North Carolina Coastal Federation NOAA Marine Debris Program

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Recommendations for Improved Marine Construction to reduce damage, losses, and marine debris resulting from storms in North Carolina

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North Carolina Coastal Federation, a 501(c)(3) non-profit organization, founded in 1982, that engages the community in protecting and restoring the health and productivity of the N.C. coast.

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I. Introduction and Background

After Hurricane Florence, aerial and visual observations of damage to waterfront structures, primarily docks and piers, revealed extensive and significant damage. Treated lumber, floats, polystyrene and other debris from these structures was deposited in the public trust waters, wetlands and dredge spoil islands along the central and southern portion of North Carolina's coast (Appendix A). The amount and extent of debris was unprecedented in recent history.

Recognizing the extent and impacts of the debris to the coastal environment and economy of fishing and tourism, the North Carolina General Assembly awarded funding in 2019 through the North Carolina Department of Environmental Quality to the North Carolina Coastal Federation to remove debris from public trust waters that fall outside the scope of traditional cleanup programs. The project focused on consumer and heavy wooden debris from damaged docks and piers that had washed up after the storm (Appendix B). The debris was collected primarily by hand by small crews of fishermen/women using skiffs (Appendix C). A total of 204 tons of debris was picked up in Onslow and Carteret counties over seven months, along with three abandoned and derelict vessels (Appendix D).

Thanks to additional funding provided by the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program in 2019 (Appendix E), the removal work was extended to include Pender and New Hanover Counties. An additional 115 tons of debris was collected from these areas over six months.

Then in late 2019, the North Carolina Division of Coastal Management (DCM) provided matching funds and received funding from the USDA Natural Resources Conservation Service Emergency Watershed Protection Program to remove debris and abandoned and derelict vessels (ADVs) from the central and southern coastal areas. DCM contracted with the federation to implement the project. Between July 1, 2020 and July 31, 2021, a total of 569 tons of debris and 21 ADVs have been removed from the public trust waters of these regions, including several state parks and coastal reserves.

Roughly 85% of debris removed has been from storm-damaged residential docks and piers (Appendix F). In addition to continuing removal efforts, this project serves to provide a case study on large-scale marine debris removal for distribution by NOAA for other regions. These cleanup efforts will support the development of recommendations for state-wide standards and model local ordinances for more storm resilient marine construction and will also increase education and outreach on marine debris in the estuarine environment.

A. Characterization of debris: Post-Florence surveys

1. Using NOAA's aerial imagery acquired post-Florence (September 2018), federation staff completed an assessment of storm damaged piers and structures along the Central and Southeast coasts. Large storm debris fields were also identified throughout the regions:

Area	Estimated Total Docks	Visibily Damaged Docks	Percentage Damaged
Harkers Island	143	103	72%
Taylors Creek, Beaufort	159	37	23%
Bogue Sound (Mainland, AB bridge to EI bridge)	417	290	70%
Bogue Sound (Island, AB bridge to EI bridge)	638	440	69%
Cedar Point (EI bridge to twin bridges)	100	56	56%
Swansboro (twin bridges to Hammocks Beach State Park)	96	60	63%
New River, Sneads Ferry, Chadwick Bay	192	110	57%
Topsail Island (New River Inlet to Topsail Inlet)	608	205	34%
Corcus Ferry Road to Figure 8 Bridge	225	109	48%
Figure 8 Bridge to Masonboro Inlet (Wrightsville Beach)	600	260	43%
Masonboro Inlet to Snows Cut	320	175	55%
Snows Cut to Carolina Beach	338	158	47%

2. In early 2019, LDSI Inc. gathered information and performed a survey by boat of debris and abandoned and derelict vessels visible along the Atlantic Intracoastal Waterway from Core Sound to the Cape Fear River. Debris and vessels recorded through this survey can be found in their waterway debris mapping tool.
3. Marine debris recovered
    a) Marine debris included household trash, plastic, bottles, cans, foam pieces, fishing gear, tires, building supplies, pressure treated wood, decking, and boards and pilings (Appendix G).
    b) In order to maintain habitat quality and not cause disturbance to the surrounding marsh vegetation, crew members hauled out wood by hand to piles that the contractor could reach with heavy equipment from the waterway (Appendix H).

B. Primary question: how can we reduce the amount of residential dock and pier debris left in public trust waters after storm events?

II. Existing statutes, rules, ordinances

A. A preliminary review of existing statutes, rules, and ordinances revealed:

1. While commercial docks and piers have building code requirements in N.C., residential docks and piers are exempt from the state building code (Chapter 36).
2. Coastal municipalities in N.C. are prohibited by state law (§143-151.8) from adopting any building code standards other than state codes (not considered a major life and safety issue).
    a) Regulations on docks, however, are generally prescribed by DCM and local zoning ordinances, which likewise can be more stringent than State requirements (Appendix I).
3. Most municipalities require local building permits, in addition to DCM permits, but these permits only evaluate whether or not a dock/pier can be built, location in waterway/AEC, length/width, etc.

4. Once constructed, the structure can be inspected, but since it is exempt from the building code, there is nothing for local staff to inspect other than whether it exists or not. This one-time inspection is not always conducted, and is primarily for tax/property records.

B. North Carolina State Building Code
   1. Section 3601.2 (1) *Docks, piers, gangways and catwalks, other than residential and farm docks and piers exempted from this chapter in the exceptions below, shall be designed by a registered design professional.*

      Exceptions: The following structures are exempt from the requirements of this chapter:
      (5) *Piers and docks associated with one- and two-family dwelling meeting the exceptions of the North Carolina Residential Code.*
   2. Section R327 from the North Carolina Residential Code exempts residential docks from Chapter 36 of the state building code and specifies size requirements, heights, number of boat slips, roof area, etc. (Appendix J).

C. Division of Coastal Management
   1. See tables outlining structure requirements, retrieved from CAMA Handbook for Coastal Development. Requirements do not address building materials or methods.

D. Office of the State Fire Marshal (OSFM)
   1. OSFM goes further into the pier and dock permit requirements as applied to Section R327. As noted, pier and dock structures meeting all of the limitations of the exception of Section R327.1 are not subject to any other minimum code requirements. If the structure exceeds the limitations of the exception, then compliance with Chapter 36 of the NC Building Code is required.

E. Telephone interviews were conducted with contractors, engineers, land use planners, inspectors, regulatory staff, agency staff and scientists. Below are highlights and common themes regarding existing statutes, rules and ordinances (full summaries can be found in Appendix K).
   1. Contractors and engineers:
      a) In general, building codes have been drifting away from damage reduction approaches and moving towards life-safety issues. The building code council is not beyond looking at damage reduction, but so much is local site-selection driven that standard design change is not really feasible.
      b) The existing code is decent, but often not enforced; local building inspectors either lack training or do not care as much about water dependent structures as they do homes. Including required maintenance/inspections of waterfront structures in N.C. code would be a major improvement.
      c) Previous versions of code attempted to set design limits where they thought professional design might be an advantage, but ended up overdesigning residential structures that did not

need it. Requirements were not significantly improving residential docks/piers; the last round of amendments removed the requirement for residential docks and piers to be designed by a licensed Professional Engineer.

d) Most important thing from a contractor's perspective is vibrating the pilings sufficiently. This makes a huge difference; when they're washed in, the hole is blown out and it takes a long time for the sediment to build back up and does not fill in as well. By vibrating the pilings, the seal is tight; they recommend a 10-foot minimum - it all revolves around a solid foundation. It is also important to build with good quality hardware (especially for saltwater) and lumber.

e) Most newer docks are built fairly well, the problem is typically with older docks that are band-aided/pieced together year after year, storm after storm. An area to focus on is follow-up in dock repair, especially after storms. There are so many emergency permits issued, with few to quality check the work; some contractors purposely build something they know will not last to keep themselves in business. It is recommended property owners look for builders with at least 10 years of experience, avoid pop up contractors, do their homework and vet the builder. Maintenance and repair are key.

f) Importance of site-specific engineering: many builders have no idea what goes into wave and wind criteria. The problem is not how to design, but how to have a *functional* water-dependent use.

g) All about confidence and how much risk the property owner is willing to take. It comes down to how much money you want to put into it - do you want a frame with strong pilings that stay in place, but the boards will wash out? Do you just want to rebuild each time? Do you want a structure that will be partially damaged, totally damaged, with a specific storm height? Recommended careful consideration into how we characterize the narrative, suggested focusing on the cost of rebuilding (market debris reduction as secondary benefit).

h) Factors preventing property owners from building more durable structures: expense, not knowing better, and timeframe - everyone wants it built now.

2. Planning and local government staff:

    a) Up until 2017, residential docks and piers located in VE flood hazard zones had to be engineered by a registered design professional (same as current commercial docks and piers requirements). Once the residential building code was amended in 2017, this was no longer required. Building code has recently been weakened, but most government staff maintain that requiring an engineer to design structures is unnecessary; the same effect can be achieved by focusing on materials and techniques.

b) No local governments interviewed addressed building materials in local codes (Appendix L). Pending DCM approval, drawings must be approved by local building inspector's office.

c) Some jurisdictions may have more restrictive standards; in general, law and administrative code prevents local jurisdictions from developing standards that exceed state level BUT local zoning departments can impose additional zoning restrictions (building departments cannot).

    (1) Because of this, local building department staff think a zoning ordinance is the best path forward, but planners are often cautious of ordinance changes, preferring to see changes made through DCM.

3. Agency staff:

    a) DCM does not address building code issues at all; they simply permit the structures. Local governments have building code guidelines and are addressed in the building permits. Property owners often ask about structure recommendations, but since they are a public agency, DCM is very wary of promoting any kind of technique, method, etc. Instead, speak in general terms, listing pros and cons for different techniques. They recommend property owners only get what they need - for example, just because they can have up to 2,000 square feet doesn't mean they should.

    b) DCM does not think it is likely they would incorporate any requirements into the General Permit, the extensive vetting and very high threshold required to prove the recommendations are in everyone's best interest would likely prohibit anything from being adopted coastwide. Could see DCM providing BMP's to property owners as a resource, without official endorsement. As for implementation, they think focusing on strong public outreach is important, as well as drafting ordinances that local governments could adopt.

    c) Department of Public Safety - have not found any additional construction standards beyond what is recommended in the N.C. NFIP Model ordinance, FEMA Technical Bulletins, N.C. Building Code, or ASCE 24. All of which require construction which remains in place or breaks apart during the occurrence of the base flood and demonstrates no harmful diversion of flood waters or wave runup and wave reflection that would increase damage to adjacent buildings and structures.

    d) N.C. Residential Code makes exceptions for smaller docks associated with single-family homes. Only larger docks have to comply with any code requirements. We may want to ask the OSFM whether code changes would be warranted.

III. Additional questions/recommendations raised during fact-finding

A. How to address 'cutoff debris' (post-construction debris intentionally left in public waters by contractor/builder)? Removal crews found large amounts during clean-up.
   1. In N.C., there are no specific DCM rules addressing this type of debris.
   2. In Florida, they recognize that construction of structures over coastal waters raises numerous issues related to debris that might enter the water. Florida's Joint Coastal Permit (JCP) carries the following construction requirement – "*During pier construction, there shall be no construction debris discarded into the Gulf of Mexico (or Atlantic Ocean).*"
   3. Dock maintenance: removal crews reported numerous residential structures that are still standing, but are in tremendous disrepair. How can we prevent these structures from becoming debris after the next storm event?
      a) DCM: no CRC rule or statutory language that requires owners to maintain docks or authorizes DCM to take any action when a structure deteriorates.
      b) USACE: keeping docks, piers, boathouses, etc. maintained in good condition is a standard federal requirement but the Corps is unable to enforce due to limited resources.
         (1) SE dock disrepair inventory (South Wings Imagery)
         (2) South Wings flew and took aerial photos over the project area, imagery helped guide target areas for cleanup, as well as helped establish a complete picture of the scope of structures in disrepair.

B. Construction impacts: what are the impacts on the environment *during* construction?
   1. Do we want to take into consideration or evaluate damage done while building structures (equipment, cranes, etc.)? How long-lasting are these impacts? Do 'better practices' have more severe impacts? Are these addressed by DCM/Corps?

