PART 4 – ADDITIONAL INVESTIGATIONS

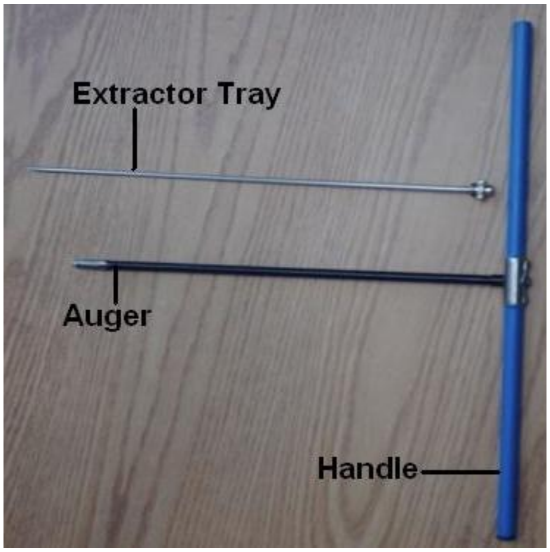

Figure 4.2.3.5 Equipment Used for Boring and Coring

Figure 4.2.3.6 Simple Application of the Boring Tool

PART 4 – ADDITIONAL INVESTIGATIONS

Figure 4.2.3.7 Wood Core Removed By an Increment Borer

Advantages

- Relatively simple and portable tools involved;
- Drilling provides a rapid initial assessment of interior deterioration;
- Coring produces a sample which can be further analyzed in detail in the laboratory;
- The core can be used to determine the depth and extent of existing preservative treatment and sound wood;
- The inspection hole is useful for the insertion of a shell depth indicator, to obtain further data.

Disadvantages

- Interpretation of shavings and cores subject to experience of inspector, or must be sent to approved laboratory for analysis;
- The surface treatment is interrupted by the inspection hole which must be treated and plugged.

4.2.3.5 Shell-Depth Indicator

A shell-depth indicator is a metal bar or rod which is notched or hooked at one end and inscribed with ruled markings along its length (Figure 4.2.3.8). The hooked end is inserted into the inspection hole and pulled back along the side of the hole. As it is removed, the hook will be easily pulled through voids and decayed areas but will catch on the edges of solid sections (Figure 4.2.3.9). The inspector can thus determine the depth and extent of decay and remaining solid portions as read from the ruler markings.

PART 4 – ADDITIONAL INVESTIGATIONS

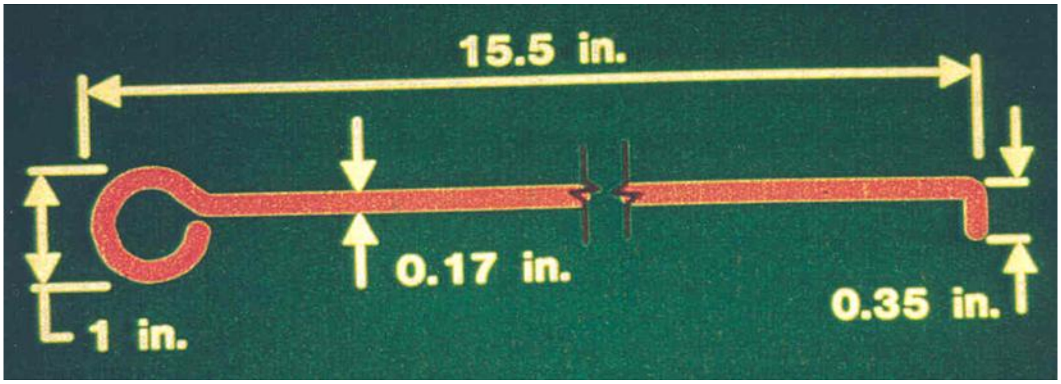

Figure 4.2.3.8 Schematic of a Shell Depth Indicator

Figure 4.2.3.9 Use of a Shell Depth Indicator

Note: the wood member has been partially sectioned to illustrate the application of the indicator.

Advantages

- Highly portable and easy to use;
- Can determine depth of decay

PART 4 – ADDITIONAL INVESTIGATIONS

- Can be used to estimate residual strength.

Disadvantages

- Needs to be used in conjunction with drilling or coring;

4.2.3.6 Sonic Testing

Several methods, including sonic wave velocity, acoustic emission and stress wave analysis have been used for examining wood. These methods typically involve the use of devices which emit and pick up sound waves as they travel over the surface and through the depth of the wood. The variations in the travel time of the sound waves are recorded and can be related to the residual strength of the member. No direct indication of decay is obtained.

The basis for these methods is that the characteristics of a sonic wave are altered in some fashion as it passes through decayed and softer areas. With further development, these methods will offer a significant advancement in the accurate detection of decay and deterioration.

A typical device used for sonic testing is shown Figure 4.2.3.10.

