Bridge Inspection:
Underwater Inspection (BIRM)

Course No: S03-009

Credit: 3 PDH

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Inspection and Evaluation of Waterways

Topic 11.3 Underwater Inspection

11.3.1 Introduction

The need for underwater inspections is great. Approximately 86 percent of the bridges in the National Bridge Inventory (NBI) are built over waterways, and most bridge failures occur because of underwater problems. Underwater members must be inspected to the extent necessary to determine with certainty that their condition has not compromised the structural safety of the bridge.

Several bridge collapses during the 1980's, traceable to underwater deficiencies, have led to revisions in the National Bridge Inspection Standards (NBIS) (see Figure 11.3.1). As a result, bridge owners have been mandated to develop a master list of bridges requiring underwater inspections.

Figure 11.3.1 Schoharie Creek Bridge Failure

In general, the term "underwater inspection" is taken to mean a hands-on inspection requiring underwater breathing apparatus and related diving equipment. The expense of such inspections necessitates careful consideration of candidate bridges.

Bridge Selection Criteria

Bridges that cross waterways often have foundation elements located in water to provide the most economical total design. Where these elements are continuously submerged (see Figure 11.3.2), underwater inspection and management techniques must be used to establish their condition so that failures can be avoided.

Figure 11.3.2 Liberty Bridge over Monongahela River

In many cases, a multi-disciplinary team including structural, hydraulic and geotechnical engineers must evaluate a bridge located over water. Underwater inspection is therefore only one step in the total investigation of a bridge.

Selection Criteria

Various factors influence the underwater bridge inspection selection criteria. In accordance with the *AASHTO Manual for Condition Evaluation of Bridges*, all structures must receive routine underwater inspections at intervals not to exceed sixty months or 72 months with FHWA approval. This is the maximum interval permitted between underwater inspections for bridges which are both in excellent condition underwater and which are located in passive, nonthreatening environments. More frequent routine and in-depth inspections may be desirable for many structures and necessary for critical structures. The bridge owner must determine the inspection interval that is appropriate for each individual bridge. Factors to consider in establishing the inspection frequency and levels of inspection include:

- Age
- Type of construction materials
- Configuration of the substructure
- Foundation Depth
- Adjacent waterway features such as dams, dikes, or marinas
- Susceptibility of streambed materials to scour
- Maintenance history
- Saltwater environment
- Waterway pollution
- Damage due to waterborne traffic, debris, or ice

Selected Bridges

Those bridges that require underwater inspection must be noted on individual inspection and inventory records as well as be compiled in a master list. For each bridge requiring underwater inspection, the following information should be included as a minimum:

- Type and location of the bridge
- Type and frequency of required inspection
- Location of members to be inspected
- Inspection procedures to be used
- Dates of previous inspections
- Maximum water depth and velocity (if known)
- Special equipment requirements
- Findings of the last inspection
- Follow-up actions taken on findings of the last inspection
- Type of foundation
- Bottom of foundation elevation or pile tip elevation

11.3.2

Methods of Underwater Inspection

The location of underwater elements must be identified and a description of the underwater elements must be included in the inspection records. The inspection frequency and procedures for each bridge requiring underwater inspection must be included in the inspection record. The elements requiring underwater inspections must be inspected according to these procedures.

There are three general methods used to perform underwater inspections:

- Wading inspection
- Self-contained diving (SCUBA)
- Surface-supplied diving

Wading Inspection

Wading inspection is the basic method of underwater inspection used on structures over wadable streams. The substructure units and the waterway are evaluated using a probing rod, sounding rod or line, waders, and possibly a boat. Regular bridge inspection teams can often perform wading inspections with waders and a life preserver or a boat (see Figure 11.3.3).

Figure 11.3.3 Wading Inspection

Self-contained Diving

In this mode, the diver operates independently from the surface, carrying his/her own supply of compressed breathing gas (typically air). SCUBA, an acronym for Self-Contained Underwater Breathing Apparatus, is the most common type of self-contained diving equipment used (see Figure 11.3.4). Self-contained diving is often employed during underwater bridge inspections. This dive mode is best used at sites where environmental and waterway conditions are favorable, and where the duration of the dive is relatively short. Extreme care should be exercised when using self-contained equipment at bridge sites where the waterway exhibits low visibility and/or high current, and where drift and debris may be present at any height in the water column.

Figure 11.3.4 Self-Contained Inspection Diver

Surface-Supplied Diving As its name implies, surface-supplied diving uses a breathing gas supply that originates above the water surface. This breathing gas (again, typically compressed air) is transported underwater to the diver via a flexible umbilical hose. Surface-supplied equipment provides the diver with a nearly unlimited supply of breathing gas, and also provides a safety tether line and hard-wire communications system connecting the diver and above water personnel. Using surface-supplied equipment, work may be safely completed under adverse conditions that often accompany underwater bridge inspections, such as: fast current, cold and/or contaminated water, physically confined space, submerged drift and debris, and dives requiring heavy physical exertion or of relatively long duration (see Figure 11.3.5).

Figure 11.3.5 Surface-Supplied Diving Inspection

Method Selection Criteria In determining whether a bridge can be inspected by wading or whether it requires the use of diving equipment, water depth should not be the sole criteria. Many factors combine to influence the proper underwater inspection method:

- Water depth
- Water visibility
- Current velocity
- Streambed conditions (softness, mud, "quick" conditions, and slippery rocks)
- Debris
- Substructure configuration

11.3.3

Diving Inspection Intensity Levels

Originating in the United States Navy and offshore diving industry, the designation of standard levels of inspection has gained acceptance. Three diving inspection intensity levels have evolved as follows:

Level I:	Visual, tactile inspection
Level II:	Detailed inspection with partial cleaning
Level III:	Highly detailed inspection with nondestructive testing

Level I

Level I inspection consists of a "swim-by" overview at arm's length with minimal cleaning to remove marine growth. Although the Level I inspection is referred to as a "swim-by" inspection, it must be detailed enough to detect obvious major damage or deterioration. A Level I inspection is normally conducted over the total (100%) exterior surface of each underwater element, involving a visual and tactile inspection with limited probing of the substructure and adjacent streambed. The results of the Level I inspection provide a general overview of the substructure condition and verification of the as-built drawings. The Level I inspection can also indicate the need for Level II or Level III inspections and aid in determining the extent and selecting the location of more detailed inspections.

Level II

Level II inspection is a detailed inspection that requires that portions of the structure be cleaned of marine growth. It is intended to detect and identify high stress, damaged and deteriorated areas that may be hidden by surface growth. A Level II inspection is typically performed on at least 10% of all underwater elements. In some cases, cleaning is time consuming and should be restricted to critical areas of the structure. The thoroughness of cleaning should be governed by what is necessary to determine the condition of the underlying material. Removal of all growth is generally not needed. Generally, the critical areas are near the low waterline, near the mud line, and midway between the low waterline and the mud line. On pile structures, horizontal bands, approximately 150 to 300 mm (6 to 12 inches) in height, should be cleaned at designated locations:

- Rectangular piles - the cleaning should include at least three sides
- Octagonal piles - at least six sides
- Round piles - at least three-fourths of the perimeter
- H-piles - at least the outside faces of the flanges and one side of the web

On large elements, such as piers and abutments, areas at least 0.09 m^2 (1 square foot) in size should be cleaned at three or more levels on each face of the element (see Figure 11.3.6). Deficient areas should be measured, and the extent and severity of the damage documented.

Figure 11.3.6 Diver Cleaning Pier Face For Inspection

Level III

A Level III inspection is a highly detailed inspection of a critical structure or structural element, or a member where extensive repair or possible replacement is contemplated. The purpose of this type of inspection is to detect hidden or interior damage and loss in cross-sectional area. This level of inspection includes extensive cleaning, detailed measurements, and selected nondestructive and other testing techniques such as ultrasonics, sample coring or boring, physical material sampling, and in-situ hardness testing. The use of testing techniques is generally limited to key structural areas, areas that are suspect, or areas that may be representative of the entire bridge element in question.

11.3.4

Types of Inspection

A comprehensive review must be made of all bridges contained in an agency's inventory to determine which bridges require underwater inspection. Many combinations of waterway conditions and bridge substructures exist. For any given bridge, the combination of environmental conditions and structure configuration can significantly affect the requirements of the inspection. It is generally accepted that there are five different types of inspections:

- Initial (inventory)
- Routine (periodic)
- Damage
- In-depth
- Special (interim)

Underwater inspections are typically either routine or in-depth inspections.

Initial Inspections

An inventory inspection is the first inspection of a bridge as it becomes a part of the bridge inventory. An inventory inspection may also apply when there has been a change in the configuration of the structure such as widening, lengthening, bridge replacement, or change in ownership (see Figure 11.3.7). The inventory inspection is a fully documented investigation, and it must be accompanied by an analytical determination of load capacity, which includes scour analyses if appropriate.

Figure 11.3.7 Bascule Bridge on the Saint Croix River

There are two primary purposes for an inventory inspection:

- Collection of Structure Inventory and Appraisal (SI&A) data
- Establish as-built conditions

The second important aspect of the inventory inspection is the determination of baseline structural conditions and the identification and listing of existing problems or locations in the structure that may have potential problems.

Aided by a prior detailed review of plans, it is during this inspection that any underwater members (or details) are noted for subsequent focus and special attention.

Routine Inspections

A routine inspection is a regularly scheduled, intermediate level inspection consisting of sufficient observations and measurements to determine the physical and functional condition of the bridge, to identify any change from "inventory" or previously recorded conditions, and to ensure that the structure continues to satisfy present service requirements.

The routine inspection must fully satisfy the requirements of the NBIS with respect to maximum inspection frequency, updating of SI&A data, and the qualifications of the inspection personnel.

