

**Phase 1 Memorandum – Coastal Engineering Review
ACAD – Evaluate Options And Make Recommendations For Managing
Vulnerable Infrastructure At Bear Island Light Saving Station Impacted By
Erosion (Bear Island, Maine)
TAR 15468**

19 February 2021

Project Background and TAR Request Summary

Bear Island Light Saving Station is a National Register-listed historic complex of lighthouse associated structures on Bear Island in Acadia National Park. The property is under a 60-year historic lease (30 years remain) and the lessee has requested assistance with managing ongoing erosion impacting the historic boathouse (ca. 1889), refer to Figure 1. Storm surge has caused erosion of the land around the granite block foundation under the boathouse and the boathouse is at risk of significant damage without structural intervention.



Figure 1 - Historic Structures at Bear Island with the Boat House Circled

The lessee, per the lease agreement, has been responsible for building and structure maintenance at the site. As part of this maintenance work, the lessee has placed large stones and granite rubble along the shoreline and filled the voids with concrete. Pictures of the repairs from a July 2020 NPS site visit report show the concrete to be in advanced stages of delamination per the American Concrete Institute's Manual of Concrete Inspection (MNL-2(19)) deterioration standards. Timber shoring was being installed during the July 2020 site visit, to help to stabilize the historic structure.

For this situation, NPS has requested that a technical review be conducted to identify the underlying physical processes causing the problem and possible engineered solutions which may be applicable to resist the impacts of these processes. For this review, EA was not tasked with nor did the team review calculations or other background design information in detail but performed a cursory review to assess possible alternatives that may be considered for stabilization of the structure.

Site Conditions

As depicted in the photos provided by NPS, the boathouse is connected to a fixed platform, with a floating dock attached via a gangway (See Figure 2 below as an example). The fixed platform is accessible underneath during normal sea state conditions and was dry during the July 2020 site visit. The old timbers show evidence of repeated wetting/drying, indicating that the water level rises to within a few feet of the top of the fixed platform. NOTE: all elevations in the following discussion are referenced to NAVD88 unless otherwise stated.



Figure 2 - Bear Island Boat House showing Structure, Fixed Dock, and Floating Dock

The elevation of the compromised structure is not available from the information provided to date. However, 2011 USGS LiDAR data available online indicates that ground elevation near the structure is approximately 7.5 ft. Reviewing the FEMA Flood Insurance Study 23009CV001A and 23009CV002A (effective July 20, 2016), the current projected 100-year storm stillwater elevation is 9.2 ft. This is taken from averaging the three closest transects (HC-98, HC-99, and HC-100), as Bear Island does not have a transect run on it. The averaged 100-year return period wave height from these transects is 15.8 ft. The boathouse structure is located within the Coastal VE zone with a base flood elevation of +14.0 ft per the Flood Insurance Rate Maps 23009C1327D and 23009C1329D (both also effective July 20, 2016).

All water elevation data for Bear Island is taken from the neighboring Bar Harbor, ME NOAA gage (8413320). Using NOAA's Online Vertical Datum Transformation tool in conjunction with setting the gage to display data at local Mean Tide Level, the Mean Higher High-Water elevation is +6.0 ft. This provides a FEMA calculated flood surge of +3.2 ft and a wave runup of +4.8 ft. It should be noted that Bear Island is too small for FEMA to separate the classification between the VE (coastal high hazard area) zone and any other flood zones, there may be some portion of the wave runup elevation that is direct wave impacts on the site. The separation of wave elevation and

wave runup is not possible without detailed numerical modeling, therefore the entire remaining flood elevation is assumed runup for the purposes of this memorandum.

NPS coastal guidance on sea level rise and storm surge projections (2018) estimate sea level rise (RCP6.0) as +0.30 ft in 2030, +0.52 ft in 2050, and +1.28 ft in 2100. The State of Maine follows USACE online tools (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html) to estimate sea level rise for similar scenarios as +0.85 ft in 2030, +1.61 ft in 2050, and +4.04 ft in 2100. Utilizing the Maine standards, as they are more conservative, provides a 100-year flood elevation (with wave runup) of 14 ft currently, 14.85 ft in 2030, 15.61 ft in 2050, and 18.04 ft in 2100.

