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Summary

Items to Take Away

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Introduction:

The world of docks, piers and wharfs in today’s world comprises a plethora of different designs, component structures, services and uses. As such, technology refinements now require a much closer review of these structures than perhaps has been completed in the past. Whether for marinas or commercial piers, understanding the total operation as well as the components making up the structure is a necessity if you are to properly understand the exposures that these structures represent. The purpose of this paper is to provide guidance in the development of the data that is necessary for the marine industry to understand how these structures are evolving, as well as to best understand the exposures that they represent.

Valuing Piers & Docks

There is no precise formula for calculating the present and in some cases replacement cost of these structures. Today, major repairs or pier replacement needs to be professionally designed and to be in full compliance with all environmental regulations. There can be many “hidden” issues and costs involved when repairs are made as a result of a loss or in the rebuilding of the piers. There must be a proactive approach to understanding these issues, and the use of a competent marine contractor and loss control professional can result in the proper assessment.

Ask any marina owner, underwriter, marine claims representative or loss control person about how to properly value pier and docks and each will probably come up with a different way. Usually there is the replacement cost approach, the agreed value approach, and then the very popular market value approach. There has been everything from amicable discussions right through to arguments about the subject of valuing piers and docks. So what is the answer? Is there a magic formula? How will it work for all parties involved? This paper will try to provide some guidance on the thought process of what actually goes into valuing piers and docks. There are no specific valuation guidelines similar to Marshall Swift / Boeckh. So we will begin with understanding the different components that need to be assessed before we can begin to value piers and docks.

Pier Components:

When one first looks at a particular pier and dock, the items that come to mind include all the components that make up the structure that goes into the water. It includes the pile structure, cross supports of different types, the walkway, and the bulkhead that may be on the shore side of the pier. And as you have correctly surmised, there is a plethora of different types of materials that may be used to construct these components. In some cases there are some very sophisticated underwater anchoring systems and different types of components to secure the pier. Also, many marinas have can moorings for their customers, bringing in another different component to the valuation. These structures however are just the beginning of additional components that may make up the piers.
Docks, Bulkheads and Wharfs

In most marina scenarios there is the addition of electrical, water, fueling, waste removal, cable, and even telephone lines to consider. For commercial piers, there may be additional service lines such as steam, welding gases, and other systems.

Also, pier structures can include launching areas (include ramps of all different construction types), bulkheads, attenuation components, and breakwaters. So as we begin to think about valuation, we must first identify all of the components and their makeup in order to determine a value.

Components of Age and Maintenance:
Adding to valuation are the varying ages and the observed maintenance of these components. As we are all painfully aware, older and poorly maintained piers will significantly increase the cost of repairs as they will be less likely to withstand any type of loss. So how do age and maintenance impact valuation?

The components will each have a typical useful life, usually provided by the manufacturer. Maintenance has a direct relationship to the useful life; poor maintenance practice will generally take away from the useful life while good maintenance practices will generally add to it. Before we assume that maintenance has more impact on the value of a pier, remember that age will also come into play, as eventually any component will need to be replaced.

Good maintenance involves preventative steps such as routine inspections of all components both above and below the water and upkeep and ultimately replacement as they wear. Each of the components should have specific maintenance and replacement schedules that are best obtained from the manufacturer.

Inspections, as well as maintenance and repair efforts, should be documented by the marina facility in writing. These records should be maintained and available for review by the underwriter and loss control professional.

Varying Age & Component Types:
While many marinas and commercial piers are made up of a single type of construction done at one given time, there are many others that are composed of different components of different ages. Typically, this type of newer/older change out process is found in more established operations. An example is the replacement of wood floating piers with either composite or newer infused and concrete components. Thus, there is another variable to consider.

Components of Pier Valuation:
We now have an understanding of the components, the age, and the maintenance practices and the varying makeup of piers. So how does this puzzle of pier valuation come together?
Looking at the structures individually should lead to a better valuation that is truly representative. If there are ten piers that are of different ages and components, they should be evaluated separately. The same applies to structures such as launching pits, ramps and fueling piers. Also, one should break out the costs of the various servicing utilities on the piers.

Many times, there is a single figure that is provided by the owner, covering all of the piers, attenuators, bulkheads, launching piers, etc. It is usually a value that the owner is comfortable with to insure. It has been our experience that these owners start with the cost of the piers, and then find a factor that satisfies their financial situation, given the cost of insurance. Some marinas use the cost along with the anticipated maintenance budget and perhaps planned replacement as the components of their calculations.

Thus, there may be a good possibility that the owner’s valuation is not close to any calculated value based on the variables discussed above. As every underwriter understands, the value usually ends up being an agreed sum that is palatable to all parties involved. In order to determine if that agreed value has a sound basis, the following approach may be taken.

Start with a schedule of the different piers, launching pits/wells, attenuators, fueling piers, ramps, and breakwaters. Since there are no trade-in value books, the calculations should start with the replacement cost, by component. Today, we can obtain the cost of the piers on a square foot basis from manufacturers and marine contractors. Any estimates must also include the costs of the service utilities, and other components that might be found on the piers.

The last component is labor cost. These are all different and one needs to understand the costs in their specific area. Putting this all together will give us a very good idea of what is would cost to replace the different components.

Applying age and maintenance practices will be a function of the survey observations. Some will use straight line depreciation; others will use what they might define as useful life; and others will simply compare the calculated value to the requested insurance amount. However, the method of refining the calculation is not the most important process. Starting from a replacement cost and then factoring in age and maintenance should allow us to best understand the values at risk.

