Condition State 4 (Severe) – that portion of the element that warrants a review to determine the effect on strength or serviceability of the element or structure; OR a structural review has been completed and the defects impact strength or serviceability of the element or structure. Elements with a portion or all of the quantity in state 4 may often have load capacity implications warranting a structural review. Within this manual, the term structural review is defined as a review by a person qualified to evaluate the field observed conditions (Subject Matter Expert) and decide the impacts of the conditions on the performance of the element. Structural reviews may include a review of the field inspection notes and photographs, review of as-built plans or analysis as deemed appropriate to evaluate the performance of the element.

Each subsection contains a detailed description for each element and is broken down into the following subsections:

- Structure Type
- Element Number and Name
- Condition State Table to Reference
- Description—Detailed identification and classification of the element.

Unlike the Michigan Bridge Element Inspection Manual (MiBEIM), the MiASIM applies to 15 different Ancillary Structure types instead of a single structure type. Although elements and associated condition states may be similar between ancillary structures, differences in the severity of condition state defects may occur due to different element design considerations. For some ancillary structures, condition state defects are grouped together for each element (e.g., concrete foundation element defects include distresses such as concrete cracking, exposed reinforcement, and erosion). Therefore, rather than referencing Condition States for each element for all ancillary structure types, each structure contains an element subsection arranged as follows:

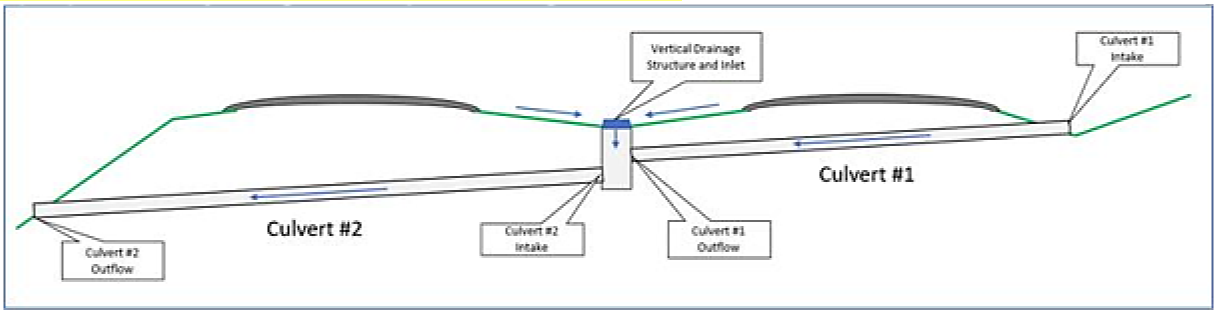
- Ancillary Structure Type
- Associated Elements – With definition of the element
- Condition States for Each Element – Guidelines for the inspector on defect severity categorization

2 CULVERTS LESS THAN 10-FOOT SPAN

2.1 Definitions

A linear drainage conduit(s) that has a combined span of less than 10 feet as measured along the centerline of the roadway, and the conduit is 12 inches in diameter or greater. Culverts are differentiated from storm sewers in that they are straight-line conduits that are open at each end and typically do not include intermediate drainage structures (manholes, catch basins etc.). When a culvert system includes intermediate drainage structures, the culverts shall be inventoried as two culverts.

Figure 2-1: Culvert Inventory Methodology



2.1.1 INVENTORY ITEMS

Ditch vegetation is an inventory item of none, partial, or full to note the amount of vegetation blocking the culvert structure opening.

The inventory requires noting the location and type of end treatment: none, headwall, headwall with wingwalls, beveled, mitered, flared, sloped, or drainage structure end section. If there is an end treatment, the type of material (metal, concrete, clay, or plastic) should also be noted.

The inventory items specific to culvert structures include the material that comprises the culvert barrel. Note the specific type of plastic pipe that is present (if unknown, select Plastic) such as Polyethylene, polypropylene, or PVC, whether the concrete pipe is prestressed or post-tensioned, reinforced, or non-reinforced (if unknown, select Concrete).

Culvert structure inventory also requires confirming the culvert shape: circular, horizontal elliptical, vertical elliptical, arch, box, or 3-sided. For metal barrels, note if the culvert is corrugated or non-corrugated.

If multiple barrel shapes, materials, or sizes are present, the inventory should reflect the specific barrel shape, material, and size of the barrel crossing beneath the roadway. Additionally, the barrel extension's shape, material, and size should be documented in the end inventory. Any relevant notes should also be included to ensure accurate and complete recordkeeping.

If there is a barrel liner, the liner material type will be inventoried.

The culvert height, width, and span should be noted in inches. The water depth at the inlet and outlet should be noted.

The culvert inventory includes culverts under bridge slopes. The inventory identifies such culverts as “beneath” berm. Inspectors should note in the application that the culvert is beneath the paved bridge slope.

Culvert inventories should indicate the presence of end section inlet/outlet protection. End section protection is identified when scour protection measures—such as riprap, field stone, channel armoring, grout-filled bags, or sheet piling—are placed immediately adjacent to the culvert inlet or outlet, or to any structural element of the end section, such as a headwall or wingwall. Safety grates and trash racks do not constitute as end section protection.

Take photos of the required inventory items listed in Section 2.2.

A complete list of inventory items is provided in the Ancillary Structures Data Dictionary.

2.1.2 ELEMENTS

Culverts Less Than 10-Foot Span are divided into four components: Approach Roadway and Embankment, Channel, End Treatments, and Culvert Structure.

End Treatments are further divided into elements: Headwall, Wingwall, and Scour.

The Culvert Structure is further divided into elements: Barrel and Joints.

The approach roadway and embankment and the channel are not divided into elements.

Elements are assigned a condition state described in Section 2.7 based on the distresses identified in each element. The following guidelines for consistent location notation provide the framework to be followed when rating a culvert element in accordance with the condition rating tables.

Consistent Location Notation Examples:

- Culvert Length - Distress locations along the culvert barrel length are referenced by using offsets measured from the outlet end and photographs. The outlet cardinal direction relative to the roadway is referenced also.
- Culvert Radius - The location of points on circular, elliptical, and arch-shaped culvert barrel cross sections is referenced like hours on a clock, with orientation of the clock looking upstream from the outlet. On non-round shaped cross sections, the locations are measured offsets from discrete locations such as corners, longitudinal seams, and foundations. The outlet cardinal direction relative to the roadway is referenced also. This allows for easy record transition for common changes such as culvert barrel length extensions for roadway widening.
- Joints - Identify offsets measured from the outlet end and photographs, rather than counting joint numbers.
- Defects are noted in the inspection report by recording the size of the defect (approximate length by width), distance from outlet, and the clock position or location on the structure wall.

Table 2-1: Culvert Less than 10-Foot Span Components and Elements

Component	Element	Element Code	Unit of Measure
Approach Roadway and Embankment	N/A	N/A	N/A
Channel	N/A	N/A	N/A
End Treatments	Headwall	12301	Each
End Treatments	Wingwall	12302	Each
End Treatments	Scour	12303	Each
Culvert Structure	Barrel	12404	Length, ft
Culvert Structure	Joints	12405	Each

2.1.3 COMPONENTS

Culverts Less Than 10-foot Span are divided into four components: the approach and roadway embankment, the channel, end treatments, and the culvert structure.

Component ratings for Culverts Less Than 10-foot Span are based on the following:

- Approach Roadway and Embankment - Consider the influence of the buried system on the length of roadway and shoulder above the culvert.
- Channel - Consider if the channel, including its watercourse, bed, and adjacent banks, may have anomalies that impact the performance or structural stability of the culvert.
- End Treatments - Consider if the end treatments may have characteristics that impact the structure's performance or if there is scour which impacts the concrete footing performance.
- Culvert Structure - Consider the barrel and joints as critical to the overall culvert structure performance.

A representation of the rating structure for Culverts Less Than 10-foot Span is illustrated in Figure 2-2.

All components are rated based on the guidance provided in Section 2.4. The overall culvert rating reflects the minimum of the Approach Roadway and Embankment and Culvert Structure component ratings.

Figure 2-2: Component-element Structure for Culverts Less than 10-Foot Span

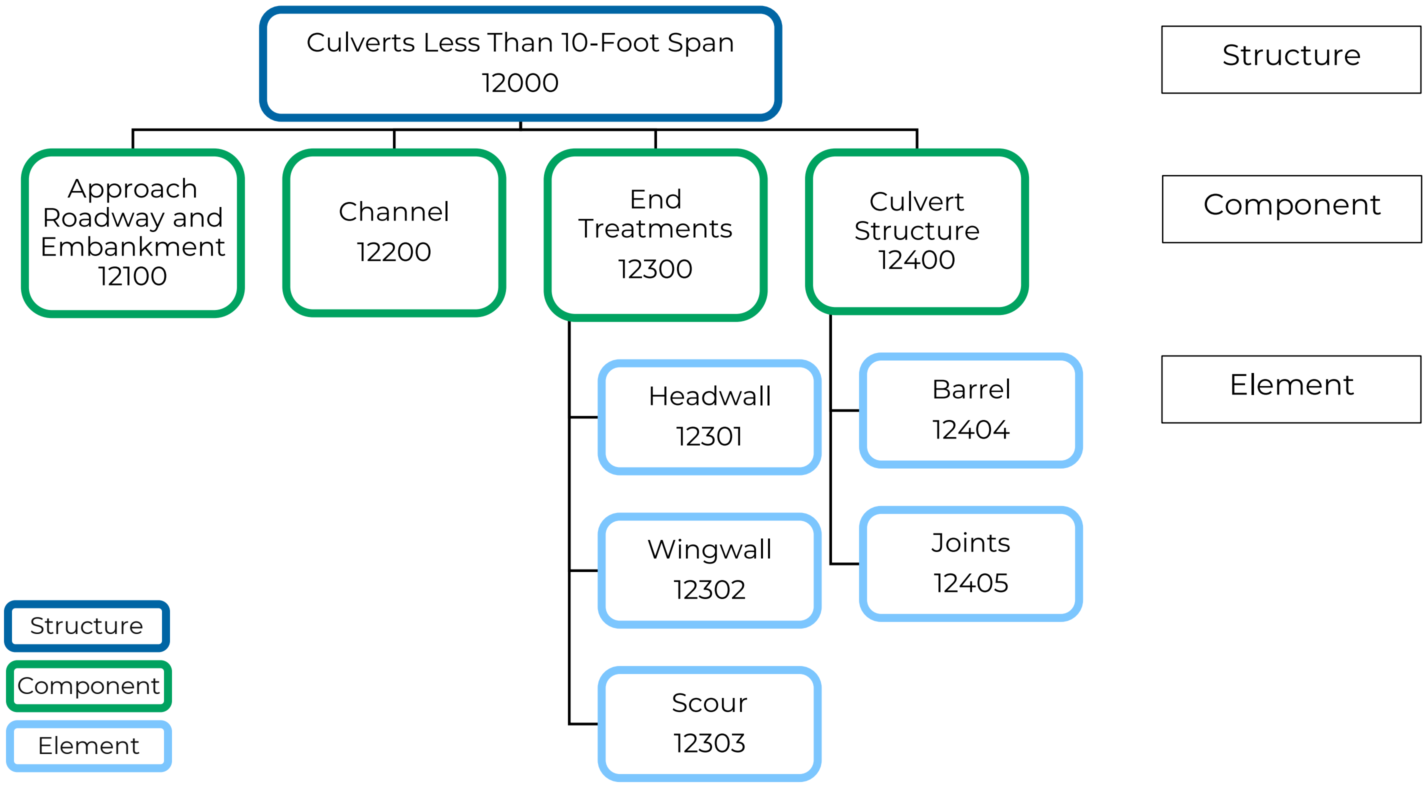
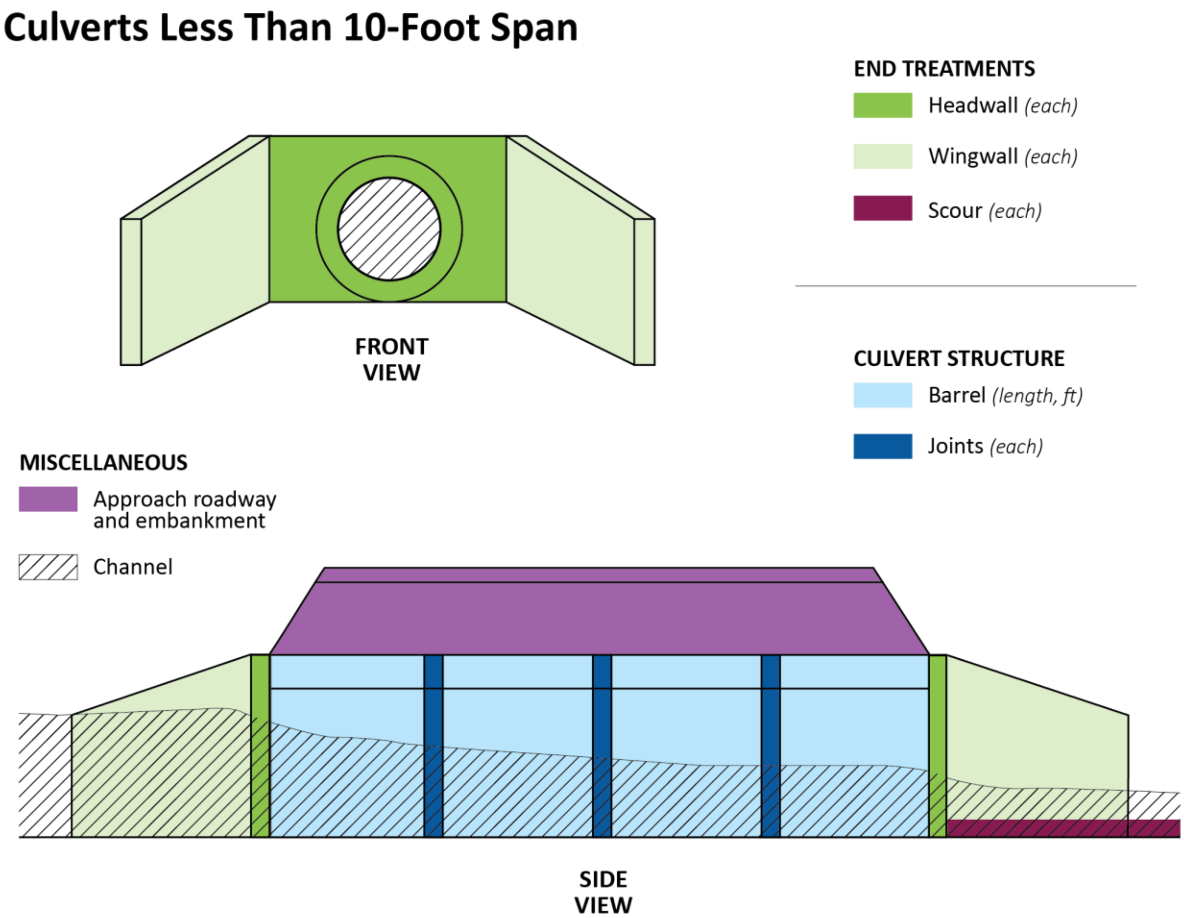


Figure 2-3: Elements and components for Culverts Less Than 10-Foot Span



2.2 Inventory Record Photographs

Inventory photos are captured during a routine inspection, saved as part of the inventory database, and follow the naming convention listed in Table 2-2.

