



Sand Island Lighthouse



Restoration Plan

Prepared for:
The Town of Dauphin Island
and Alabama Lighthouse Association



thompson
ENGINEERING

Sand Island Lighthouse Restoration Plan

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Prepared for:

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and the

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Introduction

Sand Island Lighthouse is located on a manmade rock island in the Gulf of Mexico approximately three miles south of Dauphin Island, Alabama. Construction of the 126-foot lighthouse was completed in 1873. The lighthouse functioned until 1933 when it was deactivated by the U.S. Coast Guard in response to the technological advancements made in ship board navigation equipment that caused coastal lighthouses to become obsolete.

For much of its 134 years of existence, Sand Island Lighthouse served as the principal beacon guiding ships entering Mobile Bay. The lighthouse is a significant historical structure for the Mobile Bay area and the State of Alabama. Sand Island Lighthouse is the oldest of Alabama's three coastal lighthouses and it is the last of the classic brick lighthouse design built along the coastline of the Gulf of Mexico. Having successfully weathered many major storm events and thus far resisted the effects of severe coastal erosion, the lighthouse remains a credit to its early engineering design.

Following deactivation by the U.S. Coast Guard in 1933, the lighthouse was abandoned. Neglected, the forces of nature began the relentless decay and deterioration of the tower that continue to affect the structure today. Aging over the years in the harsh Gulf coastal environment has resulted in the deterioration of the mortar binding the bricks and in the corrosion of the ironwork comprising the stairs and other structural components of the lighthouse tower. Questions also exist as to the integrity of the foundation bearing the tower. And most obvious of all, Sand Island, the lighthouse's namesake, has migrated to the west, leaving behind the tower and its blanket of protective rocks to be battered by the periodic fierce hurricanes that have attacked the lighthouse over the years.

In September 2007, Thompson Engineering, Inc. completed a study directed at investigating the feasibility of restoring the lighthouse to a condition that would preserve its major structural features and allow safe access to the public. The study was led by C. Jackson (Jack) Granade, Jr., P.E. who served as Thompson's Project Manager and Senior Structural Engineer. Principal consultants contributing to the study were John T. Walsh, P.E. of G.C. Ironworks in New York; Michael Davidson of the Mississippi Stone Guild in Eupora, Mississippi; Charles A. Weiss, Jr., Ph.D., P.E. of the U.S. Army Corps of Engineers' Engineer Research and Development Center in Vicksburg, Mississippi; and Scott L. Douglass, Ph.D., P.E. of the University of South Alabama in Mobile, Alabama.

This pamphlet provides a summary of the feasibility study's findings and recommendations. The Town of Dauphin Island and/or the Alabama Lighthouse Association should be contacted if examination of the full report is desired.

The Study

The General Services Administration transferred ownership of the Sand Island Lighthouse from the Federal Government to the Town of Dauphin Island, Alabama, in November 2003. Working closely with the Alabama Lighthouse Association to preserve this important historic landmark, the Town contracted with Thompson Engineering, Inc. in 2006 to study the feasibility of restoring the Sand Island Lighthouse. The study addressed the following principal objectives:

- Assess the condition and integrity of the foundation
- Assess condition of the masonry features
- Assess condition of the iron and metal work
- Assess the stability of the island on which the lighthouse is located

The study approached the restoration problem in two phases.

- First, Emergency Stabilization Measures were identified to stabilize the tower and prevent its further deterioration until long-term actions could be taken to restore the lighthouse.
- Second, a Long Term Restoration Plan was developed that described a comprehensive restoration program to repair structural deficiencies in the lighthouse and return the tower and the surrounding island to a safe condition that would be conducive for promoting public visits to this historic structure.

History of the Lighthouses on Sand Island

The Early Lighthouses

Lighthouses were critical to early navigation and commerce in the United States. Prior to development of the sophisticated electronic navigation equipment now in use, lighthouses served as essential sentinels marking the entrances into rivers and ports and warning mariners against hazardous shoals. Only a few of the nation's lighthouses continue to function today, with most remaining as abandoned reminders of their past importance to our country's navigation history.

The existing lighthouse tower on Sand Island is the fourth structure that has served to mark the entrance into Mobile Bay across the shifting outer bar channel.

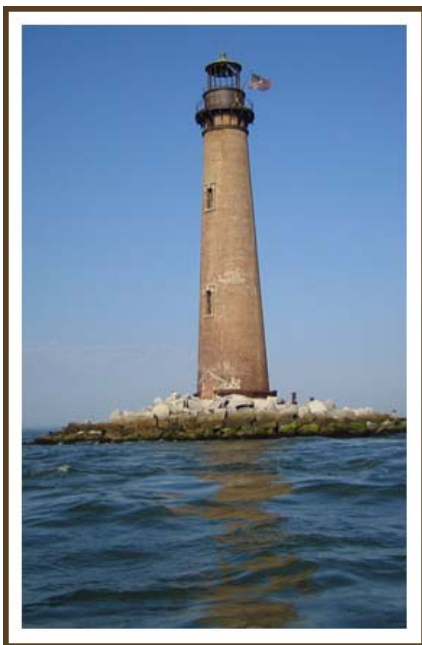


The first navigation aid constructed on Sand Island in 1830 was an unlighted iron spindle. The spindle was used to indicate the mouth of Mobile Bay so that ships desiring access to the port at Mobile could be directed to the more stable and less dangerous Petit Bois Pass to the west between Dauphin Island and Petit Bois Island. After entering the Mississippi Sound at that location, ships would then navigate along the north side of Dauphin Island before entering Mobile Bay and thence the city at the head of the bay.

