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# Sagamore Hill National Historic Site

## *Geologic Resources Inventory Report*

Photograph of a glacial erratic (mass of ice-transported bedrock) inscribed with the words “Sagamore Hill” located at the bottom of the hill just west of the Roosevelt family home. Several boulders of glacial origin are found along base slopes throughout the estate and were cleared for agricultural purposes before and during Theodore Roosevelt’s residence. The hill upon which Roosevelt built his home is a glacial kame (mound of unconsolidated glacial debris) that rises above the surrounding landscape and once offered historic vistas over the Long Island Sound.

NPS/SAGAMORE HILL NATIONAL HISTORIC SITE

# Sagamore Hill National Historic Site: Geologic resources inventory report

Science Report NPS/SR—2024/124

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# Abstract

Geologic Resources Inventory reports provide information and resources to help park managers make decisions for visitor safety, planning and protection of infrastructure, and preservation of natural and cultural resources. Information in GRI reports may also be useful for interpretation. This report synthesizes discussions from a scoping meeting held in 2010 and a follow-up conference call in 2022. Chapters of this report discuss the geologic heritage, geologic features and processes, geologic history, and geologic resource management issues of Sagamore Hill National Historic Site. Guidance for resource management and information about the previously completed GRI GIS data and poster (separate products) is also provided.

# Acknowledgements

The GRI team thanks the participants of the 2010 scoping meeting and the 2022 follow-up meeting for their assistance in this inventory. The lists of participants (below) reflect the names and affiliations of these participants at the time of the meetings. Because the GRI team does not conduct original geologic mapping, we are particularly thankful for the United States Geological Survey (USGS) and Rutgers University source maps of the area. This report and accompanying GIS data could not have been completed without them. Thanks to Trista Thornberry-Ehrlich (Colorado State University) for providing photographs and creating some of the figures in this report. Thanks to Katie KellerLynn (Colorado State University) for developing standard report content and arrangement. Additional thanks to Jack Wood (NPS GRD), Justin Tweet (NPS GRD), Vince Santucci (NPS GRD), Amanda Babson (NPS Northeast Region), Joel Dukes (NPS Northeast Region), Norb Psuty (Rutgers University), Jonathan Parker (Sagamore Hill National Historic Site), Scott Gurney (Sagamore Hill National Historic Site), Clare Connelly (Sagamore Hill National Historic Site), and Tyler Kuliberda (Sagamore Hill National Historic Site) for their professional contributions to this report.

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# Executive Summary

Comprehensive park management to fulfill the National Park Service (NPS) mission requires an accurate inventory of the geologic features of a park unit, but park managers may not have the necessary information, geologic expertise, or means to complete such an undertaking; therefore, the Geologic Resources Inventory (GRI) provides information and resources to help park managers make decisions for visitor safety, planning and protection of infrastructure, and preservation of natural and cultural resources. Information in this GRI report may also be useful for interpretation.

Sagamore Hill National Historic Site (referred to as the "historic site" throughout this report) preserves and protects the family home and estate of 26th United States President Theodore Roosevelt. Established on 10 July 1963, the 83-acre historic site is located on the Cove Neck peninsula of northern Long Island and features the Victorian-style Sagamore Hill home, in addition to historic structures, museum collections, and archeological resources associated with the Roosevelt family. The rich cultural landscape of Sagamore Hill estate includes oak-tulip woodlands, the Eel Creek tidal wetland, Cold Spring Harbor beach, and historic field patterns encompassing open pastures, agricultural fields, and an orchard.

Situated in the Atlantic Coastal Plain physiographic province of New York, the historic site occupies an area previously covered by extensive, thick ice sheets. The geology of the area is dominated by Pleistocene glacial moraine deposits composed of till (unconsolidated, poorly sorted rock material of various sizes) and outwash (layered sands and gravels) that cover older, underlying Cretaceous rocks (145 million to 66 million years ago). The glacial moraine deposits record the recessional stages of the Laurentide ice sheet following the Last Glacial Maximum approximately 21,000 years ago. Till and outwash form the gently undulating, higher elevation regions of the historic site and host several glacial features including kettles (topographic depressions formed by glacial ice), kettle ponds (kettles now filled with water), erratics (masses of ice-transported bedrock), and kames (mounds of unconsolidated glacial debris). In fact, the Sagamore Hill home was built on a glacial kame that forms the highest topographic point on Cove Neck and once offered historic vistas of Long Island Sound. The upland regions quickly transition to lowland coastal wetland and beach environments consisting of younger Quaternary Period (approximately 2.58 million to 11,700 years ago) clays, silts, sands, and gravels. These shoreline deposits represent eroded and reworked glacial moraine deposits that are influenced by dynamic coastal processes such as longshore drift (currents flowing along the shoreline), tides, and storm events associated with Cold Spring Harbor.

This GRI report synthesizes discussions from a scoping meeting for the historic site held in 2010 in addition to a follow-up meeting in 2022. The GRI team compiled the GRI Geographic Information Systems (GIS) data for the historic site using three source maps that include two USGS bedrock geologic maps and one geomorphological map completed by Rutgers University. The scoping meeting participants and the GRI team identified the best available source maps based on coverage (area mapped), map scale, date of mapping, and compatibility of the mapping to the current geologic interpretation of the area. The GRI team did not conduct original geologic mapping but compiled existing geologic information (i.e., paper maps and/or digital data) into the GRI GIS data.

This GRI report was written for resource managers to support science-informed decision making, but it may also be useful for interpretation. Sections of the report discuss distinctive geologic features and processes at the historic site, highlight geologic issues facing resource managers, describe the geologic history leading to the present-day landscape, and provide information about the GRI geologic map data. The poster illustrates these data. A table summarizes report content for each geologic map unit.

Geology is a complex science with many specialized terms. This report provides definitions of geologic terms at first mention, typically in parentheses following the term. Geologic map units in the GRI GIS data are referenced in this report using map unit symbols; for example, map unit **Qpgm** stands for the Quaternary (**Q**) planar ground moraine deposits (**pgm**), which underlie a significant portion of the Sagamore Hill estate (see "GRI products" and poster).

This report contains the following chapters:

Introduction—This chapter provides background information about the historic site and explains the GRI process and products. A geologic map in GIS format is the principal deliverable of the GRI. This chapter highlights the source maps used by the GRI team in compiling the GRI GIS data for the historic site and provides specific information about the use of these data. It also calls attention to the poster that illustrates these data.

Geologic Heritage—This chapter highlights the significant geologic features, landforms, landscapes, and stories of the Sagamore Hill estate preserved for their heritage values. These stories include the glacial history of the Long Island region, establishment of the historic site, as well as connections between Sagamore Hill and Roosevelt's political legacy.

Geologic History, Features, and Processes—This chapter describes the geologic features and processes of significance for the Historic Site and highlights them in a context of geologic time. The features and processes are discussed more-or-less in order of geologic time, from oldest to youngest.

Geologic Resource Management Issues—This chapter discusses management issues related to the historic site's geologic resources (features and processes). Issues, which are discussed alphabetically (not in order of management priority), are (1) archeological resources management; (2) climate change impacts; (3) coastal resources management; (4) disturbed lands; (5) fluvial (river), colluvial (unconsolidated deposits that accumulate at the base of hillslopes), and slope processes; (6) paleontological resources management; (7) seismic activity; and (8) tsunami activity. A table summarizing the geologic hazards that may exist at the historic site is also included. Information regarding these issues was compiled from the 2010 scoping summary (Thornberry-Ehrlich 2011), the historic site's foundation document (National Park Service 2018), natural resource condition assessment report (James-Pirri 2013), notes from the 2022 GRI follow-up meeting, research associated with the preparation of this report, and input from reviewers.

Guidance for Resource Management—This chapter is a follow up to the "Geologic Resource Management Issues" chapter. It provides resource managers with a variety of ways to find and receive management assistance with geologic resources. Also provided are a list of laws, regulations, and NPS policies that specifically apply to geologic resources in the National Park System. The NPS Geologic Resources Division can provide policy assistance and technical expertise regarding the historic site’s geologic resources.

Additional References, Resources, and Websites—This chapter provides a thorough list of additional sources of information (e.g., websites, tools, publications, organizations) that may be useful to further explore the topics presented in this report.

In addition to these chapters, “Literature Cited” compiles all the references cited in this GRI report. It serves as a source of park-specific geologic information that is applicable to the protection, management, and interpretation of the historic site’s geologic resources.

# Introduction

## Historic Site Location, Background, and Establishment

Sagamore Hill National Historic Site (referred to as the "historic site" throughout this report) is located along the north shore of Long Island on the Cove Neck peninsula in the town of Oyster Bay, Nassau County, New York. Established on 10 July 1963, the historic site preserves Sagamore Hill, the family home and 83-acre estate of the 26th U.S. President Theodore Roosevelt, who resided there from 1885 until his death in 1919. The Roosevelt home at Sagamore Hill is a Victorian Queen Anne-style house that was designed based on a rough sketch by Theodore Roosevelt himself, and features 23 rooms, huge chimneys, decorative shingles, large verandah, and prominent dormers and gables. According to the historic site's foundation document (National Park Service 2018), the site was created to preserve and interpret the structures, landscape, collections, and other cultural resources associated with Theodore Roosevelt's home and to ensure that future generations understand and appreciate the life and legacy of Roosevelt, his family, and the significant events associated with him at Sagamore Hill. Although Roosevelt initially considered naming the property "Leeholm" after his first wife, he later decided to call the estate "Sagamore Hill" in honor of Algonquin chief Sagamore Mohannis, whose Matinecock tribe lived on the land until the 17th century (Roosevelt 1913; DeCesare 1990; Bellavia and Curry 1995; Merwin and Manfra 2004).

In addition to Theodore and Edith Roosevelt's home, other historic structures and features preserved as part of the Sagamore Hill estate include the chicken house, gardener's shed, gray cottage, farm shed, ice house, new barn, old orchard, pet cemetery, pump house, stable and lodge site (destroyed in a 1944 fire), as well as traces of the old carriage road, service road, and farm roads (Figure 1; see poster). The museum and archival collections of the Sagamore Hill estate include over 93,000 items directly related to the Roosevelt family and consist of original furnishings, family letters, historic photographs, household records, photo albums, scrapbooks, political gifts from foreign dignitaries, and memorabilia related to Roosevelt's service in the Spanish-American War (see https://artsandculture.google.com/partner/sagamore-hill-national-historic-site for more information, accessed 27 September 2023). During the Roosevelt administration (1901–1909), Sagamore Hill served as the first "summer White House" and hosted numerous political and cultural icons of the 20th century (National Park Service 2018). Most importantly, the historic site is where Theodore and Edith raised their six children and experienced some of the most cherished moments of their lives.

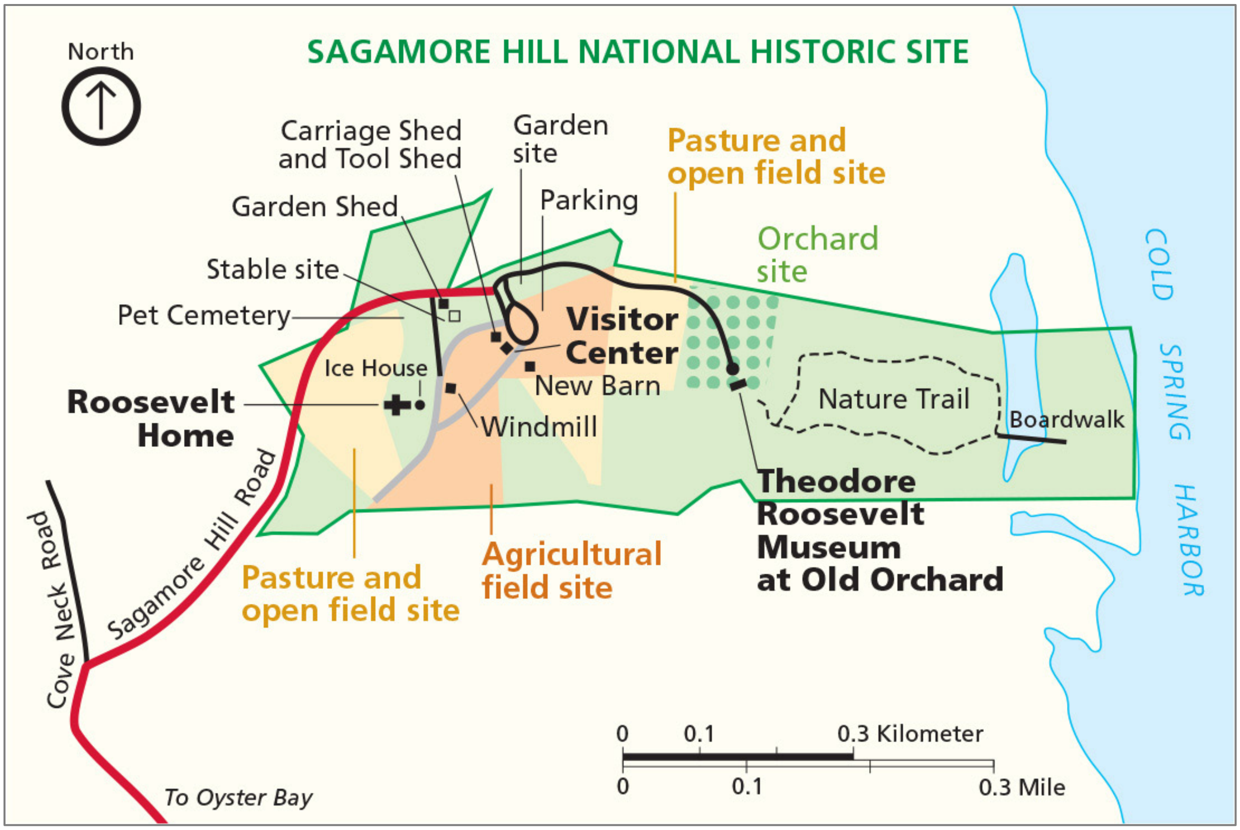

**Figure 1.** Map of Sagamore Hill National Historic Site. The historic site entrance is located on Sagamore Hill Road which branches off the peninsula's main Cove Neck Road. National Park Service maps are available at www.nps.gov/carto.

The great natural resource value of the Sagamore Hill estate lies in its diverse habitats, including oak–tulip forests, meadows, ponds, and a coastal wetland/tidal creek/dune/beach complex that are home to various kinds of flora and fauna—especially the birds that Roosevelt famously admired (James-Pirri 2013; see poster). The waters surrounding the historic site are part of the Congressman Lester Wolff Oyster Bay National Wildlife Refuge (formerly the Oyster Bay National Wildlife Refuge), a protected aquatic habitat that includes parts of Oyster Bay Harbor and Cold Spring Harbor (James-Pirri 2013). The wildlife refuge is managed by the U.S. Fish and Wildlife Service principally to protect migratory waterfowl species, but also supports fish, marine invertebrates, marine mammals, as well as New York's only remaining commercial oyster farm (see https://www.fws.gov/refuge/congressman-lester-wolff-oyster-bay for more information, accessed 27 September 2023).

## The Geologic Resources Inventory

The Geologic Resources Inventory (GRI), which is administered by the Geologic Resources Division (GRD) of the National Park Service (NPS) Natural Resource Stewardship and Science Directorate, provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. The GRI is funded by the NPS Inventory and Monitoring Program.

The GRI team is a collaboration between the NPS, GRD, Colorado State University Department of Geosciences, and University of Alaska Museum of the North. The GRI was established in 1998 by the GRD and the NPS Inventory and Monitoring Program [Division] to meet the NPS need for geologic mapping and related information. Geologic maps were identified as one of 12 natural resource data sets critical for long term science-informed park management. From the beginning, the GRI has worked with long-time NPS partner Colorado State University to ensure products are scientifically accurate and utilize the latest in GIS technology. Because Alaskan NPS units have unique scale and resource management challenges, the GRI partnered with the NPS Alaska Regional Office and, starting in 2021, the University of Alaska Museum of the North to develop GRI products.

### *GRI Products*

The GRI team completed the following tasks as part of the GRI reporting process for the historic site: (1) conducted a scoping meeting and provided a scoping summary (Thornberry-Ehrlich 2011); (2) provided geologic map data in a geographic information system (GIS) format; (3) created a poster to display the GRI GIS data; and (4) provided a GRI report (this document). GRI products are available on the "Geologic Resources Inventory—Products" website and through the NPS Integrated Resource Management Applications (IRMA) portal (see "Access to GRI Products").

GRI products are available on the GRI publications website http://go.nps.gov/gripubs and through the NPS Integrated Resource Management Applications (IRMA) portal https://irma.nps.gov/. Enter "GRI" as the search text and select a park from the unit list. Additional information regarding the GRI, including contact information, is available at http://go.nps.gov/gri.

Information provided in GRI products is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based on the information provided in GRI products. Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features in the GRI GIS data or on the poster. Based on the source map scales—1:6,000 for Psuty et al. (2016b), 1:48,000 for Isbister (1966), and 1:62,500 for Lubke (1964)—and U.S. National Map Accuracy Standards, geologic features represented in the GRI are horizontally within 3 m (10 ft), 24 m (80 ft), and 32 m (104 ft) of their true locations, respectively.

#### Scoping Meeting

On 23 June 2010, the NPS held a scoping meeting at the historic site in Oyster Bay, New York. The scoping meeting brought together historic site staff and geologic experts, who reviewed and assessed available geologic maps, developed a geologic mapping plan, and discussed geologic features, processes, and resource management issues to be included in the final GRI report. A scoping summary (Thornberry-Ehrlich 2011) summarizes the findings of that meeting.

#### GRI GIS Data

Following the scoping meeting, the GRI team compiled the GRI GIS data for the historic site. The GRI GIS data consists of two datasets: a geologic map and a geomorphologic map (Figure 2). Geologic map units in the GRI GIS data are referenced in this report using map unit symbols; for example, map unit **Qpgm** stands for the Quaternary (**Q**) planar ground moraine deposits (**pgm**), which underlie a significant portion of the Sagamore Hill estate. These data are the principal deliverable of the GRI.

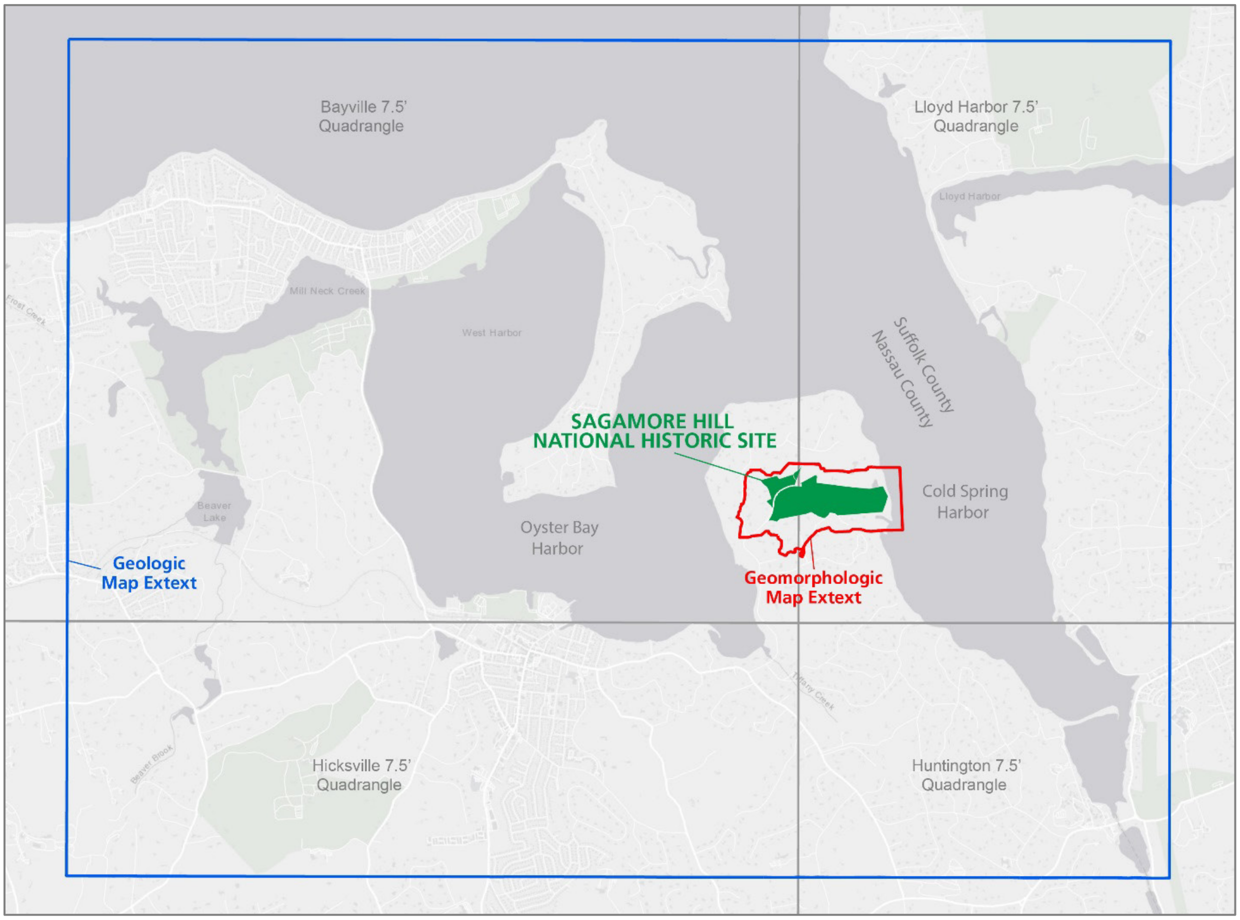

**Figure 2.** Index map of the GRI GIS data for Sagamore Hill National Historic Site. The index map displays the extents of the two datasets produced for the historic site. The boundary for the historic site (as of January 2022) is shaded in green. The extent of the geologic map is outlined in blue. The extent of the geomorphologic map is outlined in red. GRI graphic by Jim Chappell and Stephanie O'Meara (Colorado State University).