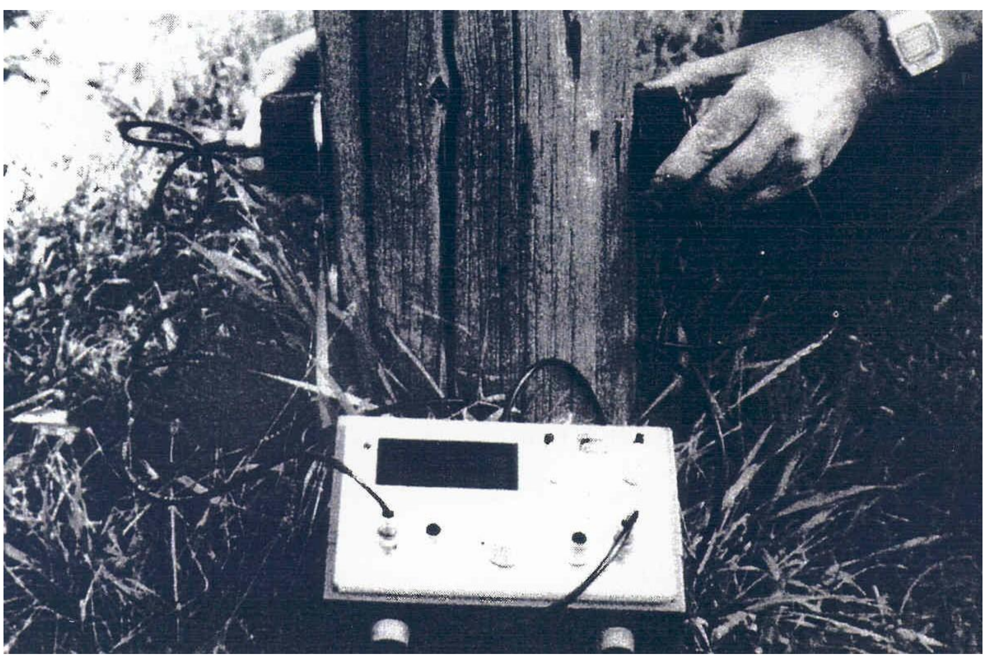

Figure 4.2.3.10 Typical Sonic Testing Equipment

Advantages

- Can determine the approximate location and area of deterioration through differential application;
- Portable
- Calibrated to give the residual strength of the component.

Disadvantages

- Still developmental to some extent;
- Cannot be used in the saturated zone at the water line;
- Requires special training in the use of the equipment;
- Core samples must be obtained and analyzed to confirm decay or deterioration and to determine the cause.

4.2.3.7 Ultrasonic Testing

Ultrasonic testing of timber is similar to sonic testing in that the variations in travel time of sound waves is measured and evaluated to provide an indication of the residual strength of a member. High frequency sound waves are induced into the wood by means of a transducer and picked up by another mounted on the opposite side.

Advantages

- Can determine the approximate location and area of deterioration;
- Can be used to evaluate the saturated zone at the water line;
- Portable

Disadvantages

- Still developmental;
- Requires special training in the use of the equipment and in the interpretation of the observations
- Core samples must be obtained and analyzed to confirm decay or deterioration and to determine the cause.

4.2.4 Post-Inspection Procedure And Treatment

Several of the inspection methods and tools described involve the removal or destruction of a portion of the wood. These locations, such as at drill and probe holes, will become entry holes for insects and decay. All the surfaces at these locations must be thoroughly treated with an approved preservative following the inspection. Holes should be plugged for their full length with treated wood plugs or dowels, slightly larger in diameter than the hole.

Generally, treatment with creosote or copper naphthenate is sufficient for bridge components.

Failure to carry out a post inspection treatment can result in development or acceleration of decay at inspection locations.

PART 4 – ADDITIONAL INVESTIGATIONS

A summary of the methods typically used for detection of defects and deterioration in wood is given in Table . This table is provided for the purposes of relative comparison of each method, and to assist the user in selecting a suitable method for a particular application.

Table 4.2.4.1 Comparison of Methods for Detecting Deterioration in Wood

	Surface Deterioration		Internal Deterioration		
Inspection Method	Exterior	Shallow Depth	Voids	Insect Attack	Decay
Probing	G	F	N	N	N
Pick Test	G	F	N	N	N
Pilodyn	G	G	N	N	N
Sounding	N	G	F	P	F
Moisture Meter	G	G	N	P	P
Drilling & Coring	N	N	G	F	G
Shell Depth Indic.	N	N	G	F	G
Sonic	N	N	F	F	F
Ultrasonic	N	N	F	F	F
Radiation	N	N	G	FG	

Legend: G - Good F - Fair/Marginal P - Poor N - Not suitable

4.2.5 References For NDT Of Wood

1. ASCE technical Committee on Wood, Evaluation, maintenance and upgrading of wood structures, A Guide and Commentary. Prepared by the Subcommittee on Evaluation , Maintenance and upgrading of Timber Structures under Technical Committee on Wood, ASCE, 1982.
2. Core H.A. and Cote W.A. Wood Structure and Identification. 2nd ed. Syracuse University Press, Syracuse, NY, 1979
3. JANEY J.R. Guide to investigation of structural failure. Report prepared for ASCE Research Council on Performance of Structures, ASCE, 1986.

PART 5 – UNDERWATER INSPECTIONS

5.1 INSPECTION OF SUBMURGED COMPONENTS

5.1.1 General

A significant number of Ontario bridges are built over waterways with abutment or pier foundations either partly or totally submerged. These components cannot be thoroughly evaluated from the water surface and must be occasionally inspected below to determine their condition and state of deterioration.

The underwater environment, in fresh water, is generally benign to all usual construction materials. Conditions beneath the surface of the water are relatively constant throughout the year and vary insignificantly from year to year. Material which is continuously submerged remains saturated and there is little oxygen available to promote deterioration. The pH of most surface water is close to neutral and temperatures below the surface vary over a narrow range between a minimum of approximately 0o to a maximum of about 20°C.

The rate of deterioration of construction materials continuously submerged in fresh water in general is no greater than in the atmosphere and usually is much less. This does not apply to portions of the structure in the wave zone that are frequently exposed to the most severe conditions of both the water and the atmospheric environment. Conditions encountered here are conducive to rapid deterioration (in spite of the fact that steps are normally taken to mitigate deterioration; concrete is air entrained, steel is painted with protective coatings and timber is pressure treated with a wood preservative) and this area must be carefully inspected. Any deterioration occurring below the water surface will be evident at the water line and this area should be observed during all routine inspections.

Another critical area for all structures founded in water is at the interface with the material underlying the foundation. Here, deterioration of the construction materials is not a significant problem compared to the potential for erosion of the stream bed under and around the foundation.

