types of revetments are less sensitive to foundation settlement (e.g., riprap), the consequences for other types could be more severe (e.g., cracking and disintegration of cast-in-place concrete mats, displacement and breakage of gabion baskets). Scour at the toe of the revetment is another possible cause for concern. As for the integrity of the skin, displacement of riprap armor caused by wave attacks should be checked. Gabion basket wire may be susceptible to corrosion and abrasion damage, causing potential unraveling of the revetment. In colder regions, the gouging of riprap by ice pile-ups and the plucking of armor units by surface ice also may be concerns.

A.4 MARINAS

A.4.1 General Description

Marinas and small-craft harbors may consist of various marine structures, many of which are common to other types of port facilities. Open-piled piers, bulkheads, timber cribs, and breakwaters may form part of a marina and are described elsewhere in this appendix. This section deals specifically with marine underwater components that are unique to marinas, such as floats and anchor systems, wave attenuators, and utilities and outfalls. Table A-4 summarizes some of the more common problem areas associated with the underwater components specific to marinas.

A.4.1.1 Floats. Floating docks at marinas typically consist of floating units that are anchored by piles or by chains and anchors. Floats can be made of many materials, such as timber, concrete, aluminum, metal, or composites. Hardware used for floats is generally hot-dip galvanized.

The *timber float* in its simplest form consists of a timber deck supported on log or timber framing. Loss of buoyancy from waterlogging of the timbers can become a problem. Modern timber floats may incorporate polystyrene floatation billets to improve buoyancy. *Concrete floats* are one of the more common types of modern floats. They usually are made from lightly reinforced or plain concrete and can be hollow or filled with foam. *Fiberglass floats* are similar to concrete floats as to the type of construction. They usually are ballasted for stability because they tend to be quite lightweight and therefore potentially unstable. *Metal floats* are commonly used as floating docks. The flotation units may consist of sealed pipes or rectangular pontoons and may be steel or aluminum.

Other materials used in float construction include foam and rubber. These materials are also used in conjunction with some of the other materials noted above. Foam billets may need to be coated to protect against deterioration caused by fuel and oil in the water.

TABLE A-4. Checklist for Underwater Inspections: Marinas

Component and Section/Part	What to Look For	Comments
Floats		
General	Excessive float misalignment, tilt, reduced freeboard	Misalignment may suggest anchor slippage; tilt or loss of freeboard could be caused by leakage or excessive marine growth.
Shell	Surface deterioration, physical damage (dents and holes) Loose or leaking access hatch covers	Check for waterlogged filler.
Joints between Float Units	Damaged, loose, or deteriorated connecting hardware Excessive float misalignment	
Fenders/Rubbing Strips	Deterioration, missing or loose members, condition of hardware	
Anchors and Anchor Chains		
Anchor Chain and Connecting Hardware	General condition, wear and corrosion, distortion	
Anchors	Misalignment or movement, instability, inadequate embedment	
Cathodic Protection	See Section A.14, Cathodic Protection Systems	

continued on next page

A.4.1.2 Anchors and Anchor Chains. Anchors for marina floats usually consist of precast concrete blocks or mushroom anchors placed directly on the bottom. They are most suitable for soft bottom conditions where they can improve resistance against sliding. Screwed-in helical piles also may be used as anchors. Chains usually are used to secure the float to the anchor.

A.4.1.3 Anchor Piles. Materials used for anchor piles may be steel, concrete, timber, or composites. The design of the anchor system usually allows for vertical movement in response to fluctuations in water level. The connection between float and pile is a critical system component subjected to heavy wear and repeated load reversals. However, this connection is usually located above the waterline.

TABLE A-4. *Continued.*

Component and Section/Part	What to Look For	Comments
Anchor Piles		
System	Damaged or "missing" piles, alignment (straightness) of piles from top to bottom	Check for "ice jacking" in cold climates.
Surfaces	Deterioration, wear and corrosion, mechanical damage	Special concerns: Integrity and condition of pile–float connection
Wave Attenuators		
Fixed Supporting Structure (Piles, Pile Caps, Deck)	See Section A.2, Open-Piled Structures	Check for bottom scour caused by down-rush of waves.
Floating Supporting Structure (Floats and Anchor System)	See applicable structure component above	
Wave Reflection Panels	Damaged or missing panels, surface deterioration, loose or deteriorated connecting hardware	

A.4.1.4 Wave Attenuators. Commonly found at marinas to reduce the effects of wind-driven waves or boat wakes, wave attenuators are most efficient for short-period waves and may consist of fixed or floating structures.

