

Assessing Vulnerability and Prioritization of Cultural Assets for Climate Change Planning in Collier County, Southwest Florida

Rachael Kangas ^{1,*} , Sara Ayers-Rigsby ² , Michael Savarese ³, Vladimir Paramygin ⁴  and Y. Peter Sheng ⁴ 

¹ Florida Public Archaeology Network, University of South Florida, Tampa, FL 33612, USA

² Florida Public Archaeology Network, Florida Atlantic University, Boca Raton, FL 33431, USA

³ Department of Marine and Earth Sciences, Florida Gulf Coast University, Fort Myers, FL 33965, USA

⁴ Engineering School of Sustainable Infrastructure and Environment, University of Florida, Gainesville, FL 32603, USA; pva@ufl.edu (V.P.); ypscheng@ufl.edu (Y.P.S.)

* Correspondence: kangasr@usf.edu

Abstract: Cultural resources are often overlooked in climate change and resiliency planning, despite them being integral to community identity and the restoration of a sense of normalcy after significant weather events. This vulnerability assessment demonstrates how cultural resources can be included in planning efforts, and how they can be prioritized based on specific criteria. To complete this assessment, a working group with local land managers and cultural resource professionals was formed, and members employed a sophisticated Geo Tool, ACUNE (Adaptation of Coastal Urban and Natural Ecosystems) for climate adaptation, to predict how cultural resources throughout Collier County, Florida, would be impacted in two specific climate scenarios. The working group selected ten significant sites in the county and used ACUNE to prioritize action at these sites, using a matrix of hazard exposure, sensitivity, adaptive capacity, and the environmental, social, and economic consequences of the loss of these sites. Based on the results of our case study vulnerability assessment of cultural resources in Collier County, the next decade (2020 to 2030) has the potential to increase the number of sites at risk of storm flooding from 267 to 318, alerting managers that immediate action is needed for the sites of greatest value. The analysis of 10 case study sites is presented to demonstrate an approach for land managers and other cultural resource professionals to prioritize action at their own sites.

Keywords: climate change; resiliency planning; archaeology; site prioritization; sea level rise mapping; vulnerability analysis; sea level rise; cultural resources; adaptation planning; Geo Tool



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1. Introduction

Cultural resources are the tangible and intangible remains of human activity, including historic buildings, archaeological sites, cemeteries, and landscapes which are significant to cultural groups [1]. Cultural resources provide “a unique and important testimony of the culture and identities of peoples” [2] and help to link modern communities temporally and spatially [3]. Climate change is impacting cultural resources globally [4–9], severing this link and impacting the quality of life for modern communities [1]. As the earth’s climate warms and the global sea levels rise, archaeological and cultural sites are vulnerable to threats from climate change [10].

Internationally, “the degradation and destruction of cultural heritage—whether tangible or intangible—constitutes a loss to the affected communities, as well as to the international community as a whole” [2]. As sites disappear due to the impact of climate change, society is losing this irreplaceable heritage. Site loss also impacts economies, especially in countries and communities with heritage tourism industries. There is a critical need to plan both an emergency-response timeline (e.g., after a hurricane), but also, in the long-term, to plan and create a “vision for protection from climate change that provides greater resilience for the overall built environment” [11,12]. The need for action to preserve cultural heritage

is reflected in the government literature and policies in countries like the United Kingdom, where Historic Environment Scotland has issued a guide for the need to incorporate planning for climate change from the national level down to the community level [13], and Norway, where the Norwegian Directorate for Cultural Resource Heritage has issued a Climate Strategy for Cultural Environment Management [13,14].

Although much research on climate change and heritage has taken place within the United States [15–18], and while a federal law, The Archaeological Resource Protection Act, defines archaeological sites as an irreplaceable part of America's heritage [19], the country does not have an overarching plan to address the impacts of climate change on cultural resources, and lacks an agency equivalent to Historic Environment Scotland or the Norwegian Directorate for Cultural Resource Heritage [1]. Recently, Sara Bronin, Chair of the Advisory Council for Historic Preservation in the U.S., gave testimony recommending the U.S. Federal Government work to draft legislation to create a climate heritage office [20]. Without a federal agency managing cultural resources in the United States, action to document or preserve sites impacted by climate change must be taken at the state and local level.

Florida, which has the second-longest coastline of any state in the United States (13,576 km [21]), is at the front lines of climate change's effects on cultural resources. In Florida, these resources cover a vast human history, spanning at least 14,000 years [22].

Florida already experiences climate change's impacts; for example, erosion and destruction of the state's valued sites [10,23]. Significant and well-recognized national and state registered sites like the Castillo de San Marcos in St. Augustine [24], the historic launch pads at Kennedy Space Station [25], numerous ancient shell mounds along the coast [10], and coastal cemeteries [26] are all experiencing the impacts of these threats.

The State of Florida's Department of Environmental Protection (DEP) has recognized these growing threats and is taking action to help communities plan for climate change [27]. The Florida Adaptation Planning Guidebook, created by DEP, offers instructions for Florida communities planning for the impacts of climate change. Related funding is offered by the State to help local governments and communities carry out each step of the process. Funding for the implementation of adaptation strategies is contingent on the completion of prerequisite steps (e.g., conducting a sensitivity analysis) [25]. This guidance and funding name cultural resources as a "critical asset", allowing for projects that fully or partially focus on cultural resources to be funded. This framework is vital for the action necessary to address the issues elucidated during assessment.

Regionally, alliances of planning jurisdictions are organizing to address more localized climate threats and adaptation strategies with groups like Southeast Florida Regional Climate Change Compact, [28] the Tampa Bay Regional Resiliency Coalition, [29] and others [30,31]. Unfortunately, despite State funding opportunities and the best intentions of regional alliances, cultural resources are often overlooked in climate change planning processes. For example, the first version of the South Florida Climate Change Compact Regional Action Plan from 2012 did not include reference to cultural resources, but the updates in 2017 and 2022 both did [32–34]. Based on the authors' combined decades of work in the field, this omission is most often an innocent lack of consideration (instead of a purposeful disregard) for cultural resources. However, this does not mitigate the impending harm to cultural resources from climate change, or the devastating loss of community and cultural identity that will be suffered when some of these resources are destroyed. Including cultural resources in adaptation planning will help ensure the sense of place and history that is integral to many communities [3], and will help managers better understand important and protected sites when planning for climate change.

Once included in planning documents and guidance, there is a need for a rigorous and straightforward process for assessing the vulnerability of cultural assets that generates both quantitative and qualitative results to aid with prioritization [35–40].

Here, we offer a vulnerability assessment methodology that uses existing climate change planning terminology (e.g., exposure, vulnerability, adaptive capacity), but with a

more nuanced approach that includes diverse perspectives and input, and also creates both quantitative and qualitative results that allow for thoughtful decision making.

This methodology was developed and tested during 2020–2021 in Collier County, Southwest Florida, and was used a cutting-edge web-based Geo Tool called ACUNE (Adaptation of Coastal Urban and Natural Ecosystems), developed by a research team led by the University of Florida and Florida Gulf Coast University, along with a group of natural and urban ecosystem leaders [39]. The ACUNE Geo Tool contains probabilistic coastal flood maps and nuisance tide flood maps for the current climate and numerous future climate scenarios, including predicted effects of the changing climate such as sea levels rising and hurricane intensification in 2030, 2040, 2060, 2070, and 2100. Importantly, the ACUNE flood maps were produced considering the compound effects of rising sea levels and hurricane-induced storm surges instead of a simple linear superposition of rising sea levels and storm surges or a bath-tub approach, which only considers the sea-level rise effect. While the ACUNE Geo Tool has been updated several times in the past five years, here we use the ACUNE products of 2022. Using this methodology, we accomplished two goals: projected large-scale changes to Collier County cultural resources over a ten-year period, and detailed the impacts of inundation on 10 highly valued sites via quantifying the specific threats of the exposure, vulnerability, and consequences of inaction into a simple score that allows resources to be compared and prioritized. This methodology is vastly applicable in any climate-change context or geographic location.

In this article, we will provide a brief background on climate projections for Florida and Collier County, introduce the ACUNE Geo Tool, and describe our working group. We will then detail our vulnerability assessment methods for analyzing large-scale changes to site impacts in Collier County using a count of all cultural sites impacted by two different flooding scenarios over a period of ten years (herein called the “full county site count”); we will detail our methodology for analyzing and assigning scores to compare and prioritize resources using ten well-known case study sites in Collier County. Finally, we present the results of our vulnerability assessment and some examples of how the results can be applied to planning decisions in Collier County.