Table 1 - 100 Year Storm with SLR Comparison

Year	NPS SLR and 100 Year Storm (ft NAVD88)	USACE SLR and 100 Year Storm (ft NAVD88)
2021	14.00	14.00
2030	14.30	14.85
2060	14.52	15.61
2100	15.28	18.04

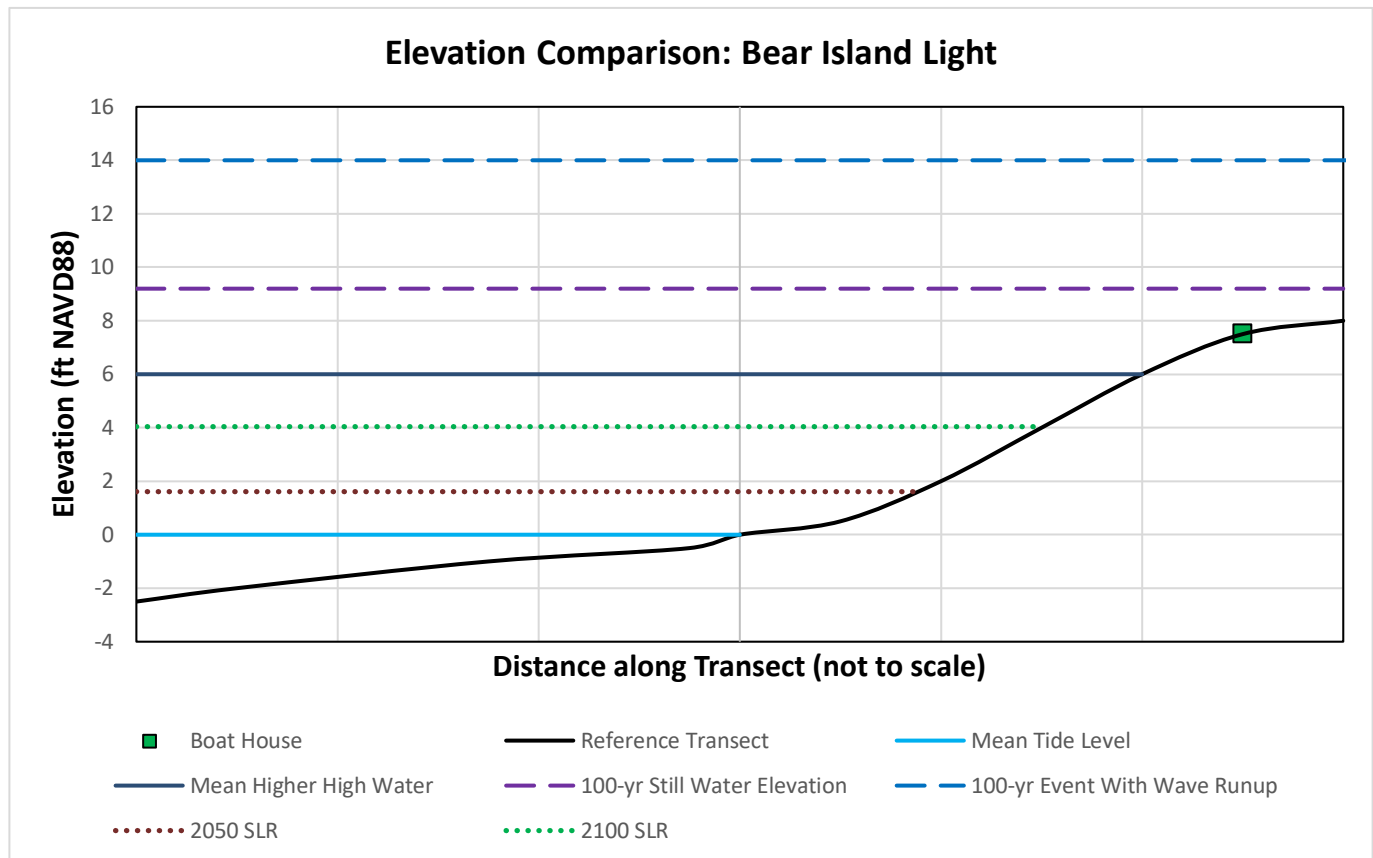


Figure 3 - Elevation Comparison

Current anecdotal information provided by the lessee, specifically his assertion that a previous winter storm “moved the structure 6 inches” as recorded in the NPS site report, indicates one structural failure mode already being experienced. That failure mode is that erosion taking place around and underneath the historic structure is allowing heavy winter storms to uplift and shift the building. This is an immediate concern and will cause significant damage or destruction of the historic facility unless addressed.

Possible Adaptation Options

Protection options for the structure in the short and long term can take a few differing approaches. These can be summarized within these three categories:

- 1) Relocation or Abandonment of the Structure
- 2) Securing the Foundation of the Structure
- 3) Shoreline Stabilization

A discussion of each follows.

1) Relocation or Abandonment:

The current location of the historic boathouse at the estimated ground elevation of 7.5 ft NAVD88 already exposes the structure to significant risk as it is within the 100-year storm event water level. As noted previously the structure is currently experiencing structural impacts at the foundation causing impacts and possibly movement of the structure. The risk of storm damage will gradually increase with climate change-associated impacts leading to increasing sea levels and frequency and severity of storms. Depending on the ultimate preservation goals for this structure, NPS could complete a cost-benefit analysis to review the preservation of the structure at its present location through the means noted below or relocation of the structure to a higher elevation on the island. Relocation sites and the relative cost of this operation could be reviewed through a more in-depth engineering analysis.