The GRI team did not conduct original geologic mapping but compiled existing geologic information (i.e., paper maps and/or digital data) into the GRI GIS data. Scoping participants and the GRI team identified the best available source maps based on coverage (area mapped), map scale, date of mapping, and compatibility of the mapping to the current geologic interpretation of an area.

The GRI GIS data for the geomorphologic map was compiled from the following source map:

- Psuty, N. P, J. McDermott, W. Hudacek, J. Gagnon, M. Towle, W. Robertson, A. Spahn, M. Patel, and W. Schmelz. 2016b. Geomorphological Map for Sagamore Hill National Historic Site and Vicinity, New York: Rutgers University, Institute of Marine and Coastal Sciences, NPS/NRSS/GRD/NRR-2016/1348. Scale 1:6,000. GRI Source Map ID 75635. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2209237.

The GRI GIS data for the geologic map was compiled from the following two source maps:

- Isbister, J. 1966. Geology and hydrology of northeastern Nassau County, Long Island, New York. U.S. Geological Survey, Washington, D.C. Water Supply Paper 1825. Scale 1:48,000. Available at: https://pubs.er.usgs.gov/publication/wsp1825.
- Lubke, E. R. 1964. Hydrogeology of the Huntington-Smithtown area, Suffolk County, New York. U.S. Geological Survey, Washington, D.C. Water Supply Paper 1669-D. Scale 1:62,500. Available at: https://pubs.er.usgs.gov/publication/wsp1669D.

The United States Geological Survey (USGS) source maps by Lubke (1964) and Isbister (1966) are larger scale hydrogeologic maps that cover portions of the Bayville, Hicksville, Huntington, and Lloyd Harbor 7.5' quadrangles which surround and incorporate the Sagamore Hill estate (Figure 2). Additionally, these geologic maps show Cold Spring Harbor, Oyster Bay Harbor, and the access road into the historic site.

The geomorphological map of Psuty et al. (2016b) is a smaller scale map of the historic site and immediately adjacent properties in parts of the Bayville and Lloyd Harbor quadrangles. The elements of this geomorphological map (incorporating form, functional processes, and sequential development) were chosen due to the small size of the historic site, combined with the existence of limited geologic formations and a dynamic coastal system (Psuty et al. 2016a).

Although the source maps of Isbister (1966) and Psuty et al. (2016b) overlap, the geomorphological map consists of several subdivided units of the older hydrogeologic map and includes surficial glacial features such as kettles (topographic depressions formed by glacial ice) and kames (mounds of unconsolidated glacial debris). Quaternary marsh deposits mapped along the historic site's coastal boundary by Isbister (1966) have been more accurately broken down by Psuty et al. (2016b) to reflect the presence of the erosional coastal scarp and bluff (**Qcsb**), wetland (**Qw**), and accretionary spit complex deposits (**Qigr**, **Qirs**, **Qagr**, **Qb**), as well as artificial fill (**Qaf**) (see poster). Additionally, the Pleistocene Harbor Hill ground moraine deposits of Isbister (1966) are separated by Psuty et al. (2016b) into planar ground moraine (**Qpgm**), dissected ground moraine (**Qdgm**), and fluvial and colluvial deposits (**Qfc**) that correlate with surficial topography and erosive processes (see poster). Many of the geologic unit descriptions, features, and processes in this report follow the more detailed geomorphological map and accompanying report of Psuty et al. (2016a, 2016b).

### GRI Poster

A poster of the geomorphologic dataset draped over a shaded relief image of the historic site and surrounding area is the primary figure referenced throughout this GRI report. The poster is not a substitute for the GIS data but is supplied as a helpful tool for office and field use and for users without access to ArcGIS. Geographic information and selected park features have been added. Digital elevation data and added geographic information are not included in the GRI GIS data but are available online from a variety of sources.

### GRI Report

On 21 September 2022, the GRI team hosted a follow-up meeting for historic site staff and interested geologic experts (see "Acknowledgements"). The call provided an opportunity to get back in touch with park staff, introduce "new" (since the 2010 scoping meeting) staff to the GRI process, and update the list of geologic features, processes, and resource management issues for inclusion in the final GRI report.

This report is a culmination of the GRI process. It synthesizes discussions from the scoping meeting in 2010 (Thornberry-Ehrlich 2011), the follow-up meeting in 2022, and additional geologic research. The selection of geologic features and processes highlighted in this report was guided by the previously completed GRI map data, and writing reflects the data and interpretation of the source map authors (i.e., Lubke 1964; Isbister 1966; Psuty et al. 2016b). Information from the historic site's foundation document (National Park Service 2018) was also included as applicable to the historic site's geologic resources and resource management. The USGS Quaternary geologic map of Stone et al. (2005) also served as a valuable resource in the preparation of the glacial history of the historic site, Long Island, and the Long Island Sound region.

Geology is complex science with a specialized vocabulary. The primary audience of GRI reports is park resource managers, but the GRI team hopes that these reports will appeal to and be useful for other audiences such as park interpreters, facility managers, and park visitors. To this end, we try to avoid technical terms and keep the writing accessible to readers without a background in geology. This report provides definitions of geologic terms at first mention, typically in parentheses following the term.

The GRI report links the GRI GIS data to the geologic features and processes discussed in the report using map unit symbols; for example, the glacial planar ground moraine deposits mapped within the historic site have the map symbol **Qpgm**. Capital letters indicate age and the following lowercase letters symbolize the unit's name. "**Q**" represents the Quaternary Period (approximately 2.58 million to 11,700 years ago) and "**pgm**" represents planar ground moraine deposits. A geologic time scale, which lists all the map units within and immediately adjacent to the historic site, is provided in Table 1 of this report. An additional geologic time scale that lists all the divisions of geologic time in stratigraphic order is provided in Table 2.

**Table 1.** Geologic units within and immediately adjacent to the historic site.

| **Geologic Time Unit** [A] | **Age** [B] | **Geologic Map Units** [C] | **Geologic Events** | **Locations** |
|---|---|---|---|---|
| Quaternary Period (Q): Pleistocene Epoch (PE) and Holocene Epoch (H) | 2.6 million to less than 11,700 years ago | Artificial fill (**Qaf**)<br>Fluvial/colluvial deposits (**Qfc**)<br>Coastal scarp/bluff (**Qcs**)<br>Wetland deposits (**Qw**)<br>Accretionary spit complex deposits (**Qb**, **Qag**, **Qig**, **Qir**) | Weathering, erosion, and reworking of glacial moraine deposits since the time of deposition about 19,000 years ago (Lewis and Stone 1991; Stone et al. 2005). Headland erosion combined with longshore currents and storm activity have slowly accreted shoreline sediment to form the Eel Creek wetland and accretionary spit. | Fluvial/colluvial deposits are mapped at the bottom of steep ravines draining the upland regions of the historic site (see poster).<br>Wetland and accretionary spit complex deposits occupy the lowland coastal environments along Cold Spring Harbor (see poster). |
| Quaternary Period (Q): Pleistocene Epoch (PE) | 2.6 million to 11,700 years ago | Planar ground moraine deposits (**Qhgm**, **Qpm**)<br>Dissected ground moraine deposits (**Qdm**) | Deposition of glacial till and outwash deposits associated with the recessional stages of the Laurentide ice sheet during the late Wisconsinan glaciation approximately 19,000 years ago (Lewis and Stone 1991; Stone et al. 2005). | Glacial moraine deposits form the rolling upland topography of the historic site (see poster). These rocks underlie a major portion of the Sagamore Hill estate, including the Roosevelt home, Theodore Roosevelt Museum at Old Orchard, visitor center, and nature trail. |
| Cretaceous Period (K) | 145.0 million to 66.0 million years ago | Magothy (?) Formation (**Ku**) | Coastal plain to shallow marine deposition (Lubke 1964). Cretaceous units of northern Long Island were removed by fluvial and glacial erosion. | ***Not exposed in the historic site.**<br>Mapped in the subsurface of northern Long Island and forms isolated exposures along the southern shore of Cold Spring Harbor. |

[A] The geologic time scale puts the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Colors correspond to USGS suggested colors for geologic maps. Letters in parentheses are abbreviations for each time division. The Quaternary Period is part of the Cenozoic Era. The Cretaceous Period is part of the Mesozoic Era.

[B] Boundary ages follow the International Commission on Stratigraphy (2022).

[C] Only geologic units mapped within or immediately adjacent to the historic site are included. Letters in parentheses correspond to GRI map unit symbols (see "GRI Products").

**Table 2.** Geologic time scale. The geologic time scale puts the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Colors correspond to USGS suggested colors for geologic maps. Letters in parentheses are abbreviations for geologic time units. Where no geologic time subdivision exists, "n/a" indicates not applicable.

| Eon | Era(s) | Period(s) | Epoch(s) | MYA [A] |
|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary (Q) | Holocene (H) | 0.0117–today |
| | Cenozoic | Quaternary (Q) | Pleistocene (PE) | 2.6–0.0117 |
| | Cenozoic | Neogene (N) | Pliocene (PL) | 5.3–2.6 |
| | Cenozoic | Neogene (N) | Miocene (MI) | 23.0–5.3 |
| | Cenozoic | Paleogene (PG) | Oligocene (OL) | 33.9–23.0 |
| | Cenozoic | Paleogene (PG) | Eocene (E) | 56.0–33.9 |
| | Cenozoic | Paleogene (PG) | Paleocene (EP) | 66.0–56.0 |
| | Mesozoic | Cretaceous (K) | Upper, Lower | 145.0–66.0 |
| | Mesozoic | Jurassic (J) | Upper, Middle, Lower | 201.3–145.0 |
| | Mesozoic | Triassic (TR) | Upper, Middle, Lower | 251.9–201.3 |
| | Paleozoic | Permian (P) | Lopingian, Guadalupian, Cisuralian | 298.9–251.9 |
| | Paleozoic | Pennsylvanian (PN) | Upper, Middle, Lower | 323.2–298.9 |
| | Paleozoic | Mississippian (M) | Upper, Middle, Lower | 358.9–323.2 |
| | Paleozoic | Devonian (D) | Upper, Middle, Lower | 419.2–358.9 |
| | Paleozoic | Silurian (S) | Pridoli, Ludlow, Wenlock, Llandovery | 443.8–419.2 |
| | Paleozoic | Ordovician (O) | Upper, Middle, Lower | 485.4–443.8 |
| | Paleozoic | Cambrian (C) | Furongian, Miaolingian, Series 2, Terreneuvian | 538.8–485.4 |
| Proterozoic | Neoproterozoic (Z) | Ediacaran, Cryogenian, Tonian | n/a | 1,000–538.8 |
| | Mesoproterozoic (Y) | Stenian, Ectasian, Calymmian | n/a | 1,600–1,000 |
| | Paleoproterozoic (X) | Statherian, Orosirian, Rhyacian, Siderian | n/a | 2,500–1,600 |
| Archean | Neo-, Meso-, Paleo-, Eo-archean | n/a | n/a | 4,000–2,500 |
| Hadean | n/a | n/a | n/a | 4,600–4,000 |

[A] Boundary ages are millions of years ago (MYA) and follow the International Commission on Stratigraphy (2022).

# Geologic Heritage

This chapter highlights the geologic features, landforms, landscapes, and stories of the historic site valued for their geologic heritage. Geologic heritage exists at the overlap of geology and humanity, and encompass important aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific qualities. It also draws connections between geologic resources and other historic site resources and stories.

## Geologic Heritage Sites and Conservation

Geologic heritage (also called "geoheritage") evokes the idea that the geology of a place is an integral part of its history and cultural identity. In 2015, in cooperation with the American Geosciences Institute (AGI), the GRD, which administers the GRI (see "Introduction"), published, *America's Geologic Heritage: An Invitation to Leadership* (National Park Service and American Geosciences Institute 2015). That booklet introduced the American experience of geologic heritage and outlined key principles and concepts, including the following five big ideas:

- America's geologic landscape is an integral part of its history and cultural identity, and Americans have a proud tradition of exploring and preserving geologic heritage.
- America's geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive.
- America's geologic heritage holds abundant values—aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific—for all Americans.
- America's geologic heritage benefits from established conservation methods developed around the world and within the United States.
- America's geologic heritage engages many communities, and involvement by individuals will ensure its conservation for future generations.

Geoheritage sites are conserved so that their lessons and beauty will remain as a legacy for future generations. Such areas generally have great potential for scientific studies, use as outdoor classrooms, and enhancing public understanding and enjoyment. Geoheritage sites are fundamental to understanding dynamic earth systems, the succession and diversity of life, climatic changes over time, evolution of landforms, and the origin of mineral deposits. Currently, the United States does not have a comprehensive national registry of geoheritage sites. Though park units are not currently established specifically for geoheritage values, any geologic component of a park's enabling legislation or planning and management documents can be considered a part of America's geoheritage.

## The Roosevelt Family and Sagamore Hill

Theodore Roosevelt first experienced the charm and natural beauty of Long Island at the age of fifteen when his parents took up summer residency near the village of Oyster Bay. During those summer months, young Roosevelt explored the wooded hills on horseback, rowed and swam the waters of the Long Island Sound, collected wildlife specimens, and developed a passion for nature, natural history, taxonomy, and ecology (Bellavia and Curry 1995; Gurney 2008). Many of the lessons learned during Roosevelt's formative years went on to inspire his politics and conservation ideals. Those aspirations left behind a legacy of established public lands totaling over 230 million acres and included the creation of 150 national forests (and the U.S. Forest Service), 51 federal bird reserves, 4 national game preserves, 5 national parks, and 18 national monuments (Gallavan and Whittingham 2016).

Throughout Roosevelt's tenure until his death in 1919, Sagamore Hill was maintained as a working family farm featuring fields and pastures for livestock as well as an orchard and garden for growing fruits and vegetables. The farm embodied many of the core principles of Theodore Roosevelt's presidency and life: the hard, honest work ethic of the "strenuous life," the importance of healthy food and clean air, the transcendence of family, and the necessity for balance in the relationship between labor and management (Merwin and Manfra 2005). The Sagamore Hill estate resides upon a glacial kame that forms the highest elevated point on the Cove Neck peninsula, offering Roosevelt a prized scenic view over the Long Island Sound. Chopping wood was one of Roosevelt's favorite exercises, as it provided necessary firewood but also maintained the properties beautiful vistas (Wilshin 1972; Bellavia and Curry 1995). The woodland, wetland, and beach areas of the historic site were used by the Roosevelt family for various recreational activities that included horseback riding, hiking, birdwatching, rifle shooting, camping, picnicking, reading, rowing, and swimming. Roosevelt spent hours romping around the estate grounds with his family, a setting he thought was most ideal for raising his children. In his autobiography, Roosevelt states:

> *There could be no healthier and pleasanter place in which to bring up children than in that nook of old-time America around Sagamore Hill. Certainly I never knew small people to have a better time or a better training for their work in after life than the three families of cousins at Sagamore Hill. It was real country, and – speaking from the somewhat detached point of view of the masculine parent – I should say there was just the proper mixture of freedom and control in the management of the children. They were never allowed to be disobedient or to shirk lessons or work; and they were encouraged to have all the fun possible. They often went barefoot, especially during the many hours passed in various enthralling pursuits along and in the waters of the bay. They swam, they trampled, they boated, they coasted and skated in winter, they were intimate friends with the cows, chickens, pigs, and other livestock.* (Roosevelt 1913, p. 247)

Several geologic features of glacial origin exist across the Cove Neck peninsula and were utilized by the Roosevelt family. Located along the northern boundary of the Sagamore Hill estate is an elongate kettle that was commonly referred to as the "Devil's Punchbowl" (see poster). During the winter months, the Roosevelt family would often ski down the slopes of the Devil's Punchbowl (Bellavia and Curry 1995; Merwin and Manfra 2004). Adjacent to the visitor center parking lot in the northeast corner of the garden site is the "Woodpile Pond," a small kettle pond (a kettle feature, now filled with water) where Roosevelt and hired fieldhands would cut and pile the winter's firewood (see poster; Hagedorn 1954; James-Pirri 2013). A unique and pronounced headland feature located along the northeast tip of the Cove Neck peninsula is Cooper Bluff, a steep, sandy cliff standing more than 50 m (160 ft) above the surrounding Oyster Bay Harbor. Although Cooper Bluff is not located on

Theodore Roosevelt's property—it was on his cousin William E. Roosevelt's estate—he often took his children and invited guests for a slide or race down Cooper Bluff (Hagedorn 1954; Bellavia and Curry 1995). As quoted by Theodore Roosevelt in his autobiography:

> *Another famous place for handicap races was Cooper's [sic] Bluff, a gigantic sand-bank rising from the edge of the bay, a mile from the house. If the tide was high there was an added thrill, for some of the contestants were sure to run into the water.* (Roosevelt 1913, p. 249)

## Sagamore Hill and Theodore Roosevelt's Political Legacy

Theodore Roosevelt cherished the Sagamore Hill property and experienced some of his life's most memorable moments there, especially the births of three of his six children (Ted, Kermit, and Ethel). The estate setting also served as the backdrop for various stages of Roosevelt's political career, including his tenure with the U.S. Civil Service Commission (1889–1895), NYC Board of Police Commissioners (1895–1897), Assistant Secretary to the Navy (1887–1889), Governor of New York (1899–1900), Vice President of the United States (1901), and President of the United States (1901–1909). During the summer White House months of the Roosevelt administration, important events unfolded at the Sagamore Hill estate related to Roosevelt's campaign for the conservation of America's natural resources—including geologic treasures such as Crater Lake, Devils Tower, the Grand Canyon, and many others. In the library of the historic site, Roosevelt would often meet with environmentalists, foresters, and advisors to strategize federal efforts to regulate public lands for the benefit of future generations (Brands et al. 2007; Gurney 2008). The Roosevelt administration sparked a significant conservation movement that leaves behind a legacy of accomplishments including the establishment of the U.S. Forest Service, passage of the National Reclamation Act of 1902, passage of the American Antiquities Act of 1906, and the protection of roughly 230 million acres of public lands. Although Roosevelt completed most of his presidential work in Washington, D.C., he continued to change the course of American and world history when he returned home to Sagamore Hill (Brands et al. 2007).

## Glacial History of Long Island and Long Island Sound

The landscape of the Sagamore Hill estate is marked by geologic features that record an interval in Earth history when thick, extensive ice sheets advanced across North America. The recent geologic history of the historic site is defined by multiple Pleistocene glacial episodes ("Ice Ages") that regionally sculpted the area of Long Island and Long Island Sound (Figure 3). Continental glaciers associated with the Laurentide ice sheet advanced south across Canada and the northern United States, beveling hills and other topographic highs while transporting vast amounts of entrained sediment en route. When the glacial ice melted and retreated, enormous quantities of rock debris were released that blanketed the landscape in the form of glacial drift or till (unconsolidated, poorly sorted rock material of various sizes), outwash deposits (layered sands and gravels), and erratics (masses of ice-transported bedrock). Although glaciers have repeatedly covered the area of the historic site, evidence of previous glaciations was destroyed or obscured by the most recent glacial event. However, predominant physiographic features of Long Island include two discontinuous, northeast-trending ridges that are remnants of two thick glacial moraines. Referred to as the Harbor

Hill-Fishers Island-Charlestown moraine and the Ronkonkoma moraine, these features are linear accumulations of glacial debris that were deposited along the margins of the Laurentide ice sheet. These moraine features resemble a ridge of hummocky hills rising slightly above the surrounding landscape of Long Island and record the maximum southern ice extent (the "Last Glacial Maximum") and subsequent deglaciation of the Long Island Sound area.