We offer this methodology as a simple template for communities and resource managers to employ, allowing them to include cultural resources in their adaptation planning. It is vital for communities to incorporate these assessments into the planning process so that they can implement appropriate action in response to threats in emergency situations, but also in long-term protection planning. Our methodology provides a guide for performing these assessments within any management area to inform adaptation strategies in order to reduce the long-term impacts of climate change on cultural resources. This is by no means the final form a vulnerability assessment must take, and we encourage communities to adapt this method to suit their unique history and needs.

Collier County, located in Southwest Florida, is the largest county in the state, spanning 1996.9 square miles, and has a population of over 375,000 people [41]. The county has diverse ecosystems, and is receiving increasing pressure from development as people seek the lifestyle the area offers. Climate change adaptation planning in the county has increased the knowledge and awareness regarding the threats that climate change and the sea-level rise (SLR) effect pose to its residents, visitors, and resources.

According to the Florida Master Site File (FMSF), the state’s official inventory of recorded cultural sites, there are over 1500 cultural sites in Collier County [42]. Due to the low topography and proximity to the Gulf of Mexico, the county and surrounding areas are at high risk for inundation caused or exacerbated by the effects of SLR. With rising sea levels, nuisance tide flooding (flooding that occurs regularly with high tide events) will become more common, and storm surge from tropical storms will cause the rising waters to push further inland, creating more severe flooding both in the depth and breadth of the land covered. With growing pressure from development and the growing threats of rising sea levels, identifying ways to make data-driven decisions about the county’s future is vital. These factors make it an ideal place to test our methodology [43].

2. Materials and Methods

2.1. ACUNE Geo Tool

This assessment used a web-based interactive decision support tool, Adaptation of Coastal Urban and Natural Ecosystems (ACUNE), in Southwest Florida [43–45]. This tool was developed by a multi-disciplinary multi-institutional science team, led by Dr. Peter Sheng from the University of Florida, and an end-user team, led by Dr. Michael Savarese from Florida Gulf Coast University, who also served as the liaison to Collier County and several cities for the tool's application. The ACUNE tool is currently accessible to local governments and NGOs for vulnerability analysis and planning activities.

Products contained in the ACUNE Geo Tool include probabilistic flood maps and nuisance tide maps for current and future climate conditions in the 21st century, incorporating the effects of sea-level rise and hurricane-induced storm surges and waves, as well as the influence of vegetation, which changes under the influence of climate change [44,45]. These products are produced using an integrated modeling system, CH3D-SWAN-WARMER, based on the coupling of a three-dimensional vegetation-resolving hydrodynamic-wave model, CH3D-SWAN [46], and a vegetation model, WARMER [47]. Probabilistic coastal flood maps incorporating the effects of sea-level rise and surges and waves are produced using the JPM-OS statistical method [48] and ensembles of tropical cyclones based on historical data, as well as predictions of the best available climate models [49,50]. The ACUNE Geo Tool provides current and future 1% annual exceedance probability flood elevation (commonly referred to as 100-year flood or Base Flood Elevation) for adaptation planning. Because of the incorporation of the cumulative effect of a large ensemble of storms, the 1% flood elevation is better than the flood elevation in any specific storm, e.g., Irma in 2017, for vulnerability analysis and the adaptation planning of various infrastructures.

More applicable to our case study, ACUNE can be used to assess the depth and geographic extent of inundation caused by nuisance flooding (i.e., by tides and SLR) or by storm surges for the 100- and 500-year flood events (i.e., 1% and 0.2% annual exceedance probability flood due to SLR and storms). Currently, ACUNE contains future flood maps for 3 target years: 2030, 2060, and 2100. For each of these years, simulations for 3 SLR magnitudes, based upon the sea level projected curves prepared by NOAA [51] representing low (17th percentile), medium (50th percentile), and high (83rd percentile) predictions, can be generated (Figure 1). These regional sea levels in Collier County are slightly higher than the global mean sea level (GMSL) contained in the NOAA report [51], due to local subsidence, which was not accounted for in the GMSL scenarios. These SLR scenarios were used as the ocean boundary conditions of coastal surge-wave model simulations for the future target years. Therefore, ACUNE provides compound flood maps due to tides and SLR, as well as compound flood maps due to future storms and SLR. The effect of rainfall on coastal flooding in this region was found to be relatively unimportant [50], hence inland flooding was not included in the current effort. Existing SLR Geo Tools, however, typically only consider flood maps due to SLR alone. These maps, often referred to as “bathtub models”, contain large errors, although they are readily available from many commercial and non-profit organizations. For this cultural resource vulnerability assessment, we used a few select maps that do not utilize the full planning potential of ACUNE, instead using the compound flood maps for both nuisance tides + SLR and storms + SLR.

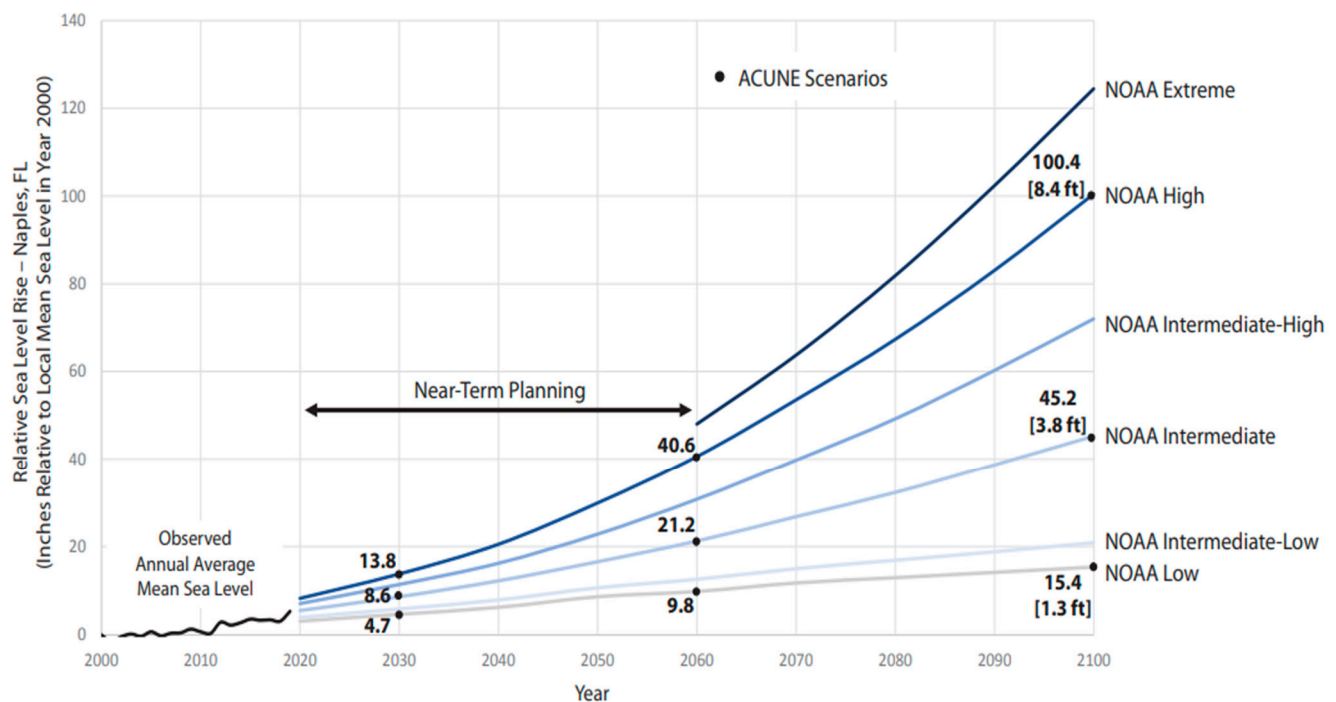


Figure 1. Sea-level rise curves produced using NOAA [51] with sea levels being used to create the ACUNE 2030, 2060, and 2100 scenarios indicated. Values indicate inches. Metric conversions for 2100 levels are 39.1, 114.8, and 255 cm for low, intermediate, and high, respectively.

2.2. Working Group

To complete the vulnerability assessment, in 2020 we assembled a working group customized to engage a cross section of professionals and residents familiar with the diversity of cultural assets in Collier County. Representatives were recruited from selected local, state, and federal partners, including the civil rights organization The National Association for the Advancement of Colored People (NAACP), the worker-based human rights organization Coalition of Immokalee Workers, the Seminole Tribe of Florida, local residents, Collier County Museums, Florida Gulf Coast University faculty, Florida State Parks, the Florida Public Archaeology Network, Rookery Bay National Estuarine Research Reserve, and the National Park Service. Engaging a diversity of voices and perspectives for projects that affect communities is crucial, and any work that aims to prioritize cultural sites must engage with as many communities as possible. Our working group undoubtedly could have included more voices. However, we made tangible efforts to contact, engage with, and incorporate groups throughout the county from diverse backgrounds, experiences, and areas of expertise.