Culvert Less Than 10-Foot Span Required Photos:

- General view of the roadway above culvert
- General view of the channel (upstream and downstream)
- General view of each end section (both sides)
- General view of the culvert barrel

Table 2-2: Culvert Less Than 10-Foot Span Photograph Naming Convention

Photo Name	Description
Culvert_Inlet	Entire inlet structure and adjacent slope
Culvert_Upstream_Channel	Channel upstream from inlet
Culvert_Barrel_From_Inlet	Barrel from inlet end
Culvert_Outlet	Entire culvert outlet structure and adjacent slope; looking into barrel
Culvert_Downstream_Channel	Channel downstream from outlet in the direction of flow
Culvert_Barrel_From_Outlet	Barrel from outlet end
Culvert_Road_Crossing	Roadway above culvert taken from inlet structure; looking in the direction of flow

Note: If there are two large culverts with a total barrel width exceeding 10', but they are separated from each other by greater than half the width of a single barrel, they are considered two culverts. Separate photos of each barrel and photos combined with all barrels should be taken.

2.3 Inspector Minimum Technical Qualifications

At least one member of the field inspection crew shall possess the following:

- A minimum experience of ten structures combined concrete inspection, steel inspection, or design experience (bridge inspection qualifies). At least three of the ten inspected structures shall be concrete structures.
- Ancillary structures inspection procedures training
- Working knowledge of inspection tools, their use, application, and limitations for the structure type being inspected.
- Inspection experience with anticipated material types, such as concrete, timber, masonry, or steel. Internal training will address inspection procedures for all anticipated material types.

2.4 Routine Inspection

Culvert standard inspection frequency is once every 5 years, unless otherwise identified for more frequent inspection.

The acceptable tolerance for intervals of less than 24 months for the next inspection is up to two (2) months after the month in which the inspection was due. The acceptable tolerance for intervals of 24 months or greater for the next inspection is up to three (3) months after the month in which the inspection was due. Exceptions to the inspection interval tolerance due to rare and unusual circumstances should be approved by MDOT's Ancillary Structures Program Manager in advance of the inspection due date plus the above tolerances.

It is recognized that severe weather, inspector safety, inspection quality, resource optimization, technological difficulties, or other unique situations may be a reason to adjust the scheduled inspection date. In these situations, the adjusted inspection date should not extend more than two (2) months after the month the inspection was due for any inspection interval less than 24 months and not extend more than three (3) months after the month the inspection was due for any inspection interval 24 months or greater. Inspection interval tolerances are intended to provide some flexibility. When tolerances are applied, the longest time period prescribed between inspections is the applicable interval plus the prescribed tolerance. For example, a routine inspection on a 12-month interval could be performed during the 14th month if the tolerance is applied. Repeatedly applying the tolerance to the next inspection will create inspection date creep and may impact an owner's ability to perform future inspections in a timely manner due to other limitations (e.g. available resources, inspection workload, schedule, seasonal weather conditions, technological difficulties, etc.). Exceptions to inspection interval tolerances due to rare and unusual circumstances should be approved by MDOT's Ancillary Structures Program Manager in advance of the inspection due date, plus the tolerance. For example, if an inspection with an interval of 24 months is due on June 17, an exception request should be approved by MDOT's Ancillary Structures Program Manager before the end of the 3-month tolerance (i.e. September 30). However, a request for exception should be made when the potential for not meeting the tolerance becomes known to provide MDOT's Ancillary Structures Program Manager with adequate time for review and approval.

Table 2-3 provides guidance for inspecting reinforced and prestressed concrete cracking.

Table 2-3: Standard Cracking Widths

Description	Reinforced Concrete	Prestressed Concrete
Hairline (HL)	<1/16" (0.0625")	< (0.004")
Narrow (N)	1/16" to 1/8" (0.0625" to 0.125")	(0" to 0.009")
Medium (M)	1/8" to 3/16" (0.125" to 0.1875")	(0.010" to 0.030")
Wide (W)	>3/16" > (0.1875")	> (0.03")

Source: FHWA Bridge Inspector's Reference Manual (Publication No. FHWA NHI 03-001, October 2002)

2.4.1 APPROACH ROADWAY AND EMBANKMENT ROUTINE INSPECTION

The approach roadway is the length of roadway and shoulder above the culvert that is influenced directly by the performance of the buried culvert system. This includes the pavement (or gravel if not paved), guardrails, and shoulders. The inspection area for the approach roadway includes the culvert span plus a minimum of 20 feet from where each side of the culvert structure ends.

The embankment inspection focuses on the immediate soil slope area. The embankment inspection is conducted visually for slope stability (sloughing or piping) and embankment erosion, which can be interrelated.

Provide photographs for all Poor or Severe condition state defects and submit the applicable Work Recs or RFAs.

2.4.1.1 Approach Roadway and Embankment Component Ratings

The purpose of approach roadway inspection is to evaluate the condition and functional adequacy, with a focus on how distress at the pavement, shoulder, and guardrail areas may indicate problems with the culvert below. For example, cracks, sags, or pavement patches may indicate a void around the buried pipe or pipe joint distress. The approach roadway inspection can provide indicators of potential distress in the culvert.

The embankment inspection, like the approach roadway, is to identify distress indicators related to erosion and slope stability that can affect the culvert performance. For example, movement of the embankment soil (sloughing) can open pipe joints, destabilize structures, and ultimately endanger the roadway.

Issues observed in the approach roadway can often be an indicator for culvert performance; however, they can equally be unrelated. Because of this, it is important for inspectors to evaluate the relationship between any identified approach roadway distress and culvert distress whenever possible.

Figure 2-4: Approach roadway, without observable distress (left), clear distress over culvert (right)

Table 2-4: Component Rating Guidelines for Culvert Less Than 10-Foot Span Approach Roadway and Embankment

Component Rating	Condition	Material	Description
9	**NEW**	All	No noticeable or noteworthy deficiencies which affect the condition of the approach pavement.

Component Rating	Condition	Material	Description
8	VERY GOOD	All	Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling, or delamination on the approach pavement.
7	GOOD	All	Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft or more, light shallow scaling allowed in the surface. Approach pavement will function as designed.
6	SATISFACTORY	All	Deterioration of the approach pavement, including repaired areas, is 2% or less of the total area. There may be a considerable number of open cracks greater than 1/16" wide at a spacing of 5 ft or less in the approach pavement. Medium scaling on the surface is 1/4" to 1/2" in depth. Settlement is minor. Approach pavement will function as designed. Embankment may have minor damage.
5	FAIR	All	Deterioration of the approach pavement, including repaired areas, is between 2% and 10% of the surface area. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth can be present. Settlement is less than 3/4 inches at the culvert centerline. Approach pavement will function as designed. Embankment may have major damage.
4	POOR	All	Deterioration on the approach pavement, including repaired areas, is between 10 - 25%. Settlement is more than 3/4 inches at the culvert centerline. Approach pavement will function as designed. Embankment may have severe damage.
3	SERIOUS	All	Deterioration in the approach pavement, including repaired areas, is more than 25% of the surface area. Urgent surface repairs may be required by the crews.
2	CRITICAL	All	Deterioration has progressed to the point where the approach pavement will not function as designed. Emergency surface repairs may be required by the crews.
1	IMMINENT FAILURE	All	Roadway or roadway shoulder above culvert closed because of approach roadway or embankment failure. Corrective action may put back in service.
0	FAILED	All	Roadway closed above culvert.

2.4.1.2 *Pavement and Shoulders*

Pavement issues may lead to infiltration, which can cause a loss of backfill around the pipe. The loss of backfill reduces the pipe lateral support and may progress to create voids near and over the pipe. This can result in undermining of pavements that can be observed as cracking, or sags/humps. Pavement types for the purpose of this inspection item may consist of asphaltic concrete, Portland Cement concrete, gravel, or other surface treatments. Field experience has shown that even flexible pavements can bridge relatively large voids, with only a small hole in the pavement hiding large subsurface voids.

When not detected and addressed, the loss of soil support can progress to pavement failure.

Settlement

Pavement or shoulder settlement can be due to many different factors such as:

- Poorly compacted materials
- A significant difference in soils used for roadway embankment compared to those used for pipe embedment
- Piping (washout of fines) along the culvert causing voids or cracks above
- Settlement of backfill material, allowing movement of the structure
- Flexible pipe barrels will deflect at their crown if:
    - Adequate lateral support is not provided by the surrounding embedment soil
    - Pipe is overloaded and deflects
- For rigid culverts, inadequate compaction or low-quality embedment soil can result in settlement on either side of the culvert, usually forming a hump over the buried pipe

Sighting along the edge of pavement or along pavement markings is also important and can reveal settlement indicators including humps, sags, and rutting.

Figure 2-5: Pavement and shoulder issues above culverts

Sags and Humps

Sags and humps can be indicator of an issue with the culvert below the roadway. They could be from settlement after construction or signs of a much larger issue with the culvert, such as joint infiltration or piping.

Rutting

Rutting is a surface depression in the wheel path that runs parallel to the direction of travel. It is typically from vehicular loads and not related to culvert condition but can sometimes be a sign that is related to a defect and/or deterioration below the surface. Determine if the rutting is repetitive on the roadway or localized to the culvert area. Rutting that appears localized to a culvert may be an indicator for deflection of the pipe or loss of backfill material, like the causes for sags and humps

Cracking

Transverse and longitudinal cracking that occurs over a buried pipe is often a distress indicator for settlement, deflection, or loss of backfill support. All open pavement cracks in the approach roadway inspection length are to be probed for the presence of voids. Record other pavement distress in the approach roadway even if it does not appear to be directly related to the culvert.

Transverse cracks are often related to culvert distress. These cracks run perpendicular to the direction of the road and are of primary interest as a distress indicator in culvert inspection. Regularly spaced transverse cracks along long stretches of roadway are usually caused by temperature-induced expansion and contraction and may not indicate culvert distress. Try to locate any sags or humps that may be associated with transverse cracks over the culvert.

Figure 2-6: Transverse cracking of pavement above culvert

Longitudinal cracks run parallel to the direction of the road. Cracks within 1 foot of the lane edge are typically caused by shoulder settlement, frost action, or poor drainage, and may be unrelated to the presence of buried pipes. Consider these factors when assessing longitudinal cracks as distress indicators for a culvert. Longitudinal cracking that is not a distress indicator for the culvert does not need to be included in the condition rating but shall be noted in the comments.

Figure 2-7: Longitudinal cracking

Alligator cracks are a form of fatigue cracking that forms a pattern of small angular pieces of pavement creating an appearance like alligator skin. This type of cracking is not typically associated with culvert distress. However, it may similarly indicate distress in the culvert if alligator cracking exists locally over the culvert but not in other areas. Note the presence of alligator cracking in the inspection report in the comments.

Figure 2-8: Pavement and shoulder alligator cracking

Slippage cracking is characterized by a generally rounded pattern caused by slippage between an overlay and underlying pavement occurring most commonly at intersections with high volumes of stop/start traffic. As with alligator cracking, slippage cracks do not typically indicate culvert distress. Note the presence of slippage cracks in the inspection report in the comments.

Figure 2-9: Slippage cracking

Other notable approach considerations

Several other factors can cause distress in the approach roadway. If present, they are noted as an important comparison basis for subsequent reviews. If necessary, they can be noted as needing an in-depth inspection. Items that shall be recorded in the notes include:

- Obvious changes in the approach roadway, such as:
  - Grade changes to the roadway, that may reduce the overflow capacity of the culvert system, or
  - The addition of a guardrail or barrier that may increase water directed into the channel.
- Pavement patches or crack sealant that have reopened and are determined to indicate:
  - Progressive settlement,
  - Leaking joints, or
  - Other ongoing problems

2.4.1.3 Embankment

The embankment inspection shall focus on the immediate soil slope area. The embankment is visually inspected for slope stability (sloughing) and embankment erosion (piping), which can be interrelated.

This includes burial cover for the pipe from the roadway shoulder, down to the bottom of the slope at the inlet and outlet ends. The inspection width is the same as defined for the approach roadway, a 20 foot minimum on either side of the culvert.

Types of embankment distress are noted below.

Figure 2-10: Example of embankment failure above a culvert

Figure 2-11: Example of embankment issues due to piping (left) or erosion (right)

Sloughing

Sloughing is the sliding or collapse of a soil slope, caused when the underlying material becomes saturated with water. Sloughing appears as a vertical cut or drop to where the sloughed mass of soil has collapsed downslope.

Tension Cracks

Tension cracks can occur at the top of the embankment slope or adjacent to the top of a retaining wall. Tension cracks are semi-circular in shape to match the slip surface, typically run parallel to the stream, roadway, or retaining wall and can be a precursor to slope failure.

Embankment Erosion

Embankment erosion refers to the loss of the surface materials on the embankment, including vegetation or other protective materials that are used to aid slope stability. Embankment erosion may indicate inadequacy of the roadway and shoulder surface storm water collection system.

There are several types of erosion. It is important to assess the severity of the erosion in relation to the roadway and culvert support. Photo documentation is also vital in determining the progression of any erosion. The following are the main types of erosion related to culverts.

Sheet Erosion

The washing away of slope vegetation and thin layers of soil as runoff water flows in sheets down the slope. Embankment slopes are prone to sheet erosion as water flows off the roadway and down the embankment. Early-stage sheet erosion starts as bare areas, puddling, exposed vegetation roots, and/or exposed subsoils (stony or rocky soils).

Gullying/Rill Erosion

Specific types of surface erosion where runoff carves channels in the soil. This typically occurs with multiple barrel pipes and/or with mitered or projecting ends.

Figure 2-12: Culvert erosion—early-stage gully/rill erosion between the culverts

Piping

Erosion of the backfill where water flows along the outside of the pipe. Piping along the outside of the barrel of the culvert can reduce backfill support and can lead to weakened embankment slope stability.

Piping typically presents as one or more of the following:

- Voids or tension cracks in the embankment soil
- Voids or tensions cracks in the roadway
- Streams of water exiting the embankment in the slope face
- Streams of water around the exterior of the pipe wall during times of high flow

Piping may occur when culvert barrel blockage or upstream embankment conditions cause increased pressure.

2.4.2 CHANNEL ROUTINE INSPECTION

The stream channel is a feature of a culvert system and consists of the watercourse, its bed, and the adjacent banks. Inspection of the channel is performed from the inlet and outlet of the structure. The channel component does not contain any associated elements. Visually observe the channel limits to identify where water typically flows into the culvert, using visual observation such as cut bank, vegetation lines, limits of channel armoring, or limits of the exposed stream bottom.

Provide photographs for all Poor or Severe condition state defects and submit the applicable Work Recs or RFAs.

2.4.2.1 Channel Component Rating

The purpose of the channel inspection is to identify channel-related anomalies that may impact the performance or structural stability of the culvert. If a culvert is blocked or the stream capacity is reduced, the waterway adequacy may change significantly. This can result in excessive ponding, flooding of nearby properties, and washouts of the roadway and embankment.

The stream channel leading to the culvert inlet and moving away from the outlet end is inspected to determine whether conditions exist that would cause damage to the culvert system (soil and structure) or adjacent property. Factors to be checked include alignment of the channel relative to the culvert (horizontal and vertical alignment), bank erosion and scour, condition of bank protection, and accumulation of sediment and debris (waterway adequacy). A brief discussion of each of these factors follows.

Poor vertical and horizontal alignment of the culvert relative to the stream channel can result in reduced hydraulic efficiency, increased erosion or sedimentation of the stream channel, damage to the embankment supporting the roadway, and damage to adjacent property. Often, protective measures are required to maintain stability of the channel and hydraulic and structural performance of the culvert.

Figure 2-13: Stream channel poor vertical alignment (left) and horizontal alignment (right)

Table 2-5: Component Rating Guidelines for Culvert Less Than 10-Foot Span Channel

Component Rating	Condition	Material	Description
9	NEW	All	No noticeable or noteworthy deficiencies affect the condition of the channel
8	VERY GOOD	All	Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition.
7	GOOD	All	Bank protection is in need of minor repairs. River control devices and embankment protection

Component Rating	Condition	Material	Description
			have a little minor damage. Banks and/or channel, have minor amounts of drift.
6	SATISFACTORY	All	Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. Minor stream bed movement is evident. Debris is restricting the channel slightly.
5	FAIR	All	Bank protection is being eroded. River control devices and/or embankment have major damage. Trees and brush restrict the channel.
4	POOR	All	Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the channel.
3	SERIOUS	All	Bank protection has failed. River control devices have been destroyed. Streambed, aggradation, degradation, or lateral movement has changed the channel to threaten the culvert and/or approach roadway now.
2	CRITICAL	All	The channel has changed to the extent the culvert is near a state of collapse.
1	IMMINENT FAILURE	All	Roadway or roadway shoulder above culvert closed because of channel failure. Corrective action may put back in service.
0	FAILED	All	Roadway above culvert closed because of channel failure. Replacement necessary.