C. Is there a path for requiring/incentivizing personal removal of structure debris following storm events?
   1. In Florida, in anticipation of such conditions that would cause design breakaway features to become dislodged as well as any other pier damage, JCP's routinely require the following specific permit condition: "*The permittee shall expeditiously recover any breakaway debris, such as pier deck sections or railing, dislodged from the pier following the impact of major storms.*"
   2. The State of Georgia (interview with Buck Bennett) has been successful in requiring private property removal of damaged/lost marine debris/ADV's using the violation notice and enforcement process associated with GA's *Coastal Marshes Protection Act.*

IV. Discussion and recommendation for policy changes (rules, regulations, ordinances)

The focus of the policy team was to find policy solutions to require stricter design and construction standards for residential docks and piers in the coastal area. To better understand the possible solutions, it is relevant to understand the current regulatory context surrounding these structures.

Regulatory Context

North Carolina State Building Code

Construction of residential docks and piers in North Carolina has been exempted from the State Building Code since 2012 (Appendix M). Section 3601.2 (1) states:

> *"Docks, piers, gangways and catwalks, other than residential and farm docks and piers exempted from this chapter in the exceptions below, shall be designed by a registered design professional.*
> *Exceptions: The following structures are exempt from the requirements of this chapter: (5) Piers and docks associated with one- and two-family dwelling meeting the exceptions of the North Carolina Residential Code."*

Furthermore, state law prohibits local governments from adopting any building codes stricter than those prescribed by the General Statute §143-138(e):

> *"Except as otherwise provided in this section, the North Carolina State Building Code shall apply throughout the State, from the time of its adoption…."*

However, the section continues to specify:

> *"However, any political subdivision of the State may adopt […] floodplain management regulations within its jurisdiction. […] No such code or regulations, other than floodplain management regulations […] shall be effective until they have been officially approved by the Building Code Council as providing adequate minimum standards to preserve and protect health and safety. Local floodplain regulations may regulate all types and uses of buildings or structures located in flood hazard areas identified by local, State, and federal agencies, and include provisions governing substantial improvements, substantial damage, cumulative substantial improvements, lowest floor elevation, protection of mechanical and electrical systems, foundation construction, anchorage, acceptable flood resistant materials, and other measures the political subdivision deems necessary considering the characteristics of its flood hazards and vulnerability."*

North Carolina Residential Code

Following the state building code residential docks and piers structures are exempted from the Residential Building Code. Section R327 from the North Carolina Residential Code exempts residential docks from Chapter 36 of the state building code and specifies size requirements, heights, number of boat slips, roof area.

Coastal Area Management Act (CAMA)

The N.C. Division of Coastal Management requires CAMA general permit for construction of residential docks and piers as regulated by 15A NCAC 07H.0208 (b)(6). These standards relate to size and dimensions of structures, access to riparian property, but do not require any design and constructions specification or prescribe the use of specific materials.

CAMA development handbook provides more detailed structural recommendations but maintains its regulatory extent on the length and size of structures.

Proposed Policy Solutions

With this regulatory framework in mind, the policy team explored various policy avenues for mandating design and construction requirements for residential docks and piers. Considered solutions addressed: 1) stronger construction and design; and 2) post-storm marine debris problems caused by poorly designed residential docks.

The first set of solutions for mandating stronger design and construction standards:

1. Reinstate the design and structural requirements in the State Building Code.
   Since 2013, the residential North Carolina State Building Code has been updated every six years. Prior to this, the updates were required every three years. The exemption for residential docks first appears in the 2012 Code update, with 2009 being the last year that included the structures in the building code. In our effort to understand the reasons behind the exemption, we communicated with multiple State Building Code Council members and discovered that during the 2012 Code update the Agency received an overwhelming number of public comments requesting the exemption. However, the vast majority of the public comments originated in inland communities where smaller docks over backyard ponds and streams are common. Thus, residential docks and piers across the state were exempted from the Code.

   Prior to the exemption the 2009 State Building Code stated:

   "The design of piers, bulkheads and waterway structures is essential for the protection of life and property without causing adverse effects to the shoreline. These structures by their very natures result in some modification of physical environment and therefore require minimum design standards."

   The Code went on to specify minimum standards for foundations, design forces, structural integrity, material selection and utilization and construction techniques (Appendix N).

   Further communications with the Council member indicate that the Agency is working on reviewing the exemption and reinstating the residential docks standards in the code and considering implementing certain criteria to differentiate among different types, sizes and geographical locations of residential docks and piers.

The group recommends that at a minimum, these previous construction standards be reinstated in the 20 coastal counties as defined by the Coastal Area Management Act. Given the increased frequency and intensity of storms, the risk of marine debris posed by residential docks and piers in these areas is high not only to private properties but also to public trust waters, recreational areas and ecologically-important coastal wetlands and other coastal habitats.

2. <u>Amend rules and laws to allow residential docks to be defined as potential flood hazard and included in flood plain ordinance</u>.
During storm surge and flood periods residential docks get detached and, as free flowing debris, pose a hazard to life and property and become an important safety issue. As such, residential docks can be defined as coastal hazards.

   By statutory authorization the North Carolina legislature delegated to local governments the responsibility to adopt regulations design to propose the public health, safety and general welfare. Under this authority local governments develop floodplain ordinances defining flood prone areas subject to periodic inundations which result in loss of life, property, health and safety hazards, disruption of commerce, all of which adversely affect the public safety, and general welfare.

   As noted above, the General Statute also allows local governments to impose stricter building codes than those prescribed by the State Code through the floodplain ordinance. However, given that the current flood plain ordinance does not apply to structures built over water, the policy group recommends two ways to address the residential docks:
   a) Consider residential docks as site-specific development that affects free-of-obstruction requirements for certain practices in the coastal zone. 44 CFR 60.3(e)(5) states, in part:

      "… that all new construction and substantial improvements within Zones V1-30, VE, and V on the community's FIRM have the space below the lowest floor either **free of obstruction** or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system..."

      The NFIP interprets the **free-of-obstruction** requirements to apply to certain site development practices that prevent the free flow of coastal flood water and waves under or around buildings or increase flood loads on nearby buildings. Construction elements outside the perimeter (footprint) of and not attached to a coastal building (e.g., bulkheads, retaining walls, decks, swimming pools, accessory structures) and site development practices (e.g., addition of fill) may alter the physical characteristics of flooding or significantly increase wave or flood forces affecting nearby buildings. As part of the design certification process for a building in Zone V, the registered design professional must consider the effects these elements and practices will have on the building and on nearby buildings.

As such, the design and construction standards and practices of residential docks would have to be taken into consideration with new construction and substantial improvements.

b) Amend the floodplain ordinances to include residential docks built over water under their purview. Under the federal law, once FEMA provides a community with the flood hazard information upon which floodplain management regulations are based, the community is required to adopt floodplain management ordinances. The coastal floodplain ordinances currently do not apply to structures built over water. The policy group recommends exploring avenues to amend the rules and regulations governing flood ordinance coverage to include residential docks.

   Funded by the Natural Resources Conservation Service Emergency Watershed Protection program and in partnership with the Division of Coastal Management, the Coastal Federation performed coastal marine debris cleanups from Hurricane Florence and Dorian. The crews started in August 2020 and found that *85% of the debris came from destroyed docks during past storms*. Large part of this debris was identified to have come from improper dock construction discards. This included pressure treated wood, railing, pilings and dock construction material. Thus, the following recommendations focus specifically on *prevention of marine debris* caused by dock construction.

   1. <u>Amend CAMA general permit for construction of residential docks and piers</u>
      Currently, an upland disposal of dock construction material is a norm, rather than an explicit written requirement in the 15A NCAC 07H.0208 (b)(6). The policy team recommends the general permit rule language be amended to explicitly include the requirement for upland disposal of docks and piers construction material.

   2. <u>Adopt policies and ordinances to require encapsulation of polystyrene docks</u>
      Select states, cities, towns, and agencies across the United States have adopted policies, ordinances, or voluntary initiatives to regulate unencapsulated polystyrene docks. As discussed at length during our technical group discussion, unencapsulated dock floats are a significant, long-lasting, and damaging source of polystyrene (foam) pollution.

      These floats are highly unstable, and susceptible to damage and complete losses during coastal storms. Once damaged and broken apart, unencapsulated polystyrene spreads (from small beads and fragments to full sized floats) throughout our coastal and aquatic ecosystems (Rozalia Dock Foam Study, in Draft, 2021) (Appendix O). When consumed by marine creatures, these foam beads/fragments can block airways or digestive tracts, and prohibit animals from absorbing nutrients (Rozalia, Rittmaster, 2018). Polystyrene contains chemicals such as benzene, styrene, and ethylene, which can leach into water and can pose significant health risks (Rozalia, Georgia Forever, 2019). Additional toxins can easily bind with polystyrene's molecular structure. As a result, these become polystyrene concentrates and magnifies these toxins within marine mammals. This toxicity moves up the food chain, affecting entire ecosystems and eventually humans (Rozalia, Marcy & Johnson, 2009).

Throughout NC's coastal and estuarine environment, the presence of this very specific marine debris is ubiquitous, and has been found in every single location surveyed by federation staff and the marine debris removal crews. The vast majority of these beads and fragments cannot be removed by current removal efforts, and are non-biodegradable, thus increasing the cumulative effect of this material in these regions.

In sharp contrast, the encapsulation process melts the hard plastic onto the polystyrene and hardens it. When damaged during storms, the encapsulated float seeps the foam interior contained rather than allowing its dispersal into the environment. Encapsulated docks last significantly longer, require far less maintenance than unencapsulated docks pose. They prevent toxin magnification, save the lives of marine animals, and ensure a healthy and aesthetic ecosystem (Rozalia).

Unencapsualted floats (left) shed polystyrene particles and break apart in the marine environment, as opposed to encapsulated (right) which do not.

Examples of different approaches to regulation of unencapsulated docks across the country can be found in Appendix P.

The policy team recommends that well-defined requirements for dock encapsulation be included in the set of standard recommendations proposed to the State Building Code as suggested in the first recommendation. In addition, we recommend that local governments implement ordinances that require dock encapsulation. The City of Wilmington adopted an ordinance incentivizing land-owners to implement dock encapsulation in exchange for a larger dock area (Appendix Q).

Summary of Policy Recommendations

1. Reinstate the residential dock and piers construction and design standards to the State Building Code proposing the integration of the new standards developed by the Technical Team of this work group (including dock encapsulation). The team recommends higher dock construction standards in 20 coastal counties as defined by CAMA.
2. Amend rules and laws to allow residential docks to be defined as potential flood hazard and included in flood plain ordinance.
3. Amend CAMA general permit for construction of residential docks and piers.
4. Adopt policies and ordinances to require encapsulation of polystyrene docks.

Sources:
2018 NORTH CAROLINA STATE BUILDING CODE
143-138. North Carolina State Building Code
Section R327
1 SUBCHAPTER 7H - STATE GUIDELINES FOR AREAS OF ENVIRONMENTAL CONCERN
SECTION .0100 - INTRODUCTION AND GENERAL COMMENTS 15A NCAC
CAMA Handbook for Development in Coastal North Carolina How to Use This Guide
Introduction About This Guide
GENERAL ASSEMBLY OF NORTH CAROLINA SESSION 2013 SESSION LAW 2013-118
HOUSE BILL 120 AN ACT TO REQUIRE APPROVAL FROM THE NORTH CA
NC DEQ: CAMA Counties

V. Discussion and recommendations for development and dissemination of Best Management Practices (BMPs) for removal and disposal of hurricane marine debris

As described above, an unprecedented amount of debris was spread out and deposited throughout the public trust marshes, tidal creeks, sounds, embayments and islands of the central and southern coastal region of North Carolina. Determining the amount, extent and removal method(s) of the debris was a new challenge. Federal and state agencies, whose resources were already stretched very thin by the storm response, relied on visual surveys by boat along major waterways and aerial photographs to estimate the degree of the debris. Areas with higher population densities, significant waterfront development and significant cultural resources (parks, reserves) were prioritized. However, as determined later by the field crews of contracted fishermen/women, it was very difficult to get an accurate sense of the scale and extent of the debris just from visual surveys. Much of the debris had been floated by the storm surge and blown by the wind far up into the wetlands and into the interiors of marsh and dredge spoil islands. Not until the field crews began scouring these areas with small skiffs and walking through the wetlands and across the islands, did the true extent of the debris fields become apparent.