The process takes some time to research but will ultimately lead to a more realistic value.
Docks, Bulkheads and Wharfs

**Particulars of Facility Inspections:**
An operation and maintenance manual should be in place at each marina or commercial docking facility. This manual should include inspections, preventive maintenance, and repairs conducted at the facility and should be updated regularly. It should also contain sections on hurricane/severe weather and emergency response planning (fire, emergency and medical).

Wooden pilings should generally be placed no closer together than 20 times the diameter of the piling. Any cross or transverse bracing should be placed above the elevation of the high water mark. For coastal wetland areas subject to the ebb and flow of the tide, the lowest structural member (normally the stringer) should be at least 18 inches from the bottom at low tide. Where feasible, floats off of fixed docks should be located so that they float no lower than 18 inches at low tide.

Pier length, width, height, plank spacing as well as north / south orientation may be subject to permitting regulations depending on location. Piling installation methods may also be restricted, with high pressure jetting being prohibited in some cases.

For example: Washington State Department of Natural Resources recommends the following habitat stewardship measures:

- Wood treated with toxic compounds should not be used for decking or pilings and other in-water components.
- Tires should not be used in moorage facilities, even as fenders.
- Foam material should be encapsulated so it cannot break up and be released into the water.
- New covered moorage and boat houses should not be allowed.
- Docks, piers and floats should be 25 feet from native aquatic vegetation or the distance that the structure will cast shade, whichever is greater.
- New or reconfigured structures should be placed to avoid impact on forage fish habitat.
- Floating or suspended watercraft lifts should be more than 9 feet waterward of the OHWM.
- Skirting is prohibited on overwater structures.
- New activities and structures should avoid existing native vegetation attached to or rooted in the substrate.

There are FRP (fiber reinforced plastic or fiberglass) composite pilings on the market that are strong enough to be driven to the highest level of resistance by a variety of methods. These types of pilings are hollow, allowing them to be installed over existing pilings, reducing the need to remove old pilings, saving labor and disposal costs. These types of pilings are easily drilled, cut, and fastened.

In new construction a hollow composite piling has greater holding strength than a traditional wooden piling. This is a function of the suction created by the hollow design, as well as the neutral or negative buoyancy of the material.
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The strength of composite pilings and construction materials can also reduce the number of pilings needed in a given application. A qualified composite materials engineer should be utilized to determine construction specifications.

Commercial Marina Guidelines:

Travel Lift Pits: Traffic control devices, such as barricades, should be used to prevent direct access to the pit and keep unaware persons from driving directly into the water. Travel lift pits should have an automatic security light for safety.

Travel lift slips should have courtesy loading docks provided, for loading and unloading operations.

Dock Flotation:

1. Flotation should be of materials designed for marine use. The flotation material should be expanded, encased, or encapsulated and contain a warranty for a minimum of 8 years against sinking, becoming waterlogged, cracking, peeling, fragmenting, or losing beads. All flotation material should resist puncture and penetration and should not be subject to damage by animals under normal conditions for the area. All flotation material should be fire resistant. The use of new or recycled plastic or metal drums or non-compartmentalized air containers for encasement should be avoided.

2. Repair or replacement should be required when flotation material no longer performs its designated function or fails to meet the specifications for which it was originally warranted.

3. Flotation should be adequate to maintain a stable and safe structure capable of supporting expected loads. At least 40 percent of the flotation should be above the waterline under all conditions.

4. Flotation should be securely fastened to the dock using galvanized steel straps, treated wood dowels, galvanized bolts, stainless steel, composite materials or other acceptable methods per approved design specifications.

5. Type GR-gasoline resistant flotation - should be required on all new gas docks and within 40 feet of a line carrying fuel or when replacing flotation under existing gas docks.

Anchorage:

1. An anchorage system should be provided for mooring all floating structures, taking into consideration water depth, tidal fluctuation, and exposure to wave and...
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wind action. Anchorage systems, such as dead man or ground stakes, should be installed flush with existing grade. Anchor cables or other securing devices should not be attached to trees, stumps, power poles, or guardrail posts. Anchor cables should be fastened with a minimum of three U-bolts or fist grip clamps. All anchor lines should be installed in a manner that will not create a tripping hazard. Anchorage systems should be so situated, marked, and/or guarded so they do not constitute a navigational or other hazard. Floating facilities should be securely anchored to prevent them from floating free during floods or storm surges.

2. Winches located on docks should have cable guards and be mounted so they do not create a hazard.

Fuel Dispensing Areas:

1. The fuel dispensing area should be located a sufficient distance from other structures to allow adequate room for safe ingress and egress of vessels to be fueled. Dispensing units should be at least 25 feet from any activity not associated with the handling of fuel.

2. Approved dispensing units, with or without integral pumps, should always be used. Units may be located on open piers, wharves, floating docks, on shore, or on piers of the solid fill type.

3. Tanks and pumps not integral with the dispensing unit should be on shore or on a pier of the solid fill type and located above the maximum water level elevation.

4. In a situation where a shore location would require excessively long supply lines to dispensers, the authority having jurisdiction may grant permission for installation of tanks on a pier. If this is the case applicable Bulk Fuel Tank Storage regulations relative to spacing, diking, and piping should be adhered to, and the quantity stored should not exceed 1,100 gallons aggregate capacity.

5. Shore tanks supplying marine service stations may be located above ground where rock ledges, limited space, or a high water table make underground tanks impractical. Applicable Bulk Fuel Tank Storage regulations relative to spacing, diking, and piping should be adhered to. All federal, state, and local regulations concerning aboveground storage tanks must be followed, including the spill prevention control and countermeasure (SPCC) regulations found in 40 CFR, Part 112.

