the natural water filtration afforded by the ecosystem, or loss of trees and other deep-rooted plants reduces slope stabilization. Flash floods, riverine/overland flooding, landslides, and erosion all have potential for long-term impacts as these hazards may damage land and ecosystems; however, they typically do not result in an irreparable loss. Affected habitats may grow back over time if left alone or with restoration efforts (replanting, invasive species control). Power outages are not expected to have any ecosystem services impacts. Stressors tied to flooding are expected to increase in probability due to tropical cyclones' intensification with climate change.

Water-borne pathogens are not expected to have any ecosystem services impacts, as their effects are primarily human-heath focused. The other stressors encompassed under water quality and supply have realized long-term consequences from their impacts to freshwater supply and aquatic ecosystems (like wetlands, corals, and mangroves).

Tsunamis have potential from their force to damage or destroy important coastal ecosystems which provide services such as wave attenuation.

5.2.4.3.2 Species Loss

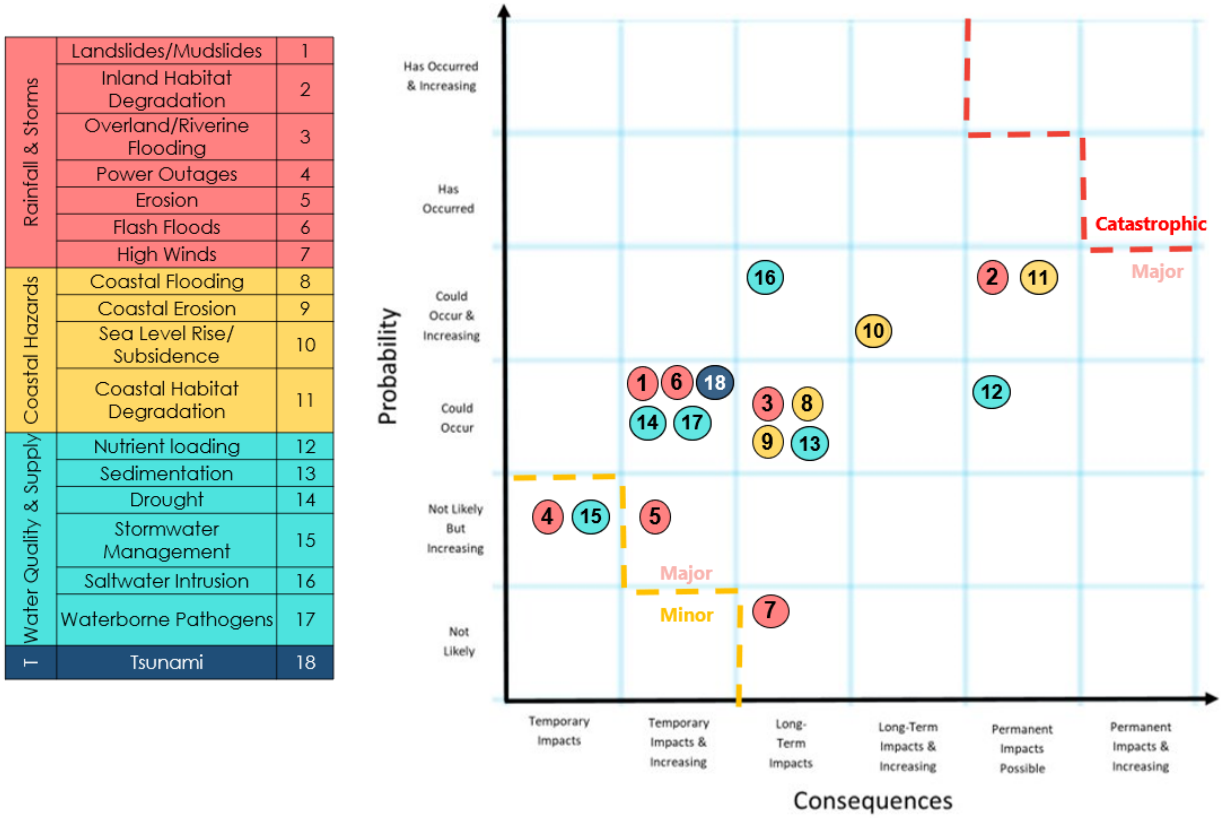


Figure 5-7. Species Loss Risk Assessment Results

Risk results for species loss are depicted in Figure 5-7. No stressors have a catastrophic risk associated with species loss.

Nutrient loading may cause permanent species loss. Nutrient loading causes algal blooms that could lead to coral die off, crown of thorns star fish attacks, impaired water quality, and die-off of food sources for both small macroinvertebrates and larger invertebrate species. Coral species may be dependent on specific water quality parameters and are often slow growing.

Coastal species such as parrotfish, giant clams, and surgeonfish were historically overfished, and as such their recovery has been relatively slow despite on-going coral recovery efforts. Additionally, five species are currently listed as endangered in American Samoa under the Endangered Species Act (ESA): two endemic American Samoan land snails (*Eua zebrina* and *Ostodes strigatus*), the American Samoa distinct population segment of the ground-dove, (*Alopecoenas [Gallicolumba] stairi),* the Pacific sheath-tailed bat, (South Pacific subspecies) (*Emballonura semicaudata semicaudata*), and the mao (*Gymnomyza samoensis*). As such, both inland and coastal habitat degradation could lead to permanent impacts to ESA-listed species.

Most other stressors may have long-term or temporary impacts, namely as habitats recover from storm impacts. Species may be impacted and have lower population counts in given years where storm or other hazard events occur; however, it is unlikely that these would result in permanent species loss.

5.2.4.3.3 Habitat Loss

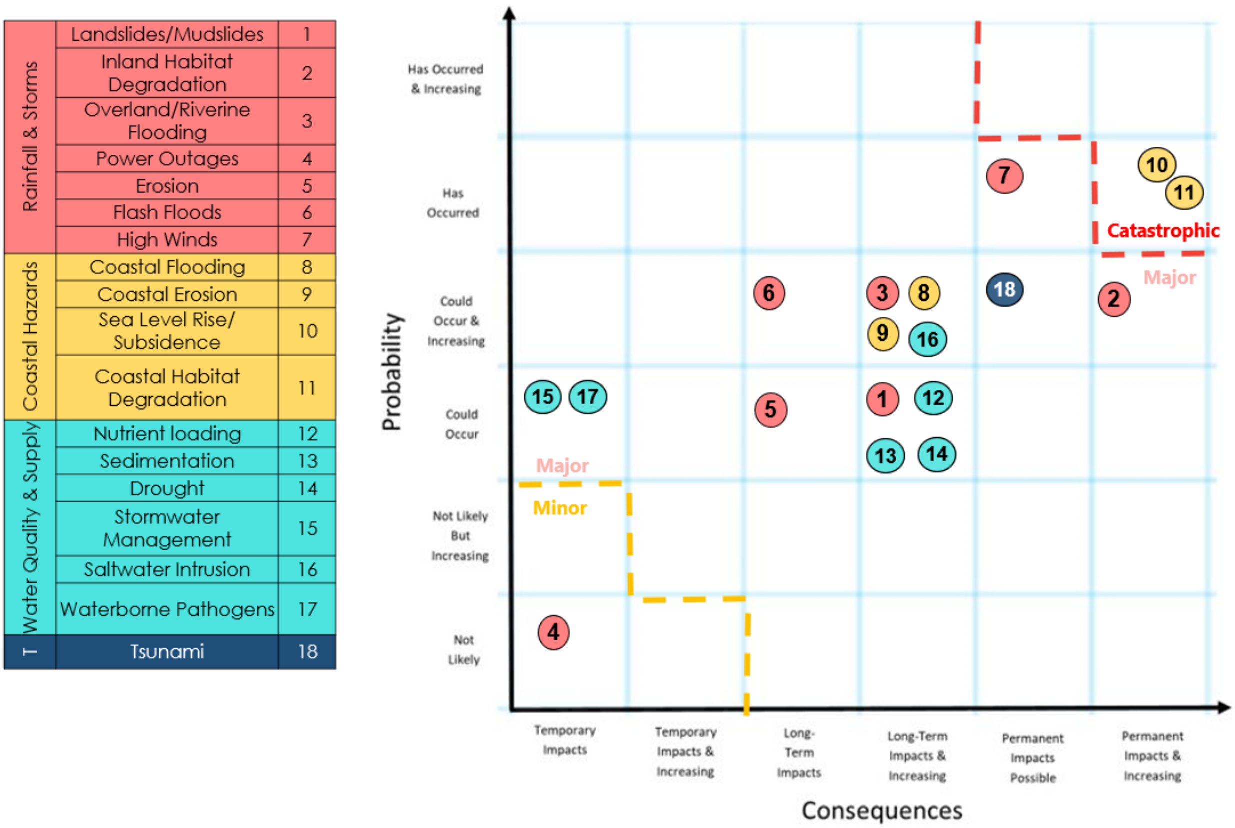


Figure 5-8. Habitat Loss Risk Assessment Results

Figure 5-8 shows the risk ratings for habitat loss. Sea Level Rise/Subsidence and coastal habitat degradation currently have realized permanent consequences relating to habitat loss. SLC is removing and migrating inland areas previously suitable for coastal habitats like mangroves. Coastal habitat like coral have experienced a decline from a multitude of disturbances, including non-native crown-of-thorns starfish invasion, tropical storm events, ocean acidification, thermal bleaching, and human disturbances. Subsidence increased dramatically following the 2009 earthquake/tsunami event.

High winds and inland habitat degradation both could result in permanent impacts. High winds can devastate agricultural crops, uproot large trees, and flatten entire forests. These winds have defoliated up to 90% of affected forests during storm events, creating the potential for permanent impacts. In 1987, high winds stripped most of the vegetation from the island of Ofu, which took five years to grow back. Wetlands and rainforests have experienced a drastic decline from development and changing environment. Other rainfall and storm stressors have possible long-term effects due to storm event impacts on the landscape. Habitat recovery from floods, landslides, and erosion is expected, although it may take time to recover to pre-impact conditions. Power outages are not expected to have habitat loss risk.

In addition to the catastrophic Sea Level Rise/Subsidence and coastal habitat degradation, coastal flooding and erosion may have long-term impacts on coastal habitats. Impacts from storm surge or erosion can impact habitats on or near-shore, which may take time to recover. Erosion may also be exacerbated from coastal development and land use practices such as agriculture.

The water quality and supply problem category has several stressors with possible long-term consequences. For example, saltwater intrusion can lead to habitat loss if the ground water supply becomes too saline for species dependent on groundwater, like wetlands. Saltwater intrusion is increasing due to rapid subsidence and SLC. Nutrient loading, sedimentation, and drought all affect water quality, which is turn leads to loss of habitat if species are unable to adapt to worsening conditions. For instance, nutrient loading may cause harmful algal blooms in waterways affecting aquatic habitat. Drought may dry up wetlands and other aquatic ecosystems. Waterborne pathogens and stormwater management are forecasted to have possible temporary impacts.

5.2.4.3.4 Cultural Resources

Rainfall & Storms	Landslides/Mudslides	1
Rainfall & Storms	Inland Habitat Degradation	2
Rainfall & Storms	Overland/Riverine Flooding	3
Rainfall & Storms	Power Outages	4
Rainfall & Storms	Erosion	5
Rainfall & Storms	Flash Floods	6
Rainfall & Storms	High Winds	7
Coastal Hazards	Coastal Flooding	8
Coastal Hazards	Coastal Erosion	9
Coastal Hazards	Sea Level Rise/ Subsidence	10
Coastal Hazards	Coastal Habitat Degradation	11
Water Quality & Supply	Nutrient loading	12
Water Quality & Supply	Sedimentation	13
Water Quality & Supply	Drought	14
Water Quality & Supply	Stormwater Management	15
Water Quality & Supply	Saltwater Intrusion	16
Water Quality & Supply	Waterborne Pathogens	17
T	Tsunami	18

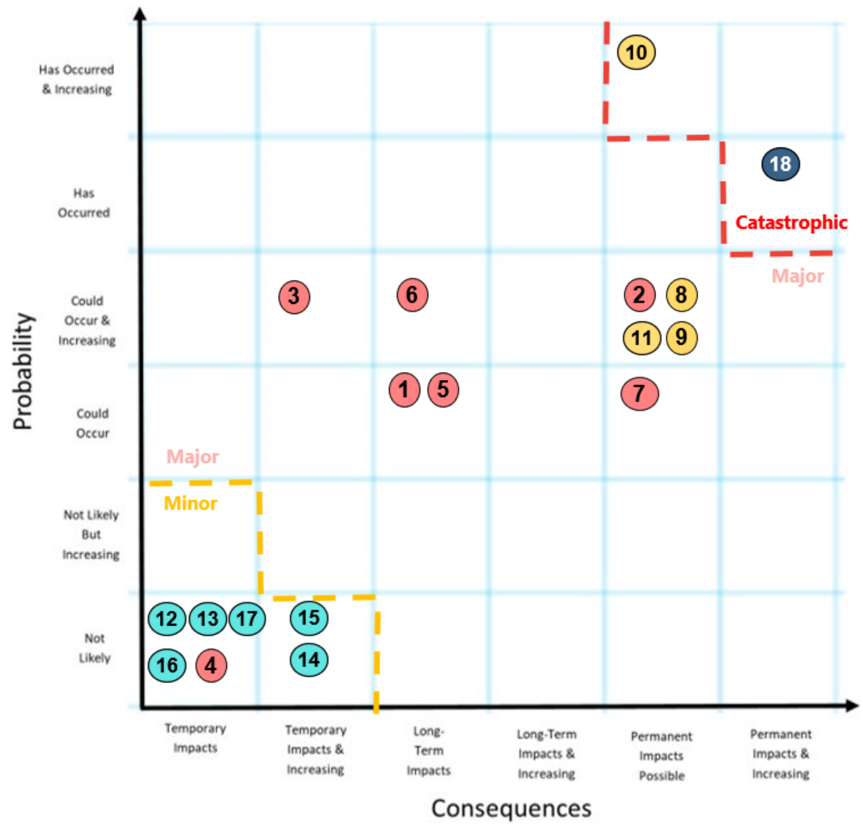


Figure 5-9. Cultural Resources Risk Assessment Results

Risk assessment results for cultural resources are shown in Figure 5-9. The primary risk associated with cultural resources is the destruction of artifacts, natural resources, burial sites, and culturally significant sites. Artifacts may be above ground or subsurface. Loss of important cultural resources is often irreparable. The potential for SLC and tsunamis to destroy coastal communities, land, and habitat, deemed these stressors as catastrophic risks for cultural resources.

USACE's correspondence with the American Samoa Historic Preservation Office (ASHPO) throughout this WA, including their responses to a cultural resource questionnaire provided in 2020 and participation in various stakeholder meetings, identified flooding, erosion, landslides, and the displacement of Samoan communities from their traditional lands to be problems with high probability and consequences for cultural resources.

This includes the irreparable damage to the integrity of archaeological sites, where the ASHPO noted cultural artifacts were washed away from their primary contexts by riverine flooding. Landslides were also documented by the ASHPO to have destroyed old villages located near mountain ridges. The village open space known as the *malae* was a concern brought up by the ASHPO, which has undergone major impacts from flooding and erosion events in the past.

Medicinal and traditional plants such as pandus trees, tea leaves, fruit trees, and native wood trees (*ifilele*) were also brought up for consideration. These culturally important plants were reported to be facing problems from erosion and habitat degradation.

Many stressors associated with rainfall and floods have permanent or long-term impacts possible due to flooding, erosion, or high wind events, damaging land, resources, and artifacts. These stressors have the potential to damage or destroy a multitude of cultural resources from sheer impact.

Coastal hazards have either a long-term or permanent impact on cultural resources. Culturally significant coastal ecosystem resources are threatened by climate changes stressors (SLC, ocean acidification, warmer temperatures) or by human impacts such as pollution or overfishing. SLC also poses a permanent risk due to its irreversible nature and impacts to coastal land. Cultural resources along the coast will be damaged without intervention from SLC. Coastal flooding and erosion pose possible permeant risks due to impacts to the land or environment and subsequent damage to documented archaeological sites which have impacts managed through the ASHPO's Disaster Management Plan, which attempts to record artifacts or features of a site before it loses its integrity.

Water quality and supply stressors are expected to have temporary impacts and are not likely to affect cultural resources as they do not physically impact the land and environment.