Horizontal Alignment

Check for erosion and indicators of changes in the direction or location of the stream channel. Plan-view sketches and site photographs are used to document the condition and horizontal alignment of the channel relative to the culvert barrel at the time of inspection. The alignment is critical for a three-sided culvert which may be susceptible to failure due to scour. Abrupt changes in stream horizontal alignment (bends) retard flow and cause increased erosion along the outside of the bend, damage to the culvert and end treatments, and increased sedimentation along the inside of the bend. Where sharp channel bends exist at either the inlet or outlet of a culvert, check for sedimentation and erosion.

Figure 2-14: Stream channel poor horizontal alignment

Vertical Alignment

Problems related to vertical alignment are usually indicated by scour or accumulation of sediment. Culverts on grades that differ significantly from the natural gradient (stream channel alignment) may present problems. Culverts on flat grades may have sediment build-up at the entrance or within the barrel. Culverts on moderate and steep grades generally have higher flow velocities than the natural stream and may have problems with outlet scour.

Figure 2-15: Vertical alignment issue leading to foundation undermining

Figure 2-16: Vertical alignment issue leading to stream degradation

Figure 2-17: Vertical alignment distress; may have progressing washout due to high flow

Waterway Adequacy

Determine the ability of the culvert to handle peak flows, changes in the watershed, changes in the stream channel which might affect the hydraulic performance, and, most commonly, levels of sedimentation and debris accumulation. Assessment of waterway adequacy includes inspection of highwater marks and waterway obstructions. Waterway adequacy may not be a large concern for smaller culvert component rating.

Figure 2-18: Blocked inlet

High Water Marks

The high-water marks may not seem important, but they be an indicator for inadequacy of the culvert and shall be investigated. Note any indications of excessive ponding, flooding, or overtopping of the roadway. If the cause is apparent, such as a blocked inlet, note in the inspection comments.

Waterway Obstructions

Accumulation of debris and sediment at the inlet or within the culvert barrel reduces both the size of the opening and the culvert's capacity to handle peak flows and may cause scour of the stream banks and roadway embankment, head cutting, or changes in the channel alignment. Debris and sediment accumulations at the culvert inlets or within the culvert barrel may result in roadway overtopping, excessive ponding, and the potential for damage due to buoyant forces. Note deposits of debris or sediment that could block the culvert or cause local scour in the stream channel. Downstream obstructions which cause water to pond at the culvert's outlet may also reduce the culvert's flow capacity.

Debris collectors are used in some culverts so that the opening is not blocked by floating materials. Identify these devices and note if their condition contributes to debris accumulation or renders them nonfunctional, or if they need repair.

Note some culverts may be designed with fill in the bottom (invert) to create a more natural stream bed for fish. Identify these culverts to distinguish intentional fill from debris accumulation.

Figure 2-19: Intentional natural streambed

Head Cutting/General Scour

General Scour extends farther along the stream and is not localized around a particular obstruction. General scour involves a gradual, fairly uniform degradation or lowering of the stream channel. It can also result in abrupt drops in the channel that move upstream during peak flows. This type of scour is referred to as head cutting. Head cutting is channel degradation associated with abrupt changes in the bed elevation that migrates in an upstream direction. Head cutting may be a serious problem if it is occurring in the channel downstream from the culvert because it may threaten the culvert outlet as it moves upstream.

Bank Erosion

Bank erosion, in contrast to general scour and head cutting, refers to loss of stream channel (bank) sidewall material and a lateral movement of the channel. Bank erosion includes expansion of the channel at a change in direction of the stream when protection is not provided or provided protection is not adequate. Signs of severe bank erosion include undercutting of bank edge and sod root overhangs.

Figure 2-20: Bank erosion

Figure 2-21: No scour (left), scour hole (right)

2.4.2.2 Channel Element Condition States

NOT USED.

2.4.3 END TREATMENTS ROUTINE INSPECTION

The end treatments are composed of headwalls and wingwalls, and the concrete footing and inverted slab associated with three-sided structures, such as concrete arches, open-bottom box culverts, and structural plate arches. Joints between the headwall and/or wingwall and the culvert barrel are assessed as part of the end treatment inspection, rather than the barrel as indicated in.

End treatments and appurtenant structures are the inlet/outlet structures and associated elements that are used to reduce erosion, retain fill material, inhibit seepage, improve hydraulic efficiency, provide structural stability to the culvert ends, and improve the appearance of the culvert. Several types of end treatments are commonly used at culvert inlets and outlets ranging from no treatment to a constructed-in-place end structure.

Three-sided structures, such as concrete arches, open-bottom box culverts, and structural plate arches, typically use concrete footings (also called foundations) to transfer vertical loads to the foundation soils. Structural plate arches are usually bolted to a base channel that is secured to the footing. Concrete arches are typically grouted into keyway recesses formed into the top surface of the footings. Invert slabs are paved or cast slabs used in lieu of a natural or open-bottom culvert or used within closed-bottom culverts to provide a widened waterway or as reinforcement for a new or deteriorated culvert.

Provide photographs for all Poor or Severe condition state defects and submit the applicable Work Recs or RFAs.

2.4.3.1 End Treatments Component Ratings

Culvert end treatments and appurtenant structures perform a variety of functions and therefore are inspected to assess their structural stability, hydraulic performance, and traffic safety characteristics. Structural stability and hydraulic performance characteristics may differ considerably with different types of end treatments. Typically, assessment of joint between the end section and first pipe segment for evidence of separation is one of the first checks to be conducted. At the upstream end, this is an indicator of a high-water event causing a buoyancy lift. At the downstream end, joint separation can result from a scour hole and/or stream degradation. Both distresses often indicate an undersized culvert. The type of end treatment will dictate inspection procedures.

Inspect the concrete footing and invert slab to identify distress and distress indicators, typically due to scour, that may indicate foundation problems.

The flow line condition is also inspected as part of the component rating of the end treatments. Flow line condition is indicated by the amount of sediment or debris accumulation within the pipe. Blockage and ponding due to trees, shrubs, sedimentation, or debris may be noted. In severe conditions, the culvert may be blocked due to mass drift accumulation. There may be high water marks indicating roadway overtopping.

In addition to the foundation (concrete footing and invert slabs), headwalls, and wingwalls, end treatments may also include:

- Projecting ends
- Sloped end sections
- Precast concrete end sections
- Aprons and flumes
- Weep holes

End Treatment Projecting Ends

Projecting ends have no end structure attached to the culvert barrel and the pipe barrel simply projects out of the embankment. Projecting outlets, such as perched outlets, often result from scour holes formed due to impact of high exit velocities and/or stream degradation. They also result from erosion and can be a barrier to fish passage.

Figure 2-22: Projecting or perched outlet

End Treatment Sloped End Sections

A sloped end section is a culvert end that has been modified to match the embankment slope. They often have safety bars that can trap debris. Culverts with mitered or skewed end treatments are inspected for the same types of problems as culverts with projecting ends. Sloped end sections include prefabricated metal or precast concrete sections that are placed on small diameter pipe.

Metal pipe culverts with a sloped end are inspected for deformation since cutting the ends reduces the structural integrity of the pipe. It is therefore important to check cut ends of culverts for signs of distress including deformation, erosion of the fill slope, and undercutting.

Figure 2-23: Sloped metal end sections

Precast Concrete End Section

Precast concrete end sections are inspected for deformation and damage similar to sloped ends.

Figure 2-24: Flared concrete end section

Aprons and Flumes

Aprons may consist of a concrete slab, grouted or un-grouted riprap, or other material. Aprons and flumes are checked for signs of undermining settlement or movement. Dry stone or un-grouted riprap is inspected for displaced or moving stones. A scour hole with a downstream mound will often form in rip-rap aprons and should generally not be disturbed by maintenance activities.

Weep Holes

Weep holes are often provided on the sidewalls and wingwalls to drain water from the backfill and reduce the hydraulic pressure on the concrete surface. Weep holes are inspected to determine if they are functioning properly. Lack of flow during wet conditions or at times when flow has previously been observed may indicate blockage. Fine soils in the flow also indicate improper functioning.

Other items that are used to assess the end treatment component rating are:

- Separation
- Voids
- End Section Drop-Off
- Settlement

Separation

Separation between the barrel and the headwall or wingwalls that exposes fill material can be serious and shall be reported for special attention as part of an RFA or Work Rec. Such separations permit the loss of the supporting soil and could lead to failure anywhere along the length of the culvert.

Voids

Metal headwall and wingwall inspections should include checking for voids behind the walls which may indicate a loss of backfill, toe-out (rotation) of the base which may indicate scour in front of the wall, and outward movement of the wall top which may indicate damage to anchor bolts.

End Section Drop-off

Erosion can cause end section displacement and drop-off in rigid pipe culverts, particularly at the outlet ends. End section drop-off is a term used to describe the condition in which the end section of the culvert barrel has separated from the rest of the line. This is usually due to outlet scour, stream degradation, or erosion of the material supporting the pipe section at the outlet end of the culvert barrel.

Settlement

Settlement exerts additional stress on the ends of the culvert and may cause blockage or end failure.

Table 2-6: Component Rating Guidelines for Culvert Less Than 10-Foot Span End Treatments

Component Rating	Condition	Material	Description
9	NEW	All	No deficiencies in any of the structural components that will affect the long-term performance.
8	VERY GOOD	All	All structural components are sound and functioning as designed. There may be superficial cracking or weathering of protective coatings and/or dirt contamination on structural components.
7	GOOD	All	All members retain full section properties and function as designed. There may be minor cracking in structural components.
6	SATISFACTORY	All	All members retain full section properties and function as designed. There may be some deterioration affecting structural members such as minor cracking, scaling, small, scattered spalls, or shallow scour. Some protective coating failures.
5	FAIR	All	Moderate deterioration affecting structural members such as cracking, scaling, scattered spalls, minor settlement, or shallow scour. Minor section loss in low or no stress areas. All members continue to function as designed.
4	POOR	All	Considerable deterioration affecting structural members such as cracking, scaling, scattered spalls, partial settlement or, scour. All end treatments continue to function as designed.
3	SERIOUS	All	Considerable deterioration affecting structural members. Structural evaluation, hydraulic, and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading, structurally engineered supports, or immediate repairs. There may be a need to increase the frequency of inspections.
2	CRITICAL	All	Deterioration has progressed to the point where the structure will not support design loads and therefore is posted for reduced loads. Emergency repairs or shoring with structurally engineered temporary supports may be required by the crews. There may be a need to increase the frequency of inspections.
1	IMMINENT FAILURE	All	Roadway or roadway shoulder above culvert closed because of end treatment failure causing embankment and approach failure. Corrective action may put back in service.
0	FAILED	All	Roadway closed above culvert.

2.4.3.2 *Headwall Element Condition States*

Headwalls and wingwalls are inspected for any signs of undermining and settlement, such as cracking, tipping/rotation, or separation of the culvert barrel from the headwall. If the headwall is comprised of a metal or concrete material will determine the types of condition state distresses which apply. Cracking, surface damage, spalling, delamination, and exposed repair will apply to concrete headwalls. Corrosion, deformation, and damage apply to metal walls. Any visible wall vertical offset is noted in the inspection report.

Figure 2-24: Concrete headwall and wingwall

Figure 2-25: Concrete headwall and metal sheet pile wingwalls

Table 2-7: Headwall Element Distresses

Unit of Measure: Length, feet. Distresses are measured as a "slice" of the diameter of the barrel's length.

Element Number	Element Name	Description	Applicable Distresses
12301	Headwall	End Treatment comprising headwall of culvert	End Treatment Cracking (Concrete)
			End Treatment Surface Damage/Spalling/ Delamination (Concrete)
			Exposed Rebar (Concrete)
			End Treatment Deformation and Damage (Metal)
			End Treatment Corrosion (Metal)

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Cracking (Concrete)

Headwall concrete cracking typically consists of longitudinal or transverse cracks.

Hairline cracks less than 0.0625 in. in width are minor and only need to be noted in the inspection notes. Moderate cracks greater than hairline cracks are described in the inspection report and noted as possible candidates for maintenance. Wide cracking may indicate overloading or poor bedding and side support and warrant further evaluation by an engineer. They may also be candidates for remedial action. These larger longitudinal cracks also allow water and oxygen to penetrate to the rebar and initiate corrosion which can lead to concrete spalling, significantly reducing the life of the headwall.

Transverse cracks may be caused by poor bedding. Cracks may occur across headwall when settlement occurs.

Surface Damage, Spalling or Delamination (Concrete)

Deterioration to a concrete headwall is typically due to:

- Surface Damage,
- Spalling, or
- Delamination

Surface Damage

Headwalls are inspected for localized damage. Damage such as dents, bulges, creases, cracks, and tears can be serious if distress is extensive and can impair the integrity of the headwall. Small and localized examples are not ordinarily critical but are noted and photographed. Severe local damage distress will usually display a poorly shaped cross section or through-wall penetration. Document the type, extent, and location of all significant wall damage distress.

Spalling

Spalling is a fracture of the concrete parallel or inclined to the surface of the concrete.

Spalls often occur along the edges of either longitudinal or transverse cracks when the crack is due to overloading or poor support rather than normal temperature or shrinkage cracking. Spalling may also be caused by corrosion of the reinforcing steel bar (rebar) when water is able to reach the rebar through wide cracks or shallow cover. As the rebar corrodes, the oxidized steel expands, causing the concrete covering to spall.

Spalling may be detected by visual examination of the concrete along the edges of cracks. Tapping with a hammer is performed along cracks to check for areas that have fractured but are not visibly debonded, as these areas will produce a hollow sound when tapped.

Figure 2-26: Spalled concrete at headwall

Delamination

Delaminations are separations along a plane parallel to a surface, as in the separation of a coating from a substrate or the layers of a coating from each other. Delaminations are not visible from the surface but can be detected by tapping along the surface with a hammer or dragging a chain to detect hollow-sounding areas. Delaminations are noted in the inspection report by recording the size of the delamination (approximate length by width on the headwall).

Exposed Rebar (Concrete)

Indicate if reinforcement is exposed and the amount of section loss. Larger cracks allow water and oxygen to penetrate to the rebar and initiate corrosion which can lead to concrete spalling, significantly reducing the life of the headwall.

Some red/brown staining emanating from cracks can be caused by iron bacteria in groundwater or other organic staining not related to rusting. Carefully examine the staining and be familiar with the differences. Staining from iron bacteria is not cause for concern and is not a condition defect.

Deformation and Damage (Metal)

Metal headwalls are inspected for localized damage. Damage, such as dents, bulges, creases, cracks, and tears, can be serious if distress is extensive and can impair the integrity of the headwall. Small and localized examples are not ordinarily critical but are noted with size and photographed. Severe local damage distress will usually cause a poorly shaped cross section or through-wall penetration. Document the type, extent, and location of all significant wall damage distress. When examining dents, the opposite side of the plate is checked, when accessible, for cracking.

Corrosion

Corrosion is the deterioration of metal due to electrochemical or chemical reactions. The inspection should include visual observations of metal corrosion. As steel corrodes, it expands considerably. Relatively shallow corrosion can produce thick deposits of scale. A pick hammer is used to scrape off heavy deposits of rust and scale for observation and nondestructive thickness measurement of the metal. A pick hammer is also used to locate unsound areas of exterior corrosion by striking the headwall with the pick end. The pick will deform the wall or break through it at locations of severe exterior corrosion.