Routine inspections of substructures in water must be conducted at least once every sixty months. Structures having underwater members which are partially deteriorated or which are in unstable channels may require shorter inspection intervals. Criteria must be established for determining the level and frequency to which these underwater elements will be inspected base on such factors as construction material, environment, age, scour characteristics, condition rating from past inspections and known deficiencies. Certain underwater structural elements may be inspected at greater than sixty month intervals, not to exceed seventy-two months, with written FHWA approval. This may be appropriate when past inspection findings and analysis justifies the increased inspection interval.

The scope of work for a routine inspection should include:

- A Level I inspection should be made on 100% of the underwater portion of the structure to determine obvious problems.
- A Level II inspection should be made on at least 10% of underwater units selected as determined by the Level I inspection.
- A Level III inspection may need to be performed to gain additional data so that the structural conditions can be evaluated with certainty.

The dive team should also conduct a scour evaluation at the bridge site, including:

- Inspect the channel bottom and sides for scour.
- Cross sections of the channel bottom should be taken and compared with as-built plans or previously taken cross sections to detect lateral channel movement or deepening (see Figure 11.3.8).
- Soundings should be made in a grid pattern (see Figure 11.3.9) about each pier and upstream and downstream of the bridge, developing contour

elevations of channel bottom, to detect areas of scour. Permanent reference point markers should be placed on each abutment/pier (see Figure 11.3.10). Data obtained from the soundings should be correlated with the original plans (if available) of the bridge foundations and tied to these markers for reference during future underwater inspections.

- Local scour and undermining should be determined with probes in the vicinity of piers and abutments (see Figure 11.3.11). In streams carrying large amounts of sediment, reliable scour depth measurements may be difficult at low flow due to scour hole backfilling.

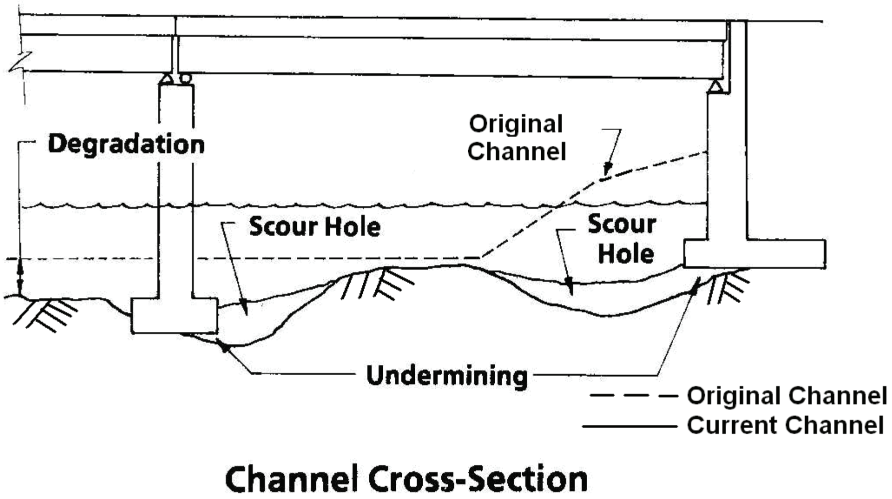


Figure 11.3.8 Channel Cross Section (Current Inspection versus Original Channel)

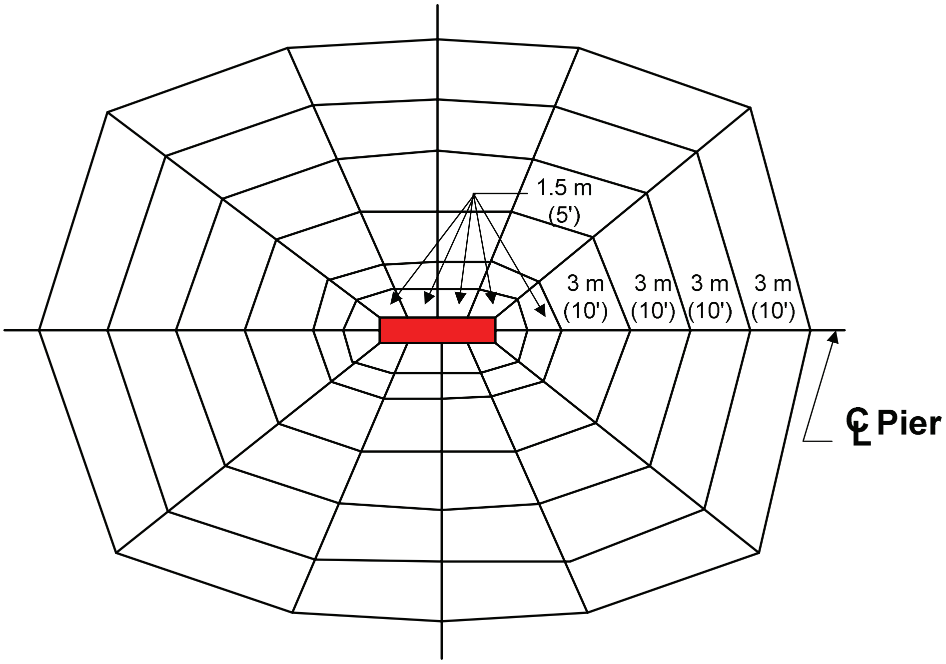


Figure 11.3.9 Pier Sounding Grid

Figure 11.3.10 Permanent Reference Point (Bolt Anchored in Nose of the Pier, Painted Orange)

Figure 11.3.11 Local Scour; Causing Undermining of a Pier

Damage Inspections

Certain conditions and events affecting a bridge may require more frequent, or unscheduled, inspections to assess structural damage resulting from environmental or accident related causes.

The scope of inspection must be sufficient to determine the need for emergency load restrictions or closure of the bridge to traffic and to assess the level of effort necessary to repair the damage. The amount of effort expended on this type of inspection will vary significantly depending upon the extent of the damage. If major damage has occurred, inspectors must evaluate section loss, make measurements for misalignment of members, and check for any loss of foundation support.

Situations that may warrant a damage inspection include:

- Bridge elements should be inspected after floods. Bridge elements located in streams, rivers, and other waterways with known or suspected scour potential should be inspected after every major runoff event to the extent necessary to ensure bridge foundation integrity (see Figure 11.3.12).
- Bridges should be inspected underwater if there is visible damage above water from vessel impact. This should be done in order to determine the extent of damage and to establish the extent of liability of the vessel owner for damages.
- Ice floes can damage substructure elements, and accumulations of ice on the elements can cause scouring currents or increase the depth of scour.
- Prop wash from vessels (i.e., turbulence caused by the propellers of marine vessels) can cause scouring currents and may propel coarse-grained bottom materials against substructure elements in a manner similar to that of blast cleaning operations.
- Buildup of debris at piers or abutments effectively widens the unit and may cause scouring currents or increase the depth of scour (see Figure 11.3.13).
- Evidence of deterioration or movement will require underwater inspection. Many underwater deficiencies only become apparent above water when the distress extends above the waterline or is manifested by lateral movement or settlement. Bridges should also by inspected underwater following significant earthquakes (see Figure 11.3.14).

Figure 11.3.12 Flood Conditions: Note Pier Settlement.

Figure 11.3.13 Buildup of Debris At Pier

Figure 11.3.14 Movement of a Substructure Unit

In-Depth Inspections

An in-depth inspection is a close-up, hands-on inspection of one or more members below the water level to detect any deficiencies not readily apparent using routine inspection procedures. When appropriate or necessary to fully ascertain the existence of or the extent of any deficiencies, nondestructive tests may need to be performed.

The inspection may include a load rating to assess the residual capacity of the member or members, depending on the extent of the deterioration or damage.

One or more of the following conditions may dictate the need for an in-depth inspection:

- Inconclusive results from a routine inspection
- Suspect hidden or internal damage
- Critical structures whose loss would have significant impact on life or property
- Unique structures whose structural performance is uncertain
- Prior evidence of distress
- Consideration of reuse of an existing substructure to support a new superstructure or planned major rehabilitation of the superstructure
- Adverse environmental conditions such as brackish and polluted water

The in-depth inspection typically includes Level II inspection over extensive areas and Level III inspection of limited areas. Nondestructive testing is normally performed, and the inspection may include other testing methods, such as extracting samples for laboratory analysis and testing, boring, and probing.

All findings should be recorded using notes and sketches. Underwater photographs and video recordings should also be used where visibility permits.

The distinction between routine and in-depth inspections is not always clearly defined. For some bridges, such as steel pile supported structures in an actively corrosive environment, it may be necessary to include Level III, nondestructive testing inspection techniques as part of routine inspections.

Special Inspections

A special inspection is scheduled at the discretion of the individual in charge of bridge inspection activities. A special inspection is used to monitor a particular known or suspected deficiency (e.g., foundation settlement or scour).

11.3.5

Qualifications of Diver-Inspectors

An underwater bridge inspection diver must complete FHWA approved comprehensive bridge inspection training course or other FHWA approved underwater bridge inspection training course.

The underwater inspector must have knowledge and experience in bridge inspection. All underwater inspections should be conducted under the direct supervision of a qualified bridge inspection team leader. A diver not fully qualified as a bridge inspection team leader must be used under close supervision.

As the ability of the underwater inspector to safely access and remain at the underwater work site is paramount to a quality inspection, the individual must possess a combination of commercial diving training and experience, which demonstrates his/her competence as a working diver.

Federal Commercial Diving Regulations

Underwater bridge inspection, using either self-contained or surface-supplied equipment, is a form of commercial diving. In the United Sates, commercial diving operations are federally regulated by both the Occupational Safety and Health Administration (OSHA), and the U.S. Coast Guard. OSHA regulates all commercial diving operations performed inland and on the coast (through 29 CFR Part 1910, Subpart T-Commercial Diving Operations). This reference should be consulted for details on commercial diving procedures and safety.