The challenges of scoring and ranking cultural sites are many, and without adequate forethought and planning can be detrimental to community cohesion, rather than fostering community growth and identity [52–54]. Working group members must make conscious choices about the value of cultural resources, and these choices, when included as part of vulnerability assessments, result in long-term planning projects which can have immense and irreversible impacts on sites. A group of only archaeologists determining the site value might result in scores that prioritize the research potential of a site that is inaccessible to the public over the value of a local site that defines community identity. While the conservation of an inaccessible site might result in future archaeological research, the destruction of a community site might deteriorate public trust in the planning process, harming community cohesion [52–54]. These challenges must be considered, and every effort taken to include as many voices as possible in the site assessments and prioritization to ensure sites' values are fully understood.

2.3. Full County Site Count

To assess the large scale changes to site impacts, working group members with access to the FMSF performed a count of all cultural sites in Collier County within the FMSF, which would be inundated under various scenarios in the future. Because the location of archaeological sites is confidential, these asset data were included in a secure GIS layer of ACUNE, and were only made available to members who had access to the FMSF. At the time of analysis in 2020, there were 1557 cultural sites in Collier County listed on the FMSF [42]. It is important to note that the FMSF does not contain every cultural site in existence in Collier County, only those which have been documented through the official process with the State of Florida. Due to processes of systemic oppression and underrepresentation, this has resulted in a disproportionate number of sites that pertain to the history of the region following European colonization. There have been numerous efforts to increase the representation of sites and histories of under-represented groups [55]; however, this bias is still present within the FMSF data.

2.4. Methodology

The group used the ACUNE tool to examine the inundation of cultural sites under the following two conditions: (1) the 1% AEP flood due to storms under 2020 climate and sea level; and (2) the 1% AEP flood due to storms and SLR (0.72 ft higher than the year 2000 sea level) under the climate conditions projected for 2030 (Figure 2). All sites among the 1557 cataloged that experienced any water on the landscape surface were counted as “impacted” for each flooding scenario.

This first assessment does not consider a site’s archaeological importance, its potential to yield new historic information, its appeal to the community, or its adaptability to climate change. This was solely to quantify the numbers and locations of sites impacted in the two scenarios, and to anticipate the growing impact on cultural resources as climate change proceeds over the next 10 years.

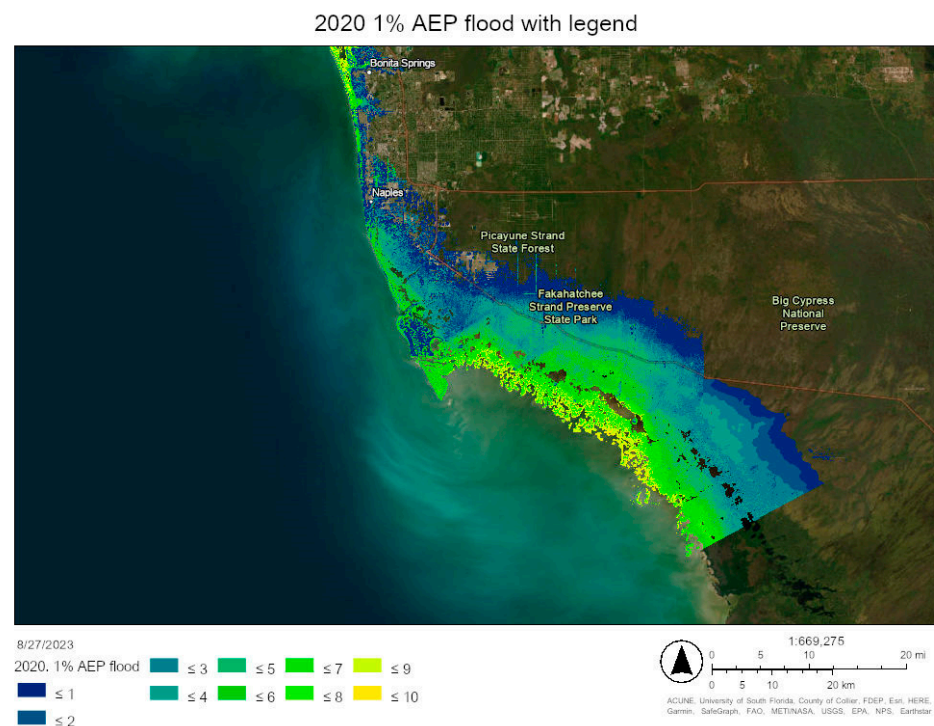


Figure 2. Cont.

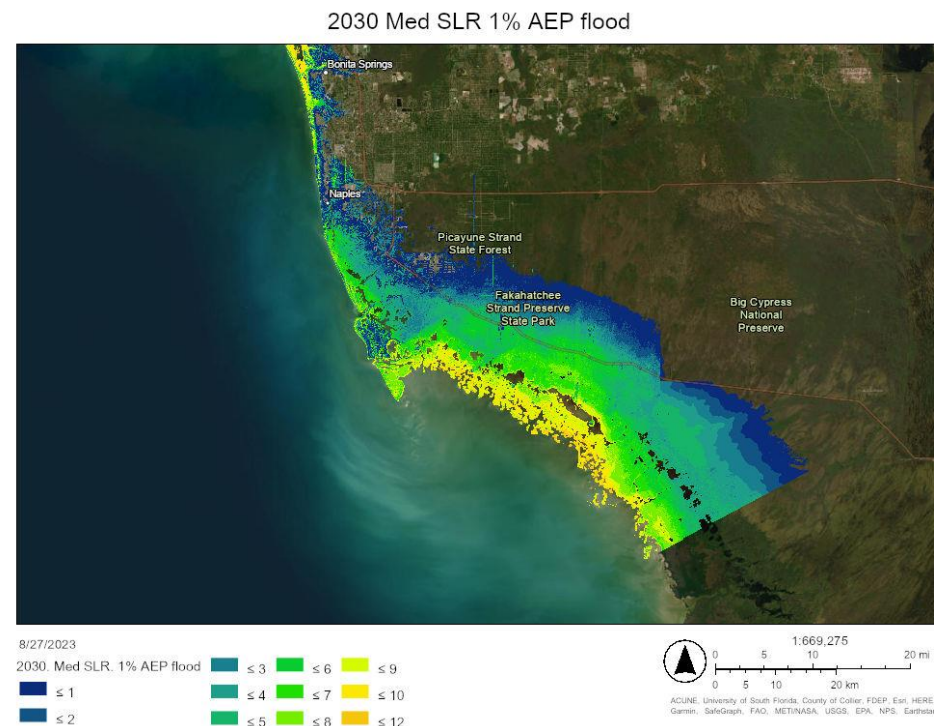


Figure 2. ACUNE flood maps used for the full county site count [56]. Top: 1% AEP flood due to storms under current climate. Bottom: 1% AEP flood due to storms and SLR (0.72 ft higher than the year 2000 sea level) under the climate conditions projected for 2030.

2.5. Case Studies

Ten case study sites, representing those most recognized by Collier County residents, were selected by the working group to serve as a proof-of-concept for the prioritization framework. This was not a list of the 10 most important sites in the county, nor was it an assessment of all sites in the county. Rather, the assessment of the ten sites demonstrates the value of this methodological approach for assessing the vulnerability of any number of assets. Importantly, members were asked to submit any significant cultural site, regardless of their FMSF listing status. Accordingly, working group members identified one previously unrecorded critical asset (e.g., Macedonia Missionary Baptist Church). Members chose the sites they were most familiar with, or sites with thorough documentation (e.g., those on the National Register of Historic Places). Each site was scored using the criteria detailed below.

Our scoring methodology for cultural sites was adapted from methods defined in the City of Naples, Florida Climate Change Vulnerability Assessment, created by AECOM [57], which used four scoring categories to assess city assets such as roads, hospitals, stormwater assets, and others. Cultural resources were not included in this assessment [57]. We updated the definitions of AECOM's four scoring categories and their detailed scoring instructions to specifically apply to cultural resources, creating the following categories and definitions that were used for each site.

