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## **4.6 SMALL BRIDGES (C-STRUCTURES)**

### **4.6.1 Introduction**

This chapter will discuss small bridge structures related to transportation facilities, commonly known as c-structures by the Wisconsin Department of Transportation. These structures can service waterway conveyance, provide pedestrian access under roadways, or act as a cattle/animal pass under roadways. Sections 4.6.2 through 4.6.4 discuss specific types of box and pipe culverts, which are widely used throughout the State. Culverts primarily serve to transfer open channel storm water drainage flow. Utility ducts and sewers are similar structures, which are not covered in this Manual. When box or pipe culvert are 20 feet or more in span, they are classified as bridges and are documented with element level inspection terminology discussed in Part 2 of this Manual.

### **4.6.2 Small Bridge Structures**

As discussed in Part 1 of this Manual, any structure greater than 20 feet in length is defined as a bridge per the Code of Federal Regulations. The State of Wisconsin categorizes smaller structures under two categories, Small Bridges (C-Structures) and Roadway Culverts. In general, C-Structures have a unique structural design and are inventoried and inspected under the direction of the Bureau of Structures. Structures not meeting this criteria (mainly pipe culverts) are inventoried and inspected under the direction of the Bureau of Highway Maintenance. This chapter will cover C-Structures in great detail.

Many structure types make up the small bridge inventory; In general, c-structures have clear openings of 20 feet or less measured along the centerline of the roadway. Refer to Figure 4.6.2-1 for structure length definition. The following structures shall be categorized as c-structures:

- Bridge-like structures (deck girders, flat slabs, rigid frames, etc.)
- Single and multi-cell box culverts (opening 20 square feet or greater)
- Arches
- Structures without a floor slab (including arches on footings)
- Structural plate pipe culvert or arches

Though rare, a Small Bridge may include multiple structural plate pipe culverts where the clear distance between openings is less than half of the smaller contiguous opening. In the case of multiple pipes, the structure length will be the distance from the extreme edges of the two outermost openings. A series of structural plate pipes are considered to be one structure when the clear distance between the openings is less than half the width of the smallest opening.

Nearly all pipe structures (except structural plate pipe culverts) are not considered c-structures and are inventoried by the Bureau of Highway Maintenance.



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## Chapter 6 – Small Bridges (C-Structures)

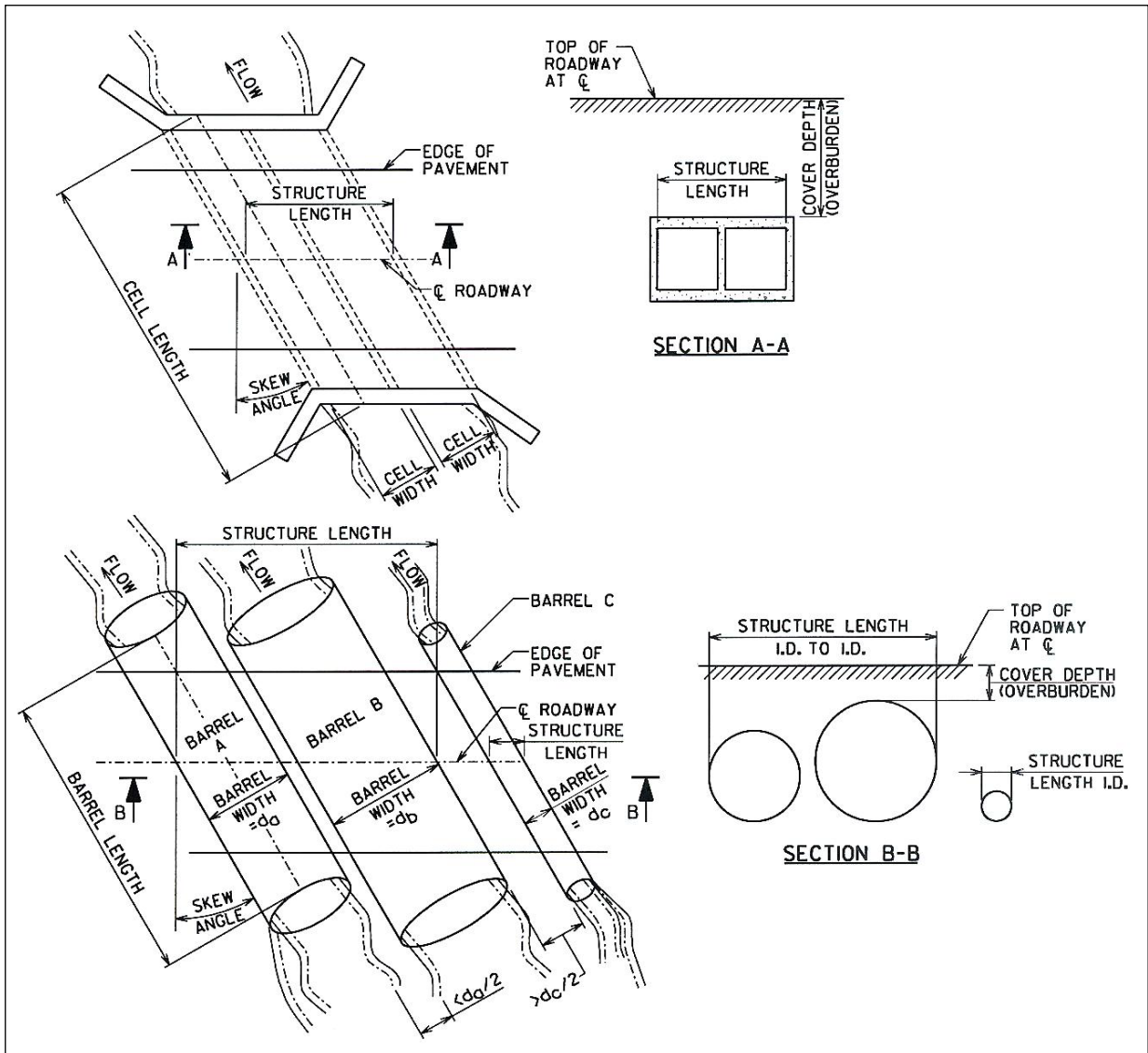


Figure 4.6.2-1: Small bridge span definitions. Note the pipes would only be considered if at least one was a structural plate pipe culvert.

Small bridge box/pipe culverts are hydraulically designed to efficiently deliver peak water flows underneath the roadway above. The hydraulic efficiency is improved when these flows submerge the inlet end of the structure. Bridges, on the other hand, are not always designed for optimum hydraulic efficiency, and may even be designed to allow water to flow over the deck under extreme flood conditions.

Small bridge box/pipe culverts generally do not have a roadway deck, and there is no distinction between substructure and superstructure. Small bridge box/pipe culverts are usually covered by roadway fill material, typically called the overburden, or an embankment. They are designed to carry the soil dead load above the structure, and also for the live loads due to traffic above. Above certain fill heights, however, live loads will arch over the structure, leaving only the soil dead loads to be carried by the structure. A small bridge box/pipe culvert's



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strength is achieved through its own material properties and lateral pressures from the surrounding soil.

Small Bridge Structures may be constructed in a manner similar to a bridge (such as using multiple rolled steel beams and a deck). Though spanning less than 20 feet, structural elements such as these should be inspected in a manner similar to a bridge as discussed in Part 2 of this Manual.

Small Bridges shall have an inspection frequency not to exceed 4 calendar years (see Part 4, Chapter 1 for more information). The structures shall be inventoried and reported within HSI. It should be noted that these structural small bridge inspections may be supplemented by hydraulic opening and debris removal maintenance inspections in accordance with Section 48 of the State Highway Maintenance Manual.

Small Bridges (C-Structures) are given “C-number” designations indicating they are not considered bridges per the FHWA guidelines, but are still inventoried and inspected with FHWA Bridge Guidelines. The inspector shall note the location (or lack thereof) of the Name ID plaque on the structure under the Structure Specific Notes within the inspection report and under the Structure ID Plaque Assessment.