The fixed structure is typically composed of an open-piled structure with vertical wave-reflection panels that protrude below the waterline. The transmitted waves are primarily reduced in height by reflection. The fixed structure may be constructed of steel, timber, concrete, composite materials, or a combination of these materials.

The floating wave attenuator usually is composed of floating dock sections, often complemented with vertical reflection panels that extend below the floats. The transmitted wave energy is dissipated in three ways: reflection by the float and the panel, friction as the wave passes under the floating structure, and inertia from the vertical and horizontal movement of the floating system. The floating docks can be constructed of timber, steel, aluminum, concrete, or composite materials.

A.4.1.5 Utilities and Outfalls. Utilities (potable water, electrical cables—including cable TV and telephone—and piping for sewage pumpouts) as well as storm sewer outfalls for upland drainage usually are found at marinas. The underwater components of these installations should be inspected as outlined in Section A.6, Pipelines and Conduits. Special care should be taken to check the conditions of flexible utility sections that span individual float units.

A.4.2 Typical Underwater Components and Common Problem Areas

A.4.2.1 Floats. Divers must inspect floating docks that are actually in the water at time of inspection. Typical problems encountered on floats usually are related to deterioration of the specific float material. Some areas of more general concern include

- impact damage, particularly for concrete and fiberglass floats that may be more susceptible to cracking and leaking
- leakage through the shell or at manhole openings
- loss of buoyancy caused by accumulation of marine growth on floats and anchor chains or by deterioration of the foam buoyancy units
- wear and stress or fatigue damage of float connecting components
- marine borer attack on timber
- coating failure on metal floats
- loss of anode mass

A.4.2.2 Anchor Systems. Buried anchors usually are not uncovered for inspection. However, wherever possible, the connection between the anchor and the anchor chain should be inspected for wear and corrosion. The anchor chain and the connecting hardware at the float also should be inspected for general condition. Periodic visual inspection of the anchor and anchor chain systems are necessary to verify integrity.

Anchor piles need to be inspected for general deterioration. Special attention needs to be paid to the sliding connections between pile and float, an area that is subjected to particularly heavy wear and abrasion from component interaction. In colder climates, vertical jacking of piles by ice is a concern.

A.4.2.3 Wave Attenuators. Wave attenuators should be inspected for structural integrity and material degradation. The particular problem areas associated with underwater portions of fixed structures are similar to open-piled piers and wharves. Underwater portions of floating structures are similar to floating docks. For both fixed and floating wave attenuators, special attention should be paid to the wave-reflector panels and the related connecting hardware.

A.5 HYDRAULIC STRUCTURES

A.5.1 General Description

Hydraulic structures include water-conveying or water-retention structures such as intakes, outfalls, dams, powerhouses, tunnels, and penstocks. The layout, design, and construction typically are influenced by topography, volume of water to be conveyed or retained, environmental and geotechnical factors, and the availability of construction materials and equipment.

A.5.1.1 Intakes and Outfalls. Intakes and outfalls are commonly associated with power stations, industrial process facilities, water supply facilities, and stormwater and wastewater discharge facilities. They may be located in freshwater or saltwater, and their construction may be open, closed, or a combination. Open structures such as canals usually are lined with concrete. Closed structures may be round, horseshoe-shaped, rectangular, or multibarrel. They may be lined or unlined, and they may be completely or partially buried or submerged. The most common construction material for intakes and outfalls is concrete, either precast or cast in place. However, many older facilities may be lined with brick, cast iron, steel, or timber.

A.5.1.2 Dams. Dams may range from small, low-risk earthen embankment structures to enormous high-head concrete arch structures. Low-risk facilities pose no major threat to life or property if breached, whereas moderate- to high-risk facilities may pose grave danger to population centers in the event of a breach. Dams are therefore licensed and regulated by the Federal Emergency Regulatory Commission based on risk assessment parameters.

Typical dam construction types include earthen, roller-compacted concrete; cast-in-place concrete; and timber cribs. Dams are constructed in many configurations depending on the topography and volume of retention. Components of dams typically include the dam structure, gates, spillways, fish ladders, and aprons.

A.5.1.3 Powerhouses. Dams are often accompanied by powerhouses located within a riverine environment. Powerhouse structures usually are founded on concrete foundations and often are equipped with intake structures, turbines, draft tubes, and discharge structures. Such facilities are commonly subjected to high flow rates and turbulence and therefore are susceptible to erosion and scour of the structure itself, the foundation, and the rock or other material beneath the foundation.

