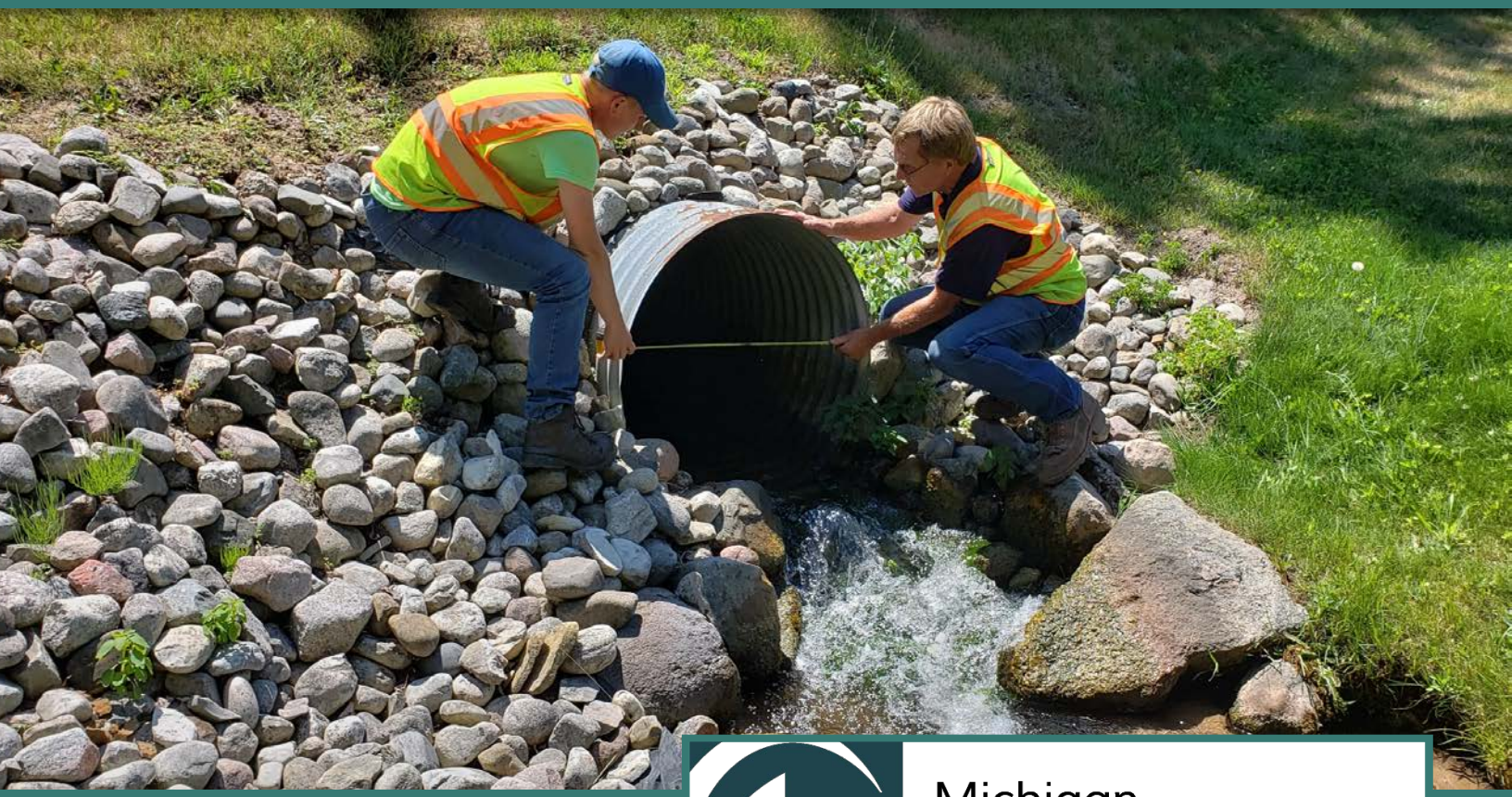
Michigan Non-NBI Culvert Structure Inspection Guide



Michigan Transportation Asset Management Council

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Purpose

The *Michigan Non-NBI Culvert Structure Inspection Guide* (Mi-NCSIG) has been developed to provide culvert safety inspectors and culvert owners with guidance for meeting the consistency standards required to submit culvert data to the Michigan Transportation Asset Management Council (TAMC) according to the "Policy for Collection of Inventory and Condition Data". This guide provides guidance for inspecting culvert structures that do not meet the National Bridge Inspection Standards (NBIS) definition of a bridge. Culvert-like structures that meet the NBIS definition of a bridge must be inspected per the National Bridge Inspection Standards and the *Michigan Structure Inspection Manual* (MiSIM).

Owners may decide to inspect larger culverts that do not meet the NBI bridge definition using the NBI and MiSIM standards. To support this decision, comparison tables are provided in Appendix B to allow uniform submittal of condition data for the purposes of the TAMC. The Mi-NCSIG covers culvert inspection program considerations, inspection format, and inspection safety. The Mi-NCSIG also includes a culvert condition rating system for rating culverts located on Michigan roads.

How to use this guide

This guide is divided into three chapters. The first chapter explains some background information about culvert inspection and asset management efforts in Michigan. It also gives additional resources that may be helpful for local road-owning agencies. The second chapter discusses inventory data and how to collect information necessary for identifying unique culverts within a local road-owning agency's network. The third chapter describes the components and characteristics associated with the collection of condition ratings of a culvert barrel and the vicinity and appurtenant structures surrounding the culvert. Definitions for terms used in this guide can be found in Appendix A, comparison tables between the previous and current culvert rating systems can be found in Appendix B, and a data dictionary can be found in Appendix D. Rating cards intended for field use are included in Appendix C.

This guide is intended to be living document, and the TAMC welcomes feedback from users. Please send questions, comments, or suggestions to CSS-TAMC@Michigan.gov.

References

There are several documents and manuals that are used as references throughout this manual. These references provide the initial basis and background material for development of this manual.