Diver Training and Certification

OSHA Safety Requirements

The OSHA standard delineates diving personnel requirements, including general qualifications of dive team members. The standard also provides general and specific procedures for diving operations, and provides requirements and procedures for diving equipment and recordkeeping.

ANSI Standards for Commercial Diver Training

American National Standards Institute (ANSI) Standards exist, which define minimum training standards for both recreational SCUBA and commercial divers. These two, separate standards provide clear-cut distinctions between recreational and commercial diver training. While not federal law, these standards constitute the consensus of both the recreational and commercial diving communities, following ANSI's requirements for due process, consensus, and approval.

The American National Standard for Divers- Commercial Diver Training-Minimum Standard (ANSI/ACDE-01-1998) requires a formal course of study, which must contain at least 625 hours of instruction. This training may come from an accredited commercial diving school, military school, or may be an equivalent degree of training achieved prior to the effective date of the Standard, which includes a documented combination of field experience and/or formal classroom instruction.

ADC International Requirements

The Association of Diving Contractors International (ADC) is a non-profit organization representing the commercial diving industry. The ADC publishes "Consensus Standards For Commercial Diving Operations", which have been developed to present the minimum standards for basic commercial diving operations conducted either offshore or inland. The Consensus Standards, in part, duplicate the ANSI standard for commercial diver training, but subdivide the minimum 625 hours of training into both a formal course of study (317 hours, minimum), and on the job training (308 hours, minimum). The ADC also formally issues OSHA-recognized Commercial Diver Certification Cards to individuals meeting minimum training standards. On the world-wide web, go to *www.adc-usa.org* for more information.

Dive Team Requirements

The Federal Highway Administration's main concern is whether the diver has knowledge and experience in underwater bridge inspection. The individual employers are in the best position to determine the specific requirements of their dive teams. Regarding staffing levels, OSHA requires a minimum of three (3) dive team members, whether conducting self-contained or surface supplied diving operations.

11.3.6

Planning an Underwater Inspection

Planning for underwater bridge inspections is particularly important because of:

- The complexity and potential hazards involved in conducting the inspection
- Unknown factors which may be discovered during the diving
- The difficulty for the bridge owner to verify the thoroughness of the inspection
- The cost of conducting underwater inspections

These factors are most influential for first-time (inventory) underwater inspections that set a benchmark for future inspections. It is, therefore, important to distinguish between the first-time and follow up inspections.

The effectiveness of an underwater inspection depends on the agency's ability to properly consider all factors:

- Method of underwater inspection (i.e., Dive mode)
- Diving inspection intensity level
- Type of inspection
- Qualifications of diver-inspectors
- Specific bridge site conditions, including access requirements, and waterway and climate conditions

With these factors considered, an agency may opt for a lower level of inspection. Depending on conditions and the type of damage found, a higher level may then be necessary to determine the actual bridge condition. It is also possible that different levels may be required at various locations on the same bridge.

11.3.7

Substructure Units and Elements

The underwater portions of bridge structures can be classified into five broad categories: bents, piers, abutments, culverts, and protection systems. Proper identification is important since various elements may require different inspection procedures, levels of inspection, or inspection tools.

Bents

Bents can be divided into two groups:

- Column bents
- Pile bents

Column bents have two or more columns supporting the superstructure and may in turn be supported by piling below the mud line. The column bents are typically constructed of concrete, but the piling may be timber, concrete, or steel.

Pile bents carry the superstructure loads through a pile cap directly to the underlying soil or rock. The piles (and pile cap) can be constructed of timber, steel, or concrete. Pile bents are generally distinguished from piers by the presence of some battered piles and also bracing which provides stability for the individual piles. See Figures 11.3.15 through 11.3.17 for photographs of pile bents of different material types.

Figure 11.3.15 Timber Pile Bent

Figure 11.3.16 Steel Pile Bent

Figure 11.3.17 Concrete Pile Bent

Important items to be noted by the inspector are collision damage, and material defects. Scour of the river bottom material at the bottom of the piles can result in instability of the piles. The underwater inspector must compare present scour and resultant pile length with that observed in previous inspections.

Piers

Piers carry superstructure loads from the pier cap to the footing, which may be a spread footing or may be supported on a deep foundation. Piers can be constructed of steel, timber, concrete, or masonry and are usually distinguished by two to four large columns or a single large shaft. As with pile bents, collision damage, material deterioration, and scour are important items to look for in an underwater inspection. It is also important for the inspector to note if the pier shaft or columns are vertical. There are three common types of piers the inspector is likely to encounter:

- Column pier
- Column pier with solid web wall (see Figure 11.3.18)
- Cantilever or hammerhead pier (see Figure 11.3.19)
- Solid shaft pier (see Figure 11.3.20)

Figure 11.3.18 Column Pier with Solid Web Wall

Figure 11.3.19 Cantilever or Hammerhead Pier

Figure 11.3.20 Solid Shaft Pier

Abutments

Abutments carry the superstructure loads to the underlying soil or rock and also retain the earth at the end of the structure. In most cases, the abutments are dry during low water periods and do not require a diving inspection. However, occasionally the abutments remain continually submerged and must be inspected underwater. Abutments can be constructed from concrete, masonry, or timber and may be supported by spread footings, piles, caissons, or pedestals.

Scour is probably the most critical item to be aware of when performing an underwater abutment inspection. Extreme local scour (undermining) could result in a forward tilting or rotation of the abutment, especially on those abutments without pile foundations (see Figure 11.3.21).

Figure 11.3.21 Severe Flood-Induced Abutment Scour

Culverts

The underwater inspection of culvert structures present unique challenges to the inspection team, as culverts exist in a wide range of sizes, shapes, lengths, materials, and environments. Areas of special concern to the dive team when conducting culvert inspections include confined space, submerged drift and debris, and animal occupation.

Physically confined space issues arise when inspecting culverts containing individual pipes, barrels, or cells with small interior dimension, or non-linear layout. Additionally, many culverts are continually either completely submerged, or exhibit limited freeboard. In northern environments, winter inspections may also include ice as a contributing factor (see Figure 11.3.22). Diving operations in physically confined space must be conducted in compliance with Federal commercial diving regulations, as well as the individual agency's Safe Practices Manual. The ADC "Consensus Standards For Commercial Diving Operations" also offers guidance for the safe conduct of confined space diving operations.

Submerged drift and debris is a persistent threat to the underwater inspection team, combining with the physically confining nature of most culvert structures to greatly increase the threat of diver entanglement. The diver may be completely unaware of the presence of drift until fouled. Surface-supplied air diving equipment should be used when conducting diving operations in physically confined and/or debris-laden culverts.

Another threat to the diver involves animals living or seeking shelter inside the culvert. Snakes are often found in and around accumulations of sediment and drift, while, in the southeast United States, alligators often reside inside culvert structures. Those structures exhibiting debris accumulations, which partially or fully constrict one end of a culvert, should be approached with caution, as excited animals may try to leave the culvert in haste, while the inspector is entering.

Figure 11.3.22 Inspection of Culvert With Limited Freeboard and Ice Cover

Protection Systems

Dolphins and fenders are often placed around substructure units to protect them from impact damage. Since these systems are usually at least partially underwater, a diving inspection should be conducted in concert with the substructure unit inspection. Additional protection systems and scour countermeasures include spur dikes, streambed armoring, rip rap, wing dams, and check dams (see Figure

11.3.23).

Figure 11.3.23 Damaged Protective System

11.3.8

Scour Investigations

Divers may be able to note scour degradation under certain conditions. The most important assessment is how much of the bent or pier is exposed when compared to plans and typical designs.

Local scour is often detectable by divers since this type of scour is characterized by holes near bents, piers, or abutments. Divers should routinely check for such scour holes. A typical approach is to take depth measurements around the substructure, both directly adjacent and at concentric intervals. It should also be noted that divers typically operate in low current situations. Sediment often refills scour holes during these periods, making detection of even local scour difficult. However, since this refilled sediment is usually soft, a diver using a probing rod can often detect the soft areas indicating scour refilling.

Depth measurements will not directly reveal the more general scour of significant sections of the streambed. However, the diver may find evidence of such scour from examination of the structure if parts of the substructure are exposed, or by comparing successive cross sections.

The diver's role is primarily to point out a potential scour problem. Almost invariably, an additional interdisciplinary engineering investigation will be needed. The diver's primary role in scour investigation is to measure scour by one of two methods:

- Sounding devices
- Diver investigations

Sounding Devices

Although sounding-sensing devices can be used independently of diving, they are commonly part of an underwater inspection. With the exception of poles and lead lines, sounding-sensing devices depend on some type of signaling system. While these systems are quite effective, they can be misinterpreted. An on-site diver can investigate questionable readings and more fully determine the channel bottom conditions.

Black and White Fathometer

The most commonly used device is the black and white fathometer. A transducer floats just below the waterline and bounces sound waves off the bottom. Depths are continuously recorded on a strip chart.

Advantages of the black and white fathometer include the following:

- Inexpensive
- Effective
- "User-Friendly" output

Disadvantages include the following:

- False readings can occasionally occur due to heavy drift or heavy turbulence
- Fathometers may also fail to detect refilled scour holes during calm water
- The strip chart moves at a constant rate and does not record a horizontal scale; unless the boat can be kept at a constant speed, the scale becomes distorted

Fathometer/Theodolite

The horizontal scale problem can be solved by using equipment, which combines a fathometer with a total station theodolite. The theodolite is set up on shore, it tracks and records the coordinates of the transducer, and it automatically records depths at specified increments using a microprocessor. The data can be processed and plotted as a topographic map.

Dual Frequency and Color Fathometer

Dual frequency and color fathometers can be used to detect refilling, since more than one frequency is utilized. With color fathometers, materials of different densities are displayed as different colors. The primary drawback is that a hard copy cannot be obtained except with videotape recordings.