A.5.1.4 Tunnels and Penstocks. Tunnels and penstocks may be associated with power stations, industrial process facilities, water supply facilities, and wastewater or stormwater discharge facilities. Tunnels are buried and may be partially or completely submerged. They are most often constructed of precast or cast-in-place concrete and may be lined with brick, cast iron, steel, or timber. Many tunnels are excavated or bored through self-supporting material and remain unlined, although lining of tunnels is also commonly used to improve hydraulic performance.

Penstocks may be above ground or buried and typically are associated with water under high pressure or velocity. Therefore, penstocks are most often constructed of steel or prestressed concrete.

A.5.2 Typical Underwater Components and Common Problem Areas

Table A-5 summarizes some typical problem areas that may apply to hydraulic structures.

A.5.2.1 Intakes and Outfalls. Intake and outfall structures typically consist of the transitional structure at the water end, the conveyance portion, and the transitional structure at the landside or service end. The transitional structures may consist of headgates, sluicegates, widened configurations, bifurcations, or other structural features. Other components of intake transitional structures may include trash racks, traveling screens, or other similar devices to keep debris or other undesirable material from passing. Outfalls may or may not be so equipped, depending on the environment. Inspection of such transitional structures should focus on not only the structure itself but also the interface between the transition element(s) and the conveyance element(s). In addition, gate tracks, gate structures, and gate sealing edges are prone to damage because they are moving elements. Finally, the transition structures often include structural framing to support trash racks, traveling screen, and other elements. This framing is often a weak link in the system as a result of corrosion or fatigue damage.

The conveyance portion of intakes and outfalls are susceptible to typical corrosion, overstress, marine borer, chemical deterioration, and other defects depending on the construction materials. Particular attention should be focused on joints, transitions, and bends, where stress concentrations may occur.

A.5.2.2 Dams. The equipment and methods for inspecting dams can vary enormously with the size and water depth at the facility, but the critical elements remain essentially the same. The most common cause of dam failures is scour or erosion. Therefore, the inspection should focus on areas where the potential for scour is the greatest: the upstream dam–mudline

TABLE A-5. Checklist for Underwater Inspections: Hydraulic Structures

Type, Component, and Section/Part	What to Look For	Comments
Intakes and Outfalls		
Gates, Trash Racks, Screens		For inspection of cathodic protection systems (if applicable), see Section A.14, Cathodic Protection Systems.
Seals	Torn, damaged, or aging seals causing leakage	
Tracks and support framing	General condition, mechanical damage	
Gate skin, screen bars	Surface deterioration, debris, or blockage	
Conveyance Structures	Depends on type of structure; see Section A.6, Pipelines and Conduits	
Dams		
Dam Structure		
Foundation and abutments	Erosion and scour	
Dam core	Deterioration, signs of overstressing	Type of degradation will depend on material.
Gates	See Intakes and Outfalls above	
Spillway and Apron: Foundation Interface	Erosion and scour, debris accumulation	
Powerhouses		
Main Structure: Foundation Interface	Erosion and scour	
Intakes, Discharge Structures, Gates, Trash Racks	See applicable structure type and section above	
Tunnels and Penstocks		
Conduit		
Shell or Lining	Deterioration, signs of overstressing or leaks	For unlined tunnels in rock, check for rock falls.
Fittings (bends, bifurcations, transitions)	Scour and erosion, overstressing, leaks	

interface, the downstream apron areas, and transitions (e.g., spillways and abutments). The downstream dam toe should be checked for signs of leakage and piping. Older concrete dams often are susceptible to chemical damage such as alkali–silica reaction or sulfate attack as well as physical damage above the waterline from freeze–thaw effects. Gates should be inspected carefully, including tracks, structure, and seals.

A.5.2.3 Powerhouses. Powerhouses are susceptible to problems similar to dams. Components such as foundations, particularly in discharge areas, often are subject to scour from the turbulent flow of sediment-laden water. Footings founded on soft rock have been known to be undermined extensively in such areas. Powerhouses also may be subjected to large lateral forces during flood events. The buildup of debris and the high water pressure can cause overstressing damage; therefore, an inspection should focus on areas that are susceptible to such damage or where such damage may be manifested.

Powerhouses may be equipped with stoplogs, gates, draft tubes, wet wells, trash racks, intake structures, and discharge structures. These areas are subject to debris accumulation and damage, strong currents, and turbulent flow and therefore are susceptible to damage caused by scour, erosion, and fatigue. Finally, older powerhouse structures constructed of concrete are often susceptible to chemical damage such as alkali–silica reaction or sulfate attack as well as physical damage above the waterline from freeze–thaw effects.