Federal and National Manuals

- *Culvert & Storm Drain System Inspection Guide*, American Association of State Highway Transportation Officials (AASHTO) 1st Edition, 2020. Available for purchase: https://store.transportation.org/Item/CollectionDetail?ID=213
- *National Bridge Inspection Standards* (NBIS)
- *Bridge Inspector's Reference Manual* (BIRM), Federal Highway Association, 2012. Available: https://www.fhwa.dot.gov/bridge/nbis.cfm

Michigan Specific Guides and Manuals

- "Policy for Collection of Culvert Inventory and Condition Data", Michigan Transportation Asset Management Council, 2021
- *Michigan Structure Inspection Manual* (MiSIM), Michigan Department of Transportation, 2017. Available: https://www.michigan.gov/mdot/programs/bridges-and-structures/structure-preservation-and-management/inspection/michigan-structure-inspection-manual

Transportation Asset Management Council Research Report

- "Michigan Local Agency 2018 Culvert Inventory Pilot Evaluation", Michigan Transportation Asset Management Council, 2018. Available: http://ctt.mtu.edu/sites/default/files/resources/assetmgmt/ctt-2018-tamcculvertpilot-report.pdf
- "2020 TAMC Culvert Condition Assessment Final Report", Michigan Transportation Asset Management Council, 2020. Available: https://www.michigan.gov/-/media/Project/Websites/tamc/Folder1/2020_TAMC_Culvert_Condition_Assessment_Final_Report.pdf?rev=08c659c2c74b440bb6f7a4dc50bcbdfd
- "2021-22 TAMC Culvert Condition Assessment Final Report", Michigan Transportation Asset Management Council, 2022

Abbreviations

AASHTO – American Association of State Highway and Transportation Officials

CSS – Center for Shared Solutions

CTT – Center for Technology and Training

FHWA – Federal Highway Administration

MDOT – Michigan Department of Transportation

NBI – National Bridge Inventory

NBIS – National Bridge Inspection Standards

TAMC – Transportation Asset Management Council

Chapter 1: Culvert Data Collection Program Considerations

This guide is intended to assist local road-owning agencies in systematically collecting culvert data for asset management purposes. An agency may choose to collect additional data, but the TAMC has developed the recommendations within this document to provide guidance on the minimum data categories to collect as well as a standardized method for culvert assessment. .

Local road-owning agencies may choose if and how to implement the recommendations in this guide. Depending on the number of culverts, area of jurisdiction, available resources, or other factors, an agency may elect to collect data all at once or in stages based on a priority determined by the agency. This chapter provides guidance for agencies that are creating or updating their internal policies and procedures with regard to culvert asset management.

1.1 Purpose for Collecting Culvert Inventory and Condition Data

Public Act 325 of 2018 requires large local road agencies to have an asset management plan that includes culvert assets; further information can be found in the TAMC's "Policy for Collection of Culvert Inventory and Condition Data".

Culvert inventory and condition data serve as the foundation and provide critical information for asset management planning and practice. Asset management enables local road-owning agencies to manage and maintain their transportation assets efficiently and effectively. Furthermore, when local road-owning agencies across the state of Michigan submit their culvert inventory and condition data to the Michigan TAMC, this data supports the TAMC in their advisement to the Michigan Infrastructure Council (MIC) on a statewide transportation asset management strategy and the processes and tools needed to implement that strategy (see MCL 247.659a). This guide provides program considerations for identifying culverts, inspection intervals, inspection equipment, and safety resources, as well as an outline of the inventory data (see Chapter 2) and condition data (see Chapter 3) that can be collected and may be submitted to the

TAMC. More information about submitting data to the TAMC can be found in Chapter 3. The outline of the culvert condition rating system in this guide serves to promote statewide consistency. This guide does not discuss how this information is to be included in an agency's asset management plan. Further information can be found in the most recently approved Michigan TAMC's "Policy for Collection of Culvert Inventory and Condition Data".

1.2 NBI Bridge or Culvert versus Non-NBI Culvert

Engineers, owners, and inspectors often refer to structures as culverts based upon the type of structure, regardless of span length. However, the span length of the structure is the critical factor for determining if the provisions of the NBIS apply. Those standards supersede the recommendations found in this guide. Culvert-like structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM. In addition, bridge-like structures that have a deck/superstructure/substructure but meet the span length definition of a culvert may be inspected using NBIS guidelines.

The NBIS provide the governing rules and regulations for the inspection of highway bridges located on all public roads throughout the entire United States. Section 650.305 of the provision provides the definition of a bridge which, briefly stated, includes those structures on public highways carrying traffic that span 20 feet or more measured from the center of the roadway. Michigan Act 354 of 1925 also has additional requirements regarding bridge safety inspection. Sections 254.19a and 254.30 necessitate biennial inspection of all bridges and culverts under state transportation department jurisdiction. Culvert structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM.

Prior to revisions in the FHWA *Bridge Inspector's Reference Manual* (BIRM), culverts were defined as any structure that did not meet the NBIS length requirements of a bridge. This method of classifying culverts did not consider the dissimilarities present in the structural characteristics and design. The current BIRM defines a culvert as a structure designed hydraulically to take advantage of submergence to increase water carrying capacity. However, this definition is disconnected from the federal requirements for inclusion in the NBIS and, so, is not incorporated in this guide.

This guide defines a culvert as a linear drainage conduit underneath a public roadway that is not considered a "bridge" by the FHWA. In other words, a culvert does not meet the span-length minimum of the NBIS. The FHWA generally considers a "bridge" as having a combined span of more than twenty feet, which requires listing on the National Bridge Inventory. Culvert structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM.

Culverts are differentiated from storm sewers in that culverts are straight-line conduits that are open at each end, and do not include intermediate drainage structures (e.g., manholes, catch basins).

1.3 Inspection Intervals

Inspection intervals should be established to ensure an agency's data accurately reflects the culvert conditions to support efficient decision making. Inspection intervals that are too short result in little to no change between data sets and an inefficient work plan. Inspection intervals that are too long may result in significant changes, missed opportunities for maintenance, and potential risk of failure. An owner should establish risk-based inspection intervals for each culvert in the inventory. Since age and condition are

common risk factors, the assigned intervals may need to be revisited for each culvert following each inspection. The maximum inspection interval set by the TAMC is 6 years if the condition data will be submitted to the statewide dashboard. Owners can develop their own risk-based interval schedule within that maximum or they may use the following recommendations.

A risk-based interval matrix could include the following risk-related culvert variables: condition rating, size, material, age, and roadway average daily traffic (ADT).

- **Condition rating**: Condition has the strongest impact on risk and, therefore, generally has the strongest impact on inspection intervals as the condition drops along the good-fair-poor-severe scale. In the case of poor or severe condition, in-depth inspections or structural analyses may be required.
- **Size:** As size increases, the impact of a failure tends to increase. Common culvert sizes are 24 inches or smaller, 24 to 48 inches (4 feet), 4 to 10 feet, and 10 feet or larger.
- **Material**: More-frequent (than otherwise required) inspection intervals may be needed where there are material-specific concerns such as corrosion potential or alkali aggregate reactivity (AAR).
- **Age**: Age of the culvert is incorporated into an agency-specific rating if it is known that certain standards or processes, which would decrease the risk of failure or premature deterioration, were not in place when the culvert was construction.
- **Roadway ADT**: Failure of culverts beneath roadways with higher average daily traffic (ADT) would lead to greater impact and could be included as a way for an owner to prioritize limited inspection resources.

Owners can develop their own risk-based interval schedule, or they may use the following recommendations. Table 1-1 correlates the controlling (most frequent) inspection interval with the different variables for each specific culvert. In the case of poor or severe condition, in-depth inspections or structural analyses may be required.