Protective coatings are examined for abrasion damage, tearing, cracking, and removal. Document the extent and location of surface deterioration problems. These problems can all contribute to corrosion of the metal headwall.

2.4.3.3 Wingwall Element Condition States

Wingwalls are inspected for any signs of undermining and settlement such as cracking, tipping/rotation, or separation from the culvert barrel. Settlement exerts additional stress on the ends of the culvert and may cause blockage or end failure.

Headwalls and wingwalls share the same condition state distresses. Refer to Sections 2.4.3.2 and 2.4.3.3, respectively, for the discussion of the condition state distresses common to both elements.

Table 2-8: Wingwall Element Distresses

Unit of Measure: Area, feet. Distresses are measured as an area of the wingwall.

Element Number	Element Name	Description	Applicable Distresses
12302	Wingwall	End Treatment comprising wingwall of culvert	End Treatment Cracking (Concrete)
			End Treatment Surface Damage/Spalling/
			Delamination
			End Treatment Deformation and Damage (Metal)
			End Treatment Corrosion (Metal)

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

2.4.3.4 Scour Element Condition States

Concrete footings and inverted slabs are typically installed at a depth below the anticipated scour level to prevent undermining and instability of the foundation. However, most older slab culverts are susceptible to scour. The scour element refers to the typical damage that occurs to the concrete footings and inverted slabs due to scour.

Table 2-9: Scour Element Distresses

Unit of Measure: Each. Distresses are measured as each footing or slab.

Element Number	Element Name	Description	Applicable Distresses
12303	Scour	Concrete footing and invert slab damage due to scour	End Treatment Scour and Stability

Details on the condition state rating schema are in Section 2.7, linked below:

[Culvert Less Than 10-Foot Span Condition State Tables]

Scour and stability are often related as scour can undermine the footing, causing rotation of the foundation and damaging stress to the culvert wall. If allowed to progress, scour can lead to collapse of the culvert. Check for scour and erosion that may cause undermining of the footings and look for any indication of rotation of the footing.

Note the extent and location of any erosion or undercutting around the ends of the culvert barrel or any end treatments. Scour may cause loss of articulated concrete block (ACB), rock, or other measures originally placed to reduce scour.

Culvert scour consists of three types of scours: stream degradation, contraction scour, and local scour. Stream degradation is long term changes in the streambed elevation due to natural or human-induced causes, which can affect the reach of the river near the culvert. Contraction scour is removal of material from the bed and banks across all or most of the channel width, resulting from the contraction of the flow area. Local scour is removal of bed material from around the culvert foundation. Local scour is caused by the acceleration of flow and vortices resulting from flow around an obstruction.

Figure 2-27: Concrete foundation and wingwall damage due to scour

The most common structural distress in concrete footings is differential settlement, typically due to scour undermining the footing. Differential settlement occurs when one section of a footing settles more than the rest of the footing. This can cause cracking in concrete, wrinkling in corrugated metal, distress to joints, or other damage or distortion in the supported culvert structure and in the footing. Flexible corrugated metal culverts can tolerate some differential settlement but will be damaged by excessive differential settlement. The inspection of footings should include a check for differential settlement along the length of a footing. This might be noticed as footing rotation, severe cracking with vertical offset, spalling, or crushing across the footing at the critical spot. If the differential settlement is severe enough, it might be evidenced by a compression or stretching of the corrugations in metal culvert barrels. Differential settlement might be apparent by visual inspection along the length of footings, if present and exposed.

Concrete inverts in arches or three-sided culverts are usually a slab-on-grade used to carry water or traffic. Invert slabs can also provide protection against erosion and undercutting and are also used to improve hydraulic efficiency. Concrete inverts are sometimes used in circular and other closed culvert shapes to protect the metal from severe abrasive or severe corrosive degradation or added as repair for corroded inverts.

Concrete invert slabs are checked for undermining and settlement. Undermining is checked by probing along the edge of the apron. Settlement can be detected by checking for cracks, rotation, and signs of movement at the joint with the headwall. The joints between concrete aprons and headwalls should also be checked for movement (separation) and water tightness. Slabs are checked for damage such as spalls, open cracks, holes, or missing portions. Undermining can lead to a perched condition where piping occurs underneath the barrel. This perched condition can be due to stream degradation, or local scour. In critical conditions, voids around the culvert might appear.

Figure 2-28: Perched outlet with large scour hole

2.4.4 CULVERT STRUCTURE ROUTINE INSPECTION

The culvert structure is composed of the culvert barrels and joints. Barrels could be plastic, concrete, corrugated metal, masonry, and timber. Each are prone to unique sets of potential distresses.

Provide photographs for all Poor or Severe condition state defects and submit the applicable Work Recs or RFAs.

2.4.4.1 Culvert Structure Component Rating

The purpose of the culvert structure inspection is to identify distress to the barrel or joints that may impact structural stability or functional performance.

Table 2-10. Component Rating Guidelines for Culvert Less Than 10-Foot Span Culvert Structure

Component Rating	Condition	Material	Description
9	NEW	All	No deficiencies in any of the structural components that will affect the long-term performance. No noticeable or noteworthy deficiencies that would affect the operation, movement, or water tightness of the joints.
8	VERY GOOD	All	All structural components are sound and functioning as designed. There may be superficial cracking or weathering of protective coatings and/or dirt contamination on structural components. Possible minor accumulation of noncompressible material and debris in the expansion opening.
7	GOOD	All	All members retain full section properties and function as designed. There may be minor cracking in the barrel. Minor deterioration with shallow hairline cracks less than 1/8" (0.125 inches) within 2 ft. of the joint. No noticeable water leakage.
6	SATISFACTORY	All	All members retain full section properties and function as designed. There may be some deterioration affecting structural members such as minor cracking, scaling, small, scattered spalls, or shallow scour. Some protective coating failures. Device components maybe uneven, misaligned or the joint opening is closed. No noticeable water leakage.
5	FAIR	All	Moderate deterioration affecting barrel such as cracking, scaling, scattered or shallow spalls, minor settlement, or shallow scour. Minor section loss in low or no stress areas. Culvert continues to function as designed. Minor leakage due to adhesion failures of the seal and/or anchorage device (less than 5% of the length).
4	POOR	All	Considerable deterioration affecting barrel and joints such as cracking, scaling, scattered spalls, partial settlement, or scour. Barrel and joints continue to function as designed. Major deterioration of surrounding concrete including cracking and spalling to steel. Leaking along more than 5% of the seal and/or anchorage device.

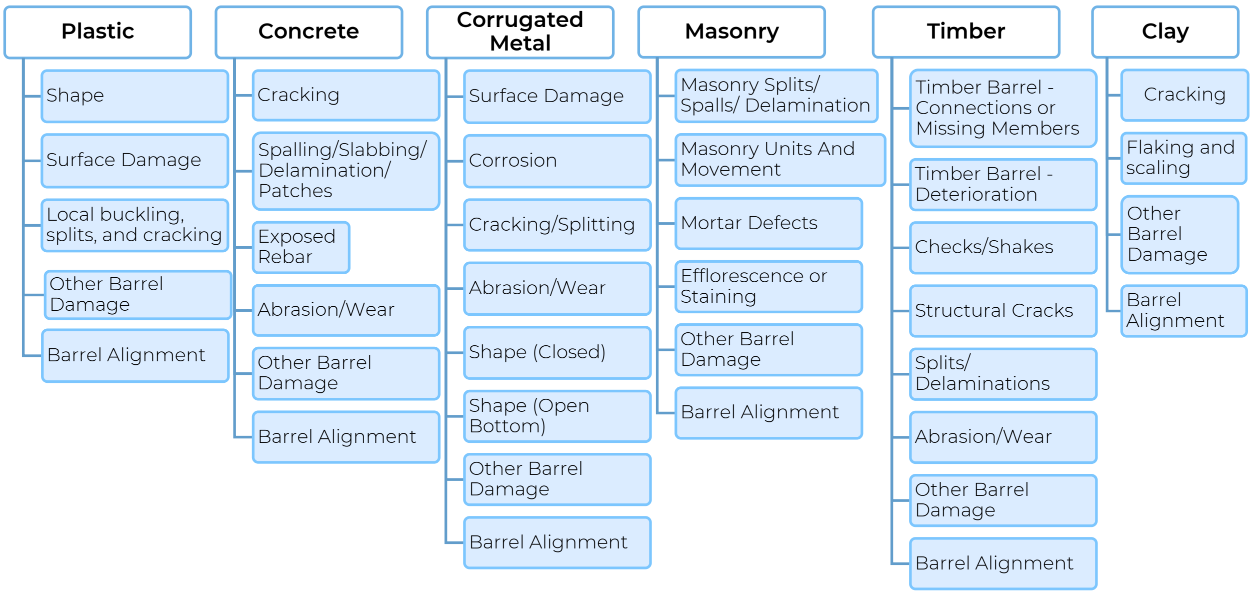
Component Rating	Condition	Material	Description
3	SERIOUS	All	Considerable deterioration affecting structural members. Possible full-depth failures. Most of barrel and joints are leaking or loose. Ride quality may be impacted. Structural evaluation, hydraulic, and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading, structurally engineered supports, or immediate repairs. There may be a need to increase the frequency of inspections.
2	CRITICAL	All	Deterioration has progressed to the point where the structure will not support design loads and therefore is posted for reduced loads. Emergency repairs or shoring with structurally engineered temporary supports may be required by the crews. There may be a need to increase the frequency of inspections.
1	IMMINENT FAILURE	All	Roadway or roadway shoulder above culvert closed because of barrel and joint failure. Corrective action may put back in service.
0	FAILED	All	Roadway closed above culvert.

2.4.4.2 Barrel Element Condition States

The purpose of the barrel element inspection is to identify distress to the barrel that may impact structural stability or functional performance.

The elements and types of condition deficiencies can vary greatly by barrel type; therefore they are broken into different inspection/rating procedures based on material. Distresses associated with multiple material types are discussed initially, followed by distresses by material type. Distresses associated with each material type are described in detail.

Figure 2-29: Applicable distresses for culvert barrel types



Barrel (Multiple Types)

Barrel Alignment

Barrel alignment is a measure of horizontal and vertical deviation from the design profile. For a pipe with no design curves or bends, the alignment should be straight.

The purpose of inspection of the barrel alignment is to identify distress indicators that result in misalignment of pipe segments. Barrel alignment may be an indicator for barrel structural distress, joint distress, or loss of support through soil piping (water flowing along the barrel exterior). Severe barrel misalignment can lead to reduced hydraulic performance.

Alignment problems may be caused by improper installation, undermining, differential settlement, or overloading. Attempt to identify which of those problems is causing the misalignment in the inspection notes.

Misalignment may be an indicator of problems in the supporting soil. The vertical and horizontal alignment of the culvert barrel is checked by sighting along the crown and sides of the culvert and by checking for differential movement or settlement at joints between pipe sections.

Vertical Alignment

Vertical alignment is checked for distortion, including warping, sagging, local crushing, and heaving. Be aware that pipes are occasionally laid with a camber (concave downward curvature along the pipe length) or a grade change to allow for fill settlement due to differential foundation soils or differential embankment loads.

Warping is characterized by deviation from flatness as a result of stresses and uneven shrinkage. Sagging is vertical deformation that can be caused by overloading or by creep (permanent deformation due to constant loading over time). Sags impede water flow which may aggravate settlement problems by saturating the supporting soil through leaking joints. Sags may also impede movement of debris and decrease flow capacity. For timber barrels, crushing typically occurs at connections where a member supports a vertical load bearing perpendicular to the direction of the wood grain.

Horizontal Alignment

Horizontal alignment is checked for straightness or as-designed smooth curvature for those culverts constructed with a curved alignment.

Figure 2-30: Loss of vertical alignment in a corrugated metal culvert

Other Barrel Damage – Insect Activity, Fire, etc.

Insect Activity

Insect activity primarily occurs in timber culverts, where insects can bore into wood structures and weaken members. Biotic degradation includes attack of the timber member by bacteria, fungi, insects, and marine borers. Bacteria and fungi degrade wood by breaking down constituents of the material that provide strength, also known as decay. Insects and marine borers degrade the strength of the structure by creating tunnels and cavities in the wood for shelter.

Insect activity is visually indicated by signs of holes in members, or the presence of powder. Typical insects that threaten wood culverts include ants, termites, beetles, worms, and marine borers.

Fire Damage

Note the extent of any charring and fire damage. Large wood members often retain structural strength after fire damage and an in-depth inspection by an Engineer is required to determine the residual capacity or to design for repair or replacement.

Plastic Barrel

Plastic barrels are often used in both culvert and storm drain applications. Plastic barrels are classified as flexible structures because their design and performance rely on soil-structure interaction; plastic barrels depend upon the soil embedment around the full pipe circumference and backfill to provide structural stability and support.

Table 2-11: Barrel Element (Plastic) Distresses

Unit of Measure: Length, feet. Distresses are measured as a "slice" of the diameter of the barrel's length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of plastic material.	Plastic Barrel – Shape change
			Plastic Barrel – Surface Damage
			Abrasion/Wear
			Barrel Alignment
			Other Barrel Damage – Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Plastic barrel inspection includes evaluation of barrel shape and wall distress. The barrel shape is evaluated relative to its as-designed shape. Wall distress is evaluated as an indicator of structural performance over time.

Typical cross section shapes for plastic barrel include corrugated wall (single-wall, dual-wall with an inner liner, or triple-wall with an inner and outer liner), ribbed profile wall, and solid-wall. The cross section is determined prior to inspection, if possible, or determined during the inspection if not present in the inventory.

Shape Change

Shape change is extremely important to monitor at all stages in the lifecycle plastic barrel but added importance is placed on the initial measurement following construction and annual inspections for the first two years of service, to ensure a good design performance and installation.

Shape change can also be an indicator that the applied loads are greater than the design loads. For condition rating purposes, shape will be quantified as the reduction in vertical diameter, e.g., distance from invert to crown (obvert), as a percent of the pipe nominal diameter.

Bulges in the pipe wall that follow an undulating inward-outward pattern along or around the pipe circumference (rippling) are identified as local buckling. Changes to the circular shape, such as wall-flattening, that increase to reverse curvature would be evaluated in the shape characteristic as global buckling, which is a separate characteristic from the local buckling described here.

Surface Damage

Wall damage, such as impacts, creases, cracks, and tears can be serious if the distress is extensive and can impair either the integrity of the barrel or permit infiltration of groundwater or backfill. Small, localized instances are not ordinarily critical but are noted along with any indications of the cause. Document the type, extent, and location of all wall distress and photograph significant instances.

Abrasion/Wear

Abrasion is generally most serious in steep areas where high flow rates carry sand and rocks that causes wear of the culvert invert. Plastic barrel materials such as HDPE, PVC, and PP have high resistance to abrasion and are often used as liners to repair other pipes that experienced abrasion-induced distress.

Mild deterioration or abrasion is noted in the inspection report. More severe surface deterioration is reported as a potential candidate for maintenance. In severe cases where the invert is completely deteriorated the RFA process is initiated.

Other types of wear for plastic barrels include buckling, splitting, cracking, and photodegradation.

Buckling, Splitting, Cracking

Buckling occur when the plastic barrel wall folds or bends due to high loads on the pipe.

Splitting can occur along plastic welded seams and/or abrupt changes in geometry in the pipe wall or corrugation, or at the bond between the walls and liners in corrugated wall pipe. Older HDPE pipes can experience cracking in the corrugated wall liner due to stresses that are residual from the manufacturing process and that may also be in locations that are not structurally significant.

Cracking in plastic barrels can occur from multiple types of distress. Plastic degrades with age, it becomes brittle with exposure to cold, and can burst due to ice freezing inside the pipe. Plastic pipe exposed to high levels of chemicals can also degrade the plastic and cause distress.

