atmosphere

MDPI

Article

Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables in Salem, Massachusetts, USA

Paul Wright [1], Susan Baker [1] and Stephen S. Young [2,*]

[1] The House of the Seven Gables, Salem, MA 01970, USA; pwright@7gables.org (P.W.); sbaker@7gables.org (S.B.)
[2] Department of Geography and Sustainability, Salem State University, Salem, MA 01970, USA
* Correspondence: syoung@salemstate.edu; Tel.: +1-781-299-0248

Abstract: Salem, Massachusetts, is one of the oldest cities in the United States (1629) and its coastal location on the Atlantic helped create one of the wealthiest cities in America during the late 18th century, but today its coastal location threatens many of its buildings due to sea level rise and increased storm activity. The House of the Seven Gables, a National Historic Landmark District, consists of five important historic buildings, the most famous being The Turner Ingersoll Mansion (1668), more commonly known as The House of the Seven Gables. Considered one of the most important houses in America, it is also one of the most threatened historic buildings due to its location on Salem's harbor. The House of the Seven Gables conducted a two-year study funded by Massachusetts Coastal Zone Management to evaluate the risks posed by climate change. This process included the use of data from groundwater monitoring wells and a tidal gauge installed on-site, along with soil samples and a detailed survey base plan including topography and subsurface infrastructure. The project team then used the Massachusetts Coastal Flood Risk Model (MC-FRM) to assess climate change impacts on the site in 2030, 2050, and 2070, and then created a plan for adaptations that should be implemented before those risks materialize. Strategies for adapting to storm surges, increasing groundwater, and intense surface water runoff were evaluated for their effectiveness and appropriateness for the historic site. The conclusion of the study resulted in a five-phase plan ending in the managed retreat of the historic buildings to higher ground on the existing site. This article goes beyond other research that suggests coastal retreats by demonstrating how to quantitatively evaluate current and future coastal issues with predictive models and how to set viable dates for adaptive solutions and a managed retreat.

Keywords: historic buildings; climate change; sea level rise; House of the Seven Gables; planned coastal retreat

check for updates

Academic Editors: Harold Enrique Huerto-Cardenas, Alessia Buda and Claudio Del Pero

Received: 26 November 2024
Revised: 20 December 2024
Accepted: 7 January 2025
Published: 15 January 2025

Citation: Wright, P.; Baker, S.; Young, S.S. Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables in Salem, Massachusetts, USA. *Atmosphere* **2025**, *16*, 84. https://doi.org/10.3390/atmos16010084

1. Introduction

1.1. Climate Change and Historic Sites

The severity and impacts of climate change have been rigorously assessed in scientific literature for decades [1–3]. Climate change is causing more frequent and more intense weather events, such as floods, droughts, hurricanes, and heatwaves, as well as increasing sea levels, wildfires, and health risks [3]. These events are causing extensive destruction around the world and costing the global economy billions of dollars each year [4]. New England, where Salem is located, is warming faster than the global average [5], and the Gulf of Maine, along Salem's coast, is warming faster than 99% of the world's marine bodies [6]. Along with this temperature increase, extreme climate events are happening more frequently, such as 1-in-1000-year floods which occurred in New England several times in 2024 [7].

Climate change is an increasing challenge for the preservation of cultural historic sites, potentially leading to an accelerated degradation or even loss of cultural heritage [8]. Cultural heritage sites include monuments, archeological sites, and historical buildings along with their contents and collections. The conservation of historic sites is important, not only for historical and cultural reasons, but also because of their social (identity of the community, sense of place, social cohesion, etc.) and economic (tourist consumption, place of living, place of conducting economic activities, etc.) aspects [9–11]. These heritage assets have always been subjected to interactions with their environment which can alter the integrity of these sites. With climate change, however, the detrimental impacts have increased dramatically [12]. Climatic changes can intensify the physical, chemical, and biological mechanisms degrading the structure or contents of the heritage sites [13–18].

1.2. House of the Seven Gables Situation

An iconic American cultural heritage site is the House of the Seven Gables in Salem, Massachusetts. In 1668, wealthy merchant and ship owner John Turner built a house on Salem's harbor destined to become one of America's most important historic homes. Officially referred to as the Turner–Ingersoll Mansion (but popularly known as The House of the Seven Gables), the house serves as the centerpiece of the National Historic Landmark District [19] known as The House of the Seven Gables Settlement Association, now composed of seven historic buildings and colonial revival seaside gardens. It is best known today as the setting of famous American author Nathaniel Hawthorne's 1851 novel, "*The House of the Seven Gables*". The museum engages annually with around 100,000 year-round visitors from all 50 states and over 35 countries through tours, public programming, settlement work with local immigrant populations, and educational offerings.

Because of its harborside location (Figure 1), the Gables is distinctly vulnerable to the effects of climate change, particularly as it relates to rising sea and groundwater levels. The campus lies at the bottom of a gradual decline with a heavily populated neighborhood to the north. The campus was extended when tidelands were filled in circa 1780 and is protected by a seawall, as are the two city streets that border the property and dead-end onto Salem harbor (Figure 2).

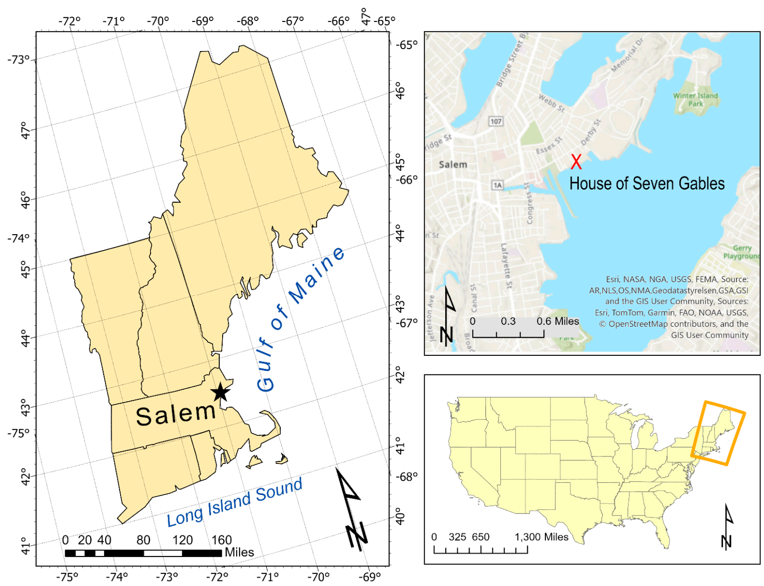

Figure 1. Location map of Salem and the House of the Seven Gables.

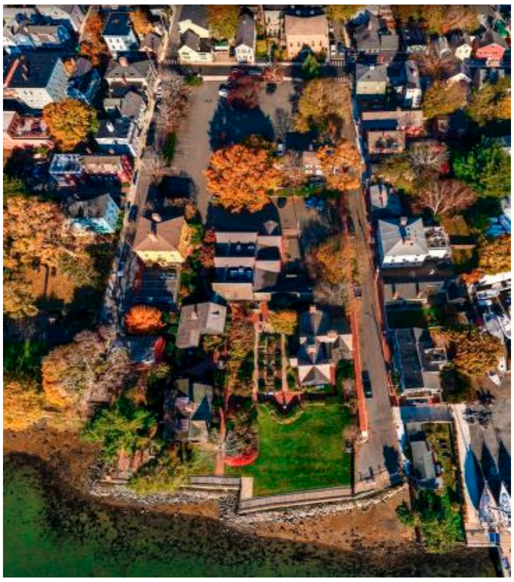

Figure 2. Aerial view of Gables campus, photo by Hugh Hou, 2023 [20].

From September 2022 to June 2024, as part of the Massachusetts ENV 23 CZM 02 Coastal Resilience Grant program [21], the House of the Seven Gables Settlement Association was awarded a grant to conduct an assessment and adaptation planning project, "Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables". Collaborating with a wide range of partners, a project team was created that included representatives from Massachusetts Coastal Zone Management (the lead policy, planning, and technical assistance agency on coastal and ocean issues within the Commonwealth of Massachusetts), Salem Sound Coastwatch (a local environmental non-profit), Union Studio Architecture & Community Design (a preservation and sustainability architectural firm), Horsley Witten Group (an engineering, design, and environmental consultancy), and Collins Engineers (an engineering firm with a specialty in seawalls). The project's objective was to assess conditions and strategize for an integrated climate adaptation plan at the historic campus.

The Gables is in the Salem Wetlands and Flood Hazard Overlay District [22] and FEMA VE: High Risk Coastal Area and AE: 1% Annual Chance of Flooding [23]. The Gables' Primm House and Counting House sit within those zones, at either corner of the property's harbor edge, and experience frequent flooding during storms. The property has been experiencing many problems on the site associated with increased precipitation, storm surge, and rising tides when combined with rising sea and groundwater levels.

Every building on the site has been impacted [24]. Of particular concern are the seawall and its short- and long-term efficacy, saltwater encroachment beyond the seawall undermining the ground, and rising groundwater that is causing increased basement flooding and water intrusion with resulting mold blooms and structural rotting, as well as the flood-prone locations of all utilities.

1.3. Response of Cultural Heritage Sites to Climate Change

Like in Salem, climate change is already adversely affecting cultural heritage sites globally, and these impacts are projected to increase over time [25,26]. Awareness of the need to reduce the impacts of climate change through climate adaptation processes has steadily increased globally [27,28]. However, scholars in both the natural and social sciences have noted the dearth of literature on cultural resources and climate adaptation planning, with most studies only estimating climate impacts on cultural resources [26]. This paper provides a needed detailed report of how a major cultural heritage site collected quantitative environmental data, analyzed the current threats, used the data with predictive models to determine future threats, then assembled various stakeholders to discuss the findings, and finally created a usable adaptation plan which includes altering the historic site and implementing a managed retreat from the coast for most of its buildings.

2. Materials and Methods

2.1. Materials and Methods Overview

To explore climate adaptations for the Gables, a project team was assembled with members from the Gables along with engineering consultants, state environmental officers, and local environmental NGO members. To determine the appropriate adaptations, the project team had to first assess the current physical state of the Gable's campus. During the assessment phase, the Gables collected data from boring and monitoring wells, soil borings and test pit analysis, geotechnical testing, topography and subsurface infrastructure mapping, waterfront and seawall inspections, tidal gauges, survey base plans, architectural analysis of building infrastructure and existing conditions, NOAA and FEMA tide and storm surge projections, and more [24]. Based on the data collected and future climate modeling, adaptation strategies were developed along with a phased timeline. The Materials and Methods section presents a comprehensive assessment of the current conditions, and the models used to evaluate the future. The Results section focuses on the proposed adaptations and timeline for implementation.

2.2. Reports Guiding the Process

Climate adaptation reports for the preservation of historic buildings by the following organizations served as a guide throughout the process.

1. National Park Service

The National Park Service has publicized several standards and documents to provide guidance for feasible and affordable adaptation strategies prior to beginning work on historic properties. The two publications used were "The Secretary of the Interior's Standards for Rehabilitation" [29] and "Guidelines on Flood Adaptation for Rehabilitating Historic Buildings" [30].

2. American Institute of Architects (AIA)

AIA published the "AIA Resilient Project Process Guide" for architects addressing resilience challenges by understanding project risks and vulnerabilities, advising clients about climate-adaptive alternatives, supporting performance goals through the design phase, implementing them in construction, and leading stakeholder engagement efforts throughout [31].

3. US Army Corps of Engineers

The US Army Corps of Engineers performed a study in 2019 on flood resilience of traditional building materials. The summary and the results of this study can be found in the "Best Practices & Precedents" Appendix of the report [32].