Because of the inadequacy of the unlighted iron spindle as a navigation aid, it was replaced in 1838 with a 55-foot lighted tower. The need for the lighthouse reflected the increasing importance of Mobile as a seaport and assisted mariners to better identify the more direct route through the mouth of Mobile Bay and across the unreliable outer bar channel into the Gulf of Mexico.

To better meet the increasing navigation needs of the Port of Mobile as commerce grew in the Gulf between the nation's burgeoning seaports, a 150-foot lighthouse was completed in 1858 to replace the smaller tower. However, that vastly improved new lighthouse only functioned for three years. With the outbreak of the Civil War and the control of the seas by the superior United States Navy, Union forces began to seize the offshore lighthouses. Once in Union hands, the lighthouses that heretofore had served as navigation aids for the Southern ports, now posed potential threats to Confederate coastal fortifications by providing elevated structures from which Union troops could spy. To eliminate the threat to Fort Morgan and Fort Gaines that protected the mouth of Mobile Bay, Confederate troops destroyed the Sand Island lighthouse with explosives in 1861. This fate was shared by 160 other lighthouses along the Gulf Coast.

Even before Civil War ended, with the control of the mouth of Mobile Bay in Union hands, the Federal Government initiated steps to replace the destroyed lighthouse marking the entrance into the bay. A temporary lighthouse having a light 48 feet above sea level was constructed in 1865. That temporary structure continued to operate until the present-day lighthouse was completed in 1873.



The Existing Lighthouse

Construction of the 126-foot Sand Island Lighthouse that marks the approach into Mobile Bay today was completed in 1873. The tower is all that remains of the various auxiliary structures that were constructed over the years after 1873 to support the lighthouse station in meeting its navigation mission.

The foundation of the lighthouse is a significant structure, made up of 171 wood pilings that are interconnected by a timber grillage and overlain with 12 feet of concrete. The tower is approximately 28 feet in diameter at its base and is comprised of bricks, forming a wall that is six feet thick near the foundation.

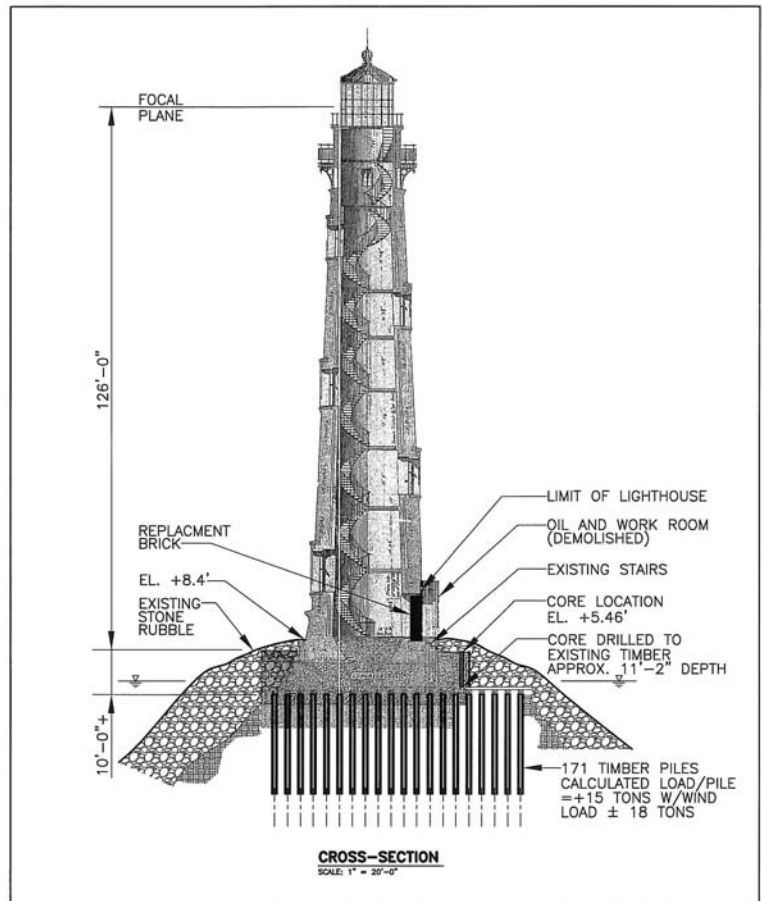
The plinth is the name of the eight-sided base upon which the circular lighthouse tower sits. The upper portion of the plinth is adorned with a brick feature covered in a cast iron ring that is collectively referred to as the cornice. The lowermost portion of the plinth consists of an extension of bricks at its base that are also covered by a cast iron ring.

