HOMEOWNER'S HANDBOOK TO PREPARE FOR NATURAL HAZARDS

REPUBLIC OF THE MARSHALL ISLANDS

By
Don Hess
Dennis Hwang
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Ben Chutaro

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UH SEA GRANT

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The Homeowner's Handbook to Prepare for Natural Hazards: Marshall Islands was modeled after the original Homeowners Handbook to Prepare for Natural Hazards by Dennis Hwang and Darren Okimoto of the University of Hawai'i Sea Grant College Program (UH Sea Grant). A special thanks goes to UH Sea Grant Communications for providing the graphics template used in preparation of this guidebook.

It is our hope that the information contained within the handbook, which is in part a compilation from numerous publications associated with natural hazards and hazard mitigation, will be widely used and adopted by stakeholders in the Marshall Islands and the region.

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Marshall Islands
Red Cross Society

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PART 1
INTRODUCTION

When a natural hazard occurs - whether it be a tropical cyclone, tsunami, extratropical storm, king tide, flood, sea-level rise, erosion, or drought - the results can be devastating for your land, your home, your family, and your possessions. Financial losses can be particularly high in the two administrative centers of the northern and southern Marshall Islands - Majuro and Ebeye, Kwajalein - which have seen explosive growth in both population and land area since the mid-1940s. This has been especially true in Majuro, where a number of lagoonal openings along Majuro Atoll were connected by the US Navy to form the single 30 mile strip of land that today is home to over half of the Marshall Islands population (see Figure 1-1). Adding to the island's horizontal growth, seawalls have become a common feature on Majuro covering over 30 percent of eastern Majuro's shoreline (McKenzie, 2006). As a result, the area comprising Delap-Uliga-Djarrit and the Amata Kabua International Airport built in 1967 - has grown by 170 acres or about 40 percent due to engineering (Ford, 2011). With this aggregation of people and development in Ebeye, Kwajalein, and eastern Majuro especially, Marshall Islanders and their homes have become increasingly exposed to potentially dangerous natural hazards.

This handbook was created to help you prepare for a natural hazard so that risks to the family and property may be reduced. While it is never possible to eliminate all damage from a natural hazard, you as a homeowner can take action and implement many small and cost-effective steps that could significantly lower your risk. Mother Nature can be intense. Your family deserves the protection that only you can provide.

Figure 1-1. Lagoonal openings in D.U.D. were closed in 1944, followed by rapid development. (Images Courtesy of Marshall Islands Visitors Authority and D. Hwang)

This handbook is divided into four parts. This introduction presents the purpose and layout of the handbook, and includes a discussion of common myths that may have prevented you from taking action in the past. A summary of the contents of this handbook is also provided in the form of 10 action items. Part 2 provides basic information on tropical cyclones, tsunamis, extratropical storms, King Tides, floods, sea-level rise, erosion, and drought that will allow you to make an educated decision about the steps to take to protect your family and property. Part 3 discusses in detail how to protect yourself and your family. Included in this section are the stock of essential emergency supplies, evacuation kit, evacuation planning, evacuation procedures, and important information that the national and local emergency management agencies and organizations want you to know even before they issue a warning. Part 4 covers how you can protect your property. Many examples are provided.

This handbook is available for free as a downloadable pdf file at the University of Hawai'i Sea Grant College Program website:
http://seagrant.soest.hawaii.edu/homeowners-handbook-prepare-natural-hazards-RMI
It will be updated on an as-needed basis as new information becomes available and feedback from the public is obtained. The handbook will be available in Marshallese in late 2015.

1.1 COMMON MYTHS AND REASONS TO PREPARE

You may be among most homeowners in the Marshall Islands who have not fully prepared for dealing with natural hazards because of complacency caused by several myths. The most commonly quoted myths are discussed below in order to remove some of the major barriers to taking action and to encourage people to prepare.

1) **"A natural hazard cannot happen to me."** Scientists agree that it is not a matter of IF the next typhoon or tsunami will occur, but WHEN. Typhoon Bavi on March 11, 2015 caused extensive damage on Ebeye, and the Marshall Islands experienced edge effects from Typhoon Pam, Maysak, and Dolphin between March and May 2015. Extratropical wave inundations have occurred regularly over the last few years, with significant damage on Majuro, Arno, and Mili on March 3, 2014. Going further back in time there were major wave inundations in 1979 and 2008, with devastating typhoons and loss of life in 1905 and 1918. The Marshall Islands has been relatively fortunate in the last few decades, although there is a good chance you will experience a major event in your lifetime. Mild to moderate wave inundations every few months, some that are intensified by King Tides, are important reminders that the islands are very vulnerable to even the slightest flooding.

2) **"If a hazard occurs, it will not be that bad."** When a tsunami or typhoon occurs, the damage can be devastating. The 1918 Typhoon caused 200 people to lose their lives out of a Majuro population of 1,100 at the time. Imagine the potential loss of life if a typhoon of the same intensity occurred today, with a Majuro population of 28,000.

3) "I have a stronger house than my neighbor so I am sufficiently prepared." Many people compare their level of preparedness against others in the community as opposed to addressing the level of preparation needed to adequately address hazard risk.

4) "Typhoons only hit the northwestern Marshall Islands so those on other islands do not need to prepare." It is a myth that only Ujelang and Enewetak atolls are at risk for typhoons. While the northwestern Marshall Islands are closer to the Micronesian Typhoon Track - other cyclonic and extratropical storms have hit the other atolls at various points in history. Also, there have been many close misses, both historically and recently.

5) "Tsunamis do not affect atolls because they are surrounded by deep water, so I am safe." While the wave will not gradually 'feel' the bottom and build-up as high as in areas with continental shelves, it will cross over the atolls at a full speed of several hundred miles an hour. Anyone caught on the first floor or outside during such an event may be washed out to sea, with higher risk if it occurs at high tide than at low tide.

6) "Installing typhoon clips does not guarantee there will be no damage during a typhoon, so I will not bother." Even though someone may wear a seat belt there is no guarantee that they will not be injured in an automobile accident. Yet most people recognize the importance of these safety devices in reducing risk and use them. Likewise, the measures discussed in this handbook could significantly reduce risk, although there are no guarantees there will be no damage.

7) "If a natural hazard occurs, the government will come to the rescue." After the March 3, 2014 extratropical wave inundation event, Marshall Islanders found that the government will not repair their damaged houses or provide any compensation for property damage. It is up to you to plan properly, strengthen your house, and carry insurance if available. After a natural hazard, the government may be overwhelmed by the number of people in need.

8) "My house survived the March 3, 2014 wave inundation, so I do not need to retrofit for extratropical wave inundations." While this wave inundation was the most significant in recent years, it was mild in comparison to the likely effects of a typhoon or tsunami. Extratropical wave inundations may submerge ground floors by a few feet and cause some structural damage, but typhoons and tsunamis have the potential of submerging everything below the second floor and destroying all but the strongest buildings.

9) **"Droughts only affect the northern Marshall Islands, so I do not need to worry."** The 2013 drought affected only the northern atolls and their 6,000 inhabitants. But this does not mean that the next drought will be limited by the same geography. In fact, the drought expected for late 2015/early 2016 will likely be regional, affecting all of the Marshall Islands and beyond.

10) **"Even if a hazard occurs, there is nothing I can do."** Many people pray and are therefore hopeful that a hazard will not befall them. Others think positively and believe that it has some effect on the outcome. While everyone's beliefs should be respected, they should not be used as substitute for preparation. Fortunately, there are many small steps you can take to significantly reduce the risk of damage to life and property. The number of options available to homeowners has never been greater. While it is not possible to eliminate all risk or damage, many reasonable steps as described in this handbook to plan and prepare can make a major difference between life and death and determines whether a house survives or receives only minor or no damage. Thus, the information in this handbook covers two major parts for preparation: (i) protecting yourself and your family, and (ii) protecting your property.

11) **"Strengthening my house is too expensive and not worth the effort."** Here are various cost-effective ways to strengthen your house:

- Adding typhoon clips or window coverings offers significant protection alone and runs on the order of a few thousand dollars. Strengthening a roof structure (trusses and rafters) with bracing can be done at a minimal cost.
- While strengthening an existing roof can be expensive, consider doing so when you are ready to replace it with a new roof as the additional cost is far more reasonable. Many homeowners who install solar photovoltaic panels reroof beforehand and this is a good time to strengthen the roof.
- Upgrading the house foundation can be expensive but may be well worth it, especially if your house is your major investment.

Ultimately, the time and money spent to prepare your house in order to minimize damage from a natural hazard are just a tiny fraction of what you might have to spend if major damages to your house occur as a result of a failure to take preventative measures. By preparing and strengthening your house, you may be able to wait out the hazard rather than evacuate to a shelter. Evacuation to a shelter should be the last resort, unless a typhoon or tsunami is approaching. There will be minimal supplies, the simplest of sanitary facilities, a bare floor, and little space (max. 10 square feet per person - 5 feet by 2 feet). You will have to bring your own supplies including bedding, medication, food, and water. By remaining at home during a mild to moderate hazard, you will be in far more comfortable conditions and have the ability to take better care of family members, including the elderly, those with special needs, and pets. Whether you can shelter in place will depend on numerous factors including your original house design, the retrofits you install, the strength of the hazard event, and if you are in one of the vulnerable areas prone to wave inundation. Nevertheless, by strengthening your house you protect your neighbors as well as yourself. A house that falls apart during a typhoon will create wind and water-borne debris that can damage adjacent properties.

1.2 TEN THINGS YOU CAN DO TO PREPARE

As covered in later parts of this handbook, here are 10 things you can do to prepare that will provide greater protection for your family and property.

1) **Gather your emergency supplies now.** The good news is many items you need are probably in your home already (see Part 3). Check and restock each month so that the supplies are complete, not outdated, or used. Expiration dates, which are hard to read because of small print, can be made more visible on the packaging with a permanent marker. Avoid rushing to a store during an emergency to gather your supplies. There will be long lines and empty shelves - you will only add to the crowd and confusion.

2) **Compile your evacuation kit.** If your evacuation plans include using a shelter for a typhoon, you will need an evacuation kit that contains water, food, clothing, medications, personal hygiene products, and other items for up to five to seven days. The kit should already be assembled and checked before typhoon season (see Part 3). If the kit will be used during evacuation for shorter period hazards such as tsunamis and extratropical wave inundations, three days may suffice.

3) **Create an evacuation plan for both an extra tropical wave inundation and a typhoon/tsunami. They are different.** For an extratropical wave inundation your plan may include sheltering in your house if it is: (i) sufficiently strong (i.e., built with strong connectors, see #6) and (ii) outside of vulnerable areas that have repeatedly flooded in the past. If you cannot use your house, use a suitable alternative structure (a friend or relative's house) or a shelter that is officially open [listen to local radio and television (see Part 3)]. For a typhoon/tsunami your plan is likely to be sheltering in one of the official shelters. There is no high ground in the Marshall Islands to escape to for tsunamis. If you have access to a good boat and can get into deep water on the ocean side quickly (not the lagoon) then this is the best option for a tsunami. Note that a tsunami may have several waves, so ensure the event is over before returning to land. Discuss, refresh, and practice drills of your evacuation plan with your family each year.

4) **Know your property and take appropriate action.** Look at where you are located. If trees overhang your house, consider trimming or cutting the branches overhead which may damage your house in a storm. By identifying the characteristics of your house you can help determine the most effective measures to strengthen the structure (see Part 4).

5) **Know your house and take appropriate action.** When was your house built? Does it have connectors to tie the roof to the wall or the wall to the foundation? When will you need to reroof? Look at your blueprints, if they are available (see Part 4).

6) **Strengthen your house.** Some houses may have typhoon clips to tie the roof to the wall, and strong connectors from the wall to the foundation. If your house was not built this way, you can still retrofit parts of the house at a reasonable cost. All households should consider the many options now available to protect your windows and doors. You can also strengthen your roof when it is time to reroof. The steps a homeowner can take will vary with each house, but for the majority of homeowners, there are a few steps that can make a significant difference (see Part 4).

7) **Insurance.** Do not gamble with your house. Obtain adequate insurance if it is available, and make sure to read any fine print.

8) **Take advantage of potential discounts for your natural disaster insurance premiums.** Coverage may vary among insurance companies, and significant discounts in your premium may be provided for reducing the risk to your house with window protection, roof-to-wall tie-downs, and wall-to-foundation tie-downs.

9) **Finance creatively.** Consider efforts to strengthen your house as your most important home improvement project. Most projects are not that expensive. For the more costly ones, a small home improvement loan and potential discounts from natural disaster insurance premiums make these projects within reach. It is a great investment to strengthen your house and provide more protection for your family (see Part 4).

10) **Seek the assistance of a qualified, licensed architect, structural engineer, or contractor.** This handbook covers work that you may be able to do yourself. If you cannot do the work, seek qualified assistance through trusted references from friends and family, emergency management agencies and organizations, or the individual contractors on-island. Even if you do the work yourself, it is always best to seek professional advice from a qualified architect, engineer, or building contractor. For simple tasks, ask your local hardware stores for initial guidance since every house is a little different (see Part 4).

PART 2
NATURAL HAZARDS: AN OVERVIEW FOR HOMEOWNERS

This part of the Handbook covers the natural hazards of most concern to the Marshall Islands. This includes: (i) tropical cyclones (tropical depressions, tropical storms, and typhoons), (ii) tsunamis, (iii) extratropical storms, (iv) King Tides, (v) sea-level rise, (vi) erosion, and (vii) drought. It is important to distinguish the hazard event and process. For example, a typhoon is an event that can cause erosion, wave inundation, flooding and high wind damage. Sea-level rise is an event that can cause erosion, wave inundation, and flooding damage. Notice that some of the major impacts we plan or design for such as erosion, wave inundation, and flooding can be caused by multiple events (typhoon, tsunami, sea-level rise).

2.1 TROPICAL CYCLONES

Tropical cyclones are intense weather systems formed in tropical latitudes (0 to 22.5 degrees north of the equator) with a well-defined circulation pattern. In the Marshall Islands, we will be interested in four categories of tropical cyclones that are classified based on the wind speed averaged over one minute at a height of 33 feet above sea level. The four categories of tropical cyclones are:

1. **Tropical Depression** - Is an organized system of persistent clouds and thunderstorms with closed low-level circulation and maximum sustained winds of 38 miles per hour. Because the winds are relatively low, the threat from wave inundation damage and wind damage is low. However, tropical depressions can drop a lot of rain and thus cause significant flooding in the Marshall Islands.

2. **Tropical Storm** - If the tropical depression grows in strength, it can become a tropical storm if the maximum sustained winds reach between 39 to 73 miles per hour. With the increased wind speed, especially at the upper range of the tropical storm, the threat from wave inundation and wind damage grows significantly. Many poorly constructed residences in the Marshall Islands would be severely damaged by a tropical storm. The risk to homes can be significantly reduced by following the retrofit measures in Part 4 of this book.

3. **Typhoon** - When the maximum sustained winds reach or exceed 74 miles per hour, the tropical cyclone has reached the status of a typhoon. Typhoons have been devastating in the Marshall Islands because of the triple threat of high wind, high water or wave inundation and high rainfall. Even strongly constructed houses can be damaged by a typhoon. That is why it is recommended that for a typhoon, residents do not shelter in their house, but in a public shelter as shown in Part 3 of this book. Even though houses should generally not be used as a shelter during a typhoon, the retrofits in Part 4 of this book are important to help reduce the risk of potential property damage. As will be

shown later, history indicates that typhoons are rare in the Marshall Islands, but frequent enough so that the threats must be planned for by the entire community (see Figures 2-1, 2-2, 2-4, and 2-5).

4. **Super Typhoon** - When the maximum sustained winds reach 150 miles per hour or over, the system has reached the status of a super typhoon. Fortunately, because of the location of the Marshall Islands at a low latitude (close to the equator) and a longitude where most typhoons are just beginning to form versus where they have had a chance to strengthen (see Figure 2-1), most tropical cyclones never attain super typhoon strength in the area. They are more common farther north and west. For example, Super Typhoon Haiyan/Yolanda struck the Philippines in November 2013 with maximum sustained winds of 195 miles per hour. This was the strongest recorded typhoon to make landfall in history. In March of 2015, Super Typhoon Maysak was responsible for extensive damage across the Federated States of Micronesia (FSM), with Chuuk, and Yap States suffering the brunt of its impact.

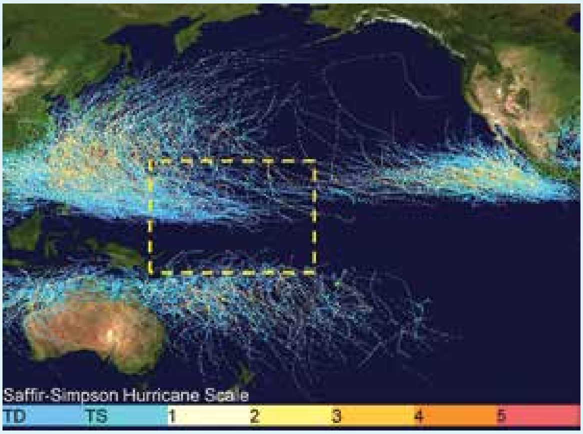


Figure 2-1. The history of tropical cyclones near the Marshall Islands (yellow dashed box) between 1985 and 2005. Although the Marshall Islands is not in the most intense region for typhoon exposure, there is still considerable risk. Note the even greater risk of typhoons to the west and north of the middle of the yellow dashed boxed area.

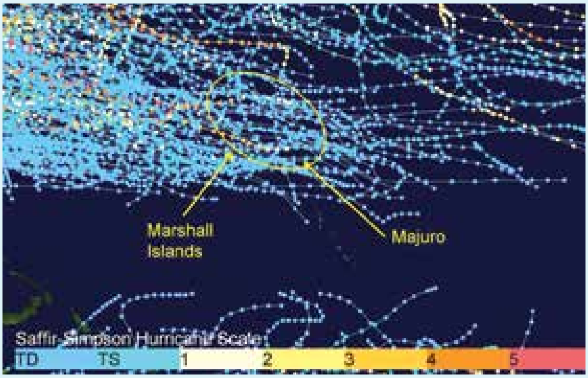
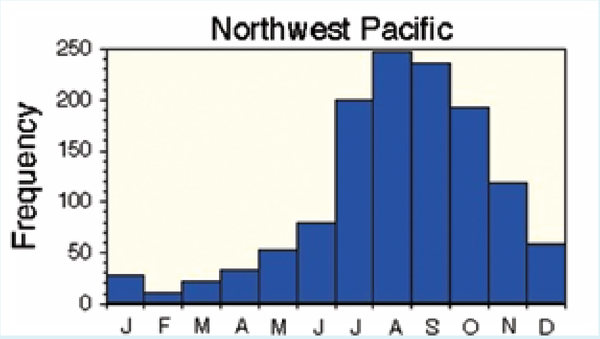


Figure 2-2. In an enlargement of the yellow dashed box in Figure 2-1, there were two typhoons that passed by the Marshalls from 1985 to 2005. During the same period, there were many tropical depressions and tropical storms that affected the Marshall Islands

The area around the Marshall Islands is unlike other storm basins worldwide in that it produces tropical cyclones all year round, save for an "off season" with a distinct minimum in February and the first half of March (Figure 2-3).

Figure 2-3. Frequency of tropical cyclones in the northwest Pacific by month (Pidwirney, 2012). The main season for tropical cyclones in the Northwest Pacific basin runs from July to November with a peak in late August/early September.



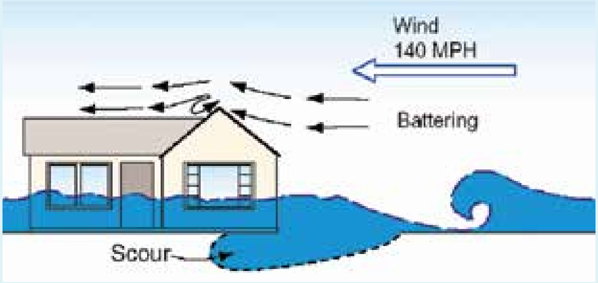


Figure 2-4. With any typhoon, there will be four key impacts that overlap. There can be Erosion/ Scour of the coastline. In addition, there is Wave Inundation and Flooding. Finally, the impacts of High Winds must be planned for. Some of the impacts, such as erosion, scour and wave inundation may diminish for inland locations.

It is important to note the differences between erosion and scour, as well as wave inundation and flooding. These are the major impacts we need to plan for.

Erosion - When more sediment leaves a shoreline area by physical processes than is deposited by biological and physical processes, than erosion of the coastline occurs. This is typically seen by retreat of the shoreline and a vertical cut in the vegetated dune (Figure 2-26).

Scour - Commonly occurs with erosion. When a large volume of water moves around a structure (house, column, or pier), there is turbulence which removes sediment around the structure.

Wave Inundation - Waves from the coast caused by a tsunami, tropical cyclone, extratropical storm, or other means move inland with velocity and impact structures.

Flooding - Accumulation of water over land can be caused by wave inundation where the waves lose height and speed. It can also be caused by heavy rainfall and poor drainage.