### 4.6.3 Small Bridge – Bridge Like Structures

For those small bridges (clear span as measured along centerline roadway less than 20') that are constructed similar to a bridge (i.e. do not have a structural bottom), the structure shall be inspected as a bridge with all pertinent bridge elements (i.e. abutment, girders, deck, bridge railing, etc.). Refer to Part 2 for discussion and elaboration on bridge elements. Note that these structures shall be inventoried and inspected as C-structures.

The remainder of this chapter shall discuss both box and pipe culverts that qualify as small bridges.



Figure 4.6.3-1: View of Name ID Plaque located on the Wing of a Culvert End Treatment.



Figure 4.6.3-2: A bridge like structure with total length less than 20 ft. This structure is designated as a small bridge in HSI, and inspected with bridge elements.

#### 4.6.4 Small Bridge – Box and Pipe Culverts

Box and Pipe culverts are constructed of a wide variety of materials, such as concrete, steel, timber, masonry, plastic, or aluminum. This section highlights the types of culvert shapes, the structural categories of culverts, and the variety of culvert end treatments that the inspector may encounter. Discussions of the various materials used to build culverts follow in Section 4.6.6.

##### 4.6.4.1 Culvert Shapes

Many culvert shapes are present throughout Wisconsin. The shape chosen for a location may or may not be dependent upon hydraulic performance requirements. Other factors that may affect the shape of culvert chosen are structural requirements, potential for clogging by debris, and the need for a natural stream bottom. Typical culvert shapes are described below.

- **Circular:** This is the most common culvert shape. Although they are hydraulically and structurally efficient, they can reduce a stream's width, and they are more prone to clogging than other shapes. Soil pressures around circular shaped culverts are directed towards the middle of the shape, and are fairly uniform all around. Most of these assets are covered under the BHM inventory/inspection program.



Figure 4.6.4-1: View of circular structural plate pipe culvert.

- **Pipe Arch:** This shape is used when the distance from the stream bottom to roadway is limited. Their shape is arched on top, and flattened on the bottom. The flattened bottom allows a wider stream to flow through the culvert. As with circular culverts, they are prone to clogging. Since these shapes closely approximate a true arch, soil pressures on the underside of the culvert are fairly low, with high reaction pressures occurring at the bottom corners of the shape. They are not as structurally efficient as a circular shape. Most of these assets are covered under the BHM inventory/inspection program.
- **Elliptical:** This shape has the same advantages and disadvantages as pipe arch culverts. Most of these assets are covered under the BHM inventory/inspection program.
- **Arch:** Arches are open shapes used when limited obstruction to stream flow is required, and where the natural stream bottom is inherently resistant to scour. They offer less obstruction to stream flow than pipe arches. The spring lines of arch culverts bear on footing foundations, and rip rap is commonly used to protect them from erosion when the stream bottom is not resistant to scour. Soil pressures on the sides of an arch culvert try to push the sides towards the center of the stream, resulting in the top of the arch being pushed up. Soil dead loads above the top of the arch help to restrain this “peaking” tendency.



Figure 4.6.4-2: View of a corrugated steel arch culvert with masonry headwalls.

- **Tied Arch:** These are similar to arch culverts, but differ in that tied arch culverts have a floor (the natural stream bed is covered).
- **Box:** These are square or rectangular shaped structures. They are commonly chosen because they are adaptable for many site conditions, and they can be used when the distance from the stream bottom to roadway is limited. Box culverts always have a floor. Some have stream bed material placed within them either manually or filled in from sediment migration in the stream. These structures are not as structurally efficient as other culvert shapes.



Figure 4.6.4-3: View of a single cell reinforced concrete box culvert.



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- **Frame:** These are similar to box culverts, but differ in that they do not have a floor (the natural stream bed is exposed). The walls of these culverts bear on footing foundations.
- **Multiple Barrel:** Though not a “shape” in the strict definition, multiple barrel or cell culverts are simply a series of pipes, arches, or boxes placed side by side. Their use is common when the distance from the stream bottom to roadway is limited. Their major disadvantage is that waterway debris is easily snagged by the cell walls or soil between the openings. Refer to Figure 4.6.4-4 for a view of a multiple barrel culverts.



Figure 4.6.4-4: Two-cell reinforced concrete culvert.

- **Various:** It is not uncommon for a culvert structure to be comprised of several different types and shapes of culverts. In this instance, the inspector shall include all elements described in Section 4.6.611 that comprise the culvert. Refer to Figure 4.6.4-5 for a view of two different culvert types acting as a single structure.





Figure 4.6.4-5: View of reinforced concrete single cell box culvert with corrugated steel pipe arch extension

#### 4.6.4.2 Structural Categories

There are two structural categories of culverts, flexible and rigid. It is important for an inspector to understand the structural behavior of a culvert so that a proper assessment can be made as to the cause of any damage found. Structural behavior is dependent upon the material from which a culvert is built.

##### **Flexible Culverts**

Culverts constructed of metal are flexible, and can be easily deformed under load if not properly installed. Because the thinness of the corrugated metal plates leaves these culverts with little bending strength of their own; they must rely on the surrounding soil/backfill material for support and shape retention.

A metal structural plate pipe culvert with no lateral soil support will “squash” or flatten into an oval shape under vertical loads. The top of the pipe will deflect downward, and the sides of the pipe will bulge outward. Properly compacted soil surrounding the pipe will restrain the sides from bulging. This keeps the culvert ring in compression, and allows the culvert to support vertical loads with acceptable deflections by way of arching action.

##### **Rigid Box Culverts**

Cast-in-place concrete, precast concrete, and masonry box culverts are considered to be rigid. The culvert material itself is stiff enough to resist bending and to support vertical loads independent of the surrounding soil. As such, tension and compression stresses due to bending are created in the pipe. When viewed from the inside of a closed pipe, a culvert will experience tensile stresses on the top and bottom surfaces, while compressive stresses will be generated on the sides. These stresses will be opposite on the soil side of the pipe. Rigid culverts do not appreciably deflect before they crack or fracture.



### **4.6.5 Small Bridge Inspection**

Many steel culverts are large enough so that the entire length can be inspected from the inside. Small culverts that cannot safely or practically be entered should be examined by looking through the opening from both ends. Locations along sectional culverts may be conveniently referred to by using pipe joints as station numbers from one end of the pipe. Defect positions along the circumference of the culvert barrel may be referenced like hours on a clock.

A routine inspection of any structure will include several items. First, an element level inspection must be performed not only on the culvert itself, but also on the roadway over the structure. An inspection must also be carried out on the wingwalls, curbs, sidewalks, and railings if these elements or assessments exist. Second, an NBI condition rating must be assigned to the culvert structure, and to the channel and channel protection. Third, an NBI appraisal rating must be assigned for the waterway adequacy and approach roadway alignment. An NBI appraisal rating must also be assigned for the railing, approach guardrail, guardrail transitions, and guardrail ends if these items exist.

Prior to inspecting a culvert, the inspector should review all available information about the culvert. This will help establish equipment needs, inspection procedure, and flag areas of existing distress. At a minimum, most culvert inspections will require rubber boots/hip waders and a flashlight. Also, a range pole/probing rod should be brought along to not only check for scour or deterioration below the water level, but also to help keep the inspector's balance while wading through muck or over loose rip rap.

#### **4.6.5.1 Inspection Hazards**

Although culverts are low level structures, they do have a number of hazards with which the inspector must contend.

##### **Inadequate Venting**

Long culverts or culverts with blocked ends may have inadequate oxygen levels, or high concentrations of toxic or explosive gasses. Many longer culverts can be considered confined space. In this event, applicable OSHA regulations should be adhered to for confined space entry. Two people should perform the inspection in these situations. When air quality is suspect, gas monitors should be carried by the inspectors during the inspection to alert them of a hazardous environment. In addition, continuous ventilation may be required throughout the inspection to provide a safe working environment. Life line ropes clipped to the inspectors may also be used so that a third inspector stationed at the entry point may pull a disabled person out of the pipe.

##### **Drowning**

Soft muck can often be a problem during an inspection. After stepping into it, it is often difficult to pull one's foot out due the water and soil pressures surrounding it. Scour holes may be present within the streambed inside of a culvert. Since it is often difficult to visually detect these, it is easy for an inspector to accidentally step into one. High water velocities, flows, and slippery culvert floors may knock an inspector off of their feet. Probing rods, life vests, and hard hats should always be used while wading through these hazardous conditions.