4. Federal Emergency Management Agency (FEMA)

FEMA manages the National Flood Insurance Program (NFIP) and produces Flood Insurance Rate Maps (FIRM) [23]. FEMA has published several technical bulletins that provide guidance on flood resiliency and planning for flood events (with a special bulletin on historic buildings) [33].

2.3. Data Collection and Condition Assessment

The project team conducted a two-year study to evaluate the risks posed by climate change. This process included the use of data from groundwater monitoring wells and a tidal gauge installed on-site, along with soil samples. Using these data, the team created a detailed survey base plan including topography and subsurface infrastructure. The project team then used the Massachusetts Coastal Flood Risk Model (MC-FRM) [34] to assess climate change impacts on the site in 2030, 2050, and 2070, and then the team created a plan for adaptations that should be implemented before the impact of those risks are felt.

2.3.1. Filled Tidelands, Tidal Shoreline, and Buffer Areas

Historically, the coastal edge of the property was naturally tideland, but it has been filled and hardened over the years to accommodate developments at the site, extending inland approximately 100 feet from the coast. The historic filled tidelands are subject to provisions of the MA Public Waterfront Act [35], providing public access across the property's filled tideland and allowing for maintenance of the seawall.

A portion of the Gables campus buffers the tidal shoreline, playing a crucial ecological role in protecting Salem Harbor. This area is safeguarded by the MA Wetlands Protection Act [36] and the Salem Wetlands Protection Ordinance [37]. Any site alterations within 100 feet of the tide line require review and permitting by the Salem Conservation Commission [38], with stricter protections within 25 and 50 feet of the shoreline. While existing conditions predate current regulations, changes are encouraged to replace paved surfaces with native vegetation. The regulations establish a 50-foot mitigation zone and a 25-foot no-disturb zone to limit development and promote a natural buffer (Figure 3).

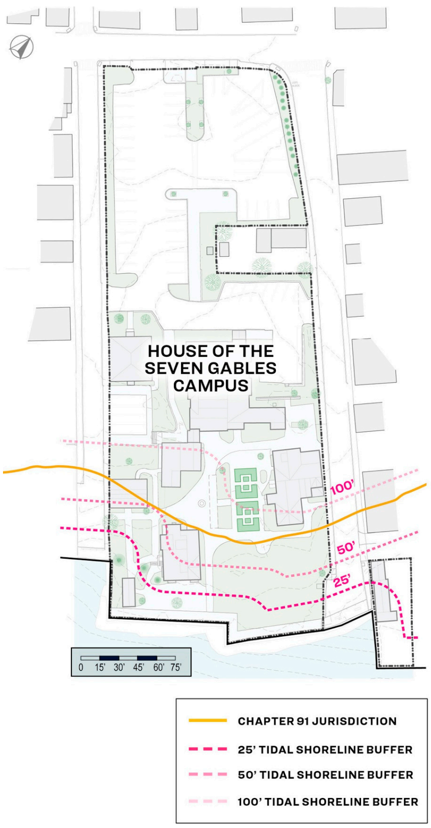

Figure 3. Filled tidelands, tidal shoreline, and buffer areas [20]. Drawing by the Horsley Witten Group. Note: this figure has a scale bar to show the size of the Gables campus, but the following campus figures do not have scale bars.

2.3.2. Coastal Flood Plain

The Gables campus' southern coastal portion lies within a coastal floodplain and, occasionally, floods during extreme tides and storms. According to FEMA's Flood Insurance Rate Map [23] (effective 16 July 2014), this area falls within zone AE (base flood elevation of 10 feet) and zone VE (base flood elevation of 13 feet), indicating significant flood risk. Development in this floodplain is regulated by local and state codes to reduce building risks and is also protected for its ecological value under the MA Wetlands Protection Act [36] and the Salem Wetlands Protection Ordinance [37]. For planning purposes, any future structures on the campus should be constructed or installed entirely outside of the VE zone and outside the AE zone (Figure 4).

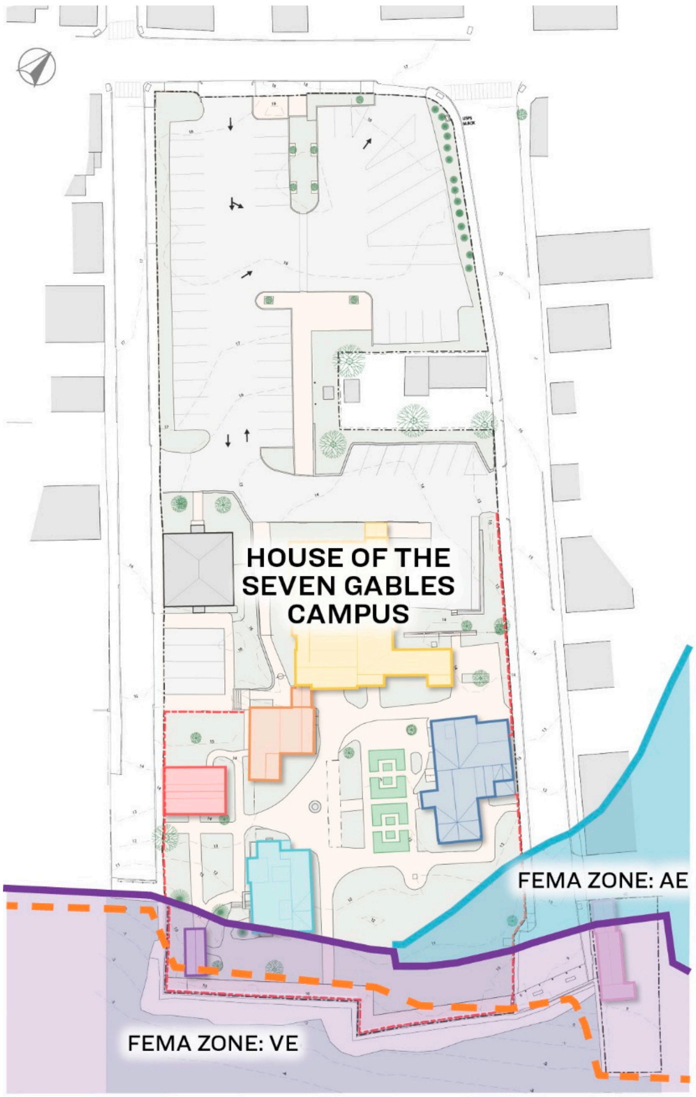

Figure 4. Coastal flood plain [20]. Drawing by the Horsley Witten Group.

2.3.3. Land Coverage

The Gables campus is a combination of buildings, gardens, parking areas, paths, and other associated landscape areas. These areas cover the land differently and can be described in terms of whether they allow rainwater to infiltrate into the ground. Impervious surfaces include rooftops, the pavement, and other highly compacted areas. These areas generate stormwater runoff during rain events and are the primary reason that stormwater management systems are required on the property. More than two thirds of the Gables campus is impervious. The pervious surfaces include grassy areas, landscaped areas, and gardens. These areas generate significantly less stormwater runoff during rain events and, sometimes, provide a place for runoff originating elsewhere to filter into the ground. Just under one third of the Gables campus can be considered pervious cover (Figure 5).

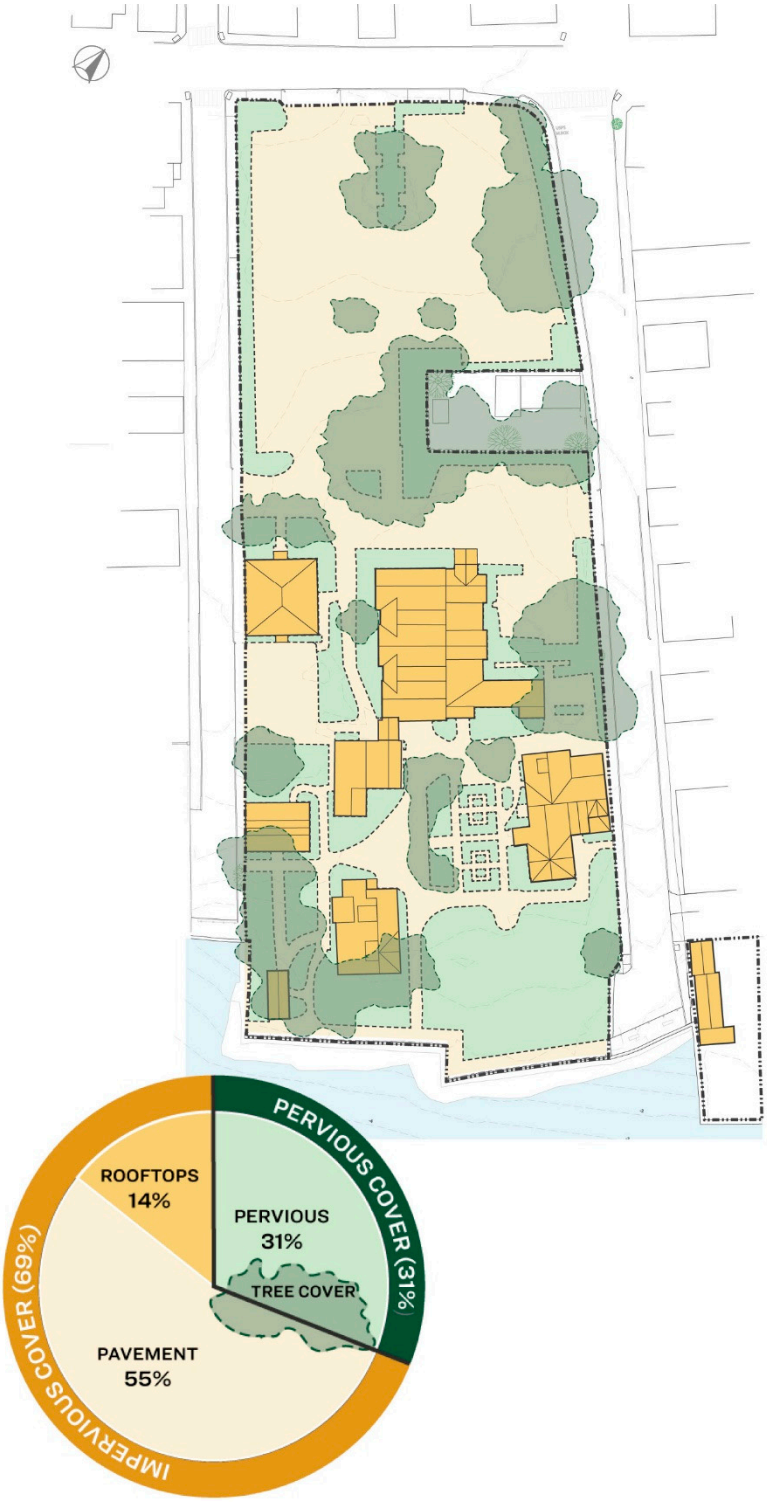

Figure 5. Land cover [20]. Drawing by the Horsley Witten Group.

2.3.4. Topography and Drainage Patterns

Figure 6 highlights the Gables campus watershed, showing pervious and impervious surfaces and surface flow directions resulting from an elevation and subsurface survey conducted by Collins Engineering [24]. Rainfall is partially directed to the City's storm drain on Hardy Street, leading to the Harbor, and partly flows overland. High tide causes backups, leading to stormwater accumulation on the campus. Landscaping depressions capture minor stormwater, but heavy rain overwhelms them and the drainage system, causing overland runoff to the harbor. Hardy and Turner Streets slope toward the campus but are partially intercepted by street drainage systems. Runoff from the upper parking lot flows to main buildings and is captured by basins connected to the Hardy Street drainage system, discharging into Salem Harbor. Severe storms cause runoff from lower areas to sheet flow over the seawall. The colonial revival gardens suffer from poor drainage and pooling water near the Turner–Ingersoll Mansion. Originally, downspouts drained directly into the Harbor, but now most drain to the land surface, as the original outlets are non-functional.