**Figure 3.** Paleogeographic reconstruction of North America during the Last Glacial Maximum. Nearly half of North America was covered by thick, extensive sheets of ice during the late Pleistocene Wisconsinan glaciation. The location of the historic site is denoted by the green star. North American Key Time Slices © 2013 Colorado Plateau Geosystems Inc. modified by Tim C. Henderson (Colorado State University).

Both glacial moraines were formed during the Wisconsinan (or Wisconsin) glaciation, the most recent glacial episode of North America. The Wisconsinan glaciation began approximately 75,000 years ago, reached the Last Glacial Maximum roughly 21,000 years ago, and ended about 11,000 years ago (Cadwell and Muller 1986; Lewis and Stone 1991; Goldthwait 1992; Sirkin 1999; Gibbard and Cohen 2008; Maliszka et al. 2020). The older Ronkonkoma terminal moraine is located approximately 8 km (5 mi) south of the Sagamore Hill estate and stretches across central Long Island from Roslyn Heights to Montauk Point and records the Last Glacial Maximum of the Laurentide ice sheet (Bennington 2003). The younger Harbor Hill-Fishers Island-Charlestown end moraine was deposited approximately 19,000 years ago across northern Long Island from Brooklyn east to Fishers Island and into Charlestown, Rhode Island (Stone et al. 2005). East of Port Jefferson, the Harbor Hill-Fishers Island-Charlestown moraine is comprised of partially submerged deposits that help define the north-central shoreline of Long Island. Glacial till deposits associated with the Harbor Hill-Fishers Island-Charlestown moraine are widely mapped within and surrounding the historic site.

By approximately 17,500 years ago, multiple glacial advances, combined with fluvial incision, had scoured the landscape north of Long Island into a long, narrow topographic depression that filled with glacial meltwater to form an ancient freshwater lake called Lake Connecticut (Stone et al. 1985; Lewis and Stone 1991; Stone et al. 2005; Poppe et al. 2013). Lake Connecticut was impounded within the area of Long Island Sound, confined between the retreating ice margin to the north and end moraine deposits to the south (Stone et al. 2005). The incremental deglaciation and northward retreat of the ice margin through the Long Island Sound region is recorded by lacustrine-fan deposits (layered clays and silts) on the former lake bottom and deltaic sediments (sands and gravels) that occur along the Connecticut shoreline where rivers drain into the Sound (Stone et al. 2005). As a precursor to the modern Long Island Sound, Lake Connecticut only lasted for a couple thousand years before erosion at the glacial lake spillway—an area just west of Fishers Island called “The Race”—lowered the lake level until the lakebed was subaerially exposed about 15,500 years ago (Figure 4; Lewis and Stone 1991; Stone et al. 2005). The development of the modern Long Island Sound tidal estuary began about 15,000 to 13,000 years ago as sea level rise slowly introduced saltwater and inundated the basin (Lewis and Stone 1991).

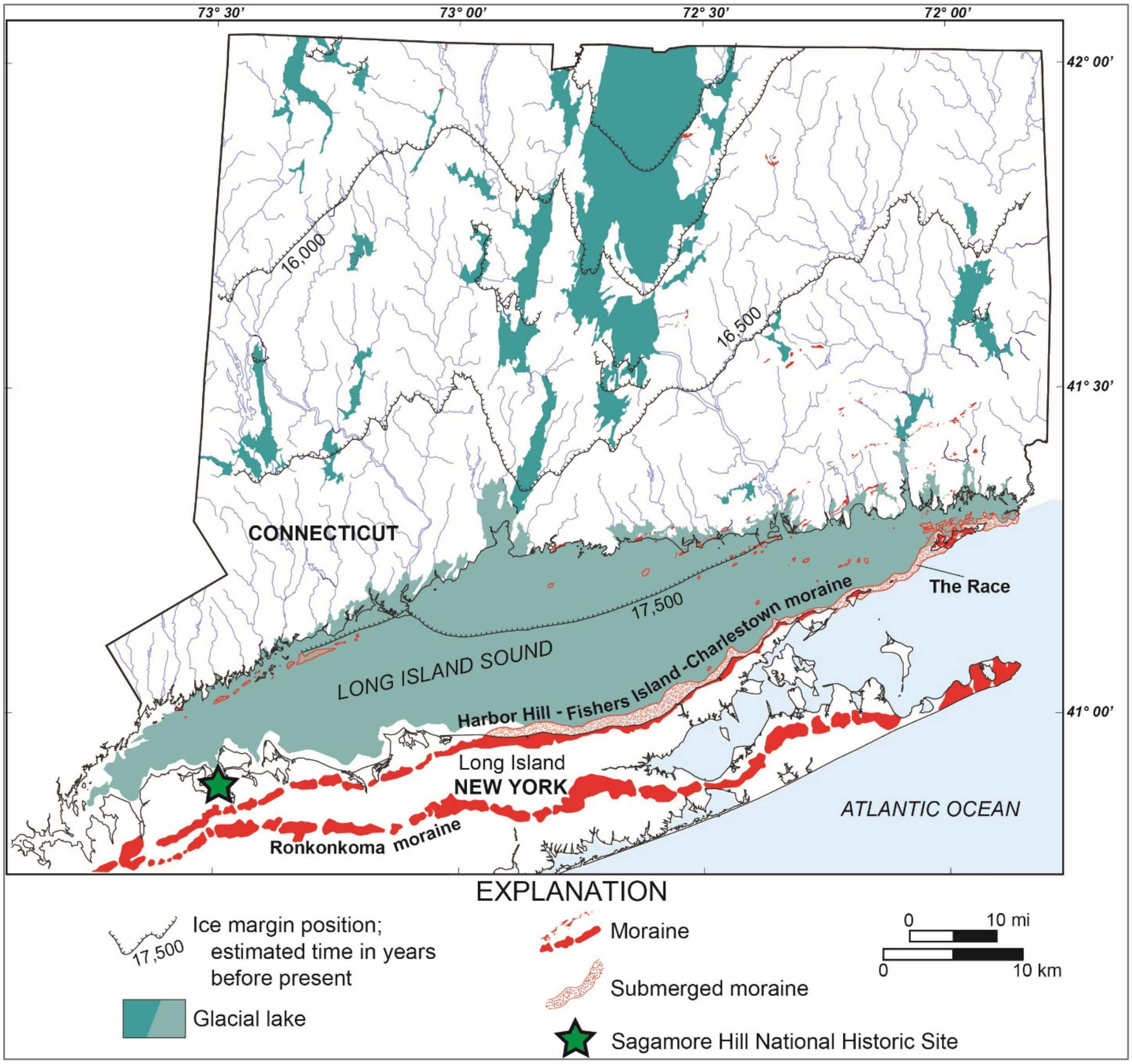

**Figure 4.** Map of glacial features in the Long Island, New York—Connecticut region. Following the Last Glacial Maximum (approximately 21,000 years ago), extensive glacial moraines and lakes developed as the Laurentide ice sheet retreated north into Canada. Ancient glacial Lake Connecticut occupied the region of Long Island Sound and was impounded by glacial deposits of the Harbor Hill-Fishers Island-Charlestown moraine. The glacial lake spillway ("The Race") is located near a section of submerged moraine just west of Fishers Island. Graphic created by Tim C. Henderson (Colorado State University) using a modified geologic map from Stone et al. (2005).

# Geologic History, Features, and Processes

This chapter describes the geologic events, features, and processes significant to the historic site's landscape and history. Selection of these features and processes was based on input from scoping and conference-call participants, analysis of the GRI GIS data, and research of the scientific literature and NPS reports. These features and processes are discussed more-or-less in order of geologic age (oldest to youngest). Geologic map units (Table 1) and a geologic time scale (Table 2) show the chronology of geologic events (bottom to top) that led to the historic site's present-day landscape; this story covers about 65 million years but emphasizes the glacial history that took place approximately 21,000 years ago.

## Bedrock and Surficial Geology

The Sagamore Hill estate is situated in the Atlantic Coastal Plain physiographic province of New York, a region characterized by a thick, seaward-dipping wedge of Cretaceous and younger strata. Although geologic exposures within the historic site consist entirely of Cenozoic Era rocks, well and borehole data extend the rock record of the north shore region of Long Island to the Precambrian or Paleozoic Era, with crystalline (metamorphic) bedrock unconformably (erosional boundary representing missing time or "gaps" in the rock record) overlain by unconsolidated Late Cretaceous and Quaternary sedimentary deposits (Lubke 1964; Isbister 1966; Kilburn and Krulikas 1987; Stumm et al. 2004). The subsurface stratigraphy that underlies the area includes (from oldest to youngest): (1) Precambrian or Paleozoic biotite-garnet schist and gneiss (layered metamorphic rocks); (2) Late Cretaceous sedimentary deposits of the Raritan Formation and Magothy Formation (**Km**); and (3) Pleistocene units of the "Jameco Gravel" and "Gardiners Clay." Although Isbister (1966) and Lubke (1964) refer to these deposits as the "Jameco Gravel" and "Gardiners Clay," correlation of these units elsewhere on Long Island is debated (Stumm et al. 2004). Much of the Cretaceous strata underlying the Cove Neck region of the historic site was removed by fluvial and glacial erosion in post-Cretaceous time and subsequently infilled by thick sequences of Pleistocene rock to form buried valleys (Figure 5; Lubke 1964; Isbister 1966).

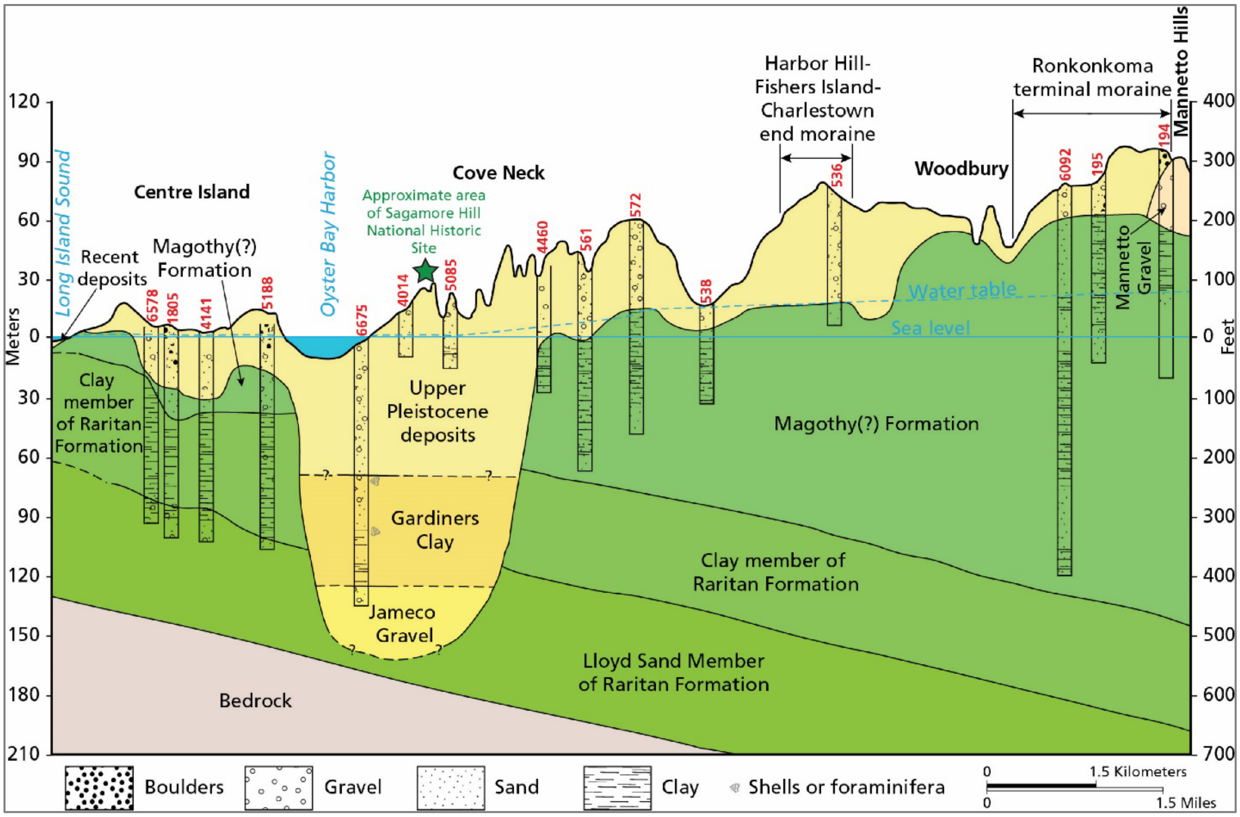

**Figure 5.** Generalized geologic cross-section of Long Island, New York from Centre Island south to the Mannetto Hills. The subsurface geology of northern Long Island consists of Precambrian or Paleozoic bedrock overlain by unconsolidated, gently dipping Cretaceous and Quaternary sediments. In the region underlying the historic site (green star), a valley eroded into Cretaceous Era strata has been filled with thick sequences of Pleistocene rock. Red numbers refer to well locations. Graphic created by Trista L. Thornberry-Ehrlich (Colorado State University) from geologic section C-C' in Isbister (1966; plate 1).

The geology of the historic site predominantly consists of Pleistocene ground moraine deposits (**Qpgm**, **Qdgm**) that include unconsolidated to semi-consolidated glacial till or outwash composed of boulders, cobbles, gravel, sand, silt, and clay (see poster). Originally mapped as "Harbor Hill ground moraine deposits" by Isbister (1966), these glacial sedimentary rocks are now associated with the regional Harbor Hill-Fishers Island-Charlestown moraine that extends across Long Island into Rhode Island (Stone et al. 2005; see "Glacial History of Long Island and Long Island Sound"). Glacial moraine deposits form the gently undulating upland regions with the Sagamore Hill estate and record the recessional stages of the Laurentide ice sheet following the Last Glacial Maximum approximately 21,000 years ago (Cadwell and Muller 1986; Lewis and Stone 1991). Till and outwash sediments host several glacial features including kettles/kettle ponds (**Qke**), kames (**Qka**), and erratics. Intermittent streams flow from the higher elevation regions of the historic site's western, southern, and eastern margins. These streams have weathered and eroded the glacial moraines, depositing Quaternary fluvial (river) and colluvial (weathered debris that accumulates at the base of hillslopes) sediments (**Qfc**) in flat, low-lying alluvial plain (floodplain or flat area composed of loose sedimentary deposits). An erosional coastal scarp and bluff (**Qcsb**) separate the western upland areas of the estate from the eastern low-lying coastal zone. The margin of the historic site along Cold Spring Harbor is a dynamic coastal environment featuring younger Quaternary beach (**Qb**), wetland (**Qw**), and accretionary spit deposits (**Qagr**, **Qigr**, and **Qirs**) (see poster).

## Glacial Features

### *Planar Ground Moraine (Map Unit Qpgm)*

Planar ground moraine deposits (**Qpgm**) underlie a significant portion of the Sagamore Hill estate and are mapped extensively along the northern shore of Long Island in the uplands north of the Harbor Hill-Fishers Island-Charlestown end moraine (see poster). These ground moraine deposits consist of unconsolidated, unstratified outwash and till containing boulders, cobbles, gravel, sand, silt, and clay that commonly range in thickness from about 1.5 to 6.0 m (5 to 20 ft) thick (Lubke 1964; Isbister 1966). Planar ground moraine deposits record a recessional glacial stage of the Laurentide ice sheet and were deposited around 19,000 years ago following the Last Glacial Maximum that produced the Ronkonkoma terminal moraine (Lewis and Stone 1991; Stone et al. 2005; Maliszka et al. 2020). The irregular, rolling topography of the ground moraine is decorated by several glacial, fluvial, and coastal features that include kettles, kames, erratics, intermittent stream valleys, and an erosional scarp.

### *Dissected Ground Moraine (Map Unit Qdgm)*

Marginal till and outwash deposits of the planar ground moraine have been eroded by colluvial processes, overland flow, and channelized flow to form steep-sided ravines that interrupt the gently rolling upland topography of the Sagamore Hill estate (see poster). Small intermittent streams have slowly dissected the ground moraine deposits to form steep slopes that sharply alter the southern, eastern, and western margins of the historic site. Headward stream erosion is more pronounced in the stream valleys along the southern and eastern margins of the site than on the western margin (Psuty et al. 2016a). Dissected ground moraine deposits (**Qdgm**) located east of the Old Orchard Museum underlie a significant portion of the 32-acre nature trail that was designated a Natural Environmental Study Area in 1968 (Bellavia and Curry 1995).

### *Kettles (Map Unit Qke)*

A glacial kettle is a steep-sloped, topographic depression that forms when stranded ice masses detach from a glacier, become wholly or partially buried, and melt (Figure 6). Kettles that become subsequently filled with water are referred to as kettle ponds or kettle lakes depending on their size. The historic site contains several kettle features (**Qke**) along the uplands by the visitor center and garden shed, as well as along the forested slopes leading to Cold Spring Harbor. A kettle feature located north of the Sagamore Hill estate is commonly referred to as the “Devil’s Punchbowl” (see poster)—the Roosevelt family would often ski down the slopes of the kettle in the winter (Bellavia and Curry 1995; Merwin and Manfra 2004). A cross-sectional profile of the Devil’s Punchbowl shows an elevation change of about 9 m (30 ft) with an approximate 37° slope (Bellavia and Curry 1995).

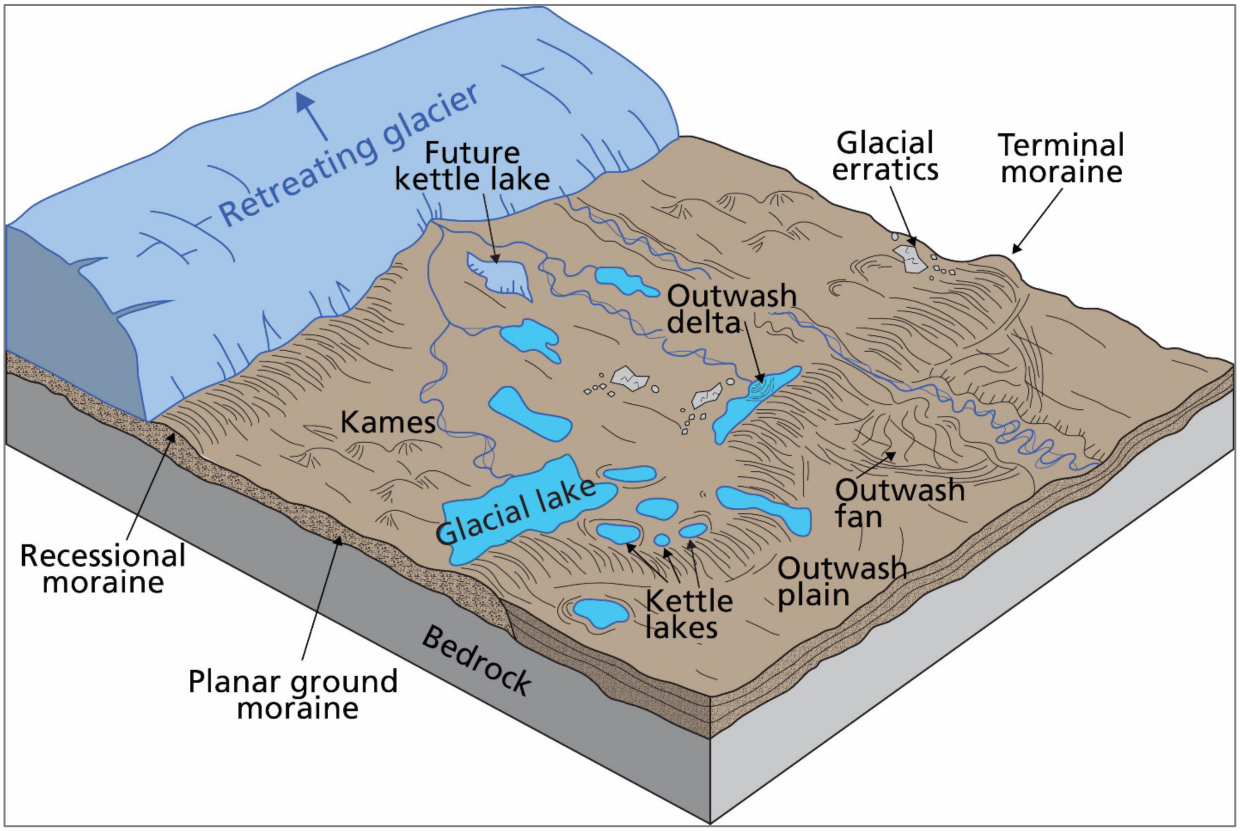

**Figure 6.** Diagram of glacial features that develop due to glacial retreat. As a glacier retreats deposits (e.g., moraine, outwash, erratics) and erosional features (e.g., kames, kettles) are left behind. The surficial geology of the historic site predominantly consists of ground moraine deposits comprised of unconsolidated till and outwash featuring kettles and erratics. The Theodore Roosevelt home sits atop a glacial kame that is the highest topographic point on the Cove Neck peninsula. Located a few kilometers south of the Sagamore Hill estate are the Ronkonkoma terminal moraine and the Harbor Hill-Fishers Island-Charlestown recessional moraine. Graphic created by Trista L. Thornberry-Ehrlich (Colorado State University).