6. In a situation where tanks are at an elevation that would produce gravity head on the dispensing unit, the tank outlet should be equipped with a pressure control valve positioned adjacent to and outside the tank block valve, and it should be adjusted so liquid cannot flow by gravity from the tank in case of pipe or hose failure.
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7. Piping between shore tanks and dispensing units should be as specified in the Bulk Fuel Tank Storage regulations, except that, where dispensing is from a floating structure, suitable lengths of oil-resistant flexible hose may be employed between the shore piping and the piping on the floating structure as made necessary by a change in water level or shoreline.

8. A readily accessible and posted fuel shut off valve from shore should be provided in each pipeline at or near the approach to the pier and at the shore end of each pipeline adjacent to the point where flexible hose is attached.

9. Piping should be located so it is protected from physical damage. Corrosion protection for piping is also required.

10. Pipes that handle Class I liquids, such as gasoline, should be grounded to control stray currents.

Storage & Handling of Fuels: The fueling station should be located to minimize the exposure to all other plant facilities. Where tide and weather exposure conditions permit, all fuel handling should be outside the main berthing area.

1. Inside fueling stations should be located near a water exit from the berthing area or at some other location from which, in case of fire aboard a boat alongside, the stricken craft may be quickly removed without endangering other boats or structures nearby.

2. When practical, fueling station docks, including the fuel system piping, should be detachable by means of a quick disconnect system that allows complete removal of the dock by pushing or towing it to a safe location should it catch fire. Also, piping disconnects should prevent spillage of any fuel.

3. Dispensing units for transferring fuels from storage tanks should be in accordance with provisions of the Flammable and Combustible Liquids Code (NFPA No. 30). Every fuel delivery nozzle should be equipped with a self-closing control valve, which will shut off the flow of fuel when the operator's hand is removed from the nozzle. THE USE OF ANY AUTOMATIC NOZZLE WITH A LATCH-OPEN DEVICE SHOULD BE PROHIBITED. In the construction of the fuel hose assembly, provisions should be made so the fuel delivery nozzle is properly bonded to the shore electric grounding facilities.

4. All boat fueling operations should be in accordance with NFPA 302, "Fire Protection Standard for Pleasure and Commercial Motor Craft" as applicable.

5. Fueling from cans should be discouraged.

6. For the purpose of this paper, fuel pipes shall mean fuel pipes (all pipelines, tubing, or hoses that are conductors of fuel from the deck filling plate to the
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engine connection. Related accessories should include any attachments to fuel pipes, such as valves, strainers, pumps, connecting fittings, etc.) should be accessible. Fuel pipe connections and accessories should be readily accessible.

7. Fuel pipes should be adequately secured against excessive movement or vibration; protected from potential damage; and should have several piping disconnects with automatic shut-off valves in the event piping is broken or separated.

8. Outlets for drawing gasoline below deck for any purpose should be prohibited.

9. When making up threaded pipe connections, an approved sealing compound, resistant to gasoline, should be used.

10. When making flared tube connections, it is essential that tubing be cut squarely and be truly flared by tools designed for those purposes.

11. SIGNS: It is recommended that locations such as fueling stations, areas used for the storage and handling of fuel or other flammable liquids, boat storage sheds, paint and woodworking shops, sail lofts, battery charging rooms, boat locker rooms, and storage rooms, display the sign: "SMOKING AND OPEN FLAMES PROHIBITED” and that this rule is enforced.

12. A means of notifying appropriate authorities must be available should a fire break out or other emergency occur.

13. A means of extinguishing small fires quickly must be readily available.

Fire Protection:
1. Portable fire extinguishers of approved type 2A:20-B:C and suitable for the hazards and circumstances should be provided throughout the property and located so an extinguisher is within 50 feet of any point. A minimum of two, 4-A:40-B:C, should be located outside of and within 30 feet of each fuel pump and in clear view in the gas dock area. These fire extinguishers should be placed at least 15 feet apart, if possible. Fire extinguishers should be inspected monthly.

2. The gasoline dispensing and other areas where flammable materials are stored or used should be posted as outlined in NFPA 303 (Fire Protection Standards for Marinas and Boatyards) or NFPA 307 (Standard for the Construction and Fire protection of Marine Terminals, Piers and Wharves) as applicable.

3. A clearly identified and readily accessible emergency switch that can be used to shut off the supply of power to gasoline pumps should be located on land and near the dispensing pumps should a leak develop.
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4. At least one Coast Guard approved throw-type flotation device (with at least 60 feet of \( \frac{3}{4} \)-inch diameter rope attached or a reach pole) should be located in clear view on the gas dock and every 200 feet on other docks.

5. Immediate notification to the nearest fire department in the event of fire should be the established operating procedure. An approved means for sounding an alarm to notify yard personnel and others of a fire on the premises should be provided.

6. All fire extinguisher locations should be clearly marked and within easy access. Fire extinguishers should be inspected monthly to ensure they operate properly, when needed.

7. Emergency phone numbers should be posted conspicuously near the telephone.

8. Combustible waste material and residues should be kept to a minimum, stored in covered metal receptacles, and disposed of daily as specified in NFPA 303.

9. National Fire Protection Codes should be consulted for specific details.

10. Local fire department personnel should be invited to inspect the facility, at least annually, with special emphasis on access to different areas of the marina in order to fight a fire.

11. Marina staff should have firefighting training and drill at least twice a year as specified in NFPA 303.

12. A safety skiff should be available and ready for use. The skiff should be equipped with a wire rope and an attached grapple hook. This skiff should be used to tow a vessel that may be on fire to open water and away from other craft or structures.