5.2.4.3.5 Environmental Risk Summary

Like the social risk summary, stressors were evaluated for each environmental risk index: ecosystem services, species loss, habitat loss, and cultural resources. The single highest ranking between indices was carried through for the overall environmental vulnerability assessment. Sea Level Rise/Subsidence, coastal habitat degradation, and tsunami were found to be catastrophic environmental risks. The summary plot is shown in Figure 5-10.

Rainfall & Storms	Landslides/Mudslides	1
	Inland Habitat Degradation	2
	Overland/Riverine Flooding	3
	Power Outages	4
	Erosion	5
	Flash Floods	6
	High Winds	7
Coastal Hazards	Coastal Flooding	8
	Coastal Erosion	9
	Sea Level Rise/ Subsidence	10
	Coastal Habitat Degradation	11
Water Quality & Supply	Nutrient loading	12
	Sedimentation	13
	Drought	14
	Stormwater Management	15
	Saltwater Intrusion	16
	Waterborne Pathogens	17
T	Tsunami	18

Figure 5-10. Environmental Risk Summary

5.2.4.4 Life Loss Risk

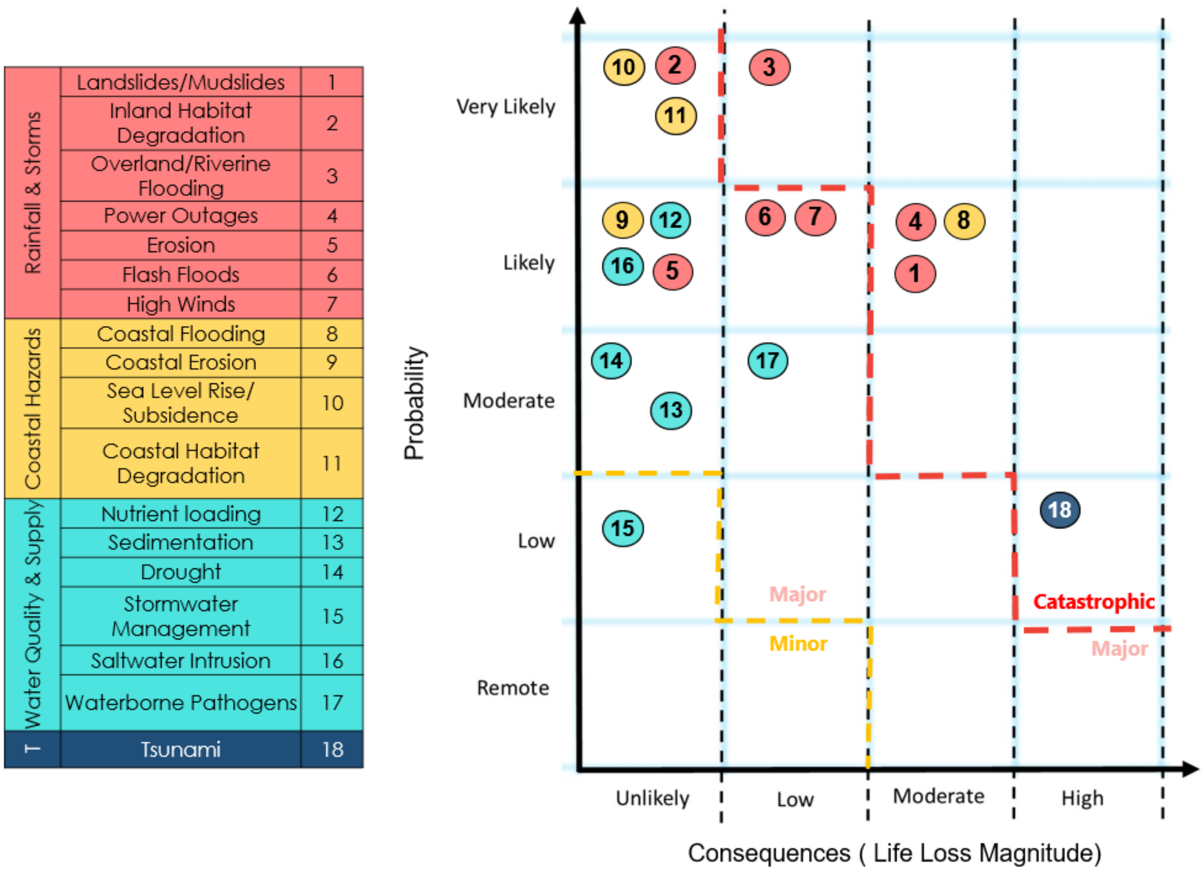


Figure 5-11. Life Loss Risk Assessment Results

Life loss risk results are shown above in Figure 5-11. The probability axis for this plot refers to the likelihood of the stressor occurring in any given year, and the consequences were measured qualitatively in terms of life loss magnitude from the stressor. Stressors in the "unlikely" consequence category were not expected to result in life loss.

Catastrophic stressors for life loss were determined to include overland/riverine flooding, landslides, power outages, coastal flooding, and tsunamis.

Overland/riverine flooding has a high chance of occurring in any given year due to American Samoa's proximity to the most active tropical cyclone belt in the southwest Pacific Ocean. Additionally, monsoon and tropical cyclones establish antecedent conditions that further allow trace amounts of rainfall to respond with significant runoff. Although the Tafuna Leone area has good soil for infiltration, most of the island contains thin erodible soils on steep slopes. Flooding reportedly has resulted in significant and widespread property damage, creating the possibility for life loss to occur. In addition, flooding previously resulted in at least one casualty.

Power outages pose a life loss risk in many parts of the world, including American Samoa. For example, the LBJ Hospital is vulnerable to power outages. Basic building operations such as lighting, security, and elevators require electricity. Resident patients at the LBJ Hospital may also rely on the electrical grid to meet feeding, hygiene, and temperature needs. Furthermore, lifesaving operations such as life support, monitoring, diagnostic capabilities, blood services, and pharmaceutical operations require a power source to function. Many of these threats also apply to the household level as well. FEMA reports that regulations do not mandate emergency standby power be available for all existing functions.

Landslides often occur following storm events when soils are loosened and saturated. In 2003, a heavy rainfall event resulted in five causalities from a landslide in Pago Pago. In 2004, another storm even resulted in a landslide that caused extensive property damage and one fatality in Fagaalu Bay. A quarry located upslope of the LBJ Hospital poses an additional landslide risk. The direct risk to lives and the indirect life loss risk posed by damage to critical infrastructure and homes creates a catastrophic life loss risk from landslides.

Destructive coastal flooding also poses a catastrophic life safety risk. High surf and storm surge during tropical cyclone and other storm events have caused widespread infrastructure and property damage and have directly resulted in causalities. Tropical Cyclone Val in 1991 resulted in 15 deaths across Tutuila and the Manu'a Islands. Furthermore, coastal flooding creates an indirect life loss risk through long-term power outages and destruction of roads to get to the LBJ Hospital and other critical facilities.

While an infrequent occurrence, the force and mass destruction from tsunamis create the risk for high magnitude life loss. In 2009, a tsunami hit around Pago Pago and resulted in 30 fatalities. Indirect life loss risk is also high from the widespread destruction of critical facilities, roads, homes, and power supply.

5.3 Risk Summary

The overall risk summary is shown below in Figure 5-12. The highest risk rating across the risk metrics (economic, social, environmental, and life loss) determined the placement of each stressor in the risk assessment summary. The stressors found to be catastrophic in any of the risk assessment plots are landslides/mudslides, overland/riverine flooding, power outages, coastal flooding, coastal erosion, sea level rise/subsidence, coastal habitat degradation, saltwater intrusion, and tsunami. While still critical to address, all other stressors were found to have a major risk rather than catastrophic. Although some stressors were ranked as minor in individual risk assessments, those stressors were not ranked as minor consistently throughout each risk metric, therefore there are no stressors ranked as minor in the overall risk summary.

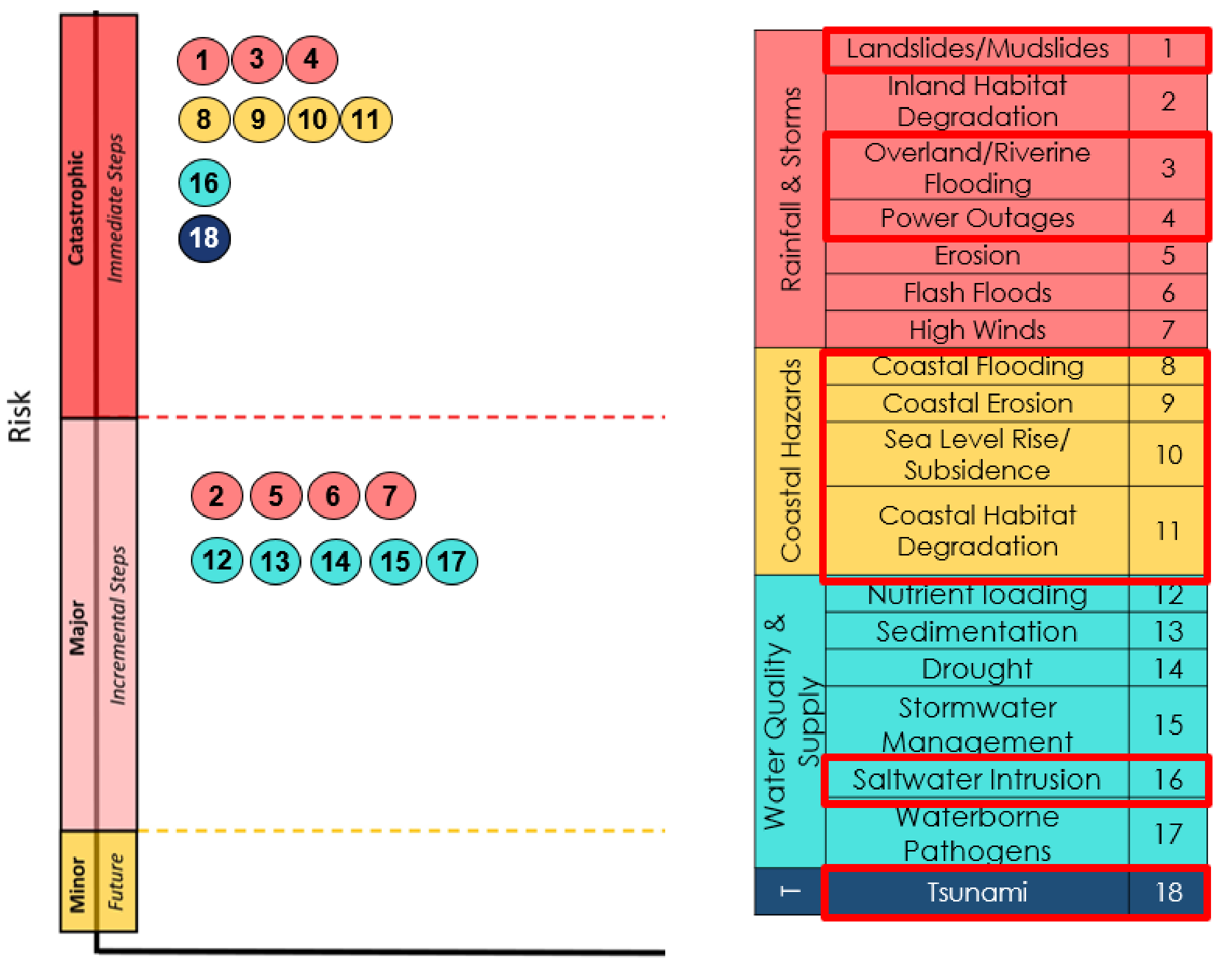


Figure 5-12. Overall Risk Summary

5.4 Uncertainty Analysis

In addition to risk, a qualitative assessment of uncertainty was also performed to identify the level of consensus among stakeholders in implementing potential risk reduction measures for each stressor. The following categories of consensus were developed to frame risk reduction recommendations: actions, evaluate options/further study, and fill data gaps (Figure 5-13). This qualitative uncertainty assessment was conducted through a review of existing information and with input from partners and stakeholders through a series of collaborative workshops. Uncertainty was broken down into three categories:

- **Action**: Implementable solutions were identified with a high level of consensus (actions can be recommended);
- **Evaluate Options:** Potential solutions could be defined with existing information (an evaluation of potential options can be recommended); or
- **Fill Data Gaps**: Additional data would be required to better define the problem and/or identify potential solutions (recommendations focus on filling data gaps).

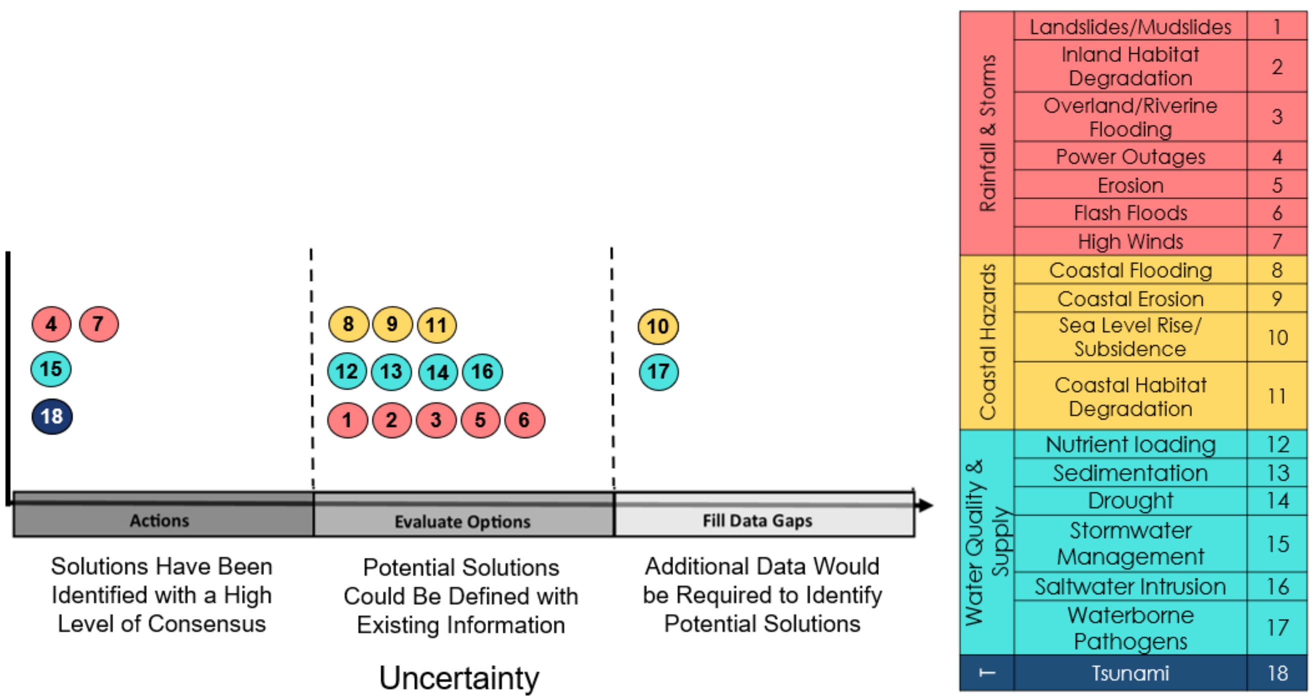
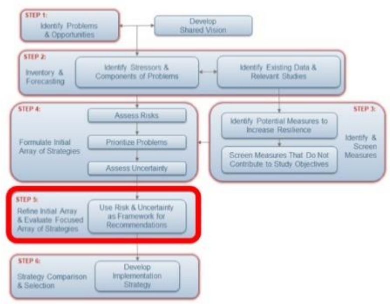


Figure 5-13. Uncertainty Analysis Results

5.5 Array of Strategies



Risk and uncertainty results were used to develop a framework for the appropriate types of (uncertainty based) and timing for (risk-based) recommendations. For problems categorized as "catastrophic," immediate steps should be taken to reduce risks through direct actions, evaluate potential options for reducing risks, or fill data gaps. For problems categorized as "major," incremental steps should be taken (or continue) to reduce these significant risks. Since no stressors ranked as "minor" across risk metrics, this category was not carried forward to the overall risk assessment summary. This risk and uncertainty analysis framed recommendations and helped prioritize actions for the near verses long-term. The results from the risk and uncertainty analysis placed the stressors into these broad recommendation categories (Figure 5-14).