Due to the geography and shallow water of the estuaries, creeks and waters of the central and southern coast, along with the spread of the debris, figuring out how to find, collect and remove the debris was a challenge. Mobilizing a fleet of marine contractors with barges and excavators was not possible or feasible for the vast majority of debris. Many contractors were in high demand to repair and replace the lost and damaged waterfront structures. Also, the water was too shallow and the habitat too sensitive for large vessels and heavy equipment. Based on earlier success employing fishermen/women to retrieve lost fishing gear, the federation turned again to local fishing communities to pull together small (3-4 people) field crews using skiffs (19-22’ long) to navigate the shallow, ever changing waters and habitats of the coast. Using their knowledge of tides, where currents and surges go and the local areas, the field crews quickly found the debris. Each crew of 3-4 people have averaged collecting one ton/2,000lbs of debris each day.

The issue of the vast amount of debris is certainly linked to the damaging forces of sustained storm surges and wind. However, as described in this report a significant amount of debris was generated due to poor construction, lack of maintenance (funding, enforcement) and very little storm preparedness. Crews found stacks of new lumber with the tags still attached from construction sites. Whole sections of pier decking lifted off pilings due to inadequate attachment (Appendix R). Sections of docks with piling attached were pulled out of the bottom due to the shallow depth of pilings.

This section provides guidance, resources and "lessons learned" from the large-scale cleanup of hurricane marine debris ongoing since early 2019. While the collection and removal of debris has been very successful, due to the hard work of the field crews, there would be a lot less debris to recover if the guidelines and recommendations in this report are adopted, followed and enforced.

Post- Storm Debris Identification, Assessment and Removal Practices

- After a significant storm event, using aerial imagery is a great help in assessing the potential scope, scale, type, and amount of debris. NOAA rapidly produces imagery for areas affected by storms:
    - https://storms.ngs.noaa.gov/storms/isaias/index.html#8/35.661/-76.191
    - https://storms.ngs.noaa.gov/storms/florence/index.html#18/34.63577/-77.19929
- Waterway surveys by boat are useful, but often greatly underestimates the amount of debris deposited in the marsh, behind berms of spoil islands and hidden in marsh hammocks.
- Surveying by drone can be useful, but has limited applications.
- Communicating with local residents and sending out small crews of people familiar with the local environment to conduct focused searches of sample areas can yield good results.

Coordination with Regulatory Agencies, Resource Managers and Local Officials

- Work with state and federal regulatory agencies to receive State and National Environmental Policy Act (SEPA and NEPA) clearances for project activities.
- Provide debris collection crews with the written regulatory guidance and NOAA Marine Debris BMPs (Appendix S), and offer training to crews to ensure compliance.
- Notify local, state, and federal agencies of debris collection activities when the field crews are active in their respective areas.

Recruiting and Setting up Debris Collection Crew

- Local fishermen/women have proven to be excellent and resourceful. Sometimes have to compete or be flexible during commercial seasons.
- Field crews are made up of Boat Owner/Operator; Field Crew Supervisor; (2) Field Crew Members.
- Initiate contact with potential crew supervisor and/or Captain.
- Describe the pay, requirements, and expectations of the job for each crew member.
- Ensure the Captain has the proper vessel to support the requirements of the job.
- Ensure the Crew Supervisor has the necessary equipment and skills to handle their job expectations.
- Meet and interview the crew to ensure proper knowledge of equipment, navigation, location, etc. is present.

- Establish clear and concise communication and exchange of information with the Crew Supervisor.
- Provide the crew with all necessary documentation, forms, etc. for the contract.
- Make sure the Crew Supervisor is aware of the format, frequency, and expectations of paperwork (debris logs, hour logs, etc.).
- Provide gear and explanation for the use of gear (sharp kit, oil spill kit, sleds, etc.) to the crew. Also, explain what gear may be required by the crew to provide if needed.
- Make sure the Crew Supervisor is supplied with the proper maps and outline the scope of the project.
- Ensure the Captain is committed to finding a place to store his vessel during the duration of the contract or is capable of shuttling his vessel to and from the location of the contract.
- Provide the Crew Supervisor with the contact information and locations necessary to facilitate the delivery, setup, and servicing of the dumpster.
- Accompany the crew at least one day out on the water to answer questions, give guidance, and examples of how to perform the requirements of the contract.
- Instruct the crew on proper dumpster loading etiquette and site maintenance expectations.
- Instruct the crew on proper environmental etiquette in order to minimize impact to the environment and surrounding areas.
- Continue communication throughout the course of the contract for questions, concerns, or necessary guidance.

Debris Collection



Typical size skiff used for debris collection (left); crews using a 4-wheel ATV and small trailer to collect debris from ocean front beach (center); and utilizing debris sleds (right) to minimize environmental impacts of removal.

Recovery and collection of debris methods vary according to the type of debris, waterbody and habitats. Often it is initially thought that barges with excavators will be most effective. However, in shallow, tidal estuaries with changing conditions, small boat crews operating by hand and with hand tools are often most effective. Small crews also seem to minimize the negative impacts to the surrounding environment.

- Shallow draft barges with excavators or landing type barges with skid-steers are useful to pick up large debris along maintained channels. They can also be useful for picking up stockpiled debris placed by small crews. If operating in an area with little to no land access to host a debris dumpster or offload debris, a barge can serve as a mobile debris collection platform for the small crews.
- On oceanfront beaches crews may be able to use a 4-wheel ATV with a small trailer to collect and haul debris to access sites. Coordination with resource and regulatory agencies must occur to ensure protection of bird and turtle nesting sites.
- Small crews made up of 4 individuals working with 21 - 24’ long shallow draft skiffs/bateaus are very effective and efficient. Larger crews tend to lead to less production and wait times.
- Crews should be outfitted with (See attached gear list):
    - <u>Gear</u>: debris sleds, trash bags, trash grabbers, wrecking bars, chainsaw, logging picks, heavy duty rope/line, small spill kit, medical/sharps container w/red bags and bucket, marsh mats, 5-gallon buckets, shrimp baskets, heavy duty garden carts for hauling debris to dumpster
    - <u>Safety/Visibility</u>: Safety glasses, gloves, first aid kit, orange work vests (best with organization logo), boat flags labelled with *Marine Debris Collection*
- Provide crews with high visibility t-shirts, safety vests, hard hats (if needed) and boat flags with project information and or logo to make the public aware of their activities for safety and educational purposes.



Crews working by hand to collect polystyrene pieces from unencapsulated floating docks (left) and examples of larger floats that are found in large numbers (center, left).

Debris Disposal

- Utilizing existing public boat ramps and access areas for staging debris dumpsters and loading works well and is preferred versus using a community, private or business access.
- State/local agencies and governments that manage boat ramps may provide a Special Use Permit, with conditions, to enable dumpster staging and debris offloading.
- Locations for dumpster placement must be accessible during all tides and also accessible for debris drop-off by the crew. There must be constant access to the dumpster for removal by the dumpster company.
- Recycling is difficult due to debris contamination. If possible, it is helpful to have a yard where reusable wood can be stored and offered to the public. Would need two dumpsters at each collecting site, one for reusable wood/ recyclable metal and the other for debris for landfill.
- 40-yard dumpsters are best, as they fill up quickly. Crews average 1 ton of debris collection/day, with a 40 yd dumpster being filled once a week on average.
- Using local waste hauling companies if possible.
- Municipal landfills will sometimes offer discounts, waive fees or provide in-kind equipment assistance with debris removal.
- Check with local landfills to see if debris needs to be sorted.
- Use traffic cones and signage to educate the public about the project and to discourage illegal dumping in the dumpster.
- Ensure weight tickets are provided and recorded for every dumpster that is emptied.

Full copies of crew SOP's, equipment estimates, member agreements, contractor agreements, signage, liability waivers, and case-study photos may be found in Appendix T.

40-yard dumpsters at removal sites. Constant access to dumpsters, a reliable removal schedule and good working relationships with local government staff are key in getting debris removed in a timely manner.

VI. Design/Construction Recommendations for Long-Term Resiliency and Prevention of Hurricane Marine Debris from Marine Construction

Introduction and Background

North Carolina is not alone when it comes to incomplete standards surrounding the construction of residential docks and piers. Upon researching other coastal states that may be prone to hurricanes, the vast majority of coastal states have similar policies to North Carolina - permit requirements and size limitations, but no standards directly related to construction. There are a number of reasons for this, including: difficulties and lack of consensus on the most effective construction standards (especially for hurricane prone areas); wide variability of factors and considerations across coastal regions; lack of expertise and resources for monitoring and enforcement; lack of education for consumers and construction professionals; market forces that can drive marine construction towards low bid, substandard construction materials and practices; lack of political support for strengthening construction standards. Nevertheless, there are numerous examples and models for resilient construction of docks, piers, and effective programs that have resulted in reduction of marine debris from damages and losses of docks, piers, etc., particularly during hurricanes and coastal storm events that are frequent along North Carolina's coastal region.

Considerations before building marine structures

Property owners and professionals need to consider a number of factors when determining marine construction needs. Overall, it is important to understand the use needs, specific site conditions, history of energy and weather conditions for the site, qualifications of the marine professional, and funding/insurance options. There are various design options and material choices. Where to locate the structures is another important factor. Understanding the tides, storm exposure, and/or bottom conditions can help determine the best location and type of dock for a given waterfront area and ensure the longevity of the structure, especially in marine and storm- prone areas. Each different docking system offers benefits and potential risks. It is critical to understand uses as well as current and historic site conditions, typical and storm energy forces, future risks, and historic damage/maintenance issues.

When choosing a design and location for a dock/pier/etc. the first step is to ask a few questions about your particular location and needs:

- What is the depth of the water and condition at the bottom?
- Should the structure(s) be permanent, adjustable or removable?
- How many boats will the dock need to accommodate at once? What about other types of watercraft, such as kayaks, canoes, paddleboards, etc.?
- Will the water level rise and fall drastically, potentially limiting the dock's usage?
- Will the dock be exposed to any ice during the winter if the surface freezes?

- What are the surface conditions of the water? Are you in an area that's prone to heavy boat traffic or frequent storms?
- What are the historic wave heights/wind energy/current velocities/storm surge for this shoreline and property?
- What is the history of damage/losses/maintenance issues for any structures at this or nearby properties?
- What is your budget? How much are you willing to put into constructing and maintaining the dock?
- Is insurance a factor in building your structures, and can you obtain a policy with rate incentives for more durable/resilient construction techniques and materials?

Considerations in Selecting a Marine Contractor

Over 85% of the marine debris removed from North Carolina's estuaries between 2019-2021 is the result of damaged and/or lost docks, piers, boat houses, etc. Many examples of damaged and/or lost structures are the direct result of substandard marine construction techniques, including lack of expertise/experience, poor construction, substandard materials, and cutting corners on both construction methods and materials.

The qualifications, experience and proof of resilient, durable, and long-standing marine construction, are extremely important factors in selecting a marine contractor. As with the selection of any contractor, property owners should be proactive in vetting and selecting a marine contractor. (Appendix U) Selecting a contractor solely based on the bid price is often not the best option, if one does not take into account the type of construction and potential for longevity. This is especially true for marine construction within coastal North Carolina, given North Carolina's long history and increasing risks of coastal storms, hurricanes, heavy boat traffic, and other marine conditions affecting the lifetime of marine structures.

Although an added up-front cost to property owners, it is advisable to hire a marine engineer for design guidance, especially within areas which are susceptible to storm energy, surges in water elevation, and significant wave, boat wake, or current conditions.

Below are some recommendations that property owners should consider before contacting a marine contractor and during their vetting and selection processes:

- Obtain and read educational materials concerning the type of marine construction project to be performed.
    - One or more options which could apply to the situation should be identified and design techniques based on proven engineering principles and construction practices for such projects should be studied.
    - Publications addressing a variety of marine construction projects are available from Sea Grant and the U.S. Army Corps of Engineers.
    - Write down as much as possible about what is intended to be accomplished by the project. The present situation should be outlined, the problem to be

solved should be stated, and preferences for type of construction and final appearance should be described.