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Some culverts have limited or no headroom. When this situation is encountered, wading should not be attempted until the water level has lowered. If that is unlikely, underwater inspection methods are required to properly perform the inspection. Refer to Part 1 for underwater inspection equipment and personnel requirements.

### **Toxic Chemicals**

Hazardous chemicals may be present in the stream water itself. A fire or explosion may result from careless behavior (smoking) in these conditions. An inspector should be aware of his work environment.

### **Animals**

Debris accumulation and low water flows within culverts may provide ideal shelter for animals. The inspector should be aware that snakes, rodents, or dead animals may be present within the culvert.

### **Quick Sand Hazards**

Quick sand is produced when water flows upward through sand. When the flow is strong enough, sand particles are lifted up out of the stream bed, and kept suspended by the turbulent nature of the upward rising water. A similar situation may be found at the outlet of a culvert conveying large quantities of water. The falling water creates a scour hole and constant turbulence to keep the streambed sand particles suspended. An inspector may accidentally step into the scour hole. Contrary to what Hollywood movies suggest, people do not sink in quick sand. The density of quick sand is greater than that of water, and people will actually float higher in the sand/water mixture than in pure water itself. An inspector found in this situation can simply swim away from the scour hole.

### **4.6.6 Small Bridge Elements**

Elements are provided to break the structure down into its main structural components. Typically, when a structure has a structural concrete or steel floor, it may be considered a culvert and the appropriate AASHTO culvert elements shall be utilized. For small bridges – bridge like structures where the structure has no floor and does not support an overburden load, the structure should be evaluated using AASHTO bridge elements. Refer to Section 4.6.3 for information.

Culvert elements are affected by appropriate material defects structural elements. Other typical structural defects associated with culvert elements include scour and settlement.

The quantity for culvert elements is the sum of the lengths of all the barrels comprising the structure in lineal feet with each linear foot capturing the defects over the entire circumference of the culvert barrel or cell. It is not uncommon for a culvert to be comprised of several different types of culverts. The sum of each barrel of each type is summed and totaled under the appropriate culvert element. The successful dissemination of the structure is based on the inspector's notes, measurements and photographs. All visible portions of the culvert should be considered during inspection, including all assessments.



### **Element Defects**

Refer to Part 2 Appendix A for defect descriptions. The defects listed are unique to the element and element material (i.e. concrete, steel, timber, etc.).

The inspector shall utilize the Defect Hierarchy concerning overlapping defects within a unit of measure when rolling up the total element condition state quantities. Refer to Part 2 Chapter 3 for the Defect Hierarchy.

When structural defects are present, the inspector shall report the defect in its entirety on the inspection report regardless if overlapping with material defects. However, only the controlling defect will be counted in the total element condition state quantity.

Structural defects shall be coded in their entirety on the inspection report regardless if overlapping with the other material defects. Structural defects represent global or external deterioration that adversely affects the structure. The scour defect should be used to capture the erosion of material along the base of a structure due to a stream or body of water. Settlement should be used for extended lengths of the structure exhibiting displacement vertically or out of plane. Structural defects should only be reported under structural elements, i.e. culvert elements, abutment elements, etc.

When assessing an element, the inspector shall utilize the specific material defects delegated to those elements. Furthermore, these defects are set into four Condition States. Each Condition State describes the progression of deterioration and severity for each defect. The Condition States are comprised of general descriptions and are uniquely colored to follow the severity the description represents.

- Condition State 1            Good            Green
- Condition State 2            Fair            Yellow
- Condition State 3            Poor            Orange
- Condition State 4            Severe            Red

The Condition States for each defect are summed up to the overall Element Condition State which provides the general condition rating for the element in the element's particular unit of measure. The sum of the defects must equal the total quantity for the element. All overlapping defects that were not included within the defect quantities (due to Defect Hierarchy), shall be included within the element or defect notes. Depending on the severity of the defect, photographic documentation may be required.

#### **4.6.6.1 Steel Culvert (Element 240)**

For c-structures, the primary type of structure using this element are structural plate steel pipe culverts. Structural plate steel pipe culverts are field assembled, built-up of several pre-curved corrugated plates. The field assembled plate sections are fastened together with bolts to form a continuous pipe. Fastened plate edges oriented along the barrel length are called seams, while plate edges transverse to the barrel are called joints. Circular, pipe arch, and arch



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underpass shapes are commonly found in sizes up to 26 feet. They are galvanized for corrosion protection.

Corrugated steel box culverts approximate a rectangular shape, though their corners are rounded, sides tilted slightly, and tops slightly curved. They are reinforced in areas of maximum bending, and are available in spans up to about 20 feet.

Long span corrugated steel structures are similar to structural plate steel pipes, but long span culverts require longitudinal and circumferential stiffening members due to their great lengths. Because their lengths are normally greater than 20 feet, they are classified as bridges. They should, however, be inspected in a manner described in this section.

### Element Level Inspection

This element describes steel culverts, including arched, round or elliptical pipes. Pipe culverts made of a metal other than steel shall be captured under element 243 Other Material Culvert.

Barrel misalignment, joint and seam condition, localized damage, and corrosion are areas of concern during any steel culvert inspection. However, due to the flexible nature of pipe, the primary area of concern is its shape.

Because steel culverts depend upon a well compacted soil to help retain their shape, excessive flattening or widening suggests a soil failure. As a minimum, the height and widest opening should be measured at both culvert ends. If culvert size and water flow permit, measurements in the middle of the barrel should also be recorded. These measurements should also be taken at 25-foot intervals between these three locations. Bolted joints are excellent places to take measurements, because they can be easily found for re-measurements on subsequent inspections. Measurements should always be taken at the inside crest of the corrugations. Critical measurements to be taken during an inspection for various barrel shapes have been reproduced from the *Culvert Inspection Manual*. Refer to Part 4, Appendix C, for these figures.

In the inspection report, steel culvert elements are recorded in units of linear feet. Although the culvert span, found in the inventory data, is measured along the centerline of the road, the culvert element quantity is calculated by taking the flow line length of the barrel times the number of barrels, or the sum of all barrel lengths if barrels differ in length. It is important to note that the culvert element may exhibit more than one defect along its length. It is the inspector's task to examine each element, determine the applicable defects and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element's state of deterioration and help generate quantity/cost estimates for future remedial work.

Maintenance inspection of steel culverts should include the following items:

- Measuring the height and width of the barrel at the ends, middle, and at 25 foot intervals in between. These measurements should be compared to the original dimensions shown on the design drawings, if available. Excessive flattening suggests a soil failure.



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- Indicating on the report the extent of any flattening found. Include the affected length along the barrel, and location of the distress.
- Examination of the roadway above for any dips, cracking, settlement, or patching that would suggest a failing culvert below.
- Checking for horizontal misalignments by sighting down the barrel length.
- Checking for vertical misalignments sighting down the barrel length, and by noting the presence of localized deep water or sediment accumulation at low spots within the barrel.
- Looking for localized damage in the form of dented, flattened, or bulged areas. Bulged areas on the bottom of a round barrel suggest culvert settlement over a local hard spot. Bulged areas on the bottom of an arch pipe suggest the corners have settled. Small areas of localized damage are usually not critical. Localized damage may jeopardize the barrel's ability to carry its ring compression loads.
- Looking for corrugation misalignments and "cusped" seams along the fastener lines. Cusped seams are an opening up of the plate lap as a result of loose fasteners, resulting in a discontinuity of the barrel curvature. They may allow moisture and backfill to leak inside of the culvert.
- Examining all seams and joints for plate separation. Measure any separations found. A small rod or flat rule should be used to probe through any separation to check for voids in the backfill.
- Checking for cracking at the bolt holes. These are usually caused by excessive barrel strains due to deflections.
- Verification of loose bolts by tapping with a hammer.
- Checking the entire barrel for the extent and severity of corrosion. The heaviest corrosion will normally appear near the water surface. Corrosion is the leading cause of steel culvert replacement. A sharp blow with the pointed end of a geologist's hammer is the accepted method for the inspector to evaluate the general integrity of the steel.
- Examining the inlet and outlet of the barrel for signs of scour or undermining underneath of a closed pipe. This could lead to piping.
- Examining for scour or footing undermining along the length of arch culverts. Undermining may allow the concrete footing to rotate, failing the arch.
- Looking for signs of abrasion along the barrel. Abrasion can accelerate the corrosion process by scraping away the metal's protective coating.
- Examination of end treatments or wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, settlement, tipping, and embankment erosion. These deficiencies can cause hydraulic inefficiencies of the culvert, and roadway settlements.