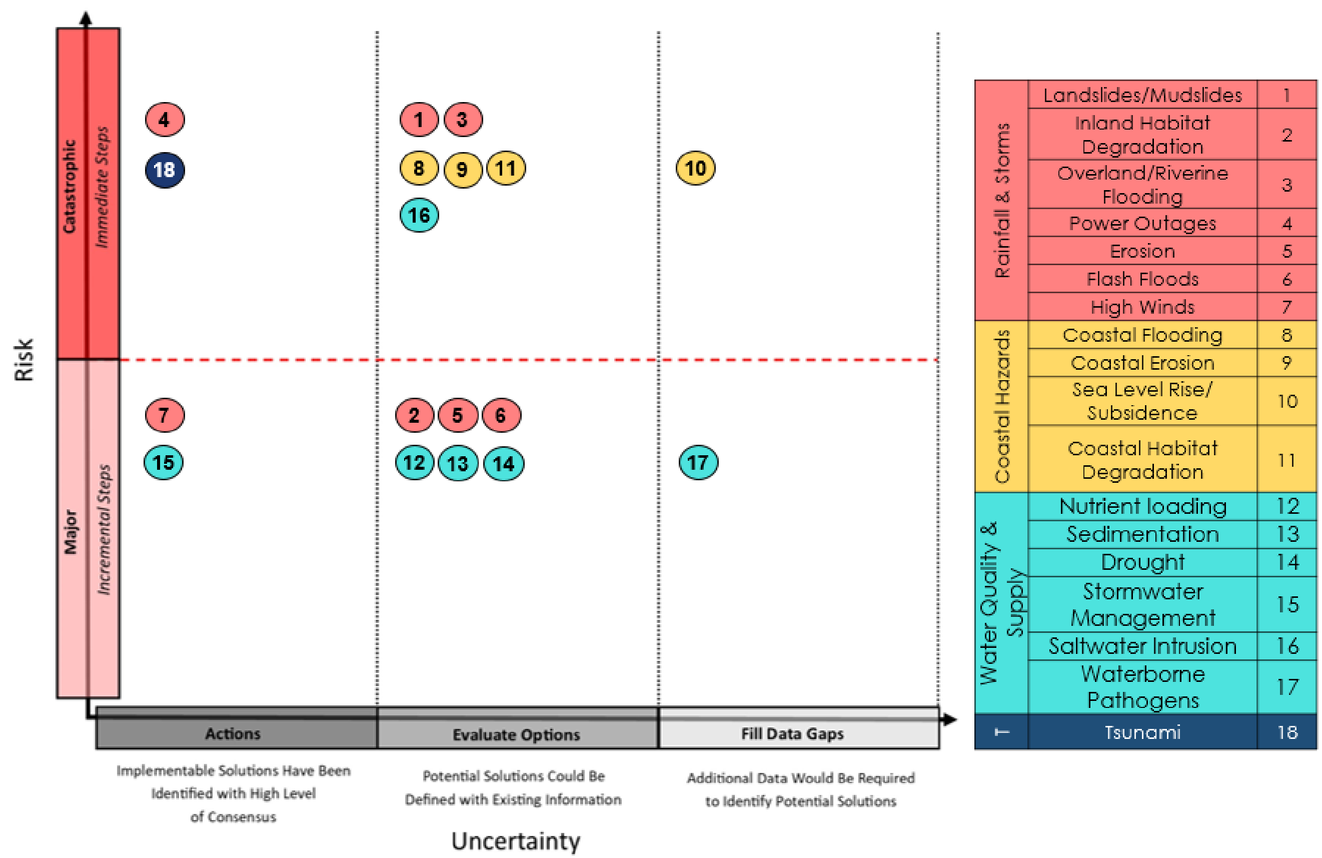


Figure 5-14. Risk and Uncertainty Summary

6 Recommendations and Implementation Strategy

Recommendations were developed based on the risk- and uncertainty-based prioritization framework to help achieve the planning goal of increasing resilience to weather related hazards in American Samoa.

Near-term actions were identified to reduce potentially catastrophic risks for which implementable solutions were identified with a high level of consensus among agencies and stakeholders; longer term, incremental actions were identified to reduce major risks with similar uncertainty. Options for near-term evaluation(s) were identified for potentially catastrophic risks where sufficient data and information exists to define potential solutions; options for incremental steps toward evaluation were identified to reduce major risks with similar uncertainty. Data gaps that should be filled in the near-term were identified for potentially catastrophic risks where warranted; incremental steps to fill data gaps were identified for major risks with similar uncertainty.

6.1 Framing Recommendations

The risk and uncertainty assessments framed recommendations that would be appropriate for the level of risk and existing knowledge and resources. Figure 6-1 below shows the broad types of recommendations the team and partners evaluated as part of this WA.

SLC was moved from the catastrophic risk/fill data gaps column to catastrophic risk/evaluate options to be considered alongside other coastal stressors in preliminary recommendations. Including SLC alongside other coastal stressors facilitated formulation of holistic recommendations.

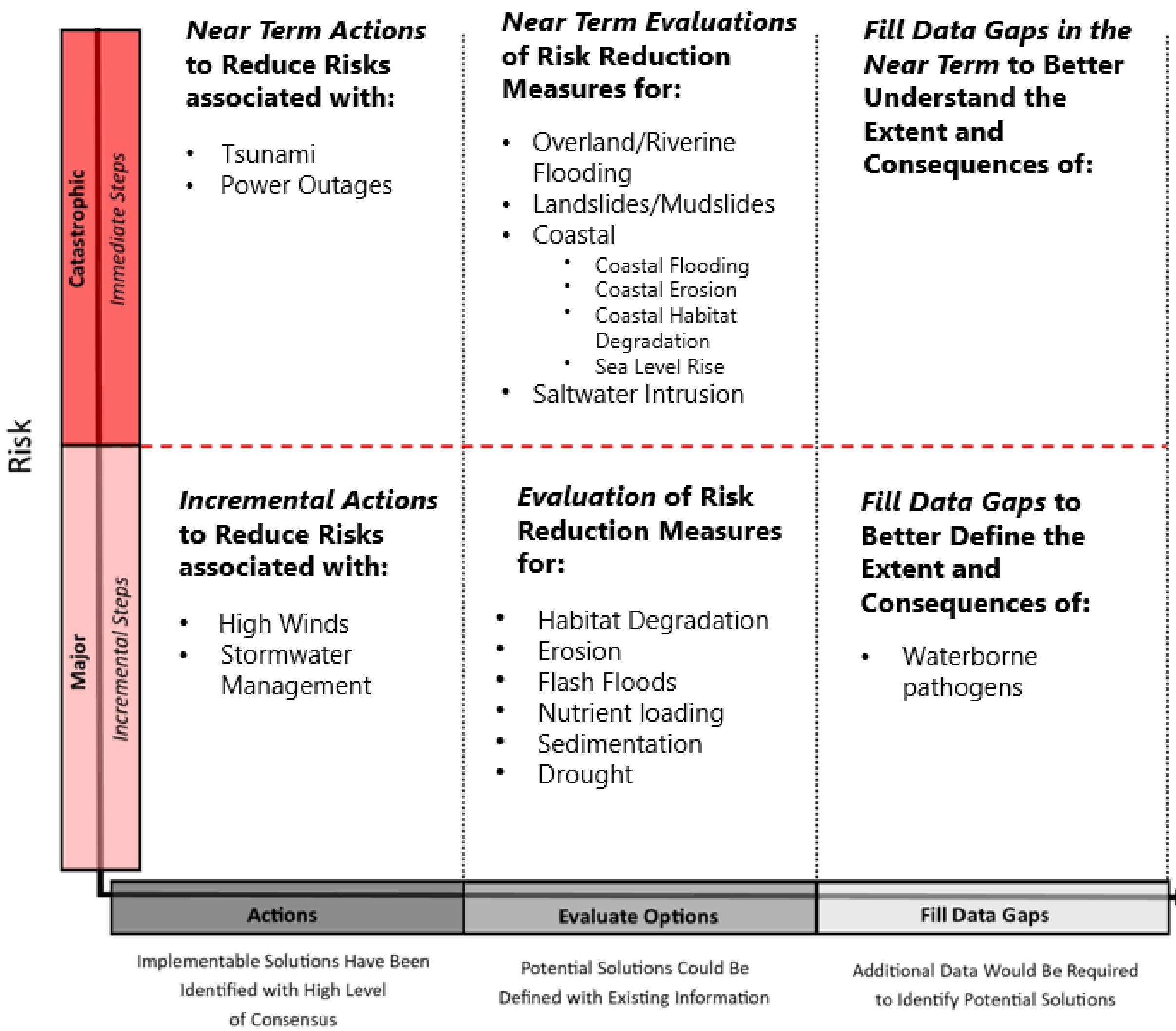
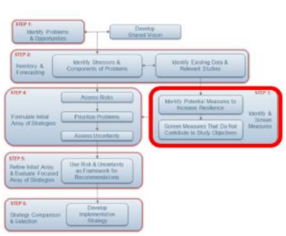


Figure 6-1. Framing Recommendations

The recommendations were developed by combining management measures, partner input, USACE expertise, and by pulling recommendations from existing reports and project requests.

Partners expressed the desire for green solutions in American Samoa in several meetings and phone calls. With this consideration, the team developed a set of nature-based and non-structural solutions to complement other structural solutions and provide a breadth of options.



6.2 Management Measures

Management measures, by themselves or grouped together, are the building blocks for recommendations. There are many ongoing efforts undertaken by partners and USACE to build resilience and address problems across American Samoa. An array of planning measures to address the problems and achieve the planning objectives described in Section 3.3 were developed by starting with those on-going or forecasted efforts (found in several reports) and gathering additional input from stakeholders and SMEs on the team.

No measures were screened from further consideration, as all identified measures contribute to the identified planning objectives. Instead, measures were compiled into recommendations through assessing the risk and uncertainty of problem categories and addressing the most critical needs based on those evaluations. Although not all measures are used in recommendations, the comprehensive list of measures was retained for future consideration by interested agencies. Section 5.2 provides details on the described risk assessment process.

Three preliminary categories of measures were identified in the initial planning iteration. These approaches are consistent with various stakeholder goals and viewpoints. The categories included the following:

- **Structural Measures** – physical modifications designed to reduce the frequency or consequence of a stressor.
- **Nature-Based Measures** – landscape features that are used to provide engineering functions relevant to risk management, while producing additional economic, environmental, and/or social benefits. These features may occur naturally in landscapes or be engineered, constructed and/or restored to mimic natural conditions.
- **Non-Structural Measures** – activities that focus on reducing or solving problems without constructing new structures. Non-structural measures include actions such as elevating or floodproofing buildings, policies, education, or emergency action exercises.

RESILIENCE means "the ability to **anticipate, prepare for,** and **adapt** to **changing conditions** and **withstand**, respond to, and **recover** from **disruptions**."
(Presidential Executive Order 13653)

Figure 6-2. USACE Principles of Resilience

The structural, nature-based, and non-structural approach aided the development and organization of measures and helped frame recommendations in later planning iterations. Identified measures contribute to the planning goal increasing American Samoa's resilience to weather related hazards. A list of measures can be found in Table 6-1. A checkmark is placed under the problem area the measure would address and notes which Principle of Resilience in Figure 6-2 (Defined in Section 3.3) the measure would contribute to.

Table 6-1. Measures

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
Structural Measures					
Submerged and/or Detached Breakwaters – used to protect a harbor, anchorage, basin, or area of shoreline from waves. Breakwaters reflect or dissipate wave energy and thus prevent or reduce incident wave height in the protected area.	–	✓	–	–	**Prepare**
Resizing Hydraulic Structures – Hydraulic structures can be used to divert, disrupt or completely stop the flow. Examples of hydraulic structures include levees, dams, artificial channels/canals, detention basins and impoundments.	✓	✓	✓	–	**Prepare, Adapt**
Slope Drains – allow water to flow downward with the aid of pipes or lined channels which extend from the top to the bottom of a cut or fill slope. They are designed to protect slopes from runoff.	✓	–	✓	–	**Prepare**
Terraced Hillsides – involves leveling a hillside's ground in sections so that the flat areas, the terraces, stack above one another like stairs. Terracing prevents rainfall runoff on sloping land from accumulating and causing serious erosion.	✓	–	✓	–	**Prepare, Adapt**
Diversion and Detention Basins – a diversion transfers water across watershed boundaries through a man-made pipeline or canal. Detention basins are designed to detain the stormwater runoff for some minimum time to allow particles and associated pollutants to settle.	✓	–	✓	–	**Prepare, Absorb**
Upper Watershed Sediment Capture – an area of land that drains all the streams and rainfall to a common body of water, temporarily stores the water and transports it from the land surface to the water body. A sediment capture is a temporary settling basin installed along a waterway or low-lying area to capture eroded or disturbed soil that is washed off during rainstorms. They protect the water quality of downstream streams, rivers, lakes, or bays.	–	–	✓	–	**Absorb**

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
Water Wells & Boosters Backup Power Supply – generators, batteries, and solar panels are options for getting power or when an electrical grid is interrupted.	–	–	✓	–	**Recover**
Seawalls – are built parallel to the shoreline as a reinforcement of the coastal profile. Prevents or alleviates overtopping and flooding of the land due to storm surge and waves; often consists of vertical face structures but can consist of loose rock or rubble mounds that deflect wave action through their array of voids and openings which spreads and absorbs wave energy. Some configurations of seawalls can have negative consequences due to redirected wave energy.	–	✓	–	–	**Prepare**
Revetments – are sloping shore-parallel structures, made from erosion-resistant material, constructed directly on an existing slope, embankment, or dike. They protect the area from strong waves and currents by dissipating and reducing wave action. Revetments are usually constructed out of stone, but other materials have been used with success including concrete-mat, willow plantings, gabions, and a host of other materials. Riprap and quarry-stone designs can tolerate some movement and remain functional, while concrete, wooden, or asphalt slabs are unable to tolerate settling.	–	✓	–	–	**Prepare**
Water Tank Reinforcements – keeps water tanks intact and the water inside safe and secure. Constructed for storing water, both steel and concrete tanks can be reinforced.	–	–	✓	✓	**Prepare, Adapt**
Beach Nourishment – the practice of adding large quantities of sand or sediment to beaches to combat erosion and increase beach width.	–	✓	–	–	**Prepare, Absorb**
Improve Wastewater Systems/Septic Systems – includes two specific techniques: converting basic septic systems to either centralized sewer systems or advanced septic systems and repairing existing sewage system components.	✓	–	✓	–	**Prepare**
Desalination – a process which turns saline water into freshwater by removing mineral components.	–	–	✓	–	**Prepare**
Road Compaction – a process by which the volume of air in soil is reduced by using external, mechanical forces. This provides a necessary flat base and gives the soil underneath higher resistance and greater stability by adding friction from the interlocking particles.	–	–	✓	–	**Prepare**

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
Wattles – shortening long, steep sloped mountainsides into shorter reaches.	✓	–	✓	–	**Prepare**
Alternative Energy – Infrastructure to enable energy generation from renewable sources such as solar, wind, or tides.	✓	–	–	–	**Prepare**
Nature-Based Measures					
Plantings on Dirt Roads/Cesspools – plant grass or keep existing native vegetation; direct all surface drainage away from roads and cesspools; use shallow-rooted plants near cesspools	–	✓	✓	–	**Absorb**
Mangrove Plantings – can provide shoreline protection with their root systems, trapping sediments and sand and helping to prevent shoreline erosion. During extreme weather events, these plant systems dampen waves and reduce the associated energy in the water. They also provide fish habitat and store carbon.	–	✓	✓	–	**Absorb**
Sloped Plantings – plant vegetation on slopes greater than 25%. For any slopes greater than 50% (1 foot vertical for every 2 feet horizontal run) install plants that do not require mowing.	–	✓	✓	–	**Absorb**
Vegetation Enhancements – provides aesthetic and environmental benefits without compromising the reliability of levees, floodwalls, embankment dams, and appurtenant structures. Roots from plantings also provide slope stability which may lessen erosion. Vegetation plantings should consider both human use, cultural significance, and the environmental processes and characteristics of the entire area influenced by the project.	✓	✓	✓	–	**Absorb**
Reef Balls – artificial reef modules designed to mimic natural reefs; made from concrete and placed in oceans to form reef habitat.	–	✓	–	–	**Absorb**
Reef Enhancements – protect and restore reefs and support adaptive management efforts that increase the resilience of local reef systems.	–	✓	✓	–	**Absorb**
Shoreline Protection – used to retain or rebuild natural systems (cliffs, dunes, wetlands, and beaches) or to protect infrastructure landward of the shoreline. Shore protection contributes to storm damage reduction and coastal erosion mitigation.	✓	✓	–	–	**Absorb**