The granite rock framing the entrance door and five windows came from the remains of the old tower that was destroyed in the Civil War. The conical roof of the tower is covered in copper.

Eight flights of spiral iron stairs provide access from the ground floor to the watch room where the light was once located. Each of the first six and the final eighth flights makes a half revolution within the tower. A landing is located at the top of each flight. The seventh flight makes a full 360-degree revolution of the tower prior to opening onto the watch room. Anchored within the brick walls of the tower, the iron stairs and landings do not require center supports which results in the tower being open throughout its center from the floor to the top.

The second order Fresnel lens that was once contained within the lighthouse was reported to have been visible for a distance of over 17 miles. The lens has been removed from the Lighthouse and is now on display in the museum at Fort Morgan.

The lighthouse is surrounded by heavy granite stones and other rock materials that have been placed at various times since the 1880s to protect its foundation.



Details of Sand Island Lighthouse

Forces Acting on the Lighthouse

Two principal forces of nature, coastal erosion and weathering, act separately and in combination to adversely affect the physical integrity of the lighthouse tower.

Coastal Erosion

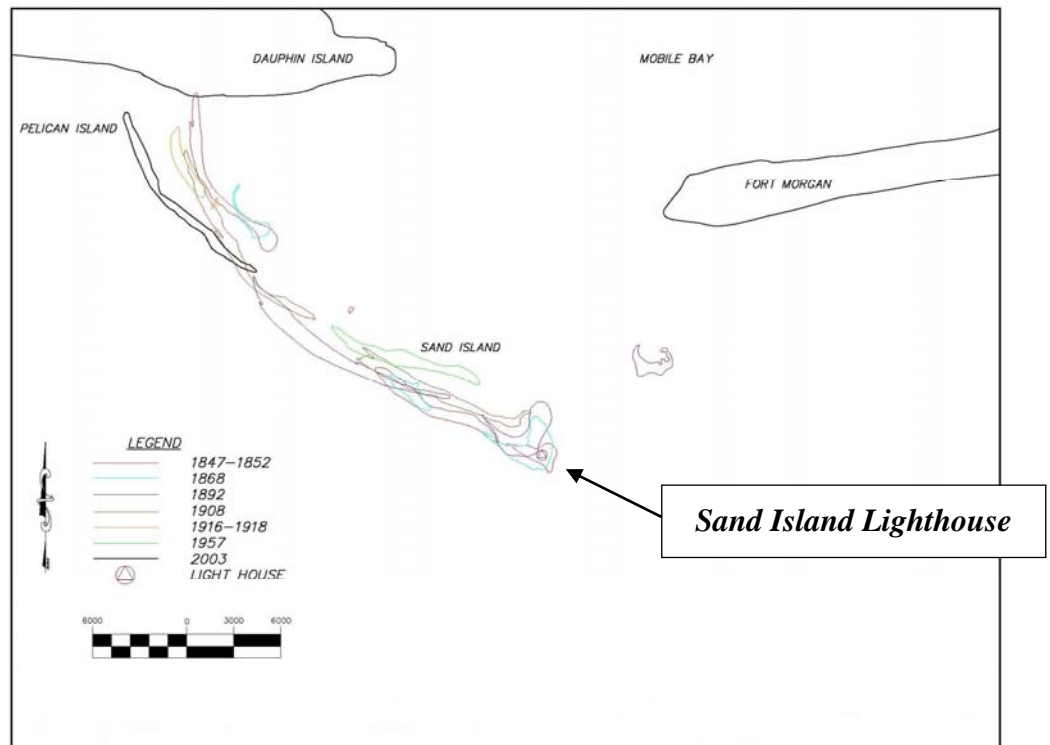
Coastal erosion is threatening to undermine the tower's foundation. The erosion results from two processes that, although they work independently of one another, are having a synergistic negative effect on the foundation underlying the lighthouse. Those forces are (1) the predominant east-to-west littoral drift of sand which has resulted in the migration of Sand Island to the west, away from the lighthouse; and (2) the regular exchange of tides between Mobile Bay and the Gulf of Mexico that continuously moves and reworks bottom sediments in the vicinity of the mouth of Mobile Bay.

Sand Island is part of the outer bar located at the mouth of Mobile Bay in the open waters of the Gulf of Mexico. Comprised entirely of unconsolidated sands, the island is highly unstable, with its shoreline being continually reconfigured by the effects of tidal flows, littoral drift, and the forces of tropical storms. Examination of historic maps and coastal surveys document the history of continual change that has always characterized Sand Island's shoreline. Sand Island has continued to migrate to the west, leaving the Lighthouse in the open waters of the Gulf of Mexico. As the island sands have moved westward, only the existing blanket of rocks remains to protect the Lighthouse's foundation from being undermined.