With respect to the personnel performing an inspection, the underwater environment is hostile. It is cold, particularly when one is submerged for an extended period of time, usually dark and frequently loaded with sediment to the point where no light penetrates.

A wide variety of methods have been developed for underwater inspection. Several of these techniques are described ranging from low water wading, skin diving, and diving with SCUBA or a surface supported air supply. Each method has particular applications and can provide reliable information on the condition of the structure. The use of divers using SCUBA or a surface supply is regulated by the Department of Labour and the "Diving Regulations", O. Reg. 634/86 of the Occupational Health and Safety Act are rigidly enforced.

During any underwater investigation, all structural components are visually inspected, where visibility permits, or examined tactually. Observed conditions are recorded through notes and taped recordings of voice communications between the diver and the surface, underwater photography with a hand held still camera or video or with a remotely operated robot when conditions demand its use. Remote observations can also be made using sonar or ground penetrating radar.

5.1.2 Safety

Working on or near the water in any capacity involves a great degree of risk and precautions must be taken to ensure the safety of all personnel. The inspection team should be comprised of no less than three persons who are always in visual contact and each must wear a DOT approved personal floatation device. Additional safety procedures which must be followed are identified in Part 2, Section 2.1.3.

Inspection work performed by a diver, whether with SCUBA or a surface air supply, is governed by the "Diving Regulations" under the Occupational Health and Safety Act which require the team to be comprised of at least three persons, the diver, a stand-by diver, and a tender. One of them must be identified as the Dive Supervisor who must not enter the water while the work is in progress. In addition, the Regulations clearly identify the minimum equipment requirements as well as safety precautions. Under the Act, the ultimate responsibility for the safety of the workers lies with the employer so it is incumbent upon the owner to ensure that those employed for this work are competent and qualified to carry it out.

5.1.3 Training and experience

Visibility beneath the water surface is often restricted and the entire bridge component may not be visible. The overall condition must therefore be pieced together from a series of observations of discrete segments. A meaningful assessment will depend upon the inspectors ability to understand what he sees, or feels, and how it relates to the overall structure and its integrity. The underwater inspector should be knowledgeable in bridge design and construction details and should know where to look for specific problems and common defects. Alternately, a diver lacking this experience must be in direct voice contact with a knowledgeable and experienced inspector on the surface who can direct the investigation and evaluate the observations during the course of the work.

All underwater investigations should be carried out under the direct supervision of a Professional Engineer who can certify the completeness and correctness of the work.

When the inspection is carried out by a diver, all members of the diving team must be fully trained in the use of all diving equipment and devices and in the performance of underwater work.

5.1.4 Non-Destructive Testing Of Underwater Structures

Non-destructive testing techniques similar to those used above water can be applied to quantify any defects identified below the water surface but in each case the equipment and procedures require modification. These techniques are listed again with considerations for underwater use.

PART 5 – UNDERWATER INSPECTIONS

5.1.4.1 Ultrasonic Testing

Ultrasound techniques can be used effectively under water. When used underwater, the transducers must be enclosed in a waterproof housing. The method is used extensively to determine the residual thickness of metal sections when only one surface is exposed or when quick, accurate measurements are required of any component. Because the water provides a sound connection of the transducer and the section being measured, a couplant is not required.

Ultrasonic testing of concrete under ideal conditions is difficult to successfully carry out. This is due to the unique cracking patterns that develop in the material and block the sound waves. The problems encountered are compounded underwater and although it can be used, the results are not always reliable.

When this technique is used for wood inspection the equipment must be calibrated for saturated timber material. Residual strength of the timber can be determined through the application of empirical methods and formulas which are dependent upon the wood species. Relative measurements can be made for a single component by comparing observations from a questionable area to those from at a known sound location within the same member. Care and experience are required to assess the results obtained.

5.1.4.2 Magnetic Particle Inspection

Magnetic particle testing techniques are also used underwater for cracks or discontinuities in the surface of components. The process is the same as used on the surface except the magnetic particles are in a water suspension of fluorescent dye (Figure 5.1.4.1). The flux leakage at the defect creates an accumulation of the coloured particles indicating location and size. This deposit can be measured and photographed to create a permanent record. The surface still must be cleaned with a wire brush or a waterjet.