Abandonment of the structure can also be gauged as an option based upon a cost-benefit analysis. If the coastal impacts are left unmitigated, these will eventually lead to the collapse of the boathouse. If this is the chosen option, the state of the structure should be monitored, with demolition occurring once it is no longer safe for use to prevent the generation of debris following a structural collapse.

2) Secure the Foundation:

This strategy has been employed by both the USGC and the lessee for an ongoing period starting before 1990 to varying degrees of success. The next iteration in this process could entail several steps to reinforce the existing structure to the ongoing coastal impacts to the most practicable extent. This could include the following:

- a. Rebuilding or stabilization of the understructure of the building with timber and/or more durable material, including steel. This step would include structural engineering design based on the existing conditions and projected wave force loading.
- b. Installation of concrete fill within the understructure. This would necessarily include reinforcement of the concrete and drilling into the rock substrate to anchor this new structural component. This would also involve engineering design and will require geotechnical evaluation of the foundational areas through subsurface drilling.

- c. In addition to both items a and b or just item a above, an adjacent-to-foundation armoring system could be devised including riprap, sheet pile, or reinforced concrete outside of the existing foundation footprint.

3) Shoreline Stabilization:

This concept would be similar to 2c above but would either be physically touching the foundation or located a distance from the foundation out in the water. The location would be based upon engineering analysis to determine the most beneficial placement based on the resources available. This solution would also require a thorough geotechnical analysis of the subsurface to determine applicability and possible design constraints. The primary goal of the stabilization would be to dissipate wave force before it could impact the boathouse structure. The challenge of such a structural solution lies in the expected water levels. These structures would be able to greatly reduce wave force to a certain water level, but unless projecting to elevations which would significantly impair the view-scape of the area, they will not be able to fully protect the boathouse structure. Depending on preservation goals, such structures may also need to be configured in such a way as to allow functional use of the docks associated with the boathouse.

There are various options for shoreline stabilization near the boathouse which could include, but are not limited to, the following:

- a. Steel Sheet Piles – These could be installed to provide resistance against the projected wave forces in a location either adjacent or offset from the existing foundation. As the substrate is expected to be rock, there would need to be extensive rock drilling to provide the necessary anchoring of the sheet piles to complete this installation. Depending on the offset distance from the foundation, the material can also be placed between the sheet pile and the foundation to create additional land surface if beneficial to the stabilization objectives.
- b. Bin Wall - A bin wall is a structure that uses steel ‘bins’ filled with material including earth, concrete, or rock to provide stabilizing weight. This structure would also necessarily need to be anchored into the substrate rock through drilling and/or laterally deployed rock anchors. In a configuration at the subject site, the front face of the bin wall would be offset from the structure with the rear wall possibly adjacent to the foundation or at a greater distance. As in the case of the steel sheet pile, material may be placed between the Bin Wall and the foundation to create additional land surface if beneficial.
- c. Rip Rap Armor Stone – Riprap of sufficient size to resist wave force could be deployed outside of the other deployed techniques (a and b above). This may allow for greater wave force dissipation and further protection of these structures. It is possible riprap could also be deployed as the primary protection adjacent to the secured foundation. This decision will need to be based upon further engineering review. Riprap armor stone can also be stabilized by additional means including concrete.

Regarding the shoreline stabilization options, it is important to consider the possible impacts to the adjacent shoreline of the island from such measures. This is the case because hard structure armoring deflects wave energy towards other portions of the shoreline. These impacts are in some cases offset by utilizing more nature-based solutions for stabilization. However, such methods which can include expansion of coastal wetlands or marine forests would not be applicable at the site primarily due to the rocky shoreline geological configuration of the island.

Summary:

The historic boathouse on Bear Island in Acadia National Park is located within the VE zone of FEMA's flood insurance rate maps and currently experiencing structural deterioration from coastal force impacts. As noted above, various options can be undertaken at the site which fall into three categories: 1) relocation or abandonment of the structure, 2) securing the foundation of the structure, and/or 3) providing shoreline stabilization.

It is suggested that, depending on the overall preservation goals for the structure, a cost-benefit analysis be undertaken to compare the various alternatives as noted within this memorandum. The act of creating a cost benefit analysis provides a valuable first step to planning for the ultimate disposition for the boathouse. The team is available to generate a 2nd Memorandum which could derive the relative costs for the items discussed herein for the cost-benefit analysis to guide the next applicable steps for the site.