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
Invasive Species Removal – to eliminate or reduce populations of plants, animals, and other living organisms that are not native to a particular area.	✓	✓	✓	–	**Absorb**
Rainwater Harvesting/Capture – process in which precipitation that falls on a site is diverted, captured, and stored for use on-site, as opposed to allowing it to run off, evaporate, or infiltrate into the soil.	✓	–	✓	–	**Prepare**
Permeable Roads, Parking Lots, And Sidewalks – porous surfaces, which allow precipitation to naturally drain through to the subsurface.	✓	✓	✓	–	**Absorb**
Gravity Fed Water Catchment Systems – use the earth's gravity to help move water intended for harvesting/capture.	–	–	✓	–	**Absorb**
Native Invertebrate Recruitment – restoring native invertebrates for natural filtration, ecosystem restoration, and wave energy dispersion.	–	✓	✓	–	**Absorb**
Non-Structural Measures					
Rain Gardens – vegetated depressions that are designed to capture drained runoff. They can also be efficient for the removal of metals, nutrients, organic compounds, solids, etc.	✓	–	✓	–	**Prepare**
Dredging – removing silt and other materials from the bottom of bodies of water. It's required in many ports of the world, to deepen and maintain navigation channels and harbor entrances.	✓	✓	–	–	**Prepare**
Gauge Installation/Early Warning Systems – an automated water gauge is a flood detection unit that monitors water levels. Data collected can be used real time to provide early warning to those in affected areas.	✓	✓	✓	–	**Prepare, Absorb, Recovery**
Installation of Subsurface Sediment Tanks – component of modern system of water supply or wastewater treatment. It allows suspended particles to settle out of water or wastewater as it flows slowly through the tank.	✓	✓	✓	–	**Prepare**
Elevate Structures Above Estimated Flood Heights – adaptive and mitigative measure to help reduce susceptibility to predictive future flood caused damage. May include stilts or other structure raising techniques. May be a good alternative to relocation.	✓	✓	–	✓	**Prepare, Adapt**
Replacement Housing Design Guides – considers use of materials, structures, site issues and planning to provide design solutions for adaptive, resilient buildings.	✓	✓	–	✓	**Prepare, Adapt**

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
Collaborative Database – virtual platform designed to support interagency information sharing, particularly for water quality monitoring.	✓	✓	✓	✓	**Prepare**
Water Quality Monitoring – sampling and analysis of water constituents to determine physical, chemical, and biological characteristics. It commonly includes temperature, pH, dissolved oxygen, conductivity, salinity, oxygen reduction potential, turbidity, and transparency.	✓	–	✓	–	**Prepare**
Disaster Recovery Plans – a plan that has a primary goal of enabling survival of a disaster and to assure critical functions can resume in order to continue normal operations.	✓	✓	✓	✓	**Prepare**
Education & Outreach – efforts to provide informative knowledge in a manner that excites public interest.	✓	✓	✓	✓	**Prepare**
Wetland Delineation – an area that is inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions.	✓	✓	✓	–	**Prepare**
Increased Shoreline Monitoring/Data Collection – use of traditional and innovative methods to monitor and collect data (e.g., hovering unmanned aerial system imagery).	–	✓	✓	–	**Prepare**
Structure Relocation – process of moving a structure from one location to another. It mainly involves two consecutive steps, disassembling and reassembling at the required destination, or raising and transporting whole.	✓	✓	–	–	**Prepare, Adapt**
Weatherproof Key Infrastructure/Utilities – flood barriers to protect critical infrastructure include levees, dikes, and seawalls. It could also involve elevating equipment or placing it within waterproof containers or foundation systems.	✓	✓	–	✓	**Prepare, Adapt**
Improve Best Management Practices (BMPs) During Construction – a product or practice used to manage stormwater runoff and the pollutants commonly associated with runoff. BMPs are policies, practices, procedures, or structures implemented to mitigate the adverse environmental effects resulting from development.	✓	✓	✓	–	**Prepare**
Agriculture BMPs – conservation practices that are tools which can be used to reduce soil and fertilizer runoff,	✓	✓	✓	–	**Prepare**

Measure	Rainfall & Storms	Coastal Flooding & Erosion	Water Quality & Supply	Tsunamis	Resilience Principle Achieved
properly manage animal waste, and protect water and air quality on farmland.					
Stormwater Management BMPs – techniques that will best manage stormwater quantity and quality on a site, based on unique conditions, and planning and engineering requirements.	✓	✓	✓	–	**Prepare**
Enforcement and Regulations – Work with agencies to develop and enforce written regulations to increase resiliency.	✓	✓	✓	✓	**Prepare**
Expand Critical Infrastructure Database – develop and maintain database documenting location and conditions of critical infrastructure for hazard analysis.	–	✓	–	✓	**Prepare**
Tsunami Preparedness and Planning – mitigation strategies designed to reduce the likelihood that coastal populations will be impacted by a tsunami, typically through removing communities from known tsunami inundation zones.	–	–	–	✓	**Prepare**
Emergency Action Plan Development – plan to reduce, or avoid, losses from hazards, assure prompt assistance to victims, and achieve rapid and effective recovery. Steps include prevention, mitigation, preparedness, response, and recovery.	✓	✓	–	✓	**Prepare, Absorb, Recover**
Emergency Response Exercises – often the best way to prepare teams to respond effectively to an emergency. The enhanced knowledge of plans, allow members to improve their own performance and identify opportunities to improve capabilities to respond to real events. Can include emergency response practices, such as table-top exercises.	✓	✓	✓	✓	**Prepare, Absorb, Recover**
Improve the Existing Tsunami Warning System – Assess the need to update, modernize, and expand American Samoa's tsunami warning system. Components of the warning system include a network of sensors to detect tsunamis and a communication infrastructure to issue timely alarms to permit evacuation of the coastal areas (seismic and sea-level observation systems).	–	–	–	✓	**Prepare**
Power Redundancies – Increase communication capacities to aid emergency response efforts. Includes ultra-high frequency radio or additional cell towers.	✓	–	–	✓	**Prepare, Absorb**

6.3 Potential Funding and Implementation Resources

Existing authorities and programs will be utilized, when possible, to implement recommendations. Below are explanations of identified funding opportunities, both from USACE and other agencies. Additional information may be found online or through coordination with agency representatives.

USACE Authorities:
Below is a summary of all USACE authorities that are available for planning, feasibility study, technical assistance or construction efforts. Most authorities require a non-federal cost share; however, cost share waivers may be available, per Section 1156 of WRDA 1986, as amended (33 U.S.C. 2310), for the categories of Planning Assistance to States, General Investigation Studies, and the Continuing Authorities Program, described below.

- **Floodplain Management Services (FPMS)** – authorized under Section 206 of the Flood Control act of 1960, as amended provides communities with technical and planning services to support effective floodplain management. FPMS efforts are often completed by Silver Jackets teams. Under the FPMS, USACE supports both riverine and coastal flood challenges and empowers communities to better understand their risks of flooding and develop plans to communicate and manage that risk. Activities provided under this authority include hydrologic and hydraulic technical services, general planning guidance, education and outreach material, and National Flood Insurance Program support. Funding is typically 100% federally provided, within limits of the authority. Requests for assistance should be in the form of a letter that includes the location and nature of the problem to be investigated.

- **Silver Jackets** – Silver Jackets teams in states and territories across the United States bring together multiple state, federal, tribal, territorial and local agencies in partnership to learn from one another in reducing flood risk and other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when such events do occur. The partnerships provide an opportunity for mentoring and networking, enabling agencies to better respond and prepare for disasters as a team, and help achieve communities that are sustainable and resilient to natural disasters, especially flooding. The interagency nature of Silver Jackets teams allows for leveraging of all available resources and authorities, including those from within USACE such as FPMS, to support local flood risk management needs.

  Coordination between USACE and ODAPM is underway to initiate the formalization of a Silver Jackets team in American Samoa.

- **Planning Assistance to States** (PAS) – Two types of planning assistance, including preparation of Comprehensive Plans and Technical Assistance, are offered through the Planning Assistance to States (PAS) program (authorized by Section 22 of WRDA 1974, as amended). Requests for assistance should be in the form of a letter that includes the location and nature of the problem to be investigated.

- Comprehensive Plans include planning for the development, utilization, and conservation of the water and related resources of drainage basins, watersheds, or ecosystems located within the boundaries of that state or territory (or group of states/territories) to comprehensively address water resource challenges.

- Technical Assistance provided through the PAS program includes support of planning efforts related to the management of water resources, including the provision and integration of hydrologic, economic, or environmental data and analysis in support of water resources management and related land resources development plans. This technical assistance may not include the preparation of site-specific designs or construction. Section 22 technical assistance is only available upon request of a government agency and/or non-federal interest. Technical assistance activities through the PAS program are cost shared (50%) with the non-federal sponsor, and voluntarily contributed funds in excess of cost share may be provided by the non-federal sponsor. The cost share for technical assistance must be provided by funds (not in-kind).

- **General Investigation (GI) -** USACE is authorized to conduct investigations related to its core mission areas of navigation, flood risk management, and ecosystem restoration, to determine if Congressional authorization and implementation of a specific Civil Works project are warranted. GIs involve jointly conducting a study with a sponsor and, if shown by the study to be feasible, the construction and implementation of the project. This approach requires that Congress provide an authorization to construct or implement the project. There are several types of planning studies and/or decision documents, but for the GI process the most common studies are Feasibility Studies, which include optimizing the plan(s) to be built, are equally cost-shared, and usually completed in 24-36 months. The first $100,000 is federally funded. If the study cost exceeds $100,000, the cost share is 50% federal and 50% non-federal. Project implementation requires both authorization and appropriation from Congress, and the cost share is typically 65% federal and 35% non-federal. Requests for assistance should be submitted in the form of a Letter of Intent from a state or local government agency to USACE.

- **USACE Engineering with Nature (EWN) Initiative** - EWN is the USACE initiative that enables more sustainable delivery of economic, social, and environmental benefits associated with infrastructure. Sustainable water resources infrastructure is achieved through the beneficial integration of engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management. Triple-win outcomes are achieved throughout EWN by systematically integrating social, environmental, and economic considerations at every phase of a project. The results are innovative and resilient solutions that are more socially acceptable, viable and equitable, and, ultimately, more sustainable.

- **USACE International and Interagency Services (IIS)** – IIS is the USACE program providing technical assistance to non-Department of Defense (DoD) federal agencies, state and local governments, tribal nations, private U.S. firms, international organizations, and foreign governments. Most IIS work is funded on a reimbursable basis. USACE provides engineering and construction services, environmental restoration and management services, research and development assistance, management of water and land related natural resources, relief and recovery work, and other management and technical services.

- **Regional Sediment Management (RSM) Program** – RSM is a research program which implements innovative management strategies to optimize the use of sediment and improve the management of projects. The program supports initiatives that develop and demonstrate sustainable practices that systematically increase benefits and reduce lifecycle costs for the Corps' Navigation, Flood Risk Management, and Environmental missions. RSM provides opportunities to collaborate with stakeholders and other agencies to leverage resources, share technology and data, and develop and implement innovative solutions to improve regional utilization and management of sediments. Proposals are typically solicited once per year in June and are submitted by USACE Districts. Projects do not require a non-federal cost share, however stakeholder and partner engagement and information sharing is strongly encouraged and considered in the proposal selection process.

  Section 7001 Annual Report – The Section 7001 Annual Report to Congress Process may be used for when study authority does not already exist for an area of interest. In Section 7001 of the Water Resources Reform and Development Act of 2014 (P.L. 113-121; 33 U.S.C. §2282d), Congress established an annual process for identifying proposals for site-specific studies and projects within USACE's water resource mission and authorities. The process includes a call for nonfederal proposals, which should be submitted to the Planning Division at the USACE District with an area of responsibility that includes the area of interest (for American Samoa this is the Honolulu District). Inclusion of a proposal in a Section 7001 annual report does not provide congressional authorization or appropriation. Rather, inclusion of a proposal in a report facilitates congressional consideration of authorizing the proposal.

- **Continuing Authorities Program (CAP)** – The CAP is a group of nine legislative authorities under which the Corps of Engineers can plan, design, and implement certain types of water resources projects without additional project specific congressional authorization. The purpose of the CAP is to plan and implement projects of limited size, cost, scope and complexity. For all sections except Section 204 and 111, the Feasibility phase may be initially federally funded up to $100,000. Any remaining feasibility phase costs will be share 50/50 with the non-federal sponsor after executing a feasibility cost sharing agreement. For Section 204 projects, the Feasibility phase is performed at 100% federal cost. For Section 111 projects, the Feasibility phase costs above the initial $100,000 will be cost shared in the same proportion as the cost-sharing provisions applicable to the construction of the federal navigation project causing the shore damages. Construction is either cost shared at 65% federal and 35% non-federal, or 75% federal and 25% non-federal, depending on the authority. Requests for assistance should be in the form of a letter describing the location and nature of the problem and requesting assistance under the program. The nine authorities included in the program are shown below in Table 6-2:

Table 6-2. CAP Authorities

AUTHORITY	PROJECT PURPOSE	FED PROJECT LIMIT
Section 14, Flood Control Act of 1946, as amended. Emergency Streambank and Shoreline Protection.	Flood risk management	$5.0M
Section 103, River and Harbor Act of 1962, as amended. Small Beach Erosion Control.	Coastal storm risk management	$10.0M
Section 107, River and Harbor Act of 1960, as amended. Small River and Harbor Improvements Projects.	Navigation improvements	$10.0M
Section 111, River and Harbor Act of 1968, as amended. Shore Damage Prevention or Mitigation.	Prevention or mitigation of shore damage caused by federal navigation projects	$12.5M
Section 204, Water Resources Development Act of 1992, as amended. Regional Sediment Management.	Beneficial uses of dredged material	$10.0M
Section 205, Flood Control Act of 1948, as amended. Small Flood Control Projects.	Flood risk management	$10.0M
Section 206, Water Resources Development Act of 1996, as amended. Aquatic Ecosystem Restoration.	Aquatic ecosystem restoration	$10.0M

AUTHORITY	PROJECT PURPOSE	FED PROJECT LIMIT
Section 208, Flood Control Act of 1954, as amended. Snagging and Clearing for Flood Control.	Snagging and clearing for flood risk management	$0.5M
Section 1135, Water Resources Development Act of 1986, as amended. Project Modifications for Improvement of Environment.	Project modifications for improvement of the environment	$10.0M

A pilot program for CAP projects in small or disadvantaged communities allows for full federal funding with no cost share requirement. The pilot program will apply for ten projects selected from across the United States that meet economic criteria. CAP projects identified in AS may qualify for this pilot program when it is implemented.

Funding Opportunities available from other agencies and organizations:

- **AS DHS, Office of Insular Affairs** – Department of Homeland Security Preparedness Grant programs provide funding to state, local, tribal and territorial governments, nonprofit agencies and the private sector in building and sustaining capabilities to prevent, protect against, respond to and recover from acts of terrorism and other hazards. The total amount for each grant program is set by Congress and the allocations are made by the Secretary.

- **AS Department of Transportation (AS DOT)** – Funding is available through the Bipartisan Infrastructure Law. Through the Territorial Highway Program, American Samoa would expect to receive approximately $24M over five years to rebuild its roads and bridges. On an average annual basis, this is about 14% more than the funding American Samoa receives under current law. American Samoa can also compete for the $15 billion of national funding in the law dedicated to megaprojects that will deliver substantial economic benefits to communities. American Samoa may also apply federal aid dollars towards climate resilience and safety projects.

- **AS Port Authority** – The American Samoa Department of Port Administration (AS-DPA) has prepared a Draft Proposal for the following capital improvement projects: 1) New Seaport Building, 2) Airport Reconstruction and, 3) the Inter-Island Transportation and Harbor Vessels. The proposed projects listed in this document are aimed towards executing the necessary infrastructure improvements to the Pago Pago Port and Pago Pago International Airport which have encountered numerous negative impacts due to the COVID-19 pandemic. The projects are designed to ensure that these critical border facilities have sustainable infrastructures to recover from the negative effects of the pandemic, and to increase economic productivity.