Photodegradation

Many plastic barrel materials provide resistance to acidity, salt, aggressive soils, fertilizers, pesticides, and other chemicals that can be corrosive to steel and concrete. However, plastic can be susceptible to photodegradation if not adequately designed or treated to be resistant to UV light. Photodegradation is the weakening of the plastic material due to oxidation from absorption of UV radiation when in sunlight for extended time periods. Buried culverts may be at risk for photodegradation at pipe ends where they are exposed to daylight at the inlet and outlet structures. The main visible effects are a mottled, chalky appearance and a color change. If this degradation is suspected, the pipe wall is lightly struck with a hammer and any fracturing or crumbling noted in the inspection report.

Concrete Barrel

Concrete culverts and storm drain barrels may be either precast or cast-in-place. Precast concrete pipe is manufactured in a fabrication facility. The manufacturing process is under controlled conditions enabling uniform quality concrete. Cast-in-place (CIP) concrete is cast at the site in formwork, placing reinforcement bars (rebar), and pouring concrete in its final location. Most CIP concrete culverts are single or multi-cell box culverts constructed using conventional bridge construction techniques. Both CIP and precast concrete culverts are somewhat protected by the soil backfill from rapid fluctuations in surface temperature and direct application chloride (salts) used for deicing. As a result, they are generally more resistant to surface material degradation than conventional concrete bridge elements, such as bridge decks.

Figure 2-31: Concrete barrel culvert

The purpose of the concrete barrel inspection is to identify distress in the pipe wall, other than misalignment, that may affect structural stability or functional performance.

Concrete culvert and storm drain barrels are classified as rigid structures because they do not bend or deflect appreciably under load before cracking or fracturing. As a result, shape evaluations, while very important in flexible structures, are of little value in inspecting concrete pipes. However, adequate stability of the surrounding soil, particularly below the pipe springline, is necessary to prevent excessive stress that can cause cracking of the pipe wall. Therefore, look for any indications of a lack of embedment soil stability as well as signs of structural distress such as cracking. Inspection of concrete barrels concentrates on distress in the walls of the structure.

Table 2-12: Barrel Element (Concrete) Distresses

Unit of Measure: Length, feet. Distresses are measured as a “slice” of the diameter of the barrel’s length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of concrete material.	Concrete Barrel - Cracking
			Concrete Barrel - Spalling/ Slabbing/Delamination/Patches
			Concrete Barrel – Abrasion/Wear
			Concrete Barrel – Exposed Rebar
			Barrel Alignment
			Other Barrel Damage – Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Cracking

Cracks typically are classified as either:

- Longitudinal Cracks
- Transverse or Circumferential Cracks

Longitudinal Cracks

Hairline longitudinal cracks in the crown and invert of the pipe usually develop as the rebar picks up the tensile stress due to circumferential bending. Measurements of crack width are taken as an indication of the structural condition of the pipe. Any visible wall vertical offset is noted in the inspection report.

Hairline cracks less than 0.01 in. in width are minor and only need to be noted in the inspection notes. Moderate cracks greater than hairline cracks are described in the inspection report and noted as possible candidates for maintenance. Major longitudinal cracking in equal to or excess of 0.1 inch in width may indicate overloading or poor bedding and side support and warrant further evaluation by an engineer.

Figure 2-32: Longitudinal crack within a concrete barrel

Transverse or Circumferential Cracking

Transverse or circumferential cracks may be caused by poor bedding. Cracks can occur across the bottom of the pipe (broken bell) when the pipe is only supported at the ends of each section. This is generally the result of poor installation practices such as not providing indentions (bell holes) in hard foundation material for the ends of bell-and-spigot-type pipe or not providing a sufficient depth of suitable bedding material. Cracks may occur across the top of pipe (broken back) when settlement occurs and rocks or other areas of hard foundation material near the midpoint of a pipe section are not adequately covered with suitable bedding material.

Spalling, Slabbing, Delamination, and Patches

Deterioration to the concrete face is typically due to:

- Spalling,
- Slabbing,
- Delamination, and
- Patches

Figure 2-33: Spalling within a box culvert

Spalling

Spalling is a fracture of the concrete parallel or inclined to the surface of the concrete.

In precast concrete pipe, spalls often occur along the edges of either longitudinal or transverse cracks when the crack is due to overloading or poor support rather than normal tension or shrinkage cracking. Spalling may also be caused by corrosion of the steel rebar when water is able to reach the rebar through wide cracks or shallow cover. As the rebar corrodes, the oxidized steel expands, causing the concrete covering to spall.

Spalling may be detected by visual examination of the concrete along the edges of cracks. Tapping with a hammer is performed along cracks to check for areas that have fractured but are not visibly debonded, as these areas will produce a hollow sound when tapped. For large arch or box-shaped culverts, this inspection will require a ladder or other safe means to access the culvert wall and top slab.

Slabbing

The terms slabbing, shear slabbing, or slab shear refer to a radial failure of the concrete which occurs from straightening of the curved reinforcement cage due to tension in rebar with inadequate concrete cover. Slabbing is characterized by large slabs of concrete peeling away from the sides of the pipe and a straightening of the reinforcing steel. Slabbing may occur under high fill depths or with severely deteriorated concrete and is accompanied by pipe deformation (deflection). Slabbing is a serious problem that can significantly weaken the structural capacity.

Concrete may experience deterioration for a number of reasons including freeze—thaw, chemical attack, and abrasion. Severe surface deterioration will make the structure a potential candidate for maintenance or repair. In the most advanced distress cases where the invert or any wall section is completely deteriorated, the rating will be severe which will lead to immediate notification through the RFA process.

Delamination

Delaminations are separations along a plane parallel to a surface, as in the separation of a coating from a substrate or the layers of a coating from each other, or, in the case of a concrete slab, a horizontal splitting, cracking, or separation of a slab in a plane roughly parallel to, and generally near, the upper surface. Delaminations are not visible from the surface but can be detected by tapping along the surface with a hammer or dragging a chain to detect hollow-sounding areas.

Figure 2-34: Concrete barrel deterioration

Patches

Visually inspect any patched areas of concrete for cracking and or spalling and sound with a hammer to evaluate the condition of the repair.

Abrasion/Wear

Deterioration, typically due to abrasion distress, is a wearing away of the concrete surface by sediment and debris that is transported by the stream. Abrasion is noted but is not typically considered to reduce the capacity of the pipe. However, the rate of abrasion is monitored by recording the level of abrasion that is present at the time of each inspection.

Mild deterioration or abrasion is noted in the inspection report. More severe surface deterioration is reported as a potential candidate for maintenance. In severe cases where the invert is completely deteriorated, notification is initiated through the RFA process.

Exposed Rebar (Concrete)

Indicate if reinforcement is exposed and the amount of section loss. Larger cracks allow water and oxygen to penetrate to the rebar and initiate corrosion which can lead to concrete spalling, significantly reducing the life of the culvert.

Some red/brown staining emanating from cracks can be caused by iron bacteria in groundwater or other organic staining not related to rusting. Carefully examine the staining and be familiar with the differences. Staining from iron bacteria is not cause for concern and is not a condition defect.

Corrugated Metal Barrel

Corrugated aluminum and corrugated steel culverts and storm drain barrels (pipes and arches) are classified as flexible structures because they respond to and depend upon the soil backfill to provide structural stability and support and are designed using concepts of soil-structure interaction. Inspection should verify both stability and integrity of the barrel. Stability of the structure and soil envelope is evaluated by checking the buried pipe cross section shape along the length. Integrity of the pipe is evaluated by checking for pipe or plate wall distress. An inspection of corrugated metal structures should evaluate shape and barrel distress at locations spaced closely enough to ensure that future deformations can be monitored from one inspection to the next. This manual provides detailed guidance on shape measurement, which is most easily accomplished using a laser profilometer or similar device. However, their inspection occurs concurrently with the corrugated metal barrel inspection, which requires the same access. Descriptions of the types of distress to look for during inspection are provided in the following paragraphs.

The purpose of the corrugated metal barrel inspection is to identify distress in the pipe wall, other than misalignment, that may affect structural stability or functional performance.

Table 2-13: Barrel Element (Corrugated Metal) Distresses

Unit of Measure: Length, feet. Distresses are measured as a “slice” of the diameter of the barrel’s length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of corrugated metal, also referred to as corrugated metal pipe.	Corrugated Metal Barrel – Surface damage
			Corrugated Metal Barrel – Corrosion
			Corrugated Metal Barrel – Cracking/ Splitting
			Corrugated Metal Barrel – Abrasion/Wear
			Corrugated Metal Barrel – Shape (Closed Shape)
			Corrugated Metal Barrel – Shape (Open Bottom)
			Barrel Alignment
			Other Barrel Damage - Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Surface Damage

All corrugated metal culverts are inspected for localized damage. Pipe damage such as dents, bulges, creases, cracks, and tears can be serious if distress is extensive and can impair the integrity of the barrel and permit infiltration of backfill. Small, localized examples are not ordinarily critical but are noted with size and location and photographed. Severe local damage distress will usually display a poorly shaped cross section or through-wall penetration. Document the type, extent, and location of all significant wall damage distress. When examining dents in corrugated steel culverts, the opposite side of the plate is checked, when accessible, for cracking or debonding of the corrosion-protective coating. If coating is present (such as 6galvanized, plastic, aluminum, or asphalt) note its presence and any distress, if appliable.

Corrosion

Corrosion is the deterioration of metal due to electrochemical or chemical reactions. Metal culverts are subject to corrosion in certain aggressive environments. Steel rapidly corrodes in highly acidic (low pH) conditions in the soil and water. Aluminum is more resistant but will corrode rapidly in highly alkaline (high pH) environments, particularly if metals such as iron or copper and their salts are present. The electrical resistivity of soil and water provide an indication of the likelihood of corrosion. In an aggressive environment, corrosion may result from the resistivity of the soil. Bacterial corrosion may also occur, particularly in the Upper Peninsula.

Figure 2-35: Corrosion of a metal culvert

Durability refers to the ability of a material to resist corrosion and abrasion. Durability problems are one of the most common causes for the repair or rehabilitation of buried metal pipe. The condition of the wall material in corrugated metal culverts and any coatings, if used, is considered when assigning a rating to the culvert barrel.

The inspection should include visual observations of metal corrosion. As steel corrodes, it expands considerably. Relatively shallow corrosion can produce thick deposits of scale. A pick hammer is used to scrape off heavy deposits of rust and scale for observation and nondestructive thickness measurement of the metal. A pick hammer can also be used to locate unsound areas of exterior corrosion by striking the culvert wall with the pick end. The pick will deform the wall or break through it at locations of severe exterior corrosion.

Protective coatings are examined for abrasion damage, tearing, cracking, and removal. Document the condition of coating, if applicable, and the extent and location of surface deterioration problems. These problems can all contribute to corrosion of the metal wall.

Figure 2-36: Loss of protective coatings contributing to corrosion

Abrasion/Wear

Abrasion is the wearing away of culvert materials, typically at the invert, by the erosive action of bedload carried in the stream. Abrasion is generally most serious in steep or mountainous areas where high flow rates carry sand and rocks. Abrasion can accelerate corrosion by wearing away protective coatings and previously corroded surfaces. Abrasion will wear the inside crests of the corrugations first.

Figure 2-37: Abrasion wearing away corrugated metal pipe corrugations

Shape (Closed Shape)

Cross section shape is an extremely important feature to evaluate when inspecting corrugated metal (flexible) culvert and storm drain barrels. The corrugated metal barrel depends on the backfill or embankment to maintain its shape and its capacity to resist buckling. When the backfill does not provide the required support, the culvert will deflect, settle, or distort. Shape changes in the culvert provide a direct indication of the competency of the supporting soil envelope, or, in some instances, application of excessive loads. Periodic observation and measurement of the culvert's shape change over time are used to verify the adequacy of the soil-structure interaction system.

The design cross section shape of the culvert is the standard against which field measurements and visual observations are compared. If the design cross section is unknown, often a comparison can be made between the unloaded and undamaged culvert ends and the loaded (buried) sections beneath the roadway or deep fills. Symmetrical shape and uniform curvature around the perimeter (circumference) are generally the critical factors. If the curvature around the top or bottom of the structure becomes too flat, the culvert wall may not be able to carry the ring compression without either buckling inward or deflecting excessively to the point of reverse curvature. Either of these distress modes leads to partial or total failure.

Corrugated metal pipes change shape safely within design deflection limits as long as there is adequate exterior soil pressure to balance the ring compression and resist increase of the pipe horizontal diameter; this is the soil-structure interaction system. Shape measurements taken at any one time do not provide conclusive data on backfill instability even when there is significant deviation from the design shape. Backfill stability cannot be reliably determined unless changes in shape are measured over time. It is therefore necessary to measure and document the shape during each inspection. If there is instability of the backfill, the pipe will continue to deflect or deform over time.

In general, the inspection process for checking shape will include visual observations for symmetrical shape and uniform curvature as well as measurements of important dimensions. Static measurements can be collected with conventional tools or with any other devices. The specific measurements to be obtained depend upon factors such as the size, shape, and condition of the structure. If shape changes greater than measurement tolerance are observed, more measurements may be necessary to accurately characterize the distress. For small structures in good condition, one or two representative measurements of the horizontal and vertical diameters from inside crest to inside crest may be sufficient. For structures with shallow cover, observations of the culvert with a few live loads passing over are recommended and deflections may be estimated by use of temporary telltales (suspended rulers to directly monitor deflection). Discernible movement in the structure from live loads may indicate possible instability and a need for more in-depth inspection.

The number of measurement locations (stations along the barrel length) depends upon the size and condition of the structure. Measurements may be required at more frequent intervals (closer stations) if significant shape changes are observed. The smaller pipes can usually be measured at longer intervals, unless specific distress is observed. If visual distortion is observed, and if culvert is accessible for entry, no fewer than three measurement locations are taken, including at least one on the culvert interior. Identify and note exact locations of measurement sections and the specific locations on the corrugation that are used to accurately monitor changes.

Closed shape inspection should include evaluation of deflection and flattening. Different closed shapes have different methods of evaluation; details on the shape types are provided for shape types:

- Round
- Ellipses
- Pipe Arches
- Metal Boxes

Round

Round and vertical elongated pipe is expected to deflect vertically during construction resulting in a slightly increased horizontal diameter. Round pipes are sometimes vertically elongated 5 percent to compensate for settlement during construction. Thus, it can be difficult to determine in the field if a pipe was round or elongated when installed if this information was not recorded in an inventory record. Larger diameter round pipe is also susceptible to vertical elongation (peaking) during compaction of backfill at the sides of the pipe.

Round and vertically elongated pipe with Good to Fair shape will generally match the design shape, with smooth, symmetrical curvature and no visible deformations. Pipe with poor to severe shape will appear deformed with shape that does not match the design shape and does not have smooth or symmetrical curvature. In-depth inspections may be necessary to compare the design diameter to the current pipe nominal diameter.

Flattening

Flattening of the pipe wall is a decrease in local curvature that may be caused by unstable backfill. Flattening of the sides may be caused by a deteriorated invert that reduces the pipe's ability to carry ring compression. Flattening of the top arc is an indication of possible distress resulting from insufficient side fill support or from vertical loads greater than the design loads. Flattening of the invert is usually less serious as pipe not installed on shaped bedding will often exhibit minor flattening of the invert arc. Severe flattening of the bottom arc would indicate possible distress in a round pipe.

Note the visual appearance of the culvert's shape and measure the horizontal diameter and vertical diameter.

Flattening of Pipes with Diameters from 4 to 10 feet

When distortion or wall curvature flattening is apparent on pipes with diameter greater than 4 feet, describe the extent of the flattened area, in terms of arc length, length of culvert affected, and the location of the flattened area. Measure and record length of the chord across the flattened area and the middle ordinate of the chord is measured.

Flattening of Pipes with Diameters less than 4 feet

For small diameter pipes, this middle ordinate may be measured by hand or by use of special bars with dial gauges, designed for this purpose. Note the chord length and ordinate measurement with a description of the location and extent of the flattened area. Record any observations for out-of-round shape.

