

Condition Assessment and Preservation Recommendations: **World War II Era Structures** Peleliu State, Republic of Palau



Stanley O. Graves, FAIA
S. Patrick Sparks, PE, SECB

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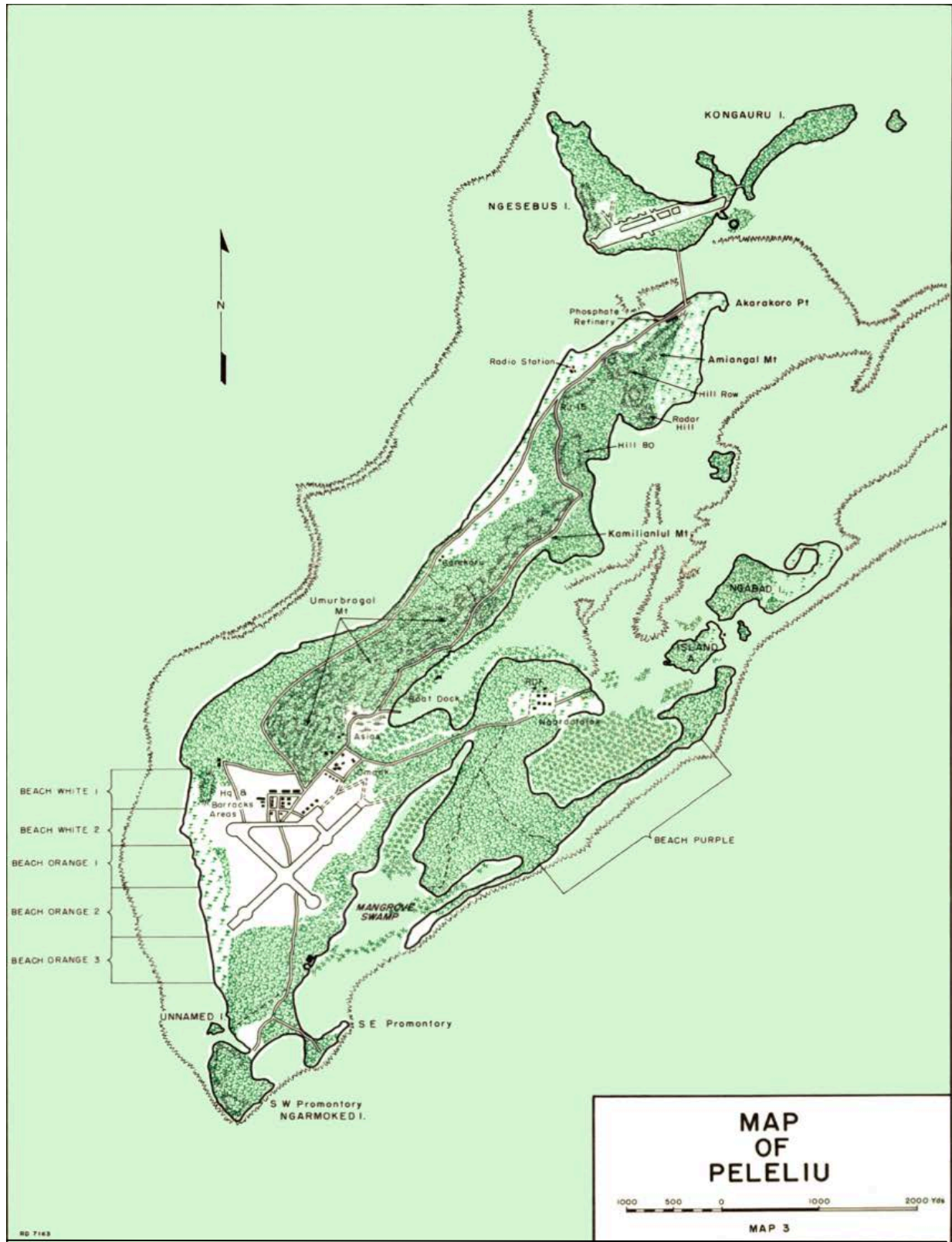
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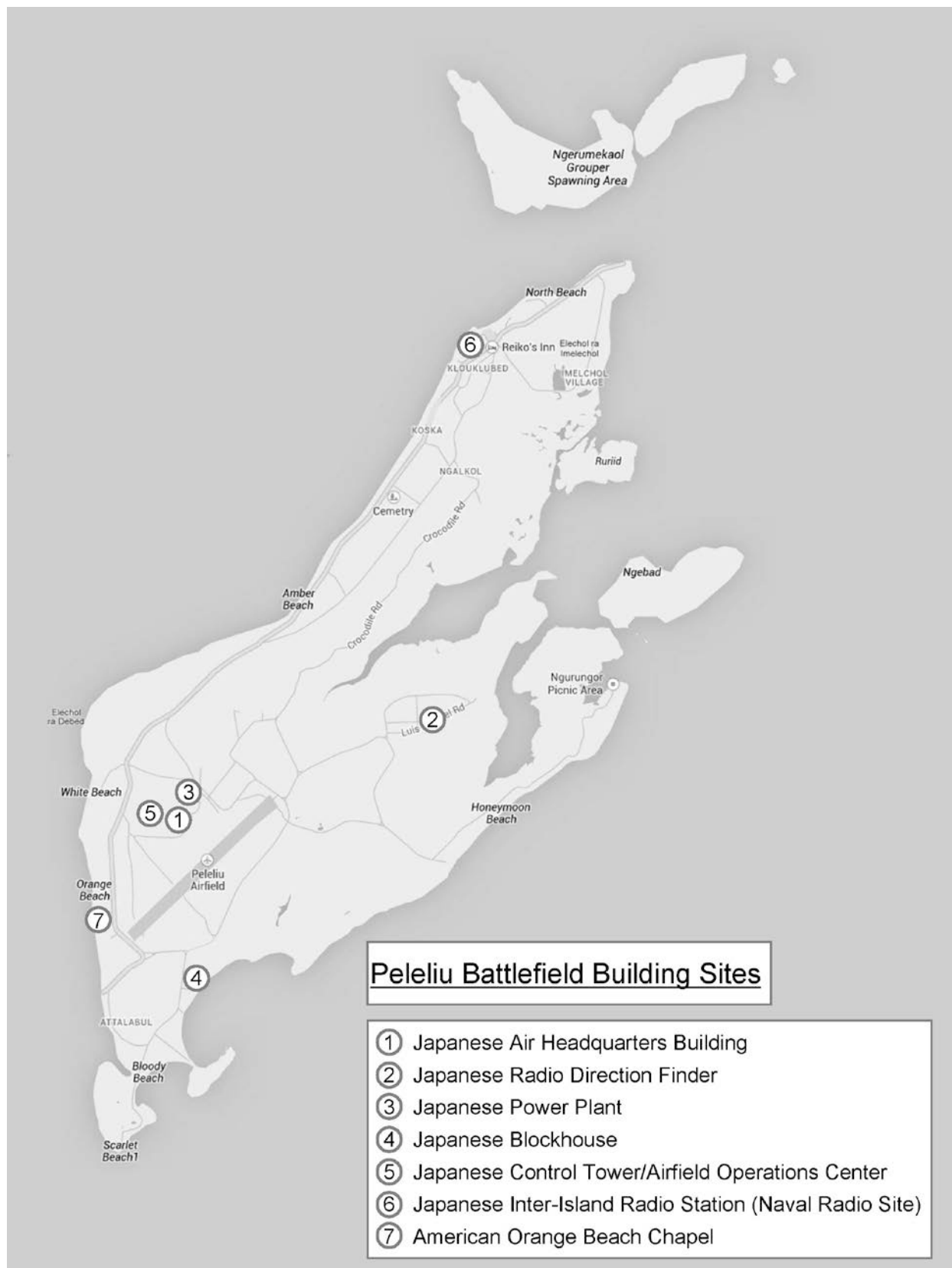
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Maps



Peleliu 1944



Overview

Peleliu Battlefield includes all of Peleliu Island, which is in the south-most of the major Palau Islands. Peleliu is 30 miles south of Koror, the capital of the Republic of Palau, and 500 miles east of the Philippine Islands. It is six miles in length and two miles in width. Today, its people live primarily in two villages that were reconstructed after World War II (WWII): The capital city Klouklubed and Imelchol; both near the north end of the island.

The battle for Peleliu Island was the longest and one of the most hard-fought battles in the entire Central Pacific amphibious operations in WWII. In contrast to earlier combat where the Japanese had vainly attempted to annihilate the enemy on the beaches, Peleliu's defenses were organized with the main line of resistance established inland, artillery and mortar fire registered on the beaches, and defenses skillfully arranged in depth in order to sustain resistance to an attack while destroying the enemy. Although the Japanese troops lost the battle, their new tactics enabled them to inflict heavy losses on American Marines and Army forces and to hold out for 74 days. Peleliu marked the conclusion of the Central Pacific drive toward the Philippines.

Today Peleliu is one of the most intact battlefields in the world, retaining most of the original Japanese buildings and defensive structures. Essentially no repairs or significant modifications have been made. In particular, the highly visible and dramatic battle damage to the reinforced concrete buildings is largely unchanged since the war.

The seven building sites included in this study are:

1. Japanese Air Headquarters Building
2. Japanese Radio Direction Finder
3. Japanese Power Plant
4. Japanese Blockhouse
5. Japanese Control Tower/ Airfield Operations Center
6. Japanese Inter-Island Radio Station (Naval Radio Site)
7. American Orange Beach Chapel

The first six sites in the study are all 1930s era-type buildings constructed of cast-in-place concrete by the Japanese. The seventh site is the Orange Beach Cemetery Chapel which is the most recently constructed (1945) and least intact of all the buildings we have visited. Indeed, it represents a radically different purpose, construction type, durability and builder than all of the other heavily-reinforced concrete military structures built by the Japanese that are a part of this study.