Bottom depths in the vicinity of the lighthouse generally range around 20 feet. However, four scour holes occur in the bottom near the lighthouse island exceeding 45 feet in depth, with one exceeding 55 feet. The holes are close enough to the toe of the lighthouse island that they may have the potential to undermine the rock blanket covering the island and the underlying sand within which the foundation of the lighthouse is embedded. This could result in the catastrophic failure of the tower.

Dredging of the Mobile Harbor Ship Channel has contributed to long term starvation of sand for the shoals around the lighthouse. The U.S. Army Corps of Engineers dredges sand from the Mobile Harbor Bar Channel. Beginning in 1999, the Corps has regularly disposed of this material in the Sand Island Beneficial Use Area (SIBUA) to the south of the lighthouse. If this sand could be disposed of immediately to the east and updrift of the lighthouse on a regular basis, it could assist in replenishing the sand that has been lost through erosion and prevent the existing rock island supporting the lighthouse from being undermined.

Dredging of the Mobile Harbor Bar Channel occurs about every other year, unless tropical storm events results in excessive shoaling of the channel that may necessitate more frequent dredging. The quantity of material dredged from the Bar Channel and disposed in the SIBUA averages over 1 million cubic yards for each dredging action. Discussions with Corps personnel indicate the reliability of placing the material at the lighthouse is problematic. Presently, draft limitations of many hopper dredges make it difficult for some of these vessels to operate efficiently and safely in the depths near the lighthouse. If the operating efficiency of hopper dredges near the lighthouse could be improved without increasing dredging costs, it would be possible to take advantage of a perpetual supply of free sand to protect the toe of the lighthouse island.



Historic Changes in Sand Island Shoreline Since 1847

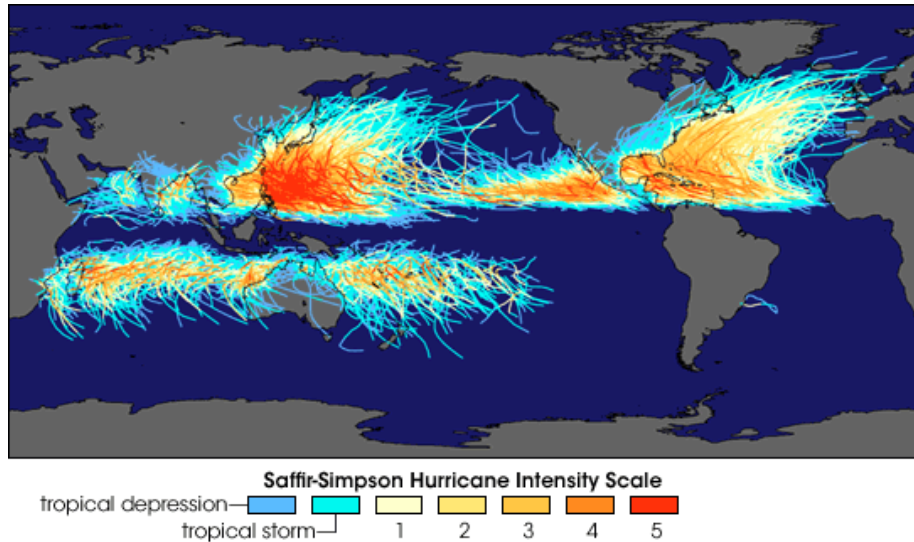
Weathering

The effects of weather, salt spray, blowing sand, and wave action are constantly corroding the iron stairs and deteriorating the mortar binding the tower's bricks. The effects of these conditions, particular wind-driven sand are most pronounced during powerful tropical storms that occasionally affect this area. While the alternating effects of sun, heat, cold, wind, moisture, and salt have relentlessly attacked the bricks, mortar, metal, and concrete of which the Lighthouse is made, it is the tropical cyclonic storms that offer the single greatest threat to the tower. The greatest threat posed by tropical storms and hurricanes to the Sand Island Lighthouse is associated with the combination of storm surge; the battering effects of crashing

waves; and the powerful winds that blow continuously for hours in a single direction putting considerable stress on the tower.

The Gulf of Mexico is a frequent target for tropical storms and hurricanes. The accumulation of hurricane tracks over the last 150 years reveals that the northern Gulf of Mexico has historically been in the path for many Category 3 and 4 hurricanes. The streak of bright red through the center of the northern Gulf in which the Sand Island Lighthouse is located highlights that this region experiences the majority of the strongest Category 5 hurricanes.

Storm wave forces may eventually destroy the lighthouse if nothing is done. The wave climate around the lighthouse is extreme due to the lighthouse's location in the open Gulf of Mexico. A large breaking wave could produce enough force at the base of the lighthouse to severely damage or even cause failure to the lighthouse. The most important protection for the lighthouse over the past century has been the large rocks that blanket the existing small island upon which the lighthouse stands.



Worldwide Tracks of Tropical Cyclones Over the 150-Year Period Through 2006

Existing Condition of the Lighthouse

The Thompson Engineering Study revealed the following information about the conditions of the major features of the lighthouse.