- Checking for excessive joint openings between headwalls, wingwalls, aprons, etc.



Figure 4.6.6-1: Barrel with good alignment - Condition State 1.



Figure 4.6.6-2: Surface corrosion near the waterline – Corrosion Condition State 2.



Figure 4.6.6-3: Light to moderate bolt corrosion – Connection Condition State 2.

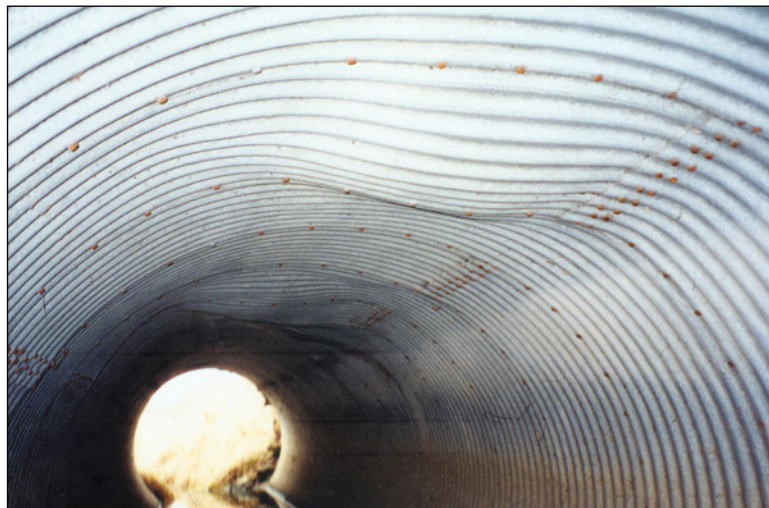


Figure 4.6.6-4: Severe bulging in numerous locations – Distortion Condition State 3.





Figure 4.6.6-5: Severely distorted barrel – Distortion Condition State 4.

#### 4.6.6.2 Reinforced Concrete (RC) Culvert (Element 241)

Concrete box culverts may be cast-in-place (CIP), or precast. CIP concrete culverts are typically box or arch shaped with the box shape being more common. The advantage of CIP culverts is that they can be designed to fit the specific needs of a site. The hydraulic openings of box shaped culverts are commonly referred to as cells. Multiple cell box culverts are common.

Precast culverts are available in several standard shapes including circular, box, elliptical, pipe arch, and arch. The hydraulic openings of circular, elliptical, pipe arch, and arch-shaped culverts are commonly referred to as barrels. Sizes up to 12 feet wide are commonly available for closed shapes.

Proper bedding compaction and preparation during construction is critical if precast closed sections are to perform well in service. Properly prepared bedding material (usually crushed stone) under the sections will evenly support the culvert sections. Voids within the bedding will force the rigid culvert sections to span over these soft spots, often resulting in transverse cracks. Voids under the mid-length of a section will lead to cracks on the bottom half of the pipe at mid-length. Voids under the ends of a section will lead to cracks on the top half of the pipe at mid-length.

Improper compaction of fill material on the sides of a culvert may lead to longitudinal cracks. Without proper soil side support, the pipe will want to flatten under vertical loads. Because concrete is a rigid material, it will not flex, and longitudinal cracks along the top, bottom, and sides of the pipe will result.

The soil surrounding concrete culverts is very effective in protecting them from severe temperature fluctuations, deicing chemicals, and impact loading. As a result, they tend to hold up fairly well, and do not deteriorate as quickly as concrete bridge elements.



### **Element Level Inspection**

Barrel misalignment, joint condition, and localized wall damage are areas of concern during any concrete culvert inspection. Since they are classified as rigid culverts, they will not deform under load as do corrugated steel culverts. However, they will show signs of distress due to overloading or differential settlement. The distress usually shows up as longitudinal or transverse cracks.

On the inspection report form, reinforced concrete culvert elements are recorded in units of lineal feet. Although the culvert span, found in the inventory data, is measured along the centerline of the road, the culvert element quantity is calculated by taking the flow line length of the barrel times the number of barrels, or the sum of all barrel lengths if barrels differ in length. It is important to note that the culvert element may exhibit more than one defect along its length. It is the inspector's task to examine each element, determine the applicable defects and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element's state of deterioration and help generate quantity/cost estimates for future remedial work.

Maintenance inspection of concrete culverts should include the following items:

- Examination of the roadway above for any dips, cracking, settlement, or patching that would suggest a failing culvert below.
- Checking for horizontal misalignments by sighting down the culvert length.
- Checking for vertical misalignments by sighting down the culvert length and noting the presence of localized deep water or sediment accumulation at low spots within the culvert.
- Looking for open joints. Open joints may allow water infiltration into the culvert, possible allowing the backfill material to enter the culvert as well. This can lead to roadway settlement above, and debris accumulation within the culvert. Open joints that allow water to flow out of the culvert (exfiltration) may cause soil erosion around the culvert. This can lead to culvert (and roadway) settlements.
- Looking for cracks, delaminations, or spalls at expansion joints or precast section joints. This type of deterioration suggests improperly functioning joints, possible due to culvert settlements.
- Looking for longitudinal cracks along the barrel or cell length. These may be caused by excessive overloads or improper fill compaction of barrel sections, or lateral differential settlements of box sections. Medium to wide crack widths should be measured and recorded.
- Examination of box culvert tops when these elements double as the riding surface of traffic above. Longitudinal cracks in the culvert top may be caused by traffic overloads.



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- Looking for transverse cracks. These may be caused by differential settlements along the culvert length, often the result of improper bedding material preparation.
- Checking the entire barrel or cell for delaminating, spalls, exposed reinforcing steel, cracking and leaching. Note the location of such defects.
- Examining the inlet and outlet of the barrel for signs of scour or undermining underneath of a closed pipe. This could lead to piping.
- Examining for scour or footing undermining along the length of arch culverts. Undermining may allow the concrete footing to rotate, failing the arch.
- Looking for signs of abrasion along the length of the culvert.
- Examining any anchor bolt conditions at the springline of precast culverts.
- Examination of end treatments or wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies of the culvert, and roadway settlements.
- Checking for excessive joint openings between headwalls, wingwalls, apron, etc.



Figure 4.6.6-6: Reinforced Concrete Culvert - Condition State 1.



Figure 4.6.6-7: Deterioration on Culvert Wall – Heavy Density Cracking with Efflorescence  
Condition State 4.

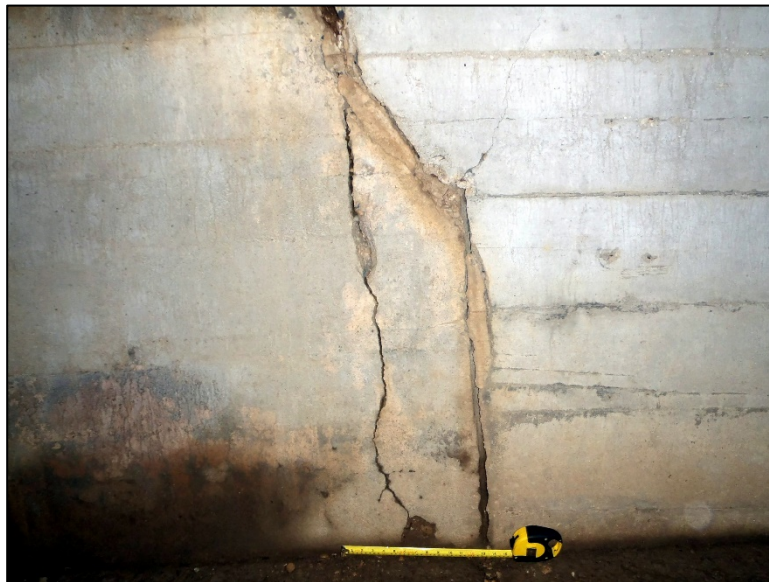


Figure 4.6.6-8: Differential Settlements Between Box Segments – Settlement Condition  
State 3.