Table 1-1 Recommended Maximum Inspection Intervals				
Non-NBI Culvert Inspection*	Maximum Inspection Interval (in months)			
	≤12	≤24	≤48	≤72
Condition Rating				
Good				X
Fair			X	
Poor		X**		
Severe	X**			
Size (inches)				
≤24				X
>24 and ≤48				X
>48 and ≤120			X	
>120 (10 feet) and <240 (20 feet)		X		
Material				
No material-specific concerns				X
Material-specific concerns			X	
Age**				
Consider increasing frequency as appropriate				
ADT**				
If limited resources require an agency to exceed the above recommendations for some structures, ADT maybe used to prioritize which culverts pose the least risk to extended frequencies.				
* Culvert structures that meet the National Bridge Inspection Standards (NBIS) definition of a bridge MUST be inspected per the NBIS and the *Michigan Structure Inspection Manual* (MiSIM) ** In the case of poor and severe condition in-depth inspections or structural analysis may be required; use engineering judgment to obtain culvert-specific frequencies				

1.4 Inspection Equipment

A variety of equipment may be necessary for proper culvert inspections. Hand tools or other aids for field inspection ensure efficient and comprehensive results. The equipment should be well organized and easily accessible to limit time spent searching for particular items while parked near traffic. In addition, specialized access equipment may be necessary to observe elements that cannot be viewed from the culvert's adjacent surfaces and to perform in-depth inspections. This section describes recommended equipment that the inspection team may desire during routine culvert inspections. Prior to performing field work, the agency's lead inspector should review the AASHTO *Culvert & Storm Drain System Inspection Guide* for other beneficial and advanced inspection equipment recommendations.

Personal protective equipment (PPE) should be used in accordance with Michigan Occupational Safety and Health Administration (MIOSHA) and the employing agency's safety plan. Commonly-used PPE include safety vests, steel- or composite-toe boots, gloves, hard hats, and safety glasses. When working near water, life jackets are recommended. Waders or hip boots are suggested in order to decrease the likelihood of contact with pollutants and organisms and to provide insulation while working in cold surface waters. Other PPE may be needed when working in confined spaces, at heights above 6 feet, or in the presences of other vulnerabilities. MIOSHA standards contain precaution and preparedness items that should be implemented before exposure to hazards at the culvert site.

During the culvert file review, the lead inspector should review the previous inspection findings to determine whether specialized equipment or particular tools are required for assessing a culvert's condition. The standard equipment that every lead inspector should have access to during field work may be categorized according to gear required for improving visual observation, for diagnosing or identifying defects that are not visible, and for accurate recording of the deficiencies identified. Failure to have access to these tools may result in repeated visits to the structure causing inefficient use of time and increased labor costs. A summary of recommended equipment is provided in Table 1-2. Additional information regarding tools for culverts that are challenging to access or that require specialized equipment to complete the culvert inspection can be found in the *AASHTO Culvert and Storm Drain System Inspection Guide* section 3.8.

Table 1-2 Recommended Inspection Equipment

Visual Observation	Diagnosis or Identification of Unexposed Defects	Documentation Equipment
Binoculars	Rock pick hammer, sounding rod, or chain	Camera
Ladder	Scour or probing rod or shovel	Marking tool – chalk, lumber crayon, paint stick
Flashlight	Plumb bob	Maps
Cleaning tools – wire brush, paint scraper	Fathometer	Smartphone
Boat or raft	8- to 10-foot-long straight edge	Computer, tablet, or paper forms
Mirror	Measuring tools – tape measure, measuring wheel	Surveying equipment
Chest waders or rubber boots	Level	

Binoculars, ladders, mirrors, and flashlights are practical tools that allow enhanced visual observation of surfaces from a distance or surfaces that are shielded from daylight. These items improve judgment on whether additional investigation beyond a routine inspection is needed. Inexpensive hand tools like putty knives and steel brushes that allow cleaning or removal of rust and debris can be helpful to determine the extent and severity of distresses.

Rock pick hammers, steel sounding rods, or chains can be used to identify voids behind horizontal and vertical surfaces. Generally, surface areas that are sounded during a routine inspection are limited by accessibility. Rods are used to probe for scour and loose soil conditions and feel for irregularities on submerged components. Shovels may be necessary to expose the end of the culvert. Boats or rafts are essential when the water depth adjacent to submerged culvert elements where wading is not feasible. Fathometers are recommended for underwater inspections conducted from a boat or raft. Fathometers are inexpensive devices that improve detection of active scour but may not substitute for probing since scour holes filled with loose streambed materials may not be detected with the instruments.

Cameras are necessary to record the condition of culvert at the time of inspection. Photographs should be made of the transverse view of the roadway in each direction of traffic, elevation of the structure, and any elements that experienced a rating change from the previous inspection. Tools like tape measures and crack gauges quantify defects and can provide a scale for photographs. The lead inspector should carry tape measures of adequate length for the size of the culverts that are anticipated during the inspection. Electronic distance meters may also be used at locations where measurements with a physical tape are

inefficient or difficult. Levels quantify the extent that items are out of plumb, such as when settlement, displacement, or rotation has occurred. Smartphones, tablets, or laptops are beneficial for viewing previous inspection findings, for immediate verbal contact or correspondence with the culvert owner, for verification of the longitude and latitude values, and for recording inspection data.

1.5 Safety Resources

Local road-owning agencies should follow their in-house policies and procedures for work that is on or adjacent to roadways when conducting culvert inspections. These policies will be unique to the agency and the types of safety hazards that may be present. If an agency does not have an established policy for this type of work, safety information pertaining to culvert and bridge inspection can be found in the following resources:

- *Culvert & Storm Drain System Inspection Guide* Section 3.10, AASHTO, 1st Edition, 2020. Available for purchase: https://store.transportation.org/Item/CollectionDetail?ID=213
- *Michigan Structure Inspection Manual (MiSIM)* Chapter 13 – Bridge Inspection Safety, Michigan Department of Transportation, 2017. Available: https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773_59525-326737--,00.html
- *Bridge Inspector's Reference Manual* (BIRM) Chapter 2- Safety Fundamentals for Bridge Inspectors, Federal Highway Association, 2012. Available: https://www.fhwa.dot.gov/bridge/nbis.cfm
- Agency's in-house policies and procedures pertaining to culvert and bridge inspection.

Chapter 2: Culvert Inventory Data Collection

Culvert inventory data encompasses information describing a unique culvert structure that helps to identify and distinguish it from other culverts as well as compare and contrast it an agency's other culvert assets. The data fields that the TAMC included in the recommendations for culvert inventory data collection is intended to balance functionality within an asset management program with relative ease for field personnel to collect. This chapter catalogs the minimum level of detail and extent for culvert inventory data collection; however, a local road-owning agency may choose to collect additional inventory data that is relevant for their organization.