- Potential contractors should be given as clear a picture of the project as can be provided, as well as needs and uses for the structure.
    - It is best to allow contractors to propose a range of feasible designs from which the client can choose a final project.
    - Important information that can be presented to the contractor includes: the exact location of the project; a description of the problem to be solved; specific site conditions (best gathered during a site evaluation); site conditions and history of tide, wave, storms and current conditions, changes to the shoreline, etc.; the general composition of shoreline sediments (i.e., sand, clay, cobbles); any restrictions that would preclude needed equipment access to the construction site; and/or a rough description of the client's needs and proposed uses for the structure.
- What type of licensing and certifications do you have?
    - It is always better and safer to work with licensed and certified marine contractors. This may not be needed for smaller, residential settings, but may be worth considering.
- Does the contractor carry a Commercial Marine Liability Insurance Policy and a USL&H Endorsement on their Workman's Comp. Policy?
    - This may not be needed for smaller, residential settings, but may be worth asking.
- Are you experienced in marine construction in this area?
    - It is important that a contractor has experience in constructing marine structures. At the same time, you need someone who is especially experienced in building structures in your area. it is not enough if they know how to build structures. They should know and understand the challenges related to the location of your land, soil conditions, the historic energy and storm forces for the area, and design options to meet these forces.
- What design do I need for my uses?
    - When you have narrowed down your choice to a few experienced marine contractors, you may begin to discuss designs. Make sure to discuss your needs and uses for the structure. Ask them for suggestions for the ideal and most functional design and discuss the specific materials with lifetime estimates and any guarantees they would offer for their design in the event of damage and/or failure.
- What equipment will you be using?
    - Big projects require bigger equipment. You need to know that the contractor has access to the right equipment for the job, which equipment they will be using, how it will move through your space, etc.
- Do you have any references or testimonials?
    - Visiting existing structures at your project site is a good way to find local marine contractors and ask about their work.

    - Existing structure types that serve a similar purpose to a property owner's uses should be inspected and discussed with the structures' owners regarding the company that did the construction.
        - Questions to ask include: did the contractor have the proper equipment to successfully complete the project; were there any unusual problems during or subsequent to construction; how long has the project been in existence; and, is the owner satisfied with the way it has performed?
    - If the structures' owners are pleased with their structure, they will most likely be happy to share that information. Do not make the mistake of not checking references. Sometimes even the most experienced, licensed, and certified marine contractor who seems to be the most qualified person for the job may be unresponsive to needs, have a poor work ethic, hire inexperienced crews, etc.
- What is their reputation in the community?

Sources:
Seven Questions to Ask Before Hiring a Marine Contractor, Thaler Contracting
Five Questions to Ask Your Contractor, Farrell Marine
Selecting a Marine Contractor - New York Sea Grant

Recommendations and Discussion of Marine Construction Best Management Practices

Below are discussions of key factors, examples, and resources that can improve the resiliency and lifetime of marine structures in North Carolina. Recommendations for improving the resiliency of marine construction include consideration of materials and construction techniques. These include, but are not limited to, the following:

Recommendations for marine construction materials

Support pilings and decking/docking materials

A key factor in marine construction is selection of the materials. Types of structure materials that are commonly used for residential docks and piers include wood, concrete, polymer, recycled plastic/vinyl, and steel. When determining the best type of dock piling, you should consider the water conditions that your dock will have to withstand as well as the overall weight and load of the dock. A great deal of information may be obtained through an internet search. Some basic information about marine construction materials with some recommendations are included below:

Wooden Docking/Pilings

Historically, wood has been used to construct a large variety of marine structures within North Carolina and elsewhere. Untreated wood is not recommended for the coastal zone because it will soon decay if it comes in direct contact with seawater. In marine applications, timber is attacked by marine borers, insects, fungus, and rot. Marine plants, algae, crustaceans, and marine worms attach to treated timber piles, however, these do not appear to harm the strength characteristics of the wood. Typically, timber elements that are directly subject to the marine environment are then pressure-treated with some infused protective treatment (more information on this is provided below). Treated to withstand sea and brackish water, pressure-treated timber maintains its relative strength and lasts longer than untreated timber.

It is recommended to use hardwood pilings (such as greenheart) as a durable option for dock construction. Highly durable and resistant to marine borers – hardwood pilings address a major consideration in a dock piling material. Commercially available as untreated pilings, they are advertised as better than treated woods at standing up to the pressures of the job. This also has the added benefit of nothing nasty potentially leaching into the water.

Over time, most old timber pile construction will deteriorate in the marine environment. To avoid losses of the entire docking structure, existing older piers should be restored by the addition of replacement piles or by encapsulating the piles in concrete. Alternatively, piling sleeves may be heat shrunk onto wooden dock pilings before they are installed or retrofitted onto existing piles, creating a waterproof layer on the outside of the pile, which extends the strength and longevity of the dock piling.

Failed or damaged docks/piers/etc. very often require the use of undersized support pilings/posts during construction. In areas prone to heavy storm forces, strong currents, etc. the use of larger, more substantial round pilings (ie. 10”-12” diameter round pilings vs. 4” X 4” square pilings) is recommended for long-term stability.

Sources:
The Ultimate Guide to Dock Piling Materials - Decks & Docks Lumber Co.
Greenheart - Wood Species Guide

Aluminum Docks

Assembled with interlocking edges, aluminum decking planks create a lightweight, water-tight, and gapless seal. Some considerations include:

- Durability: Unlike wood that is susceptible to environmental impacts, aluminum is scratch- and weather-resistant. Aluminum socks are significantly lighter than wood, but when reinforced, may be stronger and more resilient to loads than comparable wood structures.
- Upkeep: Aluminum does not rust, but it will corrode. The corrosion process protects the aluminum from rusting. Though you do not have to worry about rust eating away the metal, you do have to worry about the structural integrity of the dock being compromised. A variety of protection methods are applied to aluminum and its alloys to enhance their corrosion resistance. Amongst the most common methods is anodizing. This is an electrolytic process which produces a hard, relatively thick film of aluminum oxide on the surface of the aluminum when the metal is made the

anode in a suitable electrolyte and current is passed through the circuit. Other protection methods include chemical conversion coatings and various paint finishes e.g. powder coating. Chemical pre-treatment prior to painting is essential. Sacrificial anodes, e.g. zinc, can be used to protect aluminum alloy structures when used in marine environments.
- Repairs: Because aluminum decking will not rot, attract damaging pests, or grow mold, repairs are usually minimal.
- Environmental Considerations: Though the mining process and refinement of ore requires a lot of energy, aluminum is heavily recycled. You can reuse uncontaminated aluminum almost indefinitely.
- Ability to Expand, Reconfigure, or Remove: Aluminum docks are typically manufactured in sections for installation, therefore, they can be added onto or reconfigured. While permanent structures like wood piling docks cannot be removed easily, aluminum docks can usually be folded and stored when not in use during the winter or seasons with heavy storms.
- Lifetime: The duration of an aluminum structure depends heavily on location and marine conditions. Aluminum frames may last from 30 to 50 years depending on conditions.

Sources:
Aluminum and Corrosion
EZ Dock

Plastic (New/Recycled or Composite) Docks

Those looking for a durable, innovative floating docking system should consider plastic decking. This type of dock material is easy to install and can cater to budgets of all kinds. It also represents a resilient option, with the durability and longevity of aluminum docks but without the higher price tag. Some considerations include:

- Durability: Plastic/composite docks are made of durable dock surface materials. In both freshwater and saltwater environments, polyethylene docks will not rot or splinter like wooden docks. The mobility of the relatively lightweight sections could allow for removal of some or all of the sections prior to hurricanes, extreme storm surges, etc. If a resin or plastic dock section is damaged, it can be easily replaced.
- Upkeep: Plastic docks are easy to maintain. Wooden docks require regular maintenance and aluminum docks require an attentive eye for rust, corrosion, or other unfavorable occurrences.
- Lifetime: Product marketing for plastic docks promote plastic docks for most low- to mid-category hurricanes. Warranties for plastic docks average about 50 years under normal conditions.

Flow-Through/Open Slatted Decking

A relatively new innovation involves plastic or heavy rubber coated flow-through decking, which is sold in varying sizes of decking modules. These products offer two benefits in coastal and storm prone areas:

- The open slatted or other open design allows water to easily flow through them, potentially reducing the pressure, lift, and potential failure of the structures during periods of extreme storm surges and waves associated with coastal storms and hurricanes, and
- The open structure allows for significant light penetration below the deck, preserving marsh and other coastal plants' growth, leading to greater stabilization of the shoreline during storms.


Flow-through plastic decking (photo courtesy of Ennett Marine Construction)

Steel Docking Structures

Steel dock pilings offer high load capacities and durable corrosion resistance. The corrosion resistance of steel dock pilings is an essential consideration in the use of steel piles/structures. When steel piles are used in seawater, they react chemically to form anodes and cathodes, resulting in the flow of electricity, which causes the corrosion of anodic areas of piles. Chemically active surface areas of underwater steel piles act as anodes and less chemically active surfaces act as cathodes. The degree of corrosion resistance is related to the overall steel wall thickness and the corrosion resistant coatings, which have been applied. By using steel dock pilings with a thick outer diameter wall and/or special coatings, you can be sure that steel dock pilings will offer durable support for years to come. Steel dock pilings offer great strength and can even be filled with concrete or other materials to increase the load capacity.

Sources:
[Dock Pilings | New & Used Structural Steel Pipe Pilings]
[Corrosion Protection Methods for Underwater Piles]

Concrete Docking/Pilings Construction

While no dock is maintenance free, many regard a concrete docking system as the strongest and lowest maintenance option among docking options. Individual concrete modules are often larger than those found on a waler connected dock. Many can be reinforced with steel or another material to improve its tensile strength. Other advantages of concrete include its resistance to decay, corrosion, and fire. When using concrete for pilings, it is important to make sure that any concrete pilings for sale have been allowed to fully cure for at least thirty days so that there is no leaching of chemicals from the piles into the water.

Concrete floating dock marinas are manufactured and assembled in modules. (Appendix V) Modular construction allows bending at the float connections to provide appropriate flexibility for a structure on the water subject to wave action. In addition, the manufacturing and installation of concrete floating docks is more manageable when floats are cast and transported in modules. A further benefit is that modules can be removed and replaced; in the unlikely event that this is necessary, individual modules can be disassembled and modified as needed.

It is reported that the port authorities in Georgia installed specially configured concrete panels at their public docks in order to foster a healthy community of marine organisms due to the lack of wooden components requiring chemical preservative treatment.

Concrete/timber docking with concrete encapsulated floats

Within industry options featuring innovative, resilient options, the Unifloat concrete floating dock system from Bellingham Marine utilizes a waler system to connect individual float modules together.

Sources:
[The Ultimate Guide to Dock Piling Materials - Decks & Docks Lumber Co.]
[Port docks playing host to marine life - News]

Walers

Walers are structural beams mounted flush to the deck of the Unifloat concrete floating dock from Bellingham Marine. They attach to the float by long rods threaded at the ends. Called “through rods,” they span the width of the float and are held in place with washers and nuts. Walers can be made of a variety of structural materials depending on the engineering requirements of the marina. These include structural timbers, composite, steel, and other materials. The vast majority of Unifloat systems employ structural timbers although Bellingham Marine has built marinas with walers of other materials as appropriate to the project. The vital structural purpose of the walers is to connect the float modules in a manner that reduces damage and loss of structures during storms. In a Unifloat marina, no other connection method, such as hinges between floats, is necessary, or in fact desirable, as the waler system has proven itself under the harshest tests nature can deliver. Walers perform two other functions. First, they protect the concrete floating dock from impact by a docking boat. Second, they present a gentle surface to the hull of a boat using the moorage, especially when the walers are built of structural timbers and when combined with protective rub rails.