PART 5 – UNDERWATER INSPECTIONS

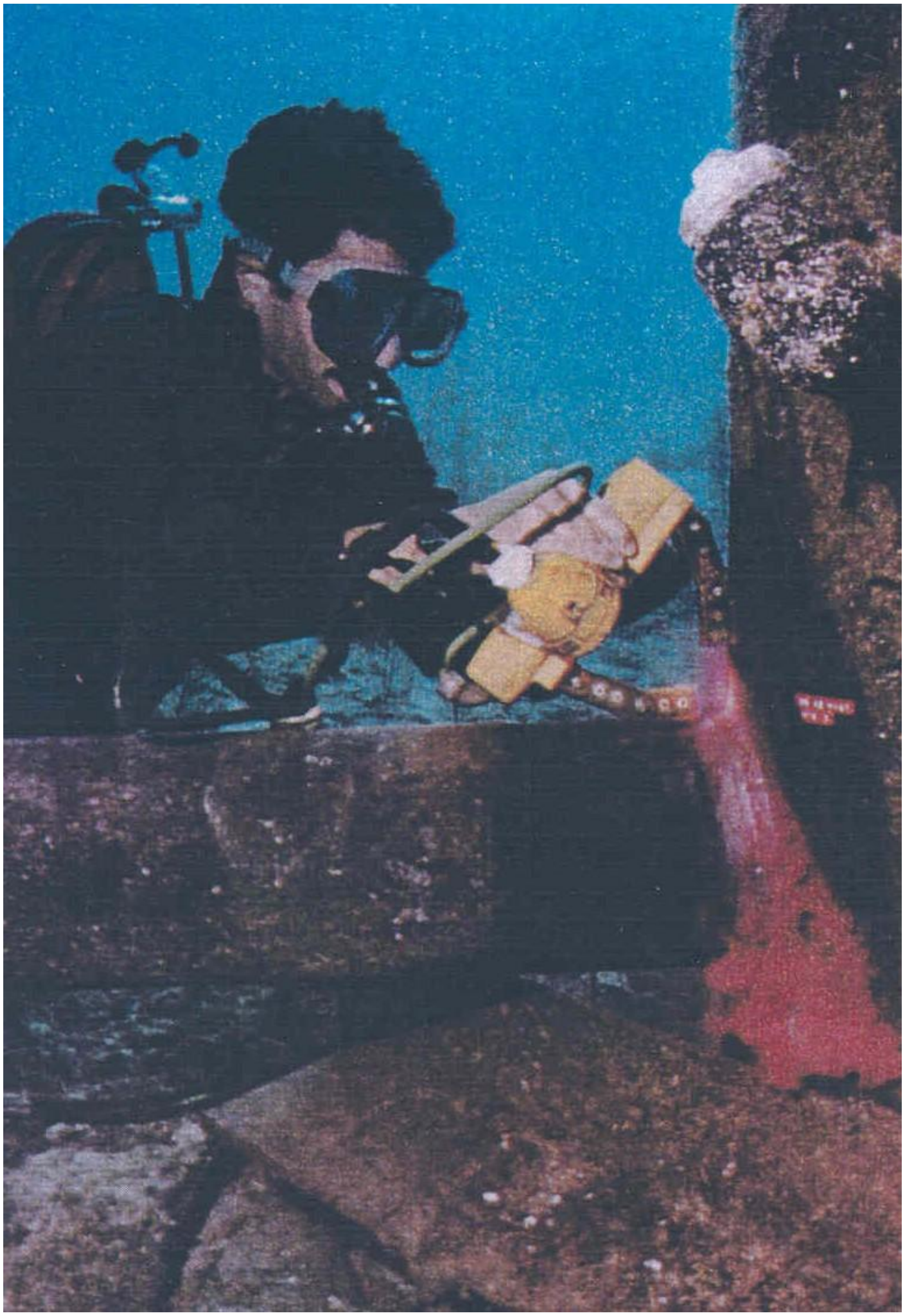

Figure 5.1.4.1 Underwater magnetic Particle Inspection

5.1.4.3 Eddy Current

Eddy current techniques can be used effectively underwater to locate defects in or near the surface of conductive components, as described in Part 5, Section 5.1.4. Ultrasonic methods are then required to quantify the size and extent of noted defects or deficiencies. The method requires a skilled diver who is also a highly trained testing technician to use the equipment and interpret the results. The greatest advantage of this system is that cleaning of the surface is not as critical as with other methods.

5.1.4.4 Radiography

Radiography is not readily adapted for underwater use and is not normally used in this environment. When conditions require the degree of detail available through the use of this technique, gamma radiation is most readily utilized but all water must be evacuated between the radiating source and the object under test.

5.1.4.5 Coring

Coring of concrete is partially destructive and consideration must be given to repair of the cavities produced where cores are removed. Cores can be tested in accordance with approved procedures to verify and correlate data obtained by other means. They can be obtained underwater with purposely designed drills or from the surface by drilling vertically downward through the structure.

5.1.4.6 Sounding

Tonal qualities of sound produced in timber and concrete, underwater, by a hammer are different than those produced above. The difference will be noted when comparing sound wood or concrete to that harbouring significant decay. Sounding may identify the presence of decay and can provide a rapid indication of the extent of significant deterioration.

5.2 EQUIPMENT AND TOOLS

5.2.1 Hand Tools

To effectively carry out an underwater inspection, the diver must have available an assortment of hand tools to facilitate cleaning, chipping, sounding, measuring etc. Many of those used in a Level 1 Inspection for identification of deterioration and quantifying its extent are also utilized in a Level 2 Inspection to determine limits of probable deterioration or deficiencies, and for quantifying size, location, distribution and severity. Where samples of material are required, power tools may be needed for cutting or coring. Extensive problems may require two or more divers in the water at the same time who must be in direct voice contact with each other.

A variety of equipment is required for underwater inspection purposes, and this can include almost all hand tools normally used during a structural inspection of any structure above water. Those most commonly employed underwater are illustrated in Figure 5.2.1.1.

PART 5 – UNDERWATER INSPECTIONS

Figure 5.2.1.1 Typical Hand Tools for Underwater Inspections

5.2.2 Power Tools

Work of any nature underwater is physically demanding and where excessive effort is needed to achieve results, power tools should be considered. These can include high pressure pumps where extensive cleaning is required, and pneumatic and hydraulic power tools such as saws and drills. The latter must be purposely designed to avoid environmental contamination.

5.2.3 Photography

In all instances where deterioration or defects are identified they should be recorded photographically if at all possible. The diving inspector should be equipped with an underwater camera or a land camera in a water-tight housing. To record small details like cracks in structural members or pits due to corrosion, a close-up lens is required. A "clear water" prism is to be used where visibility is reduced due to sediment or suspended solids.

Underwater video systems provide another means for recording observations. These must be produced with a real time commentary by the diver describing what is being recorded. In addition, a referencing system must be used to graphically identify the location on the structure of what is being viewed on the screen.

Remotely operated vehicles equipped with a video camera provide a means for the inspector to visually inspect the submerged portions of a structure without putting a diver in the water. The equipment must be used with some form of grid system to monitor the location. All observations must be interpreted immediately by the inspector and recorded on the tape as it is produced.

5.2.4 Notes And Observations

The most practical means for recording observations made underwater by a diver is to record voice communications during the inspection on tape. In addition, the diver should be equipped with some means to produce sketches, while submerged, that will illustrate the observations.