We performed simple field tests for depth of carbonation, chloride ion (salt) concentration, and relative strength of the concrete. The results of these tests are tabulated in the Appendix.

This condition assessment is intended to:

- Identify any safety concerns in need of immediate attention to insure visitor safety;
- Make recommendations for treatment that will arrest conditions that contribute to the continued deterioration of these structures;
- Make recommendations for treatments to these structures in their current ruin state that will provide for their long-term preservation and in meeting future interpretive desires;
- Make recommendations for treatment for the feasible reuse of one or more of these structures for visitor or community use (i.e. visitor center, classroom, exhibit space, administrative space).

Consultant Team

The consultant team was headed by Stanley O. Graves, FAIA, historical architect from Austin, Texas. The team also included Patrick Sparks, P.E., structural engineer from Round Rock, Texas. The field survey was conducted between 5 July 2013 and 15 July 2013.

Acknowledgements

The authors are grateful for the assistance of Ms. Sunny Ngirmang, Acting Director, Palau Bureau of Arts and Culture /HPO and Mr. Calvin Emesiochel, BAC Archeologist; they provided invaluable help with their extensive knowledge of the battlefield sites, local community and cultural resources. We also wish to thank Governor Temmy L. Shmull for his cooperation and support during our time in the State of Peleliu.

Limitations

This architectural and structural assessment was based on visual field observations of readily accessible areas. Some limited testing for chlorides and carbonation was performed to supplement the study.

The recommendations are based on the observed conditions at the subject property at the time of the assessment. Other conditions may exist, or develop over time, which were not found during the assessment. These recommendations do not represent a final design or specification. Additional investigation will be required as part of any comprehensive program or design leading to construction.

Japanese Reinforced Concrete

All of the Japanese building structures in the current study were designed and built as typed military facilities using standardized structural details. They are all constructed of cast-in-place reinforced concrete.



The reinforcement detailing (shape, orientation, length, size, and placement) indicates a thorough consideration of the kinds of forces to be resisted (blast, impact, seismic). For example, all of the columns have closely spaced ties, the floors have two layers of reinforcement, the beams are reinforced for negative flexure¹ over the supports, and there is attention paid to establishing continuity of reinforcement throughout. The walls and roofs of the fortified buildings are very thick, and have two layers of closely spaced reinforcement grids with extensive use of shear ties. These features have allowed the buildings to remain standing even with the extensive loss of walls and exterior columns.



¹ Negative flexure means the beam is bending in a curve that is concave downward, which usually occurs at the columns.

Interestingly, all of the steel reinforcement is smooth; which by the 1930s would no longer be standard practice in the West where virtually all primary reinforcement was being manufactured with deformations to improve bond to the concrete. To counter the lack of bond, the Japanese made extensive use of hooked-ends to provide the smooth bars with the necessary engagement to the concrete.

We do not have data on the strength or ductility of the steel material used in the Japanese reinforcement. However, based on the way the reinforcement was able to deform under blast loading, the steel appears to be highly ductile.

The concrete used in the building was made with imported cement and locally mined coral sand and crushed coral stone. Although the resulting concrete is highly porous due to the use of the coral aggregate, our limited testing suggests that the compressive strength has a median value of about 36.5 MPa (5,000 psi) and an allowable design value of at least 22 MPa (3,200 psi), which is sufficient for any intended re-use of the buildings.

Battle Damage VS Corrosion

The buildings have damage both from the battle and from corrosion of the reinforcement. Of the battle-damage, the most serious structural issues usually occur in cases where entire walls or columns were lost. Even in those cases, however, there are few unstable elements today. Generally all of the buildings showed a good ability to remain stable even with heavy bombardment.

“Battle damage, distinct from corrosion damage, should be considered a character defining feature of the Japanese concrete buildings.”

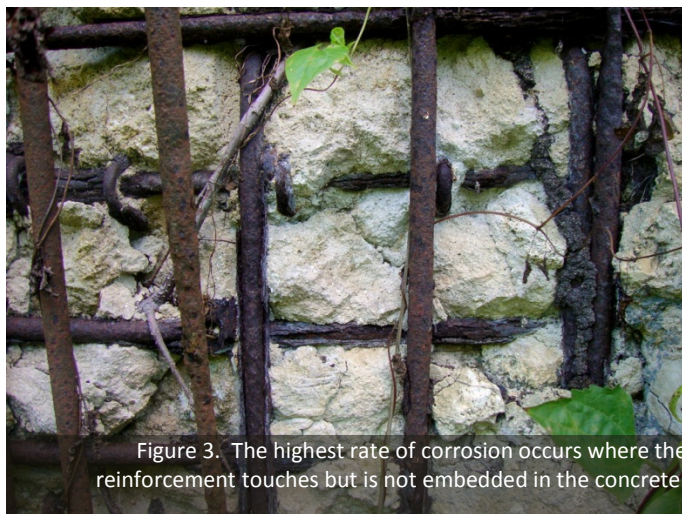


Figure 3. The highest rate of corrosion occurs where the reinforcement touches but is not embedded in the concrete.

The battle damage, including the blast holes and the associated deformed steel reinforcement, should be considered a character defining feature of the building indicative of the intensity of the offensive action. Where it has been exposed by battle damage, the reinforcement should be left exposed to aid in the battle interpretation. On the other hand, where the reinforcement has become exposed due to environmental effects, it should be preserved by appropriate methods of concrete repair.

The post-war deterioration of the concrete has been caused primarily by corrosion of the reinforcement. Steel expands greatly when it turns to rust, and it is this expansion that causes the splitting and spalling of the concrete.

The key factors that determine the rate of corrosion in concrete are: previous cracking, depth of carbonation², chloride (salt) concentration, and moisture.

Clearly, the moisture factor at Peleliu is very significant. The high porosity of the concrete, the tropical climate, vegetation, lack of roof drainage, etc. are all contributing to deterioration. Cracking also is a problem around the blast holes due to the corrosion-expansion of the rebar, invasive tree roots, and from the blast itself where there is typically a fracture zone around each point of impact.

Surprisingly, the chloride concentration in the concrete is quite low, ranging from near zero to about 500 ppm in one of the samples we tested. This is well below the level of salt that would be considered a primary cause of corrosion. This is unexpectedly low for a tropical marine environment. No doubt the heavy annual rainfall helped wash the salt out of the coral sands that were used in the concrete.

“If implemented promptly, simple measures can make a major difference in the long-term preservation of the buildings.”

Our field testing indicated that the depth of carbonation reaches 75 mm or more in the vicinity of the blast damage on most of the buildings. We did find carbonation depths of about 25 mm at two locations: one in the Inter-Island Radio Station, and the other at the Blockhouse. In these two cases, there appeared to be a somewhat higher cement factor in the concrete mixture. Overall, it appears that in most cases the carbonation has reached the reinforcing steel; intervention is needed now, but if implemented promptly, simple measures can make a major difference in the long-term preservation of the buildings.

² Carbonation is the natural process of cement absorbing carbon dioxide from the atmosphere, by which it reverts to limestone. The initially high alkalinity of the cement protects the reinforcement, but carbonation reduces the pH of the concrete, allowing the steel to rust. The rate of carbonation is affected by the porosity of the concrete and environmental factors.

Preservation

Our recommended approach is to preserve the battle damage as-is. Exceptions would be:

1. Removal of overhead falling-object hazards that are of immediate risk.
2. Where intervention is necessary to assure structural stability.
3. Limited concrete repairs on the edges of the blast holes as needed for conservation.



Figure 4. Space posts along the free edge to support a damaged slab.



Figure 5. Shoring locations to support a missing column.

Shoring

Basic shoring methods, such as heavy timber posts and properly secured beams, can be used to accomplish most of the stabilization needs of the current conditions and well into the future if preservation measures are implemented soon.

In addition, other minimally intrusive techniques such as banding of severely damaged columns to maintain confinement of the concrete may be used, as well.

Timber for shoring should be the heartwood of naturally durable species such as mahogany or iron wood. We understand that both of these are available locally. In permanent work, all hardware used in any shoring or stabilization should be stainless steel.



Figure 6. Typically, two shoring posts will support a beam.

A set of shoring design standards should be developed so that the shoring can readily be constructed and installed as needed by local workers. These standards would be a concise set of illustrated details showing the sizes and positioning of shoring timbers needed for beams, slabs,

columns, etc. The development of the standard details will require the services of a licensed structural engineer, but once developed they would be widely applicable.

A training workshop is recommended to demonstrate how to interpret and use the standard details.

Treatment to Re-alkalize the Concrete

The concrete at Peleliu may lend itself to a treatment known as re-alkalization, which is intended to reverse the negative effects of carbonation. The porosity of the concrete, which has accelerated the carbonation, actually makes re-alkalization a potentially successful preservation treatment as the concrete will more readily absorb the treatment solution. A solution of sodium carbonate³ or potassium carbonate is generally recognized as an appropriate treatment for carbonated concrete. Such treatment should have no adverse effect on the concrete⁴. Laboratory and on-site test programs are required to establish the effectiveness of the treatment.

Appropriate procedures are necessary for this process and a training workshop is recommended. The treatment solutions are highly alkaline (caustic) and personal protective equipment, emergency procedures, and clean-up protocols are necessary.

Concrete Repair

The corrosion-damaged concrete (splitting and spalling) can and should be properly repaired to protect the reinforcement. This is done by careful removal of the damaged area of concrete, cleaning the reinforcement, and applying a repair mortar. Successful concrete repairs require a good deal of care and skill. As with realkalization, a training workshop is important to assure that the work is done properly. Training needs to be conducted by instructors qualified by education and experience to perform historic concrete repair. A local certification should be developed so that those trained can then be authorized to work on the buildings.