Adjacent to the visitor center parking lot in the northeast corner of the garden site is the "Woodpile Pond," a small kettle pond where Roosevelt and hired fieldhands would cut and pile the winter's firewood (see poster; Hagedorn 1954; James-Pirri 2013). The Woodpile Pond was a favored destination by Roosevelt's children due to its large population of turtles (Hagedorn 1954; Bellavia and Curry 1995). An inventory of amphibians and reptiles within the historic site by Cook et al. (2010) shows that the Woodpile Pond habitat contains the most diverse and greatest number of species amongst all survey sites within the Sagamore Hill estate. The largest kettle pond in the historic site is located east of the Old Orchard Museum along the nature trail (Figure 1). Referred to as both the "Lower Lake" and "Heron Lake," the kettle feature sits at the confluence of several small drainage channels that have eroded into the underlying ground moraine deposits (see poster; Bellavia and Curry 1995; James-Pirri 2013; Psuty et al. 2016a). Kettles are a common feature throughout the Long Island area; in fact, the largest natural lake on Long Island—Lake Ronkonkoma—originated as a glacial kettle (Lubke 1964).

### *Kames (Map Unit Qka)*

The Sagamore Hill estate resides upon a glacial kame (**Qka**; see poster), an irregular hill or mound (hence Sagamore Hill) of accumulated till that rises above the planar ground moraine surface (Figure 6). Kame features exhibit a wide range of forms and lithologies originating from a variety of processes. Most kames develop as glacial drift material accumulates along the interface between the glacier and underlying strata, within ice cavities, or within depressions on the glacier surface (Maizels 2002; Ritter et al. 2011). Kame deposits within the historic site form the highest topographic point on the Cove Neck peninsula (51 m [167 ft] above sea level) and provided scenic views of the Long Island Sound during the tenure of Theodore Roosevelt.

### *Erratics*

As the Laurentide ice sheet advanced and retreated across North America, large masses of underlying bedrock were plucked, transported, and deposited far away (sometimes thousands of miles) from their point of origin (Figure 6). Referred to as glacial erratics, these boulders are prominent features of the historic site landscape and are commonly found at the base of steep slopes throughout the Sagamore Hill estate (Figure 7). Though not mapped as part of the GRI GIS data, the 22-acre segment of the historic site located west of the Roosevelt home contains several erratics that were cleared for agricultural purposes before and during Theodore Roosevelt's residence. At one time, historic site staff were contemplating the idea of introducing a geology trail that explored these glacial boulders as well as their potential origins (Scott Gurney, Sagamore Hill National Historic Site park ranger, personal communication October 2022).

**Figure 7.** Photograph of glacial erratics at the historic site. Large masses of foreign bedrock are commonly located at the bottom of the slopes throughout the estate. Erratics such as these are part of the cultural landscape and were cleared for agricultural purposes before and during Theodore Roosevelt's residence when the estate was a working farm. Photograph taken by Trista L. Thornberry-Ehrlich (Colorado State University).

## Fluvial and/or Colluvial Features

### *Fluvial and Colluvial Deposits (Map Unit Qfc)*

The historic site contains several intermittent streams and stream valleys that drain the uplands of the Sagamore Hill estate west into Oyster Bay Harbor as well as south and east into Cold Spring Harbor. Drainage along the stream channels has eroded the underlying ground moraine deposits to form steep slopes that are more pronounced along the southern and eastern margins of the historic site (Brock et al. 2006; Psuty et al. 2016a). As erosional processes such as rainwater, overland flow, and channelized flow dissected the Harbor Hill-Fishers Island-Charlestown ground moraine deposits, an accumulation of till debris has developed along the base of stream valley slopes to form an alluvial plain (Psuty et al. 2016a). These fluvial and colluvial deposits (**Qfc**) are mapped along the lower courses of the intermittent stream valleys (see poster).

The wetland and beach area of the eastern portion of the historic site are traversed by Eel Creek, a small tidal creek that underlies the nature trail boardwalk leading to Cold Spring Harbor. The Eel

Creek tidal inlet is a particularly dynamic coastal feature, with a migratory channel and mouth that respond to both seasonal changes and storm activity. The tidal channel discharges near the southern terminus of the accretionary spit and has been known to display cutbank incision resulting from fluvial erosion (Figure 8). The channel mouth features a small tidal delta that has developed due to tidal and wave interaction along the southern end of the accretionary spit. Tidal currents directed in and out of the Eel Creek channel have mobilized sediments to form tidal deltaic shoals and distributary channels that share in the southerly extension of the accretionary spit (Psuty et al. 2016a, 2016b; Psuty and Endicott 2016). Periods of maximum tidal transport potential (highest current flow energies attributable to tides) are associated with larger tidal ranges (spring versus neap tides) and tend to occur during mid-tide excursion between high and low tides (Psuty and Endicott 2016).

**Figure 8.** Photograph of Eel Creek. This south-facing view of Eel Creek shows cutbank incision. Situated at mean high tide, the Eel Creek tidal channel and mouth are migratory shoreline features that shift due to erosive forces associated with tides, waves, and storm activity. Photograph taken by Trista L. Thornberry-Ehrlich (Colorado State University).

## Coastal Features

### *Coastal Scarp and Bluff (Map Unit Qcsb)*

Dissected ground moraine deposits near the eastern margin of the Sagamore Hill estate feature a low coastal scarp and bluff (**Qcsb**; see poster) that sharply separate the forested uplands from the adjoining wetland and beach regions. The coastal scarp exposes a variety of till sediments (well-rounded gravels, sand, silt, and clay) that have been eroded and re-worked into adjacent beach deposits (Psuty and Endicott 2016). Development of the erosional surface occurred at an earlier stage in the geomorphological evolution of the Cove Neck peninsula and records an older, pre-existing shoreline position along Cold Spring Harbor. The incision of the coastal scarp occurred at a time when shoreline erosion exceeded deposition and rising sea level truncated the margin of the ground moraine surface (Psuty et al. 2016a). Following the formation of the scarp, waves and longshore currents eroded coastal headlands north of the historic site and transported sediment south along the east-facing side of the peninsula. These dynamic coastal forces have slowly and continuously reshaped the geology of the shoreline and created several landforms including the scarp, Eel Creek wetland, and the accretionary spit. The establishment of the wetland and spit has not only widened and lengthened the historic site's shoreline but also helped buffer the coastal scarp from waves, currents, and storms.

The northern shore of Long Island contains numerous headland bluffs and features of glacial origin that rise abruptly above the Long Island Sound. At the northeast tip of the Cove Neck peninsula just north of the Sagamore Hill estate is a unique and pronounced headland feature referred to as Cooper Bluff, a sandy cliff standing more than 50 m (160 ft) above the surrounding Oyster Bay Harbor and slopes sharply downward towards the beach. Although Cooper Bluff is not located on Theodore Roosevelt's property—it was on his cousin William E. Roosevelt's estate—he often took his children and invited guests for a slide or race down Cooper Bluff (Hagedorn 1954; Bellavia and Curry 1995).

### *Wetland (Map Unit Qw)*

A narrow, 10-acre wetland or saltmarsh (referred to as the "Eel Creek wetland" in this report) is situated between the coastal scarp and accretionary spit complex near the eastern boundary of the historic site (see poster). The Eel Creek wetland is sustained by the Eel Creek tidal channel, which traverses the wetland and discharges into Cold Spring Harbor (Figure 9). Wetland deposits (**Qw**) are predominantly comprised of sand, silt, and clay mixed with plant detritus accumulated in marshy areas (Isbister 1966). The nature trail boardwalk extends across the Eel Creek wetland and its associated tidal channel to provide views of wildlife and Cold Spring Harbor. Both the wetland and Eel Creek sit at mean high tide, making these regions highly susceptible to flooding events that impact the nature trail and coastal zone of the historic site (Peek et al. 2015, 2023; see "Geologic Resource Management Issues").

**Figure 9.** Photograph of Eel Creek wetland and tidal channel at high tide looking north. The wetland region of the historic site is a biologically rich habitat sustained by Eel Creek. The Eel Creek tidal channel traverses the wetland and has a migratory outlet into neighboring Cold Spring Harbor. (NPS/TYLER KULIBERDA).

The Eel Creek wetland is a dynamic, tidally influenced ecosystem that is home to numerous species including crabs, oysters, mussels, wading birds, shorebirds, songbirds, and birds of prey (National Park Service 2018). As a bird enthusiast, Theodore Roosevelt identified over 40 avian species around the historic site in a 24-hour period and spent many days with his family by the wetland and beach enjoying the local flora and fauna (Roosevelt 1913). The easternmost woodland and wetland area of the Sagamore Hill estate was designated a Natural Environmental Study Area in 1968 for individuals sharing in the conservationist ideals of Theodore Roosevelt. The study area previously offered guided tours by staff of the Theodore Roosevelt Bird Sanctuary and encompasses vital habitats that host bird, waterfowl, and mammal species (Bellavia and Curry 1995). Current use of the study area is limited due to overgrown understory vegetation that has increased the presence of deer ticks which are known to spread Lyme Disease (Bellavia and Curry 1995).

### *Accretionary Spit Complex (Map Units Qb, Qagr, Qigr, and Qirs)*

A combination of storm activity and longshore currents progressing north to south along the eastern shoreline of the Cove Neck peninsula have eroded coastal headlands updrift of the historic site and transported sediment in a southerly direction to form an accretionary spit complex. According to the GRI source map and accompanying report by Psuty et al. (2016a, 2016b), the spit complex is a beach and dune-ridge system composed of reworked glacial moraine deposits that form four distinct geomorphologic features: (1) an active beach (**Qb**); (2) active gravelly ridge (**Qagr**); (3) inactive gravelly ridge (**Qigr**); and (4) inter-ridge swale (**Qirs**) (see poster). Situated along the Cold Spring Harbor boundary of the historic site, the dynamic spit feature has slowly extended southward as a distinct accumulation of sand and gravel. The progressive migration of the coastal feature occurs as sediments near the northern margin of the spit are mobilized and later deposited at the southern terminus (Psuty et al. 2016a; Psuty and Endicott 2016). A coastal survey analysis of the historic site showed that from 2012 to 2016 the southern end of the spit had extended approximately 18.5 m (60 ft) to the south, while the northern shoreline of the historic site had experienced a net erosion of 1 to 4 m (3 to 13 ft) (Figure 10; Psuty and Endicott 2016; Endicott 2017). Over thousands of years, the southern migration and accretion of the spit complex has effectively widened the historic site's shoreline, influenced the development of Eel Creek and Eel Creek wetland, as well as provided an erosional buffer to inland coastal areas.

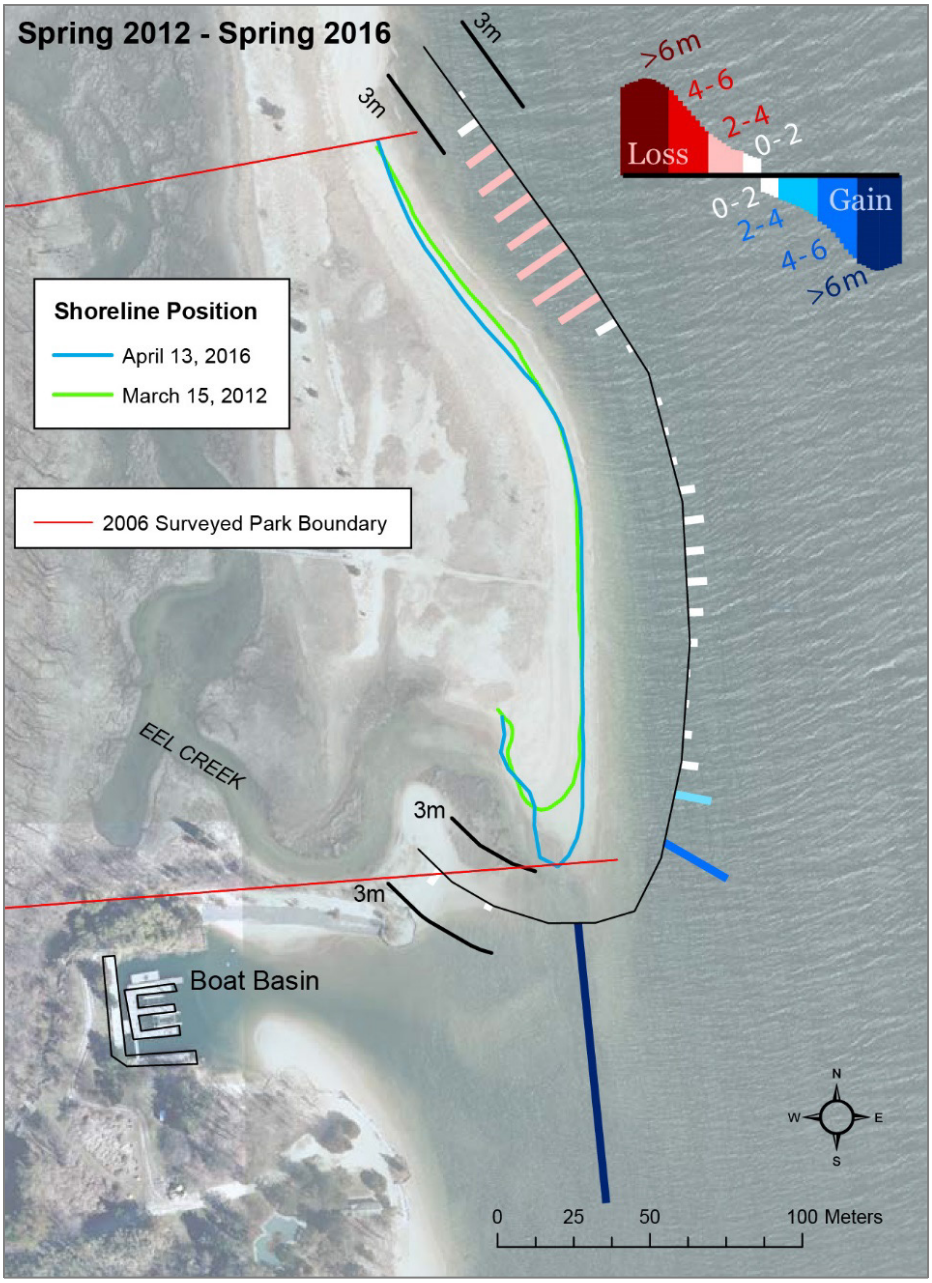

**Figure 10.** Map of shoreline change from spring 2012 to spring 2016. Surveyed shoreline positions at the historic site are shown for March 2012 and April 2016, which depict the direction and dimensions of neap tide swash line (zone of turbulence where waves break on the beach) shift along Cold Spring Harbor. The thin black line positioned offshore is a baseline that has vectors of measurement representing shoreline change spaced at 10 m (30 ft) intervals. Regions where the most recent surveyed shoreline positions show seaward displacement are represented by blue shaded vectors, while red shaded vectors indicate landward (erosional) displacement. The length of individual vectors indicates the degree of shoreline change. Dimensional changes less than 2 m (6 ft) are shown as white vectors rather than blue or red. From 2012 to 2016 the southern end of the spit extended approximately 18.5 m (60 ft) to the south, while the northern shoreline of the historic site eroded 1 to 4 m (3 to 13 ft) (Psuty and Endicott 2016; Endicott 2017). Figure 6 from Psuty and Endicott (2016).

Active Beach

An active beach (**Qb**) extends across most of the eastern boundary of the historic site and forms a series of small projections and embayments in the shoreline. Beach deposits form the seaward margin of the accretionary spit complex and largely consist of unvegetated, well-sorted gravel and sand that are constantly reworked by coastal processes such as tides, longshore currents, and storm events (Figure 10 and Figure 11; see poster). Longshore currents generate pulses of erosion and sedimentation that are generally directed north to south along the spit face, migrating beach deposition and slowly extending the accretionary spit southward (Endicott 2017; Psuty et al. 2016a). Analyses of coastal change at the historic site by Psuty and Endicott (2016) and Endicott (2017) have shown that southerly beach migration has shifted sediment deposition into a nearby boat basin south of the Sagamore Hill estate and is actively constricting the stream channel leading into the basin (see "Geologic Resource Management Issues").

**Figure 11.** Photograph of beach deposits and a spider crab along the shoreline of the historic site. Beach deposits within the historic site are composed of well-sorted, re-worked glacial moraine deposits of various rock types and sizes. (NPS/MARIE C. CLIFFORD).

Active Gravelly Ridge

Situated directly inland from the beach is the active gravelly ridge (Qagr; see poster), a vegetated ridge or foredune feature that stands about 2 m (6 ft) above sea level and contains fine sand incorporated with coarser beach sediments (Figure 12; Psuty et al. 2016a). The term "active" is indicative of the age of the ridge—the foredune is part of the younger, dynamic stage in the evolutionary development of the accretionary spit.

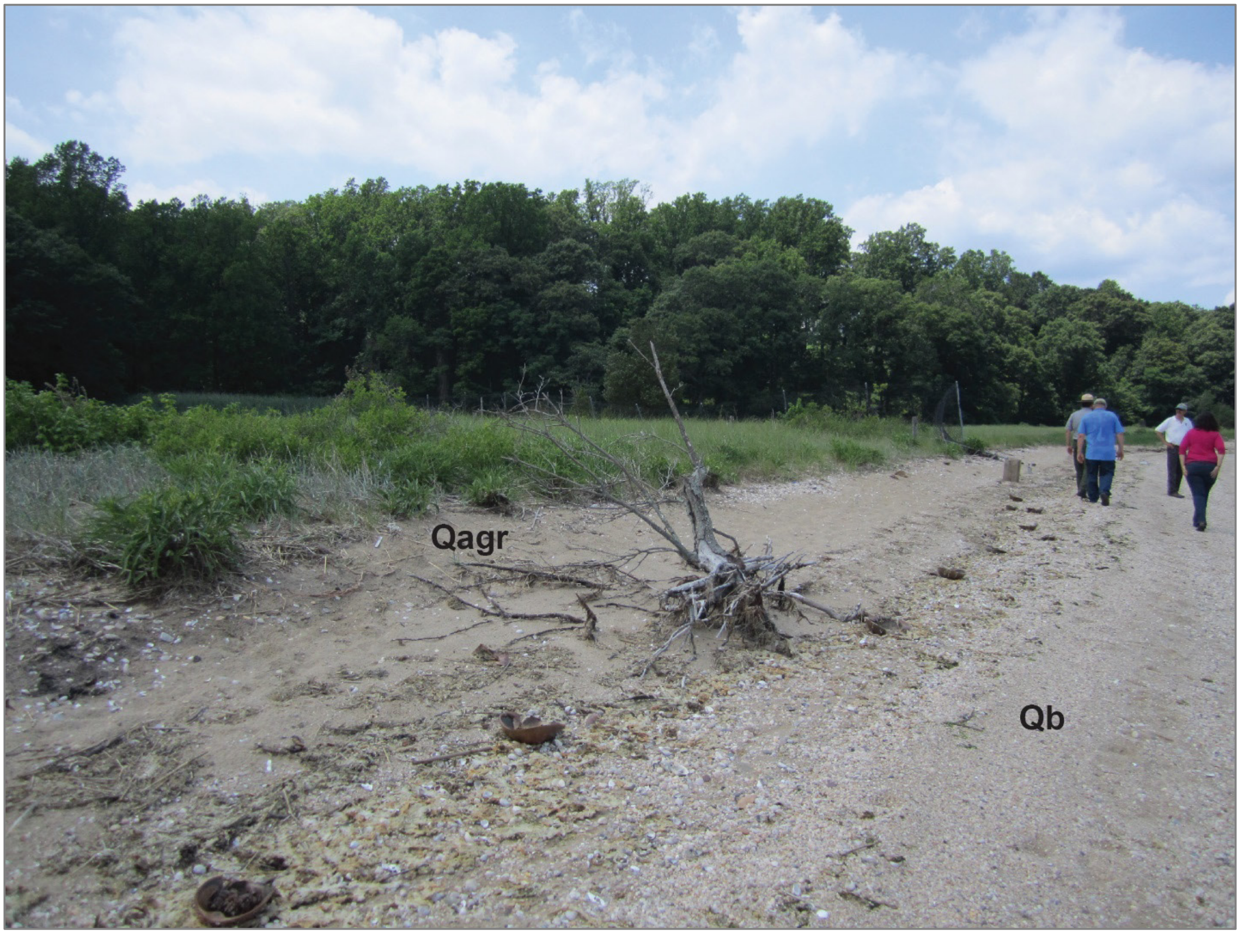

**Figure 12.** Photograph of the coastal beach and foredune region at the historic site. The dynamic shoreline of the historic site is composed of a low-lying beach (Qb) adjacent to a vegetated foredune ridge (Qagr). The foredune stands approximately 2 m (6 ft) above sea level. Low elevation areas of the historic site along Cold Spring Harbor are particularly susceptible to storm damage and flooding, as the coastal boundary of the site currently sits at mean high tide. Photograph taken by Trista L. Thornberry-Ehrlich (Colorado State University).