Electrical Systems

1. All electrical work should be performed and inspected by a licensed electrician. The requirements of the annual inspection are specified in NFPA 303. All electrical installations should meet the requirements of all state and local codes and the National Electric Code.

2. Lighting sufficient for the anticipated activities should be provided for all marina areas but should be low intensity and pointed in a downward direction to prevent interference with vessel navigation.

Walkways

1. Main walkways should not be less than 4 feet wide. The minimum width between berthing slips should not be less than 3 feet when used as access to boats.
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2. Walkways should be kept free from mud, ice, snow, grease, or any other material or obstructions that could create a slipping or tripping hazard.

3. Walkways should be structurally sound. Flooring or decking should not be less than 1-inch rough, 2 inch by 6 inch S3S, 3/4 inch exterior plywood, or other material capable of supporting a minimum design load of 50 pounds per square foot. The use of composite grating that will not have an uplifting force during periods of flooding or storm surge is strongly recommended.

4. Walkways should be even, free from protruding bolts and nails, and have a slip-free surface. Carpeting should not be used to provide a non-slip surface.

5. Walkways from shore-to-dock should have a maximum slope of 3 to 1; be free from excessive spring, deflection, and lateral movement; and be adequately supported with flotation.

6. Walkways should be above the water level at all times.

7. Shore-to-dock walkways should have a standard 42-inch high solid handrail with an intermediate rail securely installed on each side.

8. Where feasible, walkways from shore-to-dock should be constructed to allow access by the handicapped.

9. Access ways should be adequate for fighting fires as determined by local fire-fighting personnel.

10. Prominent signage at the beginning at the access walkway should be installed stating that swimming, diving, and running are prohibited.

11. A gate system to prevent unauthorized access as well as wandering children should be provided.

Handrails

1. Handrails should be provided on all stairways, walkways, and all office and service docks that are open to the general public.

2. Handrails should be 42 inches in height, with an intermediate rail approximately 22 inches in height. Where children may be present, a guard between the deck and the lower rail is recommended.

3. Handrails must be capable of withstanding loads of 200 pounds applied in any direction at any point with a minimum of deflection. They must be structurally sound, maintained in a state of good repair and a minimum size of 2 inch by 4 inch, or equivalent strength material. Posts for handrails should be spaced on no
more than 8-foot centers. Handrails should be smooth-surfaced with no protruding upright posts.

4. Stairways and walkways from shore-to-dock should have handrails on each side of the stairway or walkway.

5. Office and service docks should have handrails around the outside perimeter of the dock with appropriate openings for boarding and fueling boats. Handrails are required where public exposure warrants them. For example, places on the dock where people tend to congregate or where the walkway is so narrow that two people carrying gear cannot pass each other safely should have handrails. Also, handrails are required where walkways end or make sharp turns that would lead people to walk directly into the water. Handrails are required at the main walkway end of boat storage stalls whenever the dock layout requires shore visitors to pass these openings on their way to other public use facilities.

6. Gates and signs should be installed to limit access to boat storage and repair areas to authorized personnel only.

**Throwable Lifesaving Devices and First Aid**

1. At least one throw-type lifesaving device with 60 feet of 3/8-inch diameter rope attached and/or a reach pole should be available on each dock. On docks more than 200 feet long, one device should be located every 200 feet along the dock. Rope should be made of polypropylene or some other floating material.

2. A minimum of one, 16-unit first aid kit should be available at each marina.

**Housekeeping**

1. Maintenance and operating practices should be in accordance with established procedures to control leakage and prevent accidental escape of flammable or combustible liquids. Spills should be cleaned up promptly.

2. Adequate aisles should be maintained for unobstructed movement of personnel and fire protection equipment.

3. Combustible waste material and residues in a building or operating area should be kept to a minimum, stored in covered metal receptacles, and disposed of daily as specified in NFPA 303.

4. Ground areas around buildings and unit operating areas should be kept free of weeds, trash, or other unnecessary combustible materials.
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5. All floors should be covered with a slip-free surface and kept free of any tripping or slipping hazard. Loose or rotten boards should be repaired or replaced. The use of approved composite materials is strongly recommended.

6. The entire marina area should be kept neat and clean with equipment properly stored so it does not pose any type of safety hazard to the public or marina employees.

Boat Launching Ramps

1. Launching ramps should be designed to require a deliberate turn from the access road onto the ramp. Traffic control devices, such as barricades, traffic islands, berms, or other architectural barriers, may be used to ensure access roads are not in direct alignment with the ramp. This will prevent direct access to the ramp and keep unaware persons from driving directly into the water. Where turns or control devices are not feasible, rumble strips, signs, and street lights should be installed.

2. Ramps should be between 12 to 14 feet wide per lane and should extend at least 4 feet below the low water level.

3. Slope should be between 12 and 16 percent above the water line and 15 to 20 percent below the water line.

4. Each ramp should include a minimum of one, 75-foot-diameter vehicular turnaround.

5. Ramps should have retaining curbs at the lower end of the ramp and on the outside edges of ramps where drop-offs exist or could form.

6. Ramp surfaces should be scored or patterned to provide adequate traction.

7. Where feasible, chock blocks should be provided at each launching ramp and a sign placed to encourage their use.

8. Ramps should be kept free of algae growth and silt build-up, which could create slipping hazards.

9. A sign should be located at the launching area and should include appropriate statements, such as:
   • No swimming or wading.
   • Get all passengers out of vehicle.
   • Leave door open on driver's side. Unfasten boat hold-down strap.
   • Is your drain plug in?
   • Do you have the necessary safety equipment on your boat?
   • Alcohol and boating don't mix.
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- Boat safety - make sure someone knows where you are boating and when you will return or file a Float Plan.
- The phone number for emergency services.
- No wake or similar safe boat operating instructions.