The relation between the types of tropical cyclones and the types of damage (Erosion/Scour, Wave Inundation, Flooding, and Wind) are summarized in Table 2-1.

Table 2-1. Summary of Major Impacts/Damage from Tropical Cyclones

Tropical Cyclone	Wind Speed	Likely Hazard Impacts	Comments
Tropical depression	38 mph or less	Flooding from high rain	Water from a tropical depression can enter from the top as rain, or from the bottom as a flood.
Tropical storm	39 to 73 mph	Erosion, wave inundation, flooding, wind	Impacts will vary depending on strength of the tropical storm, duration, and location.
Typhoon	74 to 149 mph	Severe erosion, wave inundation, flooding, wind	Rare, but history in the Marshall Islands and vulnerable population supports need to plan for typhoons.
Super typhoon	150 mph or greater	Catastrophic erosion, wave inundation, flooding, and wind	Fortunately, a super typhoon in the location of the Marshall Islands is extremely rare. There is no history of a super typhoon in this location.

The two typhoons that caused the most damage in the Marshall Islands occurred in 1905 and 1918 (Figure 2-5), when many of the islands were directly hit and there was significant property damage and loss of life. Dr. Dirk Spennemann used 20th century documents such as captain's ship logs and missionaries' letters to approximate the location and wind speed of the 1918 and 1905 storms.

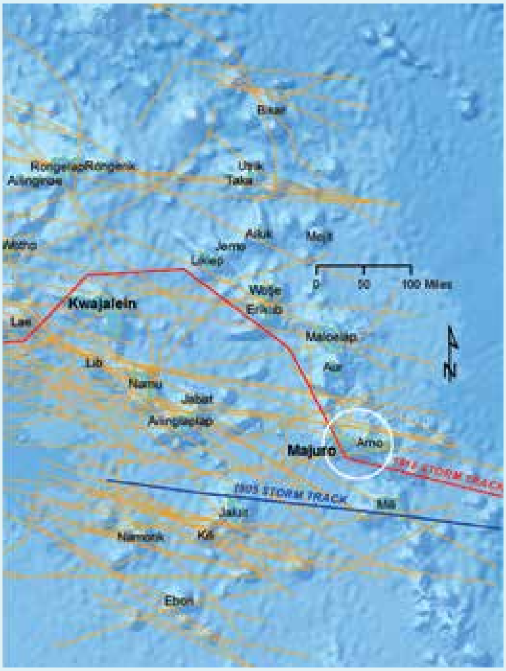


Figure 2-5. Climate researcher, Mark Stege, overlayed the work of Dr. Spennemann with IBTrACS storm tracks from 1958-2012 (see Knapp et al., 2010). The composite map shows the 1905 Typhoon (blue), 1918 Typhoon (red), and all storms 1958-2012. Majuro is circled. See the impacts of these storms in Figures 2-6 and 2-7.

Figure 2-6. Typhoon Wind Impacts - Damage to the Catholic Girl's and Nuns' Living Quarters building in Jaluit after the 1905 typhoon. Note the blown off roof, which is common from the strong winds of a typhoon. In addition, there is water damage or inundation that overtopped the log seawall and eroded or scoured sediment behind the wall (Photo Micronesian Area Research Center).

Blown off roofs from a typhoon demonstrate the need for strong roofs and attachments to the wall and foundation. How to do this is shown in Part 3 for emergency shelters and Part 4 for houses.

In addition to the strong winds, typhoons bring high water associated with elevated water levels and waves. The elevated water and waves from a typhoon, inundating low lying atolls has historically been devastating to the people of the Marshall Islands (Figure 2-7; see Spennemann, 1996). Thus it is necessary to prepare for these events with the measures discussed in Part 3.

Figure 2-7. Japanese memorial in Laura is for the 200 people of Majuro that drowned during the 1918 typhoon. At that time, the population of Majuro was roughly 1,090 (Spennemann, 1996). A 2011 census for the Marshall Islands of Population and Housing indicates a population on Majuro of 27,797, more than 25 times greater than the 1918 population. The memorial is an important reminder to Marshall Islanders of the potential risk to life from the wave inundation and flooding from a typhoon. This can help encourage citizens to prepare evacuation plans as discussed in Part 3.

The evacuation measures in Part 3 of this book are primarily driven by potential wave inundation and flooding from a typhoon which can threaten life and property (see Figures 2-4 and 2-7). However, a tsunami may also drive the evacuation. The home retrofits in Part 4 of the book are driven by the wind impacts from the typhoon (see Figures 2-4 and 2-6). In addition, the elevation measures in Part 4 are meant to address more frequent, less intense flooding associated with weather events smaller than a typhoon or a tsunami.

When there is a tropical cyclone, the residents should listen to the radio and TV for public announcements on what to do. For households without TV, radio, or cell phones, it is important that neighbors or other members in the community work to notify everyone in the area of any impending hazard (see Part 3).

The RMI National Weather Service Office (WSO) of the U.S. National Oceanic and Atmospheric Administration (NOAA) will be working with the Joint Typhoon Warning Center (JTWC) and Pacific Disaster Center (PDC) to provide useful information. Some products for planning include:

Position Estimates - This provides an hourly estimated position of a tropical cyclone if it is within radar range. These are issued hourly near the top of the hour, when a center fix for the tropical cyclone is available.

Public Advisories - Advisories provide the latest information on tropical storm/typhoon watches and warnings. They are issued every six hours when a tropical storm is expected to affect an area within 48 hours. During a watch, citizens should be closely listening to local radio or watching public TV for instructions on what to do. During a warning, they should be taking action according to their evacuation plan and the instructions from government. The PDC offers email advisories for a variety of hazards specific to the Marshall Islands that you can subscribe to.

Local Statements - Specific forecast for each island under a watch or warning, including rain, wind, surf, storm surge, as well as recommended preparations.

When a tropical storm/typhoon has the potential to approach the Marshalls, citizens should pay close attention to these WSO/NOAA/JTWC/PDC products to track a tropical cyclone and mark its progress so that appropriate actions can be taken, more than 48 hours in advance.

2.2 TSUNAMI HAZARDS IN THE MARSHALL ISLANDS

Tsunamis are large surface waves caused by a major disturbance in the ocean such as a submarine earthquake, underwater landslide, volcanic eruption, or meteor impact. By far, the most likely cause for tsunamis in the Pacific will be from an earthquake associated with the major subduction zones around the Pacific Rim known, as the Ring of Fire (see Figure 2-8 and 2-9).

Figure 2-8. Around the Pacific Rim are a series of trench systems marked by orange lines where the ocean floor sinks under the overlying crust. Sudden movement at these trench systems cause subduction zone earthquakes, and if large enough, the generation of a tsunami by the displacement of large volumes of water.

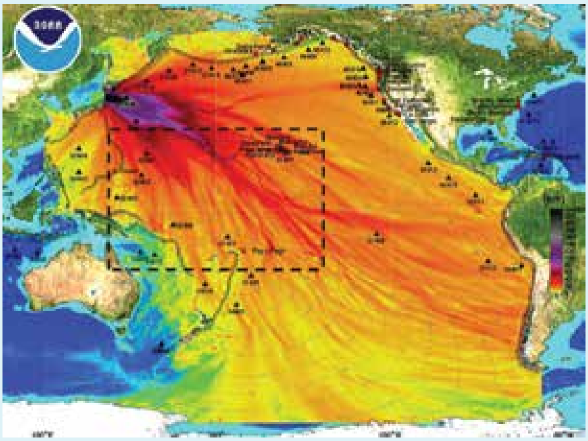
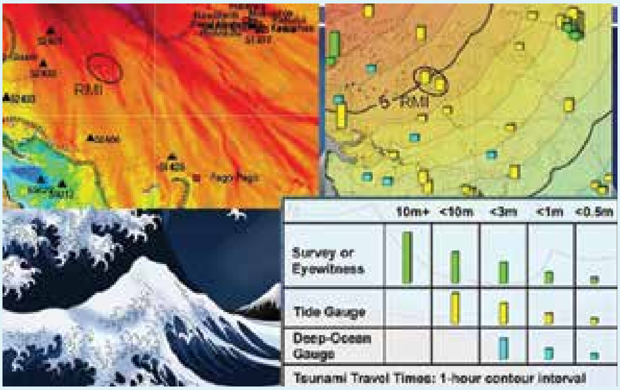


Figure 2-9. The large tsunami in Japan (Tohoku Tsunami) on March 11, 2011 was caused by a great earthquake along the Japan Trench (Figure 2-8). This is where ocean crust is being subducted or thrust under the crust to the west. The colored bar to the right in South America is water height with a top value of 240 cm or over 8 feet in the open ocean. Image courtesy of NOAA.

As tsunamis approach land, they slow down in speed and grow in height. This growing effect is most pronounced on a gently sloping continental shelf. For example, in Japan, the wave grew over 10 meters (greater than 33 feet). For Pacific Atolls, the shoaling effect is much less because instead of a gently sloping continental shelf, there is a steep and abrupt drop off to over a mile deep just outside of the ocean reef crest of the atoll. The Tohoku tsunami waves were estimated at less than 3 feet when it reached the Marshall Islands (Figure 2-10).

Figure 2-10. **For the Tohoku Tsunami, the estimated water height at the Marshall Islands was under 1 meter or 3 feet (see Robertson, 2015). The Marshall Islands were fortunate since the time of the tsunami coincided with a low tide of 3 feet.**



Because it was low tide in the Marshall Islands at the time the tsunami struck, there was limited inundation. Experts at the Weather Service Office feel the outcome could have been much worse if the tsunami struck during a high tide, with the potential for significant inundation and flooding damage.

Some major historical tsunamis in the Pacific that impacted the Marshalls include the 1957 tsunami off the Aleutian Trench and the 1960 tsunami off the Peru-Chile Trench (see Figure 2-8 for the source/location of these events). Measured inundation depths were 10-13 feet (NOAA, 2011). Modeling of earthquakes from the Kuril, Mariana, and Ryukyu trenches estimate overland flow of 3-6 feet (see Robertson, 2015).

During a tsunami watch, Marshall Islanders should tune to local radio and TV for information from the government on what to do next. The Pacific Disaster Center also offers timely email notifications of possible tsunamis in the region. It is very difficult to predict or forecast when there will be a damaging tsunami. Officials will use the best science available and they must also balance the need to avoid false alarms with the more important need to protect all lives. Each event will be different so just because there may have been a prior false alarm, do not use this excuse as a reason not to evacuate for the next event. Many lives have been lost from tsunami and typhoon inundation making the assumption that the prior event was not bad, so the next one will not be also.

Because there is generally less than three hours warning time for a tsunami, Marshall Islanders should know where the most likely shelter is - using the information in Part 3 of this book. Since many of the shelters are the second floor of schools, people can be proactive by asking school officials in advance if they have developed and practiced emergency procedures to utilize the school as a shelter.

Because of the unpredictable depth and the high velocity of tsunami inundation, it is recommended that all evacuations for a tsunami warning be to the second floor or higher of structurally sound buildings such as identified in Part 3 of this book.

2.3 EXTRATROPICAL STORMS

Extratropical storms are mid-latitude storms (outside tropical latitudes) that can produce long-wavelength (swell) which can travel great distances and impact the Marshall Islands. Some of the most notable flooding events from extratropical storms occurred in November 1979, December 2008, and March 2014 (see Figure 2-11).

Figure 2-11. This map shows the estimated extent of flood inundation from extratropical storms in November 1979; December 2008; and March 2014. The 1979 event was the largest and in several locations, the inundation crossed the island.

In late November and early December 1979, there was an extratropical storm that caused huge waves which traveled far distances and washed water over the island causing much damage (see Figures 2-12 to 2-15). The water was able to cut channels in the atoll. Because the area of wave generation was far away, it was actually clear sunny weather in Majuro.

Figure 2-12. Wave inundation and flooding during the 1979 extratropical storm in Majuro. Flooding at this location crossed the atoll. In some locations a channel was cut into the atoll. Photo courtesy of Hamilton Library, University of Hawai'i Pacific Collection.

Figure 2-13. During the 1979 inundation event, there were 100 to 300 houses that were destroyed. Many more were damaged. Wave inundation such as this is the reason elevating houses is covered in Part 4 of this book in order to reduce the risk of damage. Photo courtesy of Hamilton Library, University of Hawai‘i Pacific Collection.

Figure 2-14. During the 1979 event, there was an estimated $26 million in property damage and major portions Djarrit and Delap were covered in sediment. Photo courtesy of Hamilton Library, University of Hawai‘i Pacific Collection.

Figure 2-15. Also during the 1979 event, over 5,000 people lost use of their homes due to flooding (Hoeke et al., 2013). Photo courtesy of Hamilton Library, University of Hawai‘i Pacific Collection.

In December 2008 there was another significant inundation event that was generated by an extratropical system that caused major damage. The extent of this inundation and damage, however, was not as great compared to the 1979 events. Still there was significant inundation in Djarrit and Uliga.

In March 2014, there was again a significant inundation event that resulted from a combination of swells from an extratropical storm and a “King Tide” (see next Section 2.4). Inundation and damage started occurring several hours before the King Tide. The damage from this event can be seen in Figures 2-16 to 2-18.

Figure 2-16. Inundation in March 2014 was a result of swells generated by an extratropical storm raising water levels above normal. This made the shoreline of the Marshalls especially susceptible to further inundation and flooding from King Tides. This made the shoreline of the Marshalls especially susceptible to swell generated by an extratropical storm. The high waves inundated parts of Majuro, the Capital, as well as other communities in the outer islands, including Arno and Mili.

Figure 2-17. During the March 2014 event, about 110 homes were damaged and about 940 family members were displaced and sought sanctuary in government-designated shelters and churches. It is because of damage such as this that Part 4 of the handbook covers tools to reduce damage such as elevating of structures or building with flood resistant materials.

Figure 2-18. Even if a structure is elevated or built with flood resistant materials, during a typhoon or major tsunami, shelter should be to structurally sound buildings such as covered in Part 3 of this book. It may be acceptable to shelter in place for smaller events, such as the March 2014 floods, however, it is more than likely that inundation will be unpredictable (larger or smaller than anticipated). Thus if in doubt, evacuate to designated shelters.

Apart from damaged homes, other personal property, including cemeteries, were destroyed, contributing to alarming unsanitary conditions with wide-spread debris caused by the severe high waves and flooding. People's livelihoods were adversely impacted by the inundation and erosion caused by the hazardous waves particularly due to salt water intrusion causing damage and contamination to local food crops, drinking water supplies, and associated health risks from vector borne and water borne diseases.

2.4 KING TIDES

King Tides are simply the highest high tides of the year. They are also associated with the lowest low tides of the year. Figure 2-19 explains how King Tides develop.

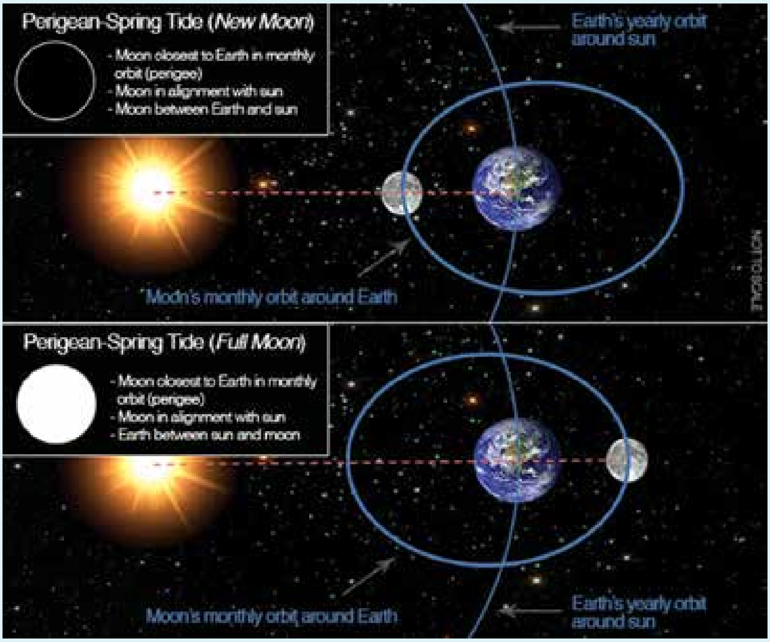


Figure 2-19. The highest tides of the month occur during the new moon (top) and the full moon (bottom). Then gravity from the moon and sun combine to create the strong tides. Even higher tides occur 3 to 4 times per year when the moon is full or new, and the moon is at its closest position to the earth. The moons distance to the earth varies since its orbit is not circular but elliptical. This creates a large variation in gravitational pull. At the moon's closest distance during a new or full moon is when there are King Tides. Image courtesy of NOS and NOAA.

King Tides have nothing to do with climate change. They are an astronomical phenomenon. However, King Tides can raise the water level so high during high tide that the shoreline on low lying atolls can be especially susceptible to erosion, flooding, and wave inundation. The March 2014 flood events (see Section 2.3 and Figures 2-16 to 2-18) are a good example of the impact of a King Tide combining with a wave inundation event such as an extratropical storm. It is also possible that a King Tide could combine with a tropical cyclone or tsunami to damage coastal areas. Finally as sea levels continue to rise, King Tide impacts will be more severe and are likely to include more loss of land through erosion.

King Tides can be accurately predicted because they are based on the orbits of the earth and moon. The Pacific Islands Ocean Observing System, or PacIOOS, is one of 11 regional associations of the U.S. Integrated Ocean Observing System (www.pacioos.org). PacIOOS has a forecast inundation tool for sea level that includes tides and swells. The tool for the Marshall Islands is available at: (http://pacioos.org/data_product/SLpred/Maj_Exc.php). The inundation tool is explained in Figures 2-20 to 2-21.

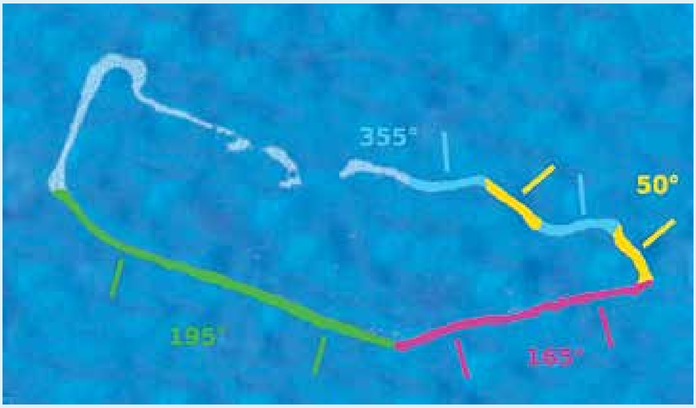


Figure 2-20. Majuro has been color coded into four shoreline sectors, depending on the orientation of the coastline with incoming waves. The shoreline sectors are perpendicular to waves coming in at 50, 165, 195, and 355 degrees of the compass. Each color represents a forecast of potential inundation. No forecasts are explicitly provided for the gray-shaded land areas.

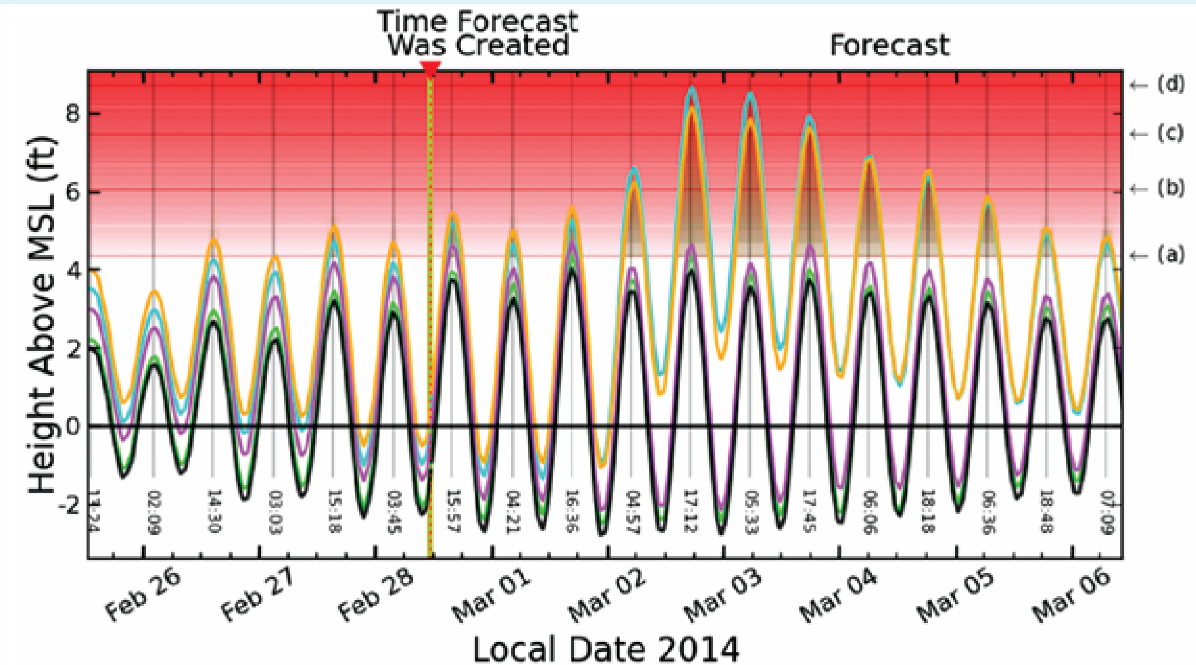


Figure 2-21. The black curve is a sea level forecast that does not include effects due to swell waves. This curve will reflect primarily the large spring tides and larger King Tides discussed in Figure 2-19. On top of the black curve are the Cyan, Orange, Magenta, and Green curves which will show the Inundation Height that indicates the potential for inundation of the land for the different sectors of Majuro due to swell waves (e.g., extratropical storms) added to the tides (high and low). If the forecast inundation height extends into the red shaded area, inundation is likely in low-lying areas. For the three days prior to the "Time Forecast Was Created," the colored curves are showing the last valid forecast for each date/time. The forecasts are updated hourly.