5.3 FREQUENCY OF INSPECTION

5.3.1 Routine Inspections

The inspection of the area at the water line is a part of the Routine Visual Detailed Inspections which will identify the need for a more thorough underwater inspection of the submerged portions of the structure.

Conditions at each structure vary considerably and the requirement for regularly scheduled underwater inspections cannot be generalized. All structures with submerged components should be inspected below the water surface at least once. This should be undertaken as soon after original construction as possible to facilitate early remedial action to rectify any construction defects or deficiencies.

The need for additional underwater inspections will be identified at the time of the initial inspection if potential problems are identified, or through the routine bridge inspection program.

Whenever an underwater inspection is warranted the minimum level of effort should be a Level 1 Visual Inspection due to the relatively high cost of mobilizing a dive team to the bridge site. Such an inspection of the entire structure can be carried out relatively quickly in the presence of minimum deficiencies and will ensure that any defects are identified and documented.

Concrete structures will experience little in the way of deterioration below the critical zone at the water line. Once the structural element in this region has been determined adequate it need not be inspected again until other major rehabilitation is required. Such structures on bedrock foundations may never need another underwater inspection.

Structures on soil foundations will require regularly scheduled underwater inspections to evaluate the stability of the stream bed adjacent to structural components and as part of this assessment a Level 1 Inspection of the structure can be incorporated. The timing of these inspections will be dependent upon the foundation material and its susceptibility to erosion. For structures in good repair, in a non-aggressive environment and on stable foundations these inspections can be scheduled at 10-year intervals. Where the stream bed is more prone to erosion the interval should be reduced to 5 years. Where stream bed erosion is a significant problem, some other means should be devised to monitor it.

Zebra mussel infestations are creating unusual problems for structures where they are established. As they grow and multiply an anaerobic environment is created at the surface of the substrate which is conducive to the development of sulphur compounds. These result in microbial induced corrosion of steel components which can be considerably more aggressive than normal oxidation. The impact of the resulting sulphates on a concrete substrate is known to exist but is yet to be evaluated. Where these creatures are established, particularly on steel components, monitoring on a yearly basis will be required in order to quantify the resulting deterioration. Their complete removal should be attempted only if all exposed surfaces are to be given a protective coating to isolate them from further infestation and to inhibit galvanic corrosion.

5.3.2 Non-Routine Inspections

Non-routine underwater inspections will be required as a result of an unusual event such as after impact by a vessel, exceptional ice conditions or accumulations of debris or where there is evidence of foundation movement. At locations with scour prone stream beds, an underwater inspection should be carried out after any exceptional flood event. This will normally be a Level 1 Inspection and will identify the need for a more thorough assessment.

5.4 INSPECTION PROCEDURES

5.4.1 Existing Data

Before an underwater inspection is carried out, the Inspector should review the as-built or construction drawings of the structure, details of any restoration or rehabilitation work carried out on the submerged portions and all previous inspection reports in order to monitor the progress of known defects or deterioration.

5.4.2 Wading

Where the water depth is relatively shallow (less than about a metre), the river bottom is reasonably hard and there is little or no current, the submerged components can be inspected during the regular routine inspections with the inspector wearing chest waders and a personal floatation device. The critical area for observations is at and immediately below the water line, and this can be readily inspected while wading. In clear water, observation below the surface can be made with the use of a simple viewing tube as illustrated in Figure 5.4.2.1 or with a conventional face mask. Where visibility below the surface is limited, the critical area can be examined tactually. During a wading inspection, the condition of the stream bed adjacent to the structure can also be evaluated.

PART 5 – UNDERWATER INSPECTIONS

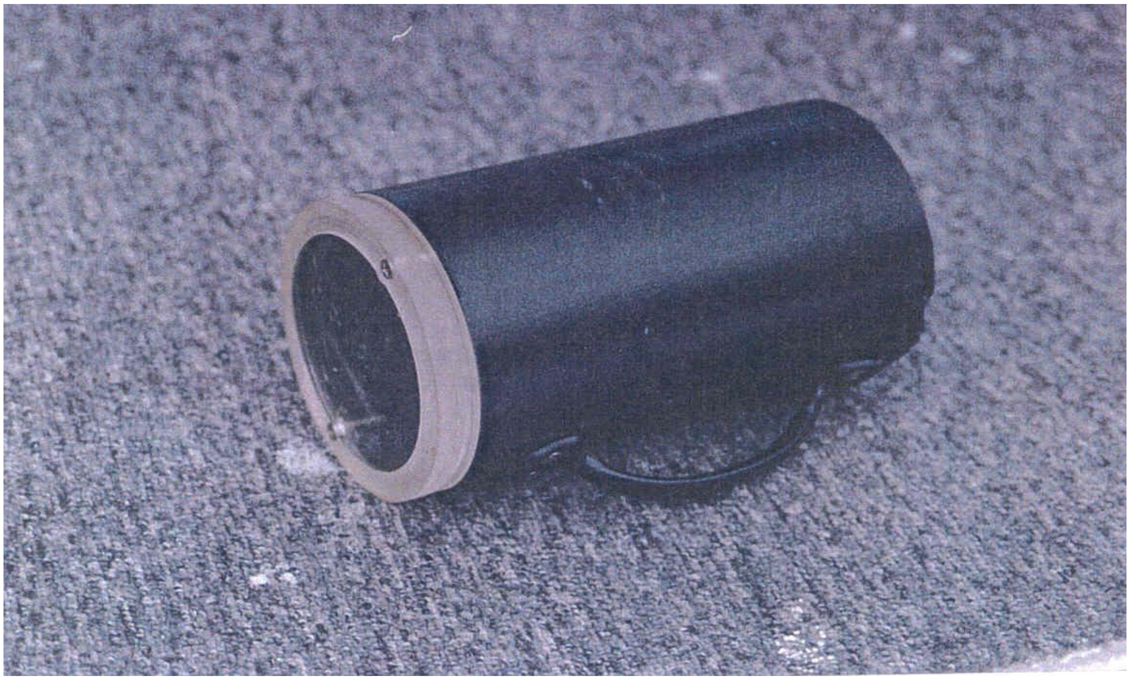

Figure 5.4.2.1 Underwater Viewing Tool

5.4.3 Skin Diving

An underwater visual inspection in shallow, clear water may be carried out from the surface by an inspector who is competent and comfortable when skin diving with a face mask, swim fins, and a snorkel. The critical area at the surface will be clearly visible as should the stream bed at the base of the foundation.