Figure 6. Topography and drainage patterns [20]. Drawing by the Horsley Witten Group.

2.3.5. Vulnerability and Critical Building Elevations

Sea level and storm surge risk are increasing and will contribute to an increased severity and frequency of flooding along the southern portion of the campus [39]. The elevations 'critical' to the future of the buildings would be those associated with the 1% annual flood risk in 2030 (high vulnerability), 2050 (medium vulnerability), and 2070 (low vulnerability), all of which are approximately 10.90′, 12.90′, and 14.60′, respectively, according to the MA Coastal Flood Risk Model (MC-FRM) [34]. These flood projections indicate that some historic buildings, as well as the formal gardens on the campus, are at risk of future flooding (Figures 7 and 8).

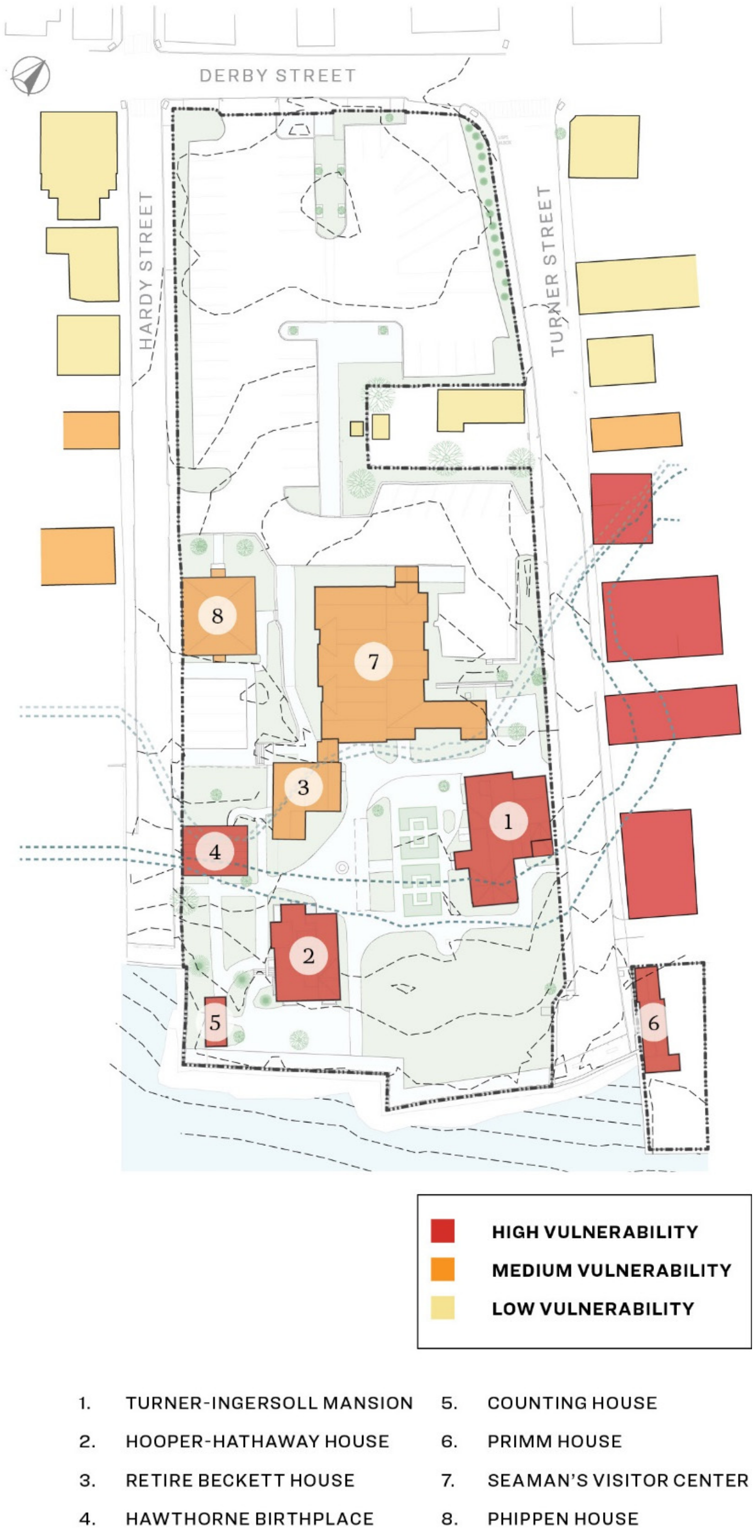

Figure 7. Building elevations [20]. Drawing by the Horsley Witten Group.

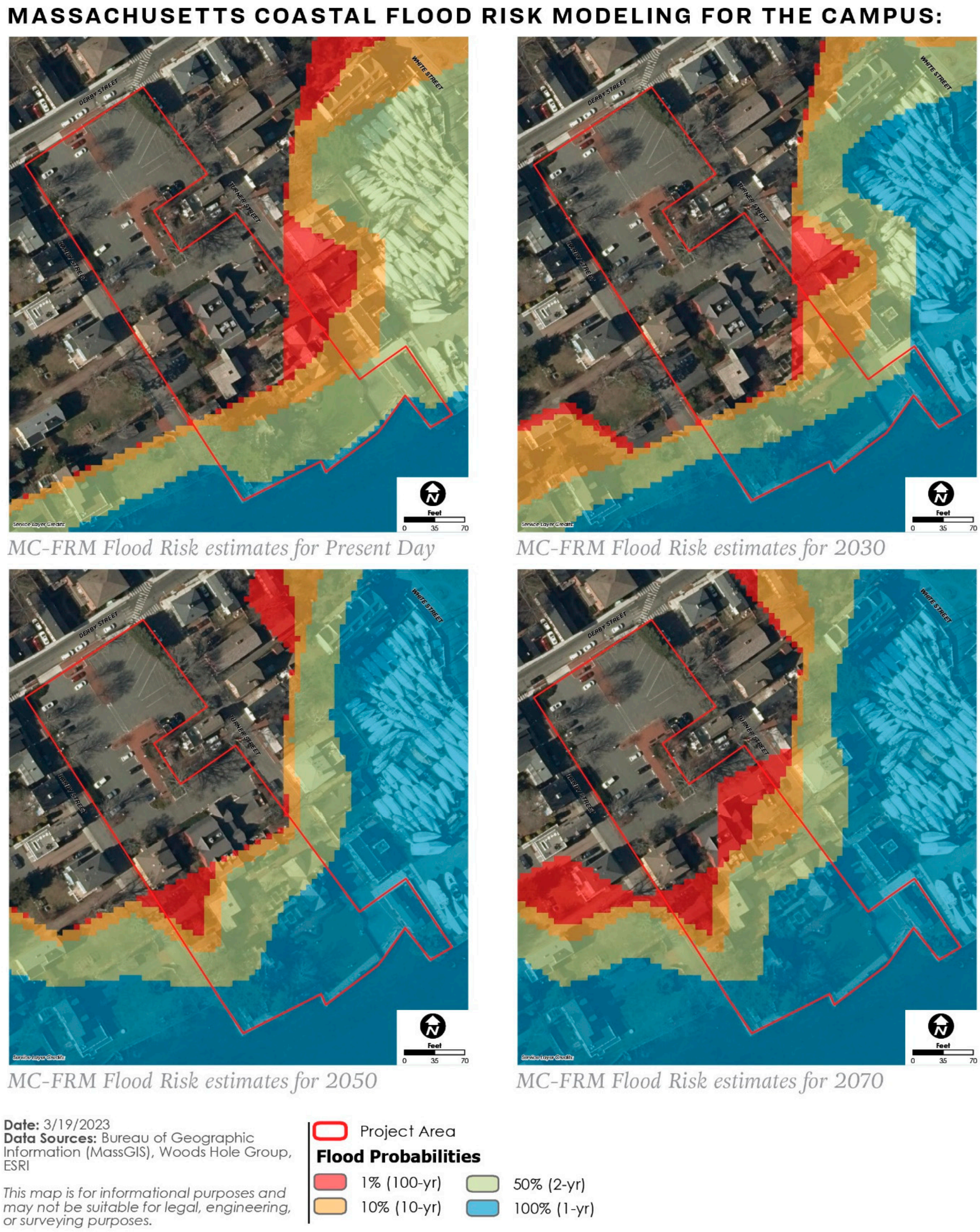

Figure 8. Coastal flood risk models [20]. Drawing by the Horsley Witten Group.

2.3.6. Groundwater Assessment and Conditions

The groundwater below the Gables is shallow and has contributed to flooding and seepage of water into the basement foundations of some Gables campus buildings. Groundwater elevation is a crucial factor to consider for designing stormwater management and drainage practices at the site. Climate change is expected to bring a higher groundwater table due to increased annual rainfall [40] and sea level rise [33]. The sea level influences the groundwater table elevation near the shoreline. The Horsley Witten Group (HWG) installed four groundwater monitoring wells at the site and installed instrumentation in those wells to record the groundwater table and harbor water elevation fluctuations for the immediate site area. Water level elevations were recorded at six-minute intervals during the two years of this planning project. The monitoring revealed [24] that groundwater within approximately two hundred eighty feet from the shoreline on the southern half of the site are tidally influenced, meaning that those groundwater levels rise and fall with a regular periodicity that is directly related to the tidal fluctuations observed in the adjacent harbor (Figure 9).