For comparison, NordiDock advertises a 50-foot section of NordiDock concrete dock 34,000lb in weight, and refers to photographic evidence in the wake of Hurricane Sandy, that concrete floating docks withstood the forces of the storm better than docks constructed from any other materials. Further, they state that new dock construction in the states of New Jersey, New York, Connecticut, and Massachusetts will need to take serious future storms into consideration*.
**Note: This fact has not been substantiated during this study.*

The patent for the original waler system (Usab’s patent) describes the function of the walers as, “…to support the bolts or other fastening means, and to distribute the forces received therefrom throughout the structure.” This is the stated benefit of the waler system: distributed loads.

To understand the importance of distributed loads, consider alternate float connection systems in use today. Typical systems employ heavy-duty hinged steel bolts or large stranded cables at the corners of the floats. There are two problems with these systems. First, the connection hardware can, and does, fail. It may weaken under repeated bending and attack from galvanic corrosion. Second, forces on the floats are not distributed, but are concentrated at the corners of the floats. Thus, enormous shear loads are focused where they can result in irreparable damage to the concrete body of the float.

Stress analysis of structures is a complicated science, but by reducing the analysis to its fundamentals we can compare the systems with clarity and understanding. The easy-to-follow example below demonstrates the advantage of distributed-load systems over point-loaded systems.

A practical example: Follow the Stresses

A large power boat is moored to a concrete floating dock in a storm. The boat's considerable "sail area," the currents in the marina, and the pulse of waves against the boat are all transmitted through its mooring lines into the floating concrete dock. These forces translate through the dock and are felt as shear forces at the module connections. In our example, the resultant shear force at the connection points between the floats is 10,000 pounds. In an actual marina during an actual storm, it could be more or less, but 10,000 lbs. gives us a round number to work with.

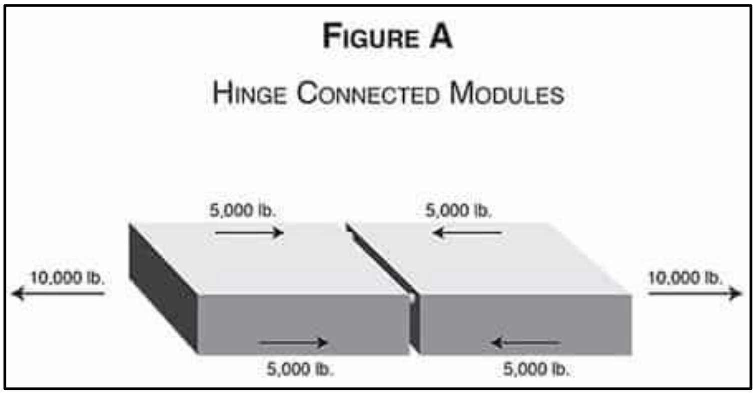


Figure A. Hinged Connection System

On the hinged or cable-connected system, the load is applied to the corners of the floats as a shear load of 5,000 lbs. applied equally to each of the four corners. The load is transferred through the hinge or cable to the concrete at the corners. The concrete structure must contend with a shear load of 5,000 lbs. at the vulnerable corners of the floats.

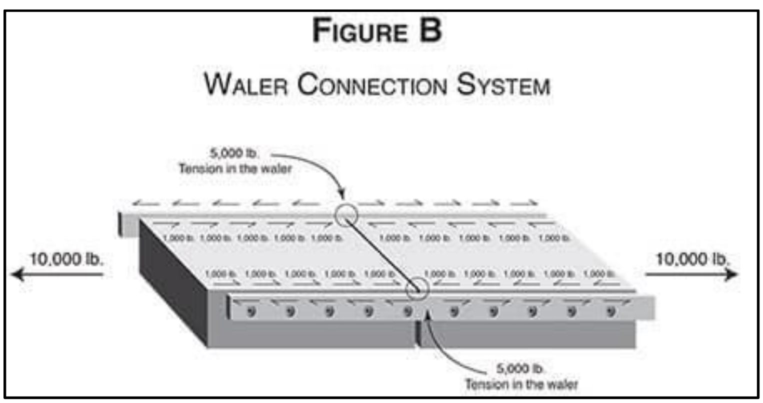


Figure B. Waler Connection System

By contrast, a Unifloat system with a typical complement of 10 through rods receives the same 10,000lb load. Unlike the hinged system, where loads are concentrated at the corners, the shear load is translated up and down the waler and distributed among all the through-rod entry/exit points. Each of the 20 entry/exit points in the concrete structure must contend with 1,000 lbs. of shear force. The waler system, with its distributed-load design, has reduced the load on the concrete structure by 80%.

Sources:
[Bellingham Marine]
[5 Reasons to choose a concrete floating dock]
[Understanding Walers: What is a Waler?]

A 2019 Industry Review of Trends in Marine Construction Materials

Regulation has pushed the need for fully encapsulated foam floats, particularly in Dade, Broward, and Palm Beach counties in Florida. New codes there prohibit exposed or coated foam; it must be in a polyethylene or concrete shell. “Foam beads on the water due to exposed foam will soon be a big cost for cleanup for marina owners,” Ryder said.

He said that area is also experiencing an active storm cycle and more severe hurricanes in the last few years. Structural walers have gotten bigger, and float modules with more reinforcement and connection frames using heavier sections of steel are more common. Other dock builders are using newer and more innovative waler designs. Golden Marine Systems has changed from a wooden waler to an aluminum waler. “It’s higher strength. It’s sort of a hybrid system,” said Mike Shanley of Golden Marine Systems, which manufactures aluminum and concrete docks.

Instead of waler-style concrete docks, SF Marinas is installing a lot of docks with single pass concrete structures. A single pass concrete structure is one solid structure that does not require bolted walers. The trends in dock material choices as builders see them often depend on the builder’s capabilities. However, certain changes in material composition have influenced the market as well. Less effective lumber treatments have made timber less desirable for many applications. Those producing concrete systems are seeing very strong markets. Marintek, which manufactures concrete and aluminum systems, still does a considerable amount of work in aluminum. “Aluminum is less expensive than concrete, so that’s a big attraction,” Berry said. “It’s much stronger and better looking and longer lasting than timber. It’s the go between.”

American Muscle Docks builds galvanized stainless steel, aluminum, and wooden docks. Some customers still choose wooden docks because it is the cheapest, said Luke Diserio of American Muscle Docks. “Aluminum has also come a long way. A lot of people are building heavier aluminum docks,” Diserio said. Processing technology has made aluminum better and more suitable for saltwater, and American Muscle Docks has begun using aluminum in ocean environments where it wasn’t before. MariCorps also produces a galvanized steel dock system, or a hybrid steel/concrete design, which allows a marina to put in a swimming pool in the docks. The trend for stainless steel docks, Ashby said, is from painted steel to galvanized.

Design trends are also influenced by many outside factors, such as weather, material availability, and technological advances.

Bellingham also uses fiberglass rods for its thru-rod system, which eliminates the use of 80 percent of the steel in the system and some maintenance costs.

Gael with Structurmarine explained how design choices can be influenced by the project cost versus understanding the total cost of ownership. Many owners are only looking at the initial price tag, not the total cost of ownership, which considers maintenance 30 years down the road.

Sources:
[Bigger and Stronger: Dock Builders Talk Trends in Design and Infrastructure]

Floating Dock Materials

Encapsulated floating dock floats

Expanded polystyrene foam is a common material to use as dock flotation because it is light and inexpensive. However, the environmental and social costs of this non-biodegradable material far outweigh its trivial benefits. When exposed to the elements, unencapsulated polystyrene will become brittle and crack, potentially crumbling into thousands of foam beads/fragments that destroy the aesthetic and health of shorelines and threaten aquatic ecosystems. (Appendix W) When consumed by marine creatures, these foam beads/fragments can block airways or digestive tracts, and even stop animals from absorbing nutrients (Rittmaster, 2018).

Furthermore, polystyrene contains chemicals such as benzene, styrene, and ethylene. In small quantities, these chemicals can leach into water (Georgian Bay Forever, 2019), and in larger quantities, can pose significant health risks. Also, other toxins can easily bind with polystyrene's molecular structure. As a result, dock foam often poisons marine animals, as polystyrene concentrates and magnifies these toxins. This toxicity moves up the food chain, affecting entire ecosystems and eventually humans. (Marcy & Johnson, 2009).

It is important to note that downstream disposal of polystyrene foam docks is not a viable solution. Materials Recovery Facilities do not make money from collecting dock foam, and therefore do not accept this type of pollution. Thus, encapsulating foam docks is an attractive alternative because doing so prevents foam dock pollution and eliminates the need for downstream cleanups. Economically, paying for encapsulated dock foam is initially more expensive than purchasing unencapsulated foam, but the investment quickly pays off. Encapsulated docks last significantly longer, require far less maintenance, and eliminate the potential risks unencapsulated docks pose. They prevent toxin magnification, save the lives of marine animals, and ensure a healthy and aesthetic ecosystem.

A variety of foam materials are used for floating docks. Most foams can be damaged by biofouling when submerged and by sunlight exposure, particularly after becoming post-storm debris. Air filled floats are not recommended or in some cases are prohibited as unreliable floatation. Encapsulating the foam reduces the likelihood of the decaying foam particles being released into the environment. A common construction practice is to partially or completely wrap the foam in a layer of filter fabric. How the filter fabric is installed likely affects the effectiveness of continued containment of the foam, if it becomes storm debris. More reliable containment is provided by partial or total encapsulation by hard, UV-resistant plastics. Biofouling is completely controlled. Foam deterioration and containment appears to be effective if fully encapsulated. Partial encapsulation (open top) can still release the foam when damaged by storms.

Hardware/Connectors - Connectors/Buffers

For energy prone areas, it is recommended to attach docking elements and supports with galvanized/hot dipped through bolts rather than lag bolts. The use of galvanized or stainless-steel hardware, including screws, bolts, nails, plates, cross-bracing, and anchors is recommended for marine environments, but ceramic coated is an option as well. Helix anchors should be tied down before a storm. For floating dock structures, the use of rubber buffer pads and/or rollers are recommended to reduce the damage to the support pilings over time, adding years to the life of the structures.


Pile supports/bumpers installed by Bellingham Marine

Marine Wood Grading/Moisture Content/Preservative Treatment

Preservative Treatment

Pressurized treatment of lumber, timbers, and piling is the most effective method of protecting wood designated for the marine environment. The pressure process allows deeper penetration of chemical components in the wood and closer control of retention levels. The choice of preservative depends on how and where wood will be used. There are three broad types of wood preservatives used in modern pressure-treating processes. Preservatives are forced into the wood's cells within a closed cylinder while under pressure. A "fixation" process bonds the preservative to the wood fiber, which results in a virtually insoluble bond that protects lumber products in service.

Several marine borers attack exposed heartwood in marine lumber typically used for docks and bulkheads. Once entering the heartwood as larvae, the borers can damage even fully preservative-treated lumber, weakening its structural capacity and shortening the useful life of the entire structure. Marine-use preservative treatment requirements are included in the North Carolina Building Codes. The preservative treatment requirement is well known through a national standard referenced in most codes. The heartwood lumber requirements (prior to treatment) are addressed in a footnote of the national standard which make them hard to find in writing and widely ignored in local practice. Enforcing the existing heartwood-exposure requirements would extend the structural lifetime of the material when installed in saltwater. On last check, with a few exceptions in North Carolina, most suppliers of marine-grade, preservative-treated lumber do not offer materials meeting the national heartwood standard. Meeting the standard requires more effort in sorting heartwood-free lumber prior to preservative treatment and raises the cost of production. Square pilings for dock and bulkhead construction almost always have exposed heartwood when sawn. They frequently do not meet the heartwood standard but can be individually encapsulated or avoided entirely in salt water exposures. Most round pilings can meet the requirements because the heartwood is fully surrounded by treatable sapwood. In general, heartwood is too dense to readily accept preservatives using typical pressure-treatment procedures and standards.