It is very important to use a repair mortar that matches the historic concrete and also has compatible physical properties (modulus of elasticity, strength, and limited shrinkage). A test program to develop an appropriate mix design is recommended. Local coral sand should be used as the aggregate in the repair mortar, with a suitable blend of white cement, fly ash, and other mineral admixtures to achieve the correct color match. Other admixtures such as plasticizers and shrinkage compensators may be helpful to improve bond and durability. In any case, consideration should be given to using ingredients that can be reasonably obtained. Development of the proper repair mortar should be carried out by a consultant or craftsman with demonstrated capability. It is generally not appropriate to use 'off-the-shelf' repair products.

³ Can be purchased as Arm & Hammer Super Washing Soda

⁴ Because there is no silica-based aggregate in the historic concrete, there is no risk of inducing alkali-silica reactivity, a potential problem with some concretes. Also, the occurrence of non-damaging efflorescence is possible, but this can easily be cleaned from the surface.

Vegetation Removal and Control

The removal and subsequent control of vegetation from these historic buildings and their immediate surroundings is the single most important thing that can be done to further their preservation. The trees and other plants growing on the buildings can cause damage in numerous ways. The plants hold moisture against the historic fabric that prevents normal drying. Roof drains become blocked by vegetation which creates ponding and accelerated deterioration. Trees can fall or blow over causing additional damage. Roots can also invade and break the concrete while opening up additional paths for water and soil intrusion. Not to mention vegetation removal is a prerequisite for any thorough building inspection and repair effort.

The rate and diversity of Peleliu's vegetative growth is a product of its year-round hot and humid climate along with an annual average rainfall of 150 inches. The landmass of low and uplifted limestone in the area of each of these buildings was almost completely denuded of vegetation, either before or during the WWII battle, resulting in a very different historic setting than exists today. The desire to reestablish the integrity of this battle period setting to a degree as well as enhance the preservation of these resources leads us to list vegetation control as our highest preservation priority.

An in-depth discussion of Peleliu's flora is beyond the scope of this report, but in general the species of plants growing in, on and around these buildings vary greatly. The amount of potential damage as well as the ease of removal depends on the size, location and method of root attachment of each plant type. The grasses, weeds, ferns and other small plants will generally be the least destructive and easiest to remove; often growing in a root mat that does not physically enter the concrete surfaces. On the other hand, the banyan with its interlocking prop roots and large twining vines can cause severe damage and must be removed with extreme care to ensure both worker safety and avoidance of building damage.

“Removal of vegetation is the single most important thing that can be done to preserve the buildings.”

The vegetative root mats, which often do not penetrate the concrete, occur on horizontal surfaces and may be lifted off in larger sections that have been separated from the whole and cleared of any overgrowth of larger plants. Both handwork and heavy equipment lifts will be needed to perform this work most efficiently. For tree roots and vine type plants that have embedded into the structure or otherwise encased portions of it, partial removal immediately followed by approved herbicide treatment may have to be repeated over multiple periods. This will allow time for the vegetation to die completely prior to removal. For larger roots, holes may need to be drilled into the remaining rootstock and the chemical poured into them. Only trained personnel under the supervision of appropriate preservation professionals should attempt this work. The Palau Forestry Office is the only agency in Palau that can use the herbicide chemicals that will need to be employed on this project; therefore any vegetation removal requiring herbicide treatment needs to be scheduled well in advance with them.

There may be cases where removal of vegetation will expose loose or crumbling building fabric. In these cases, prior inspection by the preservation architect/engineer is needed to ensure minimal

loss of material and remedial repair in a timely manner. In removing heavy vegetation on sites around the buildings, care must be taken to avoid damage to any remaining artifacts or secondary structures. Certain buildings like the Japanese Air Control Building have extensive artifact fields surrounding them and these should be inventoried and protected prior to site clearance. Hand held trimmers will generally be best suited to close-in site maintenance but care should be taken to avoid damage to the bases of structures. In more open areas, motorized mowers or shredders could also be employed as a labor and time saving method once these areas have been surveyed for artifacts and unexploded ordinance.

In summary, keeping vegetation off of and away from the historic buildings is imperative. In light of the extremely favorable growing conditions of Peleliu, weekly or biweekly maintenance and inspection will be required. This should include mowing and edging, removal of any encroaching vegetation, and cleaning of the roofs and roof drains of debris. This debris is what provides a growth medium for stray seeds. Installation of permanent roof-access ladders should also be considered in any preservation plan and in fact most of the buildings were originally equipped with such roof access.

Roof Membrane

All of the buildings need to have an appropriate and effective roof membrane. The choice of material should be driven by expected life-cycle, ease of repair, and appropriate appearance. Consideration should be given to fluid-applied waterproofing products as opposed to built-up or fabric-membrane systems. All roof runoff must be properly handled to prevent moisture damage to walls and foundations.

Japanese Air Headquarters Building

Building Description

The Japanese Air Headquarters Building is among the most if not the most historically significant building associated with the Peleliu invasion. It served as the command and control facility for the airfield and capturing the airfield was the primary goal of the invasion.

The structure is a type-built late 1930s era Japanese military air headquarters facility. It was located adjacent to the taxi way linking the two landing strips of the airfield and was the hub of numerous air support facilities in the area.



Figure 7. The Japanese Air Headquarters Building as it looked after the initial phase of the battle in the fall of 1944.

The two story building consists of a front administrative section with an attached fortified radio transmitting and receiving section (fortified) and a one story wing with mess, latrine and bathing facilities.

The main building features open porches on three sides and roof terraces facing the airfields and over the one story wing. The building is oriented along an east-west axis, having its main entry on the south side.



Figure 8. Air Headquarters in 2013.

The administrative section was constructed using a reinforced cast-in-place concrete frame with concrete floor and roof slabs, which are supported by a grid of beams spanning column-to-column throughout. The first floor is structurally suspended, having been cast on arch-shaped forms. The fortified bunker structure has thick load-bearing reinforced concrete walls on the exterior, with a single large central column supporting the second floor and roof slabs. The second floor is a two-way slab on beams, while the thick roof slab is a densely reinforced flat plate to resist bombardment.



Figure 9. Typical wainscot finish, showing engagement of original porch railing.

The building had steel windows and doors with those in the radio facility section protected by massive vault-type blast doors and shutters. The interior finishes were utilitarian but of high quality. The hallway floors were of finely textured scored cement and wood block parquet in the office spaces. The walls were of smooth plaster applied either directly to the concrete structure or on metal lath. The walls and columns typically had a terrazzo-like wainscot. The ceilings appear to have been exposed concrete or suspended plaster.

Condition Assessment

The site and the building are currently overgrown with shrubs and trees - some of them massive.

The Air Headquarters building is typical in that it has structural damage both from bombardment and from corrosion of the reinforcement. Of the battle-damage, the most serious structural issues are:

1. Loss or failure of columns has occurred at three locations. One exterior column on the south side has been removed at some time in the past, presumably as a result of severe battle damage. One column on the east wall of the north wing was likewise destroyed by artillery. Another column on the interior was badly damaged during the battle and has failed structurally at its base (Figure 12). In all cases the remaining structural frame as accommodated these losses and no significant distress is evident.
2. Cantilever slab areas occur where large portions of the roof and 2nd floor were destroyed, leaving some of the slab edges unsupported. An option for these is either to cut them back to the face of the nearest beams, or to provide vertical support at the edges with timber posts.

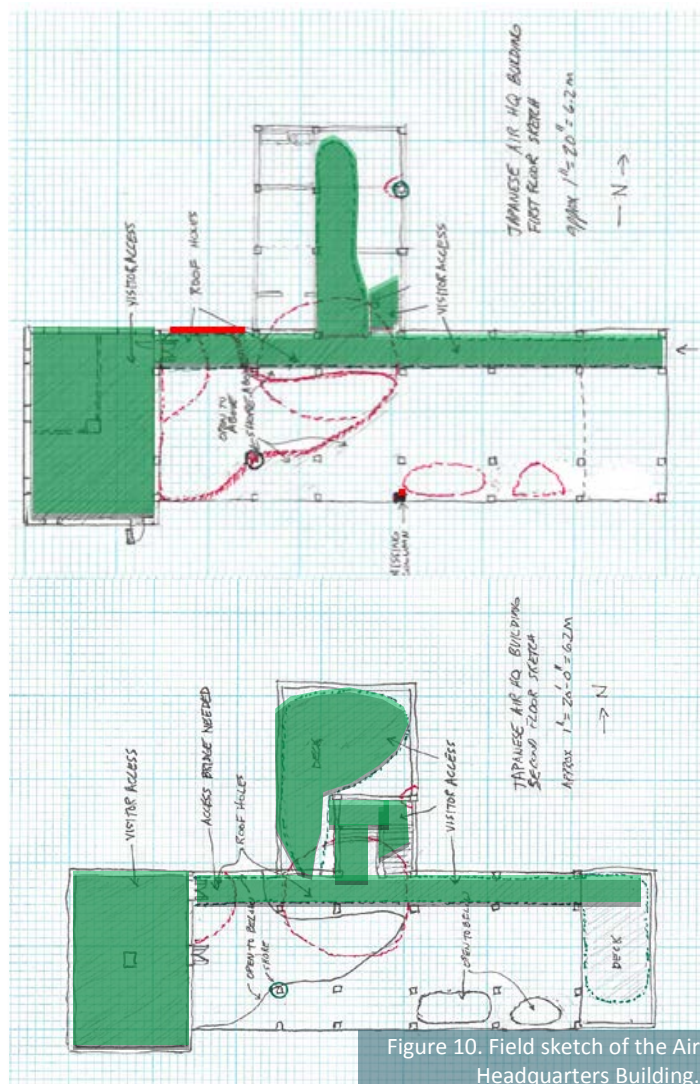


Figure 10. Field sketch of the Air Headquarters Building.