Note that using this forecast tool, inundation would have been predicted with the greatest threat between the afternoon of March 2, 2014 and the late afternoon of March 3, 2014. This is reflected in the actual damage seen in Figures 2-16 to 2-18. The figure shows the inundation was a combination of high tides and extratropical swell. This tool can help emergency managers and the public plan for potential inundation events days in advance.

2.5 SEA-LEVEL RISE

Another factor adding to the hazard risk in the Marshall Islands is sea-level rise. Sea-level rise is due to global warming, the melting of ice sheets, and the expansion of warmer water. Tide gauges on Kwajalein and Majuro have been used to document the extent of past sea-level rise (Figure 2-22).

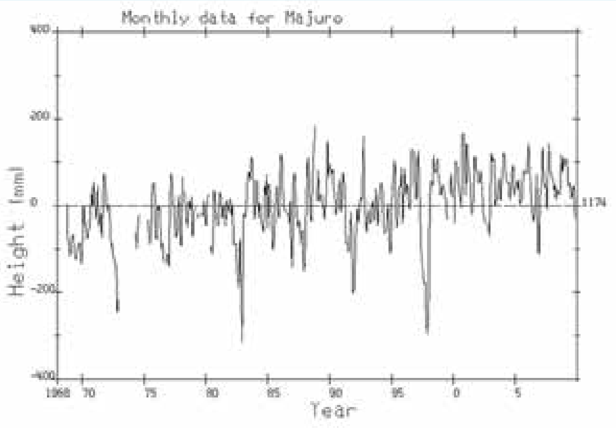
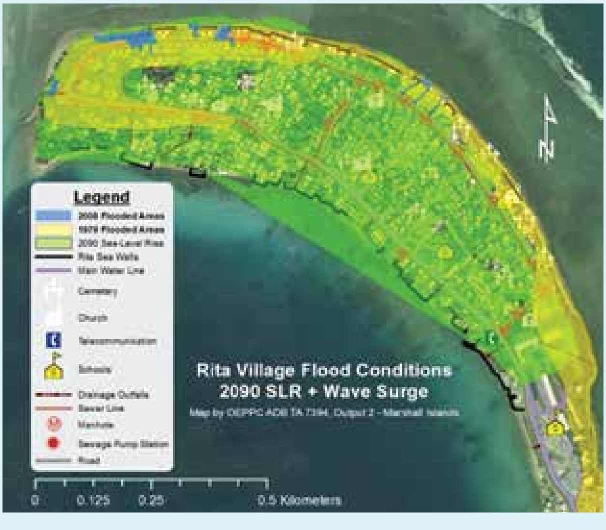


Figure 2-22. Tide gauge data for Majuro from 1968 to 2010 shows sea level has been rising in the area at a rate of about 3 mm per year. Data from NOAA Center for Operational Oceanographic Products and Services. The extreme lows in 1998 and 2003 are associated with El Niño events.

Sea-level rise is expected to accelerate in the future, but the exact amount is not certain. A projection of the impacts of sea-level rise is compared with inundation from the 1979 and 2008 extratropical storms in Figure 2-23.

Figure 2-23. The extent of wave inundation is mapped for extratropical storms in 1979 (in yellow) and 2008 (in blue). In addition, there is a projection for sea-level rise in the year 2090 using an estimated rise of 0.62 meters or 2.40 feet (in green). This is an example of flooding or wave inundation being caused by numerous events (extratropical storms and sea-level rise). Other risks for wave inundation and flooding can come from a tsunami or typhoon. Map courtesy of the Office of Environmental Planning and Policy Coordination and created by the MarTina Corporation.



Sea-level rise will increase the risk of erosion, wave inundation and flooding caused by any tropical cyclone (tropical storm or typhoon), tsunami, extratropical storm, or King Tide.

2.6 EROSION

Coral reef islands are naturally dynamic features, with their shoreline moving as a result of changes to the physical and biological environment. Reef islands are made up of sediment that is generated by the breakdown of living material on the adjacent reef. Coastal processes are physical and biological mechanisms that operate along a coastline, bringing about various combinations of sediment transport, erosion, and deposition. Human use of Majuro requires space and produces waste, which affects these natural processes and changes the location and relative proportions of erosion and accretion that would otherwise be present if it was an unpopulated area. Physical and biological processes are involved whether a coastline is eroding or accreting (Figure 2-24).

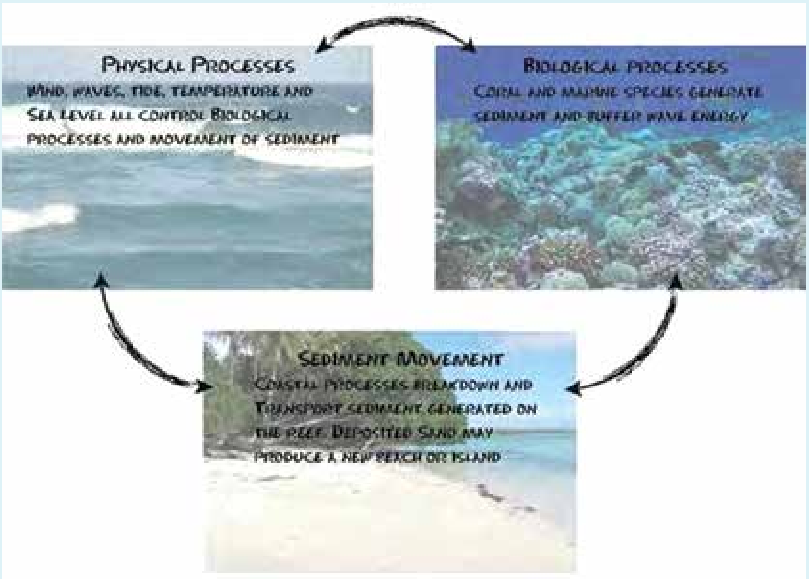


Figure 2-24. Some physical coastal processes include wind, waves, currents, tides, temperature, and sea level. They continually drive the sediment produced via biological processes and result in sediment movement that builds and erodes islands. Marine deposition on geological timescales and terrestrial deposition from episodic flooding are the overriding large-scale processes that determine where sediment accumulates over time.

Tides allow higher waves to reach the island at high tide. Island morphology shows that the highest elevation of an atoll island is on the ocean side berm (ridge), which is made up of coarse coral sediment and larger shingles (Figure 2-25). Lagoon shorelines are exposed to smaller waves, resulting in smaller berms made up of fine sediment.

Figure 2-25. The ridges of an atoll serve the important function of protecting inland areas from wave inundation and flooding. Thus they should be maintained and enhanced if possible.

Reef structure provides the greatest control on the Majuro shoreline. This is because reef width and elevation made up of rugged corals determine how much wave energy reaches the shoreline. The tropical coral reef crest in particular is responsible for an average of 86 percent of the attenuation of the wave energy as it approaches the shoreline (Ferrario et al. 2014, p4). Under stable sea level conditions, a healthy coral reef will continue to generate sediment that may be added to the island. Conversely, an unhealthy reef may not be able to sustain a continuous supply of sediment. Notwithstanding the impacts of coral bleaching and acidification, a healthy reef may also be able to grow upwards as sea level rises, contributing to adaptation and resilience to the effects of climate change (Ford 2013, p2).

The biological processes on Majuro's reef are significantly degraded due to the developed shorelines and nearshore herbivore fishing pressure in proximity to the urban center. Therefore, physical processes are likely more eroding rather than depositing sediment from biological processes over time (Figure 2-26). Coastal protection services from the ecosystem are slowly diminishing via bioerosion. Nutrient loading from run-off and sewage discharge is the primary local point source cause for the reduced ability of the reef to calcify as it becomes more algae-dominated than coral.

Figure 2-26. Erosion of the coastline at Laura, Majuro. Erosion is a serious hazard as it causes the shoreline to move inland and thus makes houses and buildings at increased risk from wave inundation and flooding. Erosion can be caused by physical processes associated with a tropical cyclone, tsunami, extratropical storm, and/or sea-level rise.

2.7 DROUGHT

Drought is directly related to the amount of rainfall the Marshall Islands receive. Weaker trade winds in the summer from April to October coincide with greater rainfall in those months, while stronger trade winds during the winter from November to March coincide with decreasing rainfall and the dry season most prominent starting in January (see Figure 2-27).

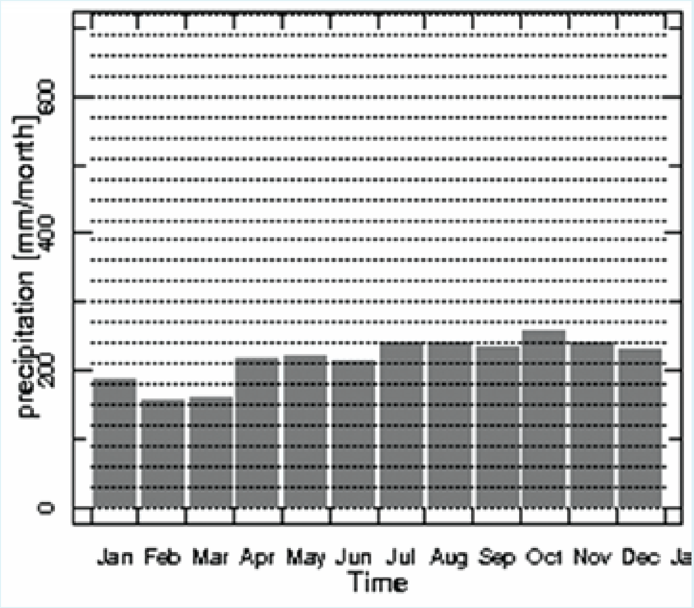


Figure 2-27. Average monthly rainfall for Majuro Weather Station is indicative of the entire Marshall Islands, where historically the dry season has been most prominent in January and extending into March, and possibly April during severe conditions. Compiled by climate researcher Mark Stege.

In April 2013, there was a severe drought that saw up to 6,400 people across 15 atolls surviving on less than a liter of water per person per day. The government declared a state of emergency on April 19 and that was followed by a state of natural disaster on May 8.

Drought is a serious problem in the islands and has led to many related problems. When there is a drought, there is a need for access to safe water and food. As a result of the drought in 2013 breadfruit and banana trees were decimated and the production of copra, or dried coconut meat was impacted. During the drought many people in affected areas had been drinking brackish well water, which was causing stomach and other health problems. The problems with brackish water will increase as sea level rises. In addition, inundation over low lying land areas can contaminate any fresh water drinking lens.

Because the Marshall Islands are susceptible to drought, it is important to have good emergency supplies as indicated in Part 3 of this book. This includes spare drinking water and a fire extinguisher since fire risk is increased during prolonged dry periods. In addition, an efficient and well-maintained water catchment system is essential as covered in Part 4 of this book.

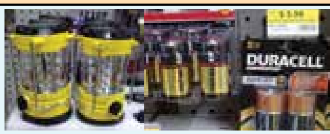
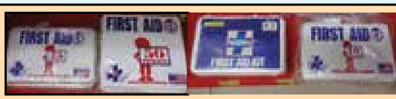
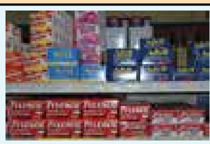
PART 3
PROTECTING YOURSELF AND YOUR FAMILY

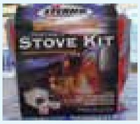
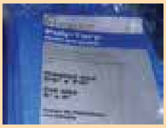
This part of the handbook covers protecting yourself and your family from natural hazards. In particular, it is important that your house has emergency supplies, an evacuation kit, and an evacuation plan for a tsunami and typhoon. This is important, because the Marshall Islands, being at or close to sea level, is very susceptible to wave inundation and flooding which can threaten life and property. If there is any one section of the book vital to families, it is Section 3.3 on having an evacuation plan.

3.1 EMERGENCY SUPPLIES

Emergency supplies will be very helpful during a major event such as a typhoon, and even for a smaller event, such as a power outage that happens often in Majuro. Gather your emergency supplies now and check them every month to make sure they are in good condition. Expiration dates can be marked on the packaging in large letters with a black permanent ink pen. Do not keep expired supplies. Here is a list of emergency supplies, many of which you can get at your local hardware or grocery store (see Table 3-1).

Table 3-1. Emergency Supplies Checklist

Item	Picture	Comment	✓
Portable radio with extra long life batteries		Important to receive emergency instructions from government officials, and carry spare batteries.	
Portable flashlight with extra long life batteries		Flashlights with light emitting diodes (LEDs) use very little energy and thus will last much longer on a set of batteries.	
First-aid kit		Comes in many different sizes. Antibiotic cream in the first-aid kit is an important accessory.	
List and supply of special medications (prescription and other)		Special medications may not be readily available during and after an emergency.	
Supply of nonperishable food		Seven days is common. Also have a manual can opener. Food for your pet.	
Water		Seven day supply of water – other than what is in your catchment system. A good estimate is one gallon per person per day for drinking, cooking, and personal hygiene.	

Item	Picture	Comment	✓
Water storage containers		Water storage containers are available at your local hardware store. You can also store water for toilet use (in bathtubs, rubbish containers, buckets, and washing machines).	
Portable stove or grill		Household electricity and gas lines may not function during and after an emergency.	
Charcoal, propane, or stove fuel		Also have matches and a lighter. Wood can be fuel and stored under a tarp, ideally elevated.	
Fire extinguisher		In many sizes. Flooding of electrical circuits can cause sparks and start a fire. During a drought, fire risk is increased.	
Disposable plates and kitchen utensils		Water for cleaning dishes may be in short supply during and after an emergency.	
Toilet items, portable toilet	 	Toilet paper, buckets, and associated cleaning materials can be handy in an emergency.	
Tarp		During high wind events there is often much roof damage. The tarps are commonly used to cover the roofs that are damaged and provide temporary shelter.	
Rope		Rope is very useful for numerous purposes. Tie down tarps, emergency life lines, etc.	
Life preservers	 	Adult or child. With rope you can create a lifeline for small inundation events as a last resort. Do not use for a tsunami due to water-borne debris. See discussion later in this section.	
Cleaning supplies	 	Very much in demand during recent inundation events in 2014.	

Item	Picture	Comment	✓
Garbage bags		Very useful for cleanup after an event. Can also be used to line buckets that serve as a toilet.	
Alternate power supplies	 	During an emergency or power outage, you may need to rely on alternate sources of power (e.g., generators, inverters, power stations, and battery chargers). Check your local hardware store.	
Siren		Not all houses will have a TV or radio. If you hear of an incoming tsunami through an official broadcast, notify your neighbors and community.	
Cell phone and landline phone	 	Cell phone networks may be overloaded during a hazard. Cordless phones with a base station will not work without electricity. If you rely on a cordless phone, get an alternate power source. Otherwise, have a corded phone that does not use electricity. Use phones only in an emergency	
Spare cash		In a power outage, ATMs will not work and banks will be closed. Purchases by credit or debit card may not be possible in an emergency because of lack of communication for card verification.	

3.2 EVACUATION KIT

During an emergency situation, such as a typhoon, and especially a tsunami, it may be necessary to leave your home quickly and go to a shelter. In Majuro, the government and Red Cross, along with USAID and the International Organization for Migration (IOM), may give out supplies after an event (Figure 3-1). However, there may not be enough supplies, or an event may not be large enough to trigger the release of aid. Also if you are on one of the outer islands, the availability of outside assistance is likely to be delayed.

For the above reasons, it is helpful to have your own evacuation kit. This will provide comfort that you have your own supplies during an emergency, because outside assistance may not be available until well afterwards.

The evacuation kit is different from your household emergency supplies. This kit is what you take with you when you evacuate your house to go to a designated shelter. Because it may be needed very quickly, the kit is usually in a portable plastic box or backpack and packed well before an emergency.

Figure 3-1. Although hygiene kits such as from IOM and USAID may be available after an emergency, it may still be useful to have your own evacuation kit with supplies. Common items in your evacuation kit are listed below. The advantage of having your own kit is that you can customize it to your own family's needs. In addition, the supplies would be available not only after an emergency, but before or during as well.

Common items in your evacuation kit can include:

- One gallon of potable water per person per day (three day supply)
- Non-perishable food (three day supply), special dietary foods and can opener if needed
- Required medications (two week supply), medical information list or directions, important documents
- Portable flashlight and radio, with spare batteries
- First-aid kit (can be smaller than the one used for household emergency supplies)
- Soap and shampoo
- Disposable plates and kitchen utensils
- Prescription eyewear and personal hygiene items for family such as toothbrush, toothpaste, toilet paper, diapers, soap, and shampoo
- Change of clothes and towels
- Pillows, blankets, and a mat

There is a fine line between bringing too many supplies that overload the shelter space and not bringing enough. If you go to a shelter, keep in mind there could be very limited space, so bring only what is recommended on this list or by government officials.

3.3 EVACUATION PLANNING

The most important part of this handbook deals with evacuation planning. If Marshall Islanders can implement only one section of the handbook, it is this section. The Marshall Islands is made up of 29 atolls and 5 islands without lagoons. The atolls and islands are very low-lying and subject to wave inundation and flooding from typhoons, tsunamis, and swells from distant storms (see Part 2). In emergency management, we plan for the worst and hope for the best. Hopefully, a damaging tsunami and typhoon will not occur. But from Part 2 of this book, we know that they are frequent enough in the region that we must plan for these extreme events, otherwise many lives may be lost.

This section is based primarily on a Rapid Visual Assessment Survey of structures in Majuro by Professor Ian Robertson of the University of Hawai'i during a four day period in January 2015. It is not a full structural assessment of all buildings, nor were any other islands or atolls looked at during this assessment. Some general principles nonetheless apply to help determine the strength of buildings and therefore their suitability as shelters. Section 3.3 consists of three subsections. First, in Section 3.3.1, "What is an ideal emergency shelter?" This is important because not all islands could be examined, nor all buildings on Majuro. Second, in Section 3.3.2, "What buildings in Majuro can be used for evacuation?" This utilizes the results of the Assessment Survey and is important because of the large population in Majuro. Finally in Section 3.3.3, "What is the role of the citizen, the government and the building owner/shelter manager if there is an incoming tsunami or typhoon?" Marshall Islanders, government agencies, and responsible organizations should assess the current situation and strive to obtain the ideal level of preparedness.

3.3.1 TEN CRITERIA FOR AN IDEAL EMERGENCY SHELTER

Not all shelters in the Marshall Islands will be ideal. Yet because of a potential emergency that could happen tomorrow, characteristics of an ideal shelter are described. This will allow government officials and Marshall Islanders to identify structures that might provide adequate protection during a tsunami or typhoon. In addition, deficiencies can be identified. Then continual improvements can be made to reach the ideal level of preparedness as quickly as possible.

All the photos for ideal shelters were taken on Majuro. Thus, there exists a base to increase shelter capacity and capability. It is urged that for all new buildings, whether they be for education, a government purpose or commercial use, that the guidelines in the report by Dr. Robertson are followed. It is also possible to create a win-win situation by having all new buildings serve a dual use, one for the purpose as intended and second as an emergency shelter.

Let's begin with characteristics of buildings we are looking for as shown in Figures 3-2 to 3-16.

The most important characteristic is that the building must have at least two floors, with adequate shelter space on the second or higher floors, and be built using a strong structural system.

Because of the low elevation in the Marshall Islands, a shelter must be a tall building with two floors or more (Figure 3-2).

Figure 3-2. For a strong tsunami or typhoon, evacuation to buildings with two floors or more is required. All things being equal, the taller the building the better. This photo taken from the third floor of the Assumption School (right) is of the two floor Administration Building for the College of the Marshall Islands (left). Both buildings are considered shelters for only the second floor or above.

Given the above, do not evacuate to the first floor of a building such as your house for a typhoon or strong tsunami. This applies even if your single floor house has been retrofitted with the measures in Part 4 of this book. Listen to official instructions from the WSO and National Disaster Committee (NDC) as they will analyze the hazard data and provide directions on who should evacuate where and when. Communication is key.

Another important criterion is for the building to have a strong structural system. The Concrete Moment Frame is structurally strong for both vertical loads (gravity) and lateral loads (wind, seismic, and flowing water) (Figure 3-3).