Ellipses

For horizontal ellipses the most important shape factor is adequate curvature in the crown section. The sides and bottom behave like the corners and bottom of relatively minor pressure when compared with the sides, which may have several times the bearing pressure of the invert. As a result, the corners and sides have the tendency to push down into the soil while the bottom does not move. The effect is as if the bottom pushed up. Inspectors should look for indications of bottom flattening and differential settlement between the side and bottom sections.

Record the visual appearance of the shape and measure both the span and the rise. If the span exceeds the design span by more than 3 percent, the span of the top arc, the mid-ordinate of the top arc, and the mid-ordinate of the bottom arc should also be measured.

Figure 2-38: Elliptical concrete barrel

Shape Evaluation

Shape evaluation of an ellipse is essentially the same as the evaluation of a crown section of round pipe (see "Round," previously), except that the curvature of the bottom should also be evaluated. Fair to Poor shape would be indicated when the bottom is flat in the center and corners are beginning to deflect downward or outward. Severe shape conditions would be indicated by reverse curvature in the bottom of arc.

Flattening and Spreading

The bottom arc is inspected for signs of flattening and the bottom corners for signs of spreading. The extent and location of bottom flattening and corner spreading are noted in the inspection report. Complete reversal of the bottom arc can occur without failure if corner movement into the foundation has stabilized. The top arc of the structure is supporting the load above and its curvature is an important factor. However, if the footing corners should fail, the top arc would also fail. The spreading of the corners is very important as it affects the curvature of the top arc.

Pipe Arches

The pipe arch is a completely closed structure that behaves as an arch. The load is transmitted to the foundation principally at the corners, which act like the footings of an arch. There is relatively little force or pressure on the large radius bottom plate. The principal type of distress in a pipe arch is a result of inadequate soil support at the corners where the pressure is relatively high. The corner may push down or out into the soil while the bottom stays in place. The effect will appear as if the bottom pushed up.

Pipe arches in good condition will have a symmetrical appearance, smooth curvature in the top of the pipe, and span within 5 percent of the as-designed span. The bottom may be flattened but should still have curvature. Pipe arches in fair condition will have minor distorted shape appearance in the top half of the pipe, no reverse curvature in bottom of the pipe, and a horizontal span 5 percent to 7 percent greater than theoretical. Pipe in Poor to Severe condition will have characteristics such as a poor shape appearance, severe deflection or distortion in the top half of the pipe, reverse curvature in the bottom of the pipe, flattening of one side, flattening of the crown, or a span more than 7 percent greater than theoretical.

Metal Boxes

Metal box culverts support loads by a combination of ring compression and conventional structure bending. The sides (legs) are straight, and the large radius top plates are heavily reinforced and have moment or bending strength that is quite significant in relation to the loads carried. The key shape factor in a box culvert is the top arc. The design geometry is very flat (large radius) and therefore cannot be allowed to deflect much without risk of buckling instability or bending distress. The span at the top is also important and cannot be allowed to increase much, due to inward or outward deflection or rotation of the side plates. Generally, an inward deflection would be more critical as an outward movement would be restrained by soil.

Shape factors to be checked visually include flattening of the top arc, outward movement of the sides, or inward deflection of the sides. Note the visual appearance of the shape and should measure and record the rise from the crown to the bottom of the base channel, and the span at the top of the straight legs.

The radius points (changes in radius from legs to haunches to top arc) are not necessarily located at the longitudinal seams. Many box culverts use double radius plates and the points where the radius changes shall be estimated. These selected measurement points are referenced to the bolt pattern to describe exactly where they are. Since these are all low-height structures, the measurement points are marked and painted for convenient repeat inspection.

Shape (Open Bottom)

Arches, unlike closed-shape pipe, have open bottoms and are typically founded on concrete spread footings or concrete caps on deep foundations. This difference between pipes and arches means that arches deflect differently during backfill. Backfill forces flatten the arch sides when they peak (raise) its top because the bottom of the arch, if well supported, cannot move inward like the wall of a round pipe.

An important shape factor in arches is symmetry. A non-symmetric arch will have racking; a racked cross section is one that is not symmetrical about the centerline of the culvert and can be. If the arch was erected with the base channels (footing connection to arch) not square to the centerline, it can cause racking of the cross section. One side tends to flatten, while the other side tends to curve more, and the crown moves laterally and possibly upward. If these distortions are not corrected before backfilling the arch, they usually get worse during backfill. Improper backfill, such as differential height on one side or excessive compaction, can also cause racking.

Visually observe if flattening of the sides, peaking or flattening of the crown, or racking to one side is present. Measure the vertical distance from the crown to the bottom of the base channels or top of footings (rise) and the horizontal distances from each of the base channels to a vertical line from the highest point on the crown (combined, these give the span). Record the curvature on the flatter side of the arch by noting chord and mid-ordinate measurements. In-depth inspections may be required to survey the culvert if major distortion, flattening, peaking, or racking is observed.

Arches in Fair to Good condition will have a good shape appearance with smooth and symmetrical curvature. Poor condition would be indicated when the arch is significantly nonsymmetrical, or when major side or top plate flattening has occurred. Arches in Poor to Severe condition will have a poor shape appearance including major distortion and deflection, extremely nonsymmetrical shape, severe flattening, or a major rise.

Masonry Barrel

Masonry barrels refer to structures constructed of individual masonry units made of stone, brick, or concrete block. Brick and concrete block structures are typically constructed with a layer of mortar placed between units. Masonry units are placed in wythes and courses. Course refers to the layer of units running horizontally. The number of courses determines the height of the wall. Wythes are the continuous vertical sections of the wall. The number of wythes determines the wall thickness. Stone masonry may be dry (no mortar), pointed (stones set in mortar), or cemented (stones set in concrete).

While new culverts are rarely constructed from masonry, a wide variety of masonry culverts are still in service.

Table 2-14: Barrel Element (Masonry) Distresses

Unit of Measure: Length, feet. Distresses are measured as a “slice” of the diameter of the barrel’s length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of masonry material.	Masonry Barrel – Masonry Units and Movement
			Masonry Barrel – Mortar Defects
			Masonry Barrel – Efflorescence or Staining
			Barrel Alignment
			Other Barrel Damage – Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

The purpose of inspection of the masonry barrel is to identify distress or potential distress using common and distress indicators in the masonry units and mortar. Barrel shape can also be an indicator of structural distress, joint/mortar distress, or loss of backfill support.

Masonry culverts are generally arch shaped, pipe arch shaped, or box shaped. These structures may be supported on footings, or with closed bottoms. The walls, floors, and top of masonry culverts are carefully inspected both visually and by tapping stones, bricks, or blocks and mortar with a geologist's rock hammer. Note any apparent signs of distress.

Many masonry culverts are very old and local development and changes in the surrounding land use may have increased the volume of storm water runoff that flows to the culvert. Hence, some may now be undersized for hydraulic capacity. When flow exceeds the culvert capacity, the culvert may overtop and suffer erosion and damage at the outlets. In addition, these historic structures may now carry heavier vehicle loads than existed at the time of their construction.

Typical items to inspect include the condition of the masonry units and mortar, movement or distortion, and weathering of the masonry. The individual stones, bricks, or blocks are checked for displaced, cracked, broken, crushed, or missing units. For some types of masonry, surface deterioration or weathering can also be a problem and can cause spalling.

Masonry Units and Movement

Identify deteriorated, loose, or dislodged units. Movement or damage of individual or grouped masonry units may occur due to:

- Acid weathering,
- Cracking and splitting,
- Freeze—thaw,
- Mortar deterioration (discussed under mortar defects),
- Shape changes, and
- Vegetation growth.

Acid Weathering

Acidic rainwater and storm water runoff can dissolve the surface of the units. Weathering typically appears as roughened surface with discoloration when compared with unweathered counterparts. Sandstone, limestone, and marble are susceptible to acid attack.

Cracking and Splitting

Cracking and splitting in masonry units are generally caused by tensile stress in the units. Cracking may be due to differential settlement or expansion of foundation soils, increased lateral earth pressure, shifting of units due to mortar deterioration, or impact damage. Note the presence and location of cracked masonry units.

Freeze-Thaw Action

Expansion of frozen water trapped behind or within a masonry unit can cause movement of the unit or internal distress. Under repeated cycling, and sometimes combined with other deterioration and erosion, units can become damaged, loose, and dislodged.

Shape Changes

Masonry arches act primarily in compression. Racking, flattened curvature, bulges in walls, or other shape deformations may indicate unstable soil conditions. The vertical and horizontal alignment is checked visually.

Vegetation

Lichen and mosses growing on the face of units can create a moist environment which accelerates chemical weathering. Higher order vegetation and trees can also plant roots between units and dislodge masonry units.

Mortar Defects

In most masonry arch culverts, mortar is used to bond the masonry units together. The condition of the mortar is checked to ensure that it is still holding strongly. It is particularly important to note cracked, deteriorated, or missing mortar especially if other deterioration is present such as loose or missing masonry units. The presence of dirt or vegetation between masonry units is noted as these can be indicators of loss of backfill or erosion behind the structure.

Efflorescence or Staining

Water infiltration can also contribute to mortar distress in cold climates as freeze—thaw cycles break the mortar apart. Water infiltration through walls or joints may be indicated by deposits caused by efflorescence (leaching of salts or chlorides) leaking through the mortar joints.

Efflorescence and staining on its own are primarily cosmetic issues due to capillary action in porous materials; therefore, its presence alone cannot cause a severe rating. However, it can sometimes lead to spalling and deterioration and is recorded and tracked during inspection.

Clay Barrel

Clay barrels are usually vitrified products made by blending clay and shale at high temperature. The vitrification process is used to develop the strength and load bearing capacities of the product, turning it into an inert ceramic pipe. Clay pipes are sometimes glazed to ensure that they will be watertight. Clay pipes are generally resistant to chemicals but are brittle and difficult to install and repair.

Table 2-15: Barrel Element (Clay) Distresses

Unit of Measure: Length, feet. Distresses are measured as a "slice" of the diameter of the barrel's length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of clay material.	Clay Barrel – Cracking
			Flaking and Scaling
			Barrel Alignment
			Other Barrel Damage – Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

[Culvert Less Than 10-Foot Span Condition State Tables]

Cracking

In comparison to other barrel materials, clay barrels are more susceptible to cracking if they experience differential settlement or blunt impacts because of weak tensile strength. Cracked clay barrels could eventually cause the culvert system to collapse. Note the presence, location, and extent of cracks on the clay barrel.

Flaking and Scaling

Over time, clay barrels develop scale which causes the barrel to flake. This flaking traps debris within the walls of the barrel. Eventually increase in trapped debris may cause blockage. Note the presence and extent of scaling and flaking within the barrel. Also note if debris is trapped within the walls of the barrel.

Timber Barrel

Timber culverts are primarily inspected for material deterioration, called biotic degradation, and mechanical damage. Biotic degradation includes attack of the timber member by bacteria, fungi, insects, and marine borers. Bacteria and fungi degrade wood by breaking down constituents of the material that provide strength, also known as decay. Insects and marine borers degrade the strength of the structure by creating tunnels and cavities in the wood for shelter. Mechanical damage may be caused by abrasion, creating marred or worn surfaces (from traffic, stream flow, or ice), impact damage (from vehicles, debris, or ice floes), long-term exposure to overload stresses, or fire.

The purpose of the timber barrel inspection is to identify distressed connections, decay, structural overload distress, or other material deterioration to allow assignment of a condition rating.

Table 2-16: Barrel Element (Timber) Distresses

Unit of Measure: Length, feet. Distresses are measured as a "slice" of the diameter of the barrel's length.

Element Number	Element Name	Description	Applicable Distresses
12404	Barrel	Barrel made out of timber material.	Timber Barrel – Connections or Missing Members
			Timber Barrel – Deterioration
			Timber Barrel – Checks/Shakes
			Timber Barrel – Structural Cracks
			Timber Barrel – Splits/ Delaminations
			Timber Barrel – Abrasion/Wear
			Barrel Alignment
			Other Barrel Damage – Insect Activity, Fire, etc.

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Visual inspection is a cursory means to assess the structure for signs of actual or potential deterioration, noting areas for further investigation. Inspection of timber culverts should also check for signs of material deterioration at the surface (exterior) and interior of wood members. Material deterioration is inspected by sounding the wood, probing, and possibly by pick testing.

Sounding the wood surface by striking it with a hammer or other object is used to detect interior deterioration based on the tonal quality of the strike sounds. A trained and experienced Inspector can typically interpret dull or hollow sounds that may indicate the presence of large interior voids or decay. Although sounding is widely used, it is often difficult to interpret because factors other than decay can contribute to variations in sound quality. In addition, sounding provides only a partial picture of the extent of decay present and will not detect wood in the incipient or intermediate stages of decay. Nevertheless, sounding still has its place in inspection and can quickly identify seriously decayed structures. When suspected advanced decay is encountered, it shall be verified by other methods such as boring or coring. Boring involves drilling into the member with an electric drill. Inspection during boring includes noting depths where drilling becomes easier and inspecting shavings for signs of decay. Coring is the removal of a solid small diameter core to evaluate for decay.

Probing is conducted with a pointed tool, such as an awl, screwdriver, pick, or knife, to identify decay near the wood surface. Degradation is indicated by excessive softness and reduced resistance to probe penetration. Although probing is a simple inspection method, experience is required to interpret results. Care shall be taken to differentiate between decay and water-softened wood that may be sound but somewhat softer than dry wood.

Connections or Missing Members

Check connections for signs of potential capacity loss. Common issues with joints include deteriorated or missing bolts/fasteners, and local defects in the wood material at load transfer zones. Timber connections made with steel plates shall also be checked for degradation. This includes surface rust and pack rust. Pack rust is a form of corrosion that occurs in metallic crevices and joints between the plate and the connected element. Pack rust can cause bulging and deterioration of the connection plate which can significantly reduce its structural capacity.

Missing members may be due to structural failure of the member or its connection, or impact from stream or ice flows. Other activities such as installation of utilities or structure modifications may remove a member in whole or part (e.g., notched or cored beam for utility conduit).

Deterioration

Visual inspection for deterioration and decay requires good lighting and is suitable for detecting intermediate or advanced surface decay. It may not detect decay in the early stages, when control is most effective, nor will a visual inspection reveal internal decay. Consequently, visual inspection should never be the sole method employed. Decay indicators are sounded and probed to assess the extent of decay. Some common decay indicators include fruiting bodies, sunken faces, staining or discoloration, insect activity, and fire damage.

Other deterioration that can occur to timber consists of:

- Fruiting bodies
- Staining or discoloration
- Sunken faces

Fruiting Bodies

Fruiting bodies are the reproductive spores of fungi that form on the surface of wood. Fruiting bodies are found in a variety of shapes such as cap-and-stem mushrooms or shelf-like, antler-like, coral-like, cage-like, trumpet-shaped, or club-shaped fungi. Fruiting bodies provide positive indication of advanced fungal attack, but do not indicate the amount or extent of decay. Some species of fungi produce fruiting bodies after small amounts of internal decay have occurred, while others develop only after decay is extensive. Fruiting bodies almost certainly indicate serious decay problems when they are present.

Staining or Discoloration

Staining and discoloration are indicators of potential decay. Members with staining have been subjected to water and potentially high moisture contents and stained areas may mean conditions are suitable for decay. Rust stains on a member face may indicate wetting-induced deterioration of the connection hardware. These areas are noted for future monitoring.

Sunken Faces

Sunken faces or localized surface depressions can indicate underlying decay. Sunken faces occur when a thin layer of intact or partially intact wood forms a depression over voids or pockets near the surface of the member.

Checks/Shakes

Checks are shrinkage cracks that occur along the radius of solid sawn timber, usually perpendicular through the growth rings. Checks can be seen along the face of members and are typically not a structural problem as they are accounted for in the engineering design values for strength. Severe checking at connections can weaken the ability of fasteners to carry load and shall be noted during inspections.