2.5.1. Scoring Categories

- Exposure—how extensive will the flooding be on the cultural resource?
- Vulnerability—an averaged score of the sensitivity and adaptive capacity
 - a. Sensitivity—will the cultural resource's function, including its physical structure, be impacted by flooding?
 - b. Adaptive Capacity—can the cultural resource be modified to reduce the impact of flooding?

- **Consequence**—what are the negative societal consequences of inaction for the history and archaeology of Collier County? The consequences of this inaction are evaluated from the following perspectives, each with its own score, and averaged for the total consequence score:
 - a. **Environmental**—what are the consequences for the surrounding natural environment with a loss of or damage to the cultural resource?
 - b. **Social**—what kind of impacts might occur to the culture or sense of place for the local community?
 - c. **Economic**—will there be workforce disruptions, a loss of real estate, impacts on tourism or significant industries, or any asset damage/loss? [57]

2.5.2. Scoring Exposure

Exposure scoring reflected the number of tested scenarios in which flooding from SLR, and storms was projected to impact sites. The ACUNE tool was used to map different SLR and storm flooding scenarios for the various planning horizons and projections of SLR (13 scenarios in all; Table 1). A site's exposure score was determined as a percentage based on the number of scenarios where any portion of the site is exposed to any amount of water. The exposure scores range from 0 (not exposed in any scenario used) to 100% (exposed to water in all 13 scenarios). Below are screen captures of the ACUNE tool viewing the Everglades City Laundry Building/Everglades City Museum with no flooding (Figure 3), with flooding under 2020 climate and a 1% AEP event (the least severe flood event tested) (Figure 4), and with flooding under 2100 climate, high SLR, and a 1% AEP event (the most severe flood event tested) (Figure 5). To view all 13 scenarios tested for all 10 case study sites, please refer to the full report completed by the authors, "Collier County Cultural Resources Vulnerability Assessment," available online at <http://www.fpan.us/wp-content/uploads/2023/12/ACUNE-Collier-County-Cultural-Resources-Vulnerability-Assessment-Final-March-2022.pdf>, accessed on 15 August 2023 [56].

Table 1. Exposure Scenarios.

Scenario	Type of Flood Map	Sea Level Rise Scenario
1	1.0%AEP flood	2100 High SLR
2	1.0%AEP flood	2100 Low SLR
3	Nuisance flooding	2100 High SLR
4	Nuisance flooding	2100 Low SLR
5	1.0%AEP flood	2060 High SLR
6	1.0%AEP flood	2060 Low SLR
7	Nuisance flooding	2060 High SLR
8	Nuisance flooding	2060 Low SLR
9	1.0%AEP flood	2030 High SLR
10	1.0%AEP flood	2030 Low SLR
11	Nuisance flooding	2030 High SLR
12	Nuisance flooding	2030 Low SLR
13	1.0%AEP flood	2020/Current sea level



Figure 3. Everglades City Laundry with no flood map.

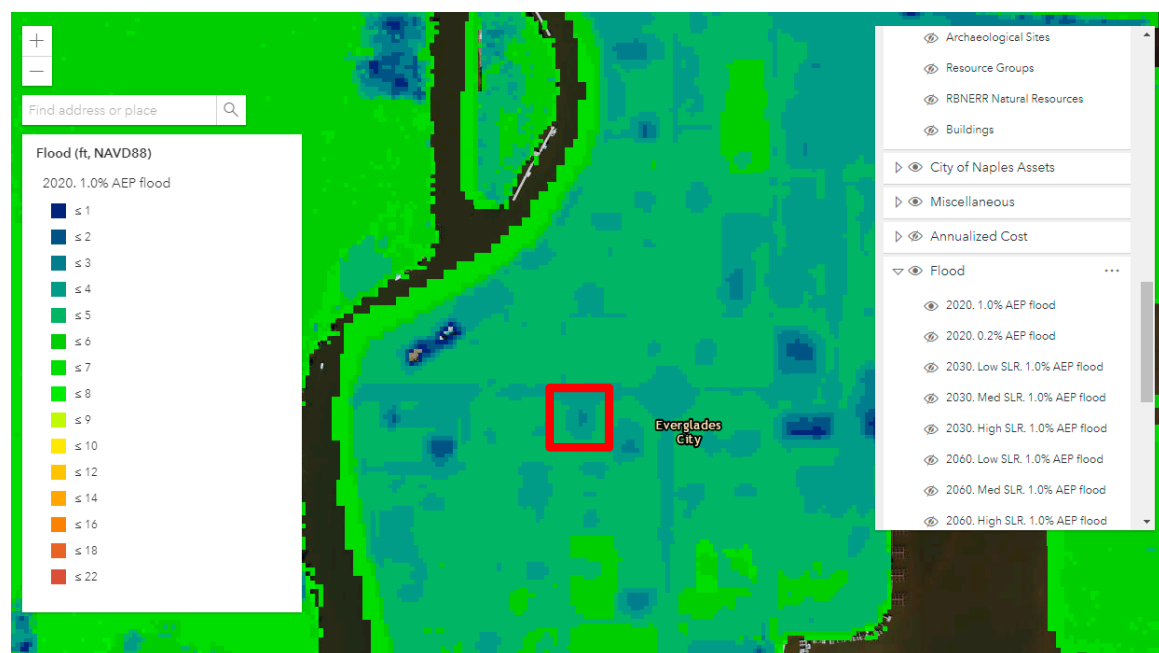


Figure 4. Everglades City Laundry (within red box), first exposed in scenario 13: 2020 1.0% AEP Flood, with between 5–6 ft of inundation depth on top of topography.

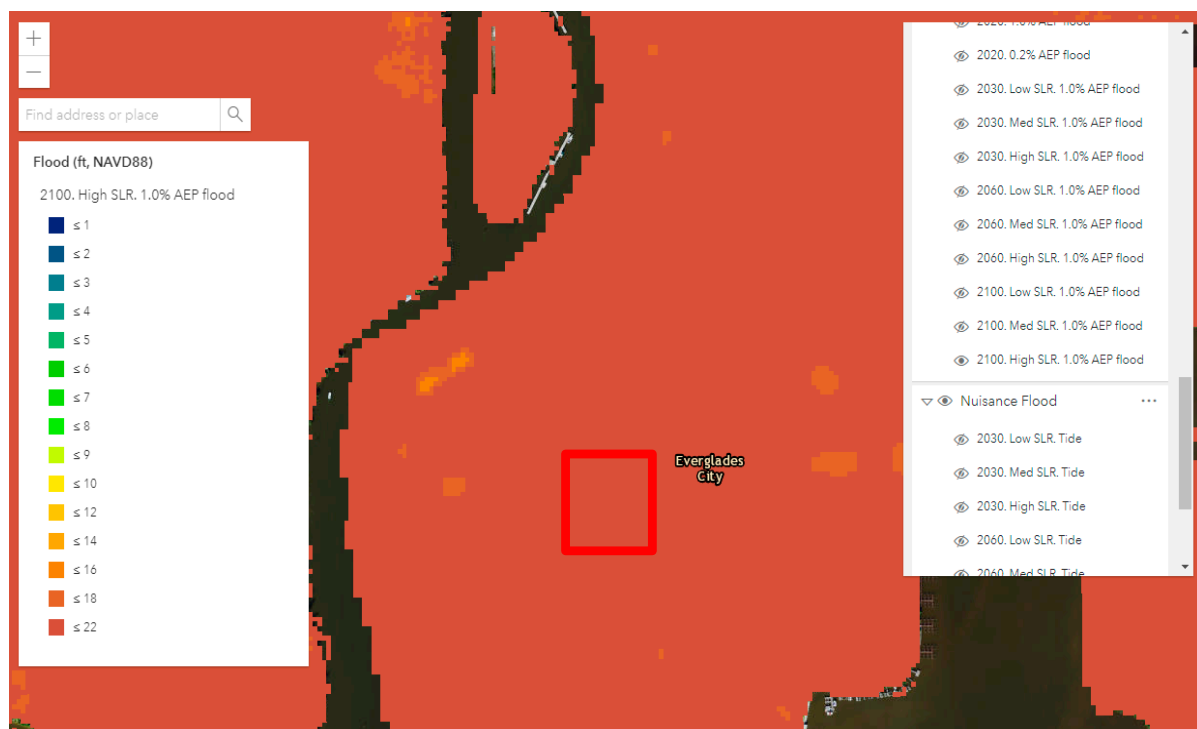


Figure 5. Everglades City Laundry (within red box) in the most severe scenario tested, scenario 1: 2100 High SLR 1.0% AEP Flood, with between 16–18 ft of inundation depth on top of topography.