The last 3 items are informational as they are not to be contained in the sign:

Boat launching, rigging, and parking areas and access roads to boat ramps should be free of overhead power lines. Where overhead power lines are present at launching, rigging, and parking areas, warning signs should be posted.

Launching ramps should have a security light for safety.

Courtesy loading docks should be provided at boat ramps. This will allow for safe loading and unloading of persons and gear.

Dry Stack Storage

Dry stack boat storage systems provide an excellent opportunity for marinas to increase revenues. These systems are well suited to marinas that require more winter storage space or are moving towards higher end “valet services” during the summer months.

Marina operators continue to increase dry stack boat storage services for boats (both inventory and post sales), trailers, water craft or inflatables. This trend is likely to stay as the handling systems become more sophisticated, new marina revenue streams are explored and water berthing for the recreational boater wanes.

While the standards, regulations and Authority having Jurisdiction (AHJ) over dry stack storage installations vary widely with the local fire or zoning authority having a significant voice in the design and installation process, there are certain minimum standards which should be considered when reviewing these types of operations during the initial underwriting submission or renewal process. Pertinent inquires may include:

1. Are the storage racks designed and constructed in accordance with AISC (American Institute of Steel Construction) specifications?
2. Who is the manufacturer and what is the date of manufacture and installation?
3. Does the installation include the use of Pre-stressed Concrete footings for free standing racks?
4. What are the total number of berths, dimensions and maximum height of storage?
5. Are the racks designed and constructed in accordance with local building code regulations?
6. Does the installation comply with NFPA 303, Chapter 7, and Section 7.2.3 In-Out Storage and Rack Storage? Including sub-sections 7.2.3.1 thru 7.2.3.5?
7. For Indoor Rack Storage does the installation comply with NFPA 303, Chapter 6, and Section 6.3.4 Indoor Rack Storage? Including sub-sections 6.3.4.1 thru 6.3.4.3?

8. For In-Out Dry Storage and Rack Storage does the installation comply with NFPA 303, Chapter 6, and Section 6.5?

9. What maintenance and inspection protocols are the racks subject to?

10. Are vessel secured (tied down) when stored in the racks? Is securing, or removal of vessels, addressed in the Heavy Weather Plan for the facility?

Documentation and / or photos should be made available to support the information requested in the above ten questions.

In summary; As NFPA 302-20, Section A.4.1 states: “While design of the marina or boatyard can reduce certain hazards, the fact remains that proper management of the facility or boatyard is an important element for reducing the risk of fire, electrical, and other hazards that threaten life and property.”
Docks, Bulkheads and Wharfs

The following section examines different types of Docks and Seawall Designs. It includes both traditional building methods as well as newer features incorporated into composite dock building projects. The Diagrams below outline some of the new features and design criteria that the use of composite dock building components allows:

![Diagram of 6 Foot Wide Timber Deck](image-url)
Seawalls & Bulkheads:

Our focus in this section will be in the design, inspection, maintenance and utilization of Seawalls, Bulkheads and Docks in the Recreational and Commercial Marine sector.

The terms *bulkhead* and *seawall* are often used interchangeably. For the purposes of this paper the term *seawall* refers to a structure that provides shoreline protection from waves but also retains soil. The term *bulkhead* refers to a vertical shoreline stabilization structure that primarily retains soil, and provides minimal protection from waves.

A bulkhead is primarily intended to retain or prevent sliding of the land; while protecting the upland area against wave action is of secondary importance. Seawalls, on the other hand, are more massive structures whose primary purpose is interception of waves.

Bulkheads may be either cantilevered or anchored (like sheet piling) or gravity structures (such as rock-filled timber cribs). Their use is limited to those areas where wave action can be resisted by such materials. In areas of intense wave action, massive concrete seawalls are generally required. These may have either vertical, concave, or stepped seaward faces.

Protective materials laid on slopes are called revetments, and will not be addressed in this paper. Additional marine structures include the quay (pronounced KEY) which is a...
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stretch of paved bank, or solid artificial landing place parallel to the navigable waterway for use in loading and unloading vessels; as well as groins, jetties and offshore breakwaters.

Both seawalls and bulkheads can be simple rubble mound structures or engineered structures of timber, steel, vinyl or reinforced concrete. Dimensions, specifications, strengths and installation quality can vary widely; as well as cost in terms of original installation, maintenance and upkeep.

Design specifications should be reviewed by a qualified engineer and installation should be supervised and conducted by trained professionals. In most cases in the United States local ordinances and zoning restrictions will have to be complied with as well.

Service life may vary greatly due to a variety of circumstances ranging from original design, materials used and preventive maintenance conducted. Often the proper construction material and method of installation has a great deal to do with the location of the installation and the forces, from both land and sea that the structure will be subject to.

Seawalls are typically located on the coast fronting beaches, and are subject to storm surges with pounding surf, eroding shorelines and overtopping waves from coastal storm events. Some localized waterfront properties may be subject to significant wave activity, even though they are not exposed to ocean waves. A coastal engineering study can provide seawall and bulkhead design information to ensure that they are designed properly to withstand the dynamic loading and overtopping effects of waves. The “rule of thumb” in bulkhead design is to account for wave impacts if the significant wave height at a project site is expected to be in excess of three feet. Unfortunately, many existing structures in use today have not been properly maintained, have exceeded their design service life and / or did not account for the coastal storm impacts that they have experienced recently.