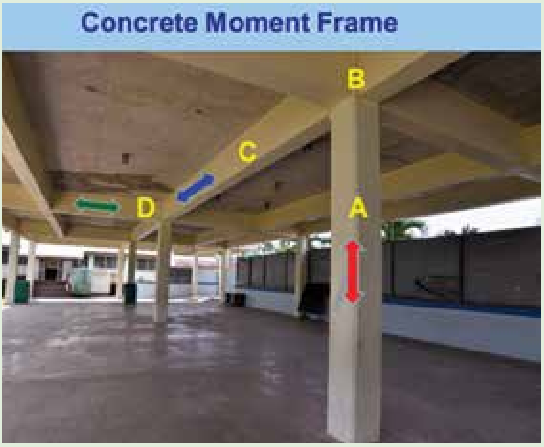


Figure 3-3. A Concrete Moment Frame has: (A) columns of concrete that are reinforced with rebar and attached rigidly at beam-column joints (B) to reinforced concrete beams such as at (C) and (D). Forces from high wind or fast moving water are resisted by the strength of the beams and columns. For example, forces in the direction of the green arrow are resisted by beam (D), in the direction of the blue arrow by beam (C), and in the direction of the red arrow by column (A). In addition, the lower floor is open. This allows water from a tsunami or typhoon to pass under the building without applying large forces from the side to the structure.

Figure 3-4. Many buildings identified as shelters have the Concrete Moment Frame – with columns (A), beams (B), and column-beam joints (C). They also have CMU blocks on the 1st and 2nd floors as infill (D) (see also Figure 4-39). While it is preferable that the first floor be open air as in Figure 3-3, this is still a strong structure if well maintained. This is the College Center at the CMI.

Examples of strong buildings with a Concrete Moment Frame and Concrete Masonry Unit (CMU) block infill are at the CMI (Administration Building, Learning Center and College Center only) (Figure 3-4), Rita Elementary School and the Marshall Islands High School. Many buildings in Majuro, including many residential houses are built with this design (see Part 4 of this book - Figures 4-1 to 4-3). However, houses cannot be used for shelter for a strong tsunami or typhoon because they lack elevation.

There are also buildings in the Marshall Islands with no Concrete Moment Frame and are CMU block infill (Figure 3-5).

Figure 3-5. The building on the right has a Concrete Moment Frame as shown by the blue columns and beams and CMU block infill (Administration Building at CMI). Compare that with the building on the left with only CMU blocks (Tole Mour Hall at CMI). The building on the right is stronger because of the Concrete Moment Frame.

Examples of buildings with just CMU block are Tole Mour Hall, Wapepe Hall, Debrum Hall and Rebbelip Hall at CMI (Figure 3-5). These buildings can be used as a shelter if well maintained although they are not as strong as the Administration and Student Center Buildings.

In addition to a strong structural system to resist lateral loads, the shelter building must also have a structurally-sound roof system to prevent uplift or damage to the roof due to high winds during a typhoon. The structural factors required for a sound roof are: good condition roofing that is well attached to the roof framing members (Figure 3-6); strong roof trusses (Figure 3-7) or roof beams (Figure 3-8); and a strong connection of the roof framing to the supporting columns, beams, or walls of the building (Figure 3-9).

Figure 3-6. Marshall Islands High School has many of the criteria looked for in a shelter. Note corrugated metal roof with sufficient fasteners and large washers to hold the metal roofing down during high wind events. The fasteners should be ring-shank nails or screws that are well-embedded into the supporting roof trusses, rafters, or purlins.

Figure 3-7. The roof trusses should be engineered and pre-manufactured. This will be standard in newer government buildings, especially schools. It will not be for older buildings. This photo shows a typical roof truss at Marshall Islands High School.

Figure 3-8. Another strong roof design is to have a ridge beam (A) attached with steel connectors to large sloping rafters (B) (top left photo). The sloping rafter (C) then connects to a horizontal beam (D) with a steel plate (bottom right photo). The beam is connected to the concrete column (E) with another steel connector. Photo from Marshall Islands Middle School.

Figure 3-9. This roof truss is connected to the CMU column with a bolted plate to prevent roof uplift during strong winds. Connection of roof trusses to the walls, beams, or columns is also important for residential houses and is covered in Part 4.

During a typhoon there will be a lot of flying debris carried by high winds. It is important that this debris does not break any of the doors or windows at the shelter, otherwise wind will enter and add to the uplift pressure on the roof. It will also bring rain and flying debris into the shelter where it could injure occupants. Any room that is used for a shelter on the second and third floors must have a strong door and window protection so that wind, rain, and debris do not break through. Thus screens such as those shown in Figures 3-10 and 3-11 should be on all the second and third floor windows. The protection is not needed for the fourth floor and above because the wind-borne debris will not get that high up. Figure 3-12 shows a strong exterior metal door at the second floor of Marshall Islands High School.

Figure 3-10. This screen at the Marshall Islands Middle School is made of strong aluminum bars in both directions and is attached to the CMU or concrete walls with embedded anchor bolts. The louver behind the screen can still be struck by small flying gravel, so should be made of shatterproof glass, glass with protective laminate, or aluminum slats for additional safety for those inside.

Figure 3-11. Security screen at Rita Elementary School helps to prevent breakage of the window by large debris. Behind the screen, the window should be shatterproof and/or a protective laminate added to the glass. Window protection is needed for any room that is a shelter on the second and third floors. All floors that are higher do not need window protection because the risk of wind-borne debris above 30 feet is less.

Figure 3-12. All exterior doors leading to the shelter areas should be sturdy metal or solid wood doors, with quality hinges and door latches to secure the shelter during high winds with potential debris impacts

Other factors to consider when selecting a suitable shelter building relate to access to the shelter level (Figure 3-13), the condition or maintenance of the building (Figure 3-14) and access to restrooms and potable water (Figure 3-15).

Figure 3-13. Some sturdy reinforced-concrete buildings have wood stairs to the second floor. They are likely to be damaged or washed away during heavy wave inundation. Such contingencies need to be planned for by having an emergency ladder readily accessible on the second floor. Note that the roof over this upper landing is also likely to be damaged or blown away during a typhoon. Photo of the Majuro Youth Center.

Figure 3-14. A potential shelter must be properly maintained. Here are examples of maintenance issues which could weaken the structure. Top left – missing washer and nut attaching waffle-crete column to the foundation. Bottom right – corrosion of hurricane clips attaching roof trusses to beam. As buildings get older, maintenance becomes a bigger issue.

Figure 3-15. An ideal shelter will have toilet facilities available on the same floor as the shelter. This is common in newer elementary schools. Other comfort criteria include minimum space standards such as 10 square feet per person. In an emergency, these criteria may be compromised in the interests of accommodating more people in the shelters.

Finally, no matter how strong a building, it will be of little use if it is not open during an emergency. Thus it is important that the WSO, NDC, and landowners where shelters are located and the people managing them, and the general public work together as one (Figure 3-16). This will require education, preparation, and practice. The Ministry of Internal Affairs is responsible for managing shelters once designated by the NDC, and this may involve delegation to the Red Cross for providing the volunteer manpower needed for staffing the shelters. **In addition, there should be redundancy in decision-making and communication since any break in delivering a key message can lead to the loss of life.**

Figure 3-16. During a typhoon or tsunami, the WSO will be analyzing data from across the Pacific and will be in communication with the NDC. The NDC will decide if evacuation is in order, what shelters are open and when. They will communicate this to the shelter landowners and managers, as well as to the general public. Warning times may range from a few hours for a tsunami, to a day and a half for an incoming typhoon. The WSO uses a satellite communication device called a "Chatty Beetle" for early warning for people in the outer islands.

With proper preparation by everyone, the goal of having the proper shelters open and accessible can be achieved.

Marshall Islanders and members of the ex-patriate community can do their part by planning for a hazard with their emergency supplies and evacuation kits. Most important, they should become familiar with the criteria summarized in Table 3-2. They can ask government officials as well as school principals what buildings will be open during an emergency as well as what back-up there is if a key person designated to open the shelter is off-island.

Table 3-2. Ten Key Criteria for the Ideal Emergency Shelters in the Marshall Islands

Criteria	Comments	✓
1. Tall building	Use second floor or higher. The taller the building the better if in good condition (Figure 3-2).	
2. Reinforced concrete	**Best** – Beam-column moment frame with open lower floor (Figure 3-3); **Good** – Moment frame with CMU infill on first and second floors (Figure 3-4); **Acceptable** – CMU walls – (solid grouted – concrete and rebar fill the holes) and **under 20 years old** (Figure 3-5).	
3. Tie down roofing	Secure roofing material to the roof (usually plywood over the trusses or rafters) with sufficient number of fasteners and large washers (Figure 3-6).	
4. Roof framing tied down	The trusses should be pre-manufactured and engineered for uniformity and strength (Figure 3-7). Roof trusses must be bolted to the beams, columns or walls to prevent lift-off during high wind events (Figure 3-9). Alternatively, ridge beam, and large sloping rafters should be connected to walls, columns, or beams with steel metal connectors (Figure 3-8).	
5. Window protection	Windows protected from debris impacts (Figures 3-10 and 3-11). Window behind screen should be shatterproof or laminated.	
6. Sturdy doors	The shelter doors should be made of metal or solid wood with quality latches and hinges to prevent their opening in high wind (Figure 3-12).	
7. Strong stairs	Some sturdy buildings have exterior wood stairs to second floor. These can be washed away during inundation events. Are there contingencies? (Figure 3-13)	
8. Well maintained	Look for newer building (under 20 years for CMU construction), no corrosion of fasteners, and no missing connections (Figure 3-14).	
9. Comfort	In the shelter rooms (second floor or higher) there should be toilet facilities and 10 square feet of space per person (Figure 3-15). In an emergency this criteria may be compromised.	
10. 24/7 access	During an emergency – the shelter spaces must be open. There must also be redundancy in case the person who opens the building is not available (Figure 3-16).	

These criteria are important for two reasons. First, not all buildings in the initial rapid assessment by Dr. Robertson could be examined on Majuro. Government, building officials, and all Marshall Islanders should use this list to examine other potential sites. Second, only Majuro from Djarrit to Laura was looked at. With this list, government officials and those knowledgeable about building practices can spot key criteria and make their own evaluations for other buildings on other islands. Also, many of the criteria are obvious and therefore members of the community can also help to spot strong buildings and see those that need additional work. If there are questions they should be raised with government officials and building owners and/or operators that are in charge of the shelters listed below.

3.3.2 SHELTERS ON MAJURO

Given the criteria in Figures 3-2 to 3-16 and summarized in Table 3-2, the results of an initial preliminary reconnaissance of emergency shelters for Majuro are presented here. First a few caveats:

1. The analysis was not a formal structural assessment for the specific goal of checking every building on-island. It was a reconnaissance as to what types of buildings are strongest to provide insight on important criteria until a more formal study and analysis can be done. This should be considered by government officials.

2. The list provided will be in constant change as buildings continue to degrade or are improved and retrofits added. Always check with government officials on updates to the list.

3. Very few of the buildings have all criteria so there are few ideal buildings. Yet some buildings are stronger than others so the purpose of this list is to point out those buildings that are relatively safer than others.

4. Of the buildings identified, probably the most important criteria for future improvement that government officials should work on is related to #5 – window protection and #10 – ensuring access 24 hours a day, 7 days a week in the case of an emergency.

Category 1 - High Priority Buildings are immediately available as shelters from a structural point of view. Some of these buildings may need additional window protection and review of roofing integrity, but are otherwise ready for sheltering inside during the next major wave inundation event (see Table 3-3).

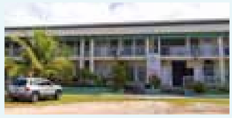
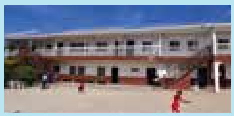
In the Table, the numbers indicate the number of people that can be accommodated based on a standard of 10 square feet per person. Because of the potential shortage of shelter space, more people may need to be accommodated, and this standard possibly reduced if retrofits of other buildings are not completed in time.

Comments here are directed to the general public. More detailed comments or information for government officials and building landowners and managers is found in the report by Dr. Robertson. The report is available from CMI and the NDC.

Before going to the shelter, confirm it is open by listening to radio v7ab and local TV. Radio reception is better on 89.9 FM but v7ab can be heard on 1098 AM. Also inform your neighbors and members of the community for any emergency, especially evacuation situations.

Table 3-3. Category 1 - High Priority Buildings

Building	#	Comments	Photo of Building
International Conference Center	480	The second floor provides well-protected shelter areas. Stay away from large unprotected windows.	
Mako (Tall Green) Building	1,200	All rooms from second to fifth floors provide good shelter space. No window protection on the second and third floor windows, so stay away from unprotected windows. Windows on fourth and fifth floor do not need protection.	
National Library and Museum	190	Second floor library provides space for sheltering. Quality reinforced Concrete Moment Frame, with CMU infill building.	
RMI Courthouse	225	Excellent shelter site with large courtrooms on second floor. Windows may need protective laminate to avoid shattering. First floor is partially open.	
Legal Services and Public Defenders Office	115	Good quality CMU building with diamond mesh screens on second floor windows. Elevated water tank should be available after event. Officials should check access given potentially important documents before declaring as a shelter.	
Public Service Commission	300	Building has security screens on all second floor windows. Glass entry door at second level is not ideal, but should already have shatterproof windows.	
Ministry of Internal Affairs	115	Good quality reinforced concrete frame and CMU infill walls. Diamond mesh window screens already installed in second floor windows.	
College of the Marshall Islands	720	College Center and Administration Buildings are sturdy reinforced Concrete Moment Frame buildings which provide good shelter space on the second floor. Diamond mesh screens already installed on the second floor windows.	
College of the Marshall Islands	1,440	Older reinforced concrete and CMU buildings (Tole Mour Hall, Wapepe Hall, Debrum Hall, and Rebbelip Hall) may experience structural wall damage during significant wave energy from a tsunami or major wave inundation, but should be strong enough to avoid collapse. Diamond mesh screens already installed on windows.	
Assumption Catholic High School	700	Good building for evacuation shelter. Classrooms at second and third floors provide good shelter space. Mesh screens should be replaced with aluminum grid screens similar to the Marshall Islands Middle School.	

Marshall Islands High School	1,615	Quality school buildings with newer construction. Some buildings have elevated water catchment tanks on the second floor. Windows have diamond mesh screens. Quality roof trusses and sheeting are present.	
Marshall Islands Middle School	775	School building with good construction. Excellent rectangular mesh aluminum window screens on the second floor should be the standard for future shelters and existing shelter retrofit. Good roof framing present.	
Laura High and Elementary School	475	Quality school buildings - newer construction with quality roof trusses and sheeting. All second floor windows protected by diamond mesh screens.	
Rita Elementary School	810	Quality school buildings - newer construction with quality roof trusses and sheeting. All second floor windows protected by diamond mesh screens. Louver slats are aluminum, not glass.	
Delap Elementary School	405	Good quality reinforced concrete moment frame with CMU infill wall buildings. Two buildings with second floor classrooms as shelter. Elementary schools have restrooms at each classroom.	
Rairok Elementary School	135	Quality school buildings - newer construction with quality roof trusses and sheeting. All second floor windows protected by diamond mesh screens.	
Independent Baptist School - Majuro Baptist Academy	380	Second floor classrooms provide shelter space with window protection already in place. Coastal protection under construction to reduce wave action on adjacent shoreline.	
Rita Assembly of God Church	160	Second floor balcony is ready for shelter.	
Rita Salvation Army	225	Second floor residential areas are available for sheltering. Windows already have security screens that will protect against windborne debris.	
Baet-ui-Ahad Mosque	70	Second floor meeting room with interior stairs. Exterior wooden staircase is unreliable.	

Category 2 - Medium Priority Buildings are suitable as shelters, but require some remedial work or require agreements with landowners and building owners (see Table 3-4).

If remedial work is required, NDC should check status of the building before using and notifying the public.

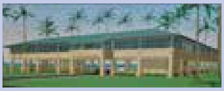
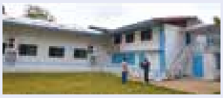
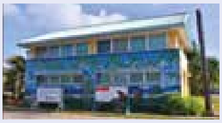
To relieve demand on shelter space elsewhere, privately-owned buildings that are not open to the public should at least encourage their employees, tenants or residents to invite their extended family members.

In the Table, the numbers indicate the number of people that can be accommodated based on a standard of 10 square feet per person. Because of the potential shortage of shelter space, more people may need to be accommodated, and this standard possibly reduced if retrofits at other buildings are not completed in time.

Comments here are directed to the general public. More detailed comments and information for government officials and building landowners and managers is found in the report by Dr. Robertson. That report is available from the CMI and NDC.

Before going to the shelter, confirm it is open by listening to radio v7ab and local TV. Radio reception is better on 89.9 FM but v7ab can be heard on 1098 AM. Also inform your neighbors and members of the community for any emergency, especially evacuation situations.

Table 3-4. Category 2 - Medium Priority Buildings

Building	#	Comments	Photo of Building
Trust Company of the Marshall Islands	210	Model building for storm and tsunami resistant design. Second floor provides excellent refuge. Need agreement with landowner and building owner to allow general public access. If acceptable to owners, employees, and their extended family members should be encouraged to stay to relieve the need for shelter space elsewhere.	
Calvary School Building	360 Future	Building structure okay, but work needed on portions of roofing, stair access to second floor and other maintenance issues before meeting shelter requirements.	
Ann's Palace Rehab. Government Building	600 Future	Good quality structural frame, but building is currently undergoing repairs for reinforcement due to corrosion. Not yet available, but second and third floors can serve as shelter when completed.	
Majuro Youth Center	45 Future	Reinforced concrete and CMU building in acceptable condition, but access to second floor via poor condition wooden stairs. There are other issues that need to be addressed for building to serve as shelter.	

Rita Assembly of God Classrooms	435 Future	Second and third floor school classrooms currently under construction - will be available when completed.	

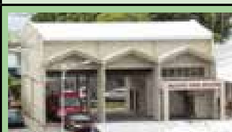
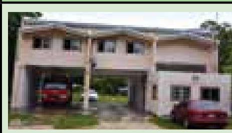
Category 3 - Low Priority Buildings can be used as shelter-in-place refuges for the current occupants, on the second floor or higher, with an estimate of the number of people who would remain at these buildings (see Table 3-5). This will reduce demand on the official shelters. **It is not recommended that additional people from the general public be sent to these buildings for sheltering. However, to relieve demand on shelter space elsewhere, privately owned buildings that are not open to the public should at least encourage their employees, tenants, or residents to invite their extended family members.**

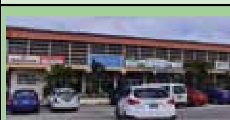
In the Table, the numbers indicate the number of people that are likely to remain in place in each building during an event.

Comments here are directed to the general public. More detailed comments or information for government officials and building landowners and managers is found in the report by Dr. Robertson. That report is available from the CMI and the NDC.

Please inform your neighbors and members of the community for any evacuation situation.

Table 3-5. Category 3 - Low Priority Buildings

Building	#	Comments	Photo of Building
Majuro Hospital Administration Building	230	Hospital wards are all at ground level. Only second floor area is in the administration building. Should be used to evacuate as many patients and staff as possible. Critical issue of where to take remaining patients.	
Marshall Islands Social Security Administration	50	Acceptable as stay-in-place refuge on second floor	
Majuro Police and Fire Station	24	Open framing at lower levels and rugged reinforced concrete building will perform well during inundation. Should be reserved as shelter-in-place refuge for emergency responders and their immediate family members.	
Laura Fire Station	36	Open framing at lower levels and rugged reinforced concrete building will perform well during inundation. Should be reserved as shelter-in-place refuge for emergency responders and their immediate family members.	
Bikini Atoll Town Hall	54	CMU and reinforced concrete building should survive inundation. Second floor acceptable as shelter-in-place for staff and their immediate family members, but not sufficient space to recommend for general public use.	

Building	#	Comments	Photo of Building
RMI Sea Patrol	54	Good quality reinforced concrete, moment frame, and CMU wall building. Should be reserved as shelter-in-place refuge for sea patrol staff and their immediate family members. This building may be used as the Emergency Operations Center.	
RMI Ports Authority	144	Good quality reinforced concrete, moment frame, and CMU wall building. Should be reserved as shelter-in-place refuge for ports authority staff, other tenants, and their extended family members.	
National Tele-communications Authority	100	Because structural system is obscured by an exterior insulation and finish system, it was not possible to determine structural integrity. Nevertheless, this building should be acceptable as stay-in-place refuge on the second floor.	
Public Works Department	50	Built inside pre-manufactured metal frame buildings. Acceptable as stay-in-place refuge on second floor.	
Marshall Islands Resort Hotel	1,350	Well constructed waffle-crete building. Should perform well during wave inundation. Acceptable for shelter-in-place at second and third floors, but do not recommend adding to tenant and staff populations.	
Robert Reimers Hotel	150	Older reinforced concrete and CMU buildings, but in acceptable condition. Acceptable for shelter-in-place at second floor, but do not recommend adding to tenant staff populations.	
Long Island Hotel	240	Reinforced concrete, moment frame, and CMU shear wall system. Should survive wind and water loads. Acceptable for shelter-in-place at second floor, but do not recommend adding to tenant and staff populations.	
Lojkar Apartments -3rd and 4th floors	500	Acceptable as stay-in-place refuge on second, third, and fourth floors. Tenants with extended family on island should invite them to reduce overall shelter needs.	
Eastern Gateway – Island Hotel	215	Old and poor quality reinforced concrete frame construction. Building is also poorly maintained. Not recommended as shelter, but can be used for shelter-in-place refuge for tenants if necessary.	
Bank of Marshall Islands Building	180	Older building, but should survive wind and water loads. Acceptable for shelter-in-place at second floor, but do not recommend adding to existing tenants.	