2.5.3. Scoring Vulnerability, Sensitivity, and Consequence

These three categories were scored by working group members based on the criteria summarized below and were detailed in the full report [56]. While these categories are inherently subjective, specific criteria were distributed to ensure that working group members evaluated sites uniformly. Working group members numerically scored each site based on each criterion to allow for the easy comparison of scores of multiple sites for initial prioritization. Members, however, also crafted short narratives for each, thereby providing a qualitative justification for their score. The qualitative data for each site are critical for making decisions about when, how, and why one site should be prioritized over another.

Scoring Vulnerability

To define the vulnerability of a site to sea-level rise and storm inundation, we averaged the score of the site's sensitivity and its adaptive capacity, each explained below. If a site is very sensitive to inundation (i.e., a historic wooden building with electrical systems would be heavily damaged by inundation), but also has a high adaptive capacity (i.e., that same historic building could be moved to a less-flood-prone location; examples from this study is the Ochopee Post Office, the smallest Post Office building in the country [58]), then that site would only be moderately vulnerable.

Scoring Sensitivity

Sites were assessed for their sensitivity to exposure to flood waters and how this exposure would impact a site based on qualitative considerations. Site sensitivity is partly dependent on the site's relative reliance on susceptible technologies for their function. For example, historic structures, like the Everglades City Laundry/Everglades City Museum with electrical wiring and wooden frame construction, are more likely to have their function compromised, and therefore are more sensitive, than a shell mound like Dismal Key.

The sensitivity to flooding was assessed based on the following set of qualitative considerations:

- Electrical equipment (flooding or inundation of electrical equipment may lead to operation malfunction or damage to the asset).
- Corrosive material (subsurface structures required for the conveyance of water, sewer, natural gas, and electrical utilities may be made of materials that could corrode prematurely if exposed to saltwater).
- Susceptible to increased frequency, duration, or depth of saltwater inundation (some assets and/or habitats have a narrow tolerance of water depth changes and may experience damage or complete loss of function—for example, an archaeological site currently protected by vegetation that may be changed/impacted by inundation).
- Susceptible to erosion/scour events (flood events may cause erosion or scour under or directly adjacent to the asset or archaeological site).
- Buildings (some buildings house equipment on lower floors that could be damaged if exposed to flooding).
- Elevation (some assets are elevated above the adjacent ground elevation, making them less sensitive to floodwaters, but access could potentially be impacted).

Each cultural resource was evaluated on a scale of zero (not sensitive) to three (highly sensitive) (Table 2).

Table 2. Scoring criteria for sensitivity, adaptive capacity, and consequence.

Criteria for Scoring Sensitivity		
Score	Rating	Definition
0	Not Sensitive	No Impact
1	Low Sensitivity	Short-term, minor, or reversible damage
2	Moderate Sensitivity	Significant, but reversible damage
3	High Sensitivity	Irreversible damage
Criteria for Scoring Adaptive Capacity		
Score	Rating	Definition
1	High adaptive capacity	Ability to adapt site to fully offset potential impacts; adaptation is possible at a reasonable cost and low level of effort
2	Low adaptive capacity	Ability to adapt site to partially offset potential impacts; or adaptation is possible, but extremely costly or difficult; creating armoring like a living shoreline to protect a site
3	No adaptive capacity	No ability to adapt asset or possible adaptation does not offset potential impacts; archaeological site would either require full excavation or be lost
Criteria for Scoring Consequence		
Score	Rating	Definition
1	Low Consequence	Negligible impacts (e.g., inconvenient or temporary effects); easy and not costly to restore
2	Moderate Consequence	Widespread impacts resulting in loss or setback of archaeological site or system; costly, but possible to restore
3	High Consequence	Significant impacts resulting in extensive loss; likely irreversible or very costly to restore

Scoring Adaptive Capacity

The adaptive capacity of a site reflects its potential to adapt to the impacts of flooding to retain its historic or archaeological integrity. For example, historic buildings can be raised or moved, while large shellwork sites cannot. The shellwork site, therefore, has less adaptive capacity. The following characteristics were considered when scoring the adaptive capacity to the flooding of built infrastructure:

- Ability to elevate infrastructure (the existing site can easily be raised to reduce its vulnerability to flooding, or can have electrical components raised out of the reach of temporary flooding).
- Ability to relocate infrastructure (site can be easily moved to higher elevation or outside of floodplain to protect it from flood damage).
- Ability to retrofit/upgrade (can be easily retrofitted with units or with water proofing material without compromising historic status).

The following characteristics were considered when scoring the adaptive capacity to the flooding of archaeological sites:

- Robustness (some sites are better able to withstand climatic changes and individual extreme events).
- Ability to retrofit/upgrade (can be easily retrofitted with units or with water proofing material without compromising historic status).

Each site was scored for the adaptive capacity on an inverse scale where a higher adaptive capacity received a lower number score, so that, when all scores are taken together, higher scores are at more threat from climate change (Table 2), with some working group members scoring with a ± 0.5 accuracy (e.g., Fakahatchee Key was scored 1.5). Shell midden sites were difficult to score because there are ways to research the sites before submersion (salvage excavation) in order to offset a loss of information, and studying sites that survive the process of submergence is time consuming and costly, but possible [59]; however, these sites are impossible to move and preserve in their entirety. These difficulties were added as notes to these sites' results tables.

Scoring Consequence

The working group evaluated the potential consequences of inaction at archaeological and cultural sites, including the potential environmental damage, potential social impacts, and potential economic damage of site loss considering the following impacts:

Potential environmental damage

- Conversion or loss of habitat (existing habitats may face deterioration or complete loss due to inundation).
- Harm to local wildlife (impacts on native or endangered species or species of interest).

Potential negative social impacts

- Cultural and historic (loss of historic communities or cultural sites that define the county's identity and provide a sense of well-being or belonging to county residents).
- Loss of archaeological knowledge/information due to the impacts on sites.

Potential economic damage

- Asset damage (partial or entire loss of site or its ability to function).
- Operation disruptions (some sites may cause a loss of revenue due to facility limitations or closure, a loss of access via primary roadway, or a loss of critical infrastructure).
- Loss of jobs (sites that currently require staffing and maintenance may no longer support those employees if the site was destroyed or no longer functional).
- Loss of tourism opportunities (tourism and visitation by seasonal and permanent residence may decline due to the loss of a site or a change in the site's accessibility or function).
- Increase in maintenance (financial burden may increase due to the increased maintenance required for exacerbated stress placed on the site or system).

Each of these three categories of consequence were scored separately (Table 2), and the scores were then averaged to create the overall consequence score. For example, a site that has a moderate environmental consequence (2), a low social consequence (1), and a moderate economic consequence (2) would be scored through averaging the three scores, resulting in a total consequence score of 1.67.

2.5.4. Using Case Study Scores

We used this multi-category scoring method to provide more detail about how, when, and why sites should be addressed in planning efforts, as opposed to many existing studies which focus solely on the timing of exposure. Less urgency may be required for a site with high exposure that also has a high adaptive capacity when exposed. Rather than preventing exposure at this site, it may be more prudent to assist with the adaptive capacity. In contrast, a site with high exposure and a low adaptive capacity may need to be prioritized as it is more likely to be negatively impacted when exposed. For example, a small historic building like the Ochopee Post Office that will be exposed to flooding in 2030 can easily be elevated or moved to a safer location, whereas a cemetery also exposed to flooding in 2030 is impossible to elevate and more difficult to move, therefore being of higher priority for resiliency planning. Many archaeological sites have low adaptive capacities, as it is not possible to simply elevate a shell mound (like Dismal Key, Fakahatchee Key, Otter Mound, or Shell Island Site) in the same manner as an air-conditioning unit, or even a roadway. Accordingly, these represent some of the most vulnerable cultural resources.

Although a study by the State of Florida, Division of Historical Resources [60] recommended a strategy of “abandonment in place”, or inaction, for archaeological sites, there are ways that the resilience of these sites can be increased through other means, like installing wave barriers or excavating the site to preserve archaeological information. The purpose of this methodology is to demonstrate how resource managers and adaptation planners can assess sites and make informed decisions to prioritize them in the planning process, deciding which resources are most appropriate for resource investment.

2.6. Aligning with Adaptation Planning Frameworks

To assess the vulnerability of cultural sites in Collier County, we modeled this assessment to align with the Florida Adaptation Planning Guidebook’s methodology created by Florida DEP [27]. While this may not be relevant to those outside of Florida, if cultural resources are to be included in the planning process, it is crucial to identify how projects fit into relevant established planning frameworks.