Grade and Quality Marks

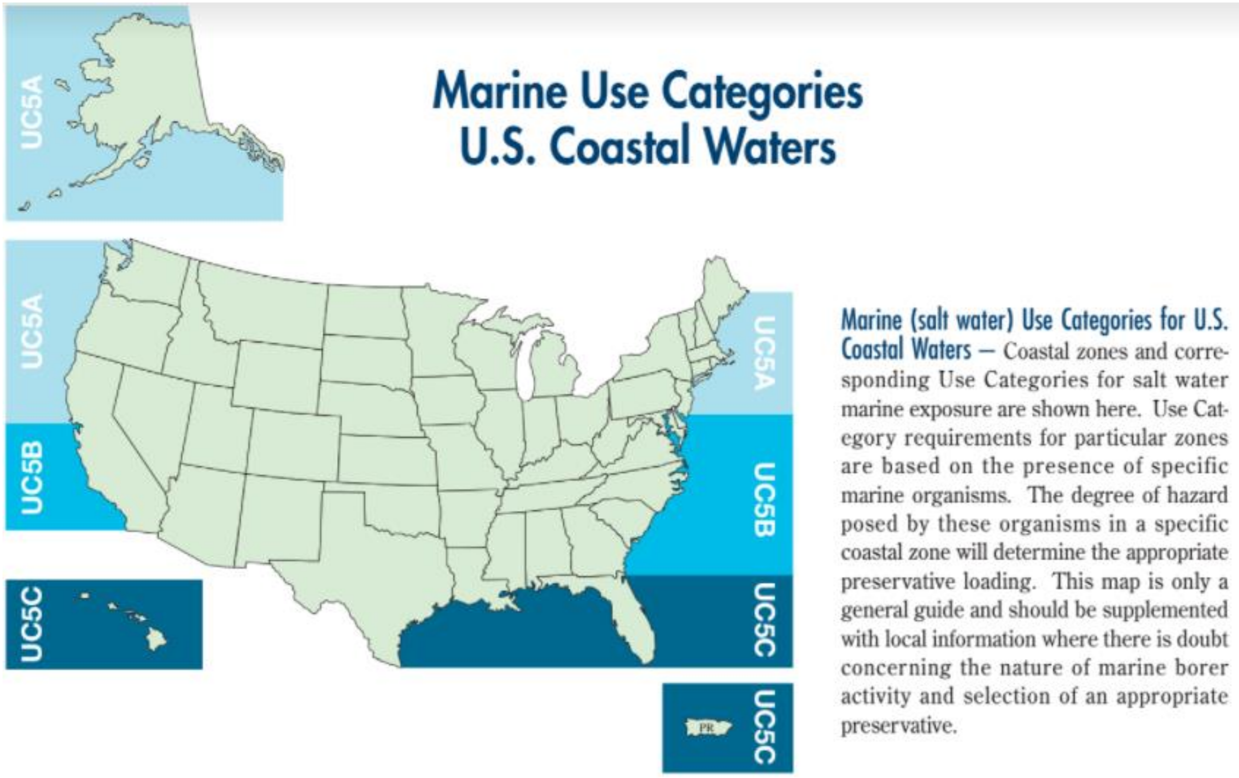
To protect the buyer and consumer, the industry has developed a system requiring ink-stamped grade marking of each piece of lumber under adequate quality control measures. This assures delivery of the grade specified for its intended use. Lumber grading and marking is monitored and inspected by agencies accredited by the American Lumber Standard Committee (ALSC). It is recommended that the buyer specify pressure-treated wood bearing ink-stamped quality marks and/or plastic end tags denoting the material was produced under supervision of an independent inspection agency accredited by the ALSC. Use of such marks by the producer pro- vides assurance that the preservative retention and penetration complies with American Wood Protection Association (AWPA) and/or Building Code specifications and that the preservative used is EPA approved and treated in compliance with federal law. Use of treated wood that does not bear an approved agency quality mark will not meet requirements of the International Code Council (ICC).

Moisture Content Requirements

Most of the in-service problems with heavy timbers and planking have been the result of inadequate drying practices prior to preservative treatment. Dimension lumber and decking used in marine applications should be kiln-dried or air-dried to 19% or less. Timbers (5x5 and larger), if specified to be kiln-dried, must be 20% or less and, if specified to be air-dried, must be 23% or less. These moisture content guidelines for untreated Southern Pine originate from the Southern Pine Inspection Bureau (SPIB).

A good resource for general guidance on quality, wood treatments, moisture content, etc. for various U.S. geographic use categories is the *Aquatic and Wetlands Structures, Design and Construction Guide*, which is compiled from various marine construction industry sources and standards (Appendix X). This resource should be a starting point for consideration and supplemented with local information regarding marine conditions, energy levels, and marine organisms.

Aquatic and Wetlands Structures, Design and Construction Guide, www.southernpine.com



Recommendations for Construction Techniques

The resilience of marine construction results from both the material selected and the methods of construction. The following include recommendations for consideration in more resilient marine construction, with the goal of reducing marine debris from damaged/lost structures:

Driving vs. Vibrating in Pilings

A driven pile is a relatively long, slender column which offers support or resistance to forces and is made of material with a predetermined shape and size that can be physically inspected prior to and during installation. It is installed by impact hammering, vibrating, or pushing into the earth. Driven piles maintain their shape during installation, they do not bulge in soft soil conditions and are typically not susceptible to damage from the installation of subsequent piles. Many hollow-section piles can be visually inspected after installation to assure integrity. Most solid-section piles are uniform in section and can be dynamically inspected to verify integrity.

When conditions warrant, the pile driving process can be easily modeled prior to installation to determine adequate and economic equipment selection. Static or dynamic testing can confirm load carrying capacities of installed piles. Dynamic testing can easily confirm proper hammer performance and its effect on the pile. Many modern hammers have impact velocity measurement devices permanently installed, providing a very high level of quality control.

Piles are ideally suited for marine and other near shore applications. There are no special casings required and no delays related to the curing of concrete. Piles driven through water can be used immediately. Pile driving is relatively easy in many soils. Since the soil at the toe is in a compacted condition for displacement piles, end bearing can often carry a substantial load. There are no "soft bottom" soil conditions, so large settlements for end bearing piles are eliminated.

Driven piles displace and compact the soil. Other deep foundation options can require the removal of soil and considerable subsidence, which can undermine the support of adjacent structures and cause excessive deformations, both of which can result in structural problems.

“Pile jetting” is a technique that is frequently used in conjunction with, or separate from, pile driving equipment for pile placement. Pile jetting utilizes a carefully directed and pressurized flow of water to assist in pile placement. The application of a concentrated jet of water at the pile tip disturbs a ring of subgrade soils directly beneath it. The jetting technique liquefies the soils at the pile tip during pile placement, reducing the friction and interlocking between adjacent subgrade soil particles around the water jet. This greatly decreases the bearing capacity of the soils below the pile tip, causing the pile to descend toward its final tip elevation with much less soil resistance, largely under its own weight. In less frequent applications, compressed air jets are used instead of pressurized water jets with the same end result.

Placing long piles in dense soils may be a time-consuming endeavor with a traditional pile hammer and driving rig. Pile jetting offers significant time and cost savings over traditional pile driving, and where appropriate, jetting techniques could eliminate the need for a driving rig altogether. Pile jetting equipment usually consists of a crane with leads to place the piles, a jet pipe (or pipes) with connecting hoses, and a jet pump. Pile jetting can be used for most types of steel, wood, and concrete piles. Precast concrete piles may be fabricated with a jet-pipe already cast-in-place, if jetting is anticipated. Piles that are placed in uniform granular soils may be installed with a jet pipe placed through or near the center pile dimension. Other piles may have two water jet pipes fitted on either side to provide evenly distributed water jet coverage during placement. Design of the jet pipe outlet(s) and pump selection reflect the anticipated soil conditions and pile types.

The applied water pressure and flow rate through the jet pipe will directly influence the volume of subgrade soils affected. Too much flow and pressure may result in poor controllability and alignment of the pile being worked, or misalign and compromise adjacent piles. Too little water flow or pressure could make the jetting technique ineffective. The type of soils supporting the piles needs to be evaluated and understood. The jetting technique creates a localized soil disturbance wherever it is used. Laboratory tests have shown pile jetting can significantly reduce the lateral strength of placed piles since the technique can erode fine soil particles from the surrounding soil matrix. Pile jetting is most effective in granular soils without significant cohesion (interlocking). Water run-off from the pump discharge hose, including erosion and turbidity control issues, is another factor that needs to be planned in advance.

The most significant challenge may be that any negative impacts of pile jetting will be latent. In a typical pile driving project, a pile hammer of known weight and drop height is used. Noting the blow counts of the pile hammer over a specified pile length allows for a straightforward assessment of pile strength. Conversely, if a pile is jetted to its final tip elevation, its final strength capacity can be empirically estimated at best, but not specifically determined.

For these reasons, the more the effects of jetting become speculative, the less recommended the technique becomes. Project costs, a completed project's end use, and factors of safety will influence a decision to allow pile jetting, and to what extent. A less risky use of jetting would be through hard sandy soils above a firm bedrock layer that provides known bearing ability at the final pile tip elevation.

<u>Sources:</u>
[Benefits of Driven Piles]
[Buildipedia.com: Home Improvement & AEC Professionals]
[Driven Piles vs. Jetted Piles - A Comparison]

Piling Heights/Depths

No standard BMP exists for piling heights and/or depths, but it is a significant consideration for the long-term stability of any pile-supported marine structure. Regardless of piling materials (i.e. wood, concrete, steel), ensuring adequate piling depths below grade is a critical component of stability, especially in areas with less cohesive soils and/or areas of high wave energy, strong currents, and frequent tidal or storm surges. Equally important is the elevation of the pilings, which allow for a floating dock structure to rise and fall during normal tide ranges, as well as during extremely higher water levels associated with hurricanes and other coastal storms. One general rule of thumb for "average" coastal dock construction within North Carolina is to ensure that ~⅓ of a piling is driven below grade (i.e. 10' below grade for a 30' piling), and ~10'-12' of the piling is elevated above normal mean high water, to allow for extremely high storm surges. One innovative approach involves standard height pilings with a "telescoping "T" Bar" option to create extended pilings during periods of higher tides and storm surge conditions.


“Telescoping” encapsulated concrete pilings

Floating vs. Fixed docks

Though there are many varieties of docks, each of them can be placed in one of two categories: removable docks and permanent docks. Permanent docks are self-explanatory — they are installed securely into the ground and the structure is intended to remain there permanently. Removable docks are typically intended to be semi-permanent and can be expanded, reconfigured, or removed if necessary.

Fixed Docks

A fixed boat dock is a boat dock type that is fixed or stationary. Many dock owners prefer fixed boat docks due to the stability they offer. This is the primary difference between a floating boat dock and a fixed boat dock. A fixed dock may be the only way to safely reach a floating dock where water depth is adequate for boat mooring. Since floating docks rest on water; they are affected to a large extent by movement in the water. Waves can impact floating docks and cause them to have irregular movements on the water, just as a boat or other watercraft would. Therefore, if stability is the main criteria, fixed docks may be the better choice for areas that have strong tides or currents and a lot of wave action, such as high traffic areas. In addition, fixed docks can often provide support for more weight than a floating dock.
Sources:
Advantages of Owning a fixed Boat Dock

Floating Dock Construction

Floating docks are platforms, most often made of decking placed over airtight buoyant “float” structures that float on the water’s surface and support the dock. They are also available as pre-built sections that can be attached in a variety of configurations and shapes. Floating dock structures are versatile and rise or fall with the water level, helping them adapt to nearly any condition, including extreme fluctuations in water levels (surges) during hurricanes and other coastal storms. In addition, during severe weather or seasons in which the structure is not in use, floating docks can often be removed, stored, and put back in place when needed. This is extremely useful in hurricane or storm-prone areas. Additionally, boats secured to fixed docks often require constant monitoring and adjustment of the securing lines (especially during more significant tide changes and/or water fluctuations during storms. Finally, because floating docks rise and fall with water levels, any critical electrical systems attached to the dock surface will not be submerged.

There are numerous types of floating dock systems available in today's market - concrete, aluminum, steel, and wood are among the most popular. Not all "like" dock systems are created equal. There is great variability in quality, performance, engineering, and design within each type. The approach used in the design, how the system is engineered, and the quality of the materials are the greatest determinants of a dock system's overall performance. It is also important to note, not all types of systems are appropriate for all environments. Sites exposed to extreme weather and higher wave conditions may benefit from a heavier weight dock system.