Shakes are separations between growth rings in the grain of the wood and can extend for some distance longitudinally into the member. Shakes are often identified by inspecting the end grain of a timber member. In contrast to checks, shakes can reduce the bending strength of a member and are noted and tracked during inspections.

Structural Cracks

Structural cracks, unlike checks and shakes, occur from an overload condition indicating the strength of a member and/or its connections has been exceeded due to service loads. Structural cracks may originate at knots on the tension face of bending members. The presence of any structural cracks that have not already been repaired will warrant a Poor or Severe rating.

Splits/Delaminations

Laminated structural timbers, called glulams, are members constructed by gluing and laminating thinner members to form a thicker (composite) section. Delaminations are separations within laminated members. Glulam beams rely on composite action to provide full strength and therefore shall remain fully laminated to function as designed. Delaminations near connections can be more important than delaminations elsewhere as they may reduce the capacity of the fasteners.

Abrasion/Wear

Abrasion and impact damage may occur due to stream flow, debris, or ice. Note section loss due to abrasion.

2.4.4.3 Joint Element Condition States

The purpose of the joint inspection is to identify distressed joints within the barrel that could affect the performance of the culvert structure. Joints are the transverse transitions between barrel sections; seams are longitudinal or helical transitions between barrel sections. Joints between the barrel and end treatments are assessed as part of the end treatment inspection. Joints may be present where the culvert barrel is extended as part of a roadway widening. Some joint movement may be a part of the manufacturing or construction tolerance. Joint failure is more common with concrete pipe. Joints are critical to the overall function of the culvert.

Table 2-17: Joints Element Distresses

Unit of Measure: Each. Record quantity of each joint.

Element Number	Element Name	Description	Applicable Distresses
12405	Joints	Joints present within the culvert barrel	Joint Separation, Offset, and Rotation
			Joint Infiltration/Exfiltration
			Joint Cracking (Concrete)

Details on the condition state rating schema are in Section 2.7, linked below:

Culvert Less Than 10-Foot Span Condition State Tables

Joint Separation, Offset, and Rotation

Vertical movement can occur in the forms of uniform settlement or differential settlement. Depending on the magnitude of the settlement realized, uniform settlement will have limited impact on the structural stability of the culvert. Differential settlements, on the other hand, may lead to serious problems in the culvert. Differential settlements may cause the opening of joints or cause culvert cracking or transverse tipping. The most common causes of vertical movement consist of soil bearing failure, soil consolidation, erosion, and material deterioration.

Inspect the culvert for evidence of vertical differential settlement, offset, or rotation as evidenced in joints. Gaskets may be exposed or missing. Backfill material may be exposed in severe cases.

Joint Infiltration/Exfiltration

Joint distresses may be identified by infiltration of soil or water through joints which are intended to be tight. In severe cases, distresses to the barrel, end treatments, and roadway embankment will result from the soil and/or water infiltration.

Exfiltration refers to water leaking from the culvert into the underlying soil. It is also an indication of distress.

Joint Cracking (Concrete)

Longitudinal cracking in concrete joints is also an indication of distress. Spalling, exposed reinforcing or exposed joint sealing would all be indications of poor joint condition. Large spalls along the spigot end would be present in severe distress cases.

2.4.5 REFERENCES

Timber Bridge Design, Construction, Inspection and Maintenance Report

FHWA-IP-86-2 Culvert Inspection Manual

FHWA NHI 12-049 Bridge Inspector’s Reference Manual Chapter 14

MDOT Drainage Manual

2.5 Work Recommendation Guidance

Culvert less than 10 feet span Work Recs are recorded to initiate preventive maintenance actions. Preventive maintenance needs are determined for each ancillary structure and the corresponding actions are identified on the Work Recs documentation. The following Work Recs are not meant to be all-inclusive and other work recommendations may be added to supplement those noted in *Table 2-18*.

Approach roadway and embankment Work Recs include repair of guardrail and approach pavement. Brush cutting or slope embankment repairs may be recommended. Heavy slope riprap may be recommended.

Channels suspected of being inadequate may be due to blocked inlets. Possible maintenance includes cleaning of the channel adjacent to culvert, removal of debris inflow or outflow, addition of riprap, or channel repairs. Scour countermeasures and/or scour monitoring systems may need to be installed or repaired.

Aprons and flumes may require additional rock if the scour has penetrated through the riprap.

Blocked weep holes are cleaned. Headwalls, wingwalls, or the foundation may need repair. Washout or erosion due to scour around the foundation may be recommended.

Culvert structure Work Recs typically consist of removal of debris, sediment, or vegetation from the barrel. Vegetation is removed from the barrels as part of regular maintenance. Culvert barrel Work Recs consist of barrel repair, sealing the barrel and cracks, installing culvert liner, and cleaning/painting/re-sealing the culvert for graffiti removal. Work Recs may be created for other items, which could include noting if a safety grate is missing or another item not otherwise specifically listed in *Table 2-18*.

Photographs should include sufficient information to determine the relationship of the defect to the element or component or entire structure. Close-up photos of each defect with deficiencies marked on the photo should be provided.

Table 2-18: Culvert Less than 10-Foot Span Work Recommendations

Number	Description of Work Recommendation	Material involved	Quantity/Unit of Measure
1	Channel – Install/Repair Scour Countermeasures	Rock or Articulated Concrete Block (ACB)	Cubic Foot
2	Channel - Monitor Scour	N/A	N/A
3	Substructure - Repair Abutment/Wings/ Headwall	Concrete	Cubic Foot
4	Repair/Replace Treatment	End Treatment Material, as needed	Each
5	Repair washouts/erosion	Stone or Other, As Needed	Cubic Foot
6	Approach Pavement Repair	Asphalt	Square Foot

Number	Description of Work Recommendation	Material involved	Quantity/Unit of Measure
7	Brush Cut	Brush	Cubic Yard
8	Culvert Cleanout	Sediment	Cubic Foot
9	Clean and/or paint/re-seal concrete for graffiti removal	Concrete	Square Foot
10	Seal Barrel	Joint Sealer	Lineal Foot
11	Seal cracks	Crack Sealer	Lineal Foot
12	Barrel repair	Barrel Material, As needed	Square Foot
13	Install Culvert Liner	Liner	Lineal Foot
14	Replace Culvert	Culvert	Lineal Foot
99	Other		

2.6 Request for Action Guidance

The culvert examples for Priority Level 1 are deemed to have caused failure or are progressing toward an impending failure of the roadway or embankment within a 1:1 slope influence of the roadbed. The culvert examples below for Priority Level 2 are deemed to threaten the roadway or embankment within a 1:1 slope influence of the roadbed. The culvert examples for Priority 3 are not deemed to threaten the roadway or embankment within a 1:1 slope influence of the roadbed but could if not addressed within the specified timeframe.

Examples of applicable priority level items include, but are not limited to:

Priority 1 Level Items

a. Major tears, splits, shape deformation or bulges resulting in major infiltration of soil, voids, and piping with accompanying settlement or sinkholes within the roadway limits

b. Holes or major section loss resulting in voids beneath invert with evidence of piping and accompanying settlement or sinkholes within the roadway limits

c. Open or displaced joints (misaligned) with evidence of soil infiltration or piping causing settlement or sinkholes in the roadway limits

d. *Concrete* – Large cracks with widespread exposed reinforcement exhibiting major corrosion and soil infiltration through cracks with settlement or sinkholes in the roadway limits

e. *Metal* – Connection hardware has many loose or missing bolts in any seam with major yielding of steel or cracking/splitting local to bolt holes reducing seam capacity and/or evidence of major soil infiltration or piping that has caused settlement or sinkholes within the roadway limits

f. *Plastic* – Barrel conditions with major wall flattening with the reversal of curvature (global buckling) or kinks

g. Severe erosion of embankment material or major soil tension cracks perpendicular to slope indicating shifting or settlement within a 1:1 slope influence of the roadbed
h. End treatment (along with any apron) is crushed or separated from the barrel and scour protection is missing with evidence of major erosion or undermining progressing toward an impending failure of the embankment within a 1:1 slope influence of the roadbed
i. Footings are severely undermined due to scour, which could progress toward an impending failure of the roadway or embankment within a 1:1 slope influence of the roadbed

Priority 2 Level Items

a. Open or displaced joints (misaligned) with significant infiltration or exfiltration of water or soil, but no settlement or sinkholes within the roadway limits
b. Holes or significant section loss resulting in voids beneath invert with evidence of piping, but no settlement or sinkholes exist in the roadway limits, however a threat is posed to the roadway or embankment within a 1:1 slope influence of the roadbed
c. *Concrete* – Cracks with widespread exposed reinforcement with significant corrosion, evidence of soil infiltration or piping, but no settlement or sinkholes in the roadway limits exists
d. *Metal* – Perforations visible or easily made, connection hardware has loose or missing bolts in any seam, corrosion with significant section loss around bolt holes or on bolts with significant yielding of steel or cracking/splitting local to bolt holes and/or evidence of soil infiltration or piping, but no settlement or sinkholes in the roadway limits exists
e. *Plastic* – Barrel conditions with significant wall flattening or reversal of curvature (global buckling) or kinks, UV degradation (barrel ends) has resulted in cracks or broken culvert walls
f. Soil tension cracks perpendicular to slope indicating shifting or settlement and/or sloughing of embankment threatens the roadway or embankment within a 1:1 slope influence of the roadbed
g. End treatment (along with any apron) is crushed or separated from the barrel, scour protection has been significantly displaced and scour has caused significant undermining causing loss of support threatening the roadway or embankment within a 1:1 slope influence of the roadbed
h. Longitudinal cracks in crown, invert, or haunches with perceptible cross-section deformation
i. Significant reconfiguration of inner liner
j. Mass drift or sediment is reducing the capacity of the culvert greater than 50% (*some culverts are intentionally recessed. Check historical plans to verify culvert invert and stream flowlines*). Culvert blockage creates excessive ponding and/or erosion that threatens the roadway or embankment within a 1:1 slope influence of the roadbed.

Priority 3 Level Items

a. Open or displaced joints (misaligned) with moderate water infiltration through leak-resistant seams with possible evidence of repeated patching or cracking transverse or longitudinally in pavement over the culvert alignment

b. *Concrete* – Cracks present with no perceptible cross-section deformation, heavy abrasion, and scaling with exposed steel reinforcement

c. *Metal* – Moderate wall buckling, deformation at worst section or local bulging, surface corrosion with minor section loss and moderate yielding of steel, or cracking/splitting local to bolt holes

d. *Plastic* – Moderate wall buckling, deformation at worst section or local bulging

e. Localized displacement of scour protection with scour exposing the vertical face of a footing or progressing toward a threat to the embankment within a 1:1 slope influence of the roadbed; however, no undermining or rotation of footing exists

f. Moderate reconfiguration of inner liner

g. Mass drift or sediment is reducing the capacity of the culvert from 33% to less than 50%. (*Some culverts are intentionally recessed. Check historical plans to verify culvert invert and stream flowlines.*) Culvert blockage creates excessive ponding and/or erosion that does not threaten the roadway or embankment within a 1:1 slope influence of the roadbed but could if not addressed within the specified timeframe.

2.7 Element Condition States

Element Number	Element	Condition States Defects Note	Link to Discussion in Section 2
12301	Headwall	Use the appropriate condition state table based on material (Concrete or Metal).	Headwall Element Condition States
12302	Wingwall	Use the appropriate condition state table based on material (Concrete or Metal).	Wingwall Element Condition States
12303	Scour	Use the appropriate condition state table.	Scour Element Condition States
12304	Barrel	Use the appropriate condition state table based on material (Plastic, Concrete, Corrugated Metal, Masonry, Clay, or Timber).	Barrel Element Condition States
12305	Joint	Use the appropriate condition state table.	Joint Element Condition States

Element 12301 (Headwall) – Concrete

Description	This element is for headwalls attached to the end of the culvert.			
Quantity Calculation	The quantity for this element is measured as "each."			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
End Treatment Cracking (Concrete)	No measurable crack width greater than hairline (maximum 0.0625 inches).	Minor cracks with no infiltration. No increase in cracking from previous inspection (if applicable).	Cracks 0.05 in. to 0.1 inches wide. Minor water infiltration through cracks.	Cracks greater than 0.1 inches wide. Water and soil infiltration through cracks.
End Treatment Surface Damage Spalling or Delamination (Concrete)	No scaling, abrasion, or other surface damage. No spalling. No hollow sounds (delaminations). Patched areas that are sound.	Light or moderate scaling (less than 0.25 in. exposed aggregate). Abrasion less than 0.25 in. deep over less than 20% of surface. Localized minor impact damage (less than 0.25 inches deep). Localized spalls less than 6 inches diameter. No exposed rebar. Small hollow sounding areas. Patch edges tightly bonded.	Moderate to severe scaling (aggregate clearly exposed). Abrasion between 0.25 and 0.5 inches deep over more than 30% of surface. Impact damage. Multiple plugged weep holes. Spalling and/or hollow sounding areas larger than 6inches diameter, rebar exposed, rust staining from spalled areas. Patch delamination.	Extensive surface damage. Includes significant exposed and/or corroded rebar. Widespread spalling or delamination with exposed and corroded rebar. Structure may be unstable.
Exposed Rebar	No Exposed rebar.	Moderate efflorescence and no rust staining emanating from cracks.	Local areas of exposed rebar. Efflorescence and/or rust staining emanating from cracks.	Widespread exposed rebar with significant corrosion. Widespread rust staining emanating from cracks

Element 12301 (Headwall) – Metal

Description	This element is for headwalls attached to the end of the culvert.			
Quantity Calculation	The quantity for this element is measured as "each."			
	Condition State Descriptions			
Distresses	**Good**	**Fair**	**Poor**	**Severe**
End Treatment Deformation and Damage (Metal)	No dents, impact damage, or abrasion.	Small dents or impact damage. Abrasion of wall or coating with no breaches in the coating exposing structural wall	Large dents/ deformation or impact damage. Abrasion of protective coating with breaches exposing the base material.	Deformation that restricts flow capacity or is resulting in scour or erosion of embankment
End Treatment Corrosion (Metal)	No corrosion.	Freckled rust or other sign of corrosion of material. No loss of section or pitting.	Corrosion of material and section loss less than 10% of thickness. Deep pitting pronounced thinning. Several holes less than 1inch diameter. Penetration possible with hammer Scour exposing vertical face of previously buried structure or footing. No undermining or rotation of footing.	Widespread corrosion, local through thickness penetrations. Holes greater than 1 in. diameter or many smaller grouped holes allowing soil migration.