Design considerations that need to be addressed include:

- Topography: elevations, grading, etc.
- Soil Properties: unit weight of soil, clay vs. sand, etc.
- Embedment/stability: depth of wall for stability
- Water Table: differential water levels behind and in front of walls can introduce additional loading on the wall.
- Freeze and thaw cycles if in a Northern location.
- Wall Material Properties: strength and performance in the marine environment
- Surcharge: live loads behind the wall such as vehicles, vessel or rack storage.
- Seasonal Variations of Shoreline Profiles and water levels.
- Design Water Levels:
  - Astronomical tides.
  - Storm surge.
  - Lake levels.

There are additional design considerations that should be addressed for seawalls:
Docks, Bulkheads and Wharfs

- Wave Forces
- Toe Scour Damage (caused at the outside base of a sea wall due to rough or flood waters eroding the foundations.)
- Wave Overtopping
- Storm Surge

If a wall or bulkhead is damaged or deteriorated, the original design may not have accounted for the above-listed effects. Original or “as-built” plans can provide a wealth of information including the age of the structure and many of the design elements listed above. The deteriorated condition of a wall may also be an indication that the wall is in need of maintenance, or that it has fulfilled its service life.

Criteria that can influence changes in the forces that the structures are subject to include:

1. Seawall and bulkhead toe protection – dredging of channels, erosion and traffic can all play a part in this.
2. Flank Protection – development or deterioration of adjacent properties, changes in usage, etc.
3. Corrosion – the electrical demands of today’s vessels continue to increase, and the need for the facility to conduct an Annual Electrical Wiring and Equipment inspection as required in NFPA 303, Chapter 5.20.6 is critical.
4. Freeze-Thaw Cycles – Areas that had not in past been subject to icing conditions may now be experiencing them for a host of reasons, including changing industrial conditions in area as well as shoaling and reduced current.
5. Marine Borer Activity – Areas that have experienced an improvement in water quality can also see an increase in marine borer activity. The Hudson River piers are a prime example of this.
6. Ultraviolet Light - ultraviolet component of sunlight quickly degrades untreated synthetic fibers and can hasten the decay of numerous materials.
7. Abrasion - Abrasion occurs where waves move sediments back and forth across the faces of structures. Shoaling can exacerbate this condition; use of armoring of steel piles at the sand line can help control this condition.
8. Vandalism and Theft - At sites where the potential for vandalism or theft exists, construction materials must be chosen that cannot be easily cut, carried away, dismantled, or damaged.
9. Geotechnical Considerations – both static and dynamic forces need periodic review by a qualified engineer.
10. Wave Forces – from both breaking and non-breaking waves as well as changes in channel depth and vessel usage in the area play a part here.

**Typical Seawall and Bulkhead Examples:**
The following photos and diagrams provide some background on basic components of seawalls and bulkheads:
Docks, Bulkheads and Wharfs

Typical Oceanfront Seawall

Curved Surface to Deflect Waves

Concrete Cap
Grade
Boulders

Wale
Tie Back
Tie Rod
Tip

Cross-section of typical seawall: Note use of boulders against wave overtopping

Concrete Cap
Grade

Water Level
Tie Rod
Anchorage

Dredge Level
(Toe)
Original Ground Configuration
Concrete Panel

Wall Height
Back Fill

Typical Bulkhead Cross Section
September 2013
Docks, Bulkheads and Wharfs

Sheet Piling Construction Materials:
The following table presents sheet piling construction materials used in both seawalls and bulkheads with general comments regarding availability, construction issues, and general performance in the marine environment:

<table>
<thead>
<tr>
<th>Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Pile/panel and sheet piling configurations common in South Florida. Most common wall material there due to the locally available aggregate; provides service life of 30+ years if correct mix and proper marine structural design implemented.</td>
</tr>
<tr>
<td>Steel</td>
<td>Steel sheet piling commonly used for bulkheads/seawalls. Material provides excellent strength characteristics for high wall exposure applications. Provides interlocking seal, and generally easy to install, even in harder substrate. Must be properly coated and maintained for long service life of 25+ years.</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Sheet piling provides good corrosion resistance, but lighter sections allow for minimal exposed wall height. Recognize corrosion potential of dissimilar metal hardware, as well as stray current corrosion. Do not use in waters with low Ph or backfill with clay-mucky soils. Difficult to install in hard substrates.</td>
</tr>
<tr>
<td>Timber</td>
<td>Most often seen utilized in northern waters, but occasionally seen on inland waterways in the south. Timber pile/wale/sheet system is common structural configuration. Generally an economical material, but has limited strength characteristics for high wall heights. Preservative treatment is essential for marine organisms. Difficult to install in hard substrates.</td>
</tr>
<tr>
<td>Vinyl/Plastic</td>
<td>Relatively new and cost-effective product with projected service life of 50+ years. Variable strength characteristics for different wall heights and strength of material can vary with manufacturer. Difficult to install in hard substrates.</td>
</tr>
<tr>
<td>Composite</td>
<td>New Composite Engineered Sheet Pile offer some of the most innovative and attractive characteristics available on the market today. These include: - Leach Zero Chemicals  - 80+ yr life cycle in saltwater (projected)  - Stronger than wood or vinyl</td>
</tr>
</tbody>
</table>
Docks, Bulkheads and Wharfs

A. SECTION MODULUS INCREASED BY PLATING

B. BOX PILES

C. MODIFIED BOX PILE DESIGN

Figure 22
Special Types of Bulkhead Sheeting (Examples A thru C)
Figure 27
Types of Front Wall (Examples A thru C)
The preceding and following figures were obtained from Department of Defense Handbook: Seawalls, Bulkheads and Quaywall; MIL-HDBK-1025/4
Comments on Types of Front Walls:

Sheet Piling. (See Figure 27, Examples A, B, and C.) This type of construction is the usual selection and should be given primary consideration even if the use of cover plates to strengthen available rolled sections is recommended. The selection of steel, timber, or concrete (for low walls, aluminum, fiberglass, and concrete may be considered) is a matter of relative cost. For concrete or timber sheet pilings, which displace a large volume of soil during installation, consideration must be given to achieving the required toe penetration without excessive driving and damage to the sheets. Jetting often is required.