Inactive Gravelly Ridge

An inactive gravelly ridge (**Qigr**; see poster) is located landward of the active gravelly ridge adjacent to the Eel Creek wetland and is an older, stranded foredune feature that represents a former shoreline position (Figure 13). The inactive gravelly ridge was formed during an earlier evolutionary stage of the spit complex and is geologically and geometrically similar to the active gravelly ridge. As dynamic coastal processes have reworked the Cold Spring Harbor shoreline, the accretionary spit has widened and extended southward allowing the new "active" foredune position to develop, stranding the older "inactive" foredune in a more landward position.

**Figure 13.** Photograph of the inactive gravelly ridge that borders Eel Creek wetland. View is facing north toward the Long Island Sound. The inactive gravelly ridge (Qigr) is an older foredune feature that was formerly an active beachfront in the earlier depositional history of the accretionary spit complex. Photograph taken by Trista L. Thornberry-Ehrlich (Colorado State University).

### Inter-ridge Swale

A topographically low region called an inter-ridge swale (**Qirs**) exists between the active and inactive gravelly ridges (Psuty et al. 2016a). The swale broadens to the south, tapers to the north, and sits about 0.5 m (1.5 ft) below the ridge crests (Psuty et al. 2016a). The low-lying nature of the inter-ridge swale makes it more susceptible to localized flooding, especially near the Eel Creek tidal channel (see "Geologic Resource Management Issues").

## Historical and Archeological Resources

The historic site maintains a vast museum and archival collection that contains over 93,000 items related to Theodore Roosevelt and his family—approximately 90% of the objects on exhibit are original to the Roosevelt home (National Park Service 2018). These historical collections provide invaluable insight into the life of the Roosevelt family and consist of original furnishings (including Theodore Roosevelt's many game trophies), family letters, historic photographs, household records, photo albums, scrapbooks, political gifts from foreign dignitaries, and memorabilia related to Roosevelt's service in the Spanish-American War (see https://artsandculture.google.com/partner/sagamore-hill-national-historic-site for more information, accessed 27 September 2023). In addition to the museum and archival collection, several archeological sites exist within the historic site that include Native American and Euro-American cultural materials, as well as historical structures and foundations dating from Theodore Roosevelt's tenure at Sagamore Hill (1885–1919).

Archeological resources in the historic site have interpretive and educational potential to increase our understanding of ancestral communities that inhabited Cove Neck and Long Island. Prior to Euro-American occupation, Long Island was home to Indigenous Peoples at a time when the relative sea level was lower and the environment was not coastal in the modern sense. Following the deglaciation of the Long Island Sound area, smaller bodies of water such as Cold Spring Harbor were probably not inundated by the sea until approximately 4,000 years ago (Merwin and Manfra 2004). Thus, any evidence of early human "coastal" settlements may have been destroyed or submerged by post-glacial sea level rise associated with the formation of the modern Long Island Sound.

Areas considered to be outside the "developed" region of the Sagamore Hill estate contain Native American archeological deposits of cultural materials including lithic tools, debitage (waste flakes formed during the process of stone tool production and sharpening), core fragments (stone cobbles with evidence of lithic flakes removed) or split cobbles, and pottery sherds (Merwin and Manfra 2004). Additional lithic sherds and projectile points have recently been recovered within the historic site as erosion continues to naturally expose new discoveries (Joel Dukes, NPS Archeologist, personal communication October 2022). Indigenous stone tools are valuable components of the historic site's museum collection and include materials made from quartz and quartzite that were recovered near the coastal region of Cold Spring Harbor.

The historic site's archeological collections management report indicates that Theodore Roosevelt's children collected Native American materials from an "Old Indian Encampment Area" situated directly north of the Sagamore Hill estate's coastal boundary (DeCesare 1990, p. 4). Additionally, the location of what may be a Native American shell midden was identified by maintenance staff within the confines of the historic site (DeCesare 1990). Other areas within the Sagamore Hill estate that may contain archeological deposits have probably undergone some degree of cultivation or development, and those resources would be expected to have undergone some degree of disturbance (National Park Service 2018).

Euro-American cultural materials found within the historic site include domestic refuse (porcelain and ironstone ceramics, bottle glass, coal, redware, creamware, pearlware, and whiteware) and architectural debris (brick, metal hardware, nails, and glass) that date from the mid-nineteenth through the early twentieth century (Merwin and Manfra 2004). These materials have been attributed to the Roosevelt family occupation of the historic site. In 2021, archaeologists made additional discoveries during a formal excavation at the former stable and lodge site (see Figure 1) and while surveying the target and rifle pit in a wooded ravine southeast of the Roosevelt home. Several structural building materials and ceramic sherds were unearthed at the stable and lodge site and may provide insight into the lives of Roosevelt's staff, farmhands, and day laborers that lived there (Lane 2021). Roosevelt himself stayed in the Lodge for a short period in 1883 before the family home was completed. The utilization of metal detectors at the target and rifle pit has turned up small toys, an arm of a compass, a small medallion, in addition to numerous shell casings and bullets that attest to Roosevelt's passion for inviting guests to go target shooting (Lane 2021).

Areas surrounding the Sagamore Hill estate associated with the Roosevelt family's tenure—both missing and extant—offer the greatest potential for future archeological discovery (Merwin and Manfra 2004). Undisturbed archeological resources provide additional research opportunities to learn more about the Roosevelt family and their lives at Sagamore Hill.

### Paleontological Resources

The NPS paleontological resource inventory evaluation by Tweet et al. (2014) reports that no fossils have been found in the geologic units underlying the historic site to date. Although the surficial Quaternary deposits of the area are not known to be fossiliferous (containing fossils), similar-aged units within about 100 km (60 mi) of the historic site have been reported to contain extinct Pleistocene mammals (Tweet et al. 2014; see also Hartnagel and Bishop 1921; Hay 1923; Jepsen 1960; Lucas 1993). However, it is possible that glacially transported fossils are present in glacial deposits or that fossils may wash up on the historic site's shoreline. Washed-in fossils would most likely be sourced from nearby Cretaceous exposures on the east side of Cold Spring Harbor (Tweet et al. 2014).

# Geologic Resource Management Issues

This chapter highlights issues (geologic features, geologic processes, and human activities affecting or affected by geology) that may require management for human safety, protection of infrastructure, or preservation of natural and cultural resources. The GRD provides technical and policy assistance for these issues (see "Guidance for Resource Management").

During the 2010 NPS scoping meeting for the historic site (Thornberry-Ehrlich 2011) and the 2022 follow-up meeting, participants (see "Acknowledgments") identified the following geologic resource management issues. These issues are ordered alphabetically, not by management priority.

- Archeological Resources Management
- Climate Change Impacts
- Coastal Resources Management
- Disturbed Lands
- Fluvial, Colluvial, and Slope Processes
- Paleontological Resources Management
- Seismic Activity
- Tsunami Activity

Resource managers may find *Geological Monitoring* (Young and Norby 2009; http://go.nps.gov/geomonitoring) useful for addressing these geologic resource management issues. The manual provides guidance for monitoring vital signs—measurable parameters of the overall condition of natural resources. Each chapter covers a different geologic resource and includes detailed recommendations for resource managers and suggested methods of monitoring.

## Archeological Resources Management

Preservation and protection of archeological resources is a priority as these resources represent an irreplaceable and unique record of the past. According to NPS Management Policies (2006), archeological resources should remain in situ whenever possible and be protected from looting, vandalism, erosion, and destruction through historic site operations.

Recommendations provided here regarding archeological resource management are described in more detail by DeCesare (1990) and Merwin and Manfra (2004). Any future construction plans at the historic site that include ground disturbance should follow procedures outlined in Section 106 of the National Historic Preservation Act of 1966. Implementation of Section 106 requires that any potential ground disturbance project needs to determine, evaluate, and assess the impacts such activities may have on any historic or prehistoric resources prior to the initiation of such work (DeCesare 1990; Merwin and Manfra 2004). To better maintain the integrity of any yet undiscovered archeological resources, indirect remote sensing methods such as ground penetrating radar, resistivity, and metal detection can be employed to help locate and identify these deposits without excavation and/or physical inspection (Merwin and Manfra 2004). It is recommended that park employees who may not have any background in cultural resource management receive training in the identification of archeological resources, and their protection from theft and vandalism (Merwin and Manfra 2004). In addition, periodic visits by historic site staff to areas with confirmed archeological deposits or high potential zones may help determine if erosion is naturally exposing or jeopardizing resources in these locations (Merwin and Manfra 2004). Archaeological sites and their condition are documented in CRIS (Cultural Resources Inventory System). Based on their sensitivity and susceptibility to potential threats, all sites are evaluated during site condition assessments, the most recent having been performed in 2022 (Joel Dukes, written communication 22 August 2023).

### Climate Change Impacts

Although climate change planning is beyond the scope of this GRI report, a discussion of climate change is included because of the potential disruption it may cause to the historic site's resources, including geologic resources. Resource managers are directed to the NPS Climate Change Response Program (https://www.nps.gov/orgs/ccrp/index.htm) to address climate change planning, which helps in the development of plausible science-based scenarios that inform strategies and adaptive management activities that allow mitigation or adjustment to climate realities. Additionally, the historic site is an official participating member of the "Climate Friendly Parks Program" (https://www.nps.gov/subjects/climatechange/cfpprogram.htm), an initiative that helps parks understand and address the long-term impacts of climate change by using tools and resources that ensure the most sustainable operations across the NPS.

Climate change manifestations that may impact geologic features and processes within the historic site include the following:

- More frequent and intense storm surges
- Increased damage to coastal habitats, features, resources, and infrastructure
- Increased flooding, coastal inundation, and permanent loss of shoreline

Anthropogenic climate change is a major management priority at the historic site, as continued sea level rise has and will continue to detrimentally affect shoreline geometry and sediment supply. Although the historic site's coastal boundary currently sits at mean high tide, even the slightest rise in sea level can have significant effects on coastal hazards and incur dramatic effects on coastal infrastructure, landforms, and resources (Peek et al. 2015; Caffrey et al. 2018). Climate change exacerbates storm impacts through the combined effect of sea level rise and changing storm characteristics. Increased storm frequency and intensity can bring extreme costs through loss of visitor access, impacts to neighboring communities and local economies, investments in recovery, irrevocable damage to unique resources, and permanent loss of land space (Caffrey et al. 2018; Sweet et al. 2022). Coastal hazard exposure estimates by Peek et al. (2015, 2023) indicate one historic site asset—the nature trail boardwalk—to be of high vulnerability. Additionally, the eastern segment of the nature trail is rated as moderate vulnerability. These exposure estimates are evaluated based on flooding potential, shoreline change, sea-level rise inundation, extreme event flooding, and reported coastal hazards (Peek et al. 2023). The value of infrastructure at risk within the historic site could cost over one million dollars if exposed to a 1 m (3 ft) rise in sea level (Peek et al. 2015).

According to *Global and Regional Sea Level Rise Scenarios for the Unites States* (Sweet et al. 2022), the historic site is projected to experience an average rise in sea level (relative to sea level in 2000) of about 0.25–0.30 m (0.8–1.0 ft) by the year 2050. By 2100 and 2150, these sea level rise projections increase to 0.6–2.0 m (2.0–6.6 ft) and 0.8–3.9 m (2.6–12.8 ft), respectively. Additional sea level rise projections for the historic site and other coastal park units within the National Park System are provided in Caffrey et al. (2018).

### Coastal Resources Management

The shoreline of the historic site along Cold Spring Harbor is a dynamic setting that features an array of coastal features including an erosional scarp (**Qcsb**), accretionary spit complex (**Qb**, **Qagr**, **Qigr**, **Qirs**) and the Eel Creek wetland (**Qw**) (see poster). Many of these geologic resources have been deposited, sculpted, and continuously reworked by longshore ocean currents, tides, winds, and storm events since the Quaternary Period (approximately 2.58 million to 11,700 years ago). With such a dynamic coastal landscape, the latest information provided in this report only represents a snapshot of the current coastal situation at the historic site. The best management decisions will need to closely monitor and follow the latest data available.

According to the scoping summary, two of the major factors influencing the geomorphological expression of the historic site’s shoreline are sea level change and sediment supply. Sea level change combined with other factors such as tidal, wave, and wind energy (magnitude and direction) govern the erosive potential and transportation of sediment along the shores of the Cove Neck peninsula. As sea levels continue to rise, coastal instability is projected to increase due to accelerated rates of erosion that will be driven by enhanced tidal levels, increased flooding, landward shoreline migration, and subsequent displacement of coastal features (Beavers et al. 2016). According to *Global and Regional Sea Level Rise Scenarios for the United States* by Sweet et al. (2022), expected sea level rise projections will lead to a shift in U.S. coastal flood regimes, including an increase in storm intensities. On a local scale, winds blowing into the embayed coast of Long Island can significantly change the relative sea level at the historic site over a short period of time that preclude accurate predictions. Over the last several decades, rising tides along Cold Spring Harbor have more routinely flooded portions of the historic site’s coast to a degree that a rope fence was constructed to prevent “social” trails where visitors would attempt to navigate around high-water zones (Figure 14; Scott Gurney, Sagamore Hill National Historic Site park ranger, personal communication October 2022). Regionally, sea levels have been continuously rising since the Last Glacial Maximum (approximately 21,000 years ago), and the rate of sea level rise in the last century was greater than any preceding century in at least 2,800 years (Caffrey et al. 2018).

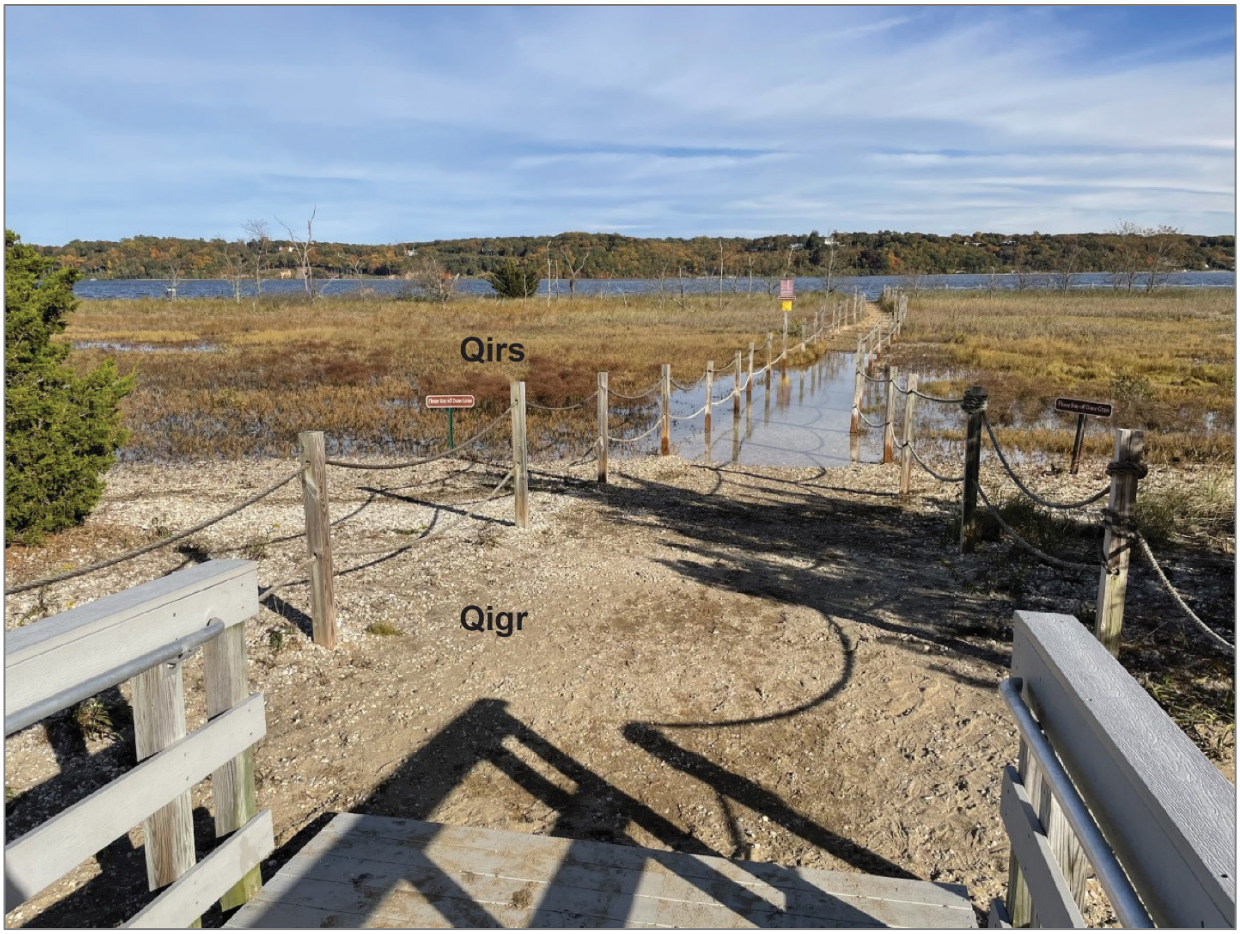

**Figure 14.** Photograph of portions of flooded shoreline along Cold Spring Harbor. The photograph is facing east across a flooded segment of beach path leading from the nature trail boardwalk toward Cold Spring Harbor. Flooding in this photo occurred during neap tide and had partially submerged the inter-ridge swale (Qirs) region of the accretionary spit complex. The dry foreground consists of the inactive gravelly ridge (Qigr). (NPS/TYLER KULIBERDA).

Rates of sediment transport and coastal feature displacement at the historic site vary depending upon the frequency and strength of storm events (Psuty and Endicott 2016). The peninsular coast of the Sagamore Hill estate is exposed to powerful and sometimes destructive coastal forces that can significantly re-shape the shoreline within a single storm event. A storm event that took place in 1992 produced high tides that knocked the nature trail boardwalk off its moorings and damaged two potentially historic Black Locust trees (Bellavia and Curry 1995). In 2010, an extended cyclonic nor'easter storm that lasted over six high tides drastically eroded several meters of beach berm (**Qb**) within the historic site and deposited sandy sediment within the Eel Creek wetland (**Qw**). The storm generated enough energy to create small erosional scarps less than 1 m (3 ft) high, in addition to washover lobes (coastal erosional features that consist of a mouth, channel, and fan) and areas of interrupted shoreline vegetation. Although the access road into the Sagamore Hill estate (Cove Neck Road) has a 2.5 m (8 ft)-high seawall, this structure was washed over during the storm. In October 2012, Hurricane Sandy ("Superstorm Sandy") made landfall as a Category 1 storm with sustained winds ranging between 120 and 150 kph (74 and 95 mph). The associated storm surge flooded the coastal zones of the historic site, permanently damaged the 111 m (366 ft)-long nature trail boardwalk (Figure 15), and forced the historic site to close for several days. Reconstruction of the boardwalk was completed in early 2014 and restored visitor access to the beach and wetland (Figure 16).

**Figure 15.** Photograph of damage to the nature trail boardwalk following Hurricane Sandy in October 2012. The sustained winds and storm surge of Hurricane Sandy irreparably damaged the 111 m (366 ft)-long boardwalk and limited visitor access to the Eel Creek wetland and Cold Spring Harbor beach. Destructive storm activity is a primary coastal management concern for the historic site. A single storm event such as Hurricane Sandy can significantly impact lowland regions, including the historic site's coastal geomorphology, habitats, resources, features, and infrastructure. (NPS/SAGAMORE HILL NATIONAL HISTORIC SITE).