2.1 Why Collect Inventory Data?

Asset inventory data serves as the foundation for asset management practice. Having current and accurate culvert inventory data allows local road-owning agencies to know what kinds of culvert assets they have and where those assets are located, to plan for and conduct inspection and condition rating (see Chapter 3), and to develop and execute a maintenance program. Typically, initial collection of culvert inventory data requires more effort than subsequent culvert inventory data collection efforts, which focus on verification of previously-collected data. If data is revised during subsequent culvert inventory data collection efforts, it is recommended to keep a record of the previous data and to make an indication of which data is new.

2.2 Inventory Data

Basic inventory data to identify a unique culvert includes location, material type, length, and shape. Additional data may be valuable for asset management purposes like the geometry of the culvert (including the width, rise, or number of barrels) and how the culvert relates to the roadway above it (including the skew angle, depth of cover, or roadway surface). The TAMC has identified the following culvert inventory fields as required and optional for asset management purposes:

- Inventory identification number
  An agency-specific identification number that uniquely identifies the culvert

- Inspection date
  Date of most recent inspection

- GPS coordinates – representative point (both ends optional)
  Location of culvert. A single point representative of the culvert establishes the approximate location of the culvert for the purposes of finding it in the field. Coordinates for both ends of the culvert may be helpful for hydrological or other modeling purposes.

  - Latitude
    Latitude coordinate for culvert

  - Longitude
    Longitude coordinate for culvert

  - Elevation (optional)
    Elevation above sea level of the upstream or downstream culvert invert

- Material type (user can add custom sub-types)
  Culvert material classified according to the following material types used in the shared database. Users may add custom sub-types for their agency's records. Sub-types may describe the material in greater detail or the presence of a liner.

  - Plastic
  - Concrete
  - Steel corrugated metal pipe (CMP)
  - Steel plate
  - Aluminum corrugated metal pipe (CMP)
  - Aluminum plate
  - Masonry
  - Timber
  - Other

- Shape (see Figure 1)
  Shape of the culvert classified according the following descriptions. Custom shapes may be defined as sub-types under "Other"

  - Round
  - Horizontal ellipse
  - Vertical ellipse
  - Pipe arch
  - Arch
  - Low-profile arch
  - High-profile arch
  - Pear
  - Box
  - Multi-cell box
  - Three-sided

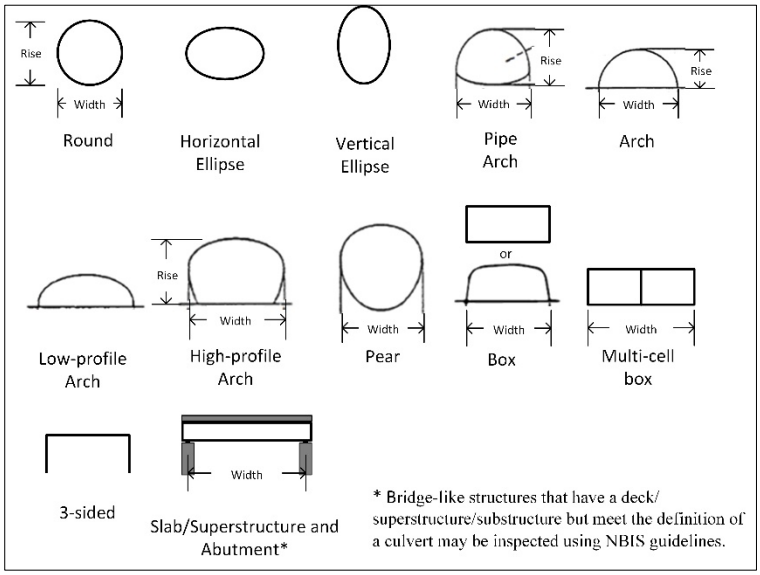


Figure 1 Culvert shapes

    - Slab/superstructure and abutment
    - Other
- Skew angle (degrees between -90 and 90; optional only if defining both ends of the culvert) (see Figure 2)

  Angle that the culvert is skewed away from a line perpendicular to the roadway (zero skew). Based on the acute angle formed by the intersection of road centerline with the culvert centerline, the angle is positive if the end rotation is clockwise and negative if the end rotation is counterclockwise.

- Length (reported in feet)

  Length of the culvert barrel from inlet to outlet

- Rise (reported in feet)

  Height or diameter of the culvert barrel at its tallest point

- Width (required for single barrels) (reported in feet)

  Side-to-side measurement of a single culvert barrel

- Span (required for multiple barrels) (reported in feet)

  Measurement of entire culvert opening when consisting of several barrels placed side by side

- Wall thickness – wall thickness of the culvert material
- Number of barrels

  Number of barrels at the culvert location

- Depth of cover (reported in feet)

  Depth of material above the culvert barrel including the road surface

- Roadway surface type

  Surface type of the road over the culvert; value may be asphalt, brick, concrete, earth, gravel, or sealcoat

- Condition rating (see Chapter 3)

Culvert inventory data may also include the following *optional* data:

- Physical route (PR) number

  PR number for the road over the culvert

- Road name

  Physical route name for the road over the culvert

- Mile point (use three digits of precision)

  Mile point on the physical route for the road over the culvert

- Installation date

  Culvert installation date, if known.

- Photographs

A road-owning agency may wish to collect additional inventory data depending on their individual needs. Culvert inventory data should be submitted along with condition data (see Chapter 3) to the Michigan TAMC.

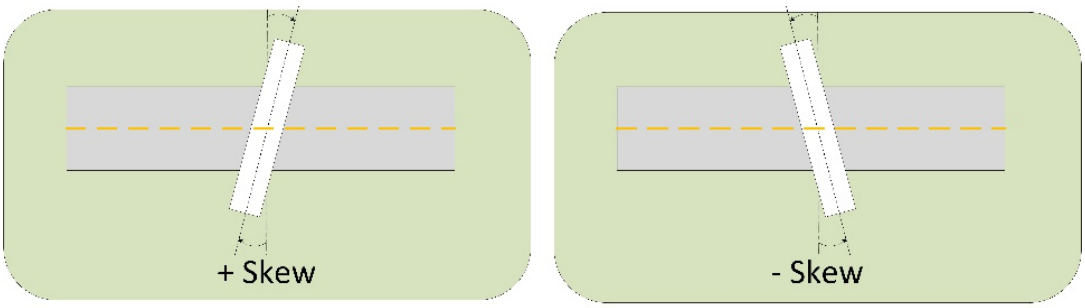


Figure 2 Culvert skew angles

Chapter 3:
Culvert Condition Rating System and Data Collection

Culvert condition data provides a snapshot of the state of a culvert barrel and surrounding vicinity and appurtenant structures. Appurtenant structures in this context refer to end treatments, headwalls, wingwalls, or other culvert components that are independent of the culvert barrel. Singular condition ratings can inform immediate and future maintenance needs while a collection of historic condition ratings can provide insight into how an organization's culvert assets are aging and can help with long-term asset management decisions.