Soldier Pile Wall (also called "King" Pile Wall). Where the strength of available sections of sheet piling is insufficient for the proposed height of wall and loading, a consideration is the use of a soldier pile wall (Figure 28, type D). By using heavy soldier beams, large bending capacities can be achieved. The sheeting between the soldier piles is draped to act as a catenary (in tension). The fill "arches" between the soldier beams so that the sheeting gets little load. For normal spacing of the soldier piles (about 6 to 12 ft), and assuming the soil behind the wall does not consist of soft clay or silt, minimum commercial sections of sheet piling should be adequate.

Soldier Beams and Lagging. Sometimes a bulkhead can be constructed in the dry. An example is when dredging is to be done after the wall has been completed. In such a case, use of soldier beams and lagging often is a more economical solution than the use of sheet piling. One of the reasons is that the lagging can be virtually any material. Timber, concrete, aluminum, galvanized steel, and corrugated fiberglass have all been used.

Close-Pile Wall. (See Figure 27, type C4.) This type of front wall construction once was common and still is economical where logs can be inexpensively obtained. The problem is that the logs (piles) do not fit well together and, despite the best efforts to seal the openings in the wall with various kinds of filters and sheathing, experience demonstrates that loss of backfill is a virtual certainty.

Double Wall. (See Figure 28, type F.) This variation of the soldier pile wall can develop great strength.

Seawall & Bulkhead Components:
Building a seawall or bulkhead starts with installing the sheet piling but the job is not complete without the wall components. These include Tie Rods, Anchors or “dead men”, wales, also called walers, cap’s and round piles & marine poles.

Tie Rods: Threaded portions of tie rods should be protected. Deterioration of the tie rods is concentrated in the 3- to 5-ft section adjacent to the bulkhead, and special protection should be provided in that location. In general, do not use wire rope for tie rods. Where tie rods are long, vertical intermediate supports should be provided at maximum 30-ft on center to prevent sagging. Consider use of a box over the tie rod to avoid loading the rod as the subsoil consolidates.
**Wales:** Wales should be located at a level which minimizes the movement in the sheet piling. Usually, this means as low a level as is economical. Generally, the wales are set at mean low water, as a compromise between the cost of installing the anchor system and the cost of (moment in) the sheet piling. An advantage of setting the wales near mean low water is that the tie rods are in permanently saturated ground. This reduces the corrosion rate in the portions of the tie rods behind the wall. However, the wales, the projecting end of the tie rods and the bolts, plates, and washers on the outside face of the wall are in a zone of active corrosion and should be sized generously.

**Protection against Impact of Berthing Vessels:** Where berthing is to be provided at a bulkhead, wales should be located on the inboard face of the piling. If located on the outboard face, exercise special care to assure protection against damage due to collision.

**Future Dredging:** A bulkhead design is sensitive to increase in the height of the exposed face. Possible future dredging requirements must be carefully considered as it is difficult to strengthen a bulkhead once it has been built.

The following figures provide some detail into the additional components involved in a successful design:
Figure 12
Bulkheads - Actual Constructions (Examples E thru G)
Figure 14
Bulkheads - Actual Constructions (Examples J and K)
Figure 16
Anchored Wall With Single Level of Anchorage
Figure 31
Types of Anchorage (Details 1 thru 3)
Coastal engineering analysis:

This is a sample picture of a coastal engineering analysis

Structural Evaluation - The American Society of Civil Engineers (ASCE) Underwater Investigations Standard Practice Manual was released in 2001 and provides guidance for the evaluation of walls. This standard is also applicable for above-water structures. Most bulkheads are along the waterfront, and should be evaluated above and below the water, whereas seawalls typically are not exposed to water on a regular basis. The following topics are related to structural bulkhead/seawall evaluation:

- Qualifications of inspection personnel
- Types and methods of inspections
- Typical forms of deterioration
- Condition Rating
- Frequency of Inspection

A comprehensive report is a key part of a proper bulkhead or seawall evaluation. All of the above items should be included along with photographs and sketches of the observed configuration with notes regarding deterioration.
Docks, Bulkheads and Wharfs

Comparison against previous reports provides an indication of the rate of deterioration. Repair recommendations, along with construction cost estimates, should be included to provide the property owner with sound engineering advice so they can plan for maintenance or repairs as necessary. The report should be completed by a registered professional engineer experienced in the evaluation of in service marine structures.

**Planning and Design Guidelines for Small Craft Harbors:**
Much has changed in marina development and operation in recent years, and new challenges confront those charged with providing access to oceans, lakes, and rivers by recreational and commercial users. Also, construction and maintenance of marinas and waterfront facilities have not kept pace with demand. Additionally, products are available now that are more predictable and cost-effective.

This Manual will enable waterfront development that produces facilities that are convenient, attractive, and safe, as well as meeting aesthetic, social, and cultural goals. New installations should follow the guidelines laid out in the 2012 edition of the American Society of Civil Engineers (ASCE) Planning and Design Guidelines for Small Craft Harbors. Topics include:
- planning, environmental, and financial considerations
- harbor entrance, breakwater, and basin design
- inner harbor structures
- land-based support facilities

Civil engineers, architects, planners, marine contractors, real estate developers, and marina owners, both public and private, should find useful material in this manual.