Figure 4.6.6-9: Joint Separation Between Pipe Segments – Settlement Condition State 3.

#### 4.6.6.3 Timber Culvert (Element 242)

Timber culverts are usually in the form of box culverts and are constructed of individual small dimension timbers. They are not common in Wisconsin, but for the proper location, they can be an economical and easy to construct installation.

##### **Element Level Inspection**

Material deterioration and decay, differential settlement, and impact damage for flood debris are the primary concerns of any timber culvert. In addition overloading may show up as wall or ceiling bulging, and by splitting and protrusion of the individual laminations.

On the inspection report form, timber culvert elements are recorded in units of lineal feet. Although the culvert span, found in the inventory data, is measured along the centerline of the road, the culvert element quantity is calculated by taking the flow line length of the barrel times the number of barrels, or the sum of all barrel lengths if barrels differ in length. It is important to note that the culvert element may exhibit more than one defect along its length. It is the inspector's task to examine each element, determine the applicable defects and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element's state of deterioration and help generate quantity/cost estimates for future remedial work.

Maintenance inspection of timber culverts should include the following items:

- Timber culverts more than twenty years old or any showings signs of distress should be completely sounded with a hammer. This is a preliminary, quick check for decay by listening for a resulting hollow sound.



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- The preservative treatment of the elements and its conditions should be noted. Because of small dimension laminations, their preservative treatment extends throughout the timber resulting in little decay. But examine the entire element for signs of decay. Signs include discolored wood, rotted texture; section loss, fruiting (fungi) bodies; and insect infestation.
- Examination of the roadway above for any dips, cracking, settlement, or patching that would suggest a failing culvert below.
- Checking for horizontal misalignments by sighting down the culvert length.
- Checking for vertical misalignments by sighting across the tops of the culvert bays. Excessive deflections indicate that the culvert is experiencing differential settlements
- Checking the walls for plumbness. A plumb bob or smart level may be used. The measured amount of deflection should be recorded
- Looking for signs of decay due to fungi or parasites.
- Looking for any wall or ceiling bulges, and note any tipped walls.
- Checking for broken or missing timbers. These may be allowing backfill material to enter the culvert, causing roadway settlement above.
- Examination of any exposed fasteners for deterioration.
- Examining the inlet and outlet of the barrel for signs of scour or undermining underneath of a culvert with a floor.
- Looking for signs of abrasion along the length of the culvert.
- Examination of end treatments for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies of the culvert, and roadway settlements.
- Checking for excessive joint openings between headwalls, wingwalls, apron, etc.
- Checking for missing laminations at the openings and inverts.
- If the claw or pointed end of a hammer penetrates the wood, that is a sign of decay. The extent of decay can also be estimated by trying to insert a chisels or other probe into suspected areas.
- All suspected decay areas may be further analyzed with a Resistograph or other similar NDE method to determine the extent of the decay. See Chapter 5 for further information. The location and the extent of such decay should be estimated and should be reported to the Program Manager.



#### 4.6.6.4 Masonry Culvert (Element 244)

Masonry culverts are not constructed anymore, but can still be found in-service. They are built of stone or brick formed into arch or box shapes. Joints between the masonry units may be mortared, set in concrete, or mortarless. Refer to Figure 4.6.6-10 for a view of a masonry culvert. Masonry is still sometimes used to construct headwalls for culverts of other material types when aesthetics is important.



Figure 4.6.6-10: Masonry Culvert with Severe Deterioration of Mortar Joints.

#### **Element Level Inspection**

Material deterioration is the primary concern of any masonry culvert. Refer back to Figure 4.6.6-10 for a view of typical deterioration. In addition, signs of soil distress or overloading may show up as wall or arch bulging.

On the inspection report form, masonry culvert elements are recorded in units of linear feet. Although the culvert span, found in the inventory data, is measured along the centerline of the road, the culvert element quantity is calculated by taking the flow line length of the barrel times the number of barrels, or the sum of all barrel lengths if barrels differ in length. It is important to note that the culvert element may exhibit more than one defect along its length. It is the inspector's task to examine each element, determine the applicable defects and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element's state of deterioration and help generate quantity/cost estimates for future remedial work.



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Maintenance inspection of other culverts should include the following items:

- Examination of the roadway above for any dips, cracking, settlement, or patching that would suggest a failing culvert below.
- Checking for horizontal misalignments by sighting down the culvert length.
- Checking for vertical misalignments by noting the presence of localized deep water or sediment accumulation at low spots within the culvert.
- Looking for cracked, crushed, or missing masonry units or mortar.
- Looking for signs of excessive masonry weathering.
- Looking for any masonry culvert wall or arch bulges. This suggests a soil failure. The location and size of such distress should be recorded.
- Indicating on the report the extent of any flattening found on plastic culverts. Include the affected length along the barrel, and location of the distress.
- Examining the inlet and outlet for signs of scour or undermining underneath of masonry culverts with a floor, or for plastic culverts.
- Examining for scour or footing undermining along the length of masonry culverts without floors. Undermining may allow the footing to rotate, failing the culvert.
- Looking for signs of abrasion along the length of the culvert.
- Examination of end treatments for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies of the culvert, and roadway settlements.
- Checking for excessive joint openings between headwalls, wingwalls, apron, etc.

### 4.6.6.5 Prestressed Concrete (PS) Culvert (Element 245)

A prestressed concrete culvert is similar to a reinforced concrete culvert in terms of inspection. Cracking will typically be less prevalent on a prestressed member due to design but any cracks found during inspection should be heavily scrutinized. Prestressing strands are subjected to higher forces when compared to mild reinforcing steel and are therefore less resilient to corrosion from water intrusion.

#### **Element Level Inspection**

On the inspection report form, prestressed concrete culvert elements are recorded in units of linear feet. Although the culvert span, found in the inventory data, is measured along the centerline of the road, the culvert element quantity is calculated by taking the flow line length of the barrel times the number of barrels, or the sum of all barrel lengths if barrels differ in length. It is important to note that the culvert element may exhibit more than one defect along its length. It is the inspector's task to examine each element, determine the applicable defects





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and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element's state of deterioration and help generate quantity/cost estimates for future remedial work.

As noted previously, any cracking found in a prestressed concrete culvert should be closely observed given the susceptibility of prestressing strands to corrosion. The limits on crack width and spacing are much less with prestressed concrete when compared to reinforced concrete.

Maintenance inspection of concrete culverts should include the following items:

- Examination of the roadway above for any dips, cracking, settlement, or patching that would suggest a failing culvert below.
- Checking for horizontal misalignments by sighting down the culvert length.
- Checking for vertical misalignments by sighting down the culvert length and noting the presence of localized deep water or sediment accumulation at low spots within the culvert.
- Looking for open joints. Open joints may allow water infiltration into the culvert, possible allowing the backfill material to enter the culvert as well. This can lead to roadway settlement above, and debris accumulation within the culvert. Open joints that allow water to flow out of the culvert (exfiltration) may cause soil erosion around the culvert. This can lead to culvert (and roadway) settlements.
- Looking for cracks, delaminations, or spalls at expansion joints or precast section joints. This type of deterioration suggests improperly functioning joints, possible due to culvert settlements.
- Looking for longitudinal cracks along the barrel or cell length. These may be caused by excessive overloads or improper fill compaction of barrel sections, or lateral differential settlements of box sections. Medium to wide crack widths should be measured and recorded.
- Examination of box culvert tops when these elements double as the riding surface of traffic above. Longitudinal cracks in the culvert top may be caused by traffic overloads.
- Looking for transverse cracks. These may be caused by differential settlements along the culvert length, often the result of improper bedding material preparation.
- Checking the entire barrel or cell for delaminating, spalls, exposed strands, cracking and leaching. Note the location of such defects.
- Examining the inlet and outlet of the barrel for signs of scour or undermining underneath of a closed pipe. This could lead to piping.
- Examining for scour or footing undermining along the length of arch culverts. Undermining may allow the concrete footing to rotate, failing the arch.