Although skin diving is not regulated by the Ministry of Labour, Immigration, Training, and Skills Development of Ontario, it must be carried out in a manner that will not jeopardise the safety of the diver. The skin diver must be tethered to a float on the surface or to another member of the inspection team on shore or in a boat.

5.4.4 Deep Diving

Where the depth is more than about a metre, particularly where there is limited visibility, most underwater inspections will be carried out by a diver equipped with SCUBA or a surface air supply. With this equipment there are few limitations. The diver can work at any depth encountered at bridges in Ontario and under all conditions of flow and visibility.

Underwater inspections can be carried out most readily using SCUBA due to its convenience and mobility but under some circumstances a surface air supply will be essential for a thorough examination of the submerged portions of a structure. The type of equipment needed for the specific site must be identified through a Site Reconnaissance Survey by the Diving Supervisor before commencing the inspection to determine water depths, flow conditions, unusual potential hazards, underwater visibility, special tool or inspection procedure requirements, etc.

5.4.5 Remote Operated Vehicles (ROVs)

ROVs are self-propelled underwater video platforms, powered either by onboard batteries or an electric tether. They can carry cameras, sonar, and other inspection tools, with operators viewing real-time video and controlling the unit from the surface. ROVs are effective for deep, inaccessible, or hazardous locations where divers cannot safely operate. However, their use is limited by tether length, potential entanglement, difficulty determining precise orientation, and impracticality in strong currents or highly turbid water.

Key considerations:

- ROVs are suitable for assessing submerged structural components.
- Operators must be trained and qualified in underwater inspection technologies.
- All sonar and imaging data must be properly recorded and archived.
- ROVs cannot replace divers when tactile inspection is required (e.g., probing timber, hammer sounding concrete, or checking for scour depth).

5.5 LEVELS OF INSPECTION

5.5.1 Levels of Inspection

With all structures in the fresh water of Ontario, deterioration of underwater components is generally going to occur at and just below the water surface and at the interface with the soil. The most severe deterioration of all materials will be in the wave zone where they are exposed to the deleterious affects of both the water and the atmospheric environment. Erosion of the stream bed and undermining of the structure is the greatest concern at the bottom. Between these two locations, little if any significant problems due to deterioration will develop except possibly in acidic streams. This may result in deterioration of all submerged components and dictate the need to assess all exposed surfaces.

One exception is masonry structures which can experience the softening and loss of mortar from all the joints in the exposed surfaces.

Another is structures infested with zebra mussels. These animals are found in the continuously submerged zone below that affected by seasonal conditions such as exposure, wave action and abrasion from ice and debris.

When an underwater inspection is to be performed the initial approach will be a visual inspection using simple, non destructive testing techniques. This should identify and describe any deficiencies in sufficient detail for a structural evaluation of the problem and form the basis for any further detailed inspection. The level of detail required will dictate the procedures and equipment to be used.

5.5.2 Level 1 – Visual Inspection

A Level 1 Inspection will provide a visual or tactile examination of the exposed underwater surfaces of a structure in sufficient detail to detect major damage or deterioration and to confirm the continuity of all structural elements. It will provide a general assessment of the condition of the submerged components and will identify the need for a more detailed inspection.

At the surface, abrasion resulting from floating ice and debris will usually provide a clean surface for observations. Below the wave zone, representative areas at known locations for potential problems such as welds, pile interlocks, connections and connectors may require cleaning with a scraper and a wire brush to remove algae or other aquatic growths in order to expose the substrate.

Concrete and timber structures can be sounded with a hammer to provide a qualitative assessment of the materials beneath the surface. In the wave zone, timbers are to be carefully probed for indications of internal decay.

The interface between the structure and the stream bed will be examined for indications of active or incipient erosion. Where there is active erosion, characteristic depressions will be observed at the upstream face of the bridge piers and abutments. Where the stream bed is in a state of dynamic stability, material being brought into the site over a period of time is essentially equal to that being carried away, probing of the bottom with a steel rod to evaluate the relative density of the stream bed material may indicate the depth of active scour under flood flow conditions. Any observed signs of erosion are to be noted and measured.

Structural deficiencies will be apparent in the exposed portions of the structure. The extent of any such defects should be traced below the water surface.

Any observed defects or deficiencies are to be noted as to size and location. Significant structural defects are to be measured and photographed in sufficient detail to facilitate a preliminary structural assessment to evaluate their impact on the safety and integrity of the structure. This assessment will confirm the need for a Level 2 Inspection.

Where excessive corrosion is found or suspected, macro photos of the cleaned surface are required for evaluation and future comparisons.

5.5.3 Level 2 – Detailed Inspection

A Level 2 Inspection is a highly detailed inspection of critical structural elements where extensive repairs or possible replacement is anticipated. It will be carried out in response to the structural evaluation of deficiencies identified by a Level 1 Inspection or to investigate obvious underwater deterioration or defects manifested in the structure above the surface. This will usually entail extensive cleaning of the structural elements to remove all algae and biofouling, obtaining detailed measurements and photographs and possibly non-destructive testing of apparent defects or of critical components. Sampling of materials for analysis and testing may also be required. These procedures will be at identified defective areas or at locations which are representative of the critical submerged portions of the structure. The specific procedures to be used will be dependent upon the type of material and its position in the structure.