Foundation

Investigation of a +11-foot core sample of the foundation did not indicate any outward signs of decay of the timber materials. In addition, the associated concrete foundation does not

appear to be in danger of failure. The concrete foundation does not show any noticeable cracks or reflective cracking in the brick walls at the base of the lighthouse. The foundation also seems to be level and the lighthouse remains relatively plumb which indicates the lighthouse foundation has not rotated or experienced differential settlement.

Despite the relatively good condition of the lighthouse's foundation materials, without the protective stone mound covering that holds the land mass in position beneath the lighthouse, the timber piling would be ineffective in continuing to support the tower.

Masonry

The lighthouse has two distinct vertical cracks (one on the east side and one on the west side) that extend for much of the height of the tower and completely through the wall from the exterior to the interior. The width of these major cracks averages about 3/8 to 1/2 inch, with the maximum width measured at 1 inch. There are also smaller, tighter vertical cracks on the



south face of the lighthouse that extend between the windows. While the south-facing cracks do not appear to extend through to the interior wall of the lighthouse, they are nevertheless a concern from a structural standpoint. When considered together, all three cracks (east, west, and south) give the impression that the

lighthouse tower is now comprised of two or three separate vertical columns of bricks, depending upon the location within the tower examined. This indicates that the lighthouse tower is considerably weakened from a structural standpoint. The east and west vertical cracks that stretch over most of the height of the tower above the plinth offer the most serious concerns for the long term stability of the lighthouse.

Exterior bricks on the west side of the lighthouse are pitted from the constant sandblasting that occurred in the early years when the lighthouse was surrounded by Sand Island. The original lighthouse was coated with tar or bitumen but this was worn off by the sand blasting and general weathering that has affected the structure.

*External Vertical
Cracking on East Side of
Lighthouse*



*Damage to Cast Iron Ring on West
Side of the Base of the Lighthouse*

The lighthouse base (i.e., plinth) has upper (i.e. cornice) and lower (i.e. base) rings of cast iron. The cast iron rings are badly deteriorated from rust and severe pounding from rock boulders that have been moved during the many storms to which the lighthouse has been exposed over the years.



Metal Features

Extreme rusting (and swelling) of the embedded I-beams that support the stair landings caused the masonry to crack and form the continuous vertical cracks on the east and west sides of the lighthouse described above.

The metal rings forming the cornice and surrounding the base of the lighthouse have also experienced considerable corrosion over the years, with the base ring being severely damaged by the pounding of wave-driven rock boulders during major storm events.



The eight flights of internal stairs, rails and landings have all experienced considerable corrosion over the life of the lighthouse, as has the lantern room and exterior platform and associated handrail surrounding the outside of the lantern room. The structural integrity of these metal features has been weakened to the point that they are unreliable for restoration. The stairs, handrails, and landings and associated hangar rods and platform brackets and all metal associated with the lantern room need to be repaired or replaced if safe access is to be provided to the top of the lighthouse.

Although the copper roof is basically intact, two panels have been bent out of place, but still remain attached to the roof.



Representative views of corroded and damaged iron in stairs, landings, platforms, handrails, and damaged roof panels.



Lower window on north side of lighthouse used to access tower

Windows and Door

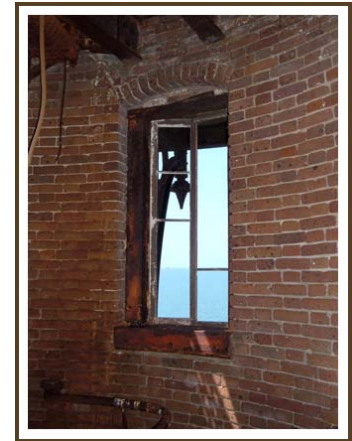
The lighthouse tower originally contained an exterior door and five windows at staggered locations along its vertical height. The door and two of the windows were located in the south side of the tower, while the other three windows were placed in the north side. They were constructed in a staggered position to allow light to enter the tower during the day for ease of transiting the stairs from the floor to the lantern room.

The original door was bricked and sealed many years ago while the lighthouse was still in service. This was probably done because of recurring problems with hurricane storm surge conditions that flooded the lower lighthouse through the door opening.

With the closing of the door, the lowermost window on the north side of the tower was converted to the entry door used by the lighthouse keeper. The lowermost window still serves today as the access point into the tower.

Four smaller windows are contained in the top of the tower just beneath the metal portion of the lantern room. The small windows are located at 90-degree positions (i.e., south, west, north, and east) around the circumference of the tower.

All of the windows are made of wood casings and glass and are seated in an iron frame. The iron materials have corroded beyond repair, the wood has rotted, and the glass is missing from the windows.



Interior view of one of the small windows near the top of the lighthouse

Conclusions

The following conclusions were developed to address the principal structural problems faced by the lighthouse. The conclusions are listed in priority order to reflect their relative importance as they relate to the potential to influence the structural integrity of the lighthouse in the near term, and the risk that that the lighthouse could experience significant - and possibly irreparable - damage if actions are not taken.