Ground-Penetrating Radar

Ground-penetrating radar and tuned transducer (low frequency sonar) equipment are also used in scour surveys. These are good in shallow water but not very effective in salty, brackish water.

Fixed Instrumentation

An alternative to the sounding and scour sensing devices used during inspections is to permanently install fixed instrumentation directly on the bridge substructure. With fixed instrumentation, local scour is continuously monitored and recorded as it occurs, unaffected by washing back of silts and sands, and making information readily available to the bridge owner by setting off a beacon-type alarm on the bridge deck (or relayed back to an office). One such instrument consists of a steel rod inside of a conduit attached to the substructure unit. The rod acts as a probe, resting on the vulnerable soil supporting the substructure. As local scour occurs the soil is washed away and the rod drops a measured distance.

Other fixed instrumentation includes fixed sonar units, sliding magnetic collars, and buried "float-out" buoys, which float to the water surface after being uncovered by local scour, activating an electronic alarm system (see Figure 11.3.24).

Researchers are studying a new method for scour detection and monitoring. The new method is based on time domain reflectometer (TDR) technology, which uses pulse transmissions to show changes in a particular environment. The TDR bridge scour monitoring system consists of a probe, which is completely buried in the sediment at appropriate locations around and near the bridge pier and footings. As erosion occurs, part of the probe is exposed to water. Then, the probe reflects a specific pulse back to the TDR box, which is on the surface, indicating how much of the probe is exposed and producing wave forms to show scour depth. The probes are designed to be left at bridge sites to detect/monitor scour.

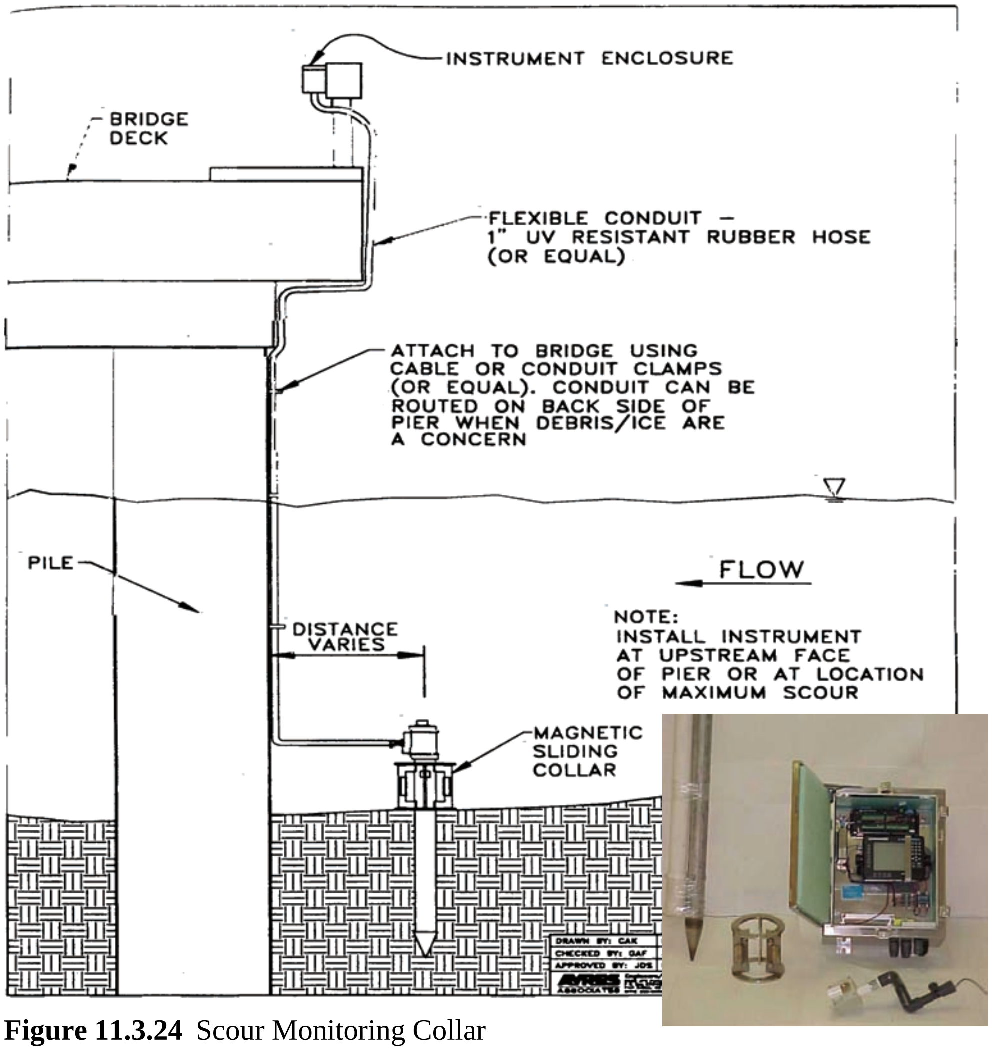


Figure 11.3.24 Scour Monitoring Collar

Diver Investigations

Diver investigations include:

- Laying out a grid pattern and taking depth measurements
- Sampling soils to determine backfilling of scour holes
- Probing to check for refilling
- Detecting undermining and scour holes (see Figure 11.3.25)
- Detecting small diameter but deep scour holes around piles
- Protective system evaluation (e.g., rip rap)

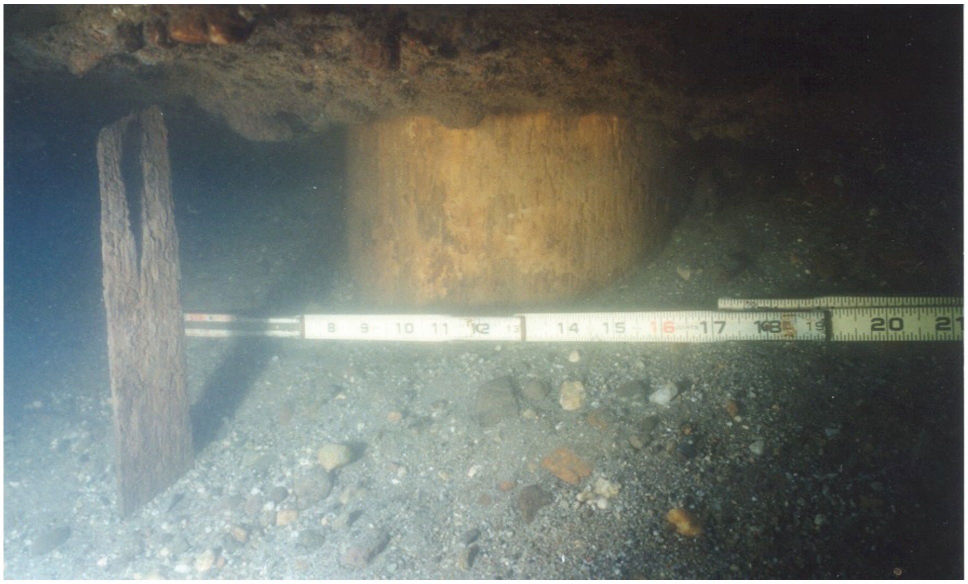


Figure 11.3.25 Pier Undermining, Exposing Timber Foundation Pile

11.3.9

Underwater Inspection for Material Defects

The materials typically used in bridge substructures are concrete, timber, steel, and masonry. An estimated 75% of all underwater elements are concrete. The balance consists of timber, steel, and masonry, in descending order of use.

Concrete and Masonry

Plain, reinforced, and prestressed concrete are used in underwater elements. Since the majority of substructures are basically compression units, concrete is a nearly ideal material choice. Some concrete damage tends to be surface damage that does not jeopardize the integrity of the system. However, concrete deterioration that involves corrosion of the reinforcement can be very serious (see Figure 11.3.26).

Cracking, delamination and spalling are typical for concrete substructures. Reinforcement exposed to water and air is subjected to section loss. Scaling occurs above the water surface while abrasion occurs in the area near thte water surface.

Masonry substructures can experience cracking of the stones and mortar joints.

See Topics 2.2 and 2.4 for detailed descriptions of concrete and masonry defects.

Figure 11.3.26 Concrete Deterioration

Timber

Timber pile bents are typical for short span bridges in many parts of the country, particularly for older bridges. The primary cause of timber deterioration is biological organisms, such as fungi, insects, bacteria, and marine borers. The ingredients for an attack include suitable food, water, air, and a favorable temperature. The waterline of pile structures offers all of these ingredients during at least part of the year. Since water, oxygen, and temperature generally cannot be controlled in a marine environment, the primary means to prevent a biological attack is to deny the food source through treatment to poison the wood as a food source. Timber piles are particularly vulnerable if the treatment leaches out (which happens with age) or if the core is penetrated. It is, therefore, important to carefully inspect in the vicinity of connectors, holes, or other surface blemishes (see Figure 11.3.27).

Figure 11.3.27 Deteriorated Timber Piling

Piles used in older bridges quite often were not treated if the piles were to be buried below the mud line (eliminating the source of food and oxygen). However, in some cases, streambed scour may have exposed these piles. Special care should be taken in differentiating between treated and untreated piles to ensure a thorough inspection of any exposed, untreated piles. With each inspection, the diameter or circumference should be noted for each timber pile. As a minimum, these measurements should be made at the waterline and mud line. Comparisons should be made with the original pile size.

Another primary caution for inspecting underwater timber piles is that the damage is frequently internal. Whether from fungal decay or borers, timber piles may appear sound on the outside shell but be completely hollow inside. While some sources recommend hammer soundings to detect internal damage, this method is unreliable in the underwater environment. One way to inspect for such damage is to take core samples. All bore holes should be plugged. Ultrasonic techniques for timber piling are also available.

See Topic 2.1 for detailed descriptions of timber material defects.