Recent Pricing Data

Recent pricing data is not included in this paper at this time for several reasons. Specifically; there are numerous variables that can greatly affect the final cost of Dock Installations. The primary take-away here should be that in general the “Old School” square footage criteria that we have been using, may seriously underestimate the actual cost of replacement once all services (electrical, water, TV, phone and in some cases fuel) are factored in. This is another reason why a comprehensive engineering study should be requested to support valuation figures provided in a submission or renewal.

**Summary:**

The construction practices and materials in this industry have remained relatively unchanged for the last 50 years. Wood, concrete and steel are still the primary construction materials utilized.

**Waterfront Infrastructure Today**
- All these materials have life-cycle shortcomings and water pollution concerns.
- Low bidder wins – Nowhere else is the saying “you get what you pay for” more apparent than in waterfront construction, given the harsh elements.
Docks, Bulkheads and Wharfs

- Current marine construction standards do not meet sustainable building requirements (life cycles, best available technology (BATs), and impact) or require subscription to best management practices (BMPs).
- Current structure life cycle estimates are questionable at best.
- Materials now exist to build 50-80+ yr projected life cycle structures, but are not the mainstream yet.

Some Reasons Why Things Haven’t Changed
- Contractors are dis-incentivized to recommend long life cycle materials out of fear they will lose repeat work or fear that costs will scare off clients.
- Engineers are dis-incentivized to recommend sustainable materials – fear of project cost backlash or they aren’t trained in composite engineering.
- Fragmented stakeholder communities (contractors, engineers, insurance, government) – No group has initiated framework for incentives.
- Short term budgets take precedence over long term costs.

Moving Forward
- We need to move away from materials that leach chemicals and have short life cycles.
- Doing so would result in:
  - Less chemical water pollution.
  - Lower construction impact on basins, marshes, etc.
  - More vibrant ecosystems to form given the luxury of time.

Adoption of policies like this will only occur:
- When independent standards are established to assess which materials are environmentally neutral.
- When a comprehensive approach is in place that allows public/private entities to vote for best projects by funneling their money towards them.
- Where industry stakeholders need to implement incentives around adopting Sustainable Infrastructure procurement policies.

Emerging Structural Material Standards in a Changing World - by Terence M. Browne, M.ASCE (Am Society of Civil Engineers)
In the last thirty years, polymer composite structural materials have been developed to improve the construction and rehabilitation of civil infrastructure. One of the most promising areas for polymer composites is infrastructure projects located in aggressive waterfront environments.

20th Century waterfront construction primarily involved concrete, steel, and timber with Environmental and Durability concerns. 21st Century waterfront construction will witness a greater involvement of polymer composites due to a Technological, Sociological, and Environmentally Aware changing world.
This evolution has led to the gradual acceptance of polymer composites as a viable option in waterfront construction and rehabilitation. ASTM International Committees, as
Docks, Bulkheads and Wharfs

Well as numerous other organizations in North America, have developed a host of new specifications, tests, and standards.

Examples of Composite Infrastructure Materials:
- Fiberglass Pilings: Leach Zero Chemicals.
- 80+ yr life cycle in saltwater - projected.
- Stronger than wood, concrete or steel.

Composite Shapes & Grating:
- Leach Zero Chemicals.
- 80+ yr life cycle in saltwater – projected.
- Stronger than current materials.

Fiberglass Sheet Pile:
- Leach Zero Chemicals.
- 80+ yr life cycle in saltwater - projected.
- Stronger than wood or vinyl.

Fiberglass Pile Mounted Artificial Reefs:
- Wave attenuation and shoreline stabilization.
- Stronger and more effective over time
- Fixed position and flushing given pile mounted

Summary:

20th century waterfront infrastructure materials (wood, concrete and steel) are having a detrimental effect on our natural ecosystems, water quality, long term budgets, safety and storm survivability.

There are composite infrastructure materials currently available that could help positively influence a myriad of issues that plague the marketplace:
- Environmental Impact
- Storm Destruction
- Maintenance Budgets
- Construction Delays
- Short Infrastructure Life Cycles

Any rebuilding or upgrading effort on a Marine Facility should incorporate, and be supported by, an engineering study. This should include the investigation into the use of composite materials; including the services of a qualified composite engineer. These steps will help to properly document the current conditions of a marine facility; as well as establishing a base line for replacement and repair costs in the event of loss. The implementation of proper engineering protocols will also have a positive impact on reducing losses; in part by utilizing new building materials and design criteria to help bring marine facility building and maintenance standards into the 21st century.
Items to Take Away

1. Today’s Marine Docks, Bulkheads and Wharfs are complex systems.
2. Understanding the technology of today is needed to understand the exposures.
3. Valuing these structures must take into account: Construction Methods, Age, Manufacturer and Maintenance practices.
4. There is no database to provide a rule of thumb for valuation. Each dock must be evaluated on its own.
5. Experienced Marine Contractors and Design Engineers should be consulted for repairs, maintenance and replacement.
6. Good maintenance practices are keys to dock longevity and safety.
7. There are different “hidden” costs involved in the replacement or repair of different types and aging docks (utility codes, environmental issues, etc.).
8. There is a need for continuing and frequent facility inspections
9. Verify the method used for valuation and understand the requested coverage and how it relates to replacement components.
10. Never underestimate the value of a good survey of the docks, bulkheads and wharfs.