- Repair the vertical cracks and add anchored stainless steel tension rings within the interior of the lighthouse to bind the tower together and restore its integrity as a solid unit. Also, embed stainless steel ties across the cracks during masonry repairs to give additional strength to the mortar.
- A critical feature of any restoration plan will be the inclusion of measures to protect and enhance the integrity of the island upon which the lighthouse foundation is embedded.

- Since the integrity of the lighthouse foundation depends upon the stability of the island's existing protective rock blanket, sidescan sonar and multibeam technology surveys should be periodically undertaken to monitor the slope of the underwater rock covering and water depths at and near the toe of the island.
- Conduct discussions with the U.S. Army Corps of Engineers to determine the feasibility of reliably disposing of material dredged from the Mobile Harbor Bar Channel immediately to the east of the Sand Island Lighthouse. The engineering, institutional, contractual and financial obstacles to this approach should be examined and solutions identified.
- The restoration plan for the lighthouse should include repair of the damages to the plinth: (1) replace damaged bricks; (2) repoint eroded mortar; and (3) replace the cast iron rings with a suitable metal that would be more resistant to corrosion and capable of withstanding the pounding from wave driven boulders to which it would be exposed periodically.
- The tower's masonry should be repaired before the present minor cracks are exacerbated by the elements. It would be desirable to repoint the mortar and replace the damaged bricks concurrent with work to repair the vertical cracks and the plinth. However, if funding limitations would prevent all masonry problems from being addressed at the same time, some of the tower masonry damage could be repaired at a later date after the more critical masonry work is undertaken.
- The internal stair system, landings, lantern room, and the platform and handrails surrounding the exterior of the lighthouse must be replaced in their entirety or repairs undertaken to make them safe. The roof should be repaired by a qualified coppersmith. The repair should consist of bending the two panels back in place and soldering clips on the underside of the panels. Similarly, small patches could be soldered over the torn section of copper panel. All metal should receive a protective coating to resist corrosion.
- A long-term restoration program should include measures to replace the windows and to provide a functioning door representative of the 1870s when the lighthouse was constructed.
- It is believed that the foundation of the lighthouse is relatively stable and is not experiencing any major structural problems. Nevertheless, a visual inspection of the foundation should be made each year to ascertain if any cracks or other problems are developing. The inspection should include the preparation of a brief narrative report and be accompanied by photographs of key lighthouse features associated with the foundation (i.e. concrete platform, lighthouse base, rock blanket, etc.).

Recommended Approach to Restoration

At 134-years of age and having been continuously exposed to the elements (sun, alternating heat and cold, salt air, moisture, and hurricane force winds) and the sustained attacks of coastal erosion, the Sand Island Lighthouse has developed a number of serious structural problems. If repairs are not pursued in a timely and systematic fashion, the future integrity of the lighthouse is in jeopardy. If it is not possible to pursue repairs of all of the problems in a single effort, specific structural issues should be addressed in the order in which they are presented below to address the most critical structural issues affecting the lighthouse in a logical phased fashion.

The repair of masonry and metals cannot be easily separated because of the integral nature they play in the structural design of the lighthouse. Therefore, such repairs should be addressed simultaneously. This is also the most cost-efficient approach.

Restoration should be pursued in two phases. The initial phase would consist of emergency stabilization repairs to prevent the lighthouse tower from collapsing. The emergency repairs would serve as the foundation for the second phase of work - addressing weathering issues, replacing damaged metals, and creating conditions that would make visits to the island possible and access into the lighthouse safer (Long-Term Restoration Plan). In addition, a regular monitoring program has been identified for specific features of the lighthouse to obtain information that could be considered in determining if additional actions are warranted.

Emergency Stabilization Measures

The Emergency Stabilization Measures consist of the minimum masonry repairs that would provide the lighthouse with the strength needed to withstand the next severe storm. *The Emergency Stabilization Measures should be implemented as soon as possible (i.e., preferably within the next two years) to address the most serious areas of deterioration that threaten the structural integrity of the Lighthouse.* The Emergency Stabilization Measures would involve the following activities:

- Seal vertical cracks by injecting a hydraulic lime slurry grout to tie and seal off all breaks in the masonry from the exterior surface through to the interior wall. Embed stainless steel ties across cracks and replace broken and missing bricks.
- Install 16 tension rings within the interior wall of the tower – a set of two rings below and above each of the eight stair landings. The purpose of the tension rings would be to stabilize the lighthouse by tying together the vertical tower segments that have been separated by the existing cracks. The tension rings would be made of high

strength stainless steel cables. The cables would extend in a circular fashion through a series of stainless steel eye-bolts that would be anchored into the interior wall of the lighthouse tower.