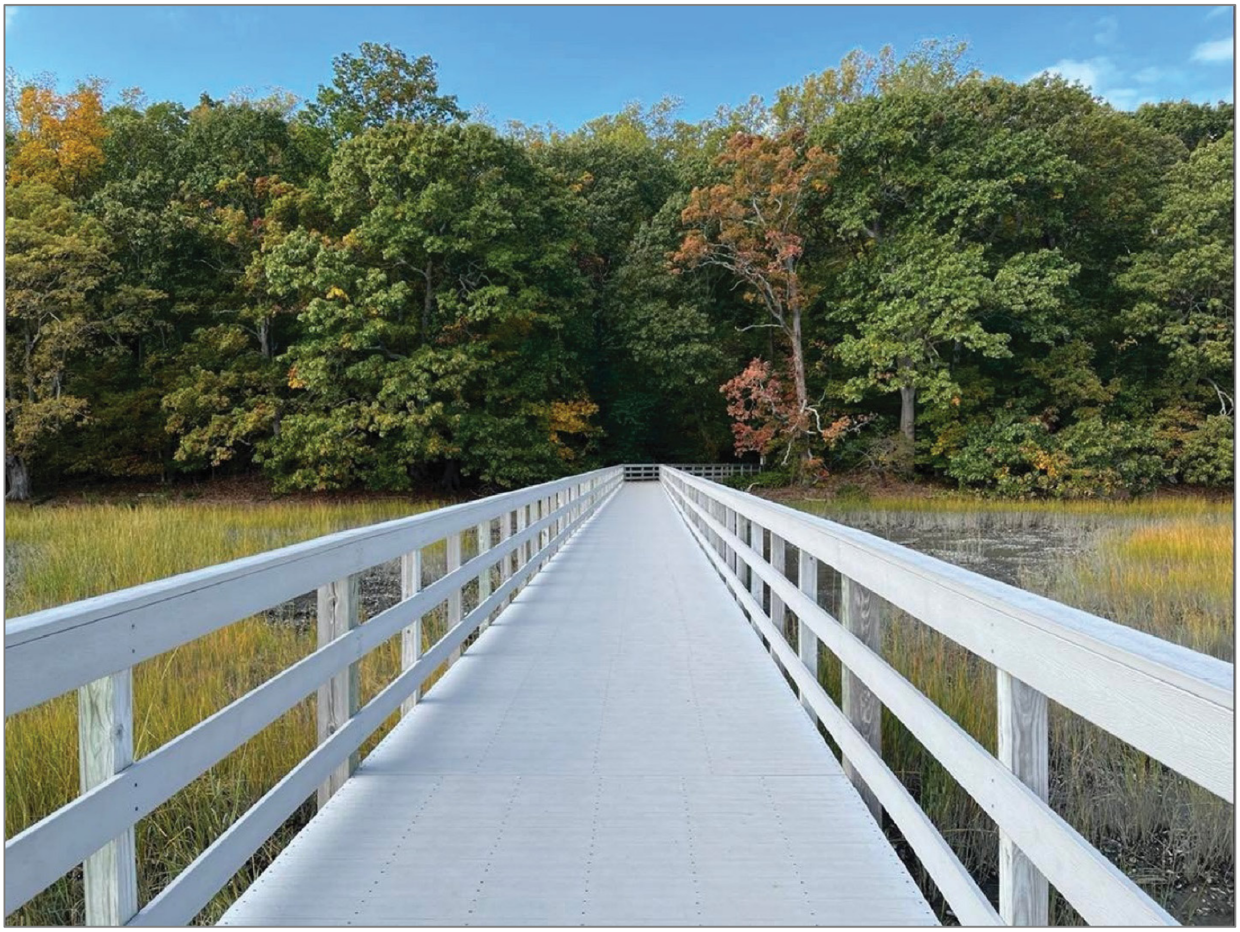

**Figure 16.** Photograph of the reconstructed nature trail boardwalk following Hurricane Sandy. View of the boardwalk is facing north across the Eel Creek wetland and adjoining forested uplands of the historic site. Reconstruction of the new boardwalk was completed in early 2014 using recycled composite decking with an improved substructure. (NPS/MARIE C. CLIFFORD).

Another possible scenario consideration as sea levels continue to rise is an expected landward shift in the historic site's coastline that will slowly encroach upon the Eel Creek wetland. Situated against the steeper slopes of the erosional coastal scarp (**Qcsb**) to the west and confined by a man-made barrier to the south (**Qaf**; see poster), the wetland (**Qw**) has limited space to migrate or adapt to rising sea level conditions. Climate change is expected to continue. Resource managers could prepare an action plan to mitigate enhanced flooding, inundation, and erosion that will impact coastal zones within and surrounding the historic site (see "Climate Change Impacts").

## Disturbed Lands

The development of residential properties and infrastructure immediately surrounding the Sagamore Hill estate provides potential concern for disturbance and park managers should be aware of threats to the historic site's viewshed and resources. Shoreline development along the Cold Spring Harbor coast has impacted natural processes (i.e., sediment transport dynamics, hydrology) within the wetland, tidal creek, and accretionary spit complex, introducing several land disturbance issues both within and surrounding the historic site (James-Pirri 2013). A small private marina basin located immediately south of the historic site's coastal boundary was previously dredged to reduce the impact of shoreline sediment that continues to slowly impinge upon its entry channel. The excavation of sediment south of the accretionary spit complex interrupted the depositional regime and created an artificial catch basin (man-made depression) that trapped material transported beyond the terminal end of the spit (Psuty and Endicott 2016). Over time, the catch basin will accumulate enough sediment until it is infilled or bridged. Attempts to dredge the entry channel to the marina basin only provide a temporary solution as the channel will continuously refill due to the natural migratory path of the spit. Although the Eel Creek tidal channel and mouth are migratory features, the construction of a man-made barrier (**Qaf**; see poster) associated with the marina basin limits the southerly migration of these tidal channel features (Figure 17). The presence of the artificial barrier limits the Eel Creek tidal channel's response to coastal flooding and erosion, posing a potential long-term threat to the Eel Creek wetland as sea level continues to rise (see "Climate Change Impacts").

**Figure 17.** Photograph of the accretionary spit complex along the coastal boundary of the historic site. View is facing south across the terminal end of the spit toward the Eel Creek tidal channel mouth. The artificial barrier that defines the southern historic site boundary can be seen just south of the tidal channel. The presence of the barrier limits the channel's response to coastal flooding and erosion, posing a potential threat to the Eel Creek wetland as sea level continues to rise. Photograph taken by Trista L. Thornberry-Ehrlich (Colorado State University).

Additional, albeit minor, degradation to the coastal area of the historic site had previously occurred due to confusion over the location of the shoreline boundary. Boaters would often misread the shoreline and mistakenly dock their watercraft vehicles on the historic site's property. To address these concerns, the historic site's staff provided signage to warn watercraft operators, and now the coastal region of Cold Spring Harbor is regularly patrolled by law enforcement in an arrangement with Fire Island National Seashore (Scott Gurney, Sagamore Hill National Historic Site park ranger, personal communication October 2022).

Immediately north of the Sagamore Hill estate, neighboring residential construction has altered the drainage pattern of Woodpile Pond (**Qka**), which is located adjacent to the visitor center parking lot (see poster). A small stream channel previously drained the kettle pond into Cold Spring Harbor until it was artificially filled in, altering the hydrologic flow in and out of the pond. These channel modifications resulted in elevated water levels that have occasionally flooded adjacent properties (Bellavia and Curry 1995; James-Pirri 2013). The affected drainage of Woodpile Pond could facilitate the expansion of invasive vegetation and impact the pond's ecosystem, which contains the greatest number of recorded amphibian and reptile species within the Sagamore Hill estate (Cook et al. 2010). Increased residential development surrounding the historic site may have additional negative impacts by enhancing habitat fragmentation and loss resulting in a reduction of biological diversity within and beyond the site's boundaries (James-Pirri 2013).

Beginning in the 1920s, the Roosevelt Memorial Association (now the Theodore Roosevelt Association) and American urban planner Robert Moses planned to construct the Northern State Parkway across the Long Island Sound linking Oyster Bay to the New York City line in honor of Theodore Roosevelt. However, the proposition of the Northern State Parkway project was opposed by residents of northern Long Island (Rodgers 1952). In 1968, the establishment of the Oyster Bay National Wildlife Refuge effectively halted the original plans for the parkway's construction across Long Island Sound (Scott Gurney, Sagamore Hill National Historic Site park ranger, personal communication October 2022). Construction of the Northern State Parkway and other mass transit projects adjacent to the Sagamore Hill estate would be impactful by increasing traffic exposure and light pollution while potentially threatening the natural soundscape (National Park Service 2018).

According to the scoping summary, the historic site contains several cultural features that could be considered disturbed lands; however, some of these are part of the historical context and are not intended for restorative purposes. Such features include glacial erratics and piles of rock debris situated at the base of the Sagamore Hill estate that were cleared for agricultural purposes before and during Theodore Roosevelt's residence. Park managers should consider how modern intrusions on the landscape (e.g., parking lot, visitor center, noise, and artificial lights), alterations and/or loss of historic buildings, aging forest structure, and vegetation growth have impacted the sense of place or historic context (Bellavia and Curry 1995). The historic site's staff are actively restoring portions of the cultural landscape for interpretive reasons, including the re-establishment of historic farm fields and replanting fruit trees in the former orchard. Furthermore, the removal and/or remediation of vegetation from hillside slopes within the historic site introduces potential risk for increased runoff and erosion.

### Fluvial, Colluvial, and Slope Processes

The coastal boundary of the historic site along Cold Spring Harbor currently sits at mean high tide and experiences daily tidal fluctuations and periodic flooding events that impact shoreline and wetland areas. Storms and tidal periods of new or full moon phase regularly flood Eel Creek, the Eel Creek wetland, and adjacent coastal areas, temporarily limiting access to the beach. During these flooding events, high tides and enhanced wave energy drive sea water over Eel Creek's bank and temporarily submerge the sandy path leading from the nature trail boardwalk to the beach (see Figure 14). Flooding of this type can occur a few times per month, especially during the spring and fall. The Eel Creek tidal channel and mouth are migratory features that slowly shift in response to coastal flooding and erosion. The Eel Creek channel shows signs of cutbank incision that exposes sandy deposits along the southeastern boundary of the historic site (see Figure 8). Resource managers and staff who are more interested in fluvial systems monitoring are encouraged to read Lord et al. (2009), which provides an overview of river and stream dynamics, but also contains helpful guidelines and methodology descriptions.

The steep gullies and intermittent stream valleys of the Sagamore Hill estate experience intervals of enhanced colluvial erosion and deposition during storms or periods of prolonged rain activity. The increased runoff, overland flow, and channelized flow that results from these events have incrementally incised the marginal planar ground moraine deposits (**Qdgm**) and formed an alluvial plain of unconsolidated glacial till and debris (**Qfc**) at the base of steeper ravine slopes (Psuty et al. 2016a; see poster). Colluvial erosion has further impacted portions of the nature trail by removing soil cover and exposing debris and garbage, most of which is considered historic from the Roosevelt family era. Over the years, historic site staff have tried to mitigate sediment loss along the trail by utilizing wood chips, but these efforts were abandoned over concerns related to invasive weed introduction (Scott Gurney, Sagamore Hill National Historic Site park ranger, personal communication October 2022).

The removal and/or remediation of vegetation from hillslopes within the historic site introduces some potential for increased runoff, erosion, and slope mobility. Issues relating to slope instability have occurred in areas just inland of the Eel Creek wetland and along portions of the nature trail. In 2016, trail crews constructed water bars or interceptor dikes along the trail to help mitigate slope stability issues that were exposing archeological resources (Joel Dukes, NPS archeologist, personal communication August 2022). Additionally, rainwater and runoff that collects along the east end of the visitor parking lot drains down slope into nearby Woodpile Pond. Considerations should be made regarding whether the parking lot runoff is a potential water quality threat to lower elevation regions within the historic site.

The GRD employs three management strategies regarding rockfalls and other slope movement hazards: (1) an Unstable Slope Management Program (USMP) for transportation corridor risk reduction; (2) quantitative risk estimation for specific rockfall hazards; and (3) monitoring of potential rockfall areas. Historic site managers can contact the GRD to discuss these options and determine if submitting a technical request is appropriate. Further information about slope movements is provided in "Guidance for Resource Management."

### Paleontological Resources Management

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). They may be body fossils (any remains of the actual organism such as bones, teeth, shells, or leaves) or trace fossils (evidence of an organism's activity such as nests, burrows, tracks, or coprolites [fossil feces]). All fossils are nonrenewable resources. Fossils in NPS areas occur in situ in rocks or unconsolidated deposits, in museum collections, and in cultural contexts such as building stones or archeological resources.

The historic site's paleontological resource inventory by Tweet et al. (2014) provides a preliminary list of recommendations for resource managers regarding paleontological resource management issues. Although fossils have not yet been documented within the historic site, it is possible that these resources may be present in underlying glacial deposits or that fossils may wash up along the shoreline (Tweet et al. 2014). According to NPS Management Policies (2006), historic site staff should systematically monitor for newly exposed fossils, especially in areas of rapid erosion, and protect significant resources by collection or on-site protection and stabilization. Staff of the historic site can receive guidance in identifying common local fossils (see "Guidance for Resource Management") and are encouraged to observe and monitor any occurrences of paleontological resources (Tweet et al. 2014). If fossils are observed in the historic site, every reasonable effort should be made to photodocument and record the paleontological resources in situ so that the integrity and associated geologic context (surrounding rock/sediment relationships) is preserved. Additional guidance on in situ paleontological resource monitoring is provided by Santucci et al. (2009) in a section of *Geological Monitoring* (Young and Norby 2009).

### Seismic Activity

The eastern continental margin of the United States is considered passive, meaning that is lacks high levels of earthquake, volcanic, or mountain building activity. However, seismic events still occur along the eastern seaboard as deep-seated geologic structures accommodate stress within the interior subsurface of the Earth's crust. Historically, there have only been six earthquake events registering greater than a magnitude 5.0 on the Richter scale within the New York state region (Wheeler et al. 2000; Tantala et al. 2005). Two of these seismic events registered a magnitude 5.2 and occurred near the Sagamore Hill estate; the most recent took place at Coney Island in 1884 and the other near Central Park in 1737 (Wheeler et al. 2000; Tantala et al. 2005). Although earthquake events larger than magnitude 5.0 are rare, there is still plenty of evidence to show the region is seismically active. Data from the USGS Earthquake Hazards Program shows approximately 500 recorded lower magnitude seismic events in New York since 1900, with many additional earthquakes that have occurred along the Connecticut-New Jersey-New York boundary (Figure 18; https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york). Although these records show that earthquakes are a common occurrence, these low magnitude events pose a very low potential hazard risk to the historic site.

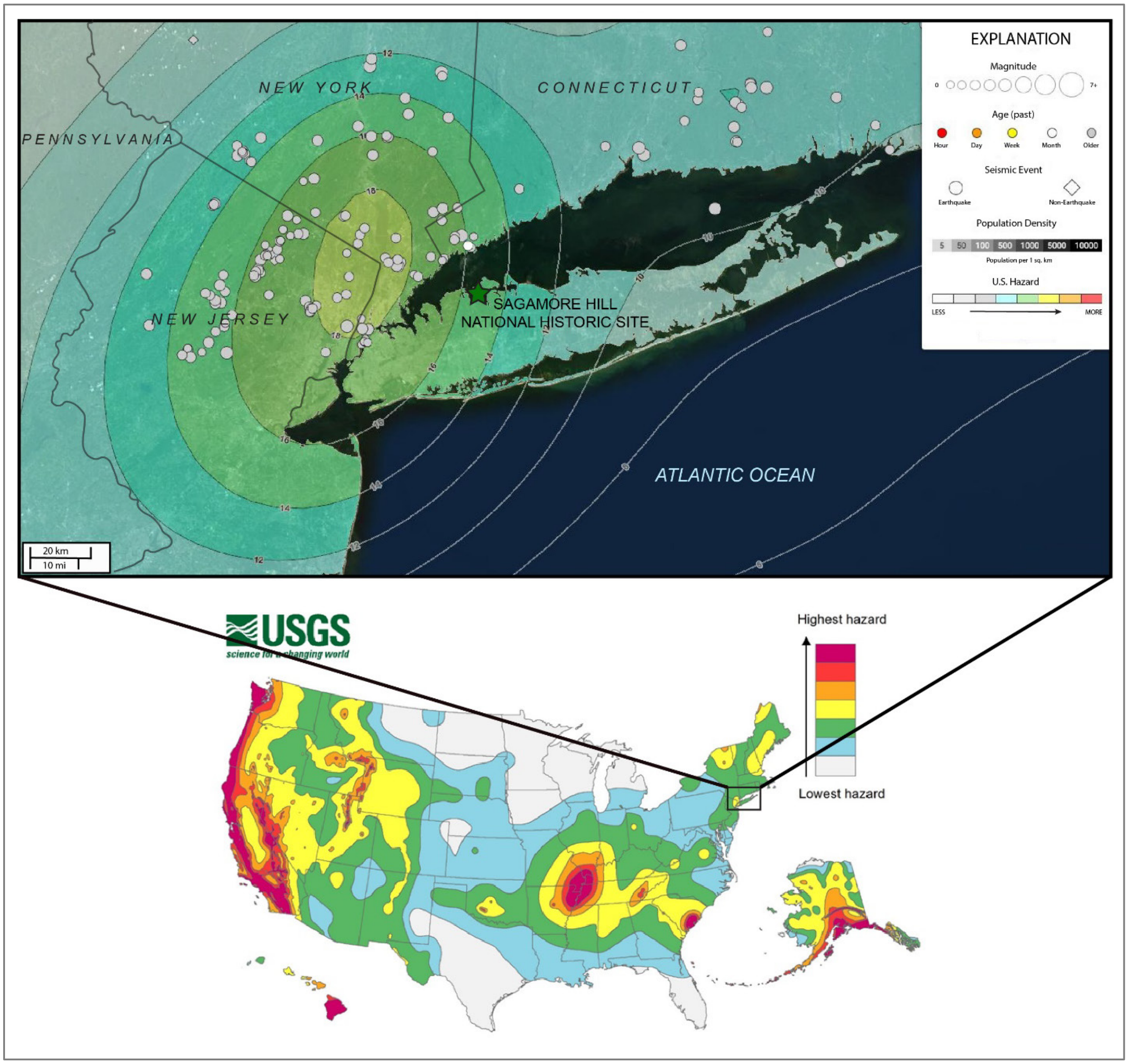

**Figure 18.** National seismic hazard map of the United States, with detailed seismic map of the Long Island area. The Long Island seismic map depicts historic earthquake activity since 1900. Numerous, low magnitude earthquake events have been recorded surrounding the historic site, but only pose a very low potential seismic hazard. Contour labels in the detailed Long Island seismic map represent the expected number of damaging earthquake occurrences per 10,000 years. The lower map shows predicted earthquake hazards across the United States for the next 50 years based on the most recent National Seismic Hazard Models (2018 for the conterminous US, 2007 for Alaska, and 1998 for Hawaii; see https://www.usgs.gov/programs/earthquake-hazards/science/introduction-national-seismic-hazard-maps). Based on both maps, the historic site is situated in an area of medium-seismic hazard relative to the rest of the country. Graphic compiled by Tim C. Henderson (Colorado State University) using graphics and data from the U.S. Geological Survey Earthquake Hazards Program (https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york; accessed 18 September 2022).

### Tsunami Activity

Large submarine disturbances (earthquakes, landslides, volcanic activity) are known to generate destructive oceanic waves that can devastate coastal and inland coastal areas. According to the U.S. Department of Interior (DOI) Strategic Hazard Identification and Risk Assessment (SHIRA), the historic site is susceptible to tsunami activity, but the hazard rating is low to very low (DOI 2023). Additionally, tsunami inundation mapping by the National Weather Service National Tsunami Hazard Mitigation Program (see Tehranirad et al. 2015) shows lines of coastal inundation along Cold Spring Harbor and the Eel Creek wetland.

### Summary of Geologic Hazards

The dynamic landscapes at many national park units present a variety of natural hazards that could endanger NPS facilities, staff, and visitors. Many of these natural hazards are geologic in nature (e.g., volcanoes, earthquakes, and landslides). NPS Policy Memorandum 15-01 (Jarvis 2015) directs NPS managers and their teams to proactively identify and document facility vulnerabilities to climate change and other natural hazards. The primary geologic hazards identified during the GRI process for the historic site are sea level change, coastal storm surge, shoreline erosion, riverine flooding, and flash flooding. Additional potential geologic hazards include seismic activity, slope movements, tsunamis, and radon exposure. Table 3 summarizes the geologic hazards at the historic site.