For example, the DEP methodology includes 4 essential components of adaptation planning as follows: (1) context, (2) vulnerability assessment, (3) adaptation strategies, and (4) implementation strategies. Each of these has associated sub-components. This project’s two goals (the full county site count and the ten case studies) executed 4 of the 11 sub-components from the DEP methodology.

To argue for the inclusion of cultural resources in the planning process, it is incumbent upon us to define how they fit within adaptation planning projects to meet local, state, or federal guidelines and how projects like ours align with existing projects and goals of planning committees and groups. The more seamlessly we can incorporate cultural resources into these established guidelines and goals, the easier it becomes for decision makers to include them.

3. Results

3.1. Full County Site Count

Of Collier County’s 1557 sites, 267 were predicted to flood under Scenario A, conditions in 2020 with 1.0% AEP Flood. Under Scenario B, conditions in 2030 Medium SLR with 1.0% AEP Flood, 318 sites were predicted to be impacted by flooding (Table 3). The 51-site difference in flooding susceptibility spans one decade, demonstrating the worsening effects of SLR and increased storminess. The magnitude of the increase in the number of affected sites across this short ten-year period (2020–2030) and under such modest SLR conditions provides resource managers with a relative sense of urgency for decision making and resilience improvement.

Table 3. Results of full county site count.

Scenario	Flood Projection	Number of Sites Impacted
A	2020 with 1.0% AEP Flood	267
B	2030 Medium SLR with 1.0% AEP Flood	318

3.2. Case Studies

Results for each of the ten sites chosen for a detailed vulnerability analysis are summarized below (Table 4, see Appendix A for more detailed results). The full report for the project includes a short description of the site and its historic and cultural significance, a table documenting the exposure determined using the ACUNE tool, vulnerability, and consequence scores determined by the working group through their qualitative analysis. The full report, including ACUNE-generated inundation maps of each site in each of the 13 exposure scenarios, is available online at <http://www.fpan.us/wp-content/uploads/2023/12/ACUNE-Collier-County-Cultural-Resources-Vulnerability-Assessment-Final-March-2022.pdf>, accessed on 15 August 2023 [56].

Table 4. Simplified results of 10 case study sites. Each un-bolded sub-category is scored out of 3, bolded categories are averaged scores of their sub-categories, and exposure is based on the percentage of the 13 flood scenarios. See Section 2 for more detail.

Site	Vuln.	Sens.	A.C.	Consq.	Env.	Social	Econ.	Exp.
Dismal Key	1.75	2	1.5	2	2	2	2	100%
Everglades City Museum/Laundry Building	2	2	2	1.67	1	2	2	92%
Fakahatchee Key	1.75	2	1.5	2	2	2	2	100%
Macedonia Missionary Baptist Church	2	2	2	2.33	1	3	3	62%
The Marco Island Historical Museum	2.5	3	2	2.33	1	3	3	54%
Ochopee Post Office	1.5	2	1	1.67	1	2	2	69%
Otter Mound	1.75	2	1.5	2	2	2	2	46%
Rosemary Cemetery	2.5	3	2	2	1	3	2	15%
Shell Island Site	1.75	2	1.5	2.3	2	3	2	100%
Smallwood Store	2	2	2	1.67	1	2	2	54%

Here, we provide the final report for the Ochopee Post Office (excluding the 13 exposure maps, available in Appendix B of the full report [56]) as an example of the product of our methodology.

3.2.1. Case Study 6: Ochopee Post Office (Smallest Post Office Building in the Country) Description of Site

Constructed in 1932, the Ochopee Post Office is a unique cultural resource in Collier County. Its status as the Nation's smallest operating post office makes it a local attraction featured on travel websites. Yet, Ochopee Post Office also serves about 300 people in three counties, including members of the Seminole Tribe of Florida and the Miccosukee Tribe of Indians of Florida, and provides an essential service to small populations living in remote parts of South Florida.

The connections to Collier County's past, particularly in terms of the early development of infrastructure and economy, specifically the construction of US 41/Tamiami Trail, make the Ochopee Post Office an important part of Florida's heritage. Furthermore, its unique status as the smallest post office building in the U.S. regularly attracts visitors from around the world seeking the "famed Ochopee postmark" [58]. The Ochopee Post Office

constitutes an irreplaceable cultural resource. Please see Table 5 for the anticipated impact to the site.

Table 5. Results of the Ochopee Post Office (Smallest Post Office Building in the Country) case study showing exposure, vulnerability, and consequence scores.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Vulnerability	1.5	Sensitivity	2 (of 3)	The building would be damaged by flooding, but its size would make repair costs lower than those of larger structures in the study list.
		Adaptive Capacity	1 (of 3)	The Ochopee Post Office's proximity to US 41 makes the site more adaptable than some—e.g., it lies in the right-of-way and likely would necessarily be part of large-scale modifications to US 41. Furthermore, it seems that the site's elevation could be increased without causing major damage to its integrity.
Consequence	1.67	Environmental	1 (of 3)	The structure has little impact on surrounding environmental systems and therefore would exert low consequences if lost.
		Social	2 (of 3)	The building is a major part of the social and economic fabric of the area. With visitors from around the world making the journey to this structure, its loss would likely result in fewer visitors.
		Economic	2 (of 3)	Being an active post office that serves many small communities, the loss of the site would significantly impact those communities and their ability to send and receive mail, a service that is older than the United States itself, that is integral to official dealings with government entities and to social life for community members.
Exposure	69%	13 flood scenarios tested	Exposed in 9 of 13 flood scenarios	Exposed in all scenarios EXCEPT 8,11,12,13

Based on the results, sites can be compared quickly based on exposure, vulnerability, or consequence numerical scores, but details about the site that are important when creating specific plans and comparing the merits and challenges of each site are also provided.

The case study results demonstrate the efficacy of this method of vulnerability assessment and prioritization. This method has great potential for serving communities globally as they confront the coming impacts of climate change on their cultural sites.

3.3. Applying Results

The two goals of our methodological case study in Collier County, Florida, (1) the evaluation of the number of cultural sites affected by two SLR flooding scenarios a decade apart and (2) the detailed vulnerability assessment and prioritization scoring of ten case study sites in the county, serve as a guide for resource managers and decision makers, illustrating the value of informed and forward-thinking adaptation planning and prioritization.

Based on the results of our case study vulnerability assessment, we see how planning decisions might be affected by our findings. Managers gain a sense of the respective timelines available to them for adaptation planning and implementation. A decade for Collier County, from 2020 to 2030, has the potential to increase the number of sites at risk of storm flooding from 267 to 318, alerting managers that immediate action is needed for the sites of greatest value. With a more detailed approach to ACUNE's simulation, the spatial

distribution of sites affected over the same decade can be acquired, showing areas of the landscape that will experience greater exposure sooner than others.

These results can also inform thoughtful planning discussions to ensure community cohesion and connection with their cultural heritage. A few examples of the conclusions that can be drawn follow:

The Ochopee Post Office has a 69% exposure, lower than half of the other sites, partially because of its more distal position relative to tidally influenced wetlands. It also exhibits a high adaptive capacity; its small size makes it easier to be relocated than, for example, the Marco Island Historical Museum. The Post Office would therefore have a lower priority, and the implementation of any adaptational strategy could wait for some time in the future and be implemented quickly.

In contrast, Dismal Key is virtually unsalvageable. It suffers from 100% exposure, impacted in all 13 future scenarios; has poor adaptive capacity (the value scored is misleadingly low because the working group assumed excavating the site underwater could be conducted sometime after inundation); and has high sensitivity scores. It would be unwise to wait and see if the inundation process submerges the key or, more likely due to the estuarine environment, erodes it and all artifacts away. Cultural resource managers, therefore, might prioritize this site for excavation.

Rosemary Cemetery has a low exposure score and will likely not be impacted until later scenarios. Once the site is exposed, however, it is incredibly sensitive and has a low adaptive capacity, which, combined, make the site extremely vulnerable. Because the site contains human burials, which are protected by law in Florida and are possibly the most sacred places of our human past, decisions about the cemetery will likely require careful planning with numerous stakeholders and descendants, many of whom do not live in the area. Therefore, now is the time to design a system for resiliency improvement, and funding may be sought over the next two decades before environmental impacts begin to seriously threaten the site. Knowing that resources may be triaged in this way can help direct limited resources to where they are most needed now.