3.1 Why Collect Condition Data?

Asset condition data provides critical information for optimizing asset management practice. Having current and accurate culvert condition data allows local road-owning agencies to know the status of their culvert assets, understand how that condition is progressing, and schedule an effective maintenance and replacement program that ensures a desired level of service across the road network. As subsequent inspections are performed and condition data is collected, the agency can be better informed in its decision-making process and resource allocation. If condition data is revised during subsequent culvert condition data collection efforts, it is recommended to keep a record of the previous data and to make an indication of the new condition ratings.

Condition data can be broken into two components: the vicinity and appurtenant structures and the culvert barrel. A local road-owning agency can make a general rating for each of these components or can rate various characteristic subcomponents to provide more detail and added value to its culvert asset management program.

3.2 Condition Data

Culvert condition data should consist of the following component category ratings:

- Inventory data (see Chapter 2)
- Vicinity and appurtenant structures (component category)
    - Rated as good, fair, poor, or severe
- Culvert barrel (component category)
    - Rated as good, fair, poor, or severe

A local road-owning agency may optionally collect condition data for culvert characteristics; agencies may find this beneficial depending on their individual needs. Culvert condition data can be submitted along with inventory data (see Chapter 2) to the Michigan TAMC.

3.3 Use of the Culvert Condition Rating System on Michigan Roads

The culvert condition rating system outlined in this guidebook is based on a qualitative scale ranging from "good" to "severe". A rating from this qualitative scale is made for each culvert component category, based on ratings for each component and/or characteristic. A "good" rating indicates a like-new component with little or no deterioration, structural soundness, and functional adequacy. This good rating will change to "fair" and then "poor" and "severe" as a component's condition degrades. A "severe" rating indicates the component is not functioning as designed and may also be structurally unsound. Components rated as "severe" require special inspection with a structural evaluation or immediate maintenance, depending on the component being evaluated.

The condition rating categories are a comparison of the existing condition with the as-designed condition. A new culvert that is properly designed and constructed would have condition ratings of "good" for all of its components. Condition ratings of culvert components and component characteristics assess structural condition, ability to perform the intended function, and possible negative impact to the entire culvert or the roadway above.

Components and characteristics that may be rated using this culvert condition rating system include the vicinity and appurtenant structures component category—roadway, channel scour and blockage, and end treatments and appurtenant structures—and culvert barrel component category—barrel condition, alignment, joints, and seams. Each component category's rating—that is, the rating of the vicinity and appurtenant structures component category and the culvert barrel component category—is determined by rating the culvert's components and characteristics and assigning an overall score (see Figure 3). A component-category-level assessment provides agencies with more information for decision-making as compared to a more general condition rating. For example, two culverts may both be rated "poor", but one might be due to sedimentation and the other due to corrosion; each case would have different solutions and would require different allocation of resources for maintenance efforts.

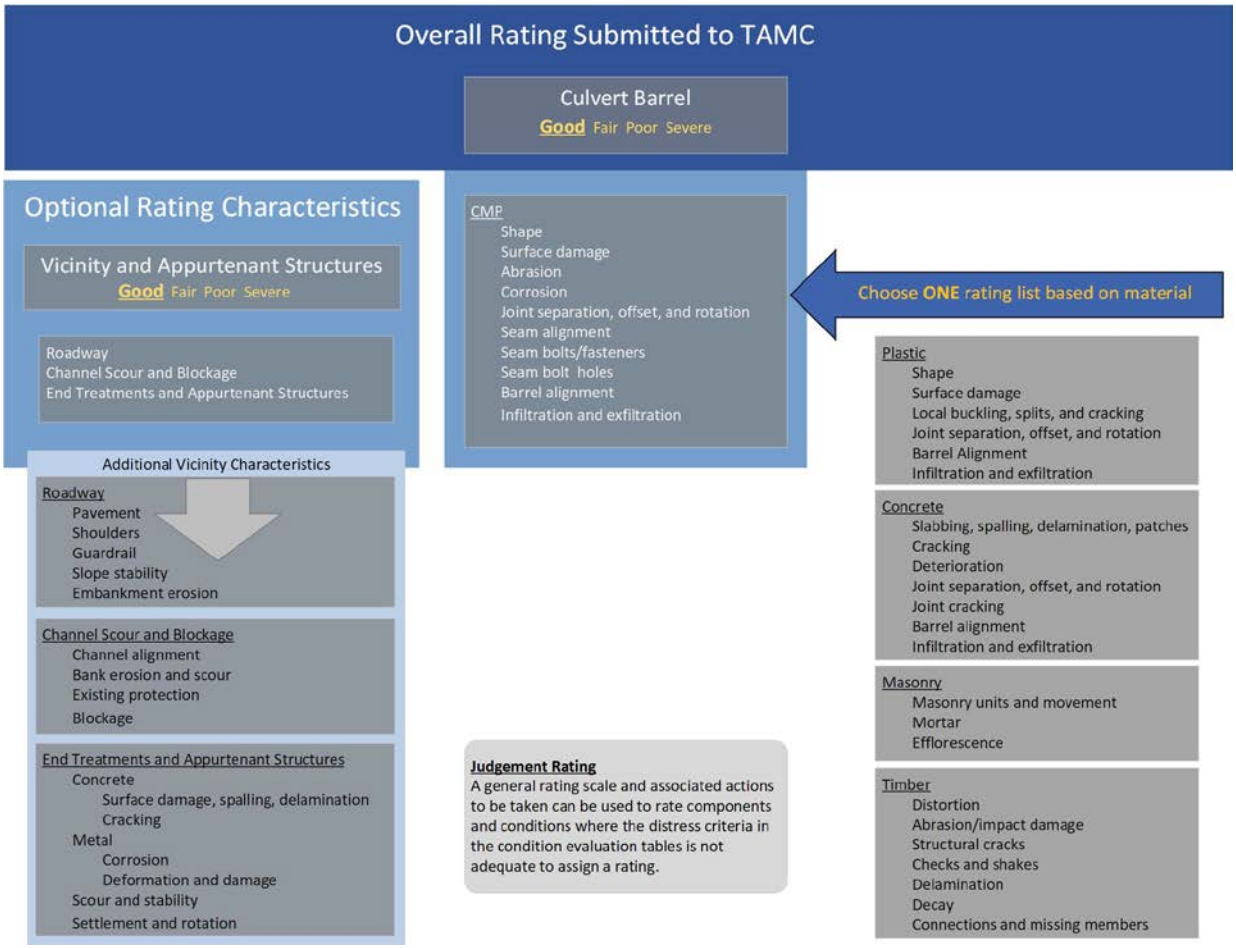


Figure 3 Culvert condition rating component flowchart

The sections of this chapter detail each culvert component, associated distress types, and condition rating descriptions for each characteristic related to that component. Each section includes a culvert condition rating table that outlines the rating scales for each culvert component. To use the culvert condition rating tables:

- Rate each culvert component's characteristic, listed in the left-hand column, using the scale from "good" to "severe" based on the worst defect or distressed condition identified during the on-site inspection. Quantified criteria may require physical measurement.
- The poorest-rating criterion determines the condition rating for a system component or characteristic where there is more than one criterion for evaluation. For example, a flexible culvert barrel may receive a "poor" rating for local poor shape even if all other factors rate as "good" along the culvert length.
- The "Not Rated" (NR) designation should be assigned if a component is not applicable to a system or inaccessible for evaluation. Reasons for not rating should be documented.
- Significant condition changes since the last inspection should be evaluated and noted even if the structure is still in "good" or "fair" condition.

- Overall component category ratings for the vicinity and appurtenant structures and culvert barrel should generally correspond to the lowest of the associated components and/or characteristics; however, this value can be adjusted based on engineering judgement. For example, an inspector may wish to record that a culvert has been blocked by sediment or debris and rate the characteristic accordingly but may be able to remove the debris while on-site thus negating the need to rate the overall condition according to that characteristic.
- Agencies may submit their culvert barrel ratings to the TAMC for use in statewide culvert data analysis.

In the event that the culvert condition rating tables are unable to facilitate an adequate assessment of component distress criteria, the culvert condition rating for a component or characteristic may be based on Table 3-1's "Action Indicated" and an inspector's judgement. The AASHTO *Culvert & Storm Drain System Inspection Guide* 's section 4 and appendix A may be resources to determine the appropriate rating.

Table 3-1 General Condition Ratings, Actions, and Descriptions

Condition Rating	Good	Fair	Poor	Severe	Not Rated
Action Indicated	Action: none Note in inspection report only	Action: none, but more frequent inspection may be warranted Inform maintenance personnel	Action: corrective action based on inspector's evaluation Recommendations made in inspection report	Action: corrective action based on engineering evaluation to specify appropriate repair Required action is urgent	Action: none
Condition Description	Like new Deterioration: none to little Structurally sound Functionally adequate	Deterioration: some Structurally sound Functionally adequate	Deterioration: significant *and/or* Functionally inadequate Requires maintenance or repair	Very poor Deterioration: severe Structurally unsound Functionally inadequate Possible imminent failure or threat to public safety	Not part of the culvert design or structure Functional adequacy not required Not an inspection item at last culvert inspection. Excludes items missing due to vandalism, damage, or deterioration.

Descriptive information collected about a culvert can be stored in Roadsoft or an agency's asset management database. This information may include:

- Photo documentation and supplemental sketches (if necessary) of severity, extent, and location of distresses in order to allow for accurate comparisons of condition during future inspections.

- References of a culvert's distress locations using offsets measured from the outlet end, identified by photographs.
- Location of points on circular, elliptical, and arch-shaped cross sections referenced like hours on a clock with orientation of the clock looking upstream from the outlet. Locations of points on non-round-shaped cross sections measured using offsets from discrete locations such as corners, longitudinal seams, and foundations.
- Joints identified using offsets and stationing measured from the culvert outlet end rather than counting joint numbers. This joint identification method allows for easy transitioning of records for common changes, such as culvert barrel length extensions for roadway widening.

3.4 Vicinity and Appurtenant Structures

The vicinity and appurtenant structures consist of the roadway above the culvert, the embankment, the stream channel that flows through the culvert, and any end treatments located at the culvert's inlet or outlet. The vicinity and appurtenant structures may exhibit signs of distress that are related to the functionality of the culvert. Some types of distress, such as embankment erosion that leads to sedimentation blocking the culvert can impact an otherwise fully functional culvert. Other distresses such as pavement settlement above the culvert, may indicate that the top of the culvert has deformed or that embankment soil is being lost through joints or openings in the culvert. The culvert and the structures surrounding it must work together to create the best service life for both the roadway and the culvert.

3.4.1 Roadway

Figure 4 The condition of the roadway and embankment can help identify distress within a culvert below. Characteristics to inspect include the pavement, guardrail, shoulders, slope stability, and embankment erosion.

Component Description

The **roadway** is the length of roadway and embankment above the buried culvert barrel that is influenced directly by the performance of the buried culvert system. The roadway inspection area should encompass a minimum length of 20 feet either side of the culvert plus the culvert span or to the extents of any wingwall structures. Inspection of the roadway and embankment may indicate problems with the culvert below and can help identify erosion and slope stability concerns, which may lead to misalignment of the barrel.

Poor compaction, loss of backfill material, poor backfill quality, movement of the culvert, and embankment slope failures are all examples of damage to the roadway vicinity that may indicate or result in culvert degradation. Roadway distress may also be due to other factors, such as temperature-induced expansion and contraction of the pavement, age of the pavement, fatigue from vehicle loads, shoulder settlement, frost action, and poor drainage.

What to Look For

The roadway is a single component rated by the minimum condition of five characteristics: pavement, shoulders, guardrails, slope stability, and/or embankment erosion.

- **Pavement or shoulder settlement** can be assessed with indicators like sags, humps, and rutting. Deflection of flexible pipe barrels at their crown is indicative of the backfill soil not providing adequate lateral support and may result in settlement of the pavement above the culvert. Settlement on either side of rigid culverts and a hump over the buried barrel is indicative of poor compaction or low-quality backfill soil.
    - **Sags and humps** are localized depressions or elevated areas of the pavement. Severity of sags and humps can be measured as the maximum deviation from a 10-foot straight edge placed on the pavement parallel to the centerline of the roadway.
    - **Rutting** is a surface depression in the wheel path that runs parallel to the direction of travel. Rutting can be measured as the maximum deviation from a 10-foot straight edge placed on the pavement perpendicular to the centerline of the roadway.
- **Pavement or shoulder maintenance history** can be seen in indicators like repeated patching of the area over the barrel.
- **Pavement or shoulder cracks** can be categorized according to its shape, pattern, and direction. All open pavement cracks in the roadway should be probed for the presence of voids.
    - **Transverse cracking** runs perpendicular to the direction of the road and is a primary distress indicator (with the exception of regularly-spaced transverse cracks along long stretches of the road).
    - **Longitudinal cracking** runs parallel to the direction of the road. Longitudinal cracking is not typically a culvert distress indicator except for when longitudinal cracking exists within one foot of the lane edge, which could indicate a slope stability issue.
- **Guardrail** that is sighted along its length can reveal misalignments and should be rated visually based on the amount of misalignment over the culvert.
- **Slope stability** considers the movement of the embankment immediately above the culvert and to the extents of the wingwall structures or inspection length. Its stability can be affected by the type of soil, loads, saturation, and steepness of the slope. Slope stability can be ascertained by inspecting for signs of movement of the soil in mass. Two key identifiers of slope stability issues are sloughing, or the sliding or collapse of a layer of soil that appears as a vertical cut or drop, and tension cracks, cracks that appear at the top of the slope and run parallel to the roadway. These identifiers generally indicate instability leading to slope failure.
- **Embankment erosion** is loss of the embankment surface materials, including any protective measures used for slope stability such as vegetation or riprap. Sheet erosion is the washing away of thin layers of soil or vegetation as runoff water flows in sheets down the slope. When water flows down the slope in streams the resulting erosion forms channels in the slope. Depending on the depth of these channels, they are described as rills or gullies. Rill erosion describes this type of erosion when these stream channels are less than 1 foot deep while gullying describes this type of the erosion when these stream channels are greater than 1 foot deep. Piping is a form of internal erosion where water flows through the embankment along the outside of a barrel and removes backfill. Piping is ascertained by the presence of voids or tension cracks in the embankment soil or by observation of water exiting the face of the slope near the culvert.