**Table 3.** Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

| Potential Hazard | Best Professional Judgement | Risk or Secondary Hazard | Sources of Geohazard Information |
|---|---|---|---|
| Sea level change | **Known Hazard** | Destruction, damage, and alteration of coastal infrastructure and environments (e.g., through saturation)<br>Inundation<br>Rising sea levels amplify the impacts of storm surges, high tides, coastal erosion, and wetland loss<br>Water quality effects<br>Fresh water supply diminished | Caffrey et al. (2018)<br>NPS scoping summary report (Thornberry-Ehrlich 2011)<br>Peek et al. (2015, 2023)<br>Sweet et al. (2022)<br>U.S. Department of the Interior (DOI) Strategic Hazard Identification and Risk Assessment (SHIRA) Risk Mapper (DOI 2023) |
| Coastal storm surge | **Known Hazard** | Flooding from increased sea level coupled with tidal amplification.<br>Enhanced erosion.<br>Destruction of infrastructure.<br>Water quality effects. | Hurricane storm surge hazard level rating of “Category 4” (SHIRA Risk Mapper, DOI 2023)<br>NPS scoping summary report (Thornberry-Ehrlich 2011)<br>Peek et al. (2015, 2023) |
| Coastal erosion | **Known Hazard** | Destruction of infrastructure.<br>Unstable shoreline | NPS scoping summary report (Thornberry-Ehrlich 2011)<br>Psuty et al. (2016)<br>Psuty and Endicott (2016) |
| Flash flood | **Known Hazard** | Sudden rising water (e.g., Woodpile Pond) resulting in localized flooding.<br>Destruction of infrastructure | Bellavia and Curry (1995)<br>Federal Emergency Management Agency (FEMA) National Flood Hazard Layer (https://www.fema.gov/flood-maps/national-flood-hazard-layer, accessed 18 September 2023)<br>James-Pirri (2013) |

**Table 3 (continued).** Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

| **Potential Hazard** | **Best Professional Judgement** | **Risk or Secondary Hazard** | **Sources of Geohazard Information** |
|---|---|---|---|
| Riverine flood | **Known Hazard** | Flooding (e.g., snowmelt, rainfall, storm activity, tidal fluctuations) along the Eel Creek tidal channel<br>Destruction of infrastructure.<br>Eel Creek tidal channel migration.<br>Eel Creek bank erosion. | SHIRA Risk Mapper (DOI 2023)<br>FEMA Map Service Center<br>Natural Resource Condition Assessment report (Cole et al. 2012)<br>NPS scoping summary report (Thornberry-Ehrlich 2011) |
| Lake, pond, and/or reservoir level change | **Known Hazard** | Sudden rising water (e.g., Woodpile Pond) resulting in localized flooding.<br>Destruction of infrastructure | Bellavia and Curry (1995)<br>James-Pirri (2013) |
| Earthquake | **Potential Hazard (very low)** | Falling objects.<br>Collapsing structures<br>Inoperability of major building systems (e.g., power, sewer, water)<br>Liquefaction; loss of strength to foundations, silt deposition, standing water<br>Trigger to other hazards (e.g., landslides, debris flows) | SHIRA Risk Mapper (DOI 2023)<br>The New York City Area Consortium for Earthquake Loss Mitigation<br>NPS scoping summary report (Thornberry-Ehrlich 2011)<br>USGS Earthquake Hazards Program, Information by Region – New York (https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york, accessed 18 September 2023)<br>USGS Earthquake Probability Map |
| Slope movements (landslide/avalanche) | **Known Hazard** | Rockfall<br>Slides or flows onto structures<br>Slides or flows from under structures<br>Damage or destruction of park infrastructure<br>Damage to or loss of natural or cultural resource sites or features<br>Human injury or casualty | GRI GIS hazard layers or slope movement deposits (e.g., “fluvial/colluvial deposits”, “coastal scarp/bluff”)<br>SHIRA Risk Mapper (DOI 2023)<br>FEMA National Risk Index (https://hazards.fema.gov/nri/map, accessed 18 September 2023)<br>Psuty et al. (2016)<br>State geological survey hazard maps |

**Table 3 (continued).** Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

| Potential Hazard | Best Professional Judgement | Risk or Secondary Hazard | Sources of Geohazard Information |
|---|---|---|---|
| Permafrost | Not applicable; not present at the historic site | Not applicable | Not applicable |
| Cave/karst | Not applicable; no known sinkhole susceptibility | Not applicable | Not applicable |
| Shrink/swell soils | **Potential Hazard (low)** | Damage or destruction of park infrastructure<br>“Heaving” of ground beneath infrastructure<br>Increased susceptibility to mass wasting events | Linear extensibility ratings are “low” (below 3%) for all the soils mapped within the historic site (see U.S. Department of Agriculture Web Soil Survey, https://www.nrcs.usda.gov/resources/data-and-reports/web-soil-survey, accessed 18 September 2023) |
| Tsunami | **Potential Hazard (low to very low)** | Coastal area inundation<br>Damage or destruction of park infrastructure<br>Enhanced erosion.<br>Water quality effects | SHIRA Risk Mapper (DOI 2023)<br>National Tsunami Watch Center<br>National Tsunami Hazard Mitigation Program Inundation Map for Huntington, NY (https://www1.udel.edu/kirby/nthmp_protect.html, accessed 18 September 2023)<br>Tehranirad et al. (2015) |
| Volcanic eruption | Not applicable; not present in or near the historic site | Not applicable | Not applicable |

**Table 3 (continued).** Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

| **Potential Hazard** | **Best Professional Judgement** | **Risk or Secondary Hazard** | **Sources of Geohazard Information** |
|---|---|---|---|
| Hydrothermal activity | Not applicable; not present in or near the historic site | Not applicable | Not applicable |
| Radon | **Known Hazard (EPA zone 3 [low])** | Health hazard | SHIRA Risk Mapper (DOI 2023)<br>EPA Map of Radon Zones: New York (https://www.epa.gov/radon/epa-map-radon-zones-and-supplemental-information, accessed 18 September 2023)<br>New York State Department of Health, Environmental Public Health Tracker, Radon: Nassau County (https://health.ny.gov/environmental/public_health_tracking/, accessed 18 September 2023) |

# Guidance for Resource Management

This chapter provides information to assist resource managers in addressing geologic resource management issues and applying NPS policy. The compilation and use of natural resource information by park managers is called for in the 1998 National Parks Omnibus Management Act (§ 204), NPS 2006 Management Policies, and the Natural Resources Inventory and Monitoring Guideline (NPS-75).

## Access to GRI Products

- GRI products (scoping summaries, GIS data, posters, and reports): http://go.nps.gov/gripubs
- GRI products are also available through the NPS Integrated Resource Management Applications (IRMA) portal: https://irma.nps.gov/. Enter "GRI" as the search text and select a park from the unit list.
- GRI GIS data model: http://go.nps.gov/gridatamodel
- Additional information regarding the GRI, including contact information: https://www.nps.gov/subjects/geology/gri.htm

## Three Ways to Receive Geologic Resource Management Assistance

- Contact the GRD (https://www.nps.gov/orgs/1088/contactus.htm). GRD staff members provide coordination, support, and guidance for geologic resource management issues in three emphasis areas: (1) geologic heritage, (2) active processes and hazards, and (3) energy and minerals management. GRD staff can provide technical assistance with resource inventories, assessments, and monitoring; impact mitigation, restoration, and adaptation; hazards risk management; laws, regulations, and compliance; resource management planning; and data and information management.
- Formally request assistance at the Solution for Technical Assistance Requests (STAR) webpage: https://irma.nps.gov/Star/ (available on the Department of the Interior [DOI] network only). NPS employees (from a park, region, or any other office outside of the Natural Resource Stewardship and Science [NRSS] Directorate) can submit a request for technical assistance from NRSS divisions and programs.
- Submit a proposal to receive geologic expertise through the Scientists in Parks program (SIP; see https://www.nps.gov/subjects/science/scientists-in-parks.htm). Formerly the Geoscientists-in-the-Parks program, the SIP program places scientists (typically undergraduate students) in parks to complete science-related projects that may address resource management issues. Proposals may be for assistance with research, interpretation and public education, inventory, and/or monitoring. The GRD can provide guidance and assistance with submitting a proposal. The Geological Society of America and Environmental Stewards are partners of the SIP program. Visit the internal SIP website to submit a proposal at https://doimspp.sharepoint.com/sites/nps-scientistsinparks (only available on DOI network computers).

### Geological Monitoring

*Geological Monitoring* (Young and Norby 2009) provides guidance for monitoring vital signs (measurable parameters of the overall condition of natural resources). Each chapter covers a different geologic resource and includes detailed recommendations for resource managers, suggested methods of monitoring, and case studies. Chapters are available online at https://www.nps.gov/subjects/geology/geological-monitoring.htm.

### Assistance with Coastal and Climate Change-Related Issues

The GRD Coastal Geology program (https://www.nps.gov/subjects/geology/coastal-geology.htm) and the NPS Water Resources Division, Ocean and Coastal Resources program (https://www.nps.gov/orgs/1439/oceans.htm) share responsibility for assisting park managers with resource issues in 88 coastal parks across 23 states. Topics of interest include beach and coastal landforms, shoreline materials, dynamic coastal processes, engineering in the coastal environment, and coastal geohazards.

Park managers may benefit from the following NPS guidance and databases for managing coastal resources, including planning for the impacts of climate change:

- The NPS *Coastal Adaptation Strategies Handbook* (Beavers et al. 2016) provides guidance about climate change adaptation to coastal park managers. Focus topics of the handbook include NPS policies relevant to climate change; guidance on evaluating appropriate adaptation actions; and adaptation opportunities for planning, incident response, cultural resources, natural resources, facilities and assets, and infrastructure. The handbook also provides guidance on developing communication and education materials about climate change impacts and details case studies of the many ways that park managers are implementing adaptation strategies for threatened resources throughout the National Park System.
- The NPS *Ocean and Coastal Park Jurisdiction Handbook* (National Park Service 2016) guides coastal resource management by providing insight for parks with boundaries that may shift with changing shorelines.
- The NPS *Cultural Resources Climate Change Strategy* (Rockman et al. 2016) connects climate science with historic preservation planning and is related to coastal resource management and planning. The strategy identifies and describes seven options for climate change adaptation of cultural resources and cultural landscapes: (1) no active intervention, (2) offset stress, (3) improve resilience, (4) manage change, (5) relocate or facilitate movement, (6) document and prepare for loss, and (7) interpret the change.
- The “Coastal Features and Processes” chapter (Bush and Young 2009) of *Geological Monitoring* (Young and Norby 2009) discusses vital signs for monitoring the following coastal features and processes: (1) shoreline change, (2) coastal vegetation cover, (3) wetland position/acreage, and (4) coastal wetland accretion.

## Historic Site-Specific Documents

The NPS prepares a variety of planning and environmental documents to help guide management of park resources and visitor use. The historic site's GRI scoping summary report (Thornberry-Ehrlich 2011), foundation document (National Park Service 2018), and Natural Resource Condition Assessment report (James-Pirri 2013) were used as primary sources of resource management information during the preparation of this report. Other valuable resources that cover historic site-specific information include the following:

- NPS Coastal Hazards & Sea-Level Rise Asset Vulnerability Assessment for Sagamore Hill National Historic Site (Peek et al. 2015, 2023)
- NPS Development of the Geomorphological Map for Sagamore Hill National Historic Site: Principal Characteristics and Components (Psuty et al. 2016a)
- NPS Archeological Overview and Assessment of Sagamore Hill National Historic Site (Merwin and Manfra 2004)
- NPS Cultural Landscape Report for Sagamore Hill National Historic Site—Volume 1: Site History, Existing Conditions and Analysis (Bellavia and Curry 1995)
- NPS Archeological Collections Management at Sagamore Hill National Historic Site (DeCesare 1990)

## NPS Natural Resource Management Guidance and Documents

- National Parks Omnibus Management Act of 1998: https://www.congress.gov/bill/105th-congress/senate-bill/1693
- NPS-75: Natural Resources Inventory and Monitoring guideline: https://irma.nps.gov/DataStore/Reference/Profile/622933
- NPS Management Policies 2006 (Chapter 4: Natural Resource Management): https://www.nps.gov/subjects/policy/management-policies.htm
- NPS Natural Resource Management Reference Manual #77: https://irma.nps.gov/DataStore/Reference/Profile/572379
- Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager: https://irma.nps.gov/DataStore/Reference/Profile/2283597

## Geologic Resource Laws, Regulations, and Policies

The following tables (Table 4, Table 5, and Table 6), which were developed by the GRD, summarizes laws, regulations, and policies that specifically apply to NPS geologic resources, processes, and energy and minerals. Table 4 summarizes law and policy for geoheritage resources, which includes caves, paleontological resources, and geothermal resources. Table 5 addresses energy and minerals, which includes abandoned mineral lands, mining, rock and mineral collection, and oil and gas operations. Table 6 pertains to active processes such as geologic hazards (e.g., landslides), coastal processes, soils, and upland and fluvial processes (e.g., erosion). The tables do not include laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, NEPA, or the National Historic Preservation Act), but do include the NPS Organic Act when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available.

**Table 4.** Geoheritage resources laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Caves and Karst Systems | **Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309** requires Interior/Agriculture to identify "significant caves" on Federal lands, regulate/restrict use of those caves as appropriate, and include significant caves in land management planning efforts. Imposes civil and criminal penalties for harming a cave or cave resources. Authorizes Secretaries to withhold information about specific location of a significant cave from a Freedom of Information Act (FOIA) requester.<br>**National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of cave and karst resources.<br>**Lechuguilla Cave Protection Act of 1993, Public Law 103-169** created a cave protection zone (CPZ) around Lechuguilla Cave in Carlsbad Caverns National Park. Within the CPZ, access and the removal of cave resources may be limited or prohibited; existing leases may be cancelled with appropriate compensation; and lands are withdrawn from mineral entry. | **36 CFR § 2.1** prohibits possessing/ destroying/disturbing…cave resources…in park units.<br>**43 CFR Part 37** states that all NPS caves are "significant" and sets forth procedures for determining/releasing confidential information about specific cave locations to a FOIA requester. | **Section 4.8.1.2** requires NPS to maintain karst integrity, minimize impacts.<br>**Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.<br>**Section 4.8.2.2** requires NPS to protect caves, allow new development in or on caves if it will not impact cave environment, and to remove existing developments if they impair caves.<br>**Section 6.3.11.2** explains how to manage caves in/adjacent to wilderness. |

**Table 4 (continued).** Geoheritage resources laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Geothermal | **Geothermal Steam Act of 1970, 30 USC. § 1001** et seq. as amended in 1988, states:<br>• No geothermal leasing is allowed in parks.<br>• "Significant" thermal features exist in 16 park units (the features listed by the NPS at 52 Fed. Reg. 28793-28800 (August 3, 1987), plus the thermal features in Crater Lake, Big Bend, and Lake Mead).<br>• NPS is required to monitor those features.<br>• Based on scientific evidence, Secretary of Interior must protect significant NPS thermal features from leasing effects.<br>**Geothermal Steam Act Amendments of 1988, Public Law 100--443** prohibits geothermal leasing in the Island Park known geothermal resource area near Yellowstone and outside 16 designated NPS units if subsequent geothermal development would significantly adversely affect identified thermal features. | **43 CFR Part 3200** requires BLM to include stipulations when issuing, extending, renewing, or modifying leases or permits to protect significant thermal features in NPS-administered areas (see 43 CFR §3201.10), prohibit the bureau from issuing leases in areas where geothermal operations are reasonably likely to result in significant adverse effects on significant thermal features in NPS-administered areas (see 43 CFR §3201.11 and §3206.11), and prohibit BLM from issuing leases in park units. | **Section 4.8.2.3** requires NPS to:<br>• Preserve/maintain integrity of all thermal resources in parks.<br>• Work closely with outside agencies.<br>• Monitor significant thermal features. |

**Table 4 (continued).** Geoheritage resources laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Paleontological Resources | **Archaeological Resources Protection Act of 1979, 16 USC §§ 470aa – mm Section 3 (1)** Archaeological Resource—nonfossilized and fossilized paleontological specimens, or any portion or piece thereof, shall not be considered archaeological resources, under the regulations of this paragraph, unless found in an archaeological context. Therefore, fossils in an archaeological context are covered under this law.<br>**Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309 Section 3 (5) Cave Resource**—the term "cave resource" includes any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems. Therefore, every reference to cave resource in the law applies to paleontological resources.<br>**National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of paleontological resources and objects.<br>**Paleontological Resources Preservation Act of 2009, 16 USC § 470aaa** et seq. provides for the management and protection of paleontological resources on federal lands. | **36 CFR § 2.1(a)(1)(iii)** prohibits destroying, injuring, defacing, removing, digging or disturbing paleontological specimens or parts thereof.<br>**Prohibition in 36 CFR § 13.35** applies even in Alaska parks, where the surface collection of other geologic resources is permitted.<br>**43 CFR Part 49** contains the DOI regulations implementing the Paleontological Resources Preservation Act, which apply to the NPS. | **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.<br>**Section 4.8.2.1** emphasizes Inventory and Monitoring, encourages scientific research, directs parks to maintain confidentiality of paleontological information, and allows parks to buy fossils only in accordance with certain criteria. |

**Table 5.** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Abandoned Mineral Lands and Orphaned Oil and Gas Wells | **The Bipartisan Infrastructure Law, Inflation Reduction Act, and NPS Line Item Construction program all provide funding for the reclamation of abandoned mineral lands and the plugging of orphaned oil and gas wells.** | **None applicable.** | None applicable. |
| Coal | **Surface Mining Control and Reclamation Act of 1977, 30 USC § 1201** et. seq. prohibits surface coal mining operations on any lands within the boundaries of a NPS unit, subject to valid existing rights. | **SMCRA Regulations at 30 CFR Chapter VII** govern surface mining operations on Federal lands and Indian lands by requiring permits, bonding, insurance, reclamation, and employee protection. Part 7 of the regulations states that National Park System lands are unsuitable for surface mining. | None applicable. |

**Table 5 (continued).** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.) | **Materials Act of 1947, 30 USC § 601** does not authorize the NPS to dispose of mineral materials outside of park units.<br>**Reclamation Act of 1939, 43 USC §387**, authorizes removal of common variety mineral materials from federal lands in federal reclamation projects. This act is cited in the enabling statutes for Glen Canyon and Whiskeytown National Recreation Areas, which provide that the Secretary of the Interior may permit the removal of federally owned nonleasable minerals such as sand, gravel, and building materials from the NRAs under appropriate regulations. Because regulations have not yet been promulgated, the National Park Service may not permit removal of these materials from these National Recreation Areas.<br>**16 USC §90c-1(b)** authorizes sand, rock and gravel to be available for sale to the residents of Stehekin from the non-wilderness portion of Lake Chelan National Recreation Area, for local use as long as the sale and disposal does not have significant adverse effects on the administration of the national recreation area. | None applicable. | **Section 9.1.3.3** clarifies that only the NPS or its agent can extract park-owned common variety minerals (e.g., sand and gravel), and:<br>• Only for park administrative uses;<br>• After compliance with NEPA and other federal, state, and local laws, and a finding of non-impairment;<br>• After finding the use is park's most reasonable alternative based on environment and economics;<br>• Parks should use existing pits and create new pits only in accordance with park-wide borrow management plan;<br>• Spoil areas must comply with Part 6 standards; and<br>• NPS must evaluate use of external quarries.<br>Any deviation from this policy requires a written waiver from the Secretary, Assistant Secretary, or Director. |

**Table 5 (continued).** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Federal Mineral Leasing (Oil, Gas, and Solid Minerals) | **The Mineral Leasing Act, 30 USC § 181** et seq., and the Mineral Leasing Act for Acquired Lands, 30 USC § 351 et seq. do not authorize the BLM to lease federally owned minerals in NPS units.<br>**Combined Hydrocarbon Leasing Act, 30 USC §181**, allowed owners of oil and gas leases or placer oil claims in Special Tar Sand Areas (STSA) to convert those leases or claims to combined hydrocarbon leases, and allowed for competitive tar sands leasing. This act did not modify the general prohibition on leasing in park units but did allow for lease conversion in GLCA, which is the only park unit that contains a STSA.<br>**Exceptions: Glen Canyon NRA (16 USC § 460dd et seq.), Lake Mead NRA (16 USC § 460n et seq.),** and Whiskeytown-Shasta-Trinity NRA (16 USC § 460q et seq.) authorizes the BLM to issue federal mineral leases in these units provided that the BLM obtains NPS consent. Such consent must be predicated on an NPS finding of no significant adverse effect on park resources and/or administration.<br>**American Indian Lands Within NPS Boundaries Under the Indian Allottee Leasing Act of 1909, 25 USC §396, and the Indian Leasing Act of 1938, 25 USC §396a, §398 and §399, and Indian Mineral Development Act of 1982, 25 USCS §§2101-2108**, all minerals on American Indian trust lands within NPS units are subject to leasing.<br>**Federal Coal Leasing Amendments Act of 1975, 30 USC § 201** prohibits coal leasing in National Park System units. | **36 CFR § 5.14** states prospecting, mining, and…leasing under the mineral leasing laws [is] prohibited in park areas except as authorized by law.<br>**BLM regulations at 43 CFR Parts 3100, 3400, and 3500** govern Federal mineral leasing.<br>Regulations re: Native American Lands within NPS Units:<br>**25 CFR Part 211** governs leasing of tribal lands for mineral development.<br>**25 CFR Part 212** governs leasing of allotted lands for mineral development.<br>**25 CFR Part 216** governs surface exploration, mining, and reclamation of lands during mineral development.<br>**25 CFR Part 224** governs tribal energy resource agreements.<br>**25 CFR Part 225** governs mineral agreements for the development of Indian-owned minerals entered into pursuant to the Indian Mineral Development Act of 1982, Pub. L. No. 97-382, 96 Stat. 1938 (codified at 25 USC §§ 2101-2108).<br>**30 CFR §§ 1202.100-1202.101** governs royalties on oil produced from Indian leases.<br>**30 CFR §§ 1202.550-1202.558** governs royalties on gas production from Indian leases.<br>**30 CFR §§ 1206.50-1206.62 and §§ 1206.170-1206.176** governs product valuation for mineral resources produced from Indian oil and gas leases. | **Section 8.7.2** states that all NPS units are closed to new federal mineral leasing except Glen Canyon, Lake Mead and Whiskeytown-Shasta-Trinity NRAs. |