Prescribed Interpretive Route



Figure 11. Broken column is currently stable but should be monitored.

As with most of the other buildings on Peleliu, the level of corrosion-related damage is high where exposed to moisture, but only in a few places has the deterioration reached the level requiring immediate intervention (see below). Most of the structural elements have sufficiently redundant reinforcement that there is no risk of collapse at this time. The largest risk is from falling pieces of concrete.

Immediate Safety Concerns

Overall the Air Headquarters Building is stable enough to be preserved as a ruin and to allow visitors to enter along a delineated interpretive route. However, a few unsafe structural conditions exist in the building and temporary shoring is recommended. These locations are at the missing column on the south wall and along the free edges of the cantilevered second floor slabs. Timber posts are adequate for temporary shoring purposes.

1. Install vertical shoring posts at the location of the missing column on the south side, under the beam on the north side, and along the unsupported 2nd floor slab edges (as indicated in Figure 10). Use 200 mm square timbers at the missing column, 150 mm square timber under the beam, and 100 mm square posts under the slab edges. Assure that the posts are installed snug tight so they will not fall out, and brace properly.
2. Remove loose pieces of concrete that pose an overhead falling-object hazard. Inspect regularly for changes in conditions.

Any further efforts may not be feasible with the current level of maintenance staffing and equipment. Even these items, which are very important, will tax the available resources and care must be taken to maintain safe working conditions.

Preservation Alternatives

Although the Japanese Air Headquarters Building was substantially damaged during the battle of Peleliu and has subsequently deteriorated from natural environmental causes and deferred maintenance, it is of such paramount importance to the overall battlefield scene and integrity that we believe every effort should be made towards its preservation.

The rear fortified section of the building which housed radio communications equipment was so massively built that it did not suffer damage nearly to the extent that the other portions of the building did and most of its exterior walls and roof structure remain intact. We therefore believe it offers the best opportunity for rehabilitation. This fortified room did in fact recently serve as a public storm shelter during typhoon Bopha and super-typhoon Yolanda; minor repairs and upkeep could allow it to continue to serve this vital community function well into the future.

This fortified portion of the Air Headquarters Building should also be considered for permanent heritage tourism functions such as a visitor's center or community meeting space. The remaining front administrative portions and first floor support wing that originally housed kitchen and toilet functions may well prove to be cost prohibitive as well as interpretively unsound to try and convert to other functional uses. Its strongest role continues to be the portrayal of that iconic image of a bombed-out administrative center whose capture was the focus of the early stages of the landing and that was soon followed by reuse as the Marine 1st Division and later the Army's 81st Divisional Headquarters.

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Recommended Preservation Approach

We recommend that the Air Headquarters Building be primarily preserved as an interpretive ruin with a delineated visitor route through the east and north wings, including access to the terraces and potentially the roof. We further recommend that the fortified (western) section of the Air Headquarters Building be rehabilitated for permanent heritage tourism functions such as a visitor's center or community meeting space.

"Its strongest role continues to be the portrayal of that iconic image of a bombed-out administrative center whose capture was the focus of the early stages of the landing."

An excellent opportunity exists to tie the interpretation of this building into that of the main Power Plant and the Air Control Building by clearing the vegetation obstructing the view between these relatively closely spaced buildings. This would allow visitors to arrive and park at the Air HQ, tour it and receive contextual information for the other two sites with the ability to walk to them on their own.

As part of a long-term preservation strategy for the structure, we recommend permanent vertical shoring posts, improved confinement of the damaged columns, column splints as necessary, or a combination of both.

Japanese Radio Direction Finder

Building Description

The Japanese Radio Direction Finder (RDF) Administration and Communications Building is set amid a complex of support buildings. These consist of a Power Plant Building to its northwest, a water tank to the southeast, what appears to be a water tank or cistern at the northeast corner, a supply building to the southwest, and a service wing to the north of the Radio Direction Finder Building that contained a bathhouse and latrine.

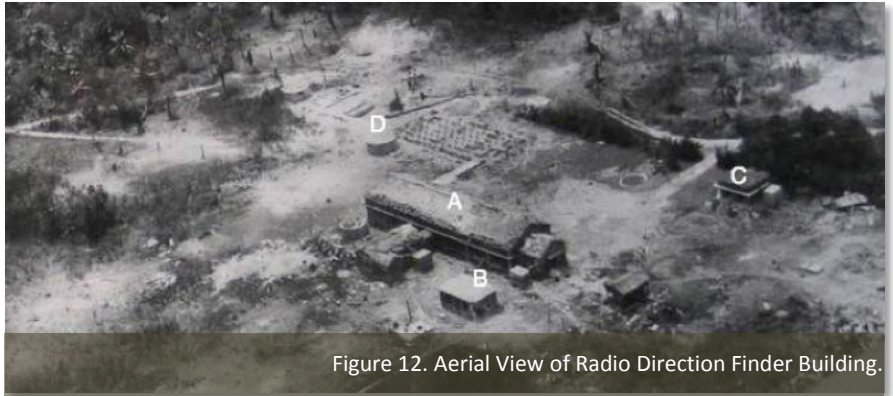


Figure 12. Aerial View of Radio Direction Finder Building.

The only one of these building subject to this report is the RDF but it should be noted the Power Plant, water tank and supply building are all in relatively good condition and



Figure 13. RDF Building after capture by US forces.

the Power Plant is particularly important in that it contains evidence of its original painted finish. The latrine wing of the RDF was inaccessible and only remnant foundations remain of what appears to have been a small additional room on the west elevation of the RDF that was originally covered by a stepped down gable roof.

The Japanese Radio Direction Finder Administration and Communications Building is historically significant due to the rarity of this building type. It is believed to be the only one of this era remaining. It played a relative minor role in the actual fighting and was

mostly abandoned by the time the US forces reached this area on D-day plus three. The general layout and structure of this building is similar to that of the Japanese Air Control Building discussed earlier but is only one story and is therefore of lighter construction. It contains the same open veranda design and T plan with the service wing to the rear.

The eastern half of the building received minor battle damage and demonstrates evidence of recent use in a rehabilitative manner with new room finishes, dividing walls, doors and window treatments.

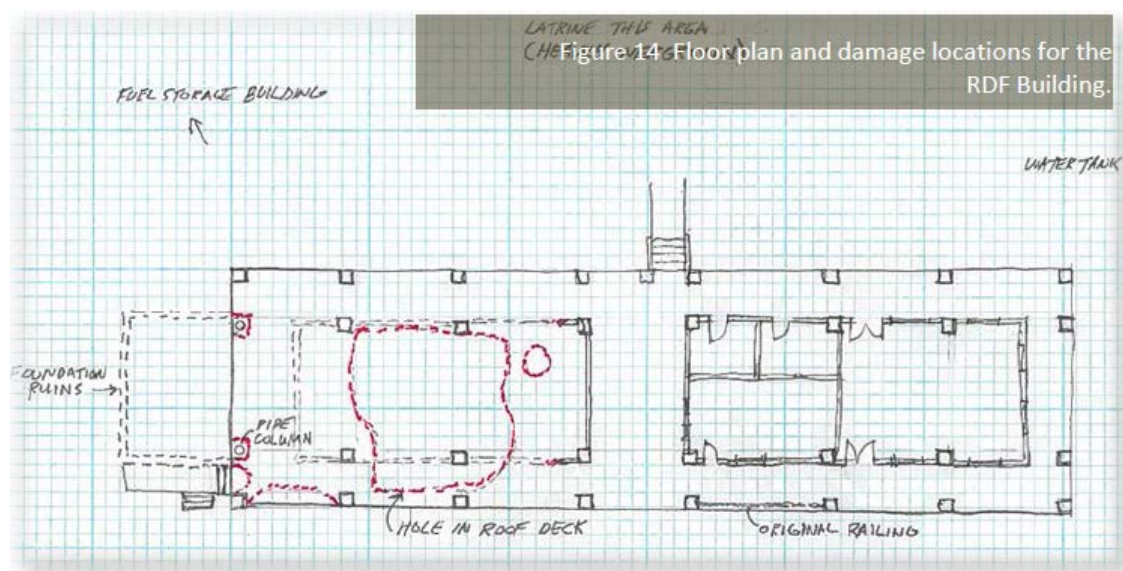
The RDF notably had a gable roof originally which is now completely gone except for a mostly intact gable end wall on the east side of the building. The entire building is also extensively overgrown with jungle vegetation and it is difficult to view or photograph from any side.

Condition Assessment

The east half of the building is still protected by an intact roof, verandah, and exterior walls is still in good condition. There is extensive blast and corrosion damage to the west end structural elements, making that end of the building a poor choice for rehabilitation.

Immediate Safety Concerns

There are three areas of immediate concern: the large broken section of beam at the southwest corner, the cantilevered slab edge in the middle of the west wing of the building, and the missing column on the south side (refer to Figure).



Recommended Low-Cost Measures

We recommend the following low-cost measures that can be implemented by local labor:

1. Remove all vegetation from the building itself, including the banyan trees and roots.
2. Remove the root mat from the roof and clean the roof of debris.
3. Assure that the roof drains are open.
4. Clear all vegetation within 30-meters of the building on all sides.
5. Assure positive site drainage away from the building.
6. Routine removal of trash and debris from the site and the building.