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- Looking for signs of abrasion along the length of the culvert.
- Examination of end treatments or wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies of the culvert, and roadway settlements.
- Checking for excessive joint openings between headwalls, wingwalls, apron, etc.

#### 4.6.6.6 Culvert Liner (Element 8802)

Culvert Liner is a Strengthening and Repair Element available only under Culvert Elements. They add structural stability to a culvert. This element will be used in conjunction with the main culvert element as a “protective system”. Refer to Section 2.6.5.3 for additional information on this element.

In most cases, a culvert liner will not increase the Condition State of the culvert element itself. For instance, a corrugated steel pipe that is corroded through the bottom (Condition State 4 Corrosion) with a culvert liner is installed would have the Steel Culvert element remain in Condition State 4 on the inspection report while the Culvert Liner element would now become the structural element to evaluate during inspections. The liner essentially becomes the main structural component while the previous culvert element remains as a place holder.

#### **Element Level Inspection**

On the inspection report form, culvert liners are recorded in units of linear feet. It is important to note that the culvert liner may exhibit more than one defect along its length. It is the inspector’s task to examine each element, determine the applicable defects and reasonably assign the appropriate Condition State to each defect. Where multiple defects exist within a unit of measure, the inspector shall refer to the Defect Hierarchy as described in Part 2 Chapter 3. The sum of all of the reported material defect condition states must equal the total quantity of the element. This will quantify the element’s state of deterioration and help generate quantity/cost estimates for future remedial work.

As a strengthening and repair system element, Culvert Liner essentially breaks down into more simply whether or not the structure is remaining effective. The inspector should take care to note any distortion or bending that may occur in the liner after its installation as this may be a sign of impending failure.

When Culvert Liners are inspected in the field, the inspector should focus his/her energies on the liner itself and no longer on the material condition of the previous culvert element. Once the liner is installed, it is assumed the liner is the new culvert element. Existing headwall configurations, unless also repaired, should still be inspected thoroughly by the inspector as these retain the roadway fill and provide protection to the embankments.

#### 4.6.6.7 Integral Wingwall (Element 8400)

This element defines the wingwalls integral with the box culvert apron, headwall or barrel. The intent of wingwalls is to retain the roadway or embankment fills adjacent to the barrel opening. A wingwall not functioning as intended may permit the loss of fill around the barrel and may occlude the barrel opening reducing hydraulic capacity. The wingwalls extend past the end of



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the barrel typically flared out, however wingwalls may also be found running parallel with the channel or parallel to the roadway. Typically a joint is found between the end of the barrel and the wingwall. The inspector shall report the wingwall as integral so long as it is anchored to apron of the end treatment. In the cases where the wingwalls are comprised of different materials and consequently not anchored to the apron or barrel of the culvert, the wingwalls shall be inspected and noted under the Culvert End Treatment assessment.

### Element Level Inspection

On the inspection report form, integral wingwalls are recorded in units of “each”. There are two material defects for integral wingwalls, Wingwall Movement and Wingwall Deterioration. As in all cases, the most severe defect Condition State, as determined by the Defect Hierarchy, is assigned to the entire element. This will quantify the wingwall’s condition and help to generate quantity/cost estimates for future remedial work.

In general, wingwalls slope down from the top of the headwall. In some instances, the wingwalls may be incorporated as retaining structures that continue well beyond the box culvert structure. While the inspector should perform his/her due diligence in the evaluation of the retaining structure adjacent to the box culvert, the inspector need only inspect a portion of the wall under the Integral Wingwall element. The length inspected should be 20 feet from the end of the barrel or the length of a 2:1 slope from the top of the headwall, whichever is greater. The remaining length should then be considered retaining wall and shall be inspected under a separate R-number structure inspection.

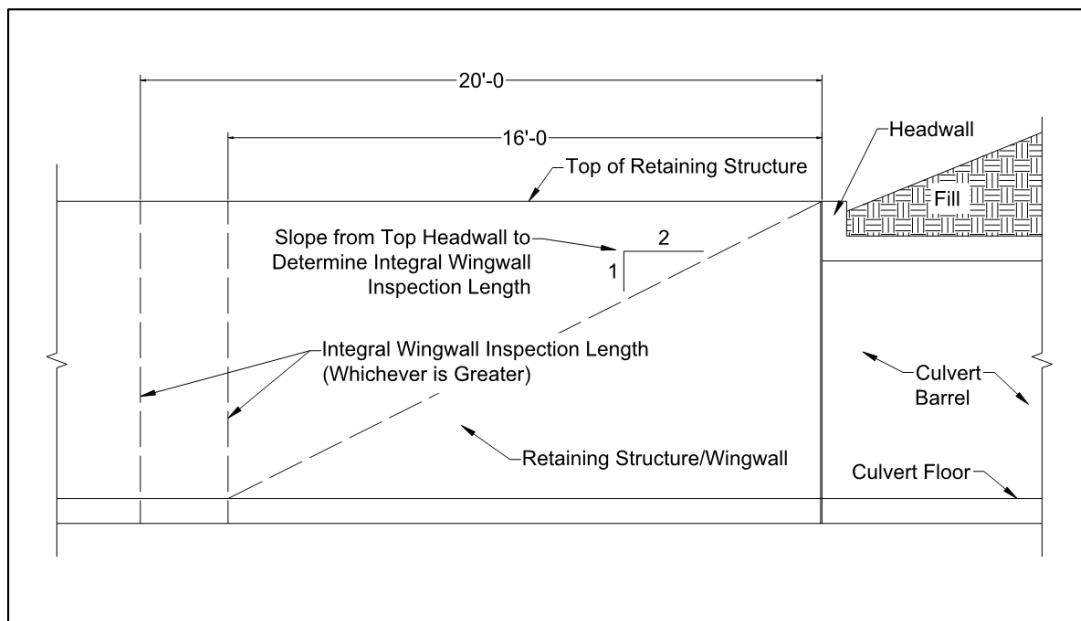


Figure 4.6.6-11: Determination of Integral Wingwall Inspection Limit When Wingwall Part of Larger Retaining Structure. For This Example, the Inspector Would Evaluate From Joint to 20'-0" Out (as it is greater than the 2:1 slope from the top of headwall) as Integral Wingwall.



Figure 4.6.6-12: View of Integral Wingwalls Parallel with Roadway.



Figure 4.6.6-13: View of Retaining walls extending beyond limits of integral wingwalls.

Maintenance inspection of integral wingwalls should include the following items:

- Visual examination of the material condition of the wingwall. Look for cracking, efflorescence, rust staining, spalling, corrosion, etc.
- Verify the vertical plumbness of the wingwall wall. Common tools for verification may include a level or plumb bob.



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- Inspect the joint between the barrel and wingwall. Check for loss of filler material within the joint. The caulking sealant should be adhered to the concrete on both sides.
- Check for rotation about the apron base. Rotation of the wingwall would be indicated at the joint between the barrel and wingwall. Measurements should be taken near the apron and near the headwall.
- Check for settlement of the apron and wingwall. This will be indicated by an observable drop between the barrel floor and the apron.



Figure 4.6.6-14: View of Wingwall Movement. Note loss of fill behind wingwall and culvert barrel – Condition State 3.

#### 4.6.7 Small Bridge Material Deterioration

There are four general types of distress that any c-structure can experience. Refer to Figure 4.6.7-1 through Figure 4.6.7-3 for views of material distress. High earth loads, water velocities, long slender sections, and age can produce the following types of distress:

- **Shear or Bending Failures:** High embankments impose high loads on all sides of a culvert and can cause shear or bending failures. This may show up as excessive global flattening, sheared off bolts, or localized dents/bulges in steel culverts. Concrete culverts will exhibit longitudinal cracking, concrete crushing, or excessive deflections.
- **Settlement:** Foundation settlement may be seen as a sag or rise (when only the pipe ends settle) in steel culverts. Differential vertical or lateral displacements at construction joints and pipe segment joints, or pipe segment joints that have opened up suggest settlement of concrete culverts. Lateral movement of concrete box sections may also be observed.
- **Scour, Undermining, and Piping:** High water velocities within long, slender openings can result in scouring and undermining of the culvert ends. Scouring or undermining



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may also occur along the footings when the culvert has no bottom. Undermining can lead to a loss of bearing, and subsequent structure settlement. Piping is the unintended flow of water around the outside of a culvert. It can begin at the inlet end where undermining under the barrel or end treatments allow water to flow. It may also occur at interior joints that have opened up due to soil settlements. Water inside of the culvert may flow out through the open joints. When this occurs, water flow can erode the soil surrounding the culvert, creating an artificial pipe. Piping can become a serious problem in that the piping area will start to erode, a culvert can lose its lateral soil support, and roadway settlements can occur.