- Repair the cast iron ring protecting the cornice in the plinth section of the lighthouse. Repair of the cornice cast iron ring and the underlying supporting bricks would provide protection against the pounding the cornice experiences during storms. The repairs should include the replacement of all missing and damaged bricks comprising the cornice. The bricks must be repaired first since they must support the covering cast iron ring. Cast iron pieces would be manufactured to replace the damaged and missing iron segments.
- Repair the cast iron ring protecting the base of the plinth section. This cast iron ring and the underlying bricks have been extensively damaged as a result of corrosion and the pounding the lowest portion of the lighthouse experiences from waves and wave-driven boulders that crash against the lighthouse during storm events. The base would be repaired by constructing a new reinforced concrete ring that would be placed on top of and envelop the existing base. Steel dowels would be drilled into the base bricks and attached to steel reinforcing bars that would be curved around the base and embedded within the concrete. The concrete would be colored to create the illusion of corroded metal to match the cornice cast iron ring. Construction of the reinforced concrete ring could be accomplished without having to disturb any of the existing protective rocks surrounding the lighthouse base. This approach would reduce the risks to the lighthouse during construction, while providing a stronger ring around the base of the lighthouse in a cost-efficient manner. The Alabama State Historic Preservation Officer supports this approach. (Note: Installation of the reinforced concrete ring and repair of the underlying damaged masonry will be accomplished during 2008 with a grant provided by the Federal Emergency Management Agency to repair damages attributed to Hurricane Ivan.)
- Reattach loose copper roof panels.
- Stabilize the lowest window on the north side of the lighthouse that is presently used to gain access to the inside of the lighthouse. This window is in danger of falling out of the tower and needs resetting with lime mortar.

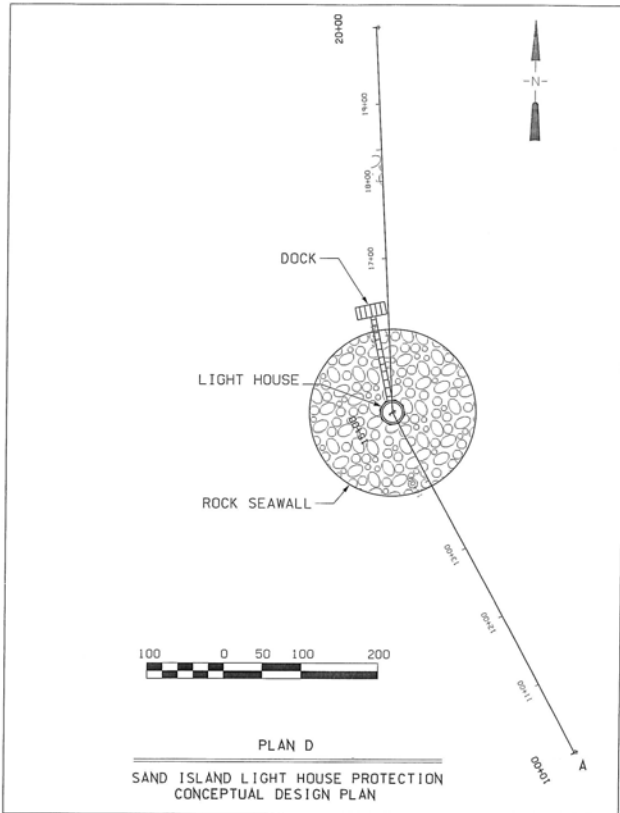
The total cost of the recommended Emergency Stabilization Measures was estimated to be \$1,300,000.

Long-Term Restoration Plan

The Long Term Restoration Plan includes a variety of repairs that should be undertaken to return the lighthouse to a condition similar to that which existed when it was last in service as a functioning aid to navigation. Implementation of these measures would allow the public to visit the island safely, including safe access into the lighthouse. *Implementation of the Long-Term Restoration Plan should begin within the next five years.* The Long-Term Restoration measures can be assigned to the following three categories of actions:

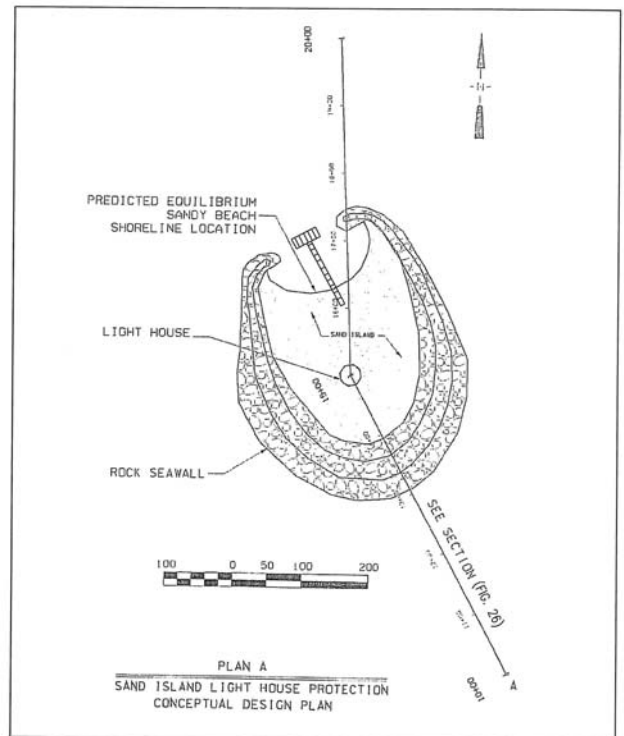
- **Stabilize lighthouse tower.** The Emergency Stabilization Measures described above represent the foundation upon which the long-term restoration efforts would be based. Actions must be undertaken as soon as possible to assure that the tower can be stabilized. If the tower cannot be stabilized to prevent its collapse, it would not be practical to pursue the balance of the Long-Term Restoration Plan.
- **Protect and enhance lighthouse island.** A major objective of the Long Term Restoration Plan would be to enhance the stability of the island within which the lighthouse's foundation is embedded. It has been over 74 years since the U.S. Coast Guard deactivated the lighthouse, and even longer since any actions were taken to place rock around the lighthouse to counter the erosion forces that have continually attacked the island. It is remarkable that the lighthouse still stands today with a foundation that appears to be relatively intact and without damage.