Marshall Islands Fishing Company	50	Acceptable as stay-in-place refuge on second floor for employees and their families.	
Uliga Shipping Agency Building	80	Acceptable as stay-in-place refuge on second floor for employees and their families.	
M & L Store Building	50	Acceptable as stay-in-place refuge on second floor for employees and their families.	
Will Mart	40	Acceptable as stay-in-place refuge on second floor for employees and their families.	

Category 4 - **Unacceptable for Refuge** - While buildings in this category may be strong under normal conditions, **they should not be used as a shelter during a strong tsunami or typhoon (see Table 3-6).** During these events, go to a Category 1 buildings (Table 3-3) or Category 2 buildings (Table 3-4), if open. If you are a relative of an employee or tenant in a Category 3 building (Table 3-5), and you are invited, then use those buildings.

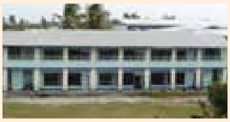
In general, unacceptable buildings during a major tsunami or typhoon are:

1. All single-story buildings of any construction
2. All timber framed buildings of any height
3. CMU block construction over 20 years old
4. Older and poorly maintained reinforced concrete buildings.

Comments here are directed to the general public. More detailed comments or information for government officials and building landowners and managers are found in the report by Dr. Robertson. That report is available from the CMI and the NDC.

Please inform your neighbors and members of the community for any emergency, especially evacuation situations.

Table 3-6. Category 4 - Buildings Unacceptable for Shelter During Strong Tsunami or Typhoon

Building	#	Comments	Photo of Building
Majuro Capital Building	0 (Future 1,500)	Building needs repair of floor slabs. Stay-in-place metal deck forms are corroding. Cannot be used as shelter until repairs are performed.	
Assumption Catholic Elementary School	0	Should not shelter due to poor connections and questionable lateral capacity of waffle-crete framing connections.	
Uliga, EZ Price Mart	0	Unknown structural system and unable to survey, so this building is not currently suitable as shelter or for shelter-in-place. Status could change with follow-up survey.	
Uliga Elementary School	0	Building in very poor condition structurally. Column spalls reduce area to 50% of original. Building should not be used as shelter.	
Marshall Islands Marine Resource Authority	0	Unknown CMU construction supporting wood framed second floor. Should not be used for sheltering.	
Majuro Stevedore and Terminal Company Building	0	Unknown structural system with exterior metal sheeting. Should not be used for sheltering.	
Office Mart	0	Older CMU construction. Not suitable for sheltering.	

PART 4
PROTECTING THE HOME

Part 4 covers what homeowners or those living in houses can do to make the existing structure more resistant against wind, flood, and wave forces. The amount of retrofit possible will vary for each house. This is because there may be existing limitations (for example, the wood is in poor condition from termites, or the house is subject to flood risk). There also may be limited access to the key parts of the house.

While the main focus of this book is to provide best practices for existing houses, some of the practices are also suitable for new homes. Many of the best practices may make a house more resilient to hazards, more efficient and thus more environmentally sustainable, while helping to adapt to climate change. Nevertheless, there is only so much that can be done with an existing structure. As with all options presented in this book, the reader should ideally refer to a professional or licensed architect, engineer, or builder before beginning any work.

In this book, a range of options are provided from the affordable to the more expensive. Traditional Marshallese methods are provided as well as options developed elsewhere, but considered feasible in the Marshall Islands. Consideration is given to cost, availability of materials, and ease of installation. A great resource for information and options are your hardware stores such as Ace Hardware or Do-it-Best, both located in Majuro and listed as partners in this book.

This part of the book deals with: a) strengthening the roof structure to deal with high wind and rain; b) protecting the wind and rain resistant envelope around the house with window covers; c) measures to reduce termite and corrosion damage; d) reducing wave and flood damage; and e) maintaining and retrofitting water catchment systems as a way to reduce risk from drought and prepare for climate change.

4.1 THE ROOF STRUCTURE AND PROTECTION FROM HIGH WINDS AND RAIN

A typical house in the Marshall Islands has concrete walls that are fairly strong against wind forces. As was discussed in Part 3, and shown in Figure 4-1, the houses commonly have a moment frame consisting of concrete poured corners and a structural bond beam. The weak link is often the attachment of the roof to the concrete walls. Thus many of the options given deal with strengthening the entire roof structure.

Let’s begin with some terminology for existing houses beginning in Figures 4-1 to 4-3.

Figure 4-1. Common parts of a Marshallese home from the outside. (A) Concrete structural bond beam. (B) Purlins typically run parallel to the length of house and are 2 inch by 3 inch lumber. (C) Aluminum or steel corrugated metal roofing. (D) Trusses typically running parallel to the width of house and consist of 2 inch by 6 inch lumber. (E) Windows and doors typically framed by 2 inch by 4 inch lumber.

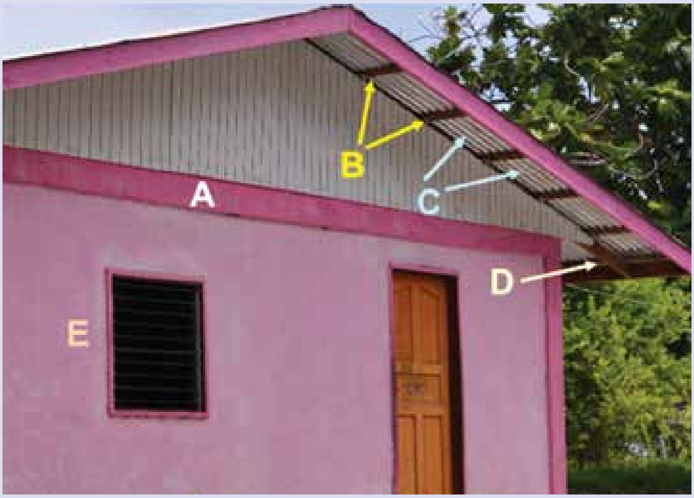


Figure 4-2. As shown in Figure 4-1, the trusses typically run parallel to the width of the house and are made of 2 inch by 6 inch lumber. On top are purlins, consisting of 2 inch by 3 inch lumber, typically running parallel to the length of the house. Attached to the purlins is the metal corrugated roof.

Figure 4-3. On top of the concrete structural bond beam is commonly a wood top plate, consisting of 2 inch by 4 inch lumber. On top of the wood plate are the trusses. To prevent wind damage during a storm, there must be a strong connection from: (a) the wood top plate to the structural bond beam; (b) the trusses to the wood top plate; (c) purlins to the trusses; and (d) metal corrugated roof to the purlins.

For a strong roof and house against the wind and rain there must be a strong connection or tie from the: (a) wood top plate to the concrete structural bond beam (Figure 4-3); (b) trusses to the wood top plate (Figure 4-3); (c) purlins to the trusses (Figure 4-2); and (4) metal corrugated roof to the purlins (Figure 4-2). It is possible, depending on access, for existing houses to be retrofitted so that some or all of these connections are strengthened. This is covered in Figures 4-4 to 4-27. These connections can be considered for existing homes in a retrofit application, depending on feasibility (access, cost, etc.). They should definitely be considered during new construction, when access is not a problem.

4.1.1 TYING THE WOOD TOP PLATE TO THE CONCRETE STRUCTURAL BOND BEAM

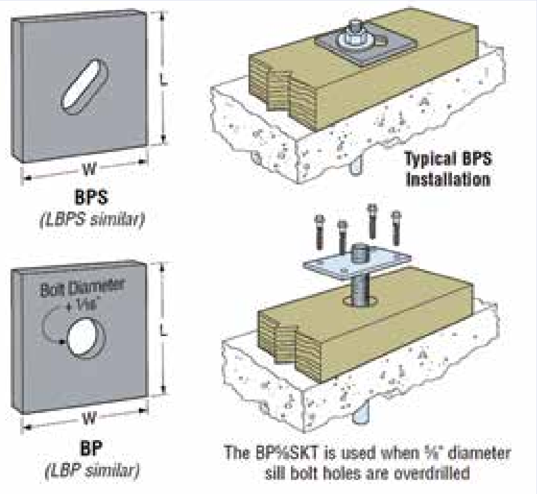
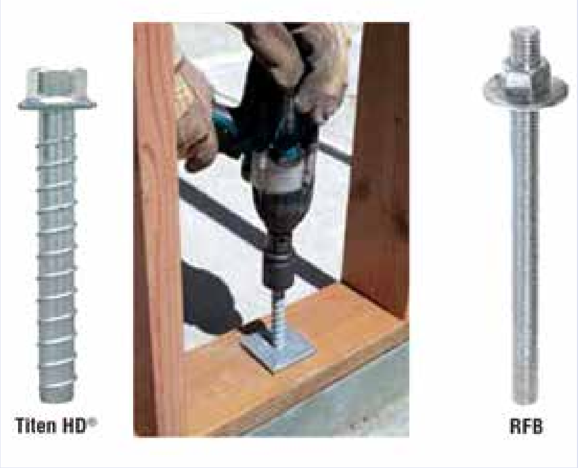


Figure 4-4. Typically, there is a 2 inch wood top plate over the concrete structural bond beam. In new installations and possibly in retrofit applications, a metal bearing plate should tie the wood plate to the concrete beam. Bearing plates and load bearing plates that are on Page 40 of the 2015-2016 Simpson Strong-Tie Wood Construction Connectors Catalogue (SWCCC) can be used (see: http://www.strongtie.com/literature/c-c-2015.html?source=halfblock). The bolts are embedded in the concrete at the time the wall is poured.

Figure 4-5. For retrofit of existing structures, where a strong connection between the wood top plate and concrete structural bond beam is needed, sill plate anchors such as on page 42 of the SWCCC can be used. Bearing plates can also be used. This retrofit requires sufficient access under the roof. A right angled impact driver may be needed. For the screw on the left (Titen HD), pre-drill the hole to the size of the shaft, with a hammer drill using a concrete bit. Then screw in with an impact drill. For the fastener to the right, drill with a 1/8 inch oversized hole, then fill in with structural epoxy.



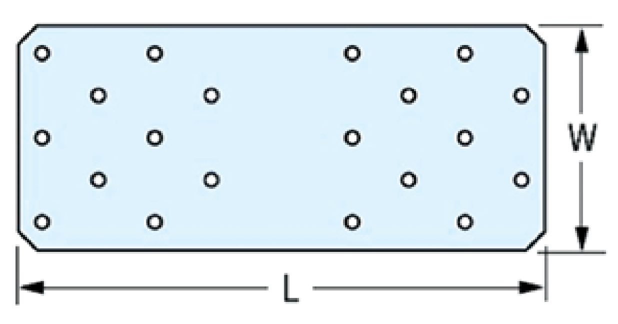


Figure 4-6. Another way to tie the wood plate to the concrete beam is to use the HTP37Z Metal Plate. This plate is 7 inches long and 3 inches wide. Five of the 1 ½ inch long 10d nails attach to the wood (see Table 4-1) and page 22 of the SWCCC. For the concrete, use five masonry screws such as a Titen Hex Head on page 173 of the SWCCC in order to match the loads. In installation, the plate is oriented with the long axis vertical. To use this, either the interior or exterior of the wood plate and wall must be flush.

Table 4-1. Note About Connector Nails

Nail	Length in Inches	Diameter in Inches	Hot Dip Galvanized (HDG) or Stainless Steel (SS)
8d Common	2.5	0.131	SS
8d by 1 ½	1.5	0.131	HDG & SS
10d Common	3.0	0.148	HDG & SS
10d by 1 ½	1.5	0.148	HDG & SS

A note about connector nails. Penny nails (designated with the letter d) typically have a certain length and diameter and are listed in the table below as a Common nail. In addition, Simpson has connector nails with the letter d that are non-traditional in length. These are commonly specified in their catalogue. Note also that some nails come in stainless steel while others in hot dip galvanized or stainless steel. It is important that the nail and connector are the same material.

4.1.2 TYING THE TRUSS TO THE WOOD PLATE OR CONCRETE BEAM

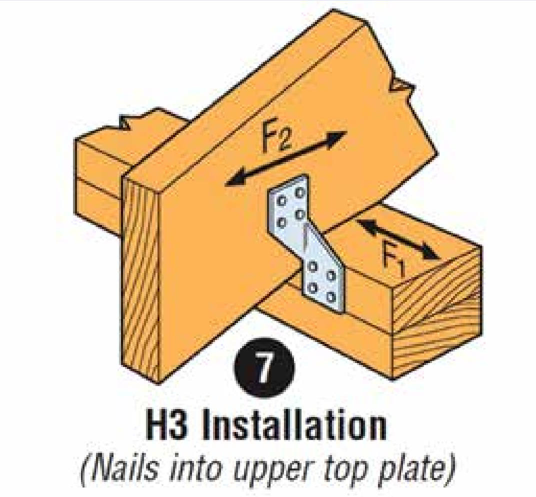


Figure 4-7. To tie the Truss to the Wood Plate, H3 clips are very useful. The H3 allows 455 lbs of upload resistance per Truss. It is useful when there is only one wood plate on top of the concrete wall (see Figure 4-3). Four 8d Common nails go into the truss and four into the one wood plate. The H3 clip is inexpensive, readily available in Majuro and suitable for retrofit applications. For other methods to tie the truss to the wood plates or wall (see Figures 4-8 to 4-14). The advantage of the H3 clip is that it provides an engineered solution to resist high winds.

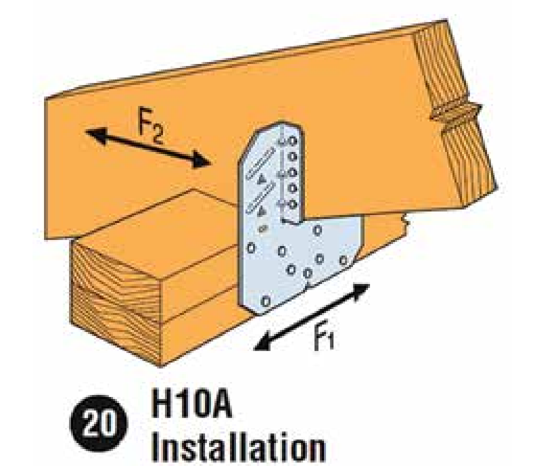
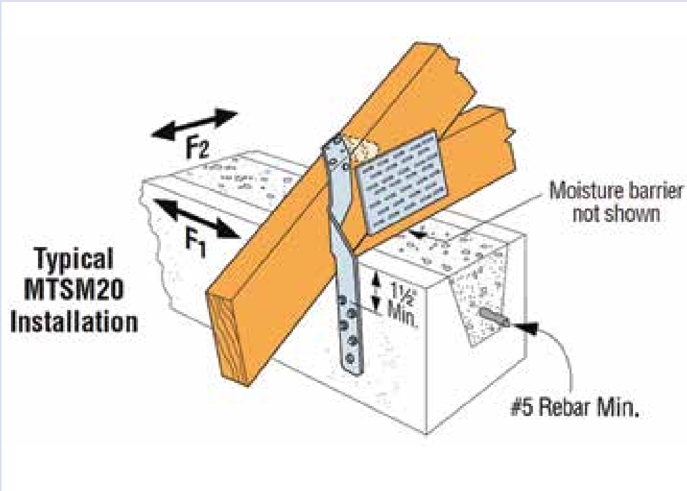


Figure 4-8. Sometimes there are two wood plates over the concrete beam. In this case the H10A clip can be used. This tie offers more than twice the upload protection compared to the H3. Follow the nailing pattern on page 196 and 197 of the SWCCC catalogue. Nine 10d by 1½ inch nails are in the truss and nine 10d by 1½ inch nails are in the wood plates. The Homeowner has the choice to use the easier to install, and less expensive H3 or the H10A, which offers more protection. Either the H3 or H10A can be used in new or retrofit applications, depending if there is access.

Figure 4-9. For new installations, the MTSM/HTSM strap offers 860 to 1175 pounds of uplift protection per truss and is suited when there is no wood plate and the connection is from the truss to the concrete wall. This can be found on page 182 of the SWCCC. Masonry screws – 4 quarter inch wide and 1¾ inch long go into the concrete and seven 10d nails go into the wood truss.



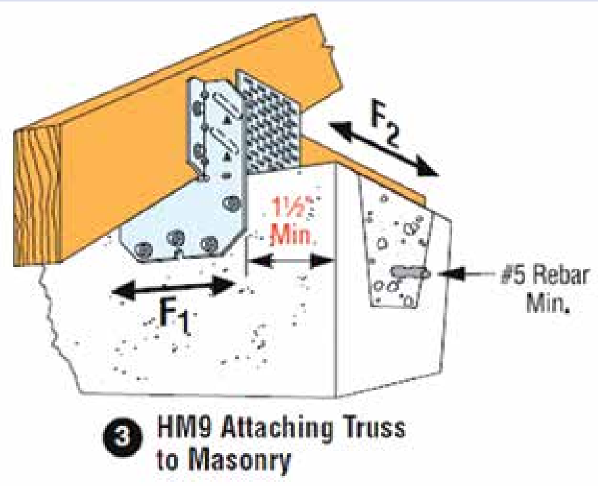


Figure 4-10. The HM9 is a connector made especially for the situation where there is no top wood plate and the attachment is directly from the truss to the concrete structural bond beam. This is good for retrofit applications and requires 4 of the SDS ¼ inch wide and 1 ½ inch long screws for the truss and 5 of the ¼ inch wide by 1 ¾ inch Titen screws for the concrete. See page 178 and 179 of the SWCCC.

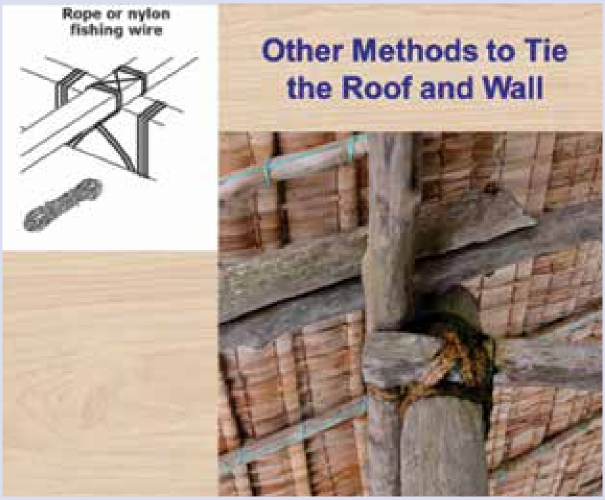
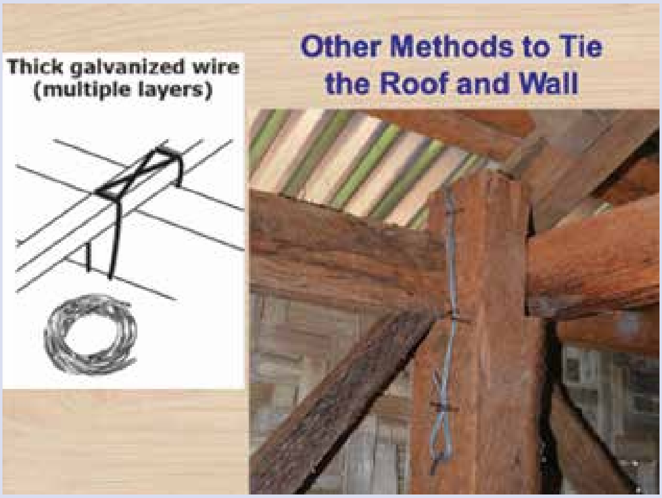


Figure 4-11. Tying roof members to post with coconut fiber rope. This is a traditional Marshallese way of tying roof members to the supporting beams. It is stronger than just toe-nailing wood members, which can be easily pulled apart in tension by high winds. Image in top-left corner from Sheltercluster.org.

Figure 4-12. Attaching roof members to a beam with multiple layers of galvanized wire. Image in top-left corner from Sheltercluster.org.