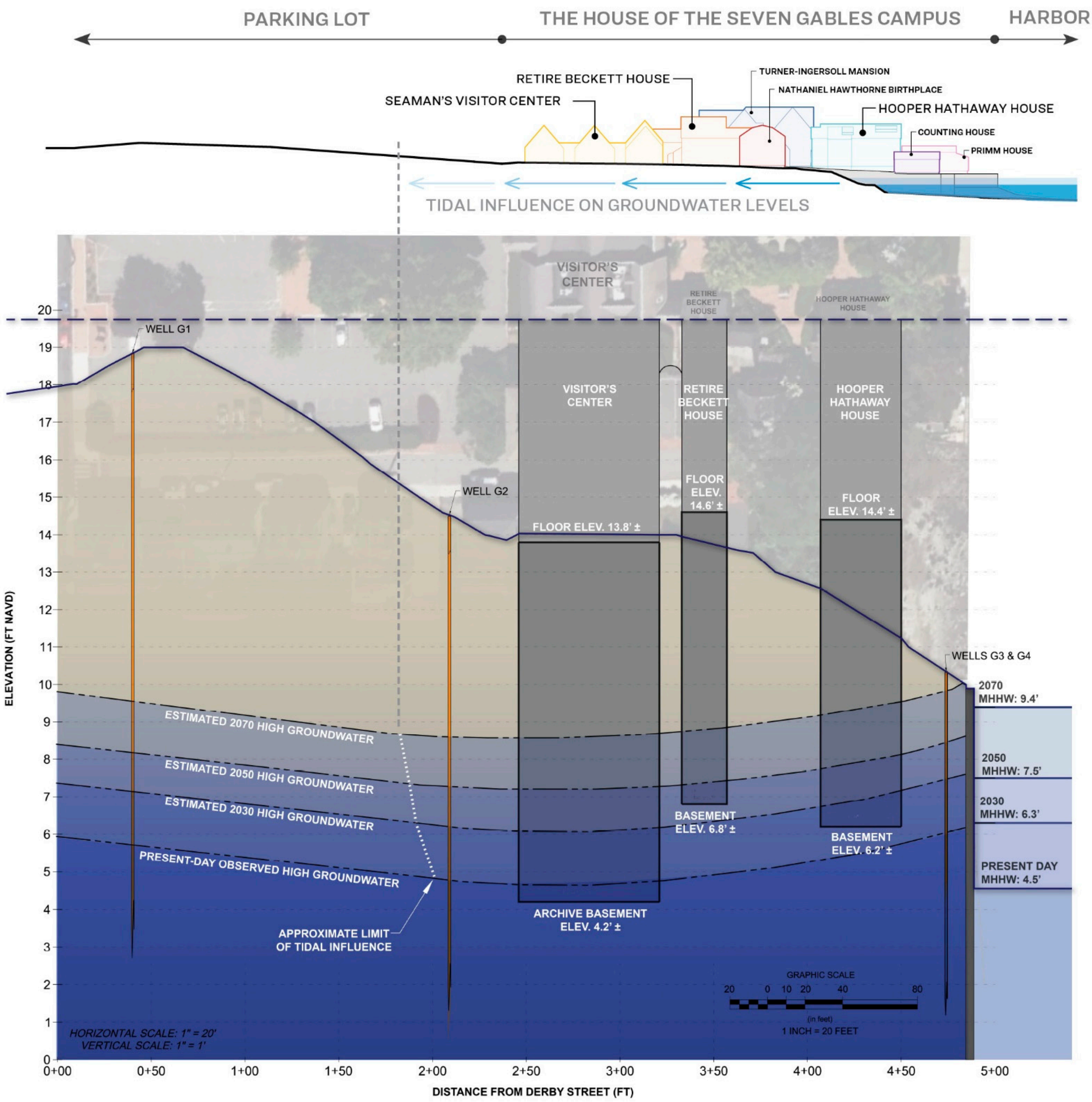

Figure 9. Estimated groundwater elevations [20]. Drawing by the Horsley Witten Group.

2.3.7. Seawater and Revetment

Collins Engineers was contracted by the Gables to perform an above-water design-level inspection of the existing seawall. The inspection was conducted by Collins personnel on 17–18 November 2022 at low tide when the wall could be observed in the dry. This inspection included a top-to-bottom examination of the 414-foot granite block seawall and adjacent riprap revetment, supplemented by an aerial survey. In addition, Collins dug test pits to determine the nature and composition of the soil and fill behind the seawall as part of its assessment. The inspection aimed to assess the seawall's condition and identify unstable areas. The structure supports historic buildings, a garden, a sidewalk, and two public streets. A preliminary geotechnical and structural analysis suggested an overall fair condition, with localized voids due to grout loss [24]. The seawall along Salem Harbor, including the section by the Gables, is crucial for protecting against coastal erosion and flooding. With a mix of public, private, and federal sections, its effectiveness depends on the consistent and ongoing maintenance efforts of all property owners (Figure 10).

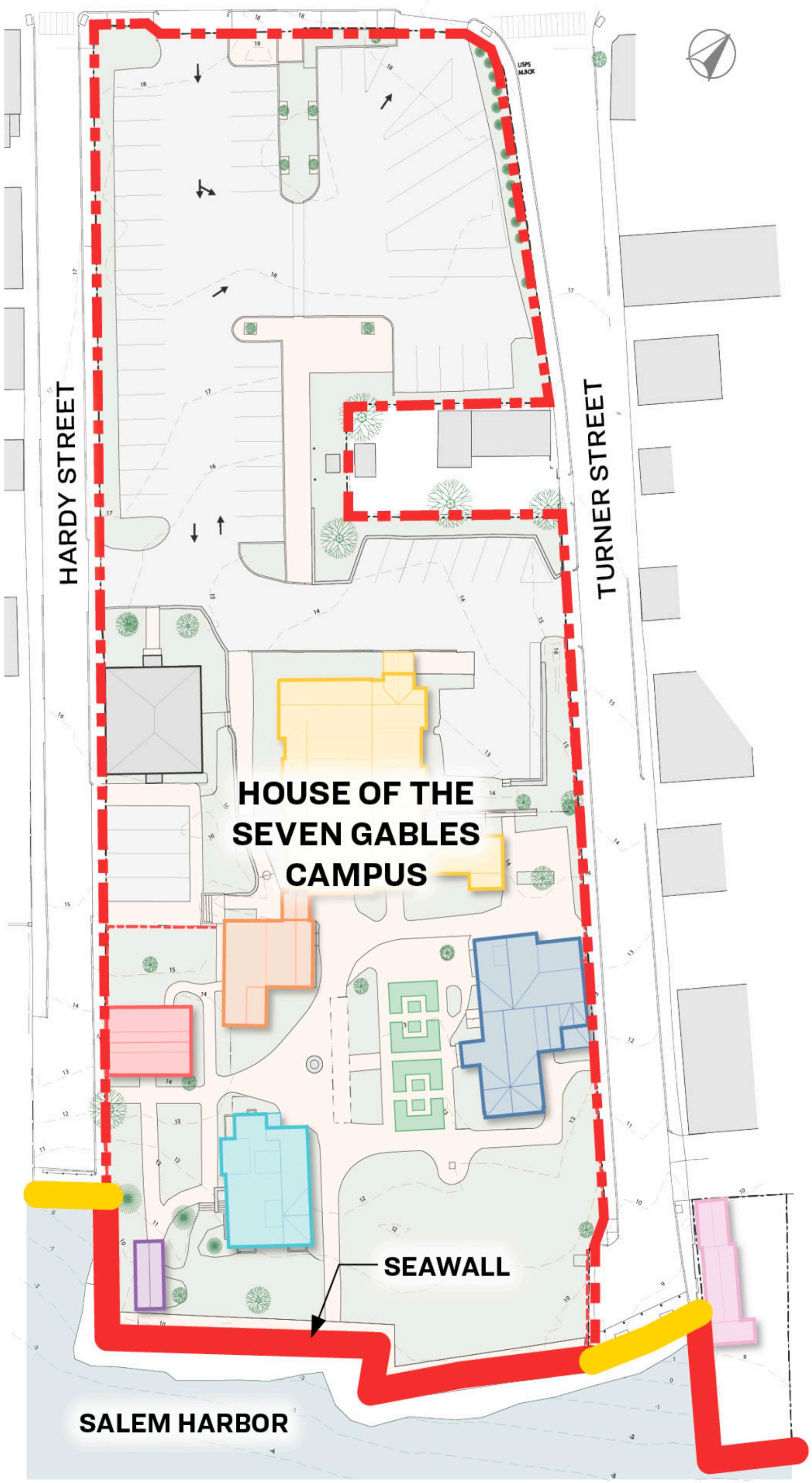

Figure 10. Seawall and revetment [20]. Drawing by the Horsley Witten Group.

2.4. Adaptation Planning

Before beginning any detailed planning for specific assets on the Gables campus, the project team took time to research and understand more fully the strategies and techniques commonly used to protect and preserve historic buildings and places at risk. The alternatives that best balanced the goal of preservation, cost, and long-term effectiveness became the adaptation tools that informed the final recommendations (Figure 11).

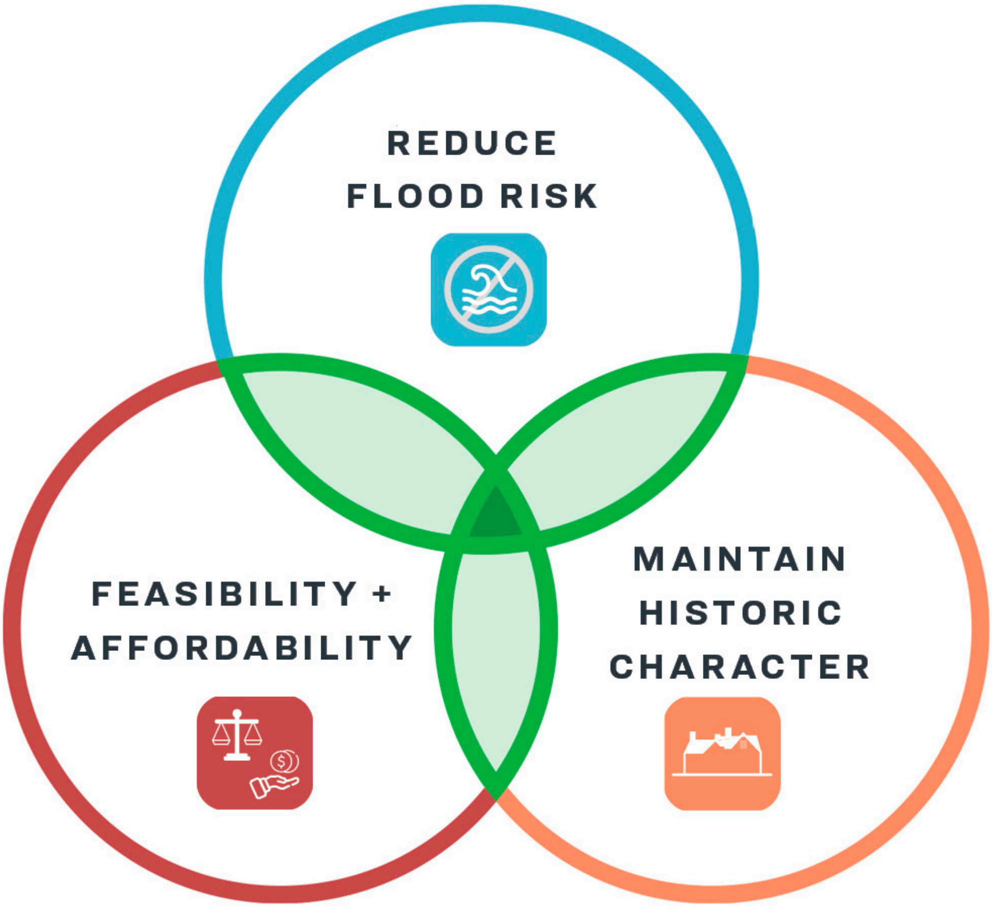

Figure 11. Adopted from the National Park Service flood adaptation guidelines [30].

3. Results

3.1. Results Overview

Too much water, increasing amounts of water in the future, and the Gable's inadequate infrastructure to handle current and future water levels were the main conclusions of the initial surveys. Therefore, the resulting adaptation strategies focus on how to adapt to and handle current and future water issues.

3.2. Stormwater

3.2.1. Stormwater Strategies

Today, most of the land use surrounding and within the Gables campus contributes to increasing stormwater runoff, rather than managing it at the source. The surrounding area is part of the larger, fully developed downtown historic neighborhood in Salem. Both on- and off-site runoff flows to the two outfalls along Turner Street and Hardy Street, both of which border the campus. These flows contribute to the strain on the larger stormwater system serving the surrounding neighborhood. The Gables must start at the source of their stormwater problem and identify opportunities to better manage stormwater on-site to manage their portion of the larger watershed. Therefore, the site plan approach recommends implementing a more site-wide strategy relying on Green Stormwater Infrastructure (GSI) to move stormwater and mitigate impacts based on the following five stormwater strategies.

1. Reduce

The first step is to reduce contributing sources of runoff and erosion. Examples include removing unnecessary paved surfaces, converting pavement to permeable surfaces and green spaces, stabilizing dirt and gravel surfaces, adding tree canopy, and disconnecting roof runoff where possible.

2. Control

The next goal is to better control the stormwater runoff. Examples may include incorporating diversion techniques to interrupt long flow paths and divert runoff or increasing the flow path and retention times with conveyance swales.