The Macedonia Missionary Baptist Church is an asset that would have remained unnoticed had the assessment not involved the right stewards, who, in this instance, included a member of the Collier County chapter of the NAACP. The church is not listed on either the FMSF or the NRHP. Had a working group of local professionals and civic leaders not been convened to assist, this asset would likely not have been considered. The social consequences of losing this site would be dire—the site is a community resource for a historically underrepresented and underserved community. Moving the site would decontextualize it and risk divorcing it from this community. The church itself has a moderate exposure, only impacted in 62% of the scenarios. Nonetheless, it scored high in sensitivity and in social and economic consequence. The cultural significance of the site for Collier's Black community should positively influence the church's priority when adaptation planning occurs. Accordingly, efforts to harden the structure or surrounding area to make it more resilient should be considered.

Lastly, the Everglades City Museum and former Everglades City Laundry is an example of a cultural asset that not only has a high exposure (in 12 of 13, or 92% of the scenarios), but one that resides in an area that already suffers from chronic nuisance and storm-surge inundation. The site scores high for sensitivity and consequence, while also having a relatively low adaptive capacity. Clearly, given its current and future high level of exposure, this asset should sit among those with the highest priority, requiring the implementation of some adaptive strategy in the near term.

Planning decisions like these can be made for all 10 of the sites based on our results, and decisions can be weighed against each other when considering funding, labor hours, community desires, and any other factors. This serves as a small example of how a management area, a specific focus area defined by exposure analysis mapping, or an entire county or region could use this methodology to score and prioritize sites.

4. Discussion

This methodology for assessing cultural resources' vulnerability to climate change, and prioritizing them through a thoughtful scoring system, is a guide for resource managers and planners to include cultural resources into adaptation planning and to prioritize which sites should have resources invested, when, and why. Case studies from other countries [13,14] and the lack of a comprehensive federal plan in the US [20] clearly illustrate the responsibility local planners and land managers in the United States have to assess the vulnerability of cultural heritage sites and prepare a plan for their future.

Presented here is our methodology of scoring the exposure, vulnerability, and consequence of specific sites based on criteria detailed above, which allows for the prioritization of sites, a crucial and often elusive step in the adaptation planning process. Our study only examined 10 sites across the county, thereby preventing any comprehensive prioritization of resource investment. However, this scoring method is applicable to any study area regardless of the spatial scale, for all sites in a management area, in a specific focus area (as defined by exposure analysis mapping), or throughout the entire county or region.

Clearly not all sites can be protected, or protected indefinitely, assuming sea-level rise persists. And not all courses of action are appropriate for every cultural asset. Adaptation strategies may be too costly, sites too spatially massive for relocation or fortification, or a site may be too culturally linked to its geographic location to justify relocation. Archaeological sites, particularly Native American shellworks located within estuarine and coastal settings, will be submerged. They can, however, be prioritized for further assessment and discussion with descendants to decide if excavation and study is appropriate to preserve knowledge before the physical site is underwater, therefore being more costly to research [59] or being destroyed entirely.

Our methodology in determining the relative exposure of assets and their vulnerability can be undertaken with simple and freely available tools, even those that merely reveal nuisance flooding by mapping sea-level height in the future against topography (i.e., a bathtub models). But tools like the ACUNE Geo Tool we used for this study are immensely helpful in justifying the confidence of our exposure analysis results and producing highly accurate maps of future nuisance and storm flooding events. Using our methodology, exposure results can be easily updated with the development of more accurate tools like ACUNE for a study area while maintaining the qualitative data and descriptions. Climate change also imposes other ill-effects on infrastructure, health, and society in general (e.g., heat, precipitation, wildfire). Vulnerability tools exist or can be developed for these factors, and the method presented herein, through comparing exposure, vulnerability, and consequence, can be applied.

Overall, the working group was able to identify and assess 10 case study cultural sites using a straightforward framework for prioritizing sites that can be used on any scale. However, this study also emphasizes the importance of assembling a diverse and equitable group when creating and prioritizing lists of sites, as well as having diverse community members involved in every step of the process, which has been demonstrated in numerous community-led projects like Scotland's Coastal Heritage at Risk, Maine's Midden Minders, and Florida's Heritage Monitoring Scouts Program [61].

5. Conclusions

Climate change is a global issue which will impact heritage worldwide [4–9]. Florida is on the front lines of exposure to inundation due to climate change and sea-level rise. Collier County has unique and valuable resources including cultural, natural, and urban assets all at risk of direct or indirect impacts in the next 80 years. This vulnerability assessment used the cutting-edge ACUNE Geo Tool along with a working group composed of diverse community members and resource managers in order to assess large scale changes to the area of impact over time, and it used ten case study sites to test a methodology in order to quantify the specific threats of exposure, vulnerability, and consequence, prioritizing resources based on important factors that are not always considered in prioritization frameworks.

Major events like 2022's Hurricane Ian clearly articulate the need for planners and land managers to have access to ACUNE-like tools which contain the best science-based prediction of current and future probabilistic coastal flood maps and nuisance-tide maps in the 21st century. Hurricane Ian did inundate many of the ten cultural sites assessed in this study, underscoring the potential imminent vulnerability requiring action. While sites like the Marco Island Historical Museum fared well, others, like the Macedonia Baptist Church, were negatively impacted by flooding. In a future study, we will compare ACUNE's hindcasted simulation of Hurricane Ian's inundation with the inundation empirically experienced by Collier County's cultural assets to further illustrate the importance of this assessment and planning strategy. Since the ACUNE Geo Tool has been updated since this study was conducted, we plan to revisit this with the latest ACUNE [<https://coastalscience.noaa.gov/news/communities-in-southwest-florida-receive-new-tools-and-information-to-plan-for-floods/>], accessed on 15 August 2023] in the near future.

This methodology is useful to those trying to identify ways to include cultural resources into adaptation planning efforts, and, once they are included, it can offer a useful path for prioritizing sites for the future allocation of resources based on qualitative and quantitative input from a variety of partners. This work is vital, enabling responses to specific disasters and emergencies, as well as creating and implementing long-term plans for protection and adaptation to climate change. Developing responses and long-term plans will help protect cultural sites and the stories they represent, as well as local and global economies that rely on heritage tourism.

As the climate crisis continues and more of our human and natural landscapes respond and change, we can create a future that is sustainable and incorporates the stories of our shared human past in order to aid us in our collective memory of where we have been and to help us shape our future. We hope these methods can play a small role in that process.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Case Study Vulnerability Assessment.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Dismal Key				
Vulnerability	1.75	Sensitivity	2	Dismal Key is a large shellwork site and therefore will likely be impacted, but will still be able to be researched even if submerged, although this research would be much more difficult and costly.
		Adaptive Capacity	1.5	Although portions of the site may be destroyed, the site may remain partially intact underwater. Additionally, it would be possible to obtain information from the site through an archaeological survey either prior to the total submersion of the site or as an underwater survey.
Consequence	2	Environmental	2	Being part of the Rookery Bay National Estuarine Research Reserve, the site is part of a delicate and protected environmental system
		Social	2	The site is widely known to local residents, even garnering some visitation from local tour guides in the area. It also has the potential to provide significant information about the archaeology and history of Collier County.
		Economic	2	If the site were destroyed, it would negatively impact the local economy by removing a tourist destination that generates income and employment.
Exposure	100%	13 flood scenarios tested	Exposed in 13 of 13 flood scenarios	Exposed in all tested scenarios
Everglades City Laundry Building/Everglades City Museum Building				
Vulnerability	2	Sensitivity	2	The site is a functioning museum with electrical and other infrastructure that could be damaged by flooding.
		Adaptive Capacity	2	Although a costly proposition, raising or moving the building is technically possible and therefore provides some adaptive capacity to the site.
Consequence	1.67	Environmental	1	The building would have only minor environmental impacts if destroyed.
		Social	2	The building is part of the historic fabric of Everglades City, and, as part of the Collier County Museum System, it attracts visitors and impacts the local community through the social events the museum hosts and attends as partners.
		Economic	2	The building is part of the historic fabric of Everglades City, and, as part of the Collier County Museum System, it attracts visitors and impacts the local economy via the money spent in the town during visits.