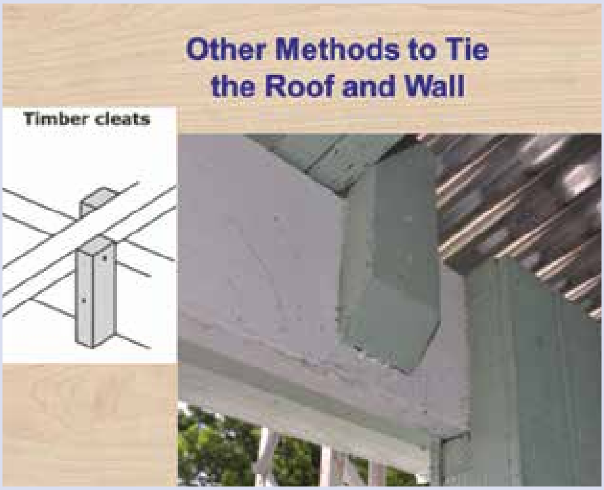
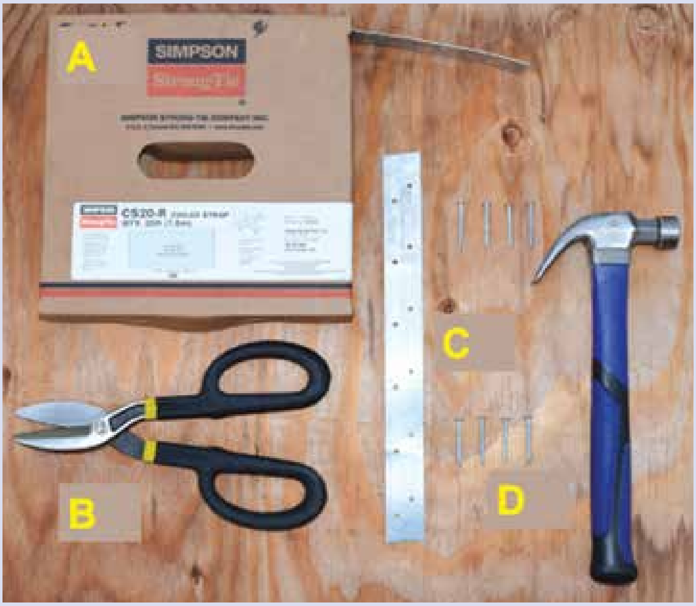


Figure 4-13. Attaching truss to beam with timber cleats. The cleats are ground contact, termite treated 2 by 4's made of Douglas fir. 8 inch pieces are beveled at the end for aesthetics and painted with 2 coats of indoor/outdoor primer and 1 coat of paint to match the wall. Three – 3 inch screws attach the cleat to the white beam. Three – 3 inch screws from the opposite side of the truss attach it to the cleat. The process is repeated if two cleats are used per truss. Photos courtesy of Ben Chutaro. Image in top-left corner from Sheltercluster.org.

Figure 4-14. Attaching roof members to the beam with galvanized metal straps. (A) Structural straps in a coil and with different lengths and thickness are available locally. (B) The strap is cut to the desired length with a metal snippet. (C) Metal strap cut to desired length. (D) Six 10d or seven 8d common nails can be used to attach each end (page 189). The length is cut as needed, or the table in SWCCC can be followed for specific design loads. This is a general purpose connector for members that are flush. For those at right angles to each other, bends may be needed, and thus other connectors may be more useful. The advantage of the coiled straps is low cost and the flexibility to adjust the length. CS-16 straps are available in Majuro at a cost of $138 for a coil of 150 feet.



4.1.3 FORTIFYING THE TRUSSES

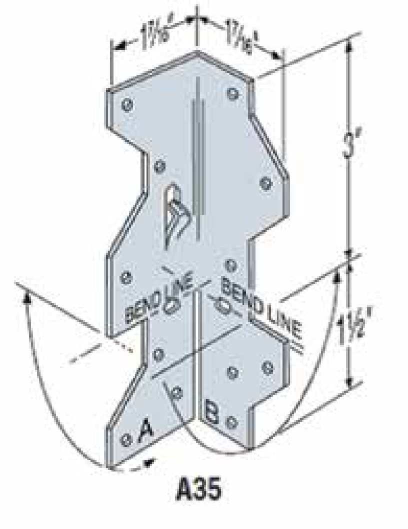
Figure 4-15. Typical roof structure can be strengthened for new construction and in retrofit applications. To tie the roof trusses, sometimes nails are used in tension, which pull out easily in high winds. Stronger is the use of wood gussets, instead of nails to tie the truss together in shear. Note the purlins are spaced 4 feet apart. If the purlins were 2 feet apart the roof would be stronger.

Figure 4-16. Strong truss connections come from the use of metal plates or wood gussets. Both the metal plates and/or wood gussets can be used for new construction or could be used for retrofit applications if the roof structure is not covered by a ceiling. Mending plates are readily available at the hardware stores in Majuro. They come in different sizes so make sure they are designed for trusses.

4.1.4 THE TRUSS-PURLIN CONNECTION

Figure 4-17. In an enlargement of Figure 4-15, on top of the trusses, are wood purlins (2 by 3's) running perpendicular to the trusses and parallel to the length of the house. The metal corrugated roof is attached to the purlins. It is important that the purlins are strongly fastened to the trusses. This can be done for new buildings and in retrofit, if a ceiling does not cover the roof structure.

Figure 4-18. The A35 clip can be used to fasten wood at right angles, such as for the truss-purlin connection. The A35 plate pictured here and on page 206 of the SWCCC has bend slots which allow instant, accurate field bends for all two- and three-way ties. The reversible design permits the A35 to secure a great variety of connections. Nine 8d 1.5 inch nails are used to make the connection. The clip is readily available in Majuro. It is important that similar metals be used. For example, use stainless steel nails for stainless steel A35 clips. Use hot dipped galvanized nails with hot dipped galvanized A35 clips. Do not mix the metals for the clip and fastener.



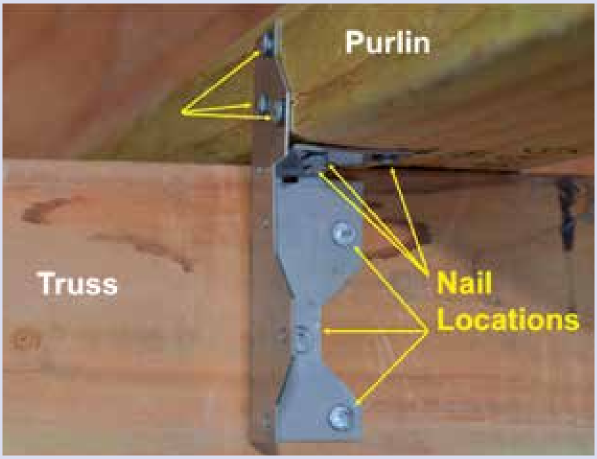


Figure 4-19. The A35 plate can strengthen the connection between the truss and purlin. This Figure shows how the A35 clip can be configured. The A35 clip is bent so that one tab and 3 of the 8d 1.5 inch nails are on the side and bottom of the purlin. Another tab with the similar fastener configuration is in the truss.

4.1.5 FASTENING THE ROOF TO THE PURLINS

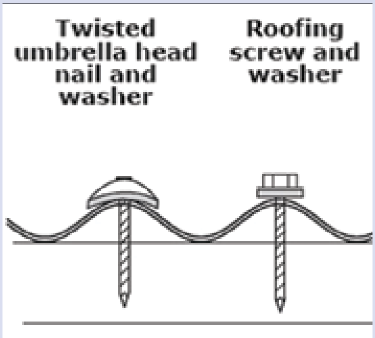


Figure 4-20. Typically corrugated metal roofing is attached to the purlins with nails. Even stronger is to use a twisted umbrella head nail and rubber washer. These are made in New Zealand. This is the connection recommended by Sheltercluster.org for their manual in the reconstruction of the Philippines after Typhoon Haiyan/Yolanda. Alternatively, a roofing screw with washer can be used. These fasteners can be used for: (i) new roofs, (ii) the retrofit of existing roofs, if the current roof is damaged, or (iii) as additional fasteners on an existing roof. For any screw or nail, the material for the fastener and the roof needs to be the same. For example, use aluminum screws to attach the aluminum roof to the purlins.

Figure 4-21. Different fasteners to tie the metal corrugated roof to the Purlins. (A) Aluminum ring shank nails with rubber washer is a strong method to attach the aluminum roof. Material is readily available in Majuro. (B) Aluminum screw with rubber washer, aluminum metal cap and another rubber washer is an even stronger method to tie the metal roof to the purlins. Unit cost is about $1. The Majuro Department of Public Works ordered these in bulk to attach the roofs for the local schools.

Figure 4-22. Roof ties with a metal wire are an inexpensive but strong method of attachment. The ties are about 50 cents for 12 and consist of a metal cap with G1 wire. Once a hole is drilled in the roof, the wire is threaded through the hole and wrapped around a screw or nail that is attached to the purlins. The screws or nails are perpendicular to the potential uplift wind forces, as opposed to being parallel, when they can more easily be pulled out. Photo courtesy of Ministry of Public Works.

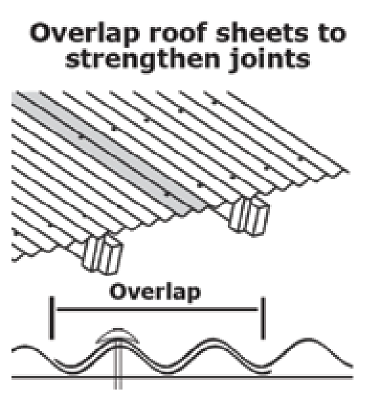


Figure 4-23. Additional measures to strengthen the roof include providing sufficient overlap of the corrugated metal sheets in order to strengthen joints (From sheltercluster.org). It is recommended that there be at least two ridges overlap. This should be done for new construction and in the repair or replacement of existing roofs.

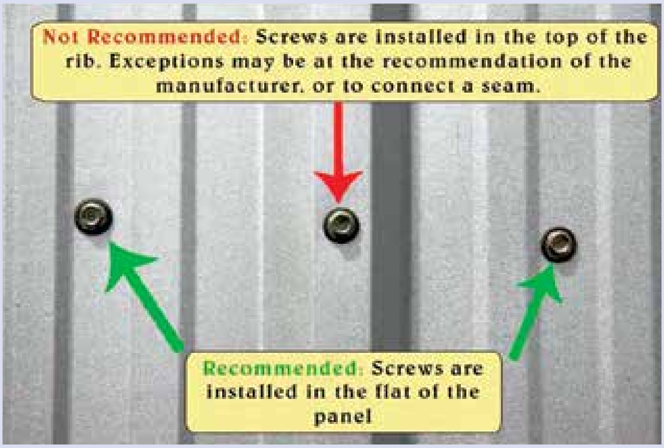
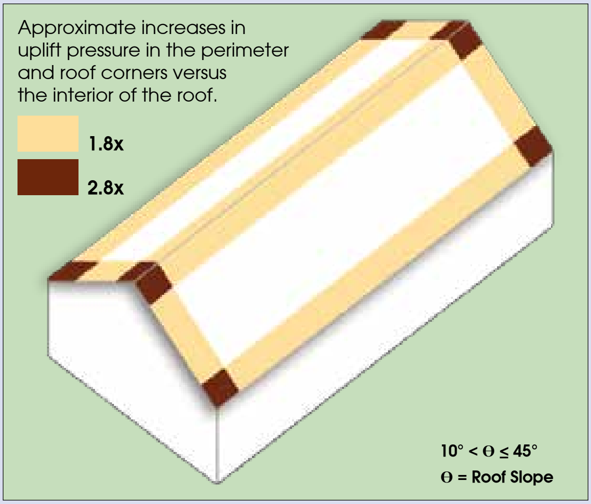


Figure 4-24. Some roofs in Majuro have flat sections that differ from undulating roof sheets shown in Figures 4-20 and 4-23. In this case, fasteners to the purlins should be in the flat lower flat portion of the panel. Photo courtesy of Christian Oakes, IOM.

Figure 4-25. For high wind events such as a typhoon, uplift pressure to blow the roof off will be greatest at the corners, roof edges and ridges. At the corners it may be 2.8 times greater. At the edges and ridges, 1.8 times greater (from Homeowner's Handbook to Prepare for Natural Hazards – Hawai'i). For this reason, use more nails or preferably screws in these areas.



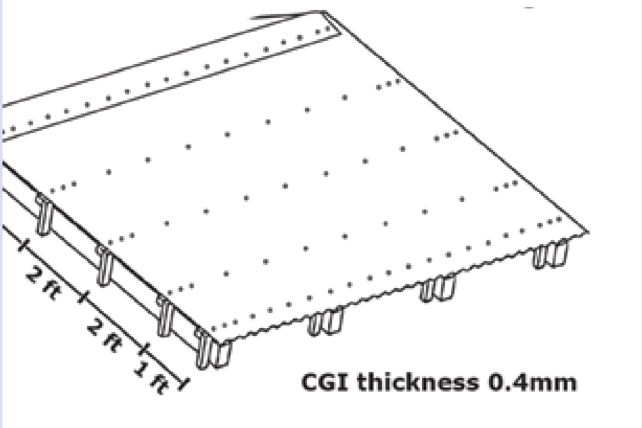


Figure 4-26. Due to greater uplift pressure on the roof edges and ridges as shown in Figure 4-25, more nails, or better yet, screws should be used to fasten the roof to the purlins at the roof edges and ridges. In addition, note the purlins are 2 feet apart to create a stronger roof (from Sheltercluster.org). This differs from the typical 4 feet spacing in the Marshall Islands.

Figure 4-27. Uplift pressure on the edges and corners of the roof is greatest (see Figure 4-25) due to overhangs. Limit the overhangs to 45 cm or 1.5 feet maximum (from Sheltercluster.org). This can be done in new design, or when roofs are repaired or replaced as a retrofit. It is very important to have the proper connections from the roof to the purlins (Figures 4-20 to 4-24) and limit overhangs. Without proper precautions, the roof can easily peel off in high winds. Providing plywood to cover the bottom of the rafter extensions will also reduce the uplift load on the roof sheeting.

The shape of a roof is important in the ability to resist wind forces on the structure. Roof shape is really a new design issue rather than a retrofit, since it is hard for an existing house to have the shape of the roof changed. For new designs, stronger roofs can have: (i) a slope of 30 degrees (see Table 4-1); (ii) a hip style roof where upward sloping roof surfaces meet in the center of the house; and (iii) trusses and purlins that are spaced 2 feet apart instead of the usual 4 feet (see Table 4-2).

Table 4-2. How to Estimate Roof Slope

Height of Roof from Ceiling/Width of Roof from Center under Ridgeline to Edge of House	Slope in Degrees
1/12	5
2/12	10
3/12	14
4/12	18
5/12	23
6/12	27
7/12	30 – ideal slope
8/12	34
9/12	37
10/12	40
11/12	42
12/12	45

4.2 PROTECTING WINDOWS FROM HIGH WIND AND DEBRIS

During a typhoon, no wind or rain should penetrate the envelope of the house (see Figure 4-28). If a window breaks, it allows the wind to enter the house and cause internal pressure that increases the uplift on the roof. Thus it is important to protect windows with a shutter, most commonly plywood.

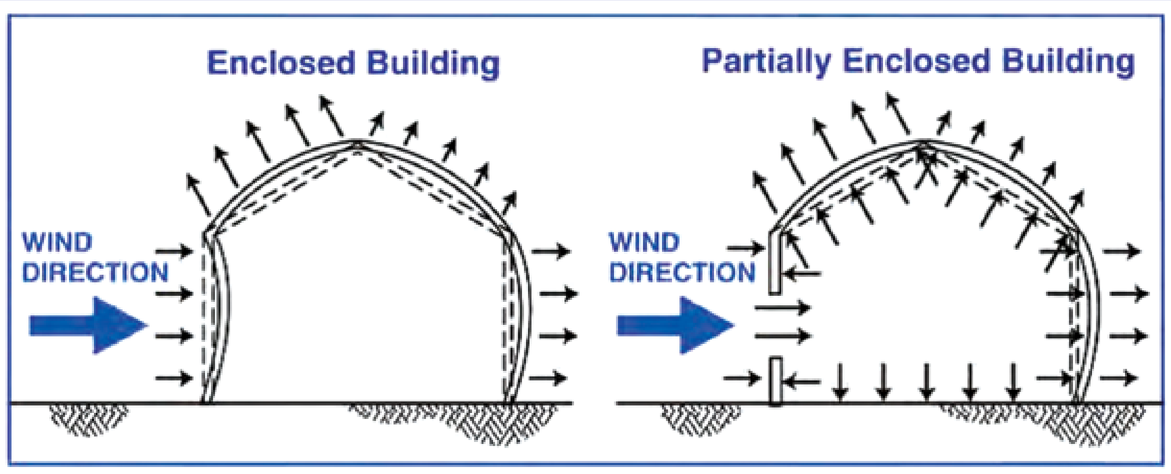


Figure 4-28. The house on the left has no openings. There is external pressure from the wind on the walls and roof only. The house on the right has an opening, either by design or because a window broke. Now there is external and internal wind pressure on the walls and roof, making it more likely for the roof to fly off. See Figure 2-6 for typical wind damage in the Marshall Islands from a typhoon, with roof blown off. This is why it is important to protect the windows with a covering such as plywood during a typhoon (see Figures 4-29 and 4-30).

Figure 4-29. Typical window for a concrete house in Majuro has the window framed by 2 inch by 4 inch, or 2 inch by 6 inch termite treated lumber. If the window framing and concrete wall are flush, plywood can be cut to overlap the treated framing lumber by 1 or 2 inches. Then fastener holes can be pre-drilled in the plywood at a pre-determined spacing to hit the middle of the 2 inch by 4 inch or 2 inch by 6 inch, while staying away from the edge of the plywood. If the window framing is inset, the plywood must be precisely cut to insert in the inset. Fastener holes should still be pre-drilled into the plywood.

Figure 4-30. For this wood framed house in Majuro, the 2 inch by 4 inch or 2 inch by inch 6 inch lumber frames the window, as in Figure 4-29. Plywood panels should be pre-cut to the proper size to overlap the window. The fasteners must go into the framing lumber (2 inch by 4 inch or 2 inch by inch 6 inch) not the wood panels covering the side of the house. Follow the 4 P's (Figure 4-31) and suggestions below.

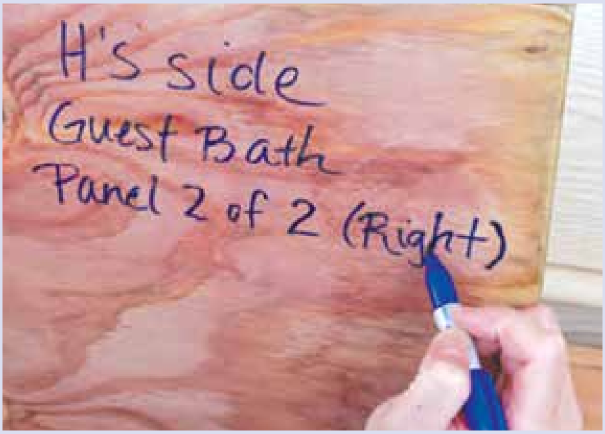
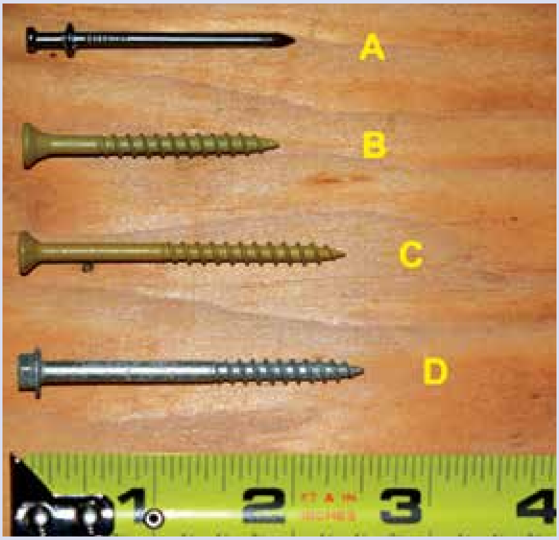


Figure 4-31. Remember the 4 P's in preparing plywood shutters. (1) Precut the plywood to the proper dimensions before an event; (2) Prelabel the plywood for the appropriate window; (3) premark the location of the fasteners on the plywood; and (4) Predrill the faster holes on the plywood. All this preparation needs to be done in advance, and generally cannot be done if there is an incoming typhoon.

Figure 4-32. Fasteners that can be used to attach plywood storm panels. A) Duplex or two-headed 2 inch nails are used to initially attach the top left and right corners of the panel to the wood framing of the window. B) #8—2 inch wood driving screw. Allows 1¼ inch embedment; C) #9—2.5 inch wood driving screw. Allows 1 ¾ inch embedment; D) #10 Lag Screw—in this case, a 2.5 inch Simpson self-driving screw. Not all lag screws are self drilling (see Tables 4-2 and 4-3).



Because of termites, precut plywood to prevent window damage should be stored on concrete or above the ground.