3. Capture

Once the stormwater is better controlled, low flow should be captured as close to the contributing source as possible. Paved inlet flumes and sediment forebays can be used to direct and pre-treat stormwater before capturing it in rain gardens and tree trenches.

4. Store

Due to poor draining soils and a high water table, infiltration of stormwater is limited. For larger storm events, when runoff exceeds capacity, additional water must be stored until the storm subsides or high tide passes, and water can be released. Examples may include retrofitting areas as detention basins, adding linear wet swales, and creating a constructed wetland.

5. Overflow

Last, but perhaps the most important, is to consider adverse impacts during the worst-case scenario, when storage systems are at capacity and the City's storm drain is inundated by high tide. It will be critical to allow water to be released from the campus by overland flow to avoid the inundation of critical infrastructure and parts of historic buildings such as basements and thresholds. Examples include integrated overland spillways, bypass structures, and pipes.

3.2.2. Green Stormwater Infrastructure (GSI) Techniques

For each strategy, specific GSI techniques were identified. GSI employs nature-based solutions to stormwater management problems often caused by urban runoff. GSI provides benefits such as beautified communities, creation of ecological habitats, and environmental sustainability and resilience. GSI can also be an effective way to incorporate native and historically appropriate plants into the landscape, contributing to the museum's preservation and education mission.

These site-specific techniques must also be designed with maintenance in mind. Each of the strategies for the Gables has techniques that can be implemented during the near-, mid-, or long-term plans for the campus, as shown in the diagrams below (Figures 12 and 13).

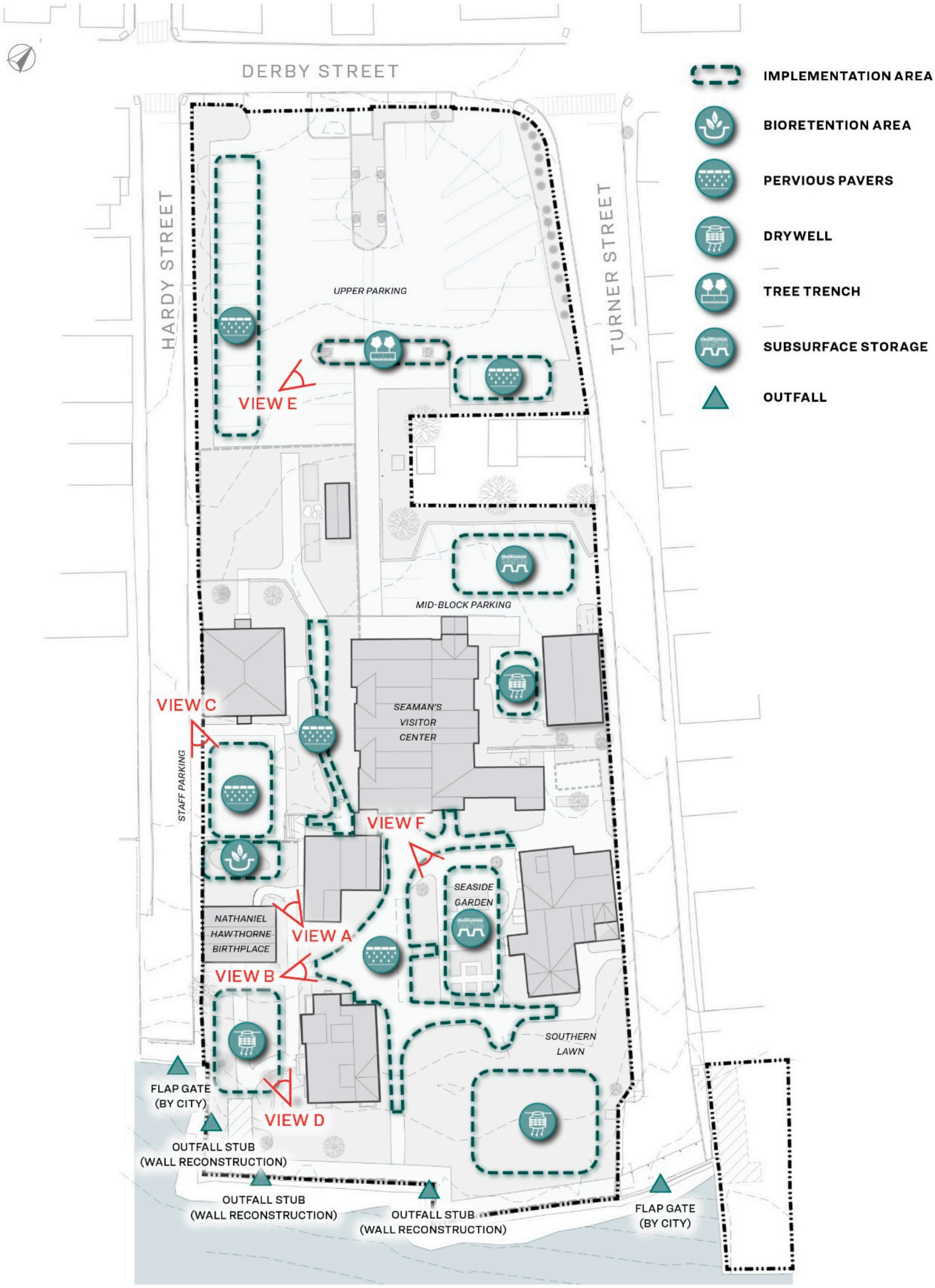

Figure 12. Proposed stormwater improvements in phase I [20]. Phasing details are described in the master planning and phasing section. Drawing by the Horsley Witten Group.

Figure 13. Proposed stormwater improvements in phase V [20]. Previous improvements from prior phases are shown grayed out but are still meant to be used. Drawing by the Horsley Witten Group.

3.3. Building Strategies

3.3.1. Broad Range of Building Strategies

Temporary and permanent building adaptation strategies to shape the future of the Gables campus were considered. The strategies involved a range of options, some of which were worth considering for implementation across the entire campus and others which would be appropriate for implementation at individual buildings. Some of the strategies considered included temporary floodgates and building wraps, building subsurface drainage systems, relocating subgrade infrastructure, dry and wet floodproofing, elevating the structure, and building relocation. Diagrams of some of these methods are located below (Figures 14–18).

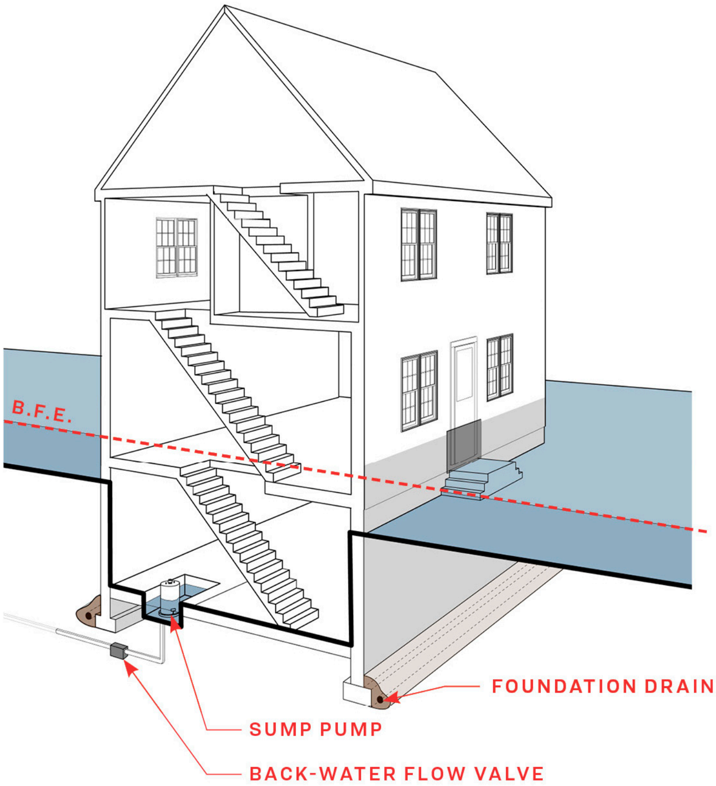

Figure 14. Building subsurface drainage systems [20].

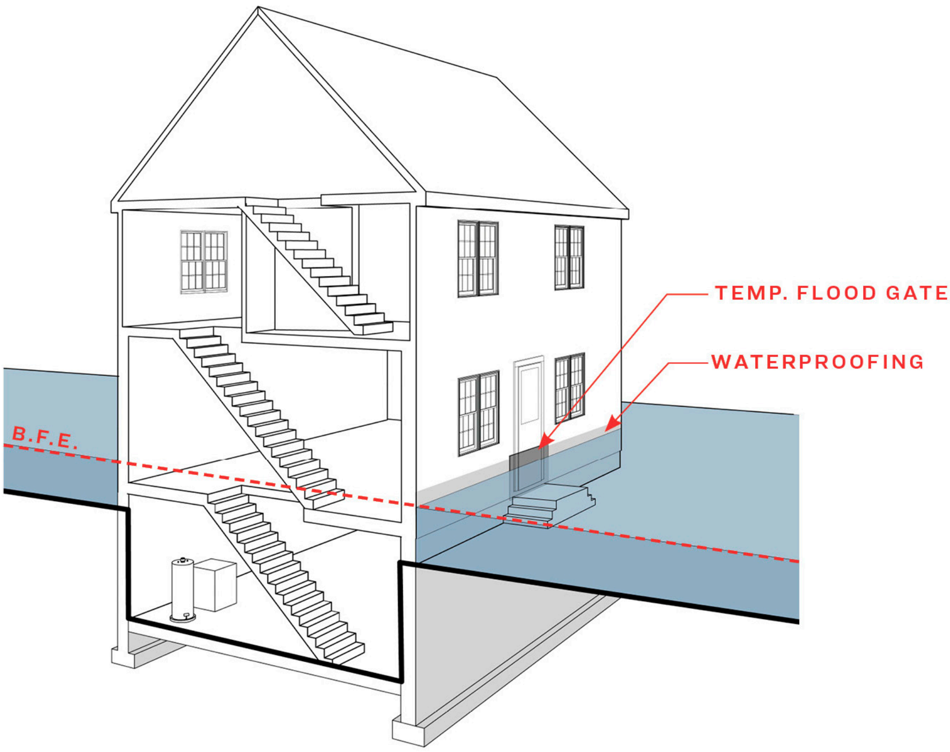

Figure 15. Dry floodproofing [20].

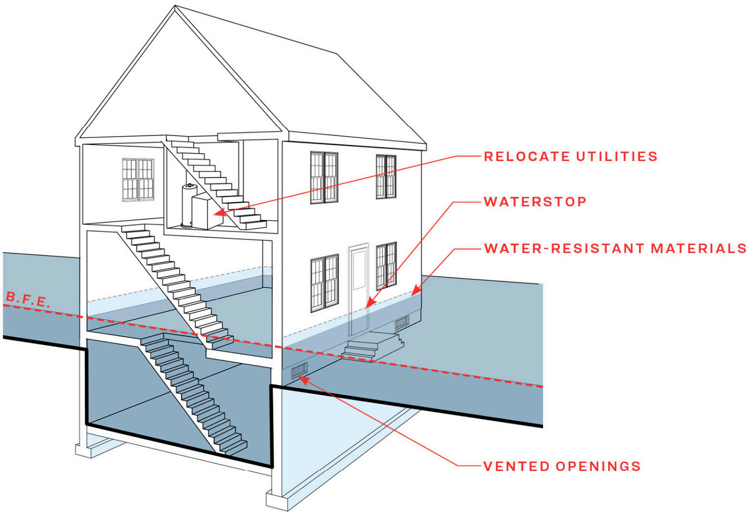

Figure 16. Wet floodproofing [20].