Table 3-2 Roadway Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Pavement	Potential distress: none for 20-foot minimum length on either side of crossing culvert	Transverse cracking: low severity (less than 0.25 inches in width) Sags or humps: low severity (less than 2 inches over 10 feet) over culvert barrel	Transverse cracking: medium severity (up to 0.5 inches in width) Sags or humps: medium severity (up to 4 inches over 10 feet) over culvert barrel Rutting in wheel path: localized over culvert Patching: evidence of repeated patching	Transverse cracking: high severity (greater than 0.5 inches in width with pavement raveling over culvert) Longitudinal cracking: high severity (greater than 0.5 inches in width with pavement raveling over culvert) Sags or humps: high severity with voids beneath pavement
Shoulders	Potential distress: none for 20-foot minimum length on either side of crossing culvert	Transverse cracking: low severity local to shoulder Longitudinal cracking: low severity local to shoulder Sags: low severity over culvert	Transverse cracking: moderate severity Longitudinal cracking: moderate severity Settlement Patches: evidence of repeated patching	Transverse cracking: high severity Longitudinal cracking: high severity Sags: high severity over culvert Voids: in roadway near culvert (piping or infiltration) Soil cracking in shoulder area Slope stability: movement in shoulder area
Guardrail	Potential distress: none for 20-foot minimum length on either side of crossing culvert	Post alignment: slight misalignment due to shoulder settlement or sliding	Post alignment: misalignment due to ground movement (not impact damage) Settlement or sags: medium severity due to ground movement Post rotation: exists due to ground movement	Settlement or sags: high severity Post rotation: exists due to ground movement (not impact damage) Guardrail may be ineffective

Condition Rating	Good	Fair	Poor	Severe
Slope Stability	Slope stability: no movement Soil sloughing: none	Slope stability: no issues	Slope stability: stable with minor sloughing	Slope stability: failure likely Soil sloughing: embankment sloughing (causes loss of support to guardrails and/or roadway, and culvert end section joint distress) Soil tension cracks: parallel to roadway (indicates shifting or settlement)
Embankment Erosion	Embankment soil erosion: none due to runoff Piping: none in embankment	Rill erosion: minor rill erosion Sheet erosion: minor (up to 10% bare ground) Embankment soil erosion: indication of storm water runoff Structure stability: not affected Structure exposure: not affected	Rill erosion: moderate rill erosion, backfill around culvert slightly displaced Piping: evidence Sheet erosion: moderate (11 to 40% bare ground), requires protection and investigation Structure exposure: early-stage exposure of inlet barrel, outlet barrel, or previously-buried end treatment	Gullying erosion: severe gullying Sheet erosion: severe (greater than 40% bare ground) Embankment soil erosion: significant loss of material Structure stability: loss of support for inlet barrel, outlet barrel, or end treatments Structure exposure: fully-exposed barrel ends with rotation of end section or end section drop-off

3.4.2 Channel Scour and Blockage

Figure 5 Culvert placement can cause damage to the area around the culvert due to scour or ineffectiveness due to blockage. The characteristics to inspect include channel alignment, bank erosion & scour, existing scour protection, and blockage.

Component Description

In the context of culvert condition rating, the channel consists of the stream bed and adjacent upstream and downstream banks near the culvert barrel. Channel scour and blockage inspection involves observing the condition of the stream leading into the culvert inlet and moving away from the outlet in the vicinity of the culvert structure.

What to Look For

Channel scour and blockage is a single component rated by four characteristics: channel alignment, bank erosion and scour, existing protection, and blockage.

- **Channel alignment** is an evaluation of the horizontal and vertical position of the culvert with respect to the channel. Ideally, the culvert barrel matches the angle and elevation of the stream bed. Damage to the embankment, roadway, and adjacent property can result from misaligned culverts along with increased erosion and sedimentation of the channel.
- **Bank erosion and scour** is the loss of stream bed material from flowing water. Bank erosion is the loss of material from the sides of the channel. Bank erosion

Figure 6 Erosion can result in a perched culvert barrel where water cascades from the outlet. This falling water can result in further erosion and eventually undermine the culvert barrel to the point that it bends or rotates downward and impedes stream flow.

may be horizontal and result in channel widening, or it may be vertical and result in undercutting of the stream banks, culvert barrel, or end treatments. Local scour is caused by a specific flow obstruction that causes a directional change in flow and is typically found at the culvert outlet. General scour extends further along the stream bed away from obstructions and may appear as a sudden change in the stream bed elevation.

- **Existing protection** may be in place to prevent scour or erosion and may be in the form of rip-rap, vegetation, or sheet piling of the embankment or headwalls, wingwalls, or end treatments of a culvert.
- **Blockage** at the inlet or within the culvert barrel can be caused by an accumulation of debris and sediment. Blockage can lead to increased water depth upstream of the culvert. This increased headwater depth can result in piping (see Section 3.4.1) in the embankment.