AS Office of the Governor – Funding allotted to clean up the Vaipito stream as well as its associated tributaries and wetland areas in order to protect Pago Pago Bay and the surrounding marine environment from sedimentation and run off. Clean-up and restoration efforts will also focus on the removal of trash and debris from target areas to reduce disease-carrying mosquito and rat populations, as well as revegetation of the lower Vaipito area with mangrove trees and riparian salt-resistant native tree species. All efforts will support the Governor's Island-Wide Clean-Up Initiative and are included in American Samoa's long-term conservation plan.

- **FEMA Hazard Mitigation Assistance Grant Programs:**
    - The Hazard Mitigation Grant Program (HMGP) provides funding to rebuild in a way that reduces, or mitigates, future natural hazard losses in communities. HMGP funding is authorized with a Presidential Major Disaster Declaration. The amount of funding made available to the applicant is generally 15% of the total federal assistance amount provided for recovery from the presidentially declared disaster and is determined by the FEMA-approved Hazard Mitigation Plan.

    - The Building Resilient Infrastructure and Communities (BRIC) competitive grant program supports hazard mitigation projects to reduce the risks from disasters and natural hazards. The BRIC program aims to categorically shift the federal focus away from reactive disaster spending and toward proactive investment in community resilience. As a competitive grant program, applicants must apply on a yearly basis and the proposed project must have positive net benefits. BRIC encourages public infrastructure projects, projects incorporating nature-based solutions, and the adoption and enforcement of modern building codes.

    - Fire Management Assistance Grant provides funding in the amount of $5,520 per acre affected by wildfires. The funding is for projects that revolve around soil stabilization, flood diversion, and reforestation projects.

    - Emergency Management Performance Grant Program provides funding for emergency management agencies that are implementing National Preparedness Systems and Goals. The goals of preparedness are prevention, protection, mitigation, response, and recovery from the threat of natural hazards.

- **Housing and Urban Development Disaster Resilience Grants:**
    - The Office of Community Planning and Development (CPD) provides billions of dollars in flexible funding to help communities recover from and build resilience to climate hazards and natural disasters, particularly low- and moderate-income

communities who are especially vulnerable due to current and historic discrimination and disinvestment. The Community Development Block Grant (CDBG) program is both a flexible and widespread program, reaching over 1,200 local governments in all states and territories. The program's scope and promotion of community-specific solutions make CDBG a powerful tool for climate resilience which requires jurisdictions to incorporate resilience to natural hazard risks into their Consolidated Plan and discuss how climate change will increase those risks and how they plan to address the impacts of climate change on low- and moderate-income residents.

- The Section 108 Loan Guarantee Program (Section 108) provides communities with a source of low-cost, long-term financing for economic and community development projects. Section 108 financing provides an avenue for communities to undertake larger, more costly projects, where they may have limited resources to invest in upfront. Section 108 can fund economic development, housing, public facilities, infrastructure, and other physical development projects, including improvements to increase their resilience against natural disasters. This flexibility of uses makes it one of the most potent and important public investment tools that HUD offers to states and local governments.

- **National Fish and Wildlife Foundation (NFWF) Resilience Fund:**
  - The National Coastal Resilience Fund restores, increases, and strengthens natural infrastructure to protect coastal communities while enhancing habitats for fish and wildlife. Established in 2018, the National Coastal Resilience Fund invests in conservation projects that restore or expand natural features that minimize the impacts of storms and other naturally occurring events on nearby communities.
  - The Coral Reef Conservation Fund – Since 2000, the NFWF has responded to the alarming decline in both the quantity and productivity of the world's coral reef ecosystems through multiple coral conservation initiatives that aim to improve management, increase public awareness, and reduce threats to coral reefs. The program works to support reef resiliency by reducing negative impacts from unsustainable fishing and land-based pollution.

- **National Oceanic and Atmospheric Administration (NOAA):**
  - Community-Based Habitat Restoration – NOAA's Community-based Restoration Program provides funding and technical assistance for restoration projects that ensure fish have access to high-quality habitat. The goal of these projects is to recover and sustain fisheries–particularly those species managed by NOAA Fisheries, or those listed as endangered or threatened under the Endangered Species Act. Projects range from improving access to habitat by removing dams

and other barriers, to restoring coral and oyster reefs, to rebuilding coastal wetlands.

- Coral Reef Conservation Program **-** Since 2001, the Coral Reef Conservation Program has provided annual funding in the form of cooperative agreements to eligible state, territorial, and commonwealth agencies for conservation projects in coral reef jurisdictions. The program provides matching awards of financial assistance that are administered as cooperative agreements. The objective is to support coral reef management and monitoring programs as well as conservation projects that seek to improve the condition of coral reef ecosystem resources.

  The Ruth Gates Coral Restoration Innovation Grants fund projects that are aimed at promoting long-term persistence of corals by supporting the science needed to incorporate resilient corals into restoration activities and to enhance the efficiency of sexual coral restoration. Projects funded are expected to have an overarching goal of bringing intervention research closer to applied restoration efforts.

  The Coral Reef Conservation Fund is a competitive grant program administered on behalf of the NOAA Coral Reef Conservation Program by the National Fish and Wildlife Foundation (mentioned above under NFWF).

- Coastal Zone Management Act – This act, administered by NOAA, provides for the management of the nation's coastal resources, including the Great Lakes. The goal is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone.

- Section 309 - Every five years NOAA provides a process under "Section 309" of the Coastal Zone Management Act (as amended) for states and territories to carry out assessments to determine if funding may be available for projects relating to wetland, coastal hazards, public access, marine debris, cumulative and secondary impacts, special area management plans, ocean resources, energy and government facility siting, and aquaculture. To be eligible for 309 funding for the next five-year period, an approved Assessment and Strategy report must be carried out by the territory (or state) by the Coastal Management Program. The "309" process calls for development of a Draft version of the Section 309 Assessment and Strategy followed by a review period, preparation of a final draft, and approval of program enhancement funding.

- NOAA Coastal Resiliency Grants - The NOAA Coastal Resilience Grants program implements projects that build resilience through sustainable ecosystem processes and functions and reduce the vulnerability of coastal communities and infrastructure from the impacts of extreme weather events, climate hazards, and changing ocean conditions. Eligible applicants are institutions of higher education, nonprofit and for-profit organizations, United States territories and states, Native American tribes, and local governments. Applicants must submit a pre-proposal by email to resilience.grants@noaa.gov. Full proposals will only be accepted from eligible applicants that received an invitation to submit a full proposal based on the strength of their pre-proposal.

- U.S. Integrated Ocean Observing System (IOOS) - national-regional partnership working to provide new tools and forecasts to improve safety, enhance the economy, and protect our environment. Integrated ocean information is available in near real time, as well as retrospectively. Easier and better access to this information is improving our ability to understand and predict coastal events - such as storms, wave heights, and sea level change.
- Regional Integrated Sciences and Assessments (RISA) Program - NOAA's Regional Integrated Sciences and Assessments (RISA) program supports research teams that help expand and build the nation's capacity to prepare for and adapt to climate variability and change.
- National Tsunami Hazard Mitigation Program (NTHMP)
  - *Mapping and Modeling (MMS)* - As the hazard assessment subcommittee, the MMS brings together expertise on modeling and mapping of tsunami hazards.
  - *Warning Coordination (WCS)* - Through the WCS, the NTHMP provides input to the operational U.S. Tsunami Warning System. Recommendations from the NTHMP help refine warning system messages, graphics, procedures, exercises, and dissemination systems so that warning system products are effective during a tsunami warning.
  - *Mitigation and Education (MES)* - The MES works to reduce tsunami impacts primarily through education and outreach that increase awareness and encourage preparedness. It also promotes and provides guidance on other risk reduction activities, such as evacuation planning and integration of tsunami risk into land-use policy and planning.

- **USDA Natural Resources Conservation Service (NRCS) Pacific Island Area:**
  - Agricultural Conservation Easement Program, Agricultural Land Easements, and Wetland Restoration Easements help restore, protect, and enhance wetlands on eligible land. ALE (Agricultural Land Easements) protects farmlands and grasslands by limiting non-agricultural uses of the land.

- Environmental Quality Incentive Program Conservation Incentive combines the best of the Conservation Stewardship Program and the Environmental Quality Incentive Program, providing annual payments for the operation's existing level of conservation and financial assistance for installation of conservation practices or enhancements. Unlike the Conservation Stewardship Program, not all acres under the applicants control need to be enrolled or assessed for eligibility for Environmental Quality Incentive Program Conservation Incentive.

- Conservation Stewardship Program, the nation's largest conservation program in terms of participating land, is designed to help farmers have more robust conservation activities. Agricultural producers and forest landowners looking to build on conservation efforts can receive annual payments for the operation's existing level of conservation and financial assistance for a wide variety of conservation activities.

- Farm Bill 2014 Reginal Conservation Partnership Program funds solutions to natural resource challenges. By leveraging collective resources and collaborating on common goals, Reginal Conservation Partnership Program demonstrates the power of public-private partnerships in delivering results for agriculture and conservation.

- Emergency Watershed Protection Program is a program that aims to relieve imminent hazards to life and property caused by floods, fires, windstorms, and other natural hazards. Financial and technical assistance is provided to remove debris from streams, protect destabilized streambanks, establish cover on critically eroding lands, repairing conservation practices, and the purchase of flood plain easements.

US Environmental Protection Agency:

- Agency Clean Water State Revolving Funds - The Clean Water State Revolving Fund (CWSRF) program is a federal-state partnership that provides communities low-cost financing for a wide range of water quality infrastructure projects. Types of projects eligible to receive assistance are construction of publicly owned treatment works, nonpoint source, national estuary program projects, decentralized wastewater treatment systems, stormwater, water conservation, watershed pilot projects, energy efficiency, water reuse, security measures at publicly owned treatment works, and technical assistance.

- Nonpoint Source and the Section 319 Grant Program - Under section 319 of the Clean Water Act, EPA annually provides grants to states for controlling nonpoint sources of pollution, such as agricultural runoff, mining activities and malfunctioning onsite septic systems. In states where onsite systems have been identified as a significant source of such pollution, these funds may be used to construct, upgrade, or repair onsite systems.

- Water Quality Monitoring Grant Program – Also known as the Section 106 Grant Program, this grant funds efforts to enhance existing monitoring efforts and help them achieve their long-term monitoring program goals.

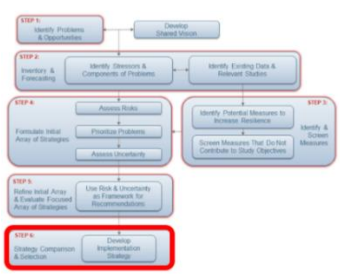
- Brownfields Technical Assistance Program – Provides technical assistance to communities and stakeholders to help address their brownfield sites, and to increase their understanding and involvement in brownfields cleanup, revitalization and reuse.

- **USGS Pacific Islands Climate Adaptation Science Center -** Funding is periodically made available through Requests for Proposals from the USGS or from funding announcements from the University Consortium. Announcements are made available on the USGS Pacific Islands Climate Adaptation Science Center website.

  The USGS Pacific Islands Climate Adaptation Science Center identifies research priorities tied closely to the needs of natural and cultural resource managers in the Pacific Islands region. Proposals typically should focus on developing "actionable science" or knowledge that can inform or be applied to specific management challenges, locally or broadly across the Pacific Islands region.

- **University of Hawai'i Sea Grant -** Hawaii Sea Grant funds research that emphasizes solution-based outcomes and applicability to pressing issues. Proposals are requested through a biennial research competition. Program development funds are also provided for select pilot projects throughout the year. Current projects address critical topics such as hazard resilience, ecosystem health, sustainable seafood, and sustainable coastal development.

6.4 Recommendations



Recommendations follow the broad outline set forth from the risk and uncertainty results (Figure 6-1.) The following sections document the proposed recommendations and possible implementation strategies, including potential funding sources and partners. Recommendations were formulated by carrying forward management measures that addressed a specific stressor while adhering to the risk and uncertainty framework. Recommendations include either stand-alone measures (if the measure was distinctly unique) or combined with similar measures for a comprehensive recommendation. The recommendations provided in the sections below address issues related to natural hazards with a nexus to water resources.

The team held several coordination meetings with partners, both group and one-on-one sessions, to gain input and concurrence on the recommendations. Partners provided valuable insights into interest in recommendations and parallel on-going efforts. Potential agencies that could champion the implementation of recommendations are noted in the following recommendation tables. Letters of support from these key agencies are included in Appendix A.

The need for addressing hazards is expedited by SLC and climate change. Recommendations include a mix of structural, non-structural, and nature-based recommendations. Strategies could include exploration of green and nature-based solutions, which deliver economic, environmental, and social benefits using natural systems. By using a combination of natural and conventional processes and materials, nature-based features can protect people, homes, and habitats. Knowledge and acceptance around these solutions is continuously growing. Study partners repeatedly expressed desire for exploration and implementation of green solutions. However, there may be several challenges to overcome including knowledge-based, political, and technical barriers along with available funding.

While there is general support for natured-based features from federal and local agencies, there needs to be buy-in from *maiti* and government officials. This may require efforts to educate and highlight the benefits, both human and ecological, that these solutions provide.

Like any solution, nature-based features need to be appropriate for the specific geomorphologic, hydrologic, hydraulic, and other conditions in order to be successful. Additionally, any solutions recommended must comply with all federal, state, or territorial regulations. Examples include federal environmental laws (Code of Federal Regulations {eCFR.gov}), USACE Regulations - Navigation and National environmental Policy Act (33 Code of Federal Regulations {CFR} Part 200 et seq.), National environmental Policy Act (40 CFR Part 1500-1508), Endangered Species Act (50 CFR Part 402), Clean Water Act (40 CFR Parts 121 and 230 Magnuson-Stevens Fishery Management and Conservation Act (50 CFR Part 600), Coastal Zone Management Act (15 CFR Part 923), Fish and Wildlife Coordination Act (16 USC 661), Marine Mammal Protection Act (50 CFR Part 216), Migratory Bird Treaty Act (50 CFR Part 21), National Historic Preservation Act (36 CFR Part 800), Clean Air Act (40 CFR Part 93, Subpart B), Wild and Scenic Rivers (36 CFR Part 297), and applicable Executive Orders (EOs), such as:

- EO 11988 - Floodplain Management
- EO 11990 - Protection of Wetlands
- EO 12322 - Water Resources Projects:
- EO 12898 - Environmental Justice
- EO 13112 - Invasive Species
- EO 13690 - Federal FRM Standards
- EO 13751 - Invasive Species Safeguarding the Nation
- EO 13990 - Climate Crisis
- EO 14008 - Tackling the Climate Crisis

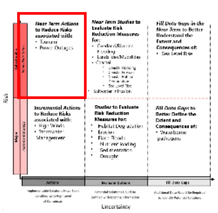
Approximately 90% of land in American Samoa is communal land. Communal land is an integral part of the social organization and is tied to both the kinship system and village organization. The cognatic descent group (ʻâiga) are the "owners" of the land, and rights to land use come with membership in the descent group. However, this may present future real estate challenges with implementation of some types of structural and non-structural recommendations. Additionally, no specific lands have been identified for recommendations.

Costs included for recommendations are rough estimates and do not include real estate. Costs are denoted by the following scale:

- $ $0-$1M
- $$ $1M-$5M
- $$$ $5M+

There is no obligation from the USACE, other federal agencies, study partners, or the American Samoa government to implement any of the proposed recommendations.

6.4.1 Near-Term Actions

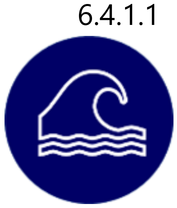


Near-term actions address stressors with high risk and low implementation uncertainty. These should be pursued as soon as possible, ideally within five years. Near-term actions may require some level of analysis to appropriately place the measure in American Samoa.

Stressors with solutions categorized as near-term actions include:

- **Tsunamis**
- **Power Outages**

6.4.1.1 Tsunami



Tsunamis pose a significant risk to human lives, health and safety, the environment, homes, and critical infrastructure. Strong waves and flooding can last for several hours in a tsunami. Presently, the islands do not have a functional warning system. The current warning system was installed about ten years ago after the 2009 tsunami and no longer functions due to a technical malfunction. However, the American Samoa Department of Homeland Security conducts regular tsunami response training opportunities. Schools and villages in American Samoa also practice tsunami drills which helped during the 2009 tsunami event. Many holistic recommendations were put forth in the 2012 USACE American Samoa Tsunami Study. Those with a nexus to this WA were added as strategies. Potential near-term actions to address tsunamis are shown below in Table 6-3.