Protection and enhancement of the island upon which the lighthouse is located is a critical component of the Long-Term Restoration Plan. However, the scope of island enhancement is dependent upon the major goals that are to be achieved and the uses that will eventually be made of the lighthouse by those responsible for managing this important cultural resource.



Additional Rock Protection for Island

If the primary goal is to protect the foundation of the lighthouse only, this could be accomplished by placing additional rock on the island without disturbing the existing rock blanket. While this approach would significantly strengthen the existing armor blanket covering the island, it would not provide an environment conducive to safely accommodating potential visitors to the lighthouse.



Enlarged Island

If a major goal of the restoration program is to provide an enlarged island that would encourage public use of the lighthouse, a 1.3-acre island having a sheltered sandy beach and a somewhat protected anchorage for visiting boats could be constructed. The shoreline of the island would be formed on three sides by a rubble-mound seawall made of rocks. The lower wave energy north-northwest facing side of the island would be left open to form a sandy beach to provide access to the island. If desired, a dock could be included across the sandy beach to further improve access. Following completion of the masonry and metal repairs, opportunities could be pursued to encourage public visitation of the lighthouse by constructing the dock and other amenities on the island.

- **Conduct remaining masonry and metal repairs.** Following stabilization of the lighthouse tower, actions should be taken to repair the extensively damaged masonry and metal features that comprise the lighthouse. Due to the integrated nature of many of the masonry and metal features, their repair cannot be easily separated and should be pursued simultaneously.

In addition to the emergency stabilization measures described above, the following additional masonry repairs would be required:

- Locate or fabricate historic brick to match existing.
- Replace missing and/or damaged brick.
- Remove all failed masonry patches and install new patches.
- Tuck point the mortar joints of the entire brick exterior with lime mortar as required.
- Grout cracks with lime grout and brick dust.
- Repair masonry at locations where steel beams supporting the stairway landings are embedded into the tower.
- Re-anchor granite window surrounds.
- Re-set and stitch brick at walled up doorway.
- Remove all Portland repairs on the interior walls and replace with lime mortar repairs.
- Render the entire tower exterior with an appropriate coating.

Full restoration of the metal work would strengthen the lighthouse tower while improving the safety of the critical stairway structure that is essential to providing safe access to the top of the lighthouse. This would require the following actions:

- Repair stairs and platforms.
- Repair iron in windows and supporting wood frames.
- Repair lantern room and appurtenant exterior platforms, railings, and decorative features.
- Provide a protective coating for all metals.

To assist future decisions regarding restoration of the Sand Island Lighthouse, two cost approaches are presented for the Long Term Restoration Plan. One approach would concentrate on providing increased protection to the lighthouse foundation, but would not create conditions that would support public use of the facility. The second approach would not only protect the lighthouse foundation, but would provide an environment conducive to public use of the lighthouse and its surrounding island. The costs for both approaches are shown below, along with the cost for the Emergency Stabilization Measures.

*Artist's Conception of
Restored Lighthouse and
Enlarged Island*



Cost Estimates (2007\$)

	Minimal Island	Enlarged Island
Emergency Stabilization Measures	\$ 1,300,000	\$ 1,300,000
Enhanced lighthouse island	9,600,000	29,700,000
Conduct remaining masonry and metal repairs	<u>5,000,000</u>	<u>5,000,000</u>
 Total Construction Costs	 \$15,900,000	 \$36,000,000

In addition to the structural repair work, a hydrographic survey using sidescan sonar and multibeam technology should be made to determine the exact slope of the rock blanket covering the island and its lateral extent away from the lighthouse and the water depths surrounding the island. Follow-up hydrographic surveys should be made on a periodic basis in future years to (1) monitor the condition of the island; (2) monitor the locations and configurations of the nearby scour holes; and (3) identify the potential for undermining of the toe of the island's rock covering. Approximately \$5,500 should be budgeted for each hydrographic survey event.

In conclusion, it must be recognized that there will always be some risk involved when repairing an old structure like the Sand Island Lighthouse. While the recommended repairs will certainly help give additional strength and stability to the lighthouse, periodic monitoring of the structure and its surrounding island should be pursued to detect any unforeseen problems in their early stages of development.