Concrete docking (with concrete floats) and Encapsulated Floating Dock

- Install breakaway decking panels and increase deck spacing
    - Minimize what breaks and design *where* you want it to break. Often, designing breakaway panels or removing panels before a storm surge arrives can prevent more significant damage to and/or total loss of docks/piers. In addition, constructing docks with increased deck spacing and/or flow through materials can minimize damaging "lift" of the structures and damages during rising water and wave energy conditions.
- Build to withstand predicted wind loads based on past storm forces
    - Build docks to withstand at a minimum the erosion, scour, and loads accompanying a minimum of the 50-year storm event (or whatever storm event is represented at this site during the past decade. The evaluation should also include the historic tidal, current, surge and wave energies at this site.

- Increase deck height
    - In many coastal areas, adjusting deck level (for fixed docks/piers) for certain storm frequency. Building docks higher than expected breaking waves and storm surges/tides can reduce damage and losses of fixed docks.
- Reinforce bracing and/or anchoring for docks/piers
    - In higher energy and/or storm prone coastal areas, provide additional bracing of the construction elements. This reinforcement may include modifications to girders/connections to pilings.
    - In addition to reinforcing construction elements, adding support anchoring is recommended to reduce damage and losses of docking structures.
    - Incorporate stainless tie downs at support points and anchors to reduce lift of structure during storms. These often include stainless steel cable that goes around the entire dock structure at each support point (pylon and cross member section that makes contact with the seafloor) that is then affixed to an anchor under the mud. This adds additional strength and reduces the likelihood of the structure becoming dislodged or "washed out" during a storm event.


Reinforced bracing for floating dock joints completed by Bellingham Marine (left); Steel cable/helix anchor system on residential dock (right).

<u>Protection Connectors From Corrosion</u>

Connectors subject to exterior or marine use should always be either stainless steel or hot dip galvanized after fabrication. Depending on bolts alone to transfer gravity loads to the piles is not a prudent practice. Over time, even hot dip galvanized or stainless-steel bolts will corrode and require replacement. A better detail when the pile width is 2-inches or more than the girder would be to notch the girder into the side of the pile to provide direct bearing on the pile. The girder may then be bolted to the vertical protrusion of the notch to provide uplift resistance, lateral load resistance and torsional stability. Figure 4603.6 in the Residential Code is another possible means of connecting the girder to the pile and providing direct bearing for the girder when the girder is too wide to notch into the pile. However, the disadvantage to this connection is the connection has little resistance to lateral loads perpendicular to the connection plates. In addition, the girder and the pile must be the same width or the connection shimmed in order to install connection plates on both sides of the girder. Connections for girders bearing on top of the pile with a plate on only one side of the girder do not provide adequate torsional restraint to prevent the girder from rolling.

NC Department of Insurance, Office of the State Fire Marshal - Engineering Division; Engineered Wood Products and Connectors in Marine and Flood Zone Environments; Code: 2018 Residential Code Section: R322.1.8 and R4605.5 (Appendix Y)

Extended Runs for Gangways

For added resilience in high tide/surge areas, it is recommended to expand a traditional gangway (i.e. 24') to an extended length (i.e. 28') to maintain connection during super low and high tides and/or storm conditions (From: Bellingham Marine, personal communication).

Additional Non-Construction Recommendations

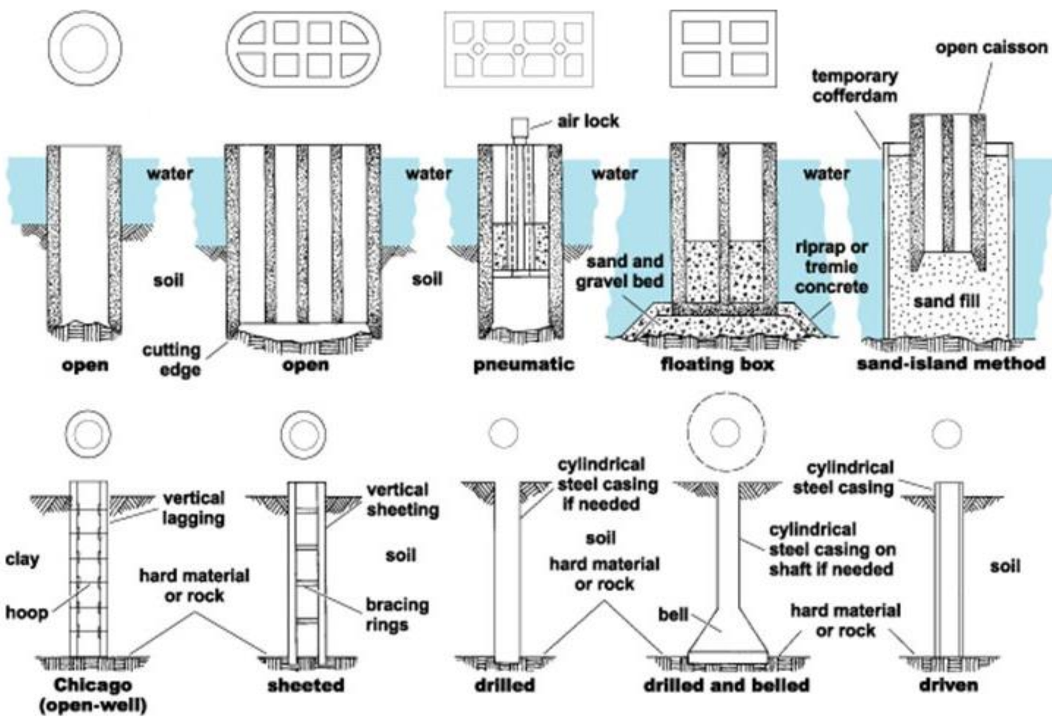
Creating Insurance Industry Incentives

One non-regulatory but effective strategy to increase the construction standards for marine construction (thereby reducing damage and/or losses of structures during storms) is through the insurance industry. One example of this program is the *Preferred Builder Credit Program,* offered through C.T. Lowndes & Co. in South Carolina. The company offers various levels of coverage/pricing for docks, piers, etc. based on the level of construction standards employed in the building. As incentives for better construction, the policy holder can qualify for better rates and policy coverage.

Promote, Fund, or Conduct Research on the Use of Modified Caissons to Strengthen Dock Pilings.

Caissons are rectangular or circular structures used in underwater construction work and can be sunk and filled with concrete to serve as a foundation in bridge construction. They often serve as the foundations for the large pilings that support the weight of bridges. If smaller, modified versions of these caissons could be made affordable to homeowners and were proven to improve the durability of residential docks and piers in storm events, they may have the potential to become widespread all along the coast.

A graphic depicting different types of caissons is included below:



Types of Caissons

Marine Contractors/Engineer Interview Results

To increase the body of local knowledge on the most resilient construction measures throughout coastal North Carolina, a preliminary questionnaire and list of marine contractors in eastern North Carolina was composed by the North Carolina Coastal Federation. Given time and funding opportunities, it would be useful to talk to contractors in different regions to determine their preferred methods of building docks and piers, if they have run into any unexpected problems, and to get their opinion on the topic of building marine structures to avoid damage and losses within our North Carolina waters. This will allow for more detailed information to be learned from marine contractors regarding their typical construction activities, standards, and best practices.

NCORR Resiliency Guide Recommendations

Limit new capital projects in high-risk areas. Where risky locations cannot be avoided, minimize risks through actions like elevating structures above the highest known or projected flood levels, designing for excess stormwater capacity, or building to fortified standards for wind. Consider climate change over the entire predicted lifespan of an asset, like a bridge or a wastewater treatment facility. Design and build – or upgrade – the asset to withstand future conditions.

Florida Department of Environmental Protection Fishing Pier Design Guidance

With the selection of a design storm event, it is important to determine the storm tide elevation across which the storm waves will propagate. Equally important as determining a design storm tide level is considering the beach and nearshore profile change caused by the erosion of the design storm event as well as the additional localized scour expected at the individual foundation piles. A geotechnical investigation with core borings is necessary for any pier construction in order to determine adequate pile penetration and breakout resistance resulting from the soil characteristics.

Pier construction techniques will likewise be important particularly when the dead loads of a construction crane need to be considered in the design of the foundation and structural members. Wind loads are specifically important for any canopies or concession buildings located on a pier. Pier decks and rails have additional design considerations.
With an acceptance of the risk, the initial question of any pier designer then settles on the storm magnitude for the selected site for pier construction. For what magnitude storm event should a pier be designed? In reality, this question is not addressed by normal building codes.

The 20-year return interval storm event is therefore the minimum design storm for which ocean and gulf fishing piers are required to be constructed in Florida. Public structures, including fishing piers, are typically designed for a 50-year life span. The probability of occurrence of a storm tide exceeding a certain elevation during a specified time period may be determined mathematically by a binomial theorem. Walton (1976) plots encounter probability versus encounter period for use in coastal construction economics of repair or replacement. The probability of occurrence for a minimum design event, a 20-year storm, during a 10-year period is about 42 percent. For a design life of 50 years, the encounter probability would be 94 percent. When considering the risk of an extreme event, the probability of having a 100-year storm during a 50-year design life would be about 40 percent.

Selection of a design storm event and associated storm tide level, leads to the determination of wave characteristics and erosion conditions for the site of a proposed fishing pier.

An important factor in designing a fishing pier's pile penetration is to determine the maximum expected localized scour around individual piles. The most important factors resulting in scour around fishing pier piles are the wave orbital velocity, the bottom current, and the diameter of the pile. Other important factors are the grain size of the bottom sediments and the shape of the pile (e.g. round, square, or octagonal). Niedoroda and Dalton (1986) provide a detailed description of the physical processes of scour around a vertical pile. Localized scour at vertical piles for fishing piers may be calculated by several methods; however, for most cases of combined waves and currents, the "rule of thumb" recommended by the Coastal Engineering Manual (USACE, 2008) is the maximum depth of scour at a vertical pile is equivalent to twice the diameter of the pile. This rule would be applicable to any shape pile commonly used in pier construction. For example, for either a two-foot square pile or for a two-foot diameter circular pile, the maximum localized scour would be expected to be at least four feet below the predicted storm eroded profile or the minimum historical profile elevation.

The principal causes of damage to ocean and gulf fishing piers are the effects of storm waves. A successful pier design requires both an understanding of the wave climate in the region and a projection of an extreme storm wave event that may reasonably be expected to occur at the pier site. With the projection of an extreme stormwave event that may reasonably be expected to occur at the pier site, wave forces may be calculated. The Wave forces act on a pier's structural members on both a horizontal and vertical plane; therefore, it is necessary to conduct separate computations for both the lateral waveforce as well as the vertical uplift forces.

Recently, there have been some breakaway deck sections dislodged from new fishing piers during tropical storm conditions that were substantially below the design storm tide elevation and wave conditions. These dislodged deck sections were located above and immediately seaward of the pile caps of those piers. It is believed that the best strategy to account for this upward wave reflection effect is to include breakaway deck sections in lieu of raising the pier deck any higher than the normal design would require. In doing so, the problem only becomes a periodic nuisance to reset the dislodged deck sections while maintaining the integrity of the structure.

Pile driving is employed in pile-supported structures to increase the density of the sediment. Piles are driven by a succession of blows either by a drop hammer or by a diesel, steam, or compressed-air-powered hammer. Diesel powered hammers and diesel vibratory hammers are most common. With vibratory hammers, a variable-speed oscillator is attached to the top of the pile, consisting of two counter-rotating eccentric weights that are in phase twice per cycle in the vertical direction. This introduces a pulsation or vibration through the pile that can be made to coincide with the resonance frequency of the pile, which creates a push-pull effect at the pile tip to disturb the soil structure, and thus improves the rate of pile driving.

Like other major structures, ocean and gulf fishing piers should be designed and constructed to safely support any anticipated normal loads without exceeding the appropriate specified allowable stresses for the materials used in the construction. The structural design of fishing piers requires the consideration of all appropriate design loads acting in combination, to include normal dead loads, live loads, construction loads, wind loads, hydrostatic loads, hydrodynamic loads, and wave loads. The depth-limited breaking wave loads for the selected design storm event are the greatest forces to be considered in the pier's design. However, the complete structural design also includes the other various loads that may reasonably be expected.