Table A1. Cont.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Exposure	92%	13 flood scenarios tested	Exposed in 12 of 13 flood scenarios	Exposed in all scenarios EXCEPT scenario 12
Fakahatchee Key				
Vulnerability	1.75	Sensitivity	2	Fakahatchee Key is a large shellworks site and therefore will be impacted by inundation, but could still be studied if submerged.
		Adaptive Capacity	1.5	It may be possible to protect the site through means like a living shoreline and other measures to increase resiliency of the site; however, it is impossible to move the entire site.
Consequence	2	Environmental	2	The site is part of the Rookery Bay National Estuarine Research Reserve and serves as an important part of the delicate environment the Reserve helps to protect. Losing the site would therefore have a moderate impact on the surrounding environment.
		Social	2	The site is part of the local knowledge of the area and has significant social ties to the area and serves as an anchor for the deep historic and archaeological history. The site has the potential to provide significant information about this archaeology and history of Collier County.
		Economic	2	The site fosters visitors to the reserve and local guides, adding to the economic sustainability of the area.
Exposure	100%	13 flood scenarios tested	Exposed in 13 of 13 flood scenarios	Exposed in all tested scenarios
Macedonia Missionary Baptist Church, River Park Community				
Vulnerability	2	Sensitivity	2	If the site were to be impacted by flooding, the damage would likely be significant and impact the ability of the community to use the space while flooded and would damage the wiring and potentially impact the infrastructure of the building; however, this damage would likely be reversible with repairs.
		Adaptive Capacity	2	Due to the cost of adaptation (for example, moving utilities to a higher level or somehow elevating the site) and the fact that the adaptations necessary for resiliency might impact the historic nature of the church, the site was evaluated to be a 2.

Table A1. Cont.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Consequence	2.33	Environmental	1	The site is in an urban area not known for especially delicate or rare environmental elements. The environmental impact would therefore be low if the site were destroyed.
		Social	3	Macedonia Missionary Baptist Church is a social cornerstone of the community. The church is a gathering place for locals and is integral to the social fabric of the River Park community.
		Economic	3	Macedonia Missionary Baptist Church is also an economic cornerstone of the community. The church impacts the local economy by providing resources to the community that would otherwise be inaccessible, and by organizing events that also impact the number of visitors and economic stability in the community.
Exposure	62%	13 flood scenarios tested	Exposed in 8 of 13 flood scenarios	Exposed in scenarios 1,2,3,5,6,7,9,10
Marco Island Historical Museum				
Vulnerability	2.5	Sensitivity	3	Utilities present in the museum, artifacts, and other materials are stored in archives. While the structure could be rehabilitated or repaired, the artifacts contained in the museum would be highly sensitive to exposure to moisture, including moisture that might come through increased humidity if the air conditioning system were compromised, for example.
		Adaptive Capacity	2	It may be possible to make the site more resilient by constructing flood protection measures or moving utilities or important assets higher within the building. The building could also be moved in its entirety, or the contents moved to a new location; however, these would all be costly and difficult scenarios. However, this site is unique on the case study list as the building itself is not the resource, the objects within the building are the cultural resources. Therefore, while the object must be housed in an appropriate space, this building is not the only option. If this building were to be impacted by climate change, it is likely most structures on Marco Island would also be similar if not more severely impacted. Therefore, moving the objects or the building would require them to be moved off the island they represent.
Consequence	2.33	Environmental	1	Loss of the site will likely have negligible impacts to wildlife and associated habitats.
		Social	3	There would be significant social impacts with the loss of the story of the history of Marco Island and its communities.
		Economic	3	Loss of jobs and a major tourist destination would significantly impact the local economy.
Exposure	54%	13 flood scenarios tested	Exposed in 7 of 13 flood scenarios	Exposed in scenarios 1,2,3,5,6,9,10

Table A1. Cont.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Ochopee Post Office				
Vulnerability	1.5	Sensitivity	2	The building would be damaged by flooding; however, the size of the building itself would make repair costs lower than larger structures in the study list.
		Adaptive Capacity	1	The Ochopee Post Office's proximity to US 41 makes the site more adaptable than some—e.g., it lies in the right-of-way and likely would necessarily be part of large-scale modifications to US 41. Furthermore, it seems that the site's elevation could be increased without causing major damage to its integrity.
Consequence	1.67	Environmental	1	The structure has little impact on surrounding environmental systems and therefore would have low consequence if lost.
		Social	2	The building is a major part of the social and economic fabric of the area. With visitors from around the world making the journey to this structure, its loss would likely result in less visitors.
		Economic	2	Being an active post office that serves many small communities, the loss of the site would significantly impact those communities and their ability to send and receive mail, a service that is older than the United States itself, integral to official dealings with government entities and to social life for community members.
Exposure	69%	13 flood scenarios tested	Exposed in 9 of 13 flood scenarios	Exposed in all scenarios EXCEPT 8,11,12,13
Otter Mound				
Vulnerability	1.75	Sensitivity	2	As a shell mound site with historic components, the site would be damaged by inundation, especially the historic elements. However, the shell mound foundation of the site would still be able to be researched if not destroyed in the inundation process and fully submerged with intact elements.
		Adaptive Capacity	1.5	Given the site's inland location (compared to sites that are on the water) and the topography of the surrounding area, the site could potentially be protected from some flooding scenarios by relatively minor changes to the site, such as the creation of a berm or other physical barriers surrounding the site.
Consequence	2	Environmental	2	The site plays an important role as a protected environment for the rare and unique tropical hardwood hammock habitat; the loss of the site would negatively impact the environment.
		Social	2	The site fosters large numbers of visitors, consisting of locals and tourists alike.
		Economic	2	The site provides maintenance and management jobs for county employees.
Exposure	46%	13 flood scenarios tested	Exposed in 6 of 13 flood scenarios	Exposed in scenarios 1,2,3,5,6,9

Table A1. Cont.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Rosemary Cemetery				
Vulnerability	2.5	Sensitivity	3	Any flooding would impact the entirety of the site because it lies mostly underground. Furthermore, damage to graves or headstones can be irreversible depending on the impacts.
		Adaptive Capacity	2	Rosemary Cemetery is an intact cemetery and therefore the only effective way to adapt the site to flooding would be to exhume and move the graves to higher ground. This is possible, but very costly.
Consequence	2	Environmental	1	The site would have low environmental impacts if lost due to its small size.
		Social	3	As a cemetery with marked and unmarked burials, the site is sacred and important to the local community, serving to tie the community to its historic past. The fact that Black residents of the Naples area may be buried in unmarked graves further ties the site to important historical actions and larger systemic issues beginning to be addressed by the State. Therefore, losing the cemetery due to climate change and flooding would have serious negative impacts on the local community.
		Economic	2	There would be moderate economic impacts if lost, mostly in terms of county staff who are charged with its upkeep and safety.
Exposure	15%	13 flood scenarios tested	Exposed in 2 of 13 flood scenarios	Exposed in scenarios 1 and 2
Shell Island Site				
Vulnerability	1.75	Sensitivity	2	As a shell mound site, this site would likely be impacted by damaging effects of the inundation process like erosion. However, if the site were to survive the process, once flooded it could still have some archaeological integrity.
		Adaptive Capacity	1.5	It may be possible to create a living shoreline or another measure to help increase the adaptive capacity of the site.
Consequence	2.3	Environmental	2	The site is part of the Rookery Bay National Estuarine Research Reserve and is an important part of the local environment in the reserve. There would be a moderate impact to the environment if this site was lost.
		Social	3	The site is easily accessible in the reserve and is part of the social fabric of the current workings of the reserve. The site also has the potential to provide significant information about the archaeology and history of Collier County. Therefore, the social impacts would be the greatest if the site were to be lost.
		Economic	2	The site is part of the reserve that attracts tourists from around the world and employs numerous people as part of the upkeep of the reserve; the economic impacts would be moderate if the site were lost.

Table A1. Cont.

Main Category	Overall Score (Avg of Component Scores)	Component Categories	Component Scores	Description
Exposure	100%	13 flood scenarios tested	Exposed in 13 of 13 flood scenarios	Exposed in all tested scenarios
Smallwood Store				
Vulnerability	2	Sensitivity	2	If the site were flooded, as it has been in the past, it could be repaired. The repairs, however, would be very costly and the damage to items inside the building would also likely be significant.
		Adaptive Capacity	2	While the Smallwood Store would only be vulnerable to more extreme storm events, it is located directly on the bay, placing it directly in danger of sea-level rise and storms. A portion of the veranda of the building sits in the bay, furthering its vulnerability to storms. The only way for the structure to adapt would be either to move it or to strengthen and/or lengthen the pilings, both of which would be extremely costly.
Consequence	1.67	Environmental	1	Environmental impact of the loss of this site would be minimal.
		Social	2	The site is a key feature of the area, and the loss of the site would have moderate impacts to the social fabric.
		Economic	2	The site is a major tourist attraction and an active store; the economic impacts would be moderate if the site were lost.
Exposure	54%	13 flood scenarios tested	Exposed in 7 of 13 flood scenarios	Exposed in all scenarios EXCEPT 3,4,8,11,12,13

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