5.5.3.1 Detailed Inspection of Steel Structures

The detailed inspection of steel structures will be directed primarily toward the joints and fasteners with particular attention being given to welds and the adjacent heat affected zones and known stress raisers. Cleaning of the components will be carried out with a wire brush or a waterjet to expose bare metal for a careful and thorough visual examination. Where defects are identified or suspected the area can be further examined using non-destructive evaluation techniques such as ultrasound, magnetic particle or eddy current as described in Part 5, Section 5.1.4 and below.

The extent of corrosion will be noted and where it appears to be excessive, the residual thickness of the material should be measured. Mechanical fasteners will be examined for corrosion and tested for tightness.

Where the structure is comprised of standard rolled sections measurements of representative elements can be obtained using conventional measuring devices once the exposed surfaces have been cleaned. Flanges of "H" piles can be measured using an outside calliper, vernier calliper or a micrometer. Where it is necessary to determine the web thickness a modified calliper as illustrated in Figure 5.5.3.1, may be used in conjunction with a vernier calliper.

Members with only one exposed surface such as pipe piles or sheet piles can be measured using ultrasound. Discreet pits in the surface of the component should be measured for depth using a pit gauge, Figure 5.5.3.2. The density of the pitting should be recorded photographically.

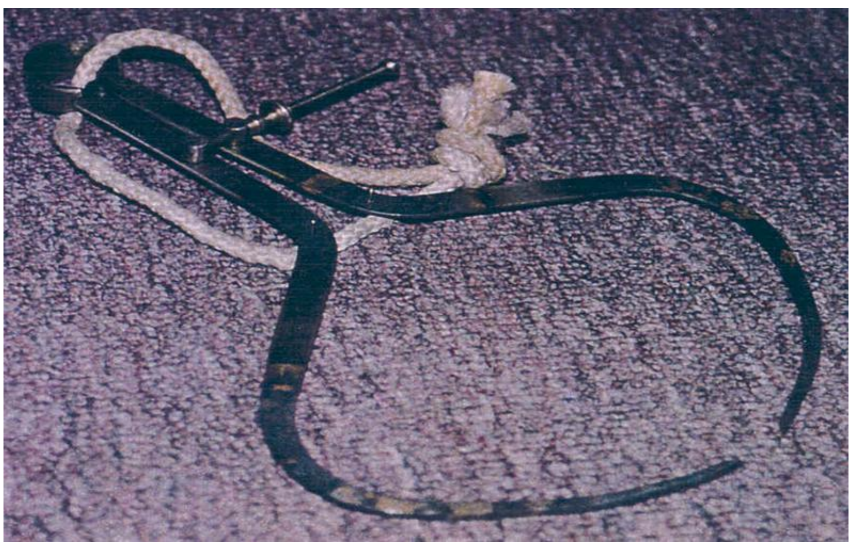

Figure 5.5.3.1 Modified Calliper for Thickness Measurements

PART 5 – UNDERWATER INSPECTIONS

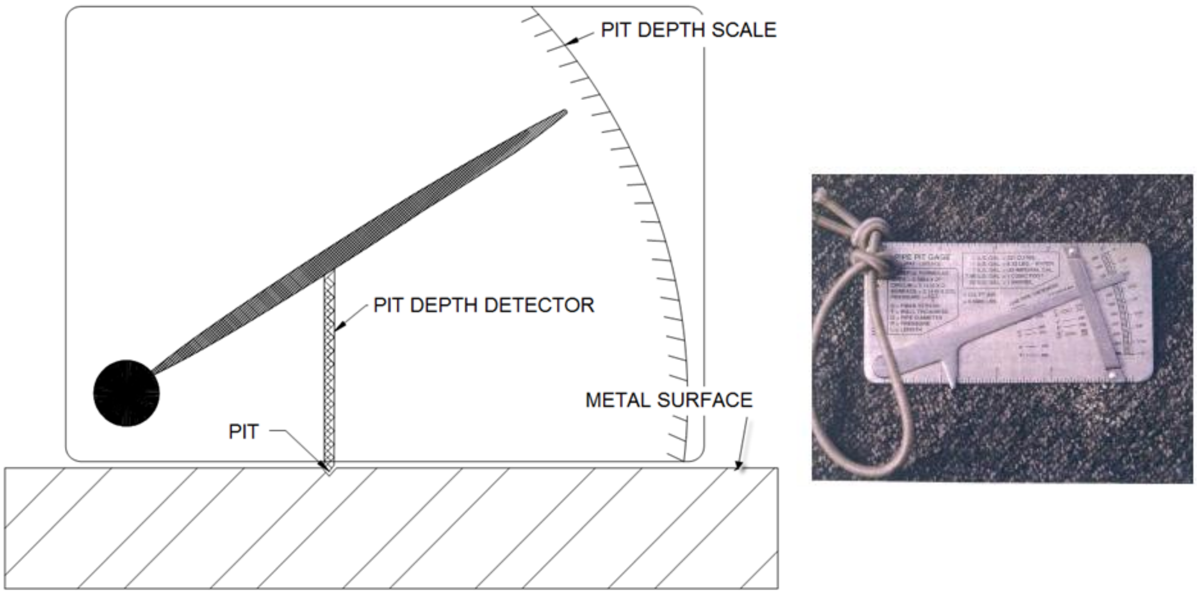

Figure 5.5.3.2 Pit Gage

5.5.3.2 Detailed Inspection of Concrete Structures

Deterioration of concrete due to exposure in fresh water is normally insignificant and a detailed inspection will be primarily to define construction defects or physical damage. This will entail a very careful visual examination with photographs of observed problems and some non-destructive evaluation techniques to define the area of concern. Several of the standard non-destructive and destructive testing procedures and equipment used to collect data on concrete components above water can be modified for use underwater.