Table 6-3. Tsunami Recommendations

	Focus	Recommendation	Potential Partners and Funding
Tsunami	Improve the Existing Warning System	Assess the need to update, modernize, and expand American Samoa's tsunami warning system. Ensure updates to the tsunami warning system consider various needs and are accessible to all.	**Estimated Cost: $$$** **Potential Funding:** ASDHS, FEMA **Champion Agency**: FEMA **Other Potential Partners/Stakeholders:** ASDHS, ODAPM
	Emergency Action Planning	Identify gaps in Emergency Action Plan coverage, including inclusive and accessible response planning and plans for private centers of commerce. Practice emergency response through training like table-top exercises. Coordinate policy requiring development and maintenance of Emergency Action Plans.	**Estimated Cost: $** **Potential Funding:** ASDHS, FEMA, FPMS-Silver Jackets **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** FEMA, ASDHS, Governor's Office, NDPTC, NOAA, ODAPM, UH
	Power and Communication Redundancies	Supplement and improve communication and power redundancies to utilize during an emergency such as alternative backup power, ultra-high frequency radio, or additional cell towers.	**Estimated Cost: $$** **Potential Funding**: DOI Office of Insular Affairs Champion Agency: FEMA, ASDHS **Other Potential Partners/Stakeholders**: ASDOC, FCC, NOAA, NWS, ODAPM

6.4.1.2 Power Outages

Power outages occur frequently during storm events and can last several months. American Samoa is largely dependent on imported fuel for power supply, and the fuel tanks are adjacent to the ocean and vulnerable to coastal flooding and SLC.

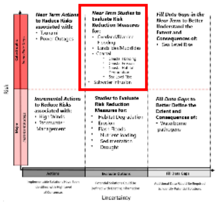
To improve resilience, American Samoa could consider bolstering emergency preparedness efforts and invest in power redundancies such as backup generators, water storage tanks, and pumps at critical facilities and evacuation centers.

Alternative energy sources such as solar panels or wind turbines would create alternative energy sources and lessen the reliance on imported fuel sources. This may be a costly endeavor; however, federal programs may help subsidize investment in green energy. This recommendation would need additional efforts to seek buy-in from the local matai and government officials. Table 6-4 shows recommendations for power outages.

Table 6-4. Power Outages Recommendations

	Focus	Recommendation	Potential Partners and Funding
Loss of Power	Emergency Preparedness	Ensure that evacuation shelters and other critical infrastructure like water wells, booster stations, and sewer lift stations have backup generators and fuel, and water storage tanks (as applicable).	**Estimated Cost: $$** **Potential Funding**: FEMA, DOI Office of Insular Affairs **Champion Agency:** FEMA **Other Potential Partners/Stakeholders**: ASDHS, ASDOC, FCC, NOAA, NWS, ODAPM
	Alternative Energy	Invest in alternative, green energy sources (solar, wind, etc.) to lessen the reliance on imported fuel and increase resiliency to often long-lasting power outages.	**Estimated Cost: $** **Potential Funding**: DOE, USDA (REAP) **Champion Agency:** ODAPM **Other Potential Partners/Stakeholders**: FEMA, ASDHS, ASDOC, ASEPA, ASPA, FCC, NOAA, NWS

6.4.2 Near-Term Evaluate Options



Stressors deemed appropriate for evaluating options in the near-term are those with catastrophic risk and moderate levels of implementation uncertainty. Additional studies are needed to better understand the problem or to identify recommended plans. Studies should be initiated in the near-term, ideally within 0-5 years and target implementation within 5-10 years.

Stressors include:

- **Overland/Riverine Flooding**
- **Coastal Flooding**
- **Coastal Erosion**
- **Sea Level Rise/Subsidence**
- **Coastal Habitat Degradation**
- **Saltwater Intrusion**

6.4.2.1 Overland/Riverine Flooding

Flooding is a common occurrence in American Samoa. To increase resiliency, partners and SMEs from USACE set forth recommendations to increase monitoring capabilities and infrastructure protection measures.

Partners from UH are actively working on securing university grant funding to augment hydrologic monitoring and to establish a monitoring network and interagency data sharing portal. Other agencies such as NWS and NPS have expressed interest in this effort which would support interagency collaboration and efforts related to hazard management, flooding, sedimentation studies, and coral health.

There is a nexus with flooding and water quality degradation. Flooding often carries human and animal waste and pollution into waterways. This leads to problems with potable water, groundwater aquifers, and aquatic ecosystems. Holistic solutions should combine recommendations from overland/riverine flooding with inland habitat degradation and nutrient loading.

Options presented in this section also overlap with flash flooding solutions (Section 6.4.4.3). Both stressors should be considered when reviewing the following list of recommendations shown in Table 6-5. Additionally, critical infrastructure protection should also be considered for Coastal Hazards. It is recommended here as riverine/overland flooding threatens critical infrastructure during storm events.

Table 6-5. Overland and Riverine Flooding Recommendations

	Focus	Recommendation	Potential Partners and Funding
Overland/Riverine Flooding	Stream Gauge Monitoring	Implement the National Water Model, a real-time hydrologic model. The gauge network will allow monitoring of real time weather and river flow conditions. This will contribute to NWS warnings, archive data for future studies, and assist ASPA with runoff and well volume calculations.	**Estimated Cost: $** **Potential Funding:** FPMS-Silver Jackets, USGS, NOAA OCM, UH, FEMA **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** USACE, ASPA, NWS, ODAPM, USGS
	Hydrologic & Hydraulic Analysis	Develop precipitation projections and conduct hydraulic analyses to consider the adequacy and/or needs to upgrade drainage way and culvert capacity in areas vulnerable to precipitation flooding.	**Estimated Cost: $** **Potential Funding:** USACE FMPS/PAS, FPMS-Silver Jackets, NFWF **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** NOAA OCM, ASPA, NWS, ODAPM, AS EPA, DPW
	Data Portal and Information Sharing	Set up geoportal database to collect and share interagency data on floods and water quality. Efforts led by the University of Hawaii (UH) are currently underway to pursue funding for this effort.	**Estimated Cost: $** **Potential Funding:** USACE FMPS/PAS, FPMS-Silver Jackets, UH, PI-CASC **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** USACE, ASPA, NWS, ODAPM, PI-CASC, ASDOC
	Critical Infrastructure Protection	Protect key transportation assets, including small boat harbors and airports, from future anticipated storm events, flooding, landslides, and SLC impacts. The USACE *Climate Related Vulnerability Assessment for Transportation Infrastructure: American Samoa* provides background information and considerations for implementation.	**Estimated Cost: $$-$$$** **Potential Funding:** USACE CAP Section 103/205, AS DOT **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ODAPM, AS DPW, AS Port Administration, DOI Office of Insular Affairs, AS DOT

6.4.2.2 Landslides/Mudslides

A detailed database for landslide/mudslide risk and past events can better inform future development decisions. BMPs should be considered to mitigate the risk of landslides, such as the quarry located upslope of the LBJ hospital.

Additional considerations to mitigate the risk of landslides can be found under erosion in Section 6.4.4.2. However, these may not be robust enough to prevent significant damage from landslides. Recommendations are provided below in Table 6-6.

Table 6-6. Landslide/Mudslide Recommendations

	Focus	Recommendation	Potential Partners and Funding
Landslides/ Mudslides	Detailed Landslide Mapping	Create database of past landslide information including location, cause, runout lengths, volumes, weather associated data, and potential hazard. Identify areas with slopes over 60% and/or new construction in these hazard areas.	**Estimated Cost: $** **Potential Funding:** ODAPM, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASDOC, FEMA, ODAPM, USGS, ASDPW, ASDHS, NWS

6.4.2.3 Coastal Hazards

All coastal stressors were determined to be of catastrophic risk. However, Sea Level Rise/Subsidence was categorized as having high implementation uncertainty whereas the other had a moderate level of uncertainty. To holistically assess possible recommendations, SLC was considered alongside all other coastal hazards. Recommendations are shown in Table 6-7.

Long-term planning and exploration of nature-based solutions will be critical to build resiliency to hazards that are worsening with SLC and climate change. Recommendations include building knowledge and technical expertise with nature-based solutions, especially in a tropical island environment and augmenting knowledge and monitoring around coastal hazards.

Long-term resilience planning is set forth as a recommendation. This would encourage communities and villages to explore long-term options for resiliency and maintaining the way of life given the impending impacts of climate change and SLC. NOAA OCM, CRAG, and village resiliency committees have partnered to carry out similar efforts, with completed plans in Amouli and Vatia.

USACE Honolulu District completed a climate vulnerability assessment in March 2020, which evaluated the risk and vulnerabilities of transportation infrastructure in villages across American

Samoa. The report also provided recommendations with rough costs and recommended areas of implementation to combat climate related stressors on critical transportation infrastructure. Figure 6-3 below depicts relative risks for transportation infrastructure.

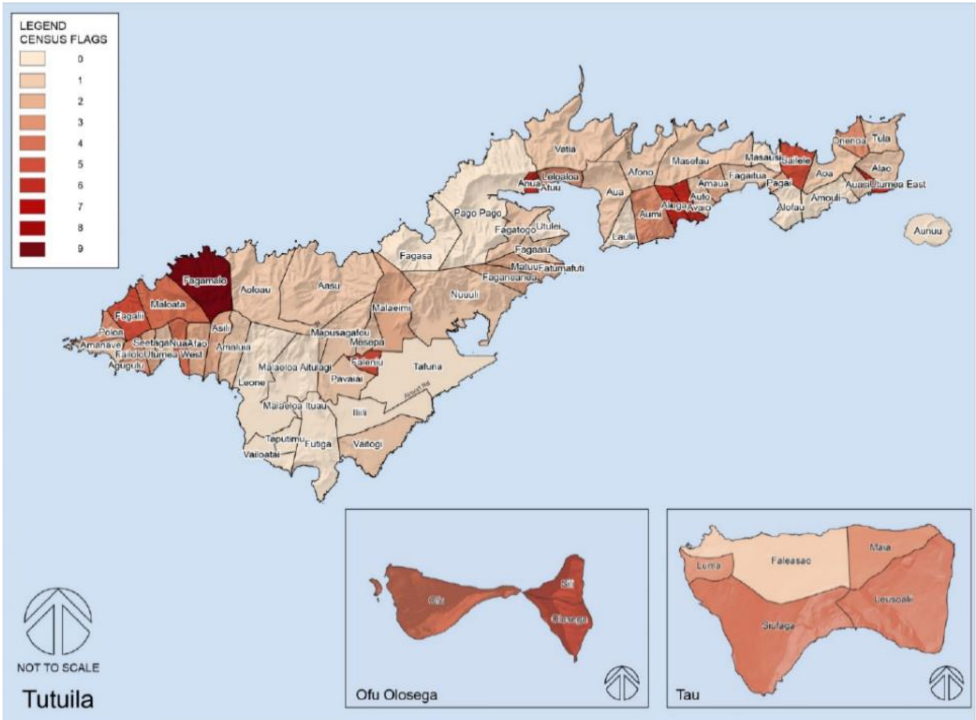


Figure 6-3. Areas of Vulnerability for Transportation Infrastructure on Tutuila (Source: USACE, 2020)

The PNRS, which is a part of the ASDOC, is responsible for conducting the environmental review process for all land-use activities in American Samoa. The PNRS board consists of agency directors or their assignee and meets twice monthly to review land-use permit applications. Additional accountability may be needed for the PNRS to ensure sound building practices and to minimize risk. Families that own land near the coast should be encouraged to elevate buildings or build with flood protective measures in place.

American Samoa Community College's Land Grant Program works with local communities to support environmental restoration efforts through providing plantings from their nurseries and may be able to assist with the provision of plants and labor.

Table 6-7. Coastal Flooding and Erosion Recommendations

	Focus	Recommendation	Potential Partners and Funding
Coastal Hazards	Green Infrastructure Assessment and Education	Inform decision makers on benefits of green infrastructure and nature-based solutions. Evaluate potential natural and nature-based features (NNBF) that would provide enhanced flood and landslide protection, beach access and/or ecosystem services.	**Estimated Cost: $** **Potential Funding:** ASCMP 309, FPMS-Silver Jackets, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders**: FEMA, NOAA OCM, ODAPM, ASEPA
	Ecosystem Restoration	Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) including restoring mangrove habitat in high priority areas (e.g., Pala Lagoon, Pago Pago Harbor, etc.), permeable greenspaces, and areas suitable for submerged/ artificial reef pilot projects.	**Estimated Cost: $** **Potential Funding:** ASCMP 309, NFWF, UH Sea Grant, USACE CAP Section 206, GI **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASEPA, AS Port Administration, CRAG, NFWF, NOAA OCM, NPS, UH Sea Grant
	Shoreline Protection	Develop solutions to protect high priority areas vulnerable to coastal flooding and erosion (e.g., Nua-Seetaga, Matafao, Asili, Aua, Laulii, and Vatia).	**Estimated Cost: $$-$$$** **Potential Funding:** USACE CAP Section 14 or 103, USACE RSM, DOT, PI-CASC, RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** *USACE, DOI Office of Insular Affairs, NOAA OCM, ODAPM, ASDPW, USGS, DOT
	Strengthen and Enforce Regulation	Strengthen the Project Notification and Review System (PNRS) to enforce zoning restrictions and limit new development in highly vulnerable areas.	**Estimated Cost: $** **Potential Funding:** ASDOC, FEMA, FPMS-Silver Jackets **Champion Agency:** ODAPM

	Focus	Recommendation	Potential Partners and Funding
			Other Potential Partners/Stakeholders: ASEPA, ASDOC, ASDPW, FEMA, Governor's Office, NOAA OCM, USACE
	Wave Exposure Analysis	Complete a wave exposure analysis to identify areas where ecosystem enhancement/green infrastructure solutions are feasible and/or where more durable structures are required.	**Estimated Cost: $** **Potential Funding**: USACE CAP/FPMS/ PAS/RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders**: FEMA, NOAA OCM, ODAPM, USGS
	Resilience Planning	Engage residents of vulnerable areas in long range village adaptation/recovery co-planning effort to combat the effects of climate change and SLC.	**Estimated Cost: $** **Potential Funding:** NOAA OCM, USACE FPMS/Silver Jackets,/PAS, PI-CASC **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** CRAG, ASDHS, ODAPM**,** UH Sea Grant, USACE, USGS
	Coastal Erosion Analysis	Complete a coastal erosion historical rate analysis and update the shoreline condition inventory to highlight high risk areas with rising sea levels and rapid subsidence levels.	**Estimated Cost: $** **Potential Funding:** USACE CAP/FPMS/ PAS/RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ODAPM, FEMA, USGS
	Expand Coastal Hazards System	Fund and implement expansion of the Coastal Hazards System, a probabilistic model for quantifying coastal hazards, to American Samoa.	**Estimated Cost: $$-$$$** **Potential Funding:** USACE, NOAA, FEMA **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ERDC/CHL, FEMA

6.4.2.4 Saltwater Intrusion

Saltwater intrusion is an issue that is worsening with SLC and the rapid rates of subsidence on Tutuila. Wells on the east side of Tutuila are pulling salty water, resulting in a long-term reliance on bottled and reverse osmosis water.

A recommendation set forth to address saltwater intrusion includes monitoring subsidence and identifying hotspots. Partners have expressed a desire to incorporate light detection and ranging (LiDAR) in monitoring efforts.

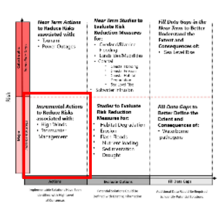
There is a need and desire expressed from partners to establish a program and develop technical expertise to monitor wells for saltwater intrusion and general water quality. Previously, a volunteer would sample wells for fluoride and log data.

See the full list of recommendations in Table 6-8.

Table 6-8. Saltwater Intrusion Recommendations

	Focus	Recommendation	Potential Partners and Funding
Saltwater Intrusion	Subsidence Study	Conduct study to identify areas affected by subsidence hotspots and promote LiDAR use to monitor subsidence zones.	**Estimated Cost: $-$$** **Potential Funding:** FPMS-Silver Jackets, USGS, FPMS, PAS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** NASA, USGS
	Well Sampling Program	Develop a well sampling program to monitor key wells in the Tafuna-Leone Plain.	**Estimated Cost: $** **Potential Funding:** USACE PAS, USGS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** AS Community College, ASPA, UH

6.4.3 Incremental Actions



Recommendations categorized as incremental actions have a low level of implementation uncertainty and pose a major, rather than catastrophic, risk. The study focused on gaining partner insight and collaboration for catastrophic risk recommendations. As such, recommendations for incremental actions and studies and filling data gaps do not have potential partners listed.