Preservation Alternatives Analysis

The Japanese Radio Direction Finder Administration and Communications Building, although heavily damaged, is important to preserve because of the rarity of its building type and as a major example of a facility reflecting the Japanese Military's extensive development on Peleliu. In light of the obvious private reuse this building and the adjacent supply building have had, we believe the best preservation option for this site is to continue and encourage this use through sensitive rehabilitation.

Recommended Approach

As a component of this rehabilitation, we suggest reconstructing the original gable roof over at least the relative intact eastern half of the building. This accurately replicated roof would provide excellent protection to the buildings surviving original concrete structure and provide a good long-term test case to evaluate the benefits of such roof protection for this construction type in this climate.

The surrounding vegetation certainly needs to be cleared and a large buffer zone kept clear surrounding all buildings in this complex.

Depending on the level of Government involvement in carrying out this needed work, a preservation easement or other form of protective agreement could be established to protect the Public's investment and ensure the sensitive ongoing reuse of this site while providing the heritage tourist with another important stop as they tour the Peleliu battlefield.

Japanese Power Plant

Building Description

This concrete structure is similar to the fuel storage bunkers and was intended to be bomb-proof. The structure measures 14.65 by 16.75 meters and is 6.30 meters high. Its walls are 0.80 meters thick with a roof that is one meter thick. Windows and doors are shielded by heavy steel shutters.

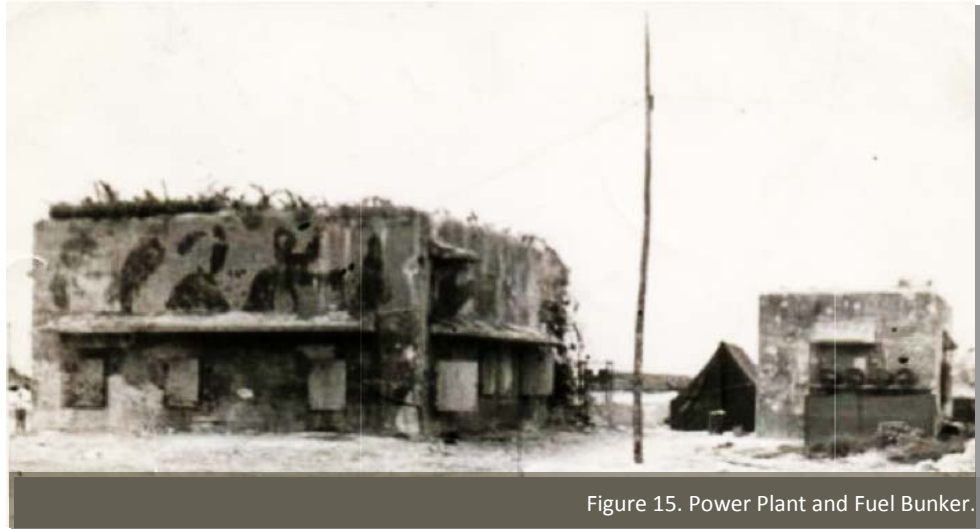


Figure 15. Power Plant and Fuel Bunker.

The Japanese Power Plant was the main source of electrical power for the island. It was supplemented by additional smaller power-generating capability at such energy intensive installations as the Naval Radio station, Radio Directional Finder and the searchlight at the “German” blockhouse. Both the Japanese Power Plant and the Japanese Air Headquarters Building were among the most prominent structures at the Airfield.

The Power Plant is the central feature of a small complex of supporting buildings including a heavily fortified Fuel Storage Building which housed diesel fuel for the plant, a protective pillbox to the southwest, and a concrete water tank on the west side originally used as a water source for cooling the plant engines. These ancillary structures are all remarkably intact with the exception of the water tank which has had a flat roof slab added over it and has a modern pole-supported corrugated-metal shed roof. It continues to function as a part of the Peleliu public water supply.

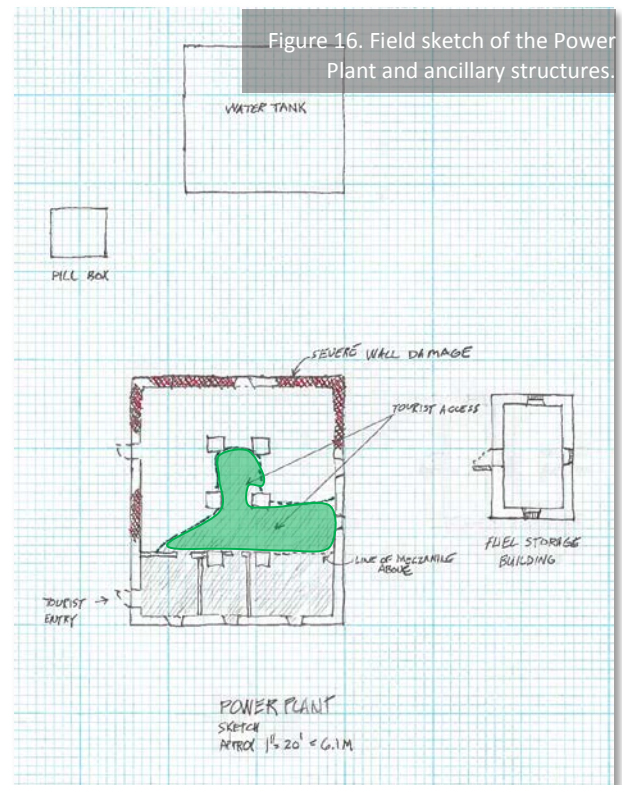
The Power Plant is a massive, utilitarian concrete structure without evidence of the fine interior finishes seen at the Air Headquarters Building. The only exception is evidence of the parquet flooring in the southeast corner in what was likely the facility manager’s office.

The exterior of the building had regularly spaced window and door openings which were all originally protected with vault-like blast doors and window shutters (now missing) and continuous reinforced awnings (burster slabs) above the openings. The adjacent Fuel Storage Building is unique in that all of its steel blast door and shutters are intact although mostly rusted shut.

According to the 2010 Peleliu Inventory of Cultural and Historical Sites (which will be used throughout this report for background information) the structure is 14.65m by 16.75m by 6.3m high.

On the interior, little of the generating equipment survives except for a pair of steel pressure tanks and some equipment framework and ceiling mounted crane remnants. There are raised floor mounts for engines on the west end of the building. Most of the space is a two-story volume with a small mezzanine along the eastern one third of the interior. The roof is supported by 6 interior columns.

Structurally, the Power Plant is similar to the other fortified buildings on the island: cast-in-place concrete with heavy 80cm walls and one-meter thick roof, all heavily-reinforced to resist bombardment.



 Prescribed interpretive route

Condition Assessment

The Power Plant building was hard-hit with naval artillery at the beginning of the American assault. The shelling caused the loss of the structural integrity of most of the north and west walls.



Figure 17. The Power Plant today.



Figure 18. The Power Plant in 1944.

Much of the concrete that remains on these walls is highly fragmented and the rebar is almost entirely exposed. Still the roof is heavily reinforced and is able to support itself even in the absence of almost a third of the exterior walls. No apparent repairs have been made since the war so the battle damage remains largely unaltered. Corrosion of the reinforcement is severe in some areas of battle damage, but elsewhere in the building there are few signs of significant rebar corrosion.

The Fuel Storage, pillbox and water tank are all in generally good condition. Like all of the buildings we examined, the window and door frames, blast shutters, and other exposed steel are significantly rusted.

Immediate Safety Concerns

The main unsafe structural conditions at the Power Plant Building are overhead falling-object hazards: loose pieces of concrete in the battle-damaged areas. Regular inspection and removal of falling-object hazards is recommended. Otherwise, the stabilization or removal of the severely fractured wall areas is beyond the capability for the local resources to safely deal with. The best approach would be to cordon off those areas as shown in the floor plan sketch.

Recommended Low-Cost Measures

We recommend the following low-cost measures that can be implemented by local labor:

1. Remove all vegetation from the building itself, including the banyan trees and roots.
2. Remove the root mat from the roof and clean the roof of debris.
3. Assure that the roof drains are open.
4. Clear all vegetation within 30-meters of the building on all sides.
5. Assure positive site drainage away from the building.
6. Routine removal of trash and debris from the site and the building.

Preservation Alternatives Analysis

The Power Plant Building is a historically significant structure with an interesting story to convey about its critically important function in providing power throughout the island's military facilities. Particularly with the surrounding support structures possessing such a high degree of integrity, this site lends itself as an important cultural tourist interpretive stop.

Due the plant's extensive wartime damage and the fact that nearly one fourth of the exterior walls are missing, we do not see a viable rehabilitation/reuse potential for this building. Its best use will be as a stabilized and interpreted ruin.

The Fuel Storage building however, does present the opportunity for rehabilitation with minimal alterations needed. With the new Peleliu water facility making use of the adjacent water tank; this building could be useful as a support/storage facility for the water department. This reuse would have the added benefit of ensuring regular activity at the site and involving another agency in ongoing maintenance responsibilities.

Recommended Approach

We believe the Power Plant can have a long-term future with minimal stabilization required to preserve it in its current ruinous state. This will involve the same vegetation removal and limited shoring we foresee at many of the other sites we are inspecting. A safe and directed tourist pathway should be created through the building with appropriate multi-lingual interpretive signage and displays. The surrounding support structures should also be cleaned of vegetation, minimally repaired (except for the additional sensitive repairs needed to convert the fuel storage building to water department needs as discussed above) and appropriately interpreted.

There is also an excellent interpretive opportunity to clear the jungle overgrowth between this complex and the nearby Japanese Air Headquarters and the Airfield Control Center. This would allow visitors to arrive by vehicle at the Air HQ and visually identify and walk to these other nearby buildings, thereby gaining an important understanding of the relationship of these major surviving components of the airfield complex.