- **General Deterioration:** Factors such as weathering, abrasion, chemical exposure, etc., cause deterioration of any construction material over time.



Figure 4.6.7-1: Concrete headwall failure. Note: Headwall deterioration would be captured under Assessment 9248 – Culvert End Treatment



Figure 4.6.7-2: Masonry headwall separating from the barrel.



Figure 4.6.7-3: Through thickness section loss at water line of wall separating two cells.

#### 4.6.8 Small Bridge Assessments

Assessments allow for the evaluation of secondary components not necessarily impacting the structural integrity of the structure. The inspector must be familiar with all the available assessments within the HSI system and appropriately capture them within the inspection report



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for each culvert or small bridge structure. Evaluating assessments provides a more accurate picture of the structure being inspected and alerting the Department of potential future issues including traffic hazards or functionality of the structure. The following section describes the two assessments unique only to culvert inspections. All other assessments must be recorded and inspected. Refer to Part 2 Chapter 7 for the definitions and assessment states for all the available assessments within HSI.

#### 4.6.8.1 Culvert End Treatments (Assessment 9248)

Culvert end treatments will encompass the headwall and apron on one end of the culvert. Culvert end treatments can be made of steel, concrete, timber and other materials and may be a combination of materials. Regardless of material composition, the headwall and/or apron shall be included under the end treatment assessment rating and evaluated based on its condition and function. Refer to Section 2.7.1.26 for additional information on this assessment. Wingwalls shall be evaluated separately under Integral Wingwall (Element 8400).

#### 4.6.8.2 Roadway Over Structure (Assessment 9325)

Culverts and closed spandrel filled arch bridges can have several inches to several feet of soil overburden placed on top. Because of this, a deck is not required to carry the live loads to the structure. A conventional roadway pavement is simply built over the fill, and traffic live loads are delivered to the structure through the soil. Roadways over structures are important elements to inspect because distress found on a roadway often indicates more serious distress to the structure below.

The assessment “roadway over structure” is to be used only if there is more than 9 inches of fill (including the thickness of pavement, if present) over the structure at any point. For example, if there is only 6 inches of fill over the crown of a structural plate arch, but 8 feet 6 inches of fill at the footings, “roadway over structure” would need to be recorded. Refer to Section 2.7.1.32 for additional information on this assessment.

#### 4.6.9 National Bridge Inventory (NBI) Overall Ratings

Part of every Routine inspection is rating the main structure according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings of these guidelines describe the existing culvert as compared to its as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition, and 0 describing failed components. Note that the NBI ratings are for small bridge – culvert structures and not small bridge – bridge like structures.

Because only a single number is used to rate the box/pipe culvert, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as isolated heavy spalling. However, widespread heavy spalling would certainly influence the rating. A proper rating will therefore consider deterioration severity plus the extent to which it is distributed throughout the culvert.

NBI ratings are used to evaluate the state of deterioration of the culvert material. Since material condition is independent of a culvert’s load carrying capacity, postings or original design capacities less than current legal loads will not influence the rating. Similarly, temporary





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substructure support does not change or improve the condition of the culvert material. Temporary strengthening methods will therefore not influence the culvert rating.

Because the NBI general condition ratings apply to a wide range of components and materials, the FHWA has developed supplemental rating guidelines within the *Culvert Inspection Manual*. These supplemental rating guidelines are used to assist the inspector in properly assigning condition ratings to culverts constructed of the most commonly used materials. The general condition ratings, along with the FHWA supplemental rating guidelines for culvert conditions, are given below. It should be noted that the supplemental rating guidelines only address corrugated steel and aluminum round pipe and pipe arches. The reader is referred to the *Culvert Inspection Manual* for supplemental rating guidelines for structural plate arch, metal box, low profile long span arch, high profile long span arch, pear shaped long span, and horizontal ellipse long span barrels.

<u>Condition Rating</u>	<u>Description</u>
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N	Not applicable. Use if structure is not a culvert.
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9	No deficiencies.
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**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – New condition.

**Cast-In-Place Concrete Culverts** – New condition.

**Masonry Culvert Barrels** – New condition.

8	There are no noticeable or noteworthy deficiencies which affect the condition of the culvert. Insignificant scrape marks caused by drift.
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**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Good, superficial rust, no pitting, minor construction defects, protective coating intact. There is smooth curvature in the barrel, and horizontal shape measurements are within 10 percent of design for round pipes, 3 percent for pipe arches. Seams and joints are tight with no openings.

**Cast-In-Place Concrete Culverts** – Good, no settlement or misalignment. Joints are tight with no defects apparent. No cracking, spalling, or scaling present; surface in good condition. The invert shows no signs of scour.

**Masonry Culvert Barrels** – Good, no settlement or misalignment. Mortar is tight with no defects apparent. No cracking, missing, or dislocated masonry present; surface in good condition. The invert shows no signs of scour.



- 7 Shrinkage cracks, light scaling, and insignificant spalling which does not expose reinforcing steel. Insignificant damage caused by drift with no misalignment and not requiring corrective action. Some minor scouring has occurred near curtain walls, wingwalls, or pipes. Metal culverts have a smooth symmetrical curvature with superficial corrosion and no pitting.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Generally good, moderate rust, slight pitting. The protective coating is ineffective. The top half of the pipe is smooth but minor flattening of the bottom may exist for round pipe, and the bottom half is flattened but still curved for pipe arches. The horizontal shape measurements are within 10 percent of design for round pipes, and within 3 to 5 percent greater than design for pipe arches. Seams and joints have minor cracking at a few bolt holes, minor openings, and a potential for backfill infiltration.

**Cast-In-Place Concrete Culverts** – Generally good, no settlement, minor misalignment at joints. Joint material is deteriorated at isolated locations. Minor hairline cracking at isolated locations; slight spalling or scaling present on invert or bottom of top slab. Minor scour at the invert.

**Masonry Culvert Barrels** – Generally good, no settlement, minor misalignment at joints. Shallow mortar deterioration at isolated locations. Surface deterioration or masonry at isolated locations. Minor scour at the invert.

- 6 Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalls on concrete or masonry walls and slabs. Local minor scouring at curtain walls, wingwalls, or pipes. Metal culverts have a smooth curvature, non-symmetrical shape, significant corrosion or moderate pitting.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Fair, fairly heavy rust, moderate pitting, slight thinning. The top half of the pipe has a smooth curvature but the bottom half has flattened significantly for round pipe, or has flattened for pipe arches. The horizontal shape measurements are within 10 percent of design for round pipe, and 5 percent greater than design for pipe arches. Minor cracking at the bolts is prevalent in one seam in the lower half of the pipe. Evidence of backfill infiltration at the joints and seams.

**Cast-In-Place Concrete Culverts** – Fair, minor misalignment and settlement at isolated locations. Joint material generally deteriorated, minor separation, possible infiltration or exfiltration; minor cracking or spalling at joints allowing exfiltration. Extensive hairline cracks, some with minor delaminations; invert or bottom of top slab scaling less than ¼ inch deep or small spalls present. Minor scour near footings.



**Masonry Culvert Barrels** – Fair, minor misalignment and settlement. Mortar has extensive areas of shallow deterioration; missing mortar at isolated locations; possible infiltration or exfiltration; minor cracking. Minor cracking of masonry units. Minor scour near footings.

- 5 Moderate to major deterioration or disintegration, extensive cracking and leaching, or spalls on concrete or masonry walls and slabs. Minor settlement or misalignment. Noticeable scouring or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection in one section, significant corrosion or deep pitting.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Generally fair, extensive heavy rust, deep pitting, moderate thinning. Significant distortion at isolated locations in the top half and extreme flattening of the invert for round pipe, or slight reverse curvature in one location for pipe arches. The horizontal shape measurements are between 10 to 15 percent greater than design for round pipe, or within 5 to 7 percent for pipe arches. Moderate cracking at the bolt holes in one seam near the bottom of pipe. Deflection of pipe caused by backfill infiltration through joints and seams.