These recommendations should initiate implementation within 0-10 years. These problems are important to address in the near-term and pose a significant risk to lives, property, the environment, and/or the economy. However, with limited resources, these recommendations may be taken as incremental steps to make continuous progress toward enhancing resiliency.

Stressors evaluated as incremental actions include:

- **High Winds**
- **Stormwater Management**

6.4.3.1 High Winds

High winds can cause damage to buildings and power systems, creating direct (through physical impact) and indirect life loss risk. To address these risks, steps should be taken to improve building resiliency, both of critical facilities and personal homes and buildings (Table 6-9). This may initially begin with education on how to properly outfit buildings and homes to better withstand high winds, which could be pursued as a Silver Jackets project if an American Samoa team is established.

Table 6-9. High Winds Recommendations

	Focus	Recommendation	Potential Partners and Funding
High Winds	Education and Outreach	Education and outreach advising on how to protect and secure homes and businesses from high winds to minimize damage and health and safety risks.	**Estimated Cost: $** **Potential Funding:** FPMS-Silver Jackets, FEMA **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASDHS, ODAPM, FEMA, NWS

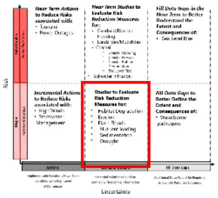
6.4.3.2 Stormwater Management

A comprehensive stormwater management plan would reduce flood risks to both new and existing buildings and infrastructure. Additionally, stormwater management is an activity FEMA's Community Rating System program, which offers flood insurance discounts when communities employ preventative measures. Table 6-10 shows recommendations for stormwater management.

Table 6-10. Stormwater Management Recommendations

	Focus	Recommendation	Potential Partners and Funding
Stormwater Management	Stormwater Policy	Develop a formal policy to ensure that new developments are required to manage stormwater 'on-site' and use of effect best management practices during construction to minimize water quality impacts.	**Estimated Cost: $** **Potential Funding:** FEMA, FPMS-Silver Jackets **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** ASDPW, USACE, NOAA OCM, ASPA
	Stormwater Planning	Develop storm water management plans for high-risk villages such as Tafuna, Leona, Malaeloa Altulagi, Nuuuli, and Aunu'u villages. Plans should include a combination of structural, non-structural, and nature-based features for comprehensive stormwater management.	**Estimated Cost: $** **Potential Funding:** FEMA, FPMS-Silver Jackets, USACE PAS **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** ASDPW, USACE, NOAA OCM, ASPA

6.4.4 Evaluate Options



Incremental studies and evaluating options should be initiated within 0-5 years with implementation targeted for within 5-10 years or sooner, if possible. Studies should first further investigate the stressor, then determine the most effective solution(s) and implementation strategy to achieve resiliency.

Stressors included as incremental studies are:

- **Inland Habitat Degradation**
- **Erosion**
- **Flash Floods**
- **Nutrient Loading**
- **Sedimentation**
- **Drought**

6.4.4.1 Inland Habitat Degradation

Solutions for inland habitat degradation will coincide with ecosystem restoration and nature-based features described in the near-term studies section (section 6.4.2). Consideration should also be given to erosion control (recommendation in section 6.4.4.2) which impacts inland habitats and can send sediment downstream into aquatic ecosystems such as wetlands. Recommendations are shown below in Table 6-11. American Samoa Community College's Land Grant Program works with local communities on out planting from their nurseries to support environmental restoration efforts and may be able to assist with the provision of plants and labor.

Table 6-11. Inland Habitat Degradation Recommendations

	Focus	Recommendation	Potential Partners and Funding
Inland Habitat Degradation	Low Impact Development	Implement systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat.	**Estimated Cost: $** **Potential Funding:** EPA, FEMA, DOT, NFWF, DOI **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** ODAPM, ASEPA, NOAA OCM, ASDPW, Ridge to Reef (NGO), ASCC, NRCS
	Wetland Monitoring	Establish a collaborative effort between ASCMP, the Wetlands Committee, and the community to conduct a thorough wetland delineation. This will improve decision making around wetland protection and restoration.	**Estimated Cost: $** **Potential Funding:** NOAA OCM, NFWF **Champion Agency:** NOAA OCM **Other Potential Partners/Stakeholders:** AS DOC, USACE (Regulatory)
	Ecosystem Restoration	Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) for inland habitat restoration including wetlands and vegetative buffers.	**Estimated Cost: $-$$** **Potential Funding:** ASCMP 309, NFWF, UH Sea Grant, USACE CAP Section 206, GI, USDA, NRCS **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** ASEPA, NOAA OCM, FEMA, Ridge to Reef (NGO), ASDOC
	Permeable Pavements	Use of porous surface with an underlying stone reservoir used in places typically filled with impermeable surfaces (like parking lots and streets). Use of permeable pavements reduces runoff, promotes groundwater recharge, and reduces concentration of water pollutants.	**Estimated Cost: $** **Potential Funding:** EPA, FEMA **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** AS EPA, AS DOC, ASDPW, NOAA OCM, ODAPM

6.4.4.2 Erosion and Sedimentation

Erosion and sedimentation affect water quality, which impacts both potable water sources and aquatic habitats. Since these two stressors have similar cause and effects, and equivalent risk and uncertainty levels, the two were considered together for recommendations. Steps should be taken to reduce erosion, using nature-based solutions when possible. Table 6-12 displays recommendations for erosion and sedimentation.

Table 6-12. Erosion and Sedimentation Recommendations

	Focus	Recommendation	Potential Partners and Funding
Erosion & Sedimentation	Erosion Control Measures	Evaluate and install erosion control measures including with materials like logs, rock walls, coir rolls, erosion control blankets, netting, wood/straw /cellulose, green armoring, and geotextile fabric. Also consider sloped plantings like vetiver grass.	**Estimated Cost: $-$$** **Potential Funding:** FEMA, USACE CAP Section 14 or 103, USACE RSM **Champion Agency:** USACE **Other Potential Partners/Stakeholders:** FEMA
	Sediment Capture Tanks	Install sediment capture tanks to intercept large sediment debris and facilitate sediment settling before releasing into waterways. Further study is needed to determine applicable sites and dimensions.	**Estimated Cost: $** **Potential Funding:** FEMA, USACE CAP Section 14 or 103 **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** USACE

6.4.4.3 Flash Floods

Flash flooding was assessed to have a major risk; however, recommendations pertaining to flash flooding are the same as those for overland riverine flooding. Please refer to section 6.4.2.1 for recommendations on overland/riverine flooding and flash flooding.

6.4.4.4 Nutrient Loading

Pollution in waterways can spur nutrient loading, which leads to toxic algal blooms and water quality degradation. Main sources of pollution include human and animal waste and trash. Programs or plans to reduce the sources of pollution could better help water quality across the territory (Table 6-13).

Regular stream water monitoring, public education and outreach, facility inspections, and enforcement of environmental and public health regulations helped reduce the leptospirosis risk and led to declines in *E. coli* concentrations. Further efforts to improve septic systems, which currently leak into ground water sources, and prevent waterway debris through pick up services could mitigate the human and environmental risks posed by nutrient loading.

Table 6-13. Nutrient Loading Recommendations

	Focus	Recommendation	Potential Partners and Funding
Nutrient Loading	Septic System Improvements	Standardize septic systems and enforce construction and septic system regulations. Identify Improved onsite disposal system technology, and build small-scale, multi-village treatment systems.	**Estimated Cost: $-$$** **Potential Funding:** None identified to date **Champion Agency:** **Other Potential Partners/Stakeholders:** ASDPW, ASPA, ASEPA
	Waterway Debris Prevention	Improve trash/bulky item pick up services to reduce debris in streams, shorelines, and reefs by tsunami, strong storms, or other natural hazards.	**Estimated Cost: $** **Potential Funding:** FPMS-Silver Jackets **Champion Agency:** FEMA **Other Potential Partners/Stakeholders:** ASDPW, ASPA, ASEPA, CRAG, USACE

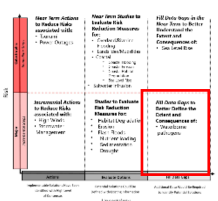
6.4.4.5 Drought

The impact of droughts on water supply and the economy can be mitigated with proactive planning efforts. Recommendations include efforts for improved drought forecasting, development of a drought management plan, and improved water supply systems (Table 6-14).

Table 6-14. Drought Recommendations

	Focus	Recommendation	Potential Partners and Funding
Drought	Improved Drought Forecasting	Provide early warning information and forecasts to improve decision making about planting and harvesting, as well as livestock management prior to the onset of drought.	**Estimated Cost: $** **Potential Funding:** USGS, PAS, NRCS **Champion Agency**: USACE **Other Potential Partners/Stakeholders:** USGS
	Drought Management Plan	Develop a drought management plan in conjunction with local industry to help address water usage and ability to secure fresh water as needed.	**Estimated Cost: $** **Potential Funding:** USGS, USACE FPMS-Silver Jackets, PAS **Champion Agency:** ODAPM **Potential Partners:** USGS, USACE
	Improve Water Supply & Storage	Address known leaks and damage to water storage containers and distribution lines.	**Estimated Cost: $-$$** **Potential Funding:** PAS, USDA **Champion Agency:** USACE **Potential Partners:** ASPA, DOI

6.4.5 Fill Data Gaps

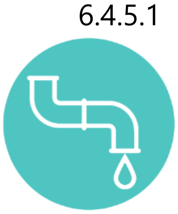


Recommendations categorized as filling data gaps address stressors that require a more detailed understanding of the problem before initiating a study or project. Steps should be taken to fill these data gaps in the near-term (0-5 years) with initiation of a study or implementation of a program taken in incremental steps (5-10 years or sooner if possible).

Stressors identified as requiring filling data gaps include:

- **Waterborne Pathogens**

6.4.5.1 Waterborne Pathogens



Waterborne pathogens were the only stressors categorized as requiring filling data gaps. To start addressing the issue of waterborne pathogens that result in cases of leptospirosis and *E. coli*, further studies must be conducted to better understand sources and pertinent statistics on infection rates.

A potential program to mitigate the inherent health and safety risks is improving access to potable water. This type of program should be accessible to all individuals in an affected community regardless of socioeconomic status. Presently, areas across the territory that remain on a long-term boil water notice have unequal access to bottled water. This type of program should close the wealth gap and offer equitable access to safe, potable water. Recommendations are shown in Table 6-15.

Table 6-15. Waterborne Pathogens Recommendations

	Focus	Recommendation	Potential Partners and Funding
Waterborne Pathogens	Data Collection	Complete a study to identify water borne illness sources, document pertinent information and statistics, and identify solutions.	**Estimated Cost: $** **Potential Funding:** USAID, EPA **Potential Champion Agency:** ODAPM **Other Potential Partners/Stakeholders:** ASPA
	Improved Public Access to Potable Water	Improve water filling stations; standardize maintenance procedures and enforce maintenance system.	**Estimated Cost: $-$$** **Potential Funding:** ASPA, NOAA, EPA, USDA **Champion Agency:** ODAPM **Other Potential Partners/Stakeholders:** ODAPM, ASPA, DOI, ASDHS

6.5 Implementation Strategy

To help prioritize limited time and resources, a general timeline for recommendation implementation is provided below in Table 6-16. Recommendations reflect the level of readiness to implement with a greater emphasis put on accelerating implementation of recommendations for catastrophic risks. The timeline provided is an estimate based on the urgency of addressing the stressor and possible implementation roadblocks, such as knowledge gaps, local approval, and funding (determined through the uncertainty analysis). Generally, near-term actions should be implemented within five years. Near-term options should be evaluated within zero to five years and implemented as soon as possible. Incremental options should be implemented as soon as possible but may have additional time available to implement as the corresponding stressor was assessed to be a major risk. Evaluating options to address major stressors should occur within zero to ten years with implementation occurring soon thereafter. Some recommendations have relatively less implementation uncertainty and, therefore, may stray from the timeline explained above.

Table 6-16. Recommendations Timing

Priority	Stressor	Recommendation	0-5 yrs	5-10 yrs	10+ yrs
Near-Term Actions	Tsunami	Improved Warning System	Implement	–	–
		Emergency Action Planning	Implement	–	–
		Power and Communication Redundancies	Implement	–	–
	Power Outages	Emergency Preparedness	Implement	–	–
		Alternative Energy	Implement	Implement	–
Near-Term Evaluate Options	Overland/Riverine Flooding	Stream Gauge Monitoring	Evaluate	Implement	–
		H&H Analysis	Evaluate	Implement	–
		Data Portal and Information Sharing	Evaluate	Implement	–
		Critical Infrastructure Protection	Evaluate	Implement	–
	Landslides/ Mudslides	Detailed Landslide Mapping	Evaluate/ Implement	–	–
	Coastal Flooding & Erosion	Green Infrastructure Education	Implement	–	–
		Ecosystem Restoration	Evaluate	Implement	–
		Shoreline Protection	Evaluate	Implement	–
		Strengthen and Enforce Regulation	Implement	–	–
		Wave Exposure Analysis	Implement	–	–
		Resilience Planning	Implement	Implement	–
		Coastal Erosion Analysis	Implement	–	–
	Saltwater Intrusion	Subsidence Study	Evaluate	Implement	–
		Well Sampling Program	Evaluate	Implement	–
Incremental Actions	High Winds	Education and Outreach	Implement	Implement	–
	Stormwater Management	Stormwater Management	Implement	Implement	–

Priority	Stressor	Recommendation	0-5 yrs	5-10 yrs	10+ yrs
		Stormwater Policy	Implement	Implement	–
		Stormwater Planning	Implement	Implement	–
Evaluate Options	Inland Habitat Degradation	Low Impact Development	Implement	Implement	–
		Permeable Pavements	Evaluate	Implement	Implement
		Wetland Monitoring	Evaluate	Implement	–
		Ecosystem Restoration	Evaluate	Implement	Implement
	Erosion & Sedimentation	Erosion Control Measures	Evaluate	Implement	Implement
		Sediment Capture Tanks	Evaluate	Implement	Implement
	Nutrient Loading	Septic System Improvements	Evaluate	Implement	Implement
		Waterway Debris Prevention	Evaluate	Implement	Implement
	Drought	Improved Drought Forecasting	Evaluate	Implement	Implement
		Drought Management Plan	Evaluate	Implement	Implement
		Improve Water Supply & Storage	Evaluate	Implement	Implement
Fill Data Gaps	Waterborne Pathogens	Improved Public Access to Potable Water	Fill Data Gaps/Evaluate	Evaluate/Implement	Implement
		Data Collection	Fill Data Gaps/Evaluate	Evaluate/Implement	Implement

7 Conclusion

The purpose of the WA is to assist with future decision-making and strategic planning in American Samoa to increase resiliency. This comprehensive WA incorporates the best available scientific literature and robust stakeholder engagement across local and federal partners. The prioritized list of recommendations addresses the problem categories, explores the opportunities, and meets the study objectives while adhering to special considerations. Table 7-1 displays how proposed recommendations address the problem areas while fulfilling study objectives and contributing to the study goal of increasing resiliency to weather related hazards.

The study objectives included:

> **Objective 1**: Reduce life loss, injuries, and public health and safety risks from natural hazards in American Samoa.
>
> **Objective 2**: Improve quantity and quality of inland and coastal ecosystems in American Samoa.
>
> **Objective 3:** Reduce economic, environmental, and social impacts from natural hazards in American Samoa.
>
> **Objective 4:** Improve territory-wide access to potable, municipal, and industrial water supply in American Samoa.

The USACE Principles of Resilience are prepare, absorb, recover, and adapt (Figure 7-1):

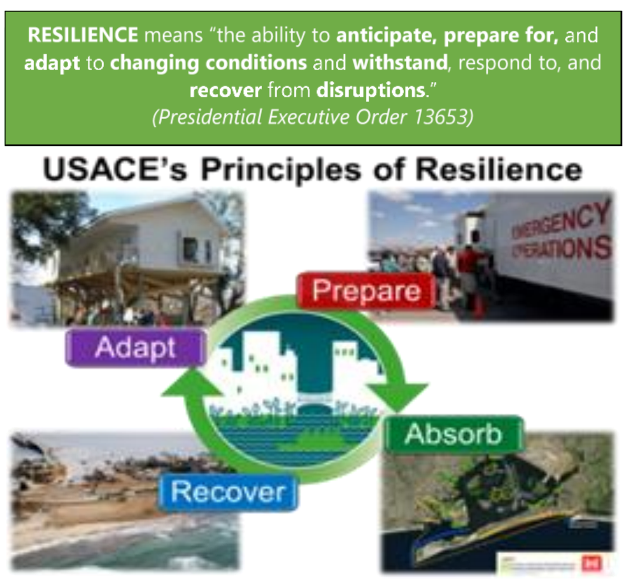


Figure 7-1. USACE Resiliency Principles

Prepare: Considers the needs of a community or system to better withstand future disruptions.