Steel

Underwater steel structures are highly sensitive to corrosion, particularly in the low to high water zone (see Figure 11.3.28). Whenever possible, steel should be measured to determine if section loss has occurred. Ultrasonic devices are particularly useful to determine steel thicknesses.

Figure 11.3.28 Deteriorated Steel Piles at Splash Zone

If submerged steel elements are partially encased in concrete, the exposed steel adjacent to the encasement is particularly susceptible to aggressive corrosion.

See Topic 2.3 for detailed descriptions of steel material defects.

Previous Repairs

The inspector must also be alert to note deterioration of previous member repairs or rehabilitation. The first step in the inspection of previous repairs is to review all existing bridge substructure plans prior to the actual inspection. Repair areas should be noted as important areas of inspection.

Typical previous repairs may include:

- Steel cover plates
- Concrete fill repairs
- Epoxy crack repairs
- Concrete encasement or jacketing
- Limited replacement of members
- Masonry stone replacement
- Underpinning and rip rap to repair scour

Hands-on Inspection of Material Underwater

When visibility permits, the diver should visually observe all exposed surfaces of the substructure. Scraping over the surface with a sharp-tipped probe, such as a knife or ice pick, is particularly useful for detecting small cracks. With limited visibility, the diver should "feel" for damage. Because orientation and location are often difficult to maintain, the diver should be systematic in the inspection. Regular patterns should be established from well-defined reference points.

Typical inspection patterns include:

- Circular or semicircular horizontal sweeps around piers or abutments beginning at the base, moving upward a specified increment, and repeating until complete
- Probing zones of undermining of piers by moving uniform increments from start to finish and recording the undermined penetration
- Down one side and up the other for piles (or inspecting in a spiral pattern)
- For scour surveys, record depths at regular increments adjacent to substructure (e.g., at each pile or 10 foot increments around piers), and then at each measured point extend radially from the substructure a uniform distance and repeat depth measurements

Major advantages of surface-to-diver communications are that the diver can be guided from the surface with available drawings, and that immediate recording of observations can be made topside along with the clarification of any discrepancies with plans.

Measuring Damage

Any damage encountered should be measured in detail. As a minimum for a Level II or III inspection include:

- Location of the damage zone both horizontally and vertically from a fixed reference point
- A good vertical reference point is the waterline, provided that the waterline is measured with respect to a fixed reference point on the bridge prior to the dive
- For undermining of foundations, take enough measurements to define the zone no longer providing soil bearing
- If plans are not available, measure the basic dimensions of damaged members (it is also usually prudent to spot check dimensions of damaged members even if plans are available)
- Check for displacements of major elements and whether they are plumb

- Locate the beginning and ends of cracks and intermediate points as needed to define the pattern
- Measure the maximum crack width and penetration depth
- Measure the length, width, and penetration of spalls or voids, making note of exposure and condition of any reinforcing steel
- Note the degree of scaling on concrete
- Measure the thicknesses of all four flange tips on steel H-piles at distressed areas, and specify the vertical location
- Locate buckles, bulges, and significant loss of section in steel members - thickness of remaining sound material should be accurately measured when significant section loss is found
- Note damage at connections
- Measure the diameter of timber piles – note extent and width of checks, and extent of any rot, if found

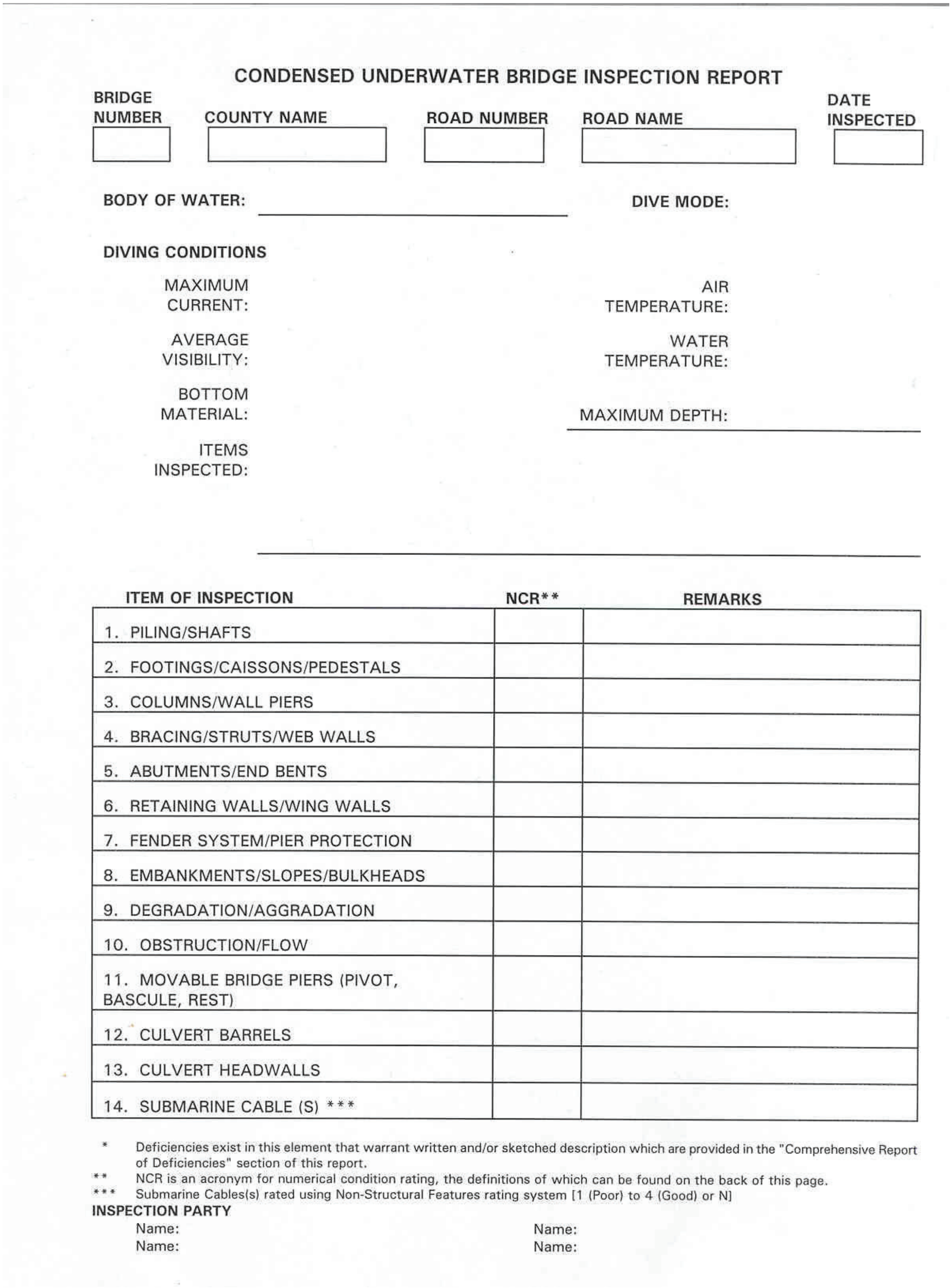
Recordkeeping and Documentation

Because of the effort spent in conducting underwater inspections, combined with the time between inspections, it is particularly important to carefully document the findings. On-site recording of all conditions is essential:

- It is recommended that sketches be used as much as possible; providing enough detail is critical since it is difficult to go back to check items once the diving is completed. Contour and plan view sketches of the area surrounding the substructure elements allow the inspector to track any scour or streambed movement. A profile of the streambed can also provide information for tracking the development of scour.
- In addition to sketches, written notes or logs should be kept, documenting the inspection.
- When significant damage is encountered, a tape recording of the diver’s observations can also prove helpful.
- Underwater photographs and/or underwater videotapes can be used to support the inspection report.

The results should also be included in an inspection form or report. Drawings and text should describe all aspects of the inspection and any damage found. The report should also include recommendations on condition assessment, repairs, and time interval for the next inspection. See Figure 11.3.29 for a sample underwater inspection form.

See Topic 4.3 for detailed descriptions of record keeping and documentation.



CONDENSED UNDERWATER BRIDGE INSPECTION REPORT

BRIDGE NUMBER	COUNTY NAME	ROAD NUMBER	ROAD NAME	DATE INSPECTED

BODY OF WATER:

DIVE MODE:

DIVING CONDITIONS

MAXIMUM CURRENT:

AIR TEMPERATURE:

AVERAGE VISIBILITY:

WATER TEMPERATURE:

BOTTOM MATERIAL:

MAXIMUM DEPTH:

ITEMS INSPECTED:

ITEM OF INSPECTION	NCR**	REMARKS
1. PILING/SHAFTS		
2. FOOTINGS/CAISSONS/PEDESTALS		
3. COLUMNS/WALL PIERS		
4. BRACING/STRUTS/WEB WALLS		
5. ABUTMENTS/END BENTS		
6. RETAINING WALLS/WING WALLS		
7. FENDER SYSTEM/PIER PROTECTION		
8. EMBANKMENTS/SLOPES/BULKHEADS		
9. DEGRADATION/AGGRADATION		
10. OBSTRUCTION/FLOW		
11. MOVABLE BRIDGE PIERS (PIVOT, BASCULE, REST)		
12. CULVERT BARRELS		
13. CULVERT HEADWALLS		
14. SUBMARINE CABLE (S) ***		

* Deficiencies exist in this element that warrant written and/or sketched description which are provided in the "Comprehensive Report of Deficiencies" section of this report.