Other tips

1. 1/2 or 7/16 inch plywood is allowed under many international residential building codes and should be sufficient for most applications in RMI.
2. 5/8 inch plywood is stronger but heavier and more expensive.
3. Termite treated plywood should be used to prevent termite damage during storage (see Section 4.3.2).
4. Marine grade plywood is stronger but 2.5 times more expensive than regular treated plywood. This wood is used for boats and docks and for temporary window protection may not be necessary.
5. Duplex nails can be used to attach the upper corners of a plywood panel to the window framing – then 2 inch screws can be used to fasten the panels (Figure 4-32).
6. Follow the fastener spacing in the table below, which depends on the longest span of the plywood panel.
7. Screws should be long enough to penetrate through the exterior wall covering and a minimum of 1-1/4 inches into the wood wall framing. For a half inch plywood panel, two inch wood screws would satisfy this requirement. Although many codes allow No. 6 Wood Screws, it is difficult to find this length in such a small diameter screw.

A note about wood screws. Buy good quality screws that will not strip. Some screws may be self driving but in most cases it maybe necessary to predrill the holes. The screws should be for exterior use and compatible with chemically treated wood. This Table should help the reader.

Table 4-3 Fastener Spacing for Plywood Shutters

Fastener Type	Fastener Spacing		
	Panel span < 4 feet	Panel Span 4 to 6 feet	Panel Span 6 to 8 feet
No. 6 Wood Screws	16 inches	12 inches	9 inches
No. 8 Wood Screws	16 inches	16 inches	12 inches

Table 4-4. No. 6, No. 8, No. 9 and No. 10 Wood Screw Facts Fastener Size Thread Diameter (see Figure 4-32 Pre-Drill)

Fastener Size	Thread Diameter (see Figure 4-32)	Pre-Drill Bit
No. 6 Wood Screws	0.138 inches or about 9/64 of an inch	7/64
No. 8 Wood Screws	0.164 inches or about 10/64 of an inch	8/64
No. 9 Wood Screws	0.172 inches or about 11/64 of an inch	9/64
No. 10 Wood Screws	0.190 inches or about 12/64 of an inch	10/64

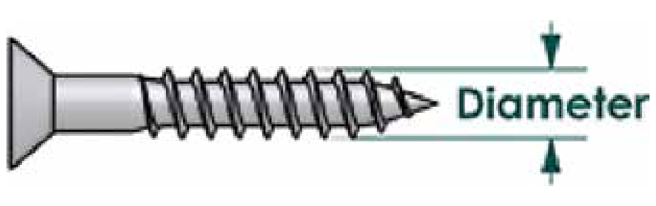


Figure 4-33. Wood screw numbers are based on the thread diameter as shown. A given number screw will have the same diameter but can have different lengths. For most plywood applications in the Marshalls, two inch long No. 6 or No. 8 screws will suffice. The key is to have at least 1¼ inch penetration into the wood framing the window (see Tip 7). As noted previously, it may be difficult to find #6 Wood Screws with sufficient length.

For deployment, listen to warnings from the NOAA WSO for a potential high wind event such as a typhoon. If a strike is imminent deployment of the shutters can begin. A partial deployment (for example, install only one third or half of the screws) can begin if there is a possibility of a strike but it is not certain. If the risk of a strike increases, all fasteners can be deployed. It is better to have too much time to deploy than too little. To have the full strength of shutter protection, all fasteners (screws) should be used according to the fastener spacing table (Table 4-3).

If the homeowner does not want to prepare and store plywood, another option is security screening, which can serve the dual purpose of providing security, while preventing breakage of windows from flying debris (see Figures 4-34 and 4-35).

Figure 4-34. Many schools in Majuro and a few houses have security screening. The advantage of the screening is that it is always on the window. The disadvantage is that small stones or debris can still penetrate the screening if the holes are sufficiently large and break the window, thus allowing in rain and wind. Security screens need to be securely fastened to the framing of the windows.

Figure 4-35. Another option for window protection is this aluminum security screen seen on a few schools such as Marshall Islands Middle School. The screen allows in light, and the openings are sufficiently small to stop most debris. The framing is bolted into the concrete masonry unit wall. While stronger than the screen in Figure 4-34, it is also more expensive. This is good window protection for houses with CMU walls (see Figure 4-1).

4.3 PROTECTION FROM TERMITES AND CORROSION

In the Marshall Islands, corrosion of metal fasteners and structural members is a significant problem due to the combination of salt and moisture. Equally destructive is the damage from termites to wood building components. This section covers some best practices to address these two issues.

4.3.1 BEST PRACTICES TO PREVENT CORROSION

Because of close proximity to the sea, the Marshall Islands is considered a severe environment for the risk of corrosion. Corrosion is caused by many factors, including salty air, and the use of wood preservatives as well as fire retardant chemicals. Corrosion can cause metal connectors and fasteners to lose their strength. Those that design buildings or choose building components should know of the risk of corrosion and select appropriate materials for the intended use. Even for the inside of houses, the close proximity to the ocean, the strong winds and open ventilation of many houses make the corrosive environment severe or at least high. In general, the two major choices for selection of fasteners in a severe or highly corrosive environment are to use stainless steel 316 or hot dipped galvanized products. Additional information can be obtained by your professional architect, engineer or designer or on page 15 of the SWCCC.

Stainless Steel - While stainless steel building fasteners and connectors are the most resistant to corrosion they are also the most expensive. Stainless steel and specifically 316 stainless steel is the first choice to reduce corrosion risk. Note that even stainless steel can corrode. Thus there should be periodic inspections by a qualified engineer or inspector, if available. With stainless steel, however, the need for inspections or maintenance should be much less than with other materials. It is also important to note that Simpson Strong-Tie does not recommend painting stainless steel fasteners or hardware. Painting does not improve corrosion resistance for stainless steel and may increase corrosion risk. However, it is possible to use a rubberized dip such as Plasti Dip (see: http://www.plastidip.com/) to spray a stainless steel fastener first and then paint the surface in case esthetics are important.

Hot Dipped Galvanized - Such connectors (clips, straps) and fasteners (screws, nails) are appropriate in corrosive environments. Although there is more corrosion risk than stainless steel, it is common to see these materials because of decreased costs. For example, stainless steel H3 clips may cost $5, but hot dipped galvanized less than a dollar. While the preference is stainless steel, the cost issue may make hot dipped galvanized the only choice. In this case, unlike for stainless steel, it is possible to paint the connectors to reduce corrosion risk. A primer for galvanized metal or spray Plasti Dip can be used. This is followed by painting the fastener.

A few tips regarding whatever material that is used.

- Because there will always be some residual corrosion risk, whatever the material, there should be periodic checks of the fasteners and connectors as part of regular building maintenance. The frequency of these inspections should depend on the materials chosen and the harshness of the corrosive environment.

- The presence of corrosion does not necessarily mean that failure is imminent so it is important that the periodic checks are by a qualified engineer or inspector, if available. Maintenance or replacement may not be needed.

- Never mix metals. Do not use hot dipped galvanized products with stainless steel. This will cause an accelerated corrosion rate.

- If you cannot find compatible fasteners and connectors – ask a few of the partners in this book (Do-it-Best or Ace Hardware) if they can order for you. These businesses are an important resource and with ingenuity and planning they can help to make houses stronger. Another important resource and partner for advice is the Carpentry Department of the College of the Marshall Islands (see the Mentor List at the end of Part 4).

- Note that chemicals in wood to prevent termite damage can increase corrosion. For treated lumber (CCA, ACQ, and CBA [see next section for descriptions]) corrosion risk is significantly higher than for Borate treated wood. This may warrant the use of more corrosion resistant fasteners and connectors (for example, stainless steel versus hot dipped galvanized).

4.3.2. BEST PRACTICES TO PREVENT TERMITE DAMAGE

Formosan termites in the Marshall Islands are ferocious and can lead to thousands of dollars of property damage if proper care is not taken. There are several strategies to prevent termite damage which are listed below. These strategies can be used separately or in combination.

Wood Naturally Resistant to Termites. Some woods such as red cedar and redwood are naturally resistant to termites. These types of woods are sometimes used without any chemical treatment. Although there is resistance, that is not to say they are impervious. Also it may be difficult to obtain this type of wood in the Marshall Islands. It is believed that Douglas Fir is more naturally resistant to termites than Pine, however, even Douglas Fir needs to be treated before use in the Marshall Islands.

Treated Wood. There are many types of treated lumber. There are products in the Marshalls from the U.S. and New Zealand. Generally, you can tell the treatment for the wood by the stamp or label that is stapled or tagged to the wood. Also ask for assistance at your local hardware store on lumber. The following types of treatments may be found:

Borate Treated Lumber (Zinc Borate [SBX DOT] or Sodium Borate). Borates are safe material (found in hand soap, laundry boosters, contact lens cleaners, eye washes, cosmetics, and medicines). Borate treated lumber is suitable for indoor use, but not outside if it rains. In this case the borate treatment may wash out of the wood. To prevent this, a good primer and two coats of exterior grade paint can be used. All field cuts should be also treated as it is unlikely that the pressure treatment of the chemicals penetrated the entire section of the lumber.

Chromated Copper Arsenate (CCA). Contains Chromium, Copper, and Arsenic. Because arsenic is a carcinogen – it has been phased out of use in the USA except for non-residential uses. Thus it is found on many exterior decks. While it is more difficult to get this material, some comes in from New Zealand and is available in the Marshall Islands.

Substitutes for CCA Including Alkaline Copper Quarternary (ACQ) and Copper Boron Azole (CBA). Once CCA was phased out because of the use of arsenic, ACQ and CBA were used as arsenic free substitutes. ACQ wood looks green like CCA wood but does not have chromium or arsenic. It has performance characteristics similar to CCA. CBA is a dark brown preservative that is copper-based. It has been used since 1992.

Ammoniacal Copper Zinc Arsenate (ACZA) Wood. Generally wood with arsenic has been phased out of residential construction. However, it can be found for commercial settings and exterior use. ACZA is resistant to leaching and thus suitable for waterborne systems (Figure 4-36). It is very resistant to termites, but also very corrosive. It is suitable for the treatment of hard woods such as Douglas Fir.

Figure 4-36. Example of ACZA wood suitable for use in the marine environment. Note the cuts or incisions on the surface to increase penetration of the chemical treatment. Because the chemicals in this wood are very corrosive, as well as the marine environment itself, stainless steel fasteners are used to attach the column to the wood joists (support for the flooring). Photo courtesy of Ben Chutaro.

Some tips for treated wood:

- Read the labels for the type of wood suitable for your use. If any questions ask your local hardware store.

- If you use CCA, ACQ, CBA, or ACZA wood, it is more corrosive than borate treated wood. The need for more corrosion resistant fasteners is in order. Generally, the ratios are ACZA is 3 times more corrosive; ACQ and CBA 2X more corrosive; and CCA about 0.25 to 0.50 morecorrosive than Borate.

- Note that CCA is much less corrosive than ACQ, CBA, or ACZA so the use of this wood may be practical in terms of reduced corrosion risk and effectiveness against Formosan termites. The trade off is arsenate/arsenic toxicity, which some researchers indicate may be driven by an abundance of caution (Interview with Christian Oakes, IOM). The CCA wood is still widely used in New Zealand and Australia.

- If you use borate treated wood, primarily for indoor use, consider properly painting the wood with two coats of interior/exterior primer and one coat of exterior grade paint.

- Some manufacturers cut or incise the wood to create better penetration of the chemical treatment. This is effective but more expensive. View labels for the amount of penetration (for example, 0.15 or 0.45 inches). The greater the better.

- Treated wood is more expensive but a good investment against the serious problem of termites. Considering thousands of dollars of damage from termite damaged wood, the investment in quality wood is worth it.

- If you use treated wood, and especially ACQ, CBA, or ACZA consider stainless steel fasteners. Another alternative is that Simpson Strong-Tie makes fasteners with a hot-dip galvanized coating called ZMAX (see pages 13 to 15 of the Simpson Strong-Tie Wood Construction Connectors 2015-2016 Catalogue).

- Treat wood that has been cut in the field (see Figure 4-37).

- Also ask assistants at your local hardware store about lumber.

Figure 4-37. If you cut treated wood, the untreated interior may now be exposed to termites. Treat the exposed cut with Copper-Green, or another product which can be used to prevent termite damage, rot, decay, fungus, and mold. Ask your local hardware store for a suitable product.

Prevent Contact Between the Ground and Wood/Lumber. It is preferable to never let wood products be in contact with the ground. For those thinking of elevating a structure for flood protection, caution should be taken if wooden posts are buried into the ground (Figure 4-38). Even treated wood in contact with the ground can be exposed to termites due to wood rot, or leaching of protective chemicals over time.

Even if wood is sitting on masonry (for example, a wooden sill plate on a concrete foundation - similar to a wood plate in Figure 4-3), but on the foundation and usually transitioning to wood framing, this may be too close to the ground and extra protection may be in order. The extra protection is often in the form of using treated lumber. Some articles suggest keeping wood sills and foundation walls at least 8 inches above grade.

Figure 4-38. While it is a good practice to elevate the structure to reduce the chance of flooding, there is risk in putting a wood pier in direct contact with the ground. Treated wood can be subject to rot from wet or moist conditions. Leaching of the wood chemicals by water can expose the wood to termite risk. These impacts can be mitigated with the type of treated wood, or surrounding the pier with crushed rock or cement.

Although the method of elevation in 4-38 may be feasible, the preferred method for elevation is shown in Section 4.4.2 and Figures 4-41, 4-42, 4-43, 4-45, and 4-48. However, in cases where there may be lack of materials, such as no available aggregate or concrete, or there is limited funding for construction, the use of wood piers may come into play. In this case, the use of ACQ wood, or one with a higher concentration treatment such as ACZA should be considered to reduce termite risk. Termite risk can also be reduced by encasing the pier in crushed rock or a cement base.

4.4 PROTECTION FROM WAVE INUNDATION AND FLOODING

There are two major ways to make structures more resistant to flood and wave inundation from the hazards described in Part 2. One way is to build extensively with flood damage resistant materials. Another is to elevate the structure. There are positives and negatives to each method which are discussed in this section. It should be noted that the section on elevation applies primarily to new design or houses, since it is difficult to elevate the existing houses.

Whatever the method to reduce flood risk, houses in the Marshalls should not be used for evacuation as a shelter during a serious storm or tsunami event. It may be sufficient to stay in the house during a high swell event that may or may not take place during a King Tide, if there is no local flooding. For a larger event, go to a shelter (see Part 3). The key is for each family member to have a plan for small and large events and listen to the directions of government officials as to where and when they should go. Thus it is important to have a good battery-operated radio or working TV. The majority of the houses in the Marshalls are not strong enough to withstand the wind and water forces associated with a typhoon or tsunami. It would be preferable to use the upper floors of a sturdy concrete building such as the College of the Marshall Islands or the Assumption School for this purpose (see Part 3 of this Book). Generally, the upper floors of schools are the safest place to shelter (see Section 3.3.1 for the ideal characteristics).

4.4.1 FLOOD DAMAGE RESISTANT MATERIALS

In the urban areas of the Marshall Islands, building with concrete is common. There are advantages and disadvantages to building with concrete. First reinforced concrete is a very strong material. When built as shown in Figure 4-1, with poured concrete corner posts and a concrete structural bond beam, it is very resistant against wind and water forces. In fact this design is typical of American Samoa where wind speeds are often greater than 125 miles per hour. As further evidence of the strength, it is the type of building configuration (reinforced concrete moment frame) that makes the best emergency shelters identified in this report (see Part 3 on Evacuation Planning and Emergency Shelters and Figures 3-3 to 3-5).

The emergency shelters identified in this report are two floors or more, so that if there is wave inundation, the water can pass through the lower floor, while people shelter in the upper floors. The problem with concrete houses in Majuro is that they are typically one floor, because of the cost to elevate or build a sturdy two floor concrete house. Therefore any water passing through can damage property and injure people. In fact no one floor house in Majuro should be used as an emergency shelter, as it is safer to go to a reinforced concrete building with a moment frame and two or more floors as discussed in Part 3.

Nevertheless, it is still a good strategy to build or retrofit a strong one floor concrete house with flood resistant materials. People would still need to go to an emergency shelter during a tsunami or typhoon, but when they come back the house is likely to be standing. Flood resistant materials are those that can stay in prolonged contact with sea water (at least 72 hours), without any significant damage (in other words, the damage should be no more than cleaning, sanitizing, or resurfacing of the material). Resistance includes damage from both standing and moving water.

Some highly resistant flood materials include:

Marine Grade Plywood - Highly resistant to flood damage and used for boats and docks. Marine grade plywood has highly durable and water resistant layers as well as waterproof glue that bonds the layers. It is roughly 2.5 times more expensive than regular treated plywood.

Recycled Plastic Lumber - Can be used for floors.

Concrete - Besides being strong, either pre-cast or cast in place concrete is highly resistant to floodwater damage, including moving water. It can be used for structural support such as for windows or for finish materials such as walls.

Concrete Blocks - Concrete Masonry Unit (CMU) blocks can be used for walls (Figure 4-39).

Figure 4-39. CMU blocks are the building blocks for many houses, commercial and government buildings in the Marshall Islands. Sometimes, the holes are left empty, and then the CMU is ungrouted. Other times they add rebar and concrete in the two holes making the CMU grouted and reinforced. Whether grouted or not, CMU blocks are a highly flood resistant material.

Other tips for wet flood proofing:

- For new houses, the preference is still to elevate (see next section 4.4.2).
- For existing houses, where elevation is not possible, if there are repairs or extensions extensions they should be built with flood-resistant materials. Anytime there is a retrofit, non-flood damage resistant materials can be replaced with flood damage resistant ones.
- Electrical outlets, light switches and other sensitive equipment such as air conditioning units can be elevated as high as possible within a room above expected flood levels.
- Polyester-epoxy or oil-based paints are acceptable wall finishes when applied to a concrete structural wall. It is not acceptable for wood as the low-permeability paint can inhibit drying of the wood wall.

4.4.2 ELEVATION OF HOUSES

In Majuro, houses have been elevated from a few feet to over 10 feet to avoid flood and wave inundation damage. (Figures 4-40 and 4-41). Elevation is a time tested effective way to prevent property damage from coastal hazards **if designed and planned for properly**. The practice of elevation is an option for new houses and is generally not feasible for existing structures. Because it is primarily for new houses, only a few design suggestions are in this section for consideration by homeowners and government officials contemplating the more formal use of this option.

Figure 4-40. This house in Majuro was elevated to prevent damage from wave inundation and flooding. This is an extreme example of elevation of structures. Many houses in Majuro have been elevated a more modest amount (see Figure 4-41). This house has a spread concrete footing (see Figure 4-42). The brown wood members forming the X pattern are cross bracing to provide additional lateral support of the structure.

Figure 4-41. Another house in Majuro was elevated about 3 feet above grade. A spread concrete footing (Figure 4-42) was utilized with concrete piers encased in PVC pipe. The piers extend into the footing and are reinforced with epoxy coated rebar. Photo courtesy of Ben Chutaro.

Advantages of Elevating to Reduce Flood Risk

- Elevation above flood/inundation waters is an effective way to prevent flood and inundation damage.
- This is especially useful for frequent, nuisance type flooding.
- Many documents in the Marshall Islands recommend elevating of structures 3 feet to reduce the risk of flood or inundation damage.
- Many areas in the Majuro have a history of frequent (two or more flooding events since the 1970's) and shallow (less than 3 feet of flooding). Elevation of new structures is an effective way to avoid damage from shallow, frequent flood, or inundation events.
- Elevation allows landowners/homeowners to plan for future flooding, inundation, and sea-level rise hazards.
- For future climate risk and hazard events, the landowner/homeowner may want to address uncertainty or risk by building higher than the historically recommended height of 3 feet above ground.

Disadvantages of Elevating to Reduce Flood Risk

- Elevating a structure is expensive. The higher the elevation, the greater the expense as piers or columns are dug deeper and need to be wider.
- Without flood/inundation maps, it is difficult to determine how high to elevate from a scientific and risk perspective.
- If flood/inundation waters exceed the amount of elevation (for example 4 feet of flooding while the structure is elevated 3 feet), damage can be significant.
- Generally elevation is for new houses and is planned beforehand. It is not possible to elevate houses already on a slab.

Suggestions for Elevating to Reduce Flood Risk

- For any elevation scenario an experienced and qualified coastal engineer and architect should be consulted, if available.
- Piers or columns to elevate are generally made of wood or concrete. In the Marshall Islands, wood should generally not be used because of the issues with termites and water rot. If wood is used, it should not be for the portion in contact with the ground (see Figures 4-42 and 4-43). If cost is an issue, special precautions may be needed (see Figure 4-38).
- An effective pier or column should have a spread footing at the base (see Figure 4-42).

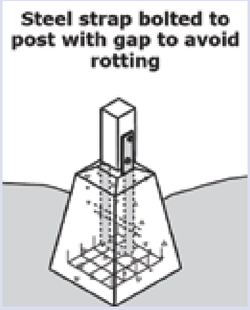


Figure 4-42. Example of a spread footing for a pier or column that could be used to elevate a house. The spread footing is wider at the base than at the surface. Typical design issues are the depth of burial, width of the column, and spacing between columns. In the Marshall Islands, because of the shallow water table, and the common presence of a hard reef rock underneath, the depth of burial is often limited. Too shallow a burial can lead to failure. In this example a wood column is attached to the concrete spread footing with a steel strap (Figure 4-43). The connecting steel strap provides a gap between the two materials. Figure courtesy of Sheltercluster.org.