Recommended Approach

*“Preserve as a Ruin;
Minimal Stabilization;
Interpretive Route.”*

Japanese Blockhouse

Building Description

This site consists of a circular “German-style” concrete blockhouse; it is 12 meters in diameter with 0.80 meter thick walls. This structure is of particular significance as it is one of the few remaining of this building type that is relatively intact.

The Japanese Blockhouse guarding Scarlet Beach was seized on D-day plus 1 and represents a heavily fortified position which required significant effort to capture. It was so named the “German Blockhouse” by American forces because of its resemblance to similar German structures that had been encountered in Europe.



Figure 19. US Marines at the Japanese Blockhouse, 1944.



Figure 20. The Japanese Blockhouse fortification, overgrown with vegetation.

The generally circular structure with one flattened side where the entrance is located has a diameter of about 12 meters with heavily reinforced walls 0.80 m thick. The Japanese also increased protection by stacking coral rocks around the walls up to 5 meters thick. The interior is divided into 4 compartments with steel, vertically sliding

shutters protecting the firing ports in each section. The center contains a circular ammunition magazine topped by a steel framed circular observation post. The interior walls were originally covered with sound deadening insulation and wood paneling which is now mostly gone.

The exterior is remarkably well preserved most likely due to the protection provided by piled coral rock around all sides, which remains to this day. It is said that this is one of the best preserved, intact blockhouses of its type in all Micronesia. It is very significant historically for this reason and the important role it played in the fighting which occurred here in the early stages of the US invasion.

Condition Assessment



Figure 21. Falling-object hazard at the Blockhouse entry.

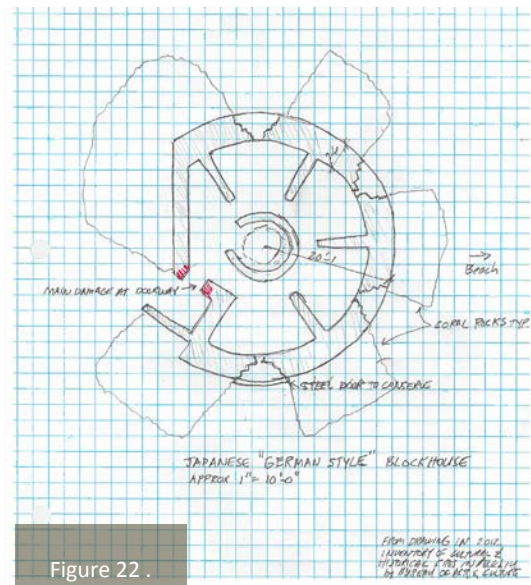


Figure 22 .

The Blockhouse is in good overall condition with only significant battle damage apparent at the entry doorway. The building is unique in that all of the steel firing port shutters survive and the one to the right of the door seems to have most of its components intact. Structurally, there is some deterioration of the bottom layer of reinforcement in the roof. However, as with the other fortified structures, there is not overall risk of collapse. The reinforcement should be cleaned and treated as described elsewhere.

Immediate Safety Concerns

The main unsafe conditions at the blockhouse are protruding steel bars and a few falling-object hazards, including a large piece of loose concrete over the entry. We recommend cutting back any dangerous protruding rebar, and removing the loose concrete pieces overhead.

Recommended Low-Cost Measures

We recommend the following low-cost measures that can be implemented by local labor:

1. Remove all vegetation from the building itself, including the banyan trees and roots.
2. Remove the root mat from the roof and clean the roof of debris.
3. Assure that the roof drains are open.
4. Clear all vegetation within 30-meters of the building on all sides.
5. Routine removal of trash and debris from the site and the building.

Preservation Alternatives Analysis

The Japanese “German Style” Blockhouse is a very good candidate for preservation in its current state with only limited concrete repairs and metal component conservation and restoration needed at this time.

Recommended Preservation Approach

Beyond the minimally required concrete repair/stabilization, at least one of the unique surviving firing port steel shutters and the observation port on top should be conserved by a qualified metals conservator. The option of restoring any missing components of the shutter to render it once again fully functional would provide a highly interesting opportunity to demonstrate exactly how this protective mechanism was employed. As with all sites, the surrounding vegetation certainly needs to be cleared and a buffer zone kept clear surrounding the blockhouse particularly the vegetation should be kept clear between this structure and the view to Scarlet Beach from each firing portal. This will allow the visitor to understand the critical and dominating importance of its placement in controlling approaches up and down the beach. The blockhouse also needs both directional signage to aid in finding it and interpretive signage describing its function and significance.

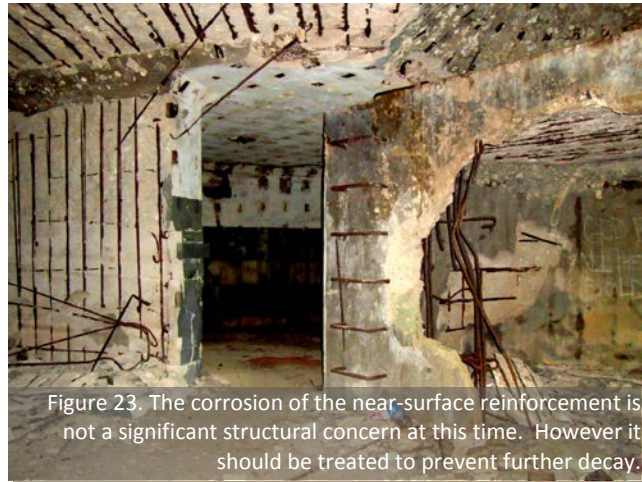


Figure 23. The corrosion of the near-surface reinforcement is not a significant structural concern at this time. However it should be treated to prevent further decay.

Japanese Airfield Operations Center

Building Description

This concrete structure was likely the main control tower for the airfield. It has a simple rectangular plan with a colonnaded verandah on all sides. Large metal blast doors, fortified roof and walls, and a deep bomb shelter in front offered protection from bombardment. It is one story, but has a room above the first floor that was originally accessed via an exterior ladder, as seen in the 1944 photo.



Figure 24. The Japanese Airfield Operations Center, with heavy damage to the west wall.

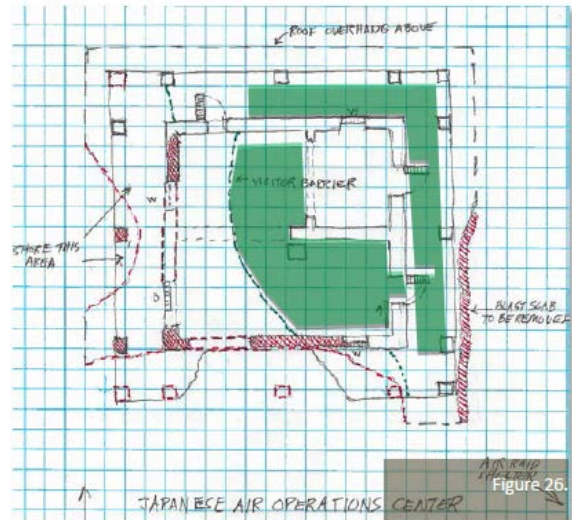


Figure 25. BAC archeologist Calvin Emesiochel surveys the deterioration of the blast-damaged south wall.

Architecturally and structurally, it has elements similar to the other Japanese concrete buildings on Peleliu. The verandah is most similar to the RDF building, while the core is similar to the fortified portions of the other structures such as that of the Air Headquarters.

This building appears to be unique in that it has infill roof slabs intended to be removed later for the addition of upper floors.

Coral rock was piled on the roof as additional protection.



 Prescribed interpretive route

Condition Assessment

Significantly, the building exhibits a duality in its condition, with the severe damage and deterioration separated from the highly intact opposite side, with the dividing line approximately along a northeast-southwest axis.

Remarkable state of preservation on the north and east faces, including the only two operable blast doors we encountered on our survey, as well as nearly intact finishes on the verandah on these two sides.

The west and south walls were heavily damaged from bombardment along with several of the verandah columns. In addition the west wall exhibits a zone of extraordinary corrosion and efflorescence. We obtained a sample of the efflorescence for testing (result to follow). Roots of a banyan tree penetrate the one-meter thick roof at this point, and water infiltration is severe. However, we expect that this extreme level of deterioration is caused by some other factor than simply moisture and carbonation. Other than this one area, there is very little significant corrosion damage on the building.



Immediate Safety Concerns

The portion of the veranda roof on the middle of the west side is structurally unsound due to the extreme deterioration in that localized area. Either shoring of the area indicated on the plan or removal of the deteriorated concrete is recommended. Also, remove the hanging concrete slab at the east side as highlighted on the plan.

Recommended Low-Cost Measures

We recommend the following low-cost measures that can be implemented by local labor:

1. Remove all vegetation from the building itself, including the banyan trees and roots.
2. Remove the root mat from the roof and clean the roof of debris.
3. Assure that the roof drains are open.
4. Clear all vegetation within 30-meters of the building on all sides.
5. Assure positive site drainage away from the building.
6. Routine removal of trash and debris from the site and the building.

Preservation Alternatives Analysis

Particularly the northeast corner room is nearly intact and could be rehabilitated for a new use. Otherwise, the structure is best utilized as a battlefield ruin with appropriate stabilization and interpretation.

Recommended Preservation Approach

Once the safety and low-cost measures are accomplished, and sufficient clearing of the forest occurs, visitor access to the roof would allow better interpretation of the overall airfield site. A view to the nearby Air HQ and Power House would be impressive and informative.

A visitor barrier with a delineated interpretive route needs to be established.

Because of the remarkable continued functioning of the two blast doors on the east wall, we recommend that they be conserved and maintained in operable condition.