** NCR is an acronym for numerical condition rating, the definitions of which can be found on the back of this page.

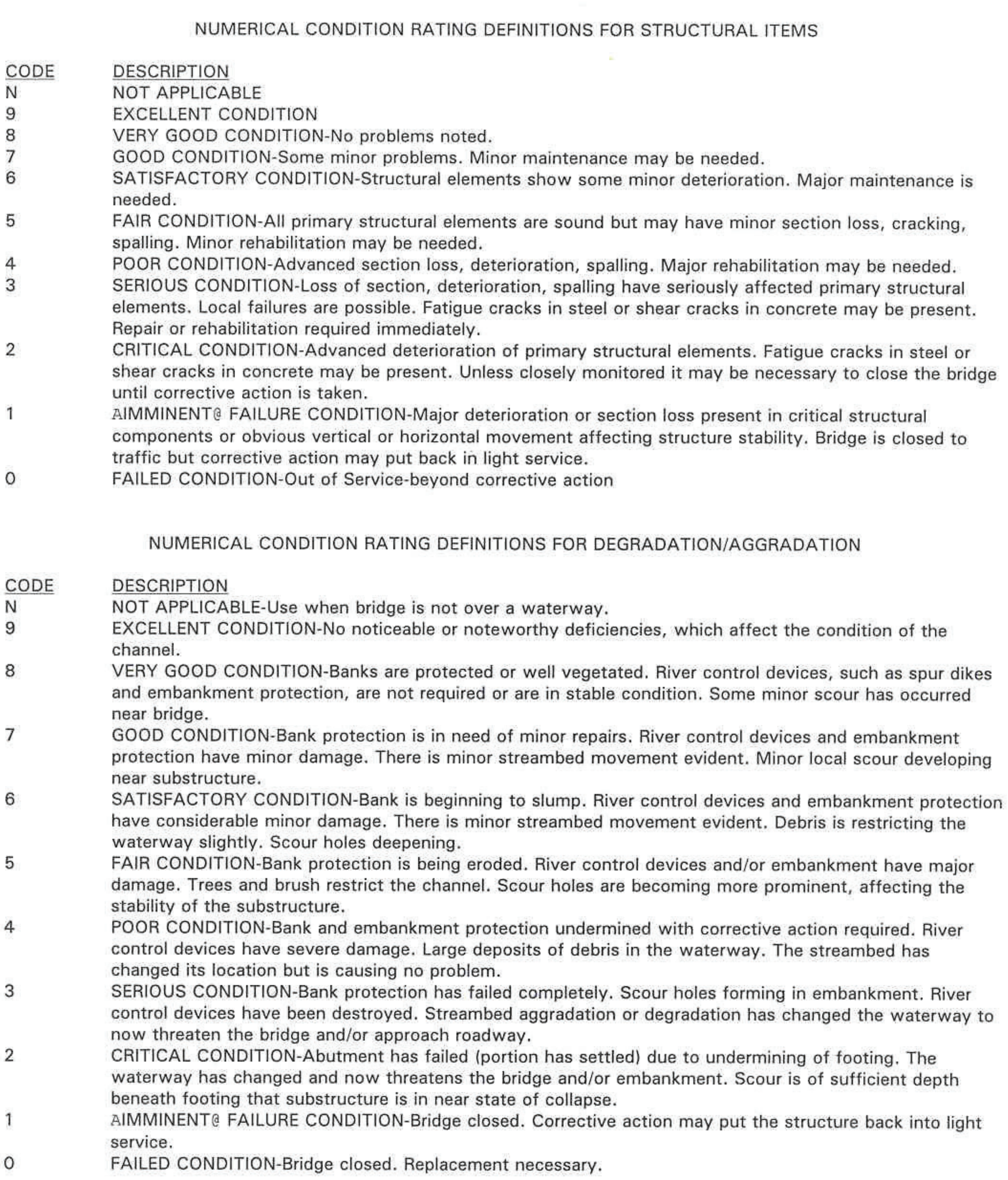
*** Submarine Cables(s) rated using Non-Structural Features rating system [1 (Poor) to 4 (Good) or N]

INSPECTION PARTY

Name:
Name:

Name:
Name:

Figure 11.3.29 Sample Underwater Inspection Form



NUMERICAL CONDITION RATING DEFINITIONS FOR STRUCTURAL ITEMS

CODE	DESCRIPTION
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION-No problems noted.
7	GOOD CONDITION-Some minor problems. Minor maintenance may be needed.
6	SATISFACTORY CONDITION-Structural elements show some minor deterioration. Major maintenance is needed.
5	FAIR CONDITION-All primary structural elements are sound but may have minor section loss, cracking, spalling. Minor rehabilitation may be needed.
4	POOR CONDITION-Advanced section loss, deterioration, spalling. Major rehabilitation may be needed.
3	SERIOUS CONDITION-Loss of section, deterioration, spalling have seriously affected primary structural elements. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present. Repair or rehabilitation required immediately.
2	CRITICAL CONDITION-Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	AIMMINENT@ FAILURE CONDITION-Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION-Out of Service-beyond corrective action

NUMERICAL CONDITION RATING DEFINITIONS FOR DEGRADATION/AGGRADATION

CODE	DESCRIPTION
N	NOT APPLICABLE-Use when bridge is not over a waterway.
9	EXCELLENT CONDITION-No noticeable or noteworthy deficiencies, which affect the condition of the channel.
8	VERY GOOD CONDITION-Banks are protected or well vegetated. River control devices, such as spur dikes and embankment protection, are not required or are in stable condition. Some minor scour has occurred near bridge.
7	GOOD CONDITION-Bank protection is in need of minor repairs. River control devices and embankment protection have minor damage. There is minor streambed movement evident. Minor local scour developing near substructure.
6	SATISFACTORY CONDITION-Bank is beginning to slump. River control devices and embankment protection have considerable minor damage. There is minor streambed movement evident. Debris is restricting the waterway slightly. Scour holes deepening.
5	FAIR CONDITION-Bank protection is being eroded. River control devices and/or embankment have major damage. Trees and brush restrict the channel. Scour holes are becoming more prominent, affecting the stability of the substructure.
4	POOR CONDITION-Bank and embankment protection undermined with corrective action required. River control devices have severe damage. Large deposits of debris in the waterway. The streambed has changed its location but is causing no problem.
3	SERIOUS CONDITION-Bank protection has failed completely. Scour holes forming in embankment. River control devices have been destroyed. Streambed aggradation or degradation has changed the waterway to now threaten the bridge and/or approach roadway.
2	CRITICAL CONDITION-Abutment has failed (portion has settled) due to undermining of footing. The waterway has changed and now threatens the bridge and/or embankment. Scour is of sufficient depth beneath footing that substructure is in near state of collapse.
1	AIMMINENT@ FAILURE CONDITION-Bridge closed. Corrective action may put the structure back into light service.
0	FAILED CONDITION-Bridge closed. Replacement necessary.

Figure 11.3.29 Sample Underwater Inspection Form (Continued)

11.3.10

Underwater Inspection Equipment

Diving Equipment

Personal diving equipment includes:

- Wetsuit or drysuit (drysuit should be used when diving in water either known or suspected to be contaminated) (see Figure 11.3.30)
- Face mask or helmet (see Figure 11.3.31)
- Breathing apparatus
- Weight belt
- Swim fins
- Knife
- Wristwatch
- Buoyancy compensator (a flotation device capable of maintaining a diver face up at the surface)
- Depth gauge
- Pressure gauge

Surface-supplied air diving equipment typically includes a compressor, which supplies air into a volume tank for storage. This compressed air is then filtered and regulated to the diver’s helmet or mask through an umbilical hose (see Figures 11.3.32 and 11.3.33). The umbilical is typically made up of several members, including, at a minimum, an air hose, strength member (or safety line), communication line, and pneumofathometer hose. The pneumofathometer provides diver depth measurements to the surface (see Figure 11.3.34). A reserve air tank, or bail-out bottle, should also be worn by the diver for emergency use.

For self-contained diving, the breathing gas supply is contained within a pressurized tank, which is carried by the diver.

Figure 11.3.30 Vulcanized Rubber Dry Suit

Figure 11.3.31 Full Face Lightweight Diving Mask with Communication System

Figure 11.3.32 Surface-Supplied Air Equipment, Including Air Compressor, Volume Tank With Air Filters, and Umbilical Hoses

Figure 11.3.33 Surface-Supplied Diving Equipment Including Helmet, or Hard Hat

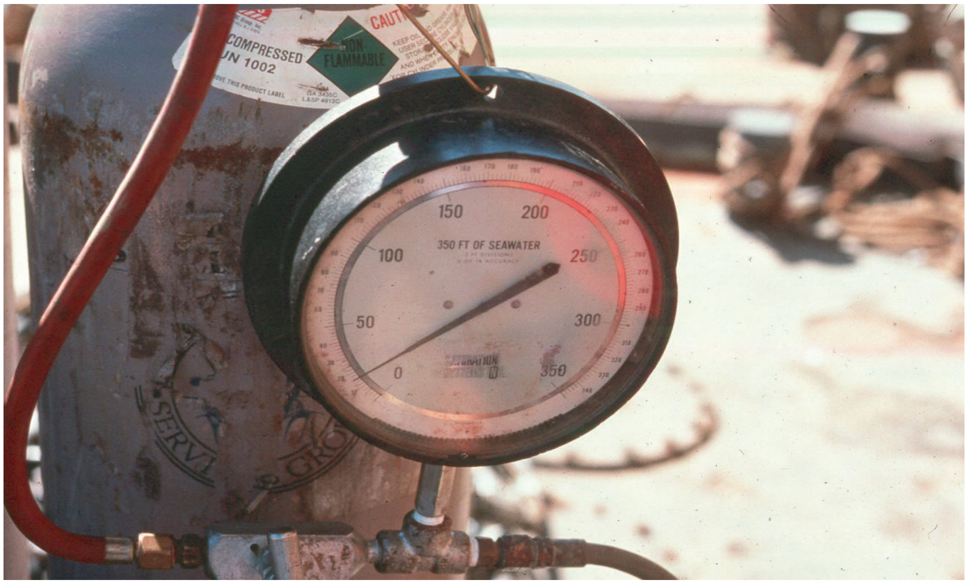


Figure 11.3.34 Pneumofathometer Gauge

Equipment malfunction leading to loss of air supply must be a constant concern to the dive team. Even in shallow water, submerged drift and debris adjacent to a bridge can make an emergency ascent an arduous affair, for both the diver and the support team. As such, a reserve air supply should always be worn by the diver (see Figure 11.3.35). Carbon monoxide poisoning can occur if the air intake of the surface supplied air compressor is located near the exhaust of other motorized equipment.