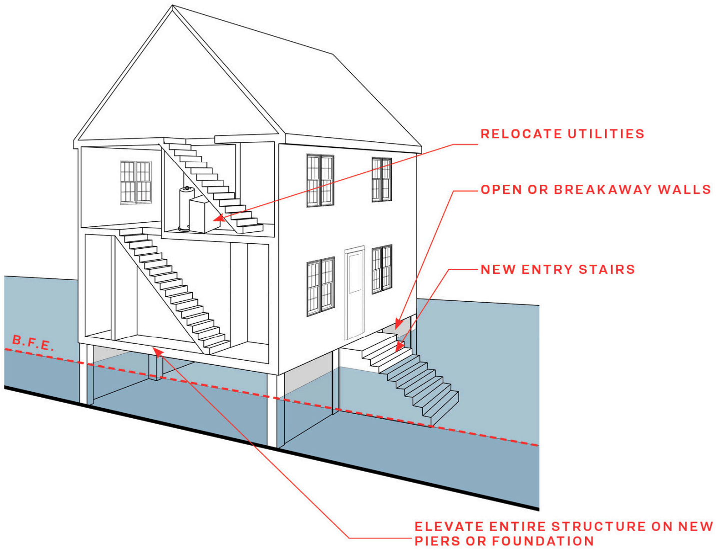

Figure 17. Elevating the structure [20].

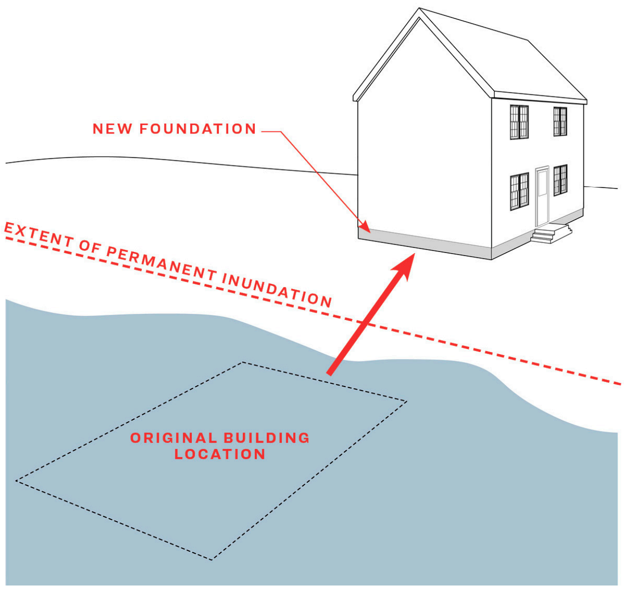

Figure 18. Building relocation [20].

3.3.2. Evaluation of Building Adaptation Strategies

Not all strategies are mutually compatible or immediately applicable for implementation at the historic Gables campus. Some adaptation strategies were considered but ultimately not included in the phased masterplan of the campus. If a strategy was not proposed to be implemented, it was because it did not comply with the identified National Park Service guidelines, which focus on being an appropriate, feasible, and affordable strategy that reduces the risk of flooding while maintaining the building's or site's historic character. The following chart (Figure 19) was used by the team to help evaluate the applicability of strategies for buildings within the campus.

EXAMPLE EVALUATION CHART FOR A SINGLE BUILDING:

STRATEGY	FEASIBLE + AFFORDABLE	REDUCE FLOOD RISK	KEEP HISTORIC CHARACTER
Temporary Measures	● ● ●	● ○ ○	● ● ●
Stormwater Management	● ● ●	● ○ ○	● ● ○
Building Subsurface Drainage Systems	● ● ○	● ○ ○	● ● ○
Protecting Utilities	● ● ●	○ ○ ○	● ● ●
Dry Floodproofing	● ● ○	● ● ○	● ● ○
Wet Floodproofing	● ○ ○	● ● ○	● ○ ○
Fill the Basement	○ ○ ○	● ○ ○	● ○ ○
Abandoning the Lowest Floor	● ○ ○	● ● ○	● ○ ○
Elevating the Interior	● ○ ○	● ● ○	● ● ●
Elevating the Exterior	● ○ ○	● ● ●	● ○ ○
Building Relocation	○ ○ ○	● ● ●	● ○ ○
Improving Building Energy-Efficiency	● ● ●	○ ○ ○	● ● ○
Landscape & Site Adaptation	● ● ○	● ● ●	● ● ○

LEVEL OF APPLICABILITY:

HIGH ● ● ● MEDIUM ● ● ○ LOW ● ○ ○ NONE ○ ○ ○

Figure 19. Strategies evaluation chart developed by the climate adaptation team [20].

3.4. Strategic Timeline and Triggers

Integrating collected scientific data points and probable timelines with environmental prompts or "triggers" as moments of action serves as a critical road map for the Gables. It not only provides a considered framework of action steps, but also guides prioritization efforts, ensuring a coordinated approach to safeguarding the campus and delineating crucial phasing and next steps. Stakeholders and team members collaborated to address challenges and solutions for the campus.

Comprehensive charts [20] were used to document and sequence adaptation strategies discussed for each building and the overall site. These charts played a crucial role in organizing the gathered data, ensuring that all considerations were addressed.

The following chart, "Timeline Triggers Map" (Figure 20), provides a thorough overview of all the contributing buildings. It includes a timeline that highlights potential storm flooding events and projects the anticipated rise in groundwater levels. This projection is particularly critical, as it identifies the specific periods when water levels are expected to infiltrate the basements of the buildings.

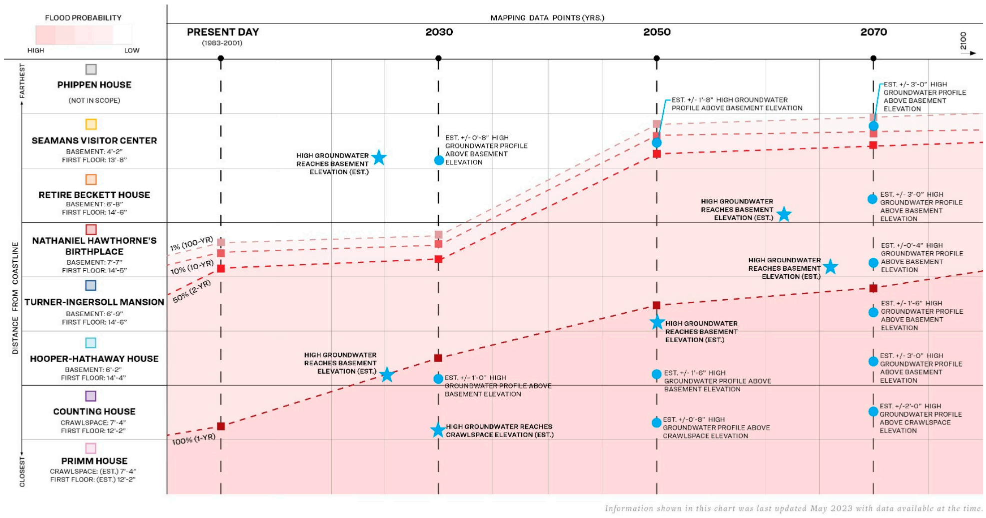

Figure 20. Timeline triggers map [20].

The "Timeline Triggers Map" served multiple purposes:

1. Risk Assessment

By predicting when and where flooding might occur, the chart enabled the project team to assess the risk levels for each building.

2. Prioritization of Interventions

The timeline helped determine the urgency and sequence of implementing adaptation strategies. Buildings most at risk were prioritized to ensure timely protective measures.

3. Phased Masterplan Development

The insights gained from the chart helped create the phased masterplan, which outlines a structured approach to implementing the adaptation strategies over time, ensuring manageable and sustainable progression. The resulting roadmap is subject to change and adjustments due to the variability of future climate conditions.

3.5. Masterplanning and Phasing

3.5.1. Masterplanning and Phasing Overview

The project team developed a five-phased adaptation, resiliency, and mitigation plan for the Gables [20]. With flexibility for each phase, the plan addresses environmental triggers, feasibility, and affordability. It focuses on the organizational structure, key priorities, and opportunities, ensuring necessary adaptations while preserving the historic significance of the Gables.

The project team worked toward an interdisciplinary managed retreat vision for the Gables, designed to be immediately actionable for short-term site enhancements while also providing a framework for long-term strategies over the coming decades, with each phase intricately linked to anticipated triggers.

Initial implementation is projected for 2030, followed by subsequent phases in 2040, 2050, 2060, and 2070, allowing for a flexibility window of ± 5 years for each phase. This flexibility accounts for environmental triggers, feasibility assessments, and affordability considerations associated with each action item.

3.5.2. Masterplan—Phase I

The first phase focuses on immediate actions to the current campus to protect vulnerable structures and critical utilities. Identified vulnerabilities, such as the Primm House and Counting House (nearest the coast), prompt targeted strategies like relocation and thorough flood risk assessments. Dry floodproofing measures for the Hooper Hathaway House and relocating critical uses and utilities to floodproof buildings are prioritized to safeguard operations and valuable collections.

Emergency deployable barriers and infrastructure updates are key components of storm preparedness, particularly for basement utilities and stored collections vulnerable to water damage. Additionally, ongoing maintenance of seawalls and site enhancements are integral for ensuring the campus's resilience and preserving its historic structures in the face of future challenges (Figures 21–23).

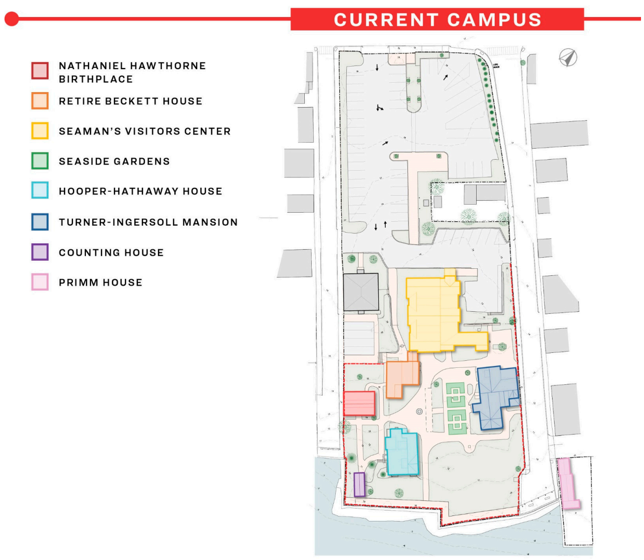

Figure 21. Current House of the Seven Gables campus map [20]. Drawing by the Horsley Witten Group.

	TRIGGERS	ACTION ITEMS
1	Increasing groundwater levels at basement elevations & basement water infiltration	Protect & Elevator Utilities
2	Within zone of annual flooding probability on campus & increased stormwater surge	Emergency Deployable Barriers
3	Insufficient size and drainage capacity	Gutters & Downspouts
4	Insufficient drainage capacity	Rain barrels & Fencing
5	Within zone of 100% annual flooding probability & seawall improvements date planned	Relocate Counting House
6	Within zone of 100% annual flood probability	Assessments Primm House
7	Within zone of 100% annual flood probability	Dry floodproof Hooper Hathaway
8	Increasing water infiltration at Hooper Hathaway Basement	New Maintenance Building
9	Routine Inspection	Seawall Maintenance
10	Within zone of 50% annual flood probability	Dry floodproof Turner-Ingersoll
11	Within zone of annual flood probability & monitored areas indicate stormwater mitigation	Site Improvements

Figure 22. Triggers and actions for phase I [20].