Absorb: Enhances the ability of a community or system to endure a disruption and limit subsequent damage. This principle can also be used as an opportunity to consider adding system component robustness, redundancy, and increased reliability.

Recover: Stresses wise and rapid repair or functional restoration of a community or system following a disruption.

Adapt: Considers modifications to a project component or system that maintains or improves future performance based on lessons learned from previous events.

This WA in conjunction with other relevant studies and efforts can be used to initiate follow on studies or projects that meet American Samoa's priorities and greatest needs.

Table 7-1. Recommendations Addressing the Objectives

Type	Stressor	Recommendation	Obj 1	Obj 2	Obj 3	Obj 4	Resilience Principle Achieved
Near-Term Actions	Tsunami	Improved Warning System	✓	–	–	–	**Prepare**
		Emergency Action Planning	✓	–	–	–	**Prepare**
		Power and Communication Redundancies	✓	–	–	–	**Absorb, Recover**
	Power Outages	Emergency Preparedness	✓	–	–	–	**Prepare**
		Alternative Energy	✓	–	✓	–	**Adapt**
Near-Term Evaluate Options	Overland/ Riverine Flooding	Stream Gauge Monitoring	–	–	✓	–	**Prepare**
		H&H Analysis	–	–	✓	–	**Prepare**
		Data Portal and Information Sharing	–	–	✓	–	**Prepare, Adapt**
		Critical Infrastructure Protection	✓	–	✓	–	**Absorb, Adapt**
	Landslides/ Mudslides	Detailed Landslide Mapping	✓	–	✓	–	**Prepare**
	Coastal Flooding & Erosion	Green Infrastructure Education	–	✓	✓	–	**Prepare**

Type	Stressor	Recommendation	Obj 1	Obj 2	Obj 3	Obj 4	Resilience Principle Achieved
		Ecosystem Restoration	✓	–	✓	–	**Absorb**
		Shoreline Protection	✓	–	✓	–	**Absorb**
		Strengthen and Enforce Regulation	✓	–	✓	–	**Prepare**
		Wave Exposure Analysis	–	–	✓	–	**Prepare**
		Resilience Planning	–	–	✓	–	**Prepare**
		Coastal Erosion Analysis	–	–	✓	–	**Prepare**
	Saltwater Intrusion	Subsidence Study	✓	–	✓	✓	**Prepare**
		Well Sampling Program	–	–	✓	–	**Prepare**
Incremental Actions	High Winds	Education and Outreach	–	–	✓	✓	**Prepare**
	Stormwater Management	Stormwater Management	–	–	✓	✓	**Prepare, Adapt**
		Stormwater Policy	–	–	–	–	**Prepare, Adapt**
		Stormwater Planning	–	–	–	–	**Prepare**
Evaluate Options	Inland Habitat Degradation	Low Impact Development	–	✓	✓	–	**Prepare, Adapt**
		Permeable Pavements	–	✓	✓	–	**Absorb**
		Wetland Monitoring	✓	–	✓	–	**Prepare**
		Ecosystem Restoration	–	–	✓	✓	**Absorb**
	Erosion & Sedimentation	Erosion Control Measures	–	✓	–	✓	**Absorb**
		Sediment Capture Tanks	–	✓	–	✓	**Prepare**
	Nutrient Loading	Septic System Improvements	–	–	✓	–	**Prepare**
		Waterway Debris Prevention	–	–	✓	–	**Prepare**
	Drought	Improved Drought Forecasting	–	–	–	✓	**Prepare**
		Drought Management Plan	–	–	–	✓	**Prepare**

Type	Stressor	Recommendation	Obj 1	Obj 2	Obj 3	Obj 4	Resilience Principle Achieved
		Improve Water Supply & Storage	–	–	✓	✓	**Prepare, Recover**
Fill Data Gaps	Waterborne Pathogens	Improved Public Access to Potable Water	–	–	✓	✓	**Prepare, Recover**
		Data Collection	–	–	✓	✓	**Prepare**

8 References

Addison, D., C.W. Filimoehala, S.J. Quintus, and T. Sapienza. (2010). Damage to Archaeological Sites on Tutuila Island (American Samoa) Following the 29 September 2009 Tsunami. Rapa Nui Journal 24:34-44.

ASDOC (2019). American Samoa Government Department of Commerce (ASDOC) Comprehensive Economic Development Strategy of American Samoa (CEDS-AS), 2018-2022

ASEPA (2016). American Samoa Reef Flats Project Report. Prepared by Nimbus Environmental Services for ASEPA. Jul 2016.

ASEPA (2020), American Samoa Watershed Protection Plan Vol 2

ASEPA (2018). Integrated Water Quality Monitoring and Assessment Report. Apr 2018.

ASEPA Watershed Management and Protection Program FY19 Annual Report (2019).

ASHPO (2002). American Samoa Historic Preservation Plan. Report on file at the American Samoa Historic Preservation Office (ASHPO), Pago Pago.

AS THMC (2020). "Hazard Mitigation Plan Territory of American Samoa." Prepared by Jamie Caplan Consulting LLC for the American Samoa Territory Hazard Mitigation Council (AS THMC). May 2020.

Bardi et al. (2005). Stream water chemical parameters for Tutuila Island, American Samoa (Vol. 46, pp. 1-17). Land Grant Technical Report.

Clark, J.T., Herdrich, D.J. (1993). Samoan Tia 'Ave and Social Structure: Methodological and Theoretical Considerations. In The Evolution and Organisation of Prehistoric Society in Polynesia, edited by M.W. Graves and R.C. Green, pp. 52-63. New Zealand Archaeological Association Monograph 19, Auckland.

Clark, J. T., Michlovic, M. G. (1996). An early settlement in the Polynesian homeland: excavations at'Aoa Valley, tutuila island, American Samoa. Journal of Field Archaeology, 23(2), 151-167.

CRAG (2020). Coral Reef Advisory Group (CRAG). "American Samoa's Healthy Coral Reef Local Action Strategy v21." 2020-2025.

CRAG (2019). Promoting the Use of Green Stormwater Infrastructure in American Samoa. Prepared by Horsely Written Group Inc for American Samoa Coral Reef Advisory Group (CRAG). Apr 2019.

Craig, P. (2009). Natural History Guide to American Samoa. 3rd Edition. National Park of American Samoa, Department Marine and Wildlife Resources and American Samoa Community College.

DHS, HURREVAC – National Hurricane Program, https://hvx.hurrevac.com

EIA (2022). US Energy Information Administration, American Samoa Territory Energy Profile https://www.eia.gov/state/analysis.php?sid=AQ

FEMA (July 2006), Flood Insurance Study Volume Vol 1 of 2, Manua and Tutuila Islands. Associated GIS layers downloaded from http://geo.pacioos.hawaii.edu/geoserver/PACIOOS/

Green, R.C., Davidson, J.M. (1974). Archaeology in Western Samoa, Volume II. Bulletin of the Auckland Institute and Museum 7, Auckland.

Hoegh-Guldberg Ove. (1999). Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50, 839-866.

IPCC (2007). Evidence for Changes in Tropical Storms, AR4 Chapter 3.8.3. Intergovernmental Panel on Climate Change (IPCC). Retrieved April 2021 from https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-8-3.html NOAA and Princeton University (2018), Projected Response of Tropical Cyclone Intensity and Intensification in a Global Climate Model

IPCC-AR5 (2014). Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Climate Change 2014 Synthesis Report

IPRC (2014). The Sea Level Seesaw of El Niño Taimasa, Vol 14 No.1. International Pacific Research Center (IPRC). Retrieved April 2021 from http://iprc.soest.hawaii.edu/newsletters/iprc_climate_vol14_no1.pdf

Jeremy M Raynal, et al. DOI. "American Samoa's Marine Protected System – Institutions, governance, and Scale." 2016.

Kirch, P.V., Hunt, T.L. (1993). The To'aga Ceramics. In The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa, edited by P.V. Kirch and T.L. Hunt, pp. 123-149. Contributions of the University of California Archaeological Research Facility No. 51. University of California, Berkeley.

Kirch, P.V., Manning, E., Tyler, J. (1993). Geoarchaeological Analysis of Sediment Samples from the To'aga Site Excavations. In The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa, edited by P.V. Kirch and T.L. Hunt, pp. 93-114. Contributions of the University of California Archaeological Research Facility No. 51. University of California, Berkeley.

Leach, H.M., Green, R.C. (1989). New Information for the Ferry Berth site, Mulifanua, Western Samoa. Journal of the Polynesian Society, 98:319-29.

Linnekin, J., Hunt, T., Lang, L. and McCormick, T. (2006). Ethnographic Assessment and Overview, National Park of American Samoa. Technical Report 152. (pp. 203) Pacific Cooperative Parks Study Unit. University of Hawaii at Manoa.

Moftakhari, H. R., AghaKouchak, A., Sanders, B. F., Allaire, M., & Matthew, R. A. (2018). What is nuisance flooding? Defining and monitoring an emerging challenge. Water Resources Research, 54, 4218– 4227. https://doi.org/10.1029/2018WR022828

NASA GSFC (2019). Coastal Land Change due to Earthquakes and Implications for Sea-Level Rise in the Samoan Islands. A funded proposal in response to NNH19ZDA001N-ESI19.

NFWF & NOAA (2021). American Samoa Coastal Resilience Assessment.

NFWF, NOAA, & NEMAC (2021). American Samoa Coastal Resilience Assessment: Stakeholder Engagement Read Ahead Materials.

NOAA Coral Reef Conservation Program and CRAG. "Green Infrastructure in American Samoa." 2019.

NOAA CoRIS (n.d.) NOAA Coral Reef Information System (CoRIS)-Regional-Portal-American Samoa. https//coris.noaa.gov/portals/samoa

NOAA (2021). El Niño/Southern Oscillation (ENSO) Technical Discussion

NOAA, Meteorological Development Laboratory, NWS (2009), The Role of the SLOSH Model in NWS Storm Surge Forecasting

NOAA NCEIa (n.d.) National Hazards Viewer (online), retrieved from https://www.ncei.noaa.gov/maps/hazards/

NOAA NCEIb (2020). Storm Events Database (online). Retrieved from https://www.ncdc.noaa.gov/stormevents/

NOAA, NCEIc (2020). and Weather Forecast Office (WFO) Pago Pago. Retrieved from https://w2.weather.gov/climate/xmacis.php?wfo=samoa

NOAA NHC (2021). National Storm Surge Hazards Maps version2. HURREVAC data retrieved from https://hvx.hurrevac.com/hvx/home.html

NOAA (2013). NOAA Technical Report NESDIS 142-8 Regional Climate Trends and Scenarios of the US National Climate Assessment-Part 8 Climate of the Pacific Islands.

NOAA & UH (n.d.) Sea Level Rise and Inundation Risks in American Samoa. Compilation of working papers.

NPA (2009). Natural History Guide to American Samoa, 3rd Edition

NRCS, (2018). Extension University of Nebraska Department of Agriculture, Soil Notebook. Retrieved May 2021 from https://extension.unl.edu/statewide/enre/2018%20Soils%20Notebook-FINAL.pdf

Parker, P.L., King, T.F. (1990). Guidelines for Evaluating and Documenting Traditional Cultural Properties. National Register Bulletin 38. Originally published 1990 (revised 1992), U.S. Department of the Interior, National Park Service, Washington, D.C.

Pacific RISA (2022). Pacific Regional Integrated Sciences and Assessments (Pacific RISA) program Retrieved Jan 2022 from https://www.pacificrisa.org/places/territory-of-american-samoa/

PIRCA (2021). Climate Change in American Samoa. East-West Center Report for the Pacific Islands Regional Climate Assessment (PIRCA). 2021.

Rupic, M., Wetzell, L., Marra, J., Balwani, S. (2018, February). 2014-2016 El Niño assessment report; an overview of the impacts of the 2014-16 El Niño on the US affiliated Pacific Islands (USAPI) [PDF]. Retrieved June 2019 from https://www.ncdc.noaa.gov/sites/default/files/attachments/ENSOTT_Report_02.26.2018%20FINAL%20draft.pdf

Sauafea-Le'au, F. (2013). Faga'alu Village watershed management and conservation plan: American Samoa, 2012-2013.

Schuler C. and El-Kadi A.I. (2018). Groundwater Recharge for Tutuila, American Samoa Under Current and Projected Climate as Estimated with SWB2, a Soil Water Balance Model

Schuler et al. "American Samoa Water Use Data: A Workplan for Evaluation and Improvement." Journal of Hydrology: Regional Studies, vol. 34, no. 7, 2018.

Schuler et al. "Isotopes, Microbes, and Turbidity: A Multi-tracer Approach to Understanding Recharge Dynamics and Groundwater Contamination in a Basaltic Island Aquifer." Groundwater Monitoring & Remediation, vol. 39, no. 1, 2018, pp. 20-35.

Schuler et al. "Ridge to Reef Management Implications for the Development of an Open-Source Dissolved Inorganic Nitrogen-Loading Model in American Samoa." Environmental Management, vol. 66, no. 10, 2020.

Schuler et al. "Source Partitioning of Anthropogenic Groundwater Nitrogen in a Mixed-Use Landscape Tutuila American Samoa." Hydrogeology Journal, vol. 25, no. 8, 2017, pp. 2419-2434.

Stover, M. (1999). Individual Land Tenure in American Samoa. The Contemporary Pacific 11 (1): 69-104.

Tapu, I. F. (2020). Who Really is a Noble?: The Constitutionality of American Samoa's Matai System. Asian Pacific American Law Journal, 24.

The World Bank (June 2020). The Global Landslide Hazard Map Final Project Report

UH-WRRC (n.d.) Daily Streamflow Forecasting in American Samoa by Machine Learning Approaches. Letter of Intent for 2022-2024 Grant Program for American Samoa.

USACE (2012). American Samoa Tsunami Study. Post 2009 South Pacific Tsunami Update. USACE, Honolulu District. Apr 2012.

USACE, HNC, & USAHFPA (2019). Assessment of Health Care Infrastructure and Services Lyndon Baines Johnson Tropical Medical Center Pago Pago, American Samoa. Apr 2019.

USACE, POH (2020). Climate Related Vulnerability Assessment for Transportation Infrastructure. Prepared by HHF Planners for USACE. Mar 2020.

US Census Bureau (2010). American Samoa Demographic Profile Summary File. 2010 Census of Population and Housing. DPSFAS/10-3 (RV). Issued Mar 2014.

US Census Bureau (2017). Selected Statistics from the 2017 Economic Census of Island Areas: American Samoa. 2017 Economic Census of Island Areas. Issued Ma.

US Climate Resilience Toolkit (2019). Collaborating for Success: Sustaining Water Supply on a Pacific Island. Retreived Feb 2022 from https://toolkit.climate.gov/case-studies/collaborating-success-sustaining-water-supply-pacific-island

USDA (1984). Soil Survey of American Samoa. https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/pacific_basin/PB630/0/american_samoa.pdf.

USDA (2018). Census of Agriculture. American Samoa (2018) Territory, District, and County Data. V1. Geographic Area Series. Part 55. AC-17-A-55. Issued Jul 2020.

Van Tilburg, H. (2007). American Samoa Maritime Heritage Inventory. Report submitted to NOAA Office of National Marine Sanctuaries.

Volk, R.D., P.A. Knudsen, K.D. Kluge, and D.J. Herdrich. (1992). Towards a Territorial Conservation Strategy and the Establishment of a Conservation Areas System in American Samoa. Pago Pago: Le Vaumatua Inc.

Welch, E. M., Dulai, H., El-Kadi, A., & Schuler, C. K. (2019). Submarine Groundwater Discharge and Stream Baseflow Sustain Pesticide and Nutrient Fluxes in Faga'alu Bay, American Samoa. Frontiers in Environmental Science, 7, 162.

WSO Pago Pago (2020). Improving Hydrological Data Collection to Support Flood and Weather Mitigation on Multiple Timescales in American Samoa. WSO Pago Pago Letter of Support. Nov 2020.