Where general deterioration of the concrete surfaces is occurring due to high or low pH of the water, the condition will be apparent near the surface where specific tests can be carried out.

5.5.3.3 Masonry

The joint pattern in masonry structures materially limits the use of non-destructive testing procedures. A qualitative assessment of the mortar joints can be made using a chisel or screwdriver and the masonry components can be sounded with a hammer.

To quantify any observations requires core drilling vertically downward because of the extreme care required to recover even the best mortar in the joints.

5.5.3.4 Wood

The standard non-destructive and destructive testing procedures and equipment used to collect data on wood components above water, as detailed in Part 5, Section 5.1.4 can be used directly or modified for use underwater.

PART 5 – UNDERWATER INSPECTIONS

5.6 SCOUR INVESTIGATIONS

5.6.1 Scour Investigations

Bridge components in or adjacent to streams need to be investigated to determine if the bridge is scour critical. A scour critical bridge is one with abutment or pier foundations which are unstable due to scouring of the stream bed or which potentially may become unstable due to scour. This assessment will be based on a geotechnical evaluation of the site, the hydrology of the tributary drainage basin with respect to observed floods and potential floods and the hydraulics of the watercourse considering the reaches upstream and downstream of the structure as well as the water passages through it.

Each bridge should be rated on its propensity for damage due to scour based on:

- Hydraulic capacity relative to the flood potential of the tributary basin;
- Water velocity through the structure under "bank full" condition and the design flood;
- Erodibility of the stream bed;
- Stability of the watercourse, does it have a tendency to meander;

Based on soil types and the water velocity through the bridge opening the following scour potential ratings should be applied.

Table 5.6.1: Scour potential ratings based on bed material and velocity

Stream bed Material	Bank Full Velocity	Rating
Granular and Silt	< 1 m/s 1-2 m/s > 2 m/s	5 3-4 2
Clay/Till	< 2 m/s 2-3 m/s > 3 m/s	5 4 3
Shale, Limestone or Granite	> 3m/s > 5 m/s	4 4 6

A rating of 6 indicates scour will never be a significant problem whereas a rating of 3 or less indicates the need for further investigations and possible protective measures. In addition to the foregoing scour rating, each structure must be rated based on the potential for collapse or severe damage as a result of scour and its impact on the travelling public.

5.6.2 Inspection Procedures For Scour

5.6.2.1 Probing

Where the erosion potential of a bridge site is great (rated 3 or lower) the stream bed may be in a state of dynamic stability with a continuous bed load moving through the site. Under these conditions there can be very significant erosion during a flood but as the flow diminishes the stream bed is re-established at or close to its original condition. Where this condition is suspected, the stream bed must be carefully evaluated by probing or through various geotechnical techniques that can produce a sub-bottom profile of undisturbed soil.

5.6.2.2 Diver Inspections

A visual examination of the stream bed by a diver will indicate if active erosion is occurring and will identify exposed piles or the underside of spread footings. Where the stream bed is in a state of dynamic stability and infilling of erosion features has occurred, probing of the bottom adjacent to abutments and piers may reveal loose sediments as well as the depth to sound material.

5.6.2.3 Sounding

The stream bed, both upstream and downstream of the structure and within the water passages should be sounded where any potential exists for scour. Sounding is best obtained by using a recording type echo sounder with particular attention being given immediately adjacent to the abutments and piers. The position of all observations should be related to the centre line of the bridge. Where the scour rating is 3 or lower, the stream bed should be re-sounded after every spring freshet and all other significant flood events. If the stream bed stabilizes at an elevation that does not threaten the stability of the structure the soundings can be scheduled at five-year intervals and after any major flood event.

The area of concern should extend approximately 30m upstream and downstream from the face of the bridge.

A narrow beam transducer (50 or less), operating at a frequency of 200kHz or more will produce a reasonably accurate indication of the bottom profile. A wider angle will result in more extraneous signals due to reflections off the vertical surface and will be more difficult to interpret.

A scanning type of sonar with a rotating head can also be used to trace down the face of a pier and across the stream bed, identifying any cavities beneath the foundation.

Sonar equipment is reasonably portable and can generally be mounted in or on any type of boat. The results are graphically recorded on a strip chart as a permanent record, and these are easily interpreted. Weed growth on the bottom will affect the accuracy of observations and air in the water will materially affect the signal, sometimes obscuring it completely.

5.6.2.4 Sub-Bottom Profiler

A sub-bottom profile can frequently be obtained using sonar operating in the range of 50kHz or less. Such equipment will obtain reasonable penetration of the loose sediments on the bottom but with some loss of detail.

PART 5 – UNDERWATER INSPECTIONS

The equipment is similar in every respect to conventional sonar although some expertise is required for interpretation of the data.

5.6.2.5 Ground Penetrating Radar

Ground penetrating radar is a relatively new procedure for geotechnical investigations and its applications are being rapidly expanded. It is well suited to sub-bottom profiling from a boat, or from surface ice. Its greatest advantage over sonar is that the signal is not affected by entrained air.

The equipment is considerably bulkier than sonar and considerable expertise is required for computer enhancement of the recorded data and for the interpretation of the results.

5.6.3 Corrective Actions

If the scour investigations and assessment indicate that the stability of a structure is jeopardised, then appropriate actions should be taken to mitigate the problem. This will usually be in the form of armour stone or rip-rap placed on the stream bed in close proximity to the bridge components' rust condition.

Any proposed method of control will require a hydraulic analysis of the watercourse downstream of the structure and through the bridge openings to determine its impact on the capacity of the water passages and on the stability of the stream bed beyond the protection.