Figure 11.3.35 Surface-Supplied Diver with a Reserve Air Tank

Surface Communications

While not required in all situations, a two-way communication system linking the diver(s) and topside personnel greatly enhance the underwater inspection. Conventional hardwire (telephone) and wireless systems exist, which can even be used during self-contained diving operations. There are several advantages provided to the underwater inspection team, through the use of direct two-way communication (see Figure 11.3.36):

- The greatest benefit to the dive team is increased safety in the event of diver entanglement or equipment malfunction.
- Allows the diver to immediately describe observations and location of deficiencies for simultaneous recording by a note taker on the surface.
- The diver can verbally interact with topside inspection personnel to clarify what is being observed, without leaving the suspect area.
- The note taker can follow drawings, verify their validity, note damage on the drawings at the proper location, and track the progress of the diver.
- Surface communication also allows an inspection team leader/engineer at the surface to discuss observations with a diver who is not yet an inspection team leader, to direct attention to specific zones, and to ensure that a satisfactory inspection is completed, according to the type and severity of damage found (see Figure 11.3.37).

Figure 11.3.36 Communication Box System

Figure 11.3.37 Surface Communication With Inspection Team Leader

Access Equipment

While inspection of short-span bridges can often be accessed from shore, many bridges require a boat or barge for access. Typically, a 5.5 m (18-foot) or larger vessel can safely handle the equipment and crew (see Figures 11.3.38 and 11.3.39). Occasionally, access is made from the bridge itself.

Figure 11.3.38 Access Barge and Exit Ladder

Figure 11.3.39 Access From Dive Boat

Tools

A number of inspection tools are available. The dive team should have access to the appropriate tools and equipment as warranted by the type of inspection being conducted.

Hand Tools

While most hand tools can be used underwater, the most useful include rulers, calipers, scrapers, probes (ice picks, dive knifes, and screwdrivers), flashlight, hammers (especially masonry and geologist's hammers), wire brushes, incremental borers, and pry bars (see Figure 11.3.40). These tools are usually tethered to the diver to prevent their loss underwater.

Figure 11.3.40 Diver-Inspector with a Pry Bar

Power Tools

Power tools include grinders, chippers, drills, hammers and saws. While pneumatic tools are sometimes used, hydraulic tools tend to be favored for heavy or extensive work.

Cleaning Tools

Light cleaning can be accomplished with scrapers and wire brushes. Heavier cleaning requires automated equipment such as grinders and chippers. One of the most effective means of cleaning is with the use of water blasters (see Figure 11.3.41). Particular care must be taken with such equipment to ensure that structural damage does not result from overzealous blasting.

Figure 11.3.41 Cleaning with a Water Blaster

Nondestructive Evaluation Equipment

- Ultrasonic measuring devices measure the thickness of steel by passing a sound wave through the member. The transducer is placed on one side only, and the thickness is displayed on an LED readout. Totally submersible or surface display units are available. They are very effective for measuring thickness.
- A V-meter is an ultrasonic device that requires two transducers and measures the distance required for the sound wave to pass through the concrete. Similar devices have also been developed for timber.
- A waterproof Schmidt hammer can be used underwater to measure concrete compression strength in-place.
- An R-meter is used to locate and measure the depth of cover and the size of reinforcing bars in concrete by inducing a magnetic field.
- Underwater magnetic particle testing equipment, typically consisting of an electromagnetic yoke and powdered metallic particles, are used to detect flaws at or near the surface of ferrous metal members. The articulating yoke is positioned on the member in question, and energized. The powdered metal particles are then sprayed over the specimen, in the area between the legs of the yoke. Discontinuities in the specimen, such as cracks, will cause a magnetic flux leakage field, which will attract the particles. As such, the inspector can readily locate deficiencies that may otherwise remain undetected.
- Parallel Seismic testing can be used to determine pile embedment lengths when as-built plans are not available. The test involves boring a hole in the vicinity of the existing pile or footing and lowering a hydrophone receiver to the bottom. While raising the receiver in small increments, a part of the foundation is struck with an instrumented hammer causing compression or shear waves to travel from the foundation into the surrounding soil. The hydrophone tracks the time it takes for the compression and shear waves to reach the receiver. By plotting the arrival times and measuring the corresponding depth of the receiver, the pile tip location can be determined.

This information is very valuable in determining a bridge's susceptibility to scour. The Parallel Seismic test can be used for steel, concrete, timber and masonry foundations (see Figure 11.3.42).

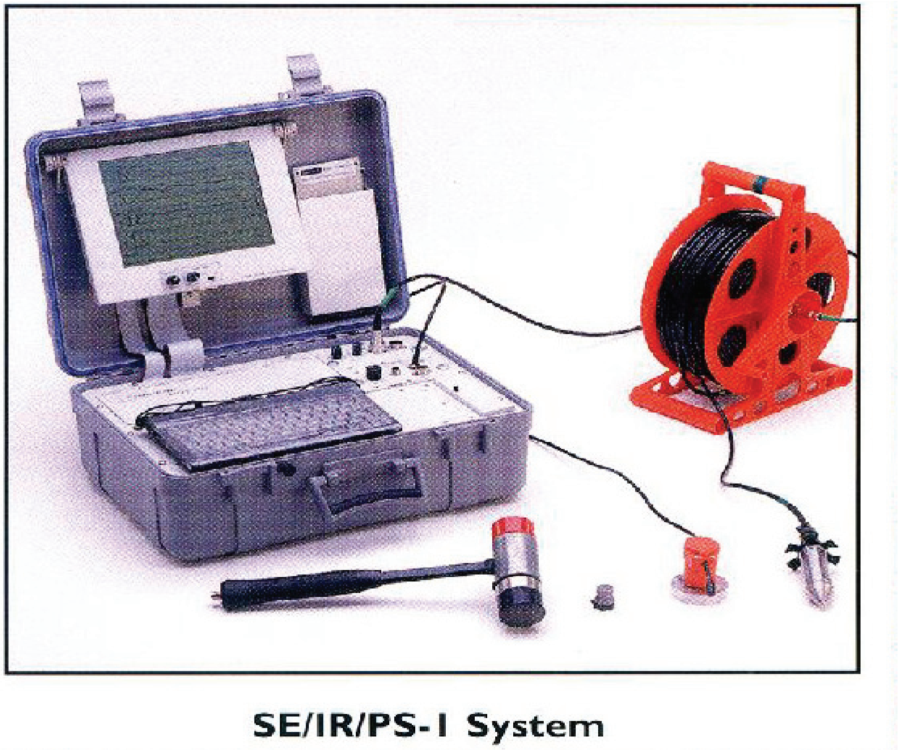


Figure 11.3.42 Parallel Seismic Testing Equipment

Coring Equipment

Coring is a partially destructive evaluation method whose use is usually limited to critical areas. Cores can be taken in either concrete or timber (see Figure 11.3.43).

Concrete coring requires pneumatic or hydraulic equipment. Deep cores (3 feet or more) can be taken to provide an interior assessment of massive substructures (see Figure 11.3.44). Two-inch diameter cores are common, but coring tools are available in other sizes (see Figure 11.3.45). Cores not only provide knowledge about interior concrete consistency but also can be tested to determine compression strength.

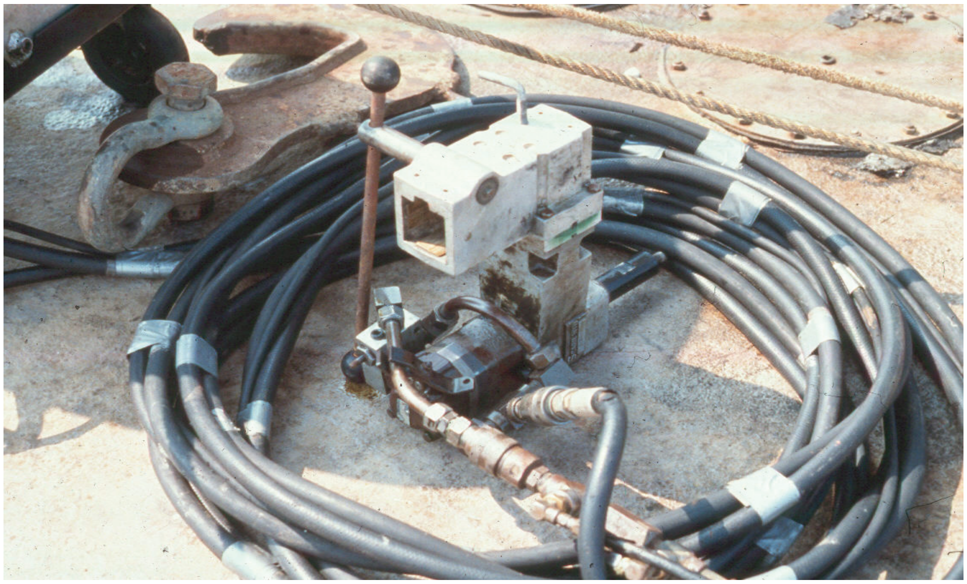


Figure 11.3.43 Coring Equipment

Figure 11.3.44 Concrete Coring Taking Place

Figure 11.3.45 Concrete Core

Timber coring is much simpler and less costly to perform than concrete coring (see Figure 11.3.46). While power tools are sometimes used, the most effective procedure is still to hand core with an increment borer. This approach preserves the core for laboratory as well as field evaluation. Examination of the core should include its compressibility, evidence of borers or other infestation, and indications of void areas. The hole should always be plugged with a treated hardwood dowel to prevent infestation.