A.5.2.4 Tunnels and Penstocks. Tunnels and penstocks under moderate to high head may be susceptible to significant stress that can cause overload damage. Concrete-lined tunnels have been known to crack extensively, leading to leakage into porous founding material. Dewatering such facilities can lead to implosion from reversal of stresses. Tunnels and penstocks constructed of prestressed concrete may be susceptible to corrosion, which may be exacerbated by conductive soil conditions in some areas. Wastewater tunnels constructed of concrete may be susceptible to attack from external chemical sources that can cause deterioration of the concrete matrix. The inspection of tunnels and penstocks should concentrate on joints, transitions, bifurcations, elbows, bends, and other areas where stress concentrations can form and leaks can develop.

A.6 PIPELINES AND CONDUITS

A.6.1 General Description

Submarine pipelines are used to convey water, gas, and oil across a body of water. Pipes used to encase or protect electrical cables or communication wires are usually referred to as *conduits*. Submarine pipelines and conduits can be divided into two broad groups: buried and exposed. The buried pipeline or conduit is placed in a trench below the mudline, which is then backfilled or placed on the bottom and covered with earth material and riprap or concrete protection. The exposed pipeline or conduit would be placed directly on the bottom and left uncovered. Intermittent structural pipe cradles or hold-down devices may be used to support and anchor the pipeline or conduit.

Materials used for submarine pipelines include precast and prestressed concrete, steel, cast iron, and plastic piping such as polyethylene and polyvinyl chloride (PVC); in the past, brick and masonry pipes were used at locations where the pipes could be laid in the dry, and the area was subsequently flooded. Conduits are commonly made from steel (with or without armored wrap) or PVC.

This section covers only the external inspection of pipelines and conduits. Internal inspections of pipelines in a flooded condition, when required, can be carried out by penetration dives (provided the pipeline is of sufficient size) or by self-propelled equipment controlled remotely.

A.6.2 Typical Underwater Components and Common Problem Areas

The inspection of buried pipelines and conduits usually is limited to verification of the integrity of the cover material. Scour as well as gouging from ice, boat anchors, or submerged logs could affect the protective cover over the pipeline or conduit and ultimately damage the installation. One area of particular concern is the transition zone from water to land, where the cover material may be subjected to wave attack.

The exposed pipeline or conduit should be checked for alignment, breaks, and signs of leakage as well as general deterioration typical to the material in question. Steel pipe may be wrapped with a protective tape, in which case the integrity and condition of the wrapping should be verified. The pipeline joints, if visible, should be inspected for general condition and tightness, and any mechanical hardware (e.g., bolts, flanges, and couplings) should be checked.

The most common types of pipeline supports and hold-down devices consist of concrete or steel cradles anchored to the bottom, and concrete collars bolted to the pipe and loosely laid on the bottom. The hardware between the pipe and the support needs to be checked for loose and missing components and general condition. Erosion and scour at the supports could affect the stability of the support and the pipeline.

Table A-6 is a summary of the main concerns regarding submarine pipelines and conduits.

TABLE A-6. Checklist for Underwater Inspections: Pipelines and Conduits

Type and Component	What to Look For	Comments
Buried Pipelines and Conduits		
Protective Cover Layer	Erosion and scour Damage to riprap or concrete cover	Special attention may be required at landfalls of buried pipelines and conduits.
Exposed Pipelines and Conduits		
System	Misalignment and breaks Signs of leakage Erosion and scour	Check pipe for loss of support, measure freespan (if applicable).
Pipe Conduit and Joints	Deterioration of material Mechanical damage Condition and tightness of joints Signs of overstressing	If pipeline or conduit is wrapped or armored, check integrity, condition, and continuity of wrapping.
Pipe/Supports and Hold-Down System	Condition of supports and anchors Deterioration and wear of pipe and connecting hardware Erosion and scour at supports	For pipelines provided with anti-buoyancy collars, check number and spacing.
Cathodic Protection	See Section A.14, Cathodic Protection Systems	

A.7 DRY DOCKS

A.7.1 General Description

Dry docks may be defined as any structure or vessel, the primary function of which is to create dry access to ships for purposes of new construction, inspection, cleaning, or repair. Dry docks are divided into four types: basin dry docks, floating dry docks, marine railways, and vertical lifts.

Basin dry docks (sometimes referred to as *graving docks*) are excavated into the earth adjacent to the waterfront with one end accessible to the water via a gate. To allow a ship access, the basin dry dock is flooded and the gate is opened. After the ship has entered the dry dock, the gate is closed and the water pumped out.

Floating dry docks are vessels that have a pontoon and wing walls that lift the ship out of the water by displacement. When water is added to the ballast tanks, the dry dock sinks enough to allow the ship to enter. Once the ship is properly positioned and supported, the ballast tanks are pumped out, thereby raising the ship out of the water.