Figure 4-43. Example of steel straps with column base available in Majuro that can be used to connect a concrete spread footing with wood columns. The wood and concrete should not be in contact because the sweating of concrete can cause wood rot. The strap provides separation between the two incompatible materials. An experienced coastal engineer or architect should be consulted to design the footing and columns, if available.

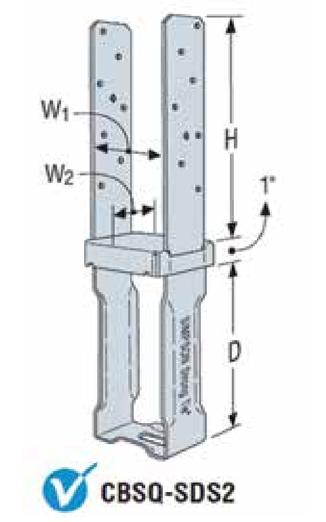


Figure 4-44. Better than treated wood in the ground (Figure 4-38), or a wood column with concrete spread footing (Figures 4-42 and 4-43), is the use of 6 inch PVC pipe extending to the base of the concrete spread footing. The PVC is reinforced with epoxy coated rebar that extends 6 feet below the surface. The rebar is also placed every 6 inches in a horizontal crisscross pattern through holes drilled in the PVC pipe. Concrete is then poured into the PVC. The only wood is 3.5 feet off the ground and is ground contact, termite treated ACZA Douglas Fir (Figure 4-36).

In addition to the discussion on elevation, there are several design proposals for new houses which may gain popularity in the Marshall Islands. These are being considered by the Department of Public Works, and companies such as Pacific International.

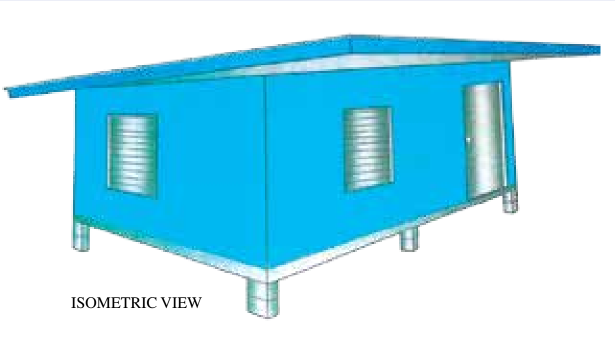


Figure 4-45. This design by the Ministry of Public Works in Majuro elevates the structure 3 feet off the ground on concrete masonry blocks (Figure 4-39). Grouting and rebar can be added to the CMU for added strength. The simple design is the cheapest and can reduce flood risk for small frequent events.

For the above house, treated wood is used and tied together with hurricane plates. This simple house cost is about $2,500. It is very inexpensive but not as strong as other designs. One method to strengthen the design is to bury the CMU piers in the ground, and to reinforce the CMU holes with epoxy coated rebar and cement or grout. Examination of many buildings in Majuro indicates corrosion of rebar in concrete because it is in direct contact with the salt content in the concrete (Figure 4-46). For this reason, rebar in concrete should be epoxy coated (Figure 4-47).

Figure 4-46. Rebar in direct contact with concrete with salt content can cause corrosion of the rebar. Thus, there may be a need to epoxy coat the rebar.

Figure 4-47. Example of epoxy coated rebar about to be encased in concrete. Any bends or cuts in the rebar that cause the epoxy to come off should be recoated.

Figure 4-48. This experimental, affordable house is designed to withstand typhoon and storm surge events. Elevation would be from 4 to 8 feet off the ground on reinforced concrete piers similar to those in Figure 4-40, 4-41 and 4-45. Once the pier foundation is set, wall frames are erected using stainless steel connection plates. Strong prefabricated panels are then used for the floor, walls and roof. The panels are made of cement, fly ash, sand and polyvinyl alcohol fibers to give it added strength (From Rockwood, et al, 2015 in Prep.).

The rough cost of the modular house design in Figure 4-48 is about $50,000 assuming the prefabricated panels can be mass produced. This house has the advantage of being as sturdy as concrete but elevated, to a sufficient level so it can withstand more than just frequent, smaller flood events. At this point, the house design is part of a research project, and something that is being explored in Majuro.

Compare the houses in Figures 4-41, 4-45, and 4-48. These are just three different designs. But there are many ways to elevate a structure (see also Figure 4-38). Note with increased strength, comes increased costs. These are the tradeoffs. Someone building a new home can choose from the different designs, depending on their budget. Modification of the different designs is also possible to make them stronger and more expensive or cheaper. For example, it is possible to build the CMU piers in Figure 4-45 with epoxy coated rebar (Figure 4-47), grout the CMU (Figure 4-39), and bury the piers (Figure 4-42), which would add cost but be stronger. It is possible to build the house in Figure 4-41 higher, with wider piers, or ones that are more closely spaced, also adding strength and cost. Conversely, it is possible to reduce cost in Figure 4-48 by making a smaller, less elaborate structure. Thus there are many design variations of the three options provided, as well as other design concepts which are not covered in detail because the major emphasis of this book is retrofit of existing structures versus the design of new structures.

In terms of elevation, the question often comes up how high to elevate a house. This is a difficult question because there are no flood maps in the Marshalls relating location, flood depth, and frequency. Given that, a good starting point is at least higher than the water levels encountered by recent flooding events. For example, if you live in Djarrit, the area was inundated by events in 1979, 2008, and 2014 (see Section 2.3). Use the highest water level encountered at the proposed site during these events to determine a minimum elevation. A safety buffer of 1 or 2 feet can be added. If cost is prohibitive, elevating to a lower level is possible, which would protect against the smallest flood events, but not the larger ones such as the 1979 event. It is also possible to build with flood resistant materials (see Section 4.4.1).

4.5 RAINWATER CATCHMENT SYSTEMS

In addition to wind, wave, and flood risks, it is necessary to plan for climate related hazards such as drought. People can help to prepare for this hazard by making sure their water catchment systems are as efficient and well maintained as possible. There are several developments in this area. Many reports can be found on the internet (check the resource list at the back of this book).

Here are some tips for water catchment systems:

Your Surroundings - Where feasible remove any trees or at least branches hanging over your roof to eliminate debris onto your roof, in your gutters, and into your water system. Keeping trees away also helps to prevent damage to the house if strong winds blow the tree over (see Figure 4-49).

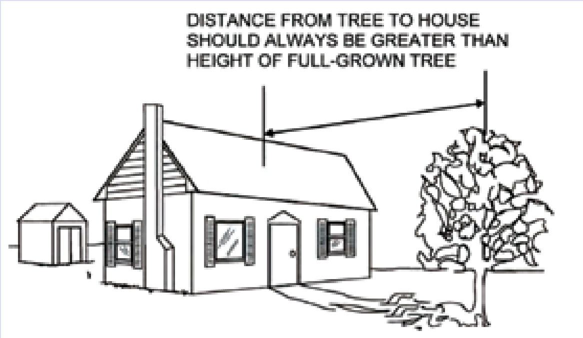


Figure 4-49. FEMA recommends keeping trees a distance greater than the height of a full grown tree. This will prevent roof damage from strong winds and also reduce risk that leaves will fall on your roof and enter the water catchment system.

Roofs - Roofs in Majuro are typically corrugated aluminum roofs or galvanized steel. They do not need to be painted. Yet there are benefits in painting the roof, including keeping the house cooler and preventing water leaks (see Figure 4-50).

Figure 4-50. If it is decided to paint the roof to keep the house cooler, the paint must not pollute the water. It is recommended that an elastomeric paint be used. Check your local hardware store for a product that will seal the roof, keep it cool and not pollute the water. The National Sanitation Foundation in the U.S. has approved the use of elastomeric coatings for catchment systems (see Macomber, 2010).

Leaf Screens - Use a leaf screen for the gutter to keep out larger debris. Consult with your local hardware store for available options. Some people have used stockings to catch small debris in the water just before it enters the water tank. This would need monitoring to replace clogged and worn stockings. Also protect openings to the water tank so that debris or animal droppings will not enter.

Gutters - Gutters can be plastic (PVC) or aluminum. Aluminum gutters should be stronger as plastic gutters attach to the fascia board with clips, while aluminum gutters attach under the aluminum roof and are part of an all aluminum system. Aluminum gutters will not corrode or crack under long exposure to sun. In terms of cost, 10 feet of aluminum gutter will be about 30 percent more than 10 linear feet of a plastic gutter.

Gutter Width - Consider capturing a larger percentage of water falling onto your roof by increasing gutter width from the normal 4 or 5 inches to 6 inches (see Report by Wallis for IOM). This will maximize rain capture. Currently, it may be hard to get plastic gutters of this size in Majuro. Four or five inch plastic gutters are the most common. Your local hardware store can possibly order a larger width. Alternatively, aluminum gutters can be bought in Majuro that are custom made with different widths (Figure 4-51). If different widths are used, make sure the fasteners are increased to account for the added weight of the gutter.

Figure 4-51. An aluminum press and cutting sheet in Majuro can make metal corrugated roof and gutters of different dimensions. This can help to ensure proper overlap of aluminum roofing sheets (two ridges of overlap – see Figure 4-23). In addition, aluminum gutters can be created that are 4, 5, or 6 inches in width. The larger gutter width will maximize water capture during a rain event.

Maintenance - Maintenance is key for an effective water collection system.

Gutters should be well maintained and a have a continuous slope leading to the downspout and water tank. Any flat areas or slumps in the gutter will pond water, leading to the collection of debris, stagnant water, and mosquitoes. Debris should be cleared even if there are screens.

Improvements - Do not wait for a hazard event or system deterioration in the roof, gutter, downspout, or tanks to make improvements. Every time the system is cleaned make inspections and always strive to improve your system in terms of capacity and durability.

Water Tank Cleaning should be done twice per month. With a first-flush system (see below), the need to clean the tank is greatly reduced and can be as little as once a quarter. Still the amount of cleaning will vary by owner. Some owners with a first flush system will still clean the tank once a month by “shocking” the water (adding a small portion of bleach). Since cleaning the tanks uses water, the benefit of the first-flush system is the reduced need for cleaning and more water. The benefits of the first-flush system are even greater in the northern islands, which receive less rain than Majuro.

First-Flush System - Combine the leaf screen with a first-flush diverter to help keep dust or microorganisms out of your water tank as rainfall begins (see Figures 4-52, 4-53, and 4-54). This information came from the EPA and also Jina David of the College of the Marshall Islands Land Grant Program.

Figure 4-52. First-flush systems help to keep your water catchment system clean and reduce the need for maintenance. Dust, debris, or fecal matter that collects on your roof is washed off when it begins to rain and collects in the diversion pipe to the right. After a sufficient amount of rain has washed the roof, and the diversion pipe is full, either a pipe bend or a floating ball valve diverts water to the left where is it collected in the water tank.

Figure 4-53. At the end of the diversion pipe is a small drain hole that allows the first flush water to slowly drain out so that the diversion pipe is empty for the next rainfall event. In addition, the threaded cap allows for the periodic removal of leaves or other debris.

Figure 4-54. First-flush systems can be ordered or they are easy to create yourself. Ask your local hardware store if you have any questions about materials or how to build one. The systems are sized for the size of the roof. As a general rule, and from existing literature, the diversion pipe must catch 5-10 gallons of water per 1,000 square feet of roof area (see University of Hawai'i Mānoa pamphlet and website). See Table 4-5 to see the relationship between first flush diverter pipe diameter width, length and amount of water to collect.

Sample Sizing – A house has a roof area of 50 feet by 40 feet to collect water or 2,000 square feet (50 feet * 40 feet =2,000 feet^2). Therefore the first flush system should collect 10-20 gallons of water.

Using 10 gallons and the following conversion factors:

7.48 gallons per 1 cubic foot
1 gallon of water per 0.1337 cubic feet
1 cubic foot equals 1,728 cubic inches
1 gallon of water equals 231 cubic inches of water
10 gallons of water equals 2,310 cubic inches

Assuming a diversion pipe of 4 inches in diameter – what length of pipe is needed to collect 10 gallons of water?

2,310 inches^3 = 3.1415 * (2 inches)^2 * length of pipe
2,310 inches^3 /(3.1415 * 4 inches^2) = 174 inches or 14.5 feet

If for example, the pipe was 6 inches wide then the length of pipe would be:
2,310 inches^3 /(3.315 * 9 inches^2) = 77.5 inches or only 6.5 feet

Table 4-5. Relationship - Pipe Diameter, Desired Volume of Flush Water, and Length

	First Flush Volume Needed in Gallons				
Pipe Diameter	5 gallons	10 gallons	15 gallons	20 gallons	25 gallons
4 inch pipe	7.3 ft.	14.5 ft.	21.8 ft.	29.0 ft.	36.3 ft.
6 inch pipe	3.2 ft.	6.5 ft.	9.7 ft.	13.0 ft.	16.1 ft.
8 inch pipe	1.8 ft.	3.6 ft.	5.4 ft.	7.2 ft.	9.1 ft.

4.6 LAND MANAGEMENT ON YOUR PROPERTY

Managing your property for natural hazards is not only about retrofits and construction practices for your house. It is also about coastal protection, whether you live on the ocean or lagoon side in the Marshall Islands. The greater your buffer to the forces of wind and water the better your chances are that the impacts of a natural hazard will be minimized. There is good guidance provided in the publication “A Landowners Guide to Coastal Protection,” a UH Sea Grant publication available through the RMI EPA and CMI at: (http://seagrant.soest.hawaii.edu/sites/default/files/publications/lowres.-shorlineguide.pdf). This section expands on that guidance and provides some useful tips on choosing an appropriate shoreline protection strategy for your property.

1. Protect your coral reefs as the first line of defense in coastal protection. This includes treading lightly on the outer reef flat during harvesting. Also, limit your fishing of herbivores such as parrotfish and surgeonfish, which are important grazers of reef damaging algae.

2. Enhance your coral reefs through fragmentation techniques to promote re-growth of vulnerable, resilient, and resistant coral species with respect to pollution and coral bleaching. Branching corals break up wave energy better than massive corals. The higher the relief of individual coral colonies, the more wave energy is absorbed before the waves reach the shore. Loose or broken pieces of coral can be righted facing up and/or securely stuck in natural holes on the reef or reef flat.

3. Build migratory berms just up from the high tide mark on the shoreline. This is about enhancing the natural geomorphic resilience of the shoreline and allowing certain areas to respond naturally to changing boundary conditions. Use of a mix of grain sizes that approximate the original make-up of ocean (coarse) and lagoon (fine) side berms (see Figure 4-55). Compaction and re-vegetation are key to its success. Migratory berms by definition require continual maintenance to be effective over time as shorelines shift. Part of this can be accomplished through continual composting of all organic material produced on the property to be placed on the berm. This is by far the most effective and environmentally-responsible method for coastal protection outside of reef and reef flat protection and enhancement.

4. Build fixed berms just up from the high tide mark on the shoreline. These are appropriate as a compromise between migratory berms in semi-rural areas and revetments/seawalls in fortified urban areas. Fixed berms are essentially revetments, but made up of a mix of grain sizes surrounding a foundation of semi-solid interior material that is ideally dug into the ground. This semi-solid interior can be made of scrap metal of various sizes sourced locally. To be effective, the ground needs to be prepped via trench excavation and placement/anchoring of material before the outer layers of the berm can be added. Geotextile cloth can be incorporated. Organic material to be continually added as with migratory berms.

5. Re-vegetate the shoreline, both above and below the high tide mark. Focus on salt-resistant varieties suitable for migratory and fixed berms. Where possible, mangrove reintroduction of native varieties is encouraged.

6. Avoid fortifying your shoreline with seawalls where possible. Seawalls have a number of negative impacts on the environment as well as your neighbor's property due to their reflective rather than absorptive character of dealing with wave energy. Hard fortification is difficult to reverse once implemented. Seek guidance from the RMI EPA and local coastal protection professionals before choosing this strategy as detailed technical guidance on the entire range of coastal protection options for the conditions seen in the Marshall Islands will be available soon.

Figure 4-55. From the UH Sea Grant publication "A Landowners Guide to Coastal Protection." The ocean side of the atoll receives more wave energy and consists of courser grained and steeper ridges or berms. The lagoon side has smaller ridges and finer sediment. It is important to build and maintain migratory and fixed ridges or berms. Also re-vegetate the shoreline below the high water mark with mangroves and above with other suitable salt-resistant varieties.

4.7 MENTORS

Many of the concepts in Part 4 of this book may be new to the general public, especially those that do not have construction or carpentry experience. Hopefully, the figures in the book will help to explain why some of the methods are important and how they can be built. If there are still questions, one source of information is to contact an experienced architect, engineer or building inspector, if available.

In addition, we have compiled a list of mentors who are willing to answer questions from the general public on many of the topics covered in Part 4. These individuals have considerable construction and/or land use planning experience and have graciously agreed to help community members.

Ben Chutaro - Ben Chutaro, Inc.
Melvin Dacillo - Ministry of Public Works
Gina David - College of the Marshall Islands – Land Grant Program
Karl Fellenius - University of Hawai‘i Sea Grant College Program
Larry Hernandez - Do-it-Best
Jerry Kramer - Pacific International
Winfredo Mendez - Ministry of Public Works
Richard Muller - Carpentry Department, College of the Marshall Islands
Mark Stege - MarTina Corporation
Yuichi Yamaguchi - Ace Hardware

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NOTES

NOTES

The University of Hawai‘i Sea Grant College Program (UH Sea Grant) supports an innovative program of research, education and extension services directed toward the improved understanding and stewardship of coastal and marine resources of the State of Hawai‘i, region, and nation. A searchable database of publications from the national Sea Grant network, comprised of 32 university-based programs, is available at the National Sea Grant Library website: http://nsgl.gso. uri.edu.

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The views expressed herein are those of the author(s) and do not necessarily reflect the views of USAID and NOAA or any of its subagencies.

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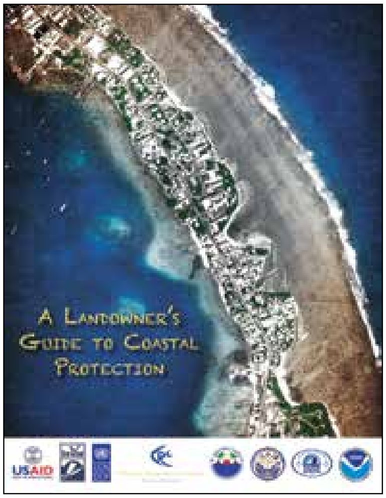
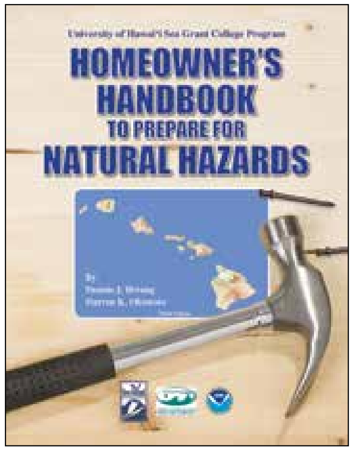
Additional UH Sea Grant Publications



Erosion and coastal inundation are serious issues for atoll nations. *A Landowner's Guide to Coastal Protection* offers straightforward advice on how coastal communities can assess coastal hazards and reduce risk. The guide is written specifically to help people in the Marshall Islands make informed development choices. However, the approach applies to any coastal settlement where waves, wind, and water converge to impact homes, livelihoods, and safety.

The Hawai‘i *Homeowner's Handbook to Prepare for Natural Hazards* provides useful tips regarding readiness for natural hazards that may affect Hawai‘i, including tsunami and hurricanes. The handbook lists local civil defense and emergency management agency information, as well as emergency shelter locations.



The third edition includes four new appendices that address installing storm panel screws, reroofing, securing photovoltaic systems, and ways to get involved with community resilience efforts.

To order copies of these publications, contact:

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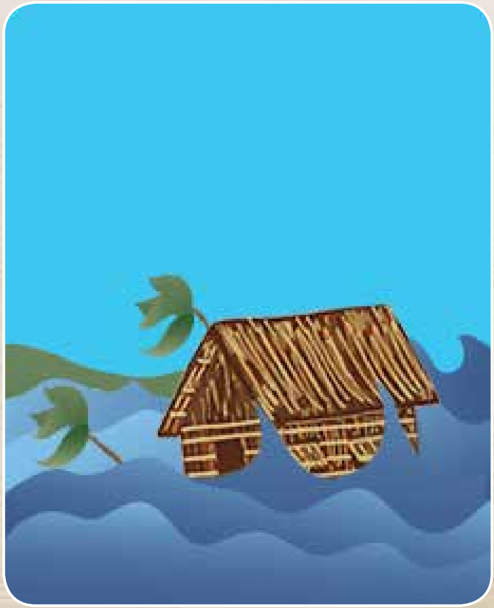

FLOODING