Japanese Inter-Island Radio Station (Naval Radio Site)

Building Description

The Japanese Inter-Island Radio Station (IIRS) site contained several structures which were common to complexes of this type. In addition to the main station building, there is a surviving Fuel Storage Building, several cooling and water storage tanks (some of which are now missing) and radio towers (also missing). The focus of this study is the central IIRS and the adjacent, fortified Fuel Storage Building.



Figure 29. The Japanese Radio Station, as viewed from the southwest.



Figure 30. Northeast view of the Japanese Inter-Island Radio Station.

The IIRS is another standardized Japanese military type construction with other examples at bases that they established across the Western Pacific. The building consists of two heavily fortified structures at the east and west ends which housed the generator and transmitting rooms, mezzanine floors within these spaces had battery storage and charging functions.

Connecting these fortified sections were lighter weight cast-in-place reinforced concrete barracks and administrative spaces with a wing to the rear north that contained latrine and mess facilities and a stairway. The interior finishes were the standard terrazzo-like wainscot and floors as seen in other major Japanese military buildings we have examined but exposed, plastered concrete ceilings instead of the suspending plaster ceiling we found at the Air Headquarters Building.

The building appeared to face south and this facade is so heavily damaged that some window and door configurations are difficult to distinguish. Projecting reinforced concrete awnings that may

have served as blast slabs were generally continuous above the doors and windows but again are heavily damaged and missing in many places. The central portion of the building had conventional steel windows and doors although the openings in the fortified ends were protected with heavy, vault-like blast doors and shutters (many of these are now missing).

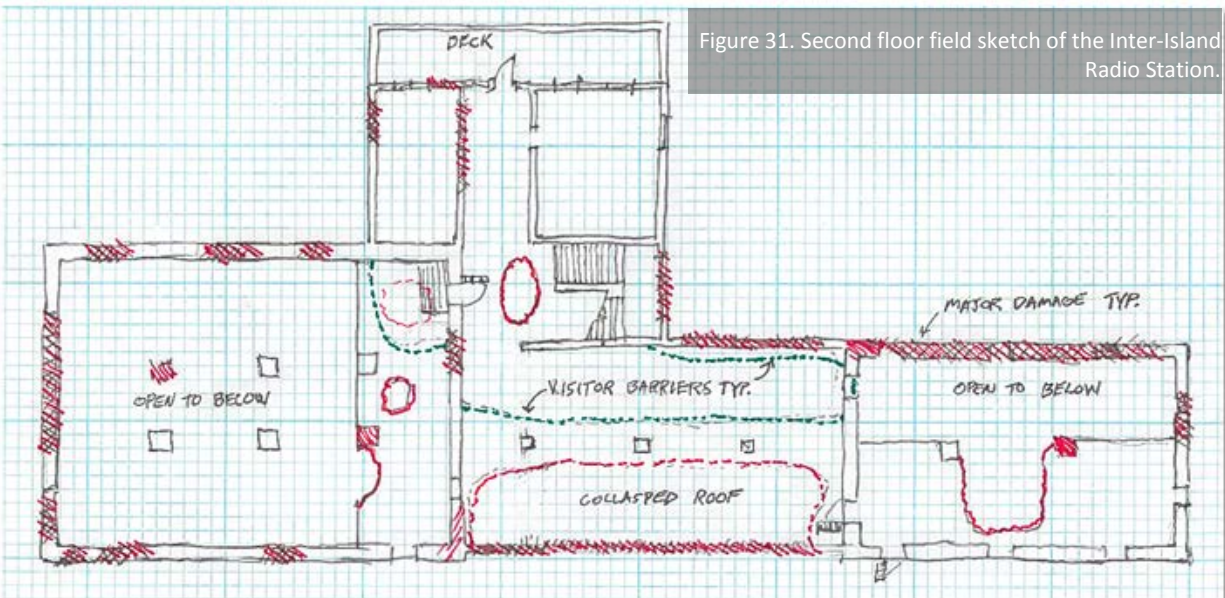
There is evidence of minimal and sporadic private use of the interior spaces and apparently the space has been partitioned off between three or four of the surrounding residences with different families using different portions of the space. This is also the most heavily vandalized building we have inspected with much modern graffiti and accumulations of trash and debris throughout. There are also minor additions of non-historic building materials particularly in the east fortified room that should be removed.

The Fuel Storage Building is again of a standard type design only distinguished by the survival of all its blast window shutters and door and the massive banyan tree that dominates the structure.

The Japanese Inter-Island Radio Station is historically significant as the largest reinforced concrete Japanese military building built on Peleliu and on September 25, 1944, was the last major facility captured by the US Marines on the island.

Condition Assessment

The building is in poor overall condition with extensive damage to south, west, and east ends. The central portion of second floor exhibits the only large areas of roof collapse we have encountered. Graffiti is abundant throughout, both historic to Marine occupation and recent. The building has much trash and debris. Overall most of the large damage areas are stable, but the building is still hazardous to enter.



Immediate Safety Concerns

There are a number of areas of severe damage, but most of them are generally stable. A large piece of roof slab is hanging from a few strands of rebar just above the second floor. This piece of slab should be cut down. Only an experienced contractor should do this work. Still, the building needs to be seen as a significant hazard and attractive nuisance with most areas cordoned off and posted with warning signs. The families that use the building should be specifically told not to enter the damaged areas.

Recommended Low-Cost Measures

We recommend the following low-cost measures that can be implemented by local labor:

1. Remove all vegetation from the building itself, including the banyan trees and roots.
2. Remove the root mat from the roof and clean the roof of debris.
3. Assure that the roof drains are open.
4. Clear all vegetation within 30-meters of the building on all sides.
5. Assure positive site drainage away from the building.
6. Removal of trash and debris from the site and the building.
7. Cordon off the damage areas and install bilingual warning signs both outside and inside the buildings.

Preservation Alternatives Analysis

The Japanese Inter-Island Radio Station is so heavily damaged that feasible alternatives for its preservation seem limited. We do not see a readily achievable reuse or rehabilitation option although its location in Kloulklubed near the arrival dock for most visitors would appear to render the site an ideal visitor contact and orientation location.

Militating against such a use is the severely damaged and dangerous spaces within the building and the limited public access to the site at the end of an unmarked small street hemmed in by adjacent private residences.

Recommended Approach

The development of a minimally stabilized and well-interpreted ruin is the best current use we foresee for the IIRS. Critical shoring, removal of overhead falling object hazards and safety signage placement should be implemented before visitors are allowed to tour the building. A prescribed and interpretive route through the site should be established with barriers/railings placed to guide the public on a safe and informative route.

If at some point in the future substantial funding becomes available that can address the complicating issues of access, private use, and ownership, a more ambitious program of site development could be considered.

As with all of the sites, the surrounding vegetation needs to be cleared and a buffer zone kept clear surrounding both buildings in this complex. All rooftop vegetation should also be removed but

extreme care will be needed in removing the larger rooftop trees on both the IIRS and Fuel Storage Building.

As was previously discussed with the Radio Directional Finder Complex and depending on the level of Government involvement in carrying out this needed work, a preservation easement or other form of protective agreement could be established to protect the Public's investment and access to this important site.

Orange Beach Chapel United States Army

Building Description

The Orange Beach Chapel is generally aligned with the cemetery flagpole and memorial cross at the north end of what was the cemetery (all remains were disinterred in 1947 for reburial in Hawaii or the United States mainland). The only remaining components of the Chapel are four L-shaped coral rock faced concrete corner walls atop a concrete slab. These four corner elements were originally topped with a dual-pitched wood-framed gable roof and a white cross-tipped spire. The sides were open air with a partially enclosed pulpit area to the rear. Its dimensions are 32 ft (9.80 m) wide by 38 ft (11.60 m) long.

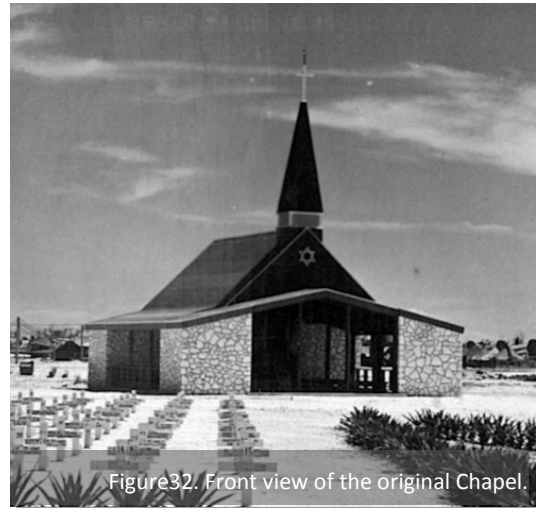


Figure 32. Front view of the original Chapel.

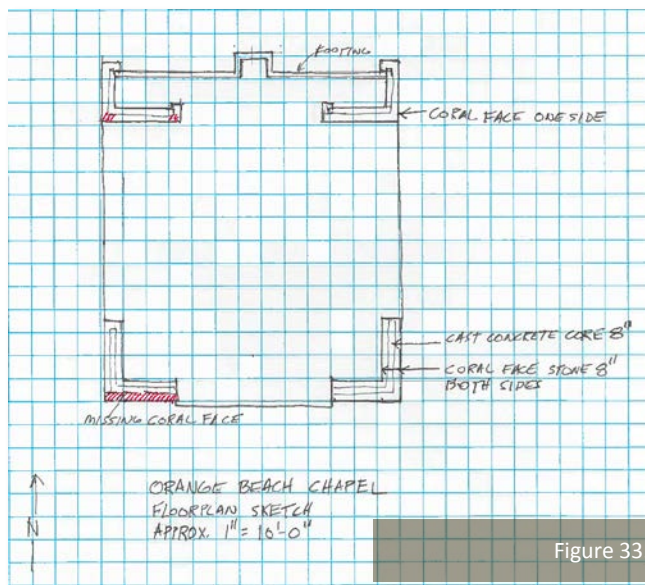


Figure 33.