**Cast-In-Place Concrete Culverts** – Generally fair, minor misalignment or settlement; possible piping. Joints are open and allowing backfill to infiltrate; significant cracking or spalling at joints. Crack widths greater than 1/8 inch with significant delamination and moderate spalling exposing reinforcing steel; large areas of surface scaling greater than ¼ inch deep. Moderate scour along footing; protective measures may be required.

**Masonry Culvert Barrels** – Generally fair, minor misalignment or settlement. Mortar generally deteriorated, loose or missing mortar at isolated locations, infiltration staining apparent. Minor cracking and slight dislocation of masonry units; large areas of surface scaling. Moderate scour along footing; protective measures may be required.

- 4 Large spalls, heavy scaling, wide cracks, considerable efflorescence, or opened construction joint permitting loss of backfill. Considerable settlement or misalignment. Considerable scouring or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection throughout, extensive corrosion or deep pitting.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Marginal, pronounced thinning (some deflection or penetration when struck with pick hammer). For round pipes, significant distortion throughout length of pipe, lower third may be kinked. For pipe arches, significant distortion along the top of arch, bottom has reverse



curvature. The horizontal shape measurements are between 10 to 15 percent greater than design for round pipe, and more than 7 percent greater for pipe arches. Moderate cracking at the bolt holes on one seam near top of pipe. Deflection caused by backfill infiltration through open joints and seams.

**Cast-In-Place Concrete Culverts** – Marginal, significant misalignment and settlement of the pipe; evidence of piping. Differential movement and separation of the joints, significant infiltration and exfiltration at joints. Extensive cracking with crack widths greater than 1/8 inch with efflorescence; spalling has caused exposure of reinforcing steel which are heavily corroded; extensive surface scaling on invert greater than 1/2 inch deep. Scour along footing with slight undermining, protection required.

**Masonry Culvert Barrels** – Marginal, significant misalignment and settlement. Mortar severely deteriorated, significant loss of mortar, significant infiltration and exfiltration between masonry units. Significant displacement of individual masonry units. Scour along footing with slight undermining, protection required.

- 3 Any condition described in Condition Rating 4 but which is excessive in scope. Severe movement or differential settlement of the segments, or loss of fill. Holes may exist in walls or slabs. Integral wingwalls nearly severed from culvert. Severe scour or erosion at curtain walls, wingwalls or pipes. Metal culverts have extreme distortion and deflection, in one section, extensive corrosion, or deep pitting with scattered perforations.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Poor, extensive heavy rust, deep pitting, scattered perforations. For circular pipes, extreme deflection at isolated locations, flattening of crown, crown radius 20 to 30 feet. For pipe arches, extreme deflection in top arch in one section; bottom has reverse curvature throughout. The horizontal shape measurements are in excess of 15 percent greater than design for circular pipes, and over 7 percent greater for pipe arches. Three inch long cracks at bolt holes on one seam.

**Cast-In-Place Concrete Culverts** – Poor, significant ponding of water due to sagging and misalignment of the pipe; end section drop off has occurred. Significant joint openings and differential movement, infiltration or exfiltration causing misalignment of culvert and depressions or settlement in the roadway. Extensive cracking with spalling, delamination and slight differential movement; scaling has exposed reinforcing steel in bottom of top slab or invert. Severe footing undermining with slight differential settlement causing minor cracking or spalling in footing and walls.

**Masonry Culvert Barrels** – Poor, significant ponding of water due to sagging and misalignment of the pipe; end section drop off has occurred. Extensive areas of missing mortar, infiltration or exfiltration causing misalignment of



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culvert and depressions or settlement in the roadway. Individual masonry units in lower part of structure missing or crushed. Severe footing undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls.

- 2 Integral wingwalls collapsed, severe settlement of roadway due to loss of fill. Section of culvert may have failed and can no longer support embankment. Complete undermining at curtain walls and pipes. Corrective action required to maintain traffic. Metal culverts have extreme distortion and deflection throughout with extensive perforations due to corrosion.

### **FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Critical, extensive perforations due to rust. For circular pipe, extreme deflection and distortion throughout pipe, flattening of crown, crown radius over 30 feet. For pipe arches, extreme deflection along top of pipe. The horizontal shape measurements are in excess of 20 percent greater than design for circular pipes, and 7 percent greater for pipe arches. Plate cracks from bolt to bolt on one seam.

**Cast-In-Place Concrete Culverts** – Critical, culvert not functioning due to misalignment. Severe cracks with significant differential movement; concrete completely deteriorated in isolated locations in top slab or invert. Severe footing undermining with significant differential settlement causing severe cracks.

**Masonry Culvert Barrels** – Critical, culvert not functioning due to misalignment. Individual masonry units in top of culvert missing or crushed. Severe footing undermining with significant differential settlement causing severe cracks in footing and distress in walls.

- 1 Bridge closed. Corrective action may put it back in light service.

### **FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Critical, invert completely deteriorated. For circular pipes, partially collapsed crown in reverse curvature. For pipe arches, the structure is partially collapsed. Seams have failed.

**Cast-In-Place Concrete Culverts** – Culvert is partially collapsed, roadway is closed to traffic. Severe footing undermining resulting in partial collapse of the structure.

**Masonry Culvert Barrels** – Culvert is partially collapsed, roadway is closed to traffic. Severe footing undermining resulting in partial collapse of the structure.



**0** Bridge closed. Replacement is necessary.

**FHWA Supplemental Rating Guidelines:**

**Steel Culvert** – Critical, partial or complete collapse.

**Cast-In-Place Concrete Culverts** – Total failure of culvert and fill, roadway is closed to traffic.

**Masonry Culvert Barrels** – Total failure of culvert and fill, roadway is closed to traffic.

The above FHWA supplemental rating guidelines for steel and aluminum culvert shapes apply only to the commonly found circular and pipe arch sections. Additional shape guidelines for structural plate arches, corrugated metal box culverts, low profile arch long-span culverts, high profile arch long-span culverts, pear shaped long-span culverts, and horizontal ellipse long-span culverts are beyond the scope of this Manual, but may be found in the Culvert Inspection Manual.

One suggested method for establishing a culvert rating is to identify phrases within the general condition/FHWA supplemental guideline language that describes a culvert condition rating more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose a structural steel plate pipe culvert has surface corrosion at the invert and waterline, plus random joint bolts that have minor to moderate corrosion. The seams are tight. The culvert is an 8 foot wide arch pipe, with a measured horizontal dimension of 8 feet 4 inches (4.2 percent greater than the design value). Condition Rating 7 indicates that there is moderate rust or pitting, and the horizontal dimension of the culvert is between 3 to 5 percent of the design value. There may be minor openings at the seams. Condition Rating 6 indicates that there is fairly heavy rust with minor pitting and slight thinning. There may be evidence of backfill infiltration at the seams, and the horizontal dimension of the culvert is greater than 5 percent of the design value. Using the method described above, Condition Rating 6 describes a situation more severe than what actually exists on the substructure. Therefore, a rating of 7 would be appropriate.

Another method to help narrow down the culvert condition rating number is to group the numbers in more general categories. Ratings of 9 to 7 apply to culverts in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggest poor/critical condition, and 1 to 0 suggest critical condition.

#### **4.6.10 Inspection of Roadway Approach and Embankment**

Deficiencies in the roadway and embankment may be indicators of structural or hydraulic problems in the culvert. Refer to Section 4.6.5.5 of this Chapter and Part 2, Chapter 6 for additional information on the inspection of Roadway Approach and Embankment.



#### **4.6.11 Inspection of Waterway**

The channel conditions and waterway adequacy should be evaluated during the inspection. Refer to Part 2, Chapter 8 for a description of these inspection procedures. Culverts, or structures with a structural floor do not require a streambed profile. The ends of each Culvert End Treatment, however shall receive an underwater probe inspection to determine streambed stability or scour hole development.