**Table 5 (continued).** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Federal Mineral Leasing (Oil, Gas, and Solid Minerals) (continued) | – | **30 CFR § 1206.450** governs the valuation coal from Indian Tribal and Allotted leases.<br>**43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM. | – |
| Mining Claims (Locatable Minerals) | **Mining in the Parks Act of 1976, 54 USC § 100731** et seq. authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas.<br>**General Mining Law of 1872, 30 USC § 21** et seq. allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA.<br>**Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities. | **36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law.<br>**36 CFR Part 6** regulates solid waste disposal sites in park units.<br>**36 CFR Part 9, Subpart A** requires the owners/operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability.<br>**43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska. | **Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at 36 CFR Parts 6 and 9A.<br>**Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries. |
| Nonfederal Minerals other than Oil and Gas | **NPS Organic Act, 54 USC §§ 100101 and 100751** | **NPS regulations at 36 CFR Parts 1, 5, and 6** require the owners/operators of other types of mineral rights to obtain a special use permit from the NPS as a § 5.3 business operation, and § 5.7 – Construction of buildings or other facilities, and to comply with the solid waste regulations at Part 6. | **Section 8.7.3** states that operators exercising rights in a park unit must comply with 36 CFR Parts 1 and 5. |

**Table 5 (continued).** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Nonfederal Oil and Gas | **NPS Organic Act, 54 USC § 100751** et seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights).<br>**Individual Park Enabling Statutes**:<br>16 USC § 230a (Jean Lafitte NHP & Pres.)<br>16 USC §450kk (Fort Union NM)<br>16 USC § 459d-3 (Padre Island NS)<br>16 USC § 459h-3 (Gulf Islands NS)<br>16 USC § 460ee (Big South Fork NRRA)<br>16 USC § 460cc-2(i) (Gateway NRA)<br>16 USC § 460m (Ozark NSR)<br>16 USC§698c (Big Thicket N Pres.)<br>16 USC §698f (Big Cypress N Pres.) | **36 CFR Part 6** regulates solid waste disposal sites in park units.<br>**36 CFR Part 9, Subpart B** requires the owners/operators of nonfederally owned oil and gas rights in parks outside of Alaska to:<br>• Demonstrate valid right to develop mineral rights;<br>• Submit an Operations Permit Application to NPS describing where, when, how they intend to conduct operations;<br>• Prepare/submit a reclamation plan; and<br>• Submit financial assurance to cover reclamation and potential liability.<br>**43 CFR Part 36** governs access to nonfederal oil and gas rights located in, or adjacent to, National Park System units in Alaska. | **Section 8.7.3** requires operators to comply with 9B regulations. |
| Recreational Collection of Rocks and Minerals | **NPS Organic Act, 54 USC. § 100101** et seq. directs the NPS to conserve all resources in parks (which includes rock and mineral resources) unless otherwise authorized by law.<br>**Exception: 16 USC. § 445c (c)** – Pipestone National Monument enabling statute. Authorizes American Indian collection of catlinite (red pipestone). | **36 C.F.R. § 2.1** prohibits possessing, destroying, disturbing mineral resources…in park units.<br>**Exception: 36 C.F.R. § 7.91** allows limited gold panning in Whiskeytown.<br>**Exception: 36 C.F.R. § 13.35** allows some surface collection of rocks and minerals in some Alaska parks (not Klondike Gold Rush, Sitka, Denali, Glacier Bay, and Katmai) by non-disturbing methods (e.g., no pickaxes), which can be stopped by superintendent if collection causes significant adverse effects on park resources and visitor enjoyment. | **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity. |

**Table 5 (continued).** Energy and minerals laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Transpark Petroleum Product Pipelines | **The Mineral Leasing Act, 30 USC § 181** et seq., and the **Mineral Leasing Act for Acquired Lands, 30 USC § 351** et seq. authorize new rights of way across some federal lands for pipelines, excluding NPS areas.<br>The only **parks with the legal authority to grant new rights of way for petroleum product pipelines** are:<br>Natchez Trace Parkway (16 USC §460a)<br>Blue Ridge Parkway (16 USC §460a-8)<br>Great Smoky Mountains National Park (P.L. 107-223 – 16 U.S.C. §403 notes)<br>Klondike Gold Rush (16 USC §410bb(c) (limited authority for the White Pass Trail unit)<br>Gulf Islands National Seashore - enabling act authorizes rights-of-way for pipelines for oil and gas transported across the seashore from outside the unit (16 USC §459h-3)<br>Gateway National Recreation Area - enabling act authorizes rights-of-way for gas pipelines in connection with the development of methane gas owned by the City of New York within the unit (16 USC §460cc-2(i))<br>Denali National Park – 2013 legislation allows for issuance of right-of-way permits for a natural gas pipeline within, along, or near the approximately 7-mile segment of the George Parks Highway that runs through the park (Public Law 113–33) | **NPS regulations at 36 CFR Part 14 Rights of Way** | **Section 8.6.4** states that new rights of way through, under, and across NPS units may be issued only if there is specific statutory authority and there is no practicable alternative. |
| Uranium | **Atomic Energy Act of 1954**: Allows Secretary of Energy to issue leases or permits for uranium on BLM lands; may issue leases or permits in NPS areas only if president declares a national emergency. | None applicable. | None applicable. |

**Table 6.** Active processes and geohazards laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Coastal Features and Processes | **NPS Organic Act, 54 USC § 100751** et. seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights).<br>**Coastal Zone Management Act, 16 USC § 1451** et. seq. requires Federal agencies to prepare a consistency determination for every Federal agency activity in or outside of the coastal zone that affects land or water use of the coastal zone.<br>**Clean Water Act, 33 USC § 1342/Rivers and Harbors Act, 33 USC 403** require that dredge and fill actions comply with a Corps of Engineers Section 404 permit.<br>**Executive Order 13089** (coral reefs) (1998) calls for reduction of impacts to coral reefs.<br>**Executive Order 13158** (marine protected areas) (2000) requires every federal agency, to the extent permitted by law and the maximum extent practicable, to avoid harming marine protected areas. | **36 CFR § 1.2(a)(3)** applies NPS regulations to activities occurring within waters subject to the jurisdiction of the US located within the boundaries of a unit, including navigable water and areas within their ordinary reach, below the mean high water mark (or OHW line) without regard to ownership of submerged lands, tidelands, or lowlands.<br>**36 CFR § 5.7** requires NPS authorization prior to constructing a building or other structure (including boat docks) upon, across, over, through, or under any park area. | **Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks unless directed otherwise by Congress.<br>**Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety.<br>**Section 4.8.1** requires NPS to allow natural geologic processes to proceed unimpeded. NPS can intervene in these processes only when required by Congress, when necessary for saving human lives, or when there is no other feasible way to protect other natural resources/ park facilities/historic properties.<br>**Section 4.8.1.1** requires NPS to:<br>• Allow natural processes to continue without interference,<br>• Investigate alternatives for mitigating the effects of human alterations of natural processes and restoring natural conditions,<br>• Study impacts of cultural resource protection proposals on natural resources,<br>• Use the most effective and natural-looking erosion control methods available, and<br>• Avoid putting new developments in areas subject to natural shoreline processes unless certain factors are present. |

**Table 6 (continued).** Active processes and geohazards laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Geologic Hazards | **National Landslide Preparedness Act, 43 USC §§ 3101–3104** strengthens the mandate to identify landslide hazards and reduce losses from landslides. Established the National Landslide Hazards Reduction Program. "…the United States Geological Survey and other Federal agencies, shall – identify, map, assess, and research landslide hazards;" Reduce landslide losses, respond to landslide events | None applicable. | **Section 4.8.1.3**, Geologic Hazards<br>**Section 9.1.1.5**, Siting Facilities to Avoid Natural Hazards<br>**Section 8.2.5.1**, Visitor Safety<br>**Policy Memo 15-01** (Climate Change and Natural Hazards for Facilities) (2015) provides guidance on the design of facilities to incorporate impacts of climate change adaptation and natural hazards when making decisions in national parks. |
| Soils | **Soil and Water Resources Conservation Act, 16 USC §§ 2011–2009** provides for the collection and analysis of soil and related resource data and the appraisal of the status, condition, and trends for these resources.<br>**Farmland Protection Policy Act, 7 USC § 4201** et. seq. requires NPS to identify and take into account the adverse effects of Federal programs on the preservation of farmland; consider alternative actions, and assure that such Federal programs are compatible with State, unit of local government, and private programs and policies to protect farmland. NPS actions are subject to the FPPA if they may irreversibly convert farmland (directly or indirectly) to nonagricultural use and are completed by a Federal agency or with assistance from a Federal agency. Applicable projects require coordination with the Department of Agriculture's Natural Resources Conservation Service (NRCS). | **7 CFR Parts 610 and 611** are the US Department of Agriculture regulations for the Natural Resources Conservation Service. Part 610 governs the NRCS technical assistance program, soil erosion predictions, and the conservation of private grazing land. Part 611 governs soil surveys and cartographic operations. The NRCS works with the NPS through cooperative arrangements. | **Section 4.8.2.4** requires NPS to<br>• Prevent unnatural erosion, removal, and contamination;<br>• Conduct soil surveys;<br>• Minimize unavoidable excavation; and<br>• Develop/follow written prescriptions (instructions). |

**Table 6 (continued).** Active processes and geohazards laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Upland and Fluvial Processes | **Rivers and Harbors Appropriation Act of 1899, 33 USC § 403** prohibits the construction of any obstruction on the waters of the United States not authorized by congress or approved by the USACE.<br>**Clean Water Act 33 USC § 1342** requires a permit from the USACE prior to any discharge of dredged or fill material into navigable waters (waters of the US [including streams]).<br>**Executive Order 11988** requires federal agencies to avoid adverse impacts to floodplains. (see also D.O. 77-2)<br>**Executive Order 11990** requires plans for potentially affected wetlands (including riparian wetlands). (see also D.O. 77-1) | None applicable. | **Section 4.1** requires NPS to manage natural resources to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities; maintain all components and processes of naturally evolving park ecosystems.<br>**Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks, unless directed otherwise by Congress.<br>**Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety.<br>**Section 4.6.4** directs the NPS to (1) manage for the preservation of floodplain values; [and] (2) minimize potentially hazardous conditions associated with flooding.<br>Section 4.6.6 directs the NPS to manage watersheds as complete hydrologic systems and minimize human-caused disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams.<br>**Section 4.8.1** directs the NPS to allow natural geologic processes to proceed unimpeded. Geologic processes…include…erosion and sedimentation…processes. |

**Table 6 (continued).** Active processes and geohazards laws, regulations, and policies.

| Resource | Resource-specific Laws | Resource-specific Regulations | NPS Management Policies 2006 |
|---|---|---|---|
| Upland and Fluvial Processes (continued) | – | – | **Section 4.8.2** directs the NPS to protect geologic features from the unacceptable impacts of human activity while allowing natural processes to continue. |

# Additional References, Resources, and Websites

## Climate Change Resources

- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
- *Global and regional sea level rise scenarios for the Unites States* (Sweet et al. 2022): https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html.
- NPS Climate Change Response Strategy (2023 Update): https://www.nps.gov/subjects/climatechange/response-strategy.htm
- NPS Green Parks Plan: https://www.nps.gov/subjects/sustainability/green-parks.htm
- NPS National Climate Change Interpretation and Education Strategy: https://www.nps.gov/subjects/climatechange/nccies.htm
- NPS Policy Memorandum 12-02—Applying NPS Management Policies in the Context of Climate Change: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- NPS Policy Memorandum 15-01—Addressing Climate Change and Natural Hazards for Facilities: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- NPS Sea Level Change website: https://www.nps.gov/subjects/climatechange/sealevelchange.htm/index.htm
- NPS Sea Level Rise Map Viewer: https://maps.nps.gov/slr/
- *Sea level rise and storm surge projections for the National Park Service* (Caffrey et al. 2018): https://irma.nps.gov/DataStore/Reference/Profile/2253283
- U.S. Global Change Research Program: http://www.globalchange.gov/home

## Days to Celebrate Geology

- Geologist Day—the first Sunday in April (marks the end of the winter and beginning of preparation for summer field work; formally celebrated in Ukraine, Kazakhstan, Belarus, Kyrgyzstan, and Russia)
- National Cave and Karst Day—6 June, also known as International Day of Caves and Subterranean World
- International Geodiversity Day—6 October: https://www.geodiversityday.org/
- Earth Science Week—typically the second full week of October: https://www.earthsciweek.org/
- National Fossil Day—the Wednesday of Earth Science Week: https://www.nps.gov/subjects/fossilday/index.htm

## Disturbed Lands Restoration

- Geoconservation—Disturbed Lands Restoration: https://www.nps.gov/articles/geoconservation-disturbed-land-restoration.htm

## Earthquakes

- ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States (USGS sponsored): https://www.shakealert.org/
- USGS Did You Feel It? reporting system: https://earthquake.usgs.gov/data/dyfi/
- USGS Earthquake Hazards Program unified hazard tool: https://earthquake.usgs.gov/hazards/interactive/
- USGS Earthquake Hazards Program, Information by Region – New York: https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york
- USGS ShakeMap: https://earthquake.usgs.gov/data/shakemap/

## Geologic Heritage

- NPS America's Geologic Heritage: https://www.nps.gov/subjects/geology/americas-geoheritage.htm
- NPS Geoheritage Sites - Examples on Public Lands, Natural Landmarks, Heritage Areas, and The National Register of Historic Places: https://www.nps.gov/subjects/geology/geoheritage-sites-listing-element.htm
- NPS Museum Collection (searchable online database): https://museum.nps.gov/ParkPList.aspx
- NPS National Natural Landmarks Program: https://www.nps.gov/subjects/nnlandmarks/index.htm
- NPS National Register of Historic Places: https://www.nps.gov/subjects/nationalregister/index.htm
- NPS Stratotype Inventory: https://www.nps.gov/subjects/geology/nps-stratotype-inventory.htm
- UNESCO Global Geoparks: https://en.unesco.org/global-geoparks

## Geologic Maps

- American Geosciences Institute (provides information about geologic maps and their uses): http://www.americangeosciences.org/environment/publications/mapping
- *General Standards for Geologic Maps* (Evans 2016)
- USGS MapView by National Geologic Map Database: https://ngmdb.usgs.gov/mapview
- USGS National Geologic Map Database: https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

## Geological Surveys and Societies

- American Geophysical Union: http://sites.agu.org/
- American Geosciences Institute: http://www.americangeosciences.org/
- Association of American State Geologists: http://www.stategeologists.org/
- Geological Society of America: http://www.geosociety.org/
- New York State Museum: http://www.nysm.nysed.gov/research-collections/geology

- USGS: http://www.usgs.gov/

### Landslides and Slope Movements

- Unstable Slope Management Program for transportation corridor risk reduction: https://usmp.info/client/credits.php
- *Geological Monitoring* chapter about slope movements (Wieczorek and Snyder 2009): http://go.nps.gov/geomonitoring
- *The Landslide Handbook—A Guide to Understanding Landslides* (Highland and Bobrowsky 2008): http://pubs.usgs.gov/circ/1325/

### New York State Geology

- *Geology of New York: A Simplified Account (2nd Edition)* (Isachsen et al. 2000): http://www.nysm.nysed.gov/publications/education-leaflets
- New York State Department of Health Radon Tracker: https://www.health.ny.gov/statistics/environmental/public_health_tracking/about_pages/radon/about_radon
- New York State Geological Association – Field Guidebooks: https://www.nysga-online.org/guidebooks/
- New York State Museum – Archaeology: http://www.nysm.nysed.gov/research-collections/archaeology
- New York State Museum – Geology: http://www.nysm.nysed.gov/research-collections/geology
- New York State Museum – GIS Data: http://www.nysm.nysed.gov/research-collections/geology/gis
- New York State Museum – Paleontology: http://www.nysm.nysed.gov/research-collections/paleontology
- New York State Museum – Publications: http://www.nysm.nysed.gov/publications
- USGS – GIS Data: https://mrdata.usgs.gov/geology/state/state.php?state=NY

### NPS Geology

- NPS America's Geologic Legacy: http://go.nps.gov/geology. This primary site for information about NPS geology includes a geologic tour, news, and other information about geology in the NPS, and resources for educators and park interpreters.
- NPS America's Geologic Heritage: https://www.nps.gov/subjects/geology/americas-geoheritage.htm
- NPS Geodiversity Atlas: https://www.nps.gov/articles/geodiversity-atlas-map.htm. The NPS Geodiversity Atlas is a collection of park-specific webpages containing information about the park's geology and links to additional resources.
- NPS Geologic Resources Inventory: http://go.nps.gov/gri
- NPS Geology subject sites:

  - Archeology: https://www.nps.gov/orgs/1038/index.htm
  - Coastal Geology: https://www.nps.gov/subjects/geology/coastal-geology.htm
  - Energy and Minerals Management: https://www.nps.gov/subjects/energyminerals/index.htm
  - Fossils and Paleontology: https://www.nps.gov/subjects/fossils/index.htm
  - Geohazards: https://www.nps.gov/subjects/geohazards/index.htm
  - Glaciers: https://www.nps.gov/subjects/glaciers/index.htm
  - Mountains—Geology and Physical Processes: https://www.nps.gov/subjects/mountains/geology.htm
  - Rivers and Streams—Fluvial Geomorphology: https://www.nps.gov/subjects/geology/fluvial-landforms.htm
  - Tectonic Landforms and Features: https://www.nps.gov/subjects/geology/tectonic-landforms.htm

### NPS Reference Tools

- NPS Technical Information Center (TIC; repository for technical documents and means to receive interlibrary loans): https://www.nps.gov/orgs/1804/dsctic.htm
- GeoRef. The GRI team collaborates with TIC to maintain an NPS subscription to GeoRef (the premier online geologic citation database) via the Denver Service Center Library interagency agreement with the Library of Congress. Multiple portals are available for NPS staff to access these records. Park staff can contact the GRI team or GRD for access.
- NPS Integrated Resource Management Applications (IRMA) portal: https://irma.nps.gov/. *Note*: The GRI team uploads scoping summaries, maps, and reports to IRMA. Enter "GRI" as the search text and select a park from the unit list.

### Relevancy, Diversity, and Inclusion

- NPS Office of Relevancy, Diversity, and Inclusion: https://www.nps.gov/orgs/1244/index.htm
- Changing the narrative in science & conservation: an interview with Sergio Avila (Sierra Club, Outdoor Program coordinator). Science Moab radio show/podcast: https://sciencemoab.org/changing-the-narrative/

### Soils

- Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS): https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- WSS_four_steps (PDF/guide for how to use WSS): https://irma.nps.gov/DataStore/Reference/Profile/2190427. *Note*: The PDF is contained within SRI_Detailed_Soils.zip, which also contains an index map of parks where SRIs have been completed. Download and extract all files.

## USGS Reference Tools

- Geographic Names Information System (GNIS; official listing of place names and geographic features): http://gnis.usgs.gov/
- Geologic Names Lexicon (Geolex; geologic unit nomenclature and summary): http://ngmdb.usgs.gov/Geolex
- National Geologic Map Database (NGMDB): http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- NGMDB Geochron Downloader: https://ngmdb.usgs.gov/geochron/
- Publications Warehouse: http://pubs.er.usgs.gov
- A Tapestry of Time and Terrain (descriptions of physiographic regions; Vigil et al. 2000): http://pubs.usgs.gov/imap/i2720/
- USGS Store (find maps by location or by purpose): http://store.usgs.gov

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