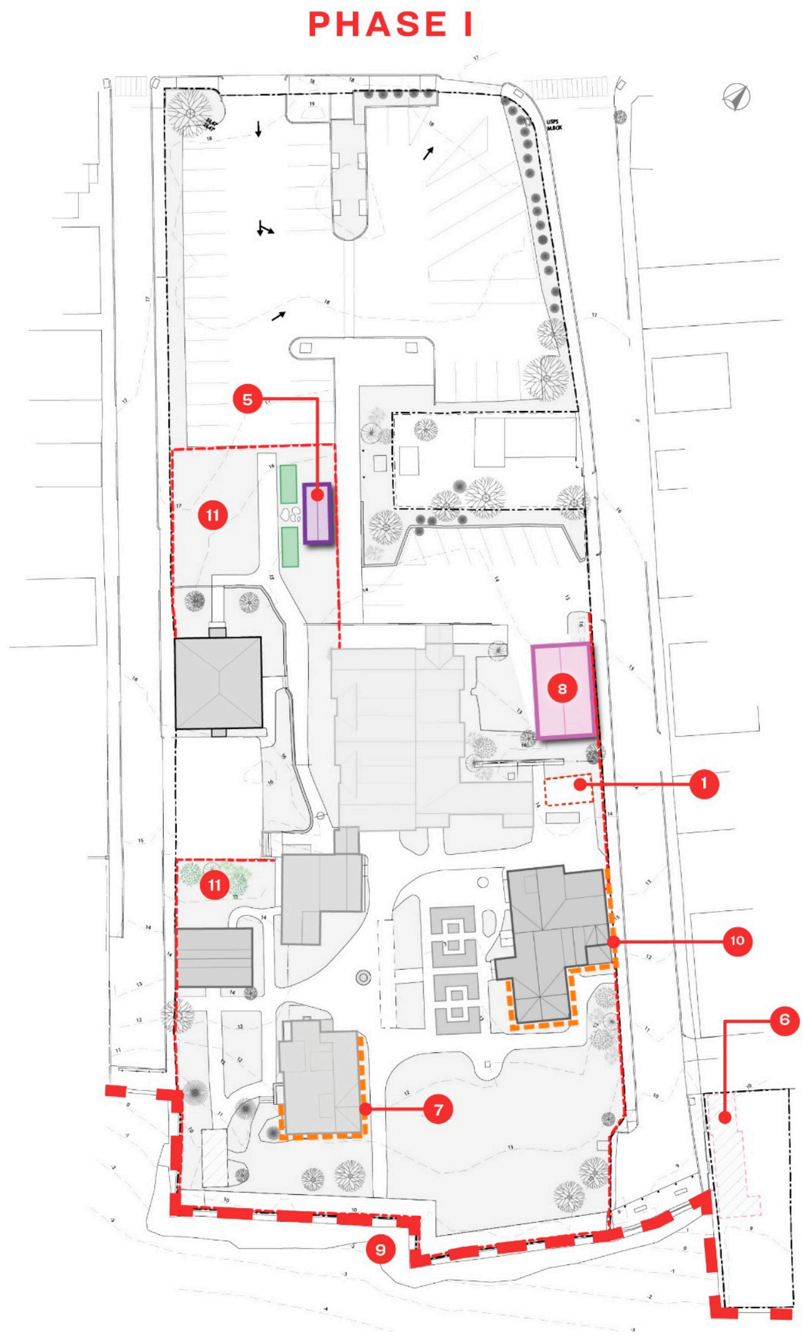

Figure 23. Phase I map for the House of the Seven Gables campus [20]. Numbers refer to locations where various actions are to take place. Drawing by the Horsley Witten Group.

3.5.3. Masterplan Phase II

The second phase of the adaptation masterplan focuses on relocating and repurposing the Hooper Hathaway house to mitigate flooding risks, enhancing both structural resilience and visitor experience. Recognizing the urgency of the situation, the Hooper Hathaway house will be relocated to the upper part of the campus along Hardy Street. By removing the workshop from the basement and relocating administrative and office spaces, Hooper Hathaway House can be repurposed as an interpretive museum space, specifically highlighting its architectural significance and its role in the history of the Gables and the Settlement Movement. This transformation not only mitigates the structural vulnerabilities of the house, but also enriches visitor experience by offering deeper insights into its historical context and architectural heritage (Figures 24 and 25).

	TRIGGERS	ACTION ITEMS
1	Within zone of 100% annual flooding probability	Relocate Hooper Hathaway House
2	Within zone of annual flooding probability & monitored areas indicate stormwater mitigation	Site Improvements
3	Routine inspection	Seawall Maintenance

Figure 24. Triggers and actions for phase II [20].

Figure 25. Phase II map for the House of the Seven Gables campus [20]. Numbers refer to locations where various actions are to take place. Drawing by the Horsley Witten Group.

3.5.4. Masterplan—Phase III

The third phase of the adaptation masterplan focuses on relocating the Retire Beckett house and Nathaniel Hawthorne Birthplace along Hardy Street, enhancing campus resilience. As part of this phase, parking facilities will also be relocated along Hardy Street, further integrating the visitor experience with the surrounding neighborhood. A new transit drop-off point is being introduced, providing visitors with public transportation options or a potential shuttle service to the museum campus. Site improvements and ongoing seawall maintenance will continue to be prioritized to ensure the campus's resilience against environmental challenges.

Also, a significant aspect of this phase involves implementing a loop trail along the museum campus' waterfront. With most buildings now situated in the upper portion of the site, the waterfront will be left open for visitors to explore via a loop trail that focuses on indigenous history and climate change (Figures 26 and 27).

	TRIGGERS	ACTION ITEMS
1	Within zone of 50% annual flooding probability	Relocate Hawthorne Birthplace
2	Within zone of 50% annual flooding probability	Relocate Retire Beckett House
3	Within zone of annual flooding probability & monitored areas indicate stormwater mitigation	Site Improvements
4	Reduce impact of annual flooding threats	Shoreline Treatment
5	Hooper Hathaway House relocation	Loop Trail w/ Indigenous History & Climate Change + Public Access
6	Decreased visitor parking on-site	Transit Drop-Off

Figure 26. Triggers and actions for phase III [20].

Figure 27. Phase III map for the House of the Seven Gables campus [20]. Numbers refer to locations where various actions are to take place. Drawing by the Horsley Witten Group.

3.5.5. Masterplan—Phase IV

The fourth phase of the adaptation masterplan proposes a new visitor center with enhanced amenities and flood mitigation measures, expanded trails, living shoreline, and the relocation and reusing of the historic barn and tea house to create an inviting entrance along Derby Street. The new Visitor Center will incorporate necessary flood mitigation measures while maintaining its central role connecting the upper campus and the waterfront. It will expand onto a new event lawn in front of the Turner–Ingersoll Mansion, providing visitors with scenic harbor views. Additionally, the loop trail and living shoreline at the existing event lawn will be expanded to enhance visitor experience.

The historic barn and tea house will be preserved, relocated, and expanded to create an inviting entrance along Derby Street, with parking consolidated along Hardy Street. These structures will serve as a café, admissions, and gift store, while the Retire Beckett House will transition into a museum interpretation and education center focusing on maritime and Salem history. Ongoing site improvements and seawall maintenance will continue throughout this phase to ensure the campus's resilience and adaptability (Figures 28 and 29).

	TRIGGERS	ACTION ITEMS
1	Seaman's Visitor Center within zone of 50% annual flooding probability & plan for construction of new Visitor Center	Relocate Historic Barn & Tea House
2	Within zone of 50% annual flooding probability	New Visitor Center
3	Within zone of annual flooding probability & monitored areas indicate stormwater mitigation	Site Improvements
4	Routine inspection	Seawall Maintenance

Figure 28. Triggers and actions for phase IV [20].

Figure 29. Phase IV map for the House of the Seven Gables campus [20]. Numbers refer to locations where various actions are to take place. Drawing by the Horsley Witten Group.

3.5.6. Masterplan—Phase V

The final phase of the masterplan involves careful relocation of the Turner–Ingersoll Mansion to protect it from escalating flooding and sea level threats, while ensuring the preservation of green spaces and maintaining the campus's historical integrity. During the intricate process of moving the mansion, its historic foundation will remain intact, serving as a tangible reminder of its storied past, inviting visitors to engage with its history through viewing and interpretation. As part of the relocation efforts, comprehensive site enhancements will be implemented to enhance stormwater management and mitigate flood risks effectively.

The relocation of the Turner–Ingersoll Mansion holds a graver connotation than the relocation of any of the other historic properties, since the Mansion still sits in its original location on its historic foundations. However, by 2070, the coastal flooding will have become too severe to protect the house from predicted annual storm flooding filling the basement and approaching the first floor, and 100-year storm flooding exceeding the first floor by 2′-0″.

Ultimately, the project team decided that preserving the building itself was more important than keeping it in place. The intent is to preserve the Mansion in its original location for as long as possible with flood protection, and then move it in phase V. The foundation will be left in place and filled in, and the Mansion moved and placed on a new foundation. The building will maintain its orientation to Turner Street (Figures 30 and 31).

	TRIGGERS	ACTION ITEMS
1	Within zone of 100% annual flooding probability	Relocate Turner Ingersoll Mansion
2	Relocation of Turner-Ingersoll Mansion	Foundation Relic
3	Within zone of annual flooding probability & monitored areas indicate stormwater mitigation	Site Improvements
4	Routine inspection	Seawall Maintenance

Figure 30. Triggers and actions for phase V [20].

Figure 31. Phase V map for the House of the Seven Gables campus [20]. Numbers refer to locations where various actions are to take place. Drawing by the Horsley Witten Group.

4. Discussion

Based on the vulnerabilities identified and the data gathered over the two-year project, the climate adaptation plan includes both immediate, actionable site improvements and long-term actions mapped out through the phased masterplan [20]. As part of the implementation, all historically significant buildings will be relocated to less vulnerable zones within the campus, ensuring their preservation for as long as possible. The remaining buildings in the medium vulnerability zone which include the non-contributing Phippen House and the newly constructed Visitor Center and Maintenance Building, will be designed to withstand major storms and flooding.

To ensure the successful implementation of the managed retreat plan and the ongoing protection of the campus, the following next steps are recommended for consideration.

1. Grants and funding opportunities: identifying and securing funding is crucial for implementing the adaptation plan.
2. Reaching out for regulatory advice and agents: engaging with regulatory bodies ensures compliance with all relevant local, state, and federal laws.
3. Ongoing monitoring of site conditions: continuous tracking of changes in groundwater levels, structural integrity, and seawall conditions will provide essential data for the timeline.

5. Conclusions

Climate change is beginning to create a challenging environment for the preservation of cultural historic sites [13]. Many historic sites which did not encounter detrimental environmental situations in the past are now finding themselves being threatened by a changing climate [15]. It has now become critical for various historic sites to evaluate their vulnerabilities and plan for future changes.

The House of the Seven Gables has stood peacefully along Salem's coast for over three centuries, but it is now being threatened by increasing amounts of water caused by the changing climate [24]. Proactive adaptation planning will ensure a resilient future for the site.

This paper details how the Gables worked with multiple stakeholders to create an adaptation plan which focuses on the balanced goals of preservation, cost, and long-term effectiveness. The details of the project team's work and the entire adaptation plan can be found in two volumes [20,24]. The innovative work conducted at the Gables campus can be summed up in the following points:

- The quantitative environmental data collected in the process of the investigation showed that storm water runoff, storm surge, and groundwater all pose significant current threats to historic resources at The House of the Seven Gables.
- By using predictive modeling from resources like NOAA and the MC-FRM, it was established that climate impacts will worsen over the next fifty years and require tailored adaptive solutions.
- A variety of stakeholders from technical engineering consultants and government officials to Gables' officials and local NGO members worked together to envision a future for the campus.
- A litany of adaptation techniques was considered that would combine effectiveness with historic appropriateness, but due to worsening conditions, extreme measures like managed retreat must be considered and implemented over a five-phase plan.