The Chapel ruins are historically significant as part of a surviving complex including the flagpole, memorial cross and two stone monuments to the US Army's 81st Infantry Division. The complex is located just inland from Orange Beach, one of two primary landing beach for the Peleliu invasion and the site of great loss of life on D-day.

The original four corner-walls have 8-inch reinforced concrete walls as a core, which is clad with 8-inch coral stone veneer, originally attached to the core with steel wire ties.

Condition Assessment

Structurally, the concrete cores are in good condition and pose no risk. The coral masonry veneer, however, is generally cracked and leaning away from the core due to the invasive roots of vegetation and corrosion of the original veneer ties. One entire wall section of the coral has fallen away completely, along with another large piece and some individual stones.

Preservation Alternatives Analysis

The Orange Beach Chapel represents a wartime era, minimally structured yet elegant memorial chapel design. Because of its light-weight wood frame construction, vulnerable exposure to high storm winds and what was undoubtedly decreased utilization after the cemetery was relocated so



Figure 34. Architect Stanley O. Graves inspects Chapel Ruins.



Figure 35. Southwest corner wall.



Figure 36. Vegetation has pushed the coral stone veneer away from the concrete wall.

soon after its construction, the chapel's advanced state of deterioration seems to be fully understandable. This does not however, lessen the important role this structure has played and can continue to play in the war's remembrance. We do not believe a full building reconstruction is warranted based on the above discussion but that a simple program of minimal repair, stabilization and protection of the surviving stone corners is most appropriate.

The stone veneer should be re-anchored with stainless steel ties and realigned to the extent possible without undue damage to the stone. The wall sections then need to be capped and all vegetation kept away from them to prevent future root pressure between the core and the faces.

A second-phase option we envision would be to construct a new pavilion over the footprint of the Chapel that would suggest the basic form of the original chapel roof, but would be open air. A visually clean and simple roof structure such as a stainless steel space frame would provide shade and seating for a contemplative space. As the only sheltered place at this highly significant and exposed location, visitors could rest and reflect on the sacrifices and meanings represented by this site, the very epicenter of the Peleliu Invasion.

Recommended approach

As a first step, we recommend the stabilized-ruin alternative, which would be low cost and would not preclude later adoption of the pavilion alternative.

1. Remove vegetation from the walls and within 30 meters all around. As with all sites, the surrounding vegetation certainly needs to be cleared and a buffer zone kept clear surrounding the Chapel and the Orange Beach Cemetery complex, particularly the vegetation should be kept clear between this structure and the view to Orange Beach . Vehicular parking should be kept back a considerable distance to the east and the entire area approached and visited on foot to maintain the site's sense of solemnity and significance.
2. Selectively reconstruct those wall sections that have fallen away or are severely distressed, using the original coral-stones and matching mortar.
3. Re-anchor the remaining coral stone to the core using stainless steel remedial wall ties.
4. Cap the walls with an appropriate metal flashing such as lead-coated stainless steel.

Final Project Summary

All seven of the buildings that are the subject of this report are of the utmost historical significance in telling the story of the 1944 Battle of Peleliu and its aftermath. While we have established a relative system to rank each building's overall importance in the chart below; but none of these sites deserve less than the application of the fullest preservation efforts available to them.

The overall preservation approach recommended here is to preserve as a battle-damaged yet stabilized ruin all of the Japanese buildings while allowing some level of visitor experience via a prescribed route through each. Some of the buildings can also accommodate a degree of new use within certain areas to provide additional utility. These uses may range from visitor's centers, interpretive displays, meeting spaces, administrative spaces, and maintenance facilities, public storm shelters to private or commercial uses. All such reuse must be done within a strict framework of acceptable preservation practices to ensure the maintenance of each site's continued historical integrity.

The Orange Beach Chapel is a unique case in that the great majority of its original building fabric is gone. It may either be repaired and stabilized in its current state as a memorial ruin or supplemented with new construction and exhibits to enhance the visitor's understanding and appreciation of the entire former cemetery and Orange Beach landing site.

The preservation of all the buildings in their current state necessitates important interventions for which time is of the essence. Removal and on-going control of vegetation is a top priority, followed by water management in the form of new protective roof membranes and runoff control, limited repair, shoring and stabilization.

We are now at a critical juncture in the life-cycle of the buildings. Reinforced concrete buildings such as these, that are subject to long-deferred maintenance typically exhibit ever-accelerating deterioration as they reach 70-75 years of age. At this point the carbonation of the concrete will have reached the reinforcement in many areas. If the recommended preservation approach is initiated soon, there is an opportunity to dramatically extend the life of these buildings. Delay in applying these protective measures will risk losing the buildings to decay and with them an irreplaceable link to the globally significant events which they so powerfully represent.

Summary Chart

BUILDINGS	Japanese Buildings						US
	Air Headquarters	Radio Direction Finder	Power Plant	Blockhouse	Airfield Operations Center	Inter-Island Radio Station	Orange Beach Chapel
FACTORS							
Historical Significance	5	4	3	4	3	4	4
Surviving Architectural & Structural Integrity	4	3	4	5	3	2	1
Current Visitor Access	5	3	4	3	1	2	5
New Use Potential	4	4	2	1	3	2	2
Feasibility of Proposed Work	4	3	4	5	3	2	3
TOTALS	22	17	17	18	13	12	15
Estimated Cost of Recommended Approach	\$ 500K	\$ 150K	\$ 50K	\$ 30K	\$ 75K	\$ 110K	\$ 45K – \$ 165K
	Highest priority project with greatest interpretation potential	Public-Private partnership potential	Important in relation to Air HQ	Best surviving condition but access needs improvement	Important in relation to Air HQ	Conflicts with private use; access needs to be addressed	Great commemorative potential

a. Factors are scored 1 through 5 with 5 being the highest conformance with the factor.

b. This preliminary estimate is for conceptual planning purposes only and does not represent a bid or guarantee of actual costs. No plans or specifications have been prepared upon which to base a detailed estimate, and the consultants do not have control over actual labor or material pricing. Upon development of a defined scope of work, a better estimate of costs can be prepared. Our estimate does not include architect/engineer fees.

Next Steps

There are numerous recommendations, strategies and treatment options outlined in this Report and it will certainly take some time for them to be fully analyzed, funded and implemented. We offer the following outline of steps as one suggested approach to move the overall project forward:

1. Ensure widespread buy-in or acceptance by all Stakeholders of the Report's overall conclusions and recommendations. This may need to involve public meetings and presentations by both BAC and NPS officials as well as the authors of this study. A well-promoted conference could also be considered as an educational, outreach and feedback opportunity.
2. Conduct follow-up on site workshops and training events with the Japanese Air Headquarters Building as the initial focus of preservation efforts. This will allow local work to be concentrated on one high profile site that can then be used as a model to be followed at the others. The invitees to this workshop could include both local representation and invitees from throughout Micronesia and beyond.
3. In conjunction with the above training efforts, develop detailed measured drawings of the Air Headquarters. These will serve as the basis for developing preliminary architectural plans and specifications for the preservation, stabilization and reuse of this building. With this level of planning, more accurate and specific cost estimates for discrete scopes of work can be developed.
4. Fundraising efforts should now be in full swing, major potential donors both nationally and internationally should be approached and depending on the degree of success, a phased or full-scale preservation effort can be designed and implemented. The 70th anniversary of the Peleliu invasion next year offers an excellent point of emphasis for this overall effort.
5. To the extent possible, the other properties identified in this Report should begin to be addressed with initial stabilization, safety improvements and protective efforts. Although this Report establishes a priority in the order of Air HQ, Blockhouse, Power Plant and Radio Direction Finder, Orange Beach Chapel, Air Operations and Inter-Island Radio Building, this work will most likely be dependent on local commitment and resources and may well progress at different rates at each site.

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Appendix

Field Test Results

Building	Carbonation ^a Depth	Chlorides ^b	Rebound Number ^c				
		ppm	Test 1	Test 2	Test 3	Location	Average
Air HQ	75mm	500	45	45	45	Column	45.0
			45	46	45	Column	45.3
Power Plant	>75mm	240	38	34	40	Column	37.3
			40	42	44	Column	42.0
			37	30	39	Wall	35.3
			35	38	34	Wall	35.7
Blockhouse	25mm	400	35	44	33	Wall	37.3
			35	45	42	Wall	40.7
			35	35	31	Wall	33.7
			34	30	31	Wall	31.7
Airfield Operations Center	-	350	39	36	35	Wall	36.7
			35	35	38	Column	36.0
			32	35	33	Wall	33.3
RDF	>75mm	0 ^d	28	27	28	Wall	27.7
			29	33	32	Wall	31.3
			42	47	41	Column	43.3
			29	27	29	Column	28.3
Inter-Island Radio	25mm	0 ^d	37	38	38	Column	37.7
			37	27	39	Wall	34.3
			Average Rebound Number				36.5
			Standard Deviation				5.6
			95% Exclusion				27.3
			Allowable Compressive Strength (MPa)				22.0
a. Using phenolphthalein 1% as reagent indicator							
b. We used a rapid field test method for soluble chlorides that has been shown to give accurate results, per David G. Boyer, “Field Determination of Chloride In Salt Impacted Soils” Safety and Environmental Solutions, Inc., Hobbs, New Mexico; http://ipec.utulsa.edu/Conf2004/Papers/boyer.pdf							
c. Schmidt Hammer L-9							
d. Chloride concentration is below the detection threshold for the field test method							