Element 12302 (Wingwall) – Concrete

Description	This element is for headwalls attached to the end of the culvert.			
Quantity Calculation	The quantity for this element is measured as "each."			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
End Treatment Cracking (Concrete)	No measurable crack width greater than hairline (maximum 0.0625 inches).	Minor cracks with no infiltration. No increase in cracking from previous inspection (if applicable).	Cracks 0.05 in. to 0.1 inches wide. Minor water infiltration through cracks.	Cracks greater than 0.1 inches wide. Water and soil infiltration through cracks.
End Treatment Surface Damage Spalling or Delamination (Concrete)	No scaling, abrasion, or other surface damage. No spalling. No hollow sounds (delaminations). Patched areas that are sound.	Light or moderate scaling (less than 0.25 in. exposed aggregate). Abrasion less than 0.25 in. deep over less than 20% of surface. Localized minor impact damage (less than 0.25 inches deep). Localized spalls less than 6 inches diameter. No exposed rebar. Small hollow sounding areas. Patch edges tightly bonded.	Moderate to severe scaling (aggregate clearly exposed). Abrasion between 0.25 and 0.5 inches deep over more than 30% of surface. Impact damage. Multiple plugged weep holes. Spalling and/or hollow sounding areas larger than 6inches diameter, rebar exposed, rust staining from spalled areas. Patch delamination.	Extensive surface damage. Includes significant exposed and/or corroded rebar. Widespread spalling or delamination with exposed and corroded rebar. Structure may be unstable.
Exposed Rebar	No Exposed rebar.	Moderate efflorescence and no rust staining emanating from cracks.	Local areas of exposed rebar. Efflorescence and/or rust staining emanating from cracks.	Widespread exposed rebar with significant corrosion. Widespread rust staining emanating from cracks

Element 12302 (Wingwall) – Metal

Description	This element is for headwalls attached to the end of the culvert.			
Quantity Calculation	The quantity for this element is measured as "each."			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
End Treatment Deformation and Damage (Metal)	No dents, impact damage, or abrasion.	Small dents or impact damage. Abrasion of wall or coating with no breaches in the coating exposing structural wall	Large dents/ deformation or impact damage. Abrasion of protective coating with breaches exposing the base material.	Deformation that restricts flow capacity or is resulting in scour or erosion of embankment
End Treatment Corrosion (Metal)	No corrosion.	Freckled rust or other sign of corrosion of material. No loss of section or pitting.	Corrosion of material and section loss less than 10% of thickness. Deep pitting pronounced thinning. Several holes less than 1 inch diameter. Penetration possible with hammer Scour exposing vertical face of previously buried structure or footing. No undermining or rotation of footing.	Widespread corrosion, local through thickness penetrations. Holes greater than 1 in. diameter or many smaller grouped holes allowing soil migration.

Element 12303 (Scour)

Description	This element is to be used for culverts that are constructed with a footing or other end treatment. Distress due to scour is typically only encountered on 3-Sided Box or Arch Culverts.			
Quantity Calculation	The quantity for this element is measured as each footing or slab.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
End Treatment Scour and Stability	No exposure of previously buried sections of footing. No rotation from installed condition.	Scour exposing any surface of previously buried structure but no exposure of the vertical face of the footing. No undermining. No rotation from installed condition.	Scour exposing vertical face of previously buried structure or footing. No undermining or rotation of footing.	Scour with significant undermining of footing. Severe rotation leading to structure distress (kinking of metal culvert; cracking of concrete culvert, cracking of mortar, displacement of masonry units).

Element 12404 (Barrel) – Plastic

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Plastic Barrel – Shape Change	Barrel maintains round shape with no local wall flattening. Vertical deformation less than 5% of nominal diameter.	Minor wall flattening. Vertical deformation 5% to 7.5% of original inside diameter.	Significant wall flattening or increased wall curvature. Vertical deformation 7.5% to 10% of nominal diameter. Visual out-of-roundness.	Major wall flattening with reversal of curvature (global buckling) and/or kinks. Vertical deformation greater than 10% of nominal diameter. Significant visual out-of-roundness.
Plastic Barrel – Surface Damage	No indication of wear, abrasion, impact damage or UV degradation.	Minor wear and abrasion with less than 10% of wall thickness impacted. Minor staining or UV degradation. Blistering over less than 25% of pipe inner surface.	Wear and abrasion that exceeds 10% of wall thickness. UV degradation causing discoloration. Blistering over greater than 25% of pipe inner surface.	Wear and abrasion that exceeds 25% of wall thickness. UV degradation resulting in cracked or broken pipe wall.
Plastic Barrel – Abrasion/ Wear	Smooth interior wall. No splits in welded seams or cracking in wall.	Initiation of local buckling indicated by rippling in wall. Wall cracking or splits, less than ¼ of circumference. No infiltration. No longitudinal cracking.	Advanced and widespread local wall buckling indicated by extensive interior surface rippling. Wall cracking or splits up to ½ of circumference. Minor water infiltration with no soil infiltration. Longitudinal cracking less than 12 inches in length.	Kinks present through the full wall thickness. Pipe wall shows local inward buckling. Wall cracking or splits greater than ½ of circumference. Cracks with indication of soil infiltration. Longitudinal cracking more than 12 inches in length.

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a “slice” of the diameter of the barrel’s length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction

Element 12404 (Barrel) – Concrete

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Concrete Barrel – Cracking	No measurable crack width. Hairline cracks (less than 0.0625-inch width) may be present.	Longitudinal cracks 0.01 to 0.05 inches wide with spacing of 3 feet or more. Some circumferential cracks with no water or soil infiltration.	Longitudinal cracks between 0.05 and 0.1 inches wide, with spacing of 1 to 3 feet. Circumferential cracks may have water infiltration. No cracks with vertical offset. No increase in cracking from previous inspection (if applicable).	Longitudinal cracks greater than 0.1 inches wide, and significant water infiltration with soil migration may be present. Cracks with vertical offset.
Concrete Barrel – Spalling/ Slabbing/ Delamination/Patches	No visual spalling, slabbing or delamination as indicated by wall visual appearance. Any patches are sound.	Localized spalls less than 0.5-inch depth and 6-inch diameter. No slabbing. Patches stable but may have small delaminations (as indicated by hollow sounds).	Spalling and/or delaminations from 0.5 to 0.75-inch depth and larger than 6-inch diameter. Deterioration from slabbing with exposed aggregate and loss of up to ½inch of surface mortar.	Widespread spalling greater than 0.75-inch depth or delamination. Slabbing of concrete with complete loss of invert or other wall section. Structure may be unstable.
Concrete Barrel – Exposed Rebar	No Exposed rebar.	Moderate efflorescence and no rust staining emanating from cracks. No exposed rebar.	Local areas of exposed rebar. Efflorescence and/or rust staining emanating from cracks.	Widespread exposed rebar with significant corrosion. Widespread rust staining emanating from cracks

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Concrete Barrel – Abrasion/ Wear	No scaling, abrasion, or other surface damage.	Minor scaling with less than 0.25-inch exposed aggregate. Abrasion less than 0.25 inches deep over less than 20% of pipe surface. Minor and localized (less than 0.25-inch depth) impact damage. May have multiple plugged weep holes.	Significant to major scaling with aggregate clearly exposed. Abrasion between 0.25 and 0.5-inch-deep over more than 30% of pipe surface. Impact damage present. May have multiple plugged weep holes. May have through wall perforation at the invert.	Major surface damage and aggregate pop-out. Complete invert deterioration and loss of pipe wall section.
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction

Element 12404 (Barrel) – Corrugated Metal

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a “slice” of the diameter of the barrel’s length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Corrugated Metal Barrel – Surface Damage	No dents or other localized damage.	Minor dents or impact damage to pipe wall or end section with no wall breaches.	Large dents or impact damage to pipe wall or end section with localized wall breaches. Breaches no more than one corrugation over circumferential length of inches.	Dents or damage that warrant engineering evaluation. Through-wall holes greater than one corrugation over a length more than 6 inches which allow unimpeded soil infiltration.
Corrugated Metal Barrel – Corrosion	Isolated areas of freckled rust may be present.	Freckled rust or corrosion of pipe wall material. No loss of section and no through wall penetration from corrosion.	Corrosion of pipe material and widespread section loss less than 10% of wall thickness. Localized deep pitting. Several holes less than 1 inch diameter. Penetration possible with hammer pick strike.	Widespread through-wall penetration. Invert missing in localized sections. Through-wall penetrations present. Holes greater than 1 inch diameter or many smaller holes closely grouped.
Corrugated Metal Barrel – Cracking/ Splitting	None present.	Steel cracking is self-arrested or arrested with holes, doubling plates, or similar. Minor yielding of steel and/or cracking/splitting less than 1 inch long local to bolt holes. Minor corrosion developing around bolt holes or on bolts.	Steel cracking is progressing. Yielding of steel and/or cracking/ splitting 1 inch to 3 inches long local to bolt holes. Corrosion with section loss around bolt holes or on bolts.	Major deterioration due to cracking impacting strength of barrel. Significant yielding of steel at bolt holes. Cracking/ splitting 3 inches or more local to bolt holes.

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a “slice” of the diameter of the barrel’s length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Corrugated Metal Barrel – Abrasion/ Wear	No damage due to abrasion.	Small or local abrasion of wall or coating. No breaches in the coating exposing structural wall or signs of corrosion.	Widespread abrasion of protective coating. Probing with a pick may show breaches by exposing wall material and allowing through wall penetration with a pick.	Abrasion has worn large holes through the metal pipe greater than one corrugation in length for more than 6 inches around the circumference.
Corrugated Metal Barrel – Shape (Closed Shape)	Smooth curvature of barrel with deformation less than 5% of nominal diameter.	Top half is smooth. Minor bulges or flattening of the bottom. Deformation 5%-10% of nominal diameter.	Significant distortions or flattening. Lower third may be kinked. Deformation 10% to 15% of nominal diameter. Visible out-of-roundness.	Major distortion throughout pipe. Local areas of reverse curvature and kinks. Deformation greater than 15% of nominal diameter. Significant out-of-roundness.
Corrugated Metal Barrel – Shape (Open Bottom)	Smooth curvature, rise and span measurements within tolerance. The mid-ordinate of the top arc half should be within 10 percent of design.	May have slight asymmetry with smooth curvature. Span may differ more than 5 percent from the design span. The mid-ordinate of the top arc half should be within 15 percent of design.	Noticeable distortion, deflection, or non-symmetrical curvature. The mid-ordinate of the top may be up to 50 percent less than design.	Major visual distortion and deflection. Curvature. Span should be within 5 percent of the design span. Mid-ordinate of the top arc half may be greater than 50 percent less than design.
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction

Element 12404 (Barrel) – Masonry

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Masonry Barrel – Masonry Units and Movement	No cracking, split or missing masonry units. No displaced masonry units. No surface deterioration. No measurable cross-sectional distortion.	Cracking of isolated individual units. Surface weathering or spalling. No movement of masonry units.	Split or cracked masonry units. Large areas with significant spalling, scaling, or weathering. Pronounced movement or dislocation of masonry units.	Widespread cracking, splitting, or cracking of masonry units. Missing masonry units. Large areas of major spalling, scaling, or weathering. Holes through structure wall. Significant movement of individual units. Visible movement or distortion of cross-sectional shape. Structure may appear unstable.
Masonry Barrel – Mortar	Mortar is intact with no deterioration.	Localized cracked or missing mortar. Widespread areas of shallow mortar deterioration, possible minor water infiltration (with no active flow) or exfiltration through joints.	Significant missing mortar and mortar deterioration. Minor water flow but no soil infiltration or exfiltration through joints. Vegetation sprouting from between units.	Missing mortar with backfill infiltration. Possible voids in roadway.
Masonry Barrel – Efflorescence or Staining	Minor areas of efflorescence less than 2 inches square.	Widespread areas of efflorescence without rust staining.	Heavy buildup of efflorescence with rust staining.	Critical rating not applicable to this element.
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction

Element 12404 (Barrel) – Clay

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Clay Barrel – Cracking	No cracking in wall.	Wall cracking less than ¼ of circumference. No longitudinal cracking.	Wall cracking up to ½ of circumference. Longitudinal cracking less than 12 inches in length.	Wall cracking greater than ½ of circumference. Longitudinal cracking more than 12 inches in length.
Clay Barrel - Flaking and Scaling	No indication of flaking and scaling	Minor flaking and scaling with no indication of trapped debris	Moderate flaking and scaling with trapped debris that minimally affects flow.	Major flaking and scaling. Trapped debris significantly obstructs flow.
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction

Element 12404 (Barrel) – Timber

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.			
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Timber Barrel – Connections or Missing Members	No loose bolts, broken welds, missing rivets, or missing fasteners. No surface rust.	Loose bolts or fasteners. Freckled rust (no pitting or section loss), rust staining on face of members but connection is functioning as designed.	Missing bolts, rivets, or fasteners, broken welds, surface rusting with some pitting, pack rust without distortion, but connection is functioning as designed.	Connection integrity is in question. Missing bolts, rivets, or fasteners, broken welds causing movement in connected elements. Heavy rusting with section loss, and/or pack rust causing distortion. Imminent collapse.
Timber Barrel – Deterioration	No sunken faces, staining, or discoloration of member surfaces. No signs of fruiting bodies.	Decay allowing probe penetration up to 10% of the member cross section. Localized hollow sounds.	Decay allowing probe penetration 10% to 20% of the member cross section but is away from connections and tension zone of bending member.	Probe penetrates more than 20% of member cross section or more than 10% near connections or in a tension zone of bending member. Fruiting bodies.
Timber Barrel – Checks/Shakes	Checks or shakes penetrating less than 5% of member thickness	Checks or shakes penetrating 5% to 50% of member cross section, but away from connections and tension zones of bending members.	Checks or shakes penetrating more than 50% of member cross section or up to 10% near connections or in a tension zone of bending member.	Checks or shakes penetrating more than 10% near connections or in a tension zone of bending member.
Timber Barrel – Structural Cracks	No structural cracking.	Structural cracking that has been arrested.	Structural cracking exists, but projects less than 5% into the member cross section.	Structural cracking exists with differential movement across crack.

Description	This element is for culvert barrel, regardless of culvert shape or culvert material type.				
Quantity Calculation	The quantity is collected in length of feet unless otherwise noted. The barrel element is measured along the flow line of the barrel times the number of barrels. Distresses are measured as a "slice" of the diameter of the barrel's length.				
	Condition State Descriptions				
Defect Type	**Good**	**Fair**	**Poor**	**Severe**	
Timber Barrel – Delamination	No separation between laminations.	Delamination length less than the total member depth and away from connections or has been arrested.	Delamination length equal to or greater than the total member depth, but only present away from connections.	Delamination near connections; imminent collapse of member or structure.	
Timber Barrel – Abrasion	No section loss due to abrasion.	Section loss of less than 10% of the member cross section.	Section loss of 10% to 20% of the member cross section.	Section loss of more than 20% of the member cross section.	
Timber Barrel – Distortion	No change in structure cross section. No warping, crushing, or sagging of individual members.	Warping or sagging of single or few members not requiring mitigation or has been previously mitigated.	Warping, sagging causing distortion of cross-sectional shape. Crushing of member(s).	Significant distortion of cross-sectional shape or widespread warping, crushing, or sagging.	
Other Barrel Damage – Insect Activity, Fire, etc.	No issues present.	Minor damage to barrel.	Moderate to significant deterioration of barrel.	Major structural defects. Barrel may have failed.	
Barrel Alignment	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding/sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction	

Element 12405 (Joint)

Description	This element is for joints which define sections between lengths of culvert barrels.			
Quantity Calculation	The quantity for this element is measured as "each."			
	Condition State Descriptions			
Defect Type	**Good**	**Fair**	**Poor**	**Severe**
Joint Separation, Offset, and Rotation	Joints are tightly installed with proper alignment and are functioning well.	Joint separation, offset, or rotation with no indication of distress. Gasket not exposed.	Joint separation, offset, or rotation in one or more joints, with exposed or missing gasket materials.	Joint separation, offset, or rotation with exposed backfill material. Multiple locations of exposed or missing gaskets.
Joint Infiltration/ Exfiltration	Joints are performing as intended with respect to infiltration and exfiltration.	Not applicable. Joint shall meet performance requirement specified in design or will rate as poor.	Joint distress identified by coarse grained soil infiltration through soil-tight joints. Fines infiltration through silt-tight joints. Any water infiltration/exfiltration through leak resistant or watertight joint.	Joint distress directly causes distress to barrel/end section, roadway/shoulder, or embankment.
Joint Cracking (Concrete)	No joint cracking.	Longitudinal cracks of 0.01 in.to 0.05 in. wide (thickness of dime) emanating from joint. No spalling. Small spalls along edge of spigot end that do not expose reinforcing or joint sealant.	Between 0.05 in. and 0.1 in. wide longitudinal cracks emanating from joint. Moderate spalls along edge of spigot end, possible exposed reinforcing or joint sealant.	Greater than 0.1 in. longitudinal cracks emanating from joint. Large spalls along edge of spigot end with associated structural cracking.