FEMA 55 Coastal Construction Manual (2011) Recommendations

In response to increased hazards and lessons learned from past storms, regulatory requirements for construction in coastal areas have increased over the past decade. Design of a successful coastal building must consider the effects of coastal hazards and coastal processes over a period of decades. Design loads and conditions are based on some probability of exceedance, and it is always possible that design loads and conditions can be exceeded. Designers can anticipate this and modify their initial design to better accommodate higher forces and more extreme conditions. The benefits of doing so often exceed the costs of building higher and stronger.

Although many aspects of coastal design and construction have improved over the years, the harsh coastal environment continues to highlight deficiencies in the design and construction process. The design and construction community should incorporate the lessons learned from past events in order to avoid repeating past mistakes, and to break the disaster-rebuild-disaster cycle.

Communicating risk to homeowners in a variety of ways, both technical and non-technical, is important so they understand the benefits and drawbacks of decisions they make. Designers should communicate how design decisions and material selections can reduce risk, and the mitigation of residual risk through insurance.

It is important for homeowners to understand how the choices they make in designing their home could potentially reduce its risk of being damaged or destroyed by natural hazards. Designers need to be familiar with the potential risks for the property and be prepared to suggest design measures that not only meet the needs and tastes of homeowners, but that also provide protection from hazard impacts. In addition, design choices that have implications for building performance during a hazard event and on insurance premiums should be discussed clearly with the homeowner.

Although the effects of natural hazards can be reduced through thoughtful design and construction, homeowners should understand that there will always be residual risk from coastal hazards as long as they choose to build in a coastal environment. Proper design elements can mitigate some of those risks, but there is no way to completely eliminate residual risk in coastal areas. As described in this chapter, mitigating natural hazard risk in a coastal environment entails implementing a series of risk reduction methods, such as physical risk reduction and risk management through insurance. While some level of residual risk will remain, owners can use these tools to protect themselves and their investments.

FEMA P-499 Home Builder's Guide to Coastal Construction (Technical Fact Sheet Series, December 2010)

FEMA has produced a series of 37 fact sheets that provide technical guidance and recommendations concerning the construction of coastal residential buildings (Appendix Z). The fact sheets present information aimed at improving the performance of buildings

subject to flood and wind forces in coastal environments and make extensive use of photographs and drawings to illustrate National Flood Insurance Program (NFIP) regulatory requirements, the proper siting of coastal buildings, and recommended design and construction practices including structural connections, the building envelope, utilities, and accessory
structures. In addition, many of the fact sheets include lists of additional resources that provide more information about the topics discussed.

Although not directly related to the scope of this current study, marine debris that has been found following coastal storms and hurricanes includes a significant amount of residential construction materials, resulting from existing structures and sites under construction. These fact sheets provide useful guidance in reducing the loss and/or damages to land-based structures during these storms.

Literature and Additional Resources

- 0322.1.8 - Engineered Wood Products and and Connectors in Marine and Flood Zone Environments
- Guide to Docking Choices: Which Types of Docks are the Best?
- North Carolina CAMA Handbook for Coastal Development
- LDSI Waterway Debris Mapping Tool
- FEMA499

VII. Outreach and Education Recommendations and Materials

In order to disseminate the recommendations and best practices described above, it is necessary to plan and implement a robust outreach and marketing campaign. This campaign, targeted towards coastal property owners, as well as marine contractors, will communicate the above findings in an effort to promote more resilient docks and piers along the NC coast and ultimately reduce the presence of marine debris in our waterways.

Without a funded plan to engage the public and ignite action by coastal property owners, however; the data and findings from this project will have little impact on this pervasive issue. In order to gain traction on regulatory avenues, we must have an informed and engaged public, which is acutely aware of the issue, thus elevating it to local, state and eventually, federal levels. Below are preliminary recommendations that are achievable with current resources, but the need still exists to create and implement a multi-year multimedia campaign which can be replicated in other states.

Extension Materials/Distribution

- Develop and launch a web page (short url: nccoast.org/docks) to highlight the problem of dock/pier derived marine debris and how the public can help.
- Utilize this web page to house all extension materials, as well as photos, infographics and user testimonials. Potential materials include:

    - BMP's and technical recommendations (as described above, edited for contractor and public audiences, respectively)
    - Trifold brochure (professionally printed)
        - Audience - coastal property owners, marine-related businesses
        - Goal - educate coastal property owners on the importance of resilient dock/pier structures
            - Include introduction to problem
            - Questions to ask their contractor
            - Recommendations for more resilient structures
            - Environmental factors they should consider
        - Include QR code to webpage and photos of what a resilient structure may look like
    - Multimedia materials - photos, videos, testimonials
        - Video of a resilient dock being constructed (time lapse) then what it looks likes after a flooding event compared to non-resilient docks
        - Testimonials from property owners who have chosen to build a better structure
        - Videos of sound construction techniques, highlight construction BMPs
- Once all materials are finalized, launch webpage and send out press release
    - Media list/press contacts in Google Drive
    - Reach out to local media contacts for more in-depth stories/reporting
        - Coastal Review Online feature series on contractors and the importance of building better docks - come out prior to hurricane season, along with pre-hurricane marine debris prevention checklist
        - Include removal work (tonnage) in press release, tie to larger problem of marine debris

Target Groups/Audiences/Avenues for Distribution

- Mail materials to property owners of derelict structures (addresses derived from South Wings aerial imagery fly-overs of areas hardest hit by Hurricane Florence); include letter and trifold brochure
- HOA's with residential dock access
- Local governments
    - Get on agendas of local boards/commissions to extend materials and speak on the importance of resilient structures
    - Make sure local government staff have materials on hand to disseminate to residents/permit seekers (this includes local building inspection/zoning offices)
- Division of Coastal Management, U.S. Army Corps of Engineers
    - A DCM representative is part of the larger stakeholder group and the Director is aware of the work, but once materials are complete, federation staff will schedule a meeting with Director Davis to share findings and see how DCM could help disseminate the information
- Contractor outreach
    - Brochure/fact sheet/flyer for contractor supply stores, boat shows

    - Similar content to trifold, but audience is strictly contractors; market resiliency as selling point

Social Media

- Succinct posts with good graphics highlighting the issue and key takeaways
- Photo drive compiled with photos from removal crews, as well as images of structures that follow construction BMPs
- Develop graphics with primary messaging for sharing on Facebook and Instagram - match to brochure
- Develop posting calendar in conjunction with press release and public roll out
- Contact property owners who have followed these recommendations, create/distribute video testimonials (i.e., why they chose to do it, what it means, why they're glad we're doing this work - storytelling)
- Share with local governments to post on their social media pages

References

"5 Questions You Should Ask Your Contractor." *Farrell Marine*, 23 July 2020, farrellmarine.com/about-us/5-questions-you-should-ask-your-contractor/.

"5 REASONS TO CHOOSE A CONCRETE FLOATING DOCK FOR YOUR HOME OR MARINA." *NordiDock Concrete Floating Dock Systems*, nordidock.com/?p=24.

"7 Questions To Ask Before Hiring A Marine Contractor Company." *Thaler Contracting Inc.*, 15 July 2019, www.thalercontracting.com/7-questions-to-ask-before-hiring-a-marine-contractor/

"Aluminum and Corrosion." *UK Aluminum Industry Fact Sheet 2*, Aluminum Federation, www.alfed.org.uk/files/Fact%20sheets/2-aluminium-and-corrosion.pdf.

"Benefits of Driven Piles." *Pile Driving Contractors Association*, www.piledrivers.org/benefits-of-driven-piles/.

Burns, M. (1999). *The dock manual: Designing, building, maintaining*. Pownal, VT: Storey Books.

Comstock, Roxie. "Understanding Walers: What Is a Waler?" *Pile Buck*, Pile Buck International, Inc., www.pilebuck.com/marine/understanding-walers-what-is-a-waler/.

Concerning floatation devices on state-owned aquatic lands and in state waters., S. 5466, 63rd Cong., State of Washington (2013).

Conno, Joe. "Advantages of Owning a Fixed Boat Dock." *Waterfront Gurus*, 19 Jan. 2020, waterfrontgurus.com/advantages-of-owning-a-fixed-boat-dock/.

"Corrosion Protection Methods for Underwater Piles." Edited by Fasi Ur Rahman, *The Constructor*, 20 Oct. 2016, theconstructor.org/geotechnical/corrosion-protection-underwater-piles/13819/.

"Dock Pilings: Choosing Pilings for Docks." *Steel Pipe Distribution | Buy & Sell Steel Piping and Tubing | New & Used*, www.crestwoodtubulars.com/dock-pilings.html.

Editor. "The Ultimate Guide to Dock Piling Materials." *Decks & Docks Lumber Co.*, 5 Nov. 2018, www.decks-docks.com/the-ultimate-guide-to-dock-piling-materials.

Engineered Wood Products and Connectors in Marine and Flood Zone Environments Code: 2018 Residential Code Date: April 10, 2019 Section: R322.1.8 and R4605.5

Find a Clean Marina. (2020). Retrieved July 15, 2020, from https://www.boatus.org/clean-boating/clean-marinas/

Georgian Bay Forever. (2019). *Lots to Reflect on this World Environment Day* [Brochure].

Guidelines for Selecting a Marine Contractor. New York Sea Grant, Jan. 2015, www.seagrant.sunysb.edu/glcoastal/pdfs/selectingacontractor.pdf.

"Homepage EN." *Bellingham Marine*, www.bellingham-marine.com/.

Kimos, Andrew. "Driven Piles vs. Jetted Piles - A Comparison." *Buildipedia*, Buildipedia.com,LLC., 11 Sept. 2009, buildipedia.com/aec-pros/construction-materials-and-methods/driven-piles-vs-jetted-piles-a-comparison.

Maine Shore and Bank Protection Projects. (n.d.). Retrieved July 15, 2020, from https://www.nae.usace.army.mil/Missions/Civil-Works/Shore-Bank-Protection/Maine/

Marcy, J. B., & Johnson, J. (2009). *Flotation Analysis for Boat Docks on U.S. Army Corps of Engineers Projects* (pp. 1-21, Rep.). Washington, D.C.: U.S. Army Corps of Engineers.

Materials and Methods of Encapsulation, Oregon State Marine Board § 250-ORS 830.110 (Oregon Secretary of State 2019).

Mayle, Mary Carr. "Port Docks Playing Host to Marine Life." *Savannah Morning News*, Gannett Co., Inc., 31 Aug. 2012, www.savannahnow.com/exchange/2012-08-30/port-docks-playing-host-marine-life#.URML0Ohmct4.

Owens, – Claude E. "Custom Modular Residential and Commercial Floating Docks." *EZ Dock*, 14 May 2021, www.ez-dock.com/.

"Pressure-Treated Southern Pine." *Southern Pine*, www.southernpine.com/pressure-treated/.

Rittmaster, R. (2018, May 11). Camden's Unencapsulated Polystyrene Ordinance: What Does it Mean for Homeowners? Retrieved July 14, 2020, from https://www.penbaypilot.com/article/camden-s-unencapsulated-polystyrene-ordinancewhat- does-it-mean-homeowners/101788

Staff, WOOD Magazine. "Greenheart." *WOOD Magazine*, 3 May 2017, www.woodmagazine.com/materials-guide/lumber/wood-species-2/greenheart.

Townshend, Anna. "Bigger and Stronger: Dock Builders Talk Trends in Design and Infrastructure." *Marina Dock Age*, The Waterways Journal Inc., 22 Mar. 2019, www.marinadockage.com/dock-builders-talk-design-infrastructure/.

Unencapsulated Polystyrene Ordinance for Blue Hill Maine. (2019, November 23). Blue Hill, ME.

United States, National Parks Service, Commercial Services. (2012). *Clean Marina Guidebook*. Retrieved July 15, 2020, from https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/NPSCS%20 Clean%20Marina%20Final%202012.pdf

United States, NOAA, Coastal Smart Growth. (n.d.). *Glossary*. Retrieved July 15, 2020, from https://coastalsmartgrowth.noaa.gov/pdf/glossary.pdf

United States, Town Council, Town of Camden. (2017). *Unencapsulated Polystyrene Ordinance* (pp. 47-48). Camden, ME: Town of Camden.