Figure 11.3.46 Timber Core

Underwater Photography and Video Equipment

Cameras come with a variety of lens and flash units. In some cases, visibility is limited and the camera must be placed close to the subject. Wide-angle lenses are therefore most often used (see Figure 11.3.47). Suspended particles often dilute the light reaching the subject and can reflect light back into the lens. When visibility is very low, clear water boxes can be used. The boxes are constructed of clear plastic and can be filled with clean water. By placing the box against the subject area, the dirty water is displaced and the camera shot can be taken through the clear water (see Figure 11.3.48).

Figure 11.3.47 Underwater Photographer

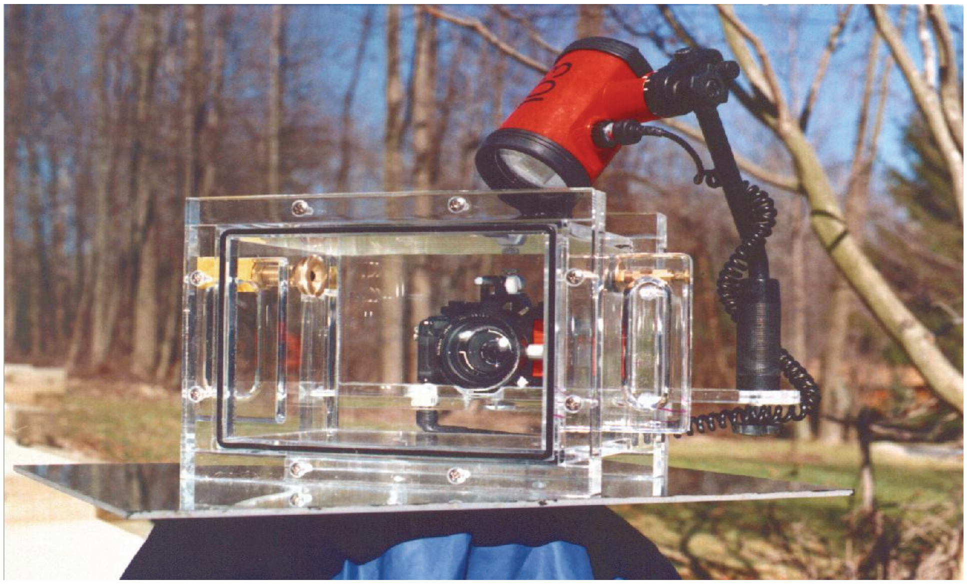


Figure 11.3.48 Camera with a Clear Box

Video equipment is available either as self-contained, submersible units or as submersible cameras having cable connection to the surface monitor and controls (see Figure 11.3.49). The latter type allows a surface operator to direct shooting while the diver concentrates on aligning the camera only. The operator can view the monitor, control the lighting and focusing, and communicate with the diver to obtain an optimum image. Since a sound track is linked to the communication equipment, a running commentary can also be obtained.

Figure 11.3.49 Underwater Video Inspection

An extension of the video camera is a remotely operated vehicle (ROV), where the diver is eliminated and the camera is mounted on a surface controlled propulsion system. Its effectiveness diminishes substantially in stream velocities greater than 0.8 m/s (1.5 knots) and is limited by cloudy water, inability to determine the exact orientation and position of the camera, and control sensitivity. Also important to note is that an ROV cannot typically perform cleaning operations prior to photos being taken.

11.3.11

Special Considerations for Underwater Inspections

Once a diver enters the water, their environment changes completely. Visibility decreases and is often reduced to near zero, due to muddy water and depth. In many cases, artificial lighting is required. There are times when tactile (by feel) inspections are all that can be accomplished, significantly compromising the condition evaluation of the element(s) being inspected.

The diver not only has reduced perceptual capabilities but is less mobile as well. Maneuverability is essential for underwater bridge inspections. With either self-contained or surface-supplied equipment, the diver may find it useful to adjust his/her underwater weight to near buoyancy and use swim fins for propulsion.

Dealing with Current

Most waterways have low flow periods when current will not hinder an inspection. Diving inspections should be planned with this consideration in mind. Divers can work in current below 0.8 m/s (1.5 knots) with relatively little hindrance. As current increases, special precautions are required. Bottom anchors, shielding devices, and special anchoring/tethering systems may be required, depending upon the site-specific conditions encountered at the bridge (see Figure 11.3.50).

Figure 11.3.50 Diving Inside a Cofferdam

Obviously, waterway conditions may sometimes be too swift to allow safe diving operations (see Figure 11.3.51).

Figure 11.3.51 Excessive Current

Dealing with Drift and Debris

The drift and debris that often collects at bridge substructures can be quite extensive (see Figure 11.3.52). This type of buildup typically consists of logs and limbs from trees that are usually matted or woven either against or within the substructure elements. Often this debris is located on the lower parts of the substructure and cannot be detected from the surface. The buildup can be so thick as to prevent access to major portions of the underwater substructure.

Removal, past history, and safety are concerns that must be addressed in dealing with the presence of drift and debris.

Figure 11.3.52 Debris

Since drift and debris are often under the water surface, it is difficult to estimate the time and cost required to remove and gain access. The removal of the drift and debris must be provided for if an inspection of the underwater elements is to proceed. While in some cases it can be removed by the inspection divers, heavy equipment, such as a hoist or underwater cutting devices, are often required.

Generally, such buildup occurs in repetitive patterns. If previous underwater inspections have been conducted, the presence of drift can be estimated based on past history. Also, certain rivers and regions tend to have a history of drift problems, while others do not. Knowledge of this record can help predict the likelihood of drift. A separate drift removal team, working ahead of the dive inspection team, could possibly be utilized.

Divers must also have a safety concern about the buildup of debris near a bridge. Occasionally, debris can be quite extensive and can lead to entanglements or sudden shifts which might entrap the diver. Divers normally approach debris from the downstream side to avoid entanglements (see Figure 11.3.52).

Cleaning

Bridges on many inland waterways are relatively clean and free of marine growth. In such cases, the inspection can be conducted with little extra effort from the diver other than perhaps light scraping.

In coastal waterways, the marine growth can completely obscure the substructure element and may reach several inches or more in thickness (see Figure 11.3.53). The cost of cleaning heavily infested substructures may be completely impractical. In such cases, spot cleaning and inspection may be the only practical alternative.

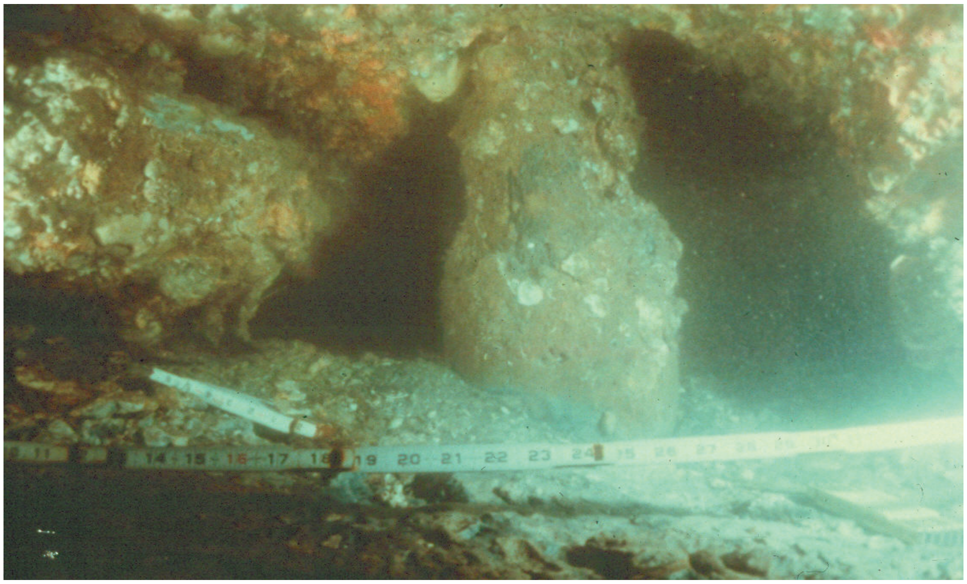


Figure 11.3.53 Cleaning a Timber Pile

Physical Limitations

This sometimes cold, dark, hostile underwater environment can result in a reduced physical working capacity. The diver is also totally dependent on external life support systems, which adds psychological stress. Things that can be done intuitively above water must be conscientiously planned and executed step-by-step underwater. For example, maintaining orientation and location during an underwater inspection requires continual attention. Distractions are plentiful and range from living organisms, such as fish, snakes, and crustaceans, to environmental conditions, such as cold, high current, and debris.

Decompression Sickness

Since the majority of bridge inspections are in relatively shallow water and of relatively short duration, decompression problems rarely occur. However, multiple dives have a cumulative effect and the no-decompression time limit decreases rapidly at depths greater than 50 feet. Therefore, divers should routinely track their time and depth as a safety precaution. OSHA requires that a decompression chamber be on-site and ready for use for any dive made outside the no-decompression limits or deeper than 100 feet of seawater.

Marine Traffic

Another hazard is vessel traffic near the dive area. There should always be someone topside with the responsibility of watching boat traffic (see Figure 11.3.54). In addition, flags should be displayed indicating that a diver is down. The international code flag "A", or “Alpha” flag (white and blue), signifies that a diver is down and to stay clear of the area. OSHA requires this flag. However, it is also prudent to display the sport diver flag (white stripe on red), since it is more likely that recreational boaters will recognize this flag (see Figure 11.3.55).

Figure 11.3.54 Commercial Marine Traffic

Figure 11.3.55 Alpha (left) and Sport Diver (right) Flags