Author Contributions: Conceptualization, P.W., S.B. and S.S.Y.; methodology, P.W. and S.B.; validation, P.W., S.B. and S.S.Y.; formal analysis, P.W. and S.B.; writing—original draft preparation, P.W., S.B. and S.S.Y.; writing—review and editing, P.W., S.B. and S.S.Y.; project administration, P.W. and S.B.;

funding acquisition, P.W. and S.B. Architectural graphics by "Horsley Witten Group". All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Coastal Zone Management (CZM) of the Commonwealth of Massachusetts (ENV 23 CZM 02).

Institutional Review Board Statement: Not applicable for studies not involving humans or animals.

Informed Consent Statement: Not applicable for studies not involving humans or animals.

Data Availability Statement: The data presented in this study are available in: The House of the Seven Gables Settlement Association. Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables, *Volume I online:* https://7gables.org/climate-resiliency, accessed on 24 November 2024 and Volume II. (Appendix) online: https://7gables.org/wp-content/uploads/2024/06/VOLUME-2.pdf, accessed on 24 November 2024.

Acknowledgments: Members of the Project Team who were not authors of this article but were instrumental in the creation of the adaptation plan include: Barbara Warren of Salem Sound Coastwatch, Kara Babcock, Douglas Kallfelz, Eline Hilgersom, Taylor Hughes of Union Studio Architecture & Community Design, Steve Stanish, Neal Price, Ellie Baker, and Jonas Procton of Horsley Witten Group, Julia Deltufo, Ryan McCoy and Allison Gilmore of Collins Engineers Inc., and Julia Knisel and Kathryn Glenn of The Massachusetts Office Of Coastal Zone Management.

Conflicts of Interest: The authors declare no conflicts of interest. The paper reflects the views of the scientists and not The House of the Seven Gables.

References

1. Broecker, W.S. Climatic change: Are we on the brink of a pronounced global warming? *Science* **1975**, *189*, 460–463. [CrossRef] [PubMed]
2. Hansen, J.; Fung, I.; Lacis, A.; Rind, D.; Lebedeff, S.; Ruedy, R.; Russell, G.; Stone, P. Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model. *J. Geophys. Res. Atmos.* **1988**, *93*, 9341–9364. [CrossRef]
3. Masson-Delmotte, V.; Zhai, P.; Pirani, A.; Connors, S.L.; Péan, C.; Berger, S.; Caud, N.; Chen, Y.; Goldfarb, L.; Gomis, M.I.; et al. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Geneva, Switzerland, 2021; Volume 2, p. 2391.
4. Newman, R.; Noy, I. The global costs of extreme weather that are attributable to climate change. *Nat. Commun.* **2023**, *14*, 6103. [CrossRef] [PubMed]
5. Young, S.S.; Young, J.S. Overall warming with reduced seasonality: Temperature change in New England, USA, 1900–2020. *Climate* **2021**, *9*, 176. [CrossRef]
6. Record, N. Maine waters are warming fast. *Bigelow Lab. Ocean. Sci. Transect.* **2014**, *6*, 8–9.
7. Bush, E. On one night, two places in the Northeast get hit with 1-in-1000 year rainfall. *NBC News*, 19 August 2024.
8. Crawley, D.B. Estimating the impacts of climate change and urbanization on building performance. *J. Build. Perform. Simul.* **2008**, *1*, 91–115. [CrossRef]
9. Cassar, M. Sustainable heritage: Challenges and strategies for the twenty-first century. *APT Bulletin* **2009**, *40*, 3–11. Available online: https://discovery.ucl.ac.uk/id/eprint/18790/1/18790.pdf (accessed on 15 April 2023).
10. Phillips, H. The capacity to adapt to climate change at heritage sites—The development of a conceptual framework. *Environ. Sci. Policy* **2015**, *47*, 118–125. [CrossRef]
11. Clemente, P. Extending the Life-Span of Cultural Heritage Structures. *J. Civ. Struct. Health Monit.* **2018**, *8*, 171–179. [CrossRef]
12. Bertolin, C. Preservation of cultural heritage and resources threatened by climate change. *Geosciences* **2019**, *9*, 250. [CrossRef]
13. Sesana, E.; Gagnon, A.S.; Ciantelli, C.; Cassar, J.; Hughes, J.J. Climate change impacts on cultural heritage: A literature review. *Wiley Interdiscip. Rev. Clim. Chang.* **2021**, *12*, e710. [CrossRef]
14. Howard, A.J.; Challis, K.; Holden, J.; Kincey, M.; Passmore, D.G. The impact of climate change on archaeological resources in Britain: A catchment scale assessment. *Clim. Chang.* **2008**, *91*, 405–422. [CrossRef]
15. ICOMOS. *Climate Change and Heritage Working Group. The Future of Our Pasts: Engaging Cultural Heritage in Climate Action. Outline of Climate Change and Cultural Heritage*; ICOMOS: Paris, France, 2019. Available online: https://indd.adobe.com/view/a9a551e3-3b23-4127-99fd-a7a80d91a29e (accessed on 15 April 2023).

16. Sabbioni, C.; Brimblecombe, P.; Cassar, M. *The Atlas of Climate Change Impact on European Cultural Heritage: Scientific Analysis and Management Strategies*; Anthem Press: New York, NY, USA, 2010; ISBN 9780857282835.
17. UNESCO World Heritage Centre. *Climate Change and World Heritage. Report on Predicting and Managing the Impacts of Climate Change on World Heritage and Strategy to Assist States Parties to Implement Appropriate Management Responses*; UNESCO: Paris, France, 2007.
18. UNESCO World Heritage Centre. Policy Document on the Impacts of Climate Change on World Heritage Properties. Document WHC-07/16.GA/10 Adopted by the 16th General Assembly of States Parties to the World Heritage Convention (October 2007). Available online: http://whc.unesco.org/en/CC-policy-document (accessed on 10 November 2024).
19. Grady, A.A. National Historic Landmark Nomination—The House of the Seven Gables, 2005. National Park Service. Available online: https://npgallery.nps.gov/NRHP/GetAsset/NHLS/73000323_text (accessed on 10 November 2024).
20. The House of the Seven Gables Settlement Association. Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables, Vol I. Available online: https://7gables.org/climate-resiliency/ (accessed on 10 November 2024).
21. Commonwealth of Massachusetts, Coastal Resilience Grant. Coastal Resilience Grant Program. Available online: https://www.mass.gov/info-details/coastal-resilience-grant-program (accessed on 15 April 2023).
22. City of Salem. Hazard Mitigation Plan. 2020. Available online: https://www.salemma.gov/sustainability-energy-and-resiliency-committee-serc/news/city-salem-hazard-mitigation-plan-2020 (accessed on 15 April 2023).
23. Federal Emergency Management Agency (FEMA) and National Flood Insurance Program (NFIP). Available online: https://www.fema.gov/flood-insurance (accessed on 15 April 2023).
24. The House of the Seven Gables Settlement Association. Preserving History: Assessments and Climate Adaptations at the House of the Seven Gables, Vol II. (Appendix). Available online: https://7gables.org/wp-content/uploads/2024/06/VOLUME-2.pdf (accessed on 10 November 2024).
25. Daly, C.; Fatorić, S.; Carmichael, B.; Hollesen, J.; Pittungnapoo, W.; Adetunji, O.; Nakhaei, M.; Herrera, A. Climate change adaptation policy and planning for cultural heritage in low- and middle- income countries. *Antiquity* **2022**, *96*, 1427–1442. [CrossRef]
26. Fatorić, S.; Seekamp, E. Are cultural heritage and resources threatened by climate change? A systematic literature review. *Clim. Chang.* **2017**, *142*, 227–254. [CrossRef]
27. Berrang-Ford, L.; Biesbroek, R.; Ford, J.D.; Lesnikowski, A.; Tanabe, A.; Wang, F.M.; Chen, C.; Hsu, A.; Hellmann, J.J.; Pringle, P.; et al. Tracking global climate change adaptation among governments. *Nat. Clim. Chang.* **2019**, *9*, 440–449. [CrossRef]
28. IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability. In *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: New York, NY, USA.
29. Hume, G.L.; Jandl, H.W.; Morton, W.B.; Weeks, K.D. The Secretary of the Interior's Standards for Rehabilitation. National Park Service. Available online: https://www.nps.gov/crps/tps/rehab-guidelines/index.htm (accessed on 15 April 2023).
30. Eggleston, J.; Parker, J.; Wellock, J. Guidelines for Flood Adaptation for Rehabilitating Historic Buildings. National Park Service. Available online: https://www.nps.gov/articles/000/guidelines-on-flood-adaptation-for-rehabilitating-historic-buildings.htm (accessed on 15 April 2023).
31. Anderson, A.; Brugger, L.; Recher, M. Resilient Project Guide for The American Institute of Architects. Available online: https://www.aia.org/resource-center/aia-resilient-project-process-guide (accessed on 30 November 2023).
32. Stynoski, P.B.; Carlson, T.A.; Brake, A.M.; Arnett, C.M.; Banko, M.L.; Landi, M.M. *Flood Resilience of Traditional Building Materials: Report of Simulated Flood Immersion According to ASTM E3075 Standard Procedures*; ERDC/CERL TR-19-8; U.S. Army Engineer Research and Development Center: Champaign, IL, USA, 2019. Available online: https://www.nps.gov/orgs/1739/upload/flood-resilience-traditional-building-materials-usace-erdc-cerl-2019.pdf (accessed on 15 April 2023).
33. Federal Emergency Management Agency (FEMA). Community Rating System. 2017. Available online: https://www.fema.gov/floodplain-management/community-rating-system (accessed on 11 April 2023).
34. Massachusetts Coastal Zone Management Office. Massachusetts Sea Level Rise and Coastal Flooding Viewer. Available online: https://www.mass.gov/info-details/massachusetts-sea-level-rise-and-coastal-flooding-viewer (accessed on 15 April 2023).
35. Commonwealth of Massachusetts. Massachusetts Public Waterfront Act-Chapter 91. Available online: https://www.mass.gov/guides/chapter-91-the-massachusetts-public-waterfront-act (accessed on 15 April 2023).
36. Massachusetts Dept of Environmental Protection. 310 CMR 10.00: Wetlands Protection Act Regulations. 2014. Available online: https://www.mass.gov/regulations/310-CMR-1000-wetlands-protection-act-regulations (accessed on 15 April 2023).
37. City of Salem. Wetlands Protection Ordinance. Available online: https://www.salemma.gov/sites/g/files/vyhlif12836/f/uploads/salem_wetland_ordinance_amended_march_28_2022.pdf (accessed on 15 April 2023).
38. Salem Historical Commission. Salem Historical Commission Guidelines Notebook. 2022. Available online: https://www.salemma.gov/sites/g/files/vyhlif12836/f/uploads/guidelines.pdf (accessed on 15 April 2023).

39. National Hurricane Center—National Oceanic and Atmospheric Administration. Storm Surge Overview. Available online: https://www.nhc.noaa.gov/surge/ (accessed on 15 April 2023).
40. Massachusetts Drought Management Task Force. Precipitation Data. Available online: https://www.mass.gov/info-details/precipitation-data (accessed on 15 April 2023).