Table 3-3 Channel Scour and Blockage Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Channel Alignment	Channel stream: aligned with culvert (horizontally and vertically) Erosion: none Flow capacity: no restrictions	Channel stream: slight angle or offset relative to culvert centerline Flow capacity: not affected Ponding: minor	Channel stream: early-stage altered alignment, channel enters or exits at moderate angle Erosion: embankment erosion Undercutting: barrel or end sections Ponding: occurring at inlet or outlet	Channel stream: severe misalignment, channel directed at bank with threat of immediate collapse Erosion: severe bank erosion
Bank Erosion and Scour	Structure stability: stable Bank erosion: none Scour: none	Structure stability: stable Bank erosion: intermittent Scour: local scour near inlet or outlet Scour exposing previously-buried features: none	Structure stability: undercutting and sod-root overhangs Bank erosion: general erosion leading to channel widening Scour: local scour or headcutting near outlet, or signs of downstream scour	Structure stability: danger of collapse with next flood event Scour: scour causing (or leading to) weakening of bank, culvert, end treatment structure, and/or roadway
Existing Protection	Protective material: installed protection meets design requirements; no noted channel bank distress	Protective material: minor material degradation Displacement: localized displacement or undermining of individual rip-rap, armor units, or other protection measures	Protective material: moderate material degradation Displacement: significant displacement of rip-rap, armor, or other protective measures, undermining or deteriorating performance of protective measures	Protective material: partial failure of rip-rap, armor, or other protective measures; culvert, embankment, roadway, or other elements in danger of collapse

Condition Rating	Good	Fair	Poor	Severe
Blockage	Waterway blockage: none, free flowing with no obstructions	Waterway blockage: to depth of less than 10% of barrel diameter Sedimentation/debris: minor sedimentation or debris accumulation Scour: none Ponding: some evidence	Waterway blockage: to depth of 10% to 30% of barrel diameter Sedimentation/debris: sedimentation, debris, trees, or shrubs creating partial blockage of channel Ponding: deeper than 10% of diameter	Waterway blockage: to depth of greater than 30% of barrel diameter Sedimentation/debris: mass drift accumulation creating blockage or severe restriction Ponding: frequent flooding, high water marks indicating roadway overtopped in high flows

End Treatments and Appurtenant Structures

Figure 7 End treatments should be inspected in relation to the surrounding vicinity. In this photo, the end treatment appears to be in good condition, but there are signs of ponding and movement of stream protection (more riprap in front of one barrel than the other).

Component Description

End treatments and appurtenant structures may be found at the inlet and outlet of the culvert barrel. These components help reduce erosion by retaining fill material and reducing seepage, they can improve the hydraulic efficiency and provide structural stability to the culvert ends. Seepage is water that flows through the embankment rather than flowing through the culvert barrel.

What to Look For

The end treatments and appurtenant structures are a component rated by six characteristics: cracking (concrete); surface damage, spalling, and delamination (concrete); deformation and damage (metal); corrosion (metal); scour and stability; and settlement/rotation. Generally, four characteristics would be applicable for a culvert with end treatments (either concrete or metal) and one of these would be applicable if no end treatments are present (scour and stability).

- **Surface damage, spalling, and delamination (concrete)** should be assessed on the concrete end treatments.
- **Cracking (concrete)** should be assessed on concrete end treatments.
- **Corrosion (metal)** should be assessed on metal end treatments.
- **Deformation and damage (metal)** may occur on metal end treatments due to impact and abrasion as well as corrosion. Deformation can impede the flow of water through the culvert barrel and result in other distresses, such as scour conditions, by concentrating flow at the outlet or piping by blocking the inlet.
- **Scour and stability** problems are indicated by undermining of soil around the barrel end or end treatment. Perched culverts (those without end structures that project out without support underneath) are one example. Unlike projecting barrel culverts, perched culverts indicate reduced

stability of the culvert end. Projecting barrel culverts are culverts that have some or all of the top and sides of the outside of the culvert visible and not covered by soil. Perched culverts are culverts that have the entire outer surface exposed and unsupported by soil underneath the culvert barrel. Scour can result in settlement and rotation of the culvert barrel.

- **Settlement/rotation** can occur due to erosion or scour of soil supporting the end treatment. It can also occur in flexible materials, such as plastic or metal, due to buoyancy if the end treatment is submerged or if the soil around the end treatment is saturated. Settlement and rotation of the culvert barrel can impede the flow of water through the culvert and result in other distresses.

Table 3-4 End Treatments and Appurtenant Structures Condition Descriptions

	Condition Rating	Good	Fair	Poor	Severe
CONCRETE	**Surface Damage, Spalling, Delamination (Concrete)**	Scaling: none Abrasion: none Surface damage: none Spalling: none Hollow sounds: none (delamination) Patches: areas remain sound	Scaling: light or moderate (less than 0.25 inches exposed aggregate) Abrasion: less than 0.25 inches in depth over less than 20% of surface Surface damage: localized superficial (less than 0.25 inch) impact damage Spalling: localized, less than or equal to 6 inches in diameter Rebar: not exposed Hollow sounds: small areas Patches: edges tightly bonded	Scaling: moderate to severe (aggregate exposed) Abrasion: 0.25 to 0.5 inches in depth over more than 30% of the surface Surface damage: impact damage Spalling: areas greater than 6 inches in diameter; rust staining from spalled areas Rebar: exposed Hollow sounds: areas greater than 6 inches in diameter Patches: areas are delaminated Weep holes: multiple plugged weep holes (water cannot drain from backfill)	Surface damage: extensive Spalling: widespread spalling or delamination; rebar exposed and corroded; structure unstable Rebar: significant exposed and/or corroded
	Cracking (Concrete)	Cracking: none greater than hairline (maximum 0.01 inches)	Cracking: between 0.01 to 0.05 inches in width (thickness of dime); no increase from previous inspection Infiltration: none Efflorescence: moderate and no rust staining emanating from cracks	Cracking: 0.05 to 0.1-inches in width; local areas of exposed rebar Infiltration: minor water infiltration through cracks Efflorescence: efflorescence and/or rust staining emanating from cracks	Cracking: greater than 0.1 inches in width; widespread exposed rebar with significant corrosion, soil infiltration through cracks Efflorescence: efflorescence and widespread rust staining emanating from cracks

	Condition Rating	Good	Fair	Poor	Severe
METAL	**Corrosion (Metal)**	Corrosion: none	Corrosion: freckled rust or other signs Section loss: none Pitting: none	Corrosion: corrosion present, penetration possible with hammer strike or sharp point Section loss: less than 10% of thickness Pitting: deep pronounced thinning Holes: less than or equal to 1 inch in diameter, several	Corrosion: widespread, local through-thickness penetrations Holes: greater than 1 inch in diameter OR many smaller, grouped holes allowing soil migration
	Deformation and Damage (Metal)	Dents/impact damage/deformation: none Abrasion: none	Dents/impact damage/deformation: small Abrasion: coating abraded, no breaches exposing structural wall	Dents/impact damage/deformation: large Abrasion: protective coating abraded with breaches exposing structural wall	Dents/impact damage/deformation: restricts flow capacity or results in scour or erosion of embankment
ALL	**Scour and Stability**	Scour exposing buried footings/structures: none Undermining of footing: none Rotation: none from installed condition	Scour exposing buried footings/structures: any surface Undermining of footing: none Rotation: none from installed condition	Scour exposing buried footings/structures: vertical face Undermining of footing: none	Scour exposing buried footings/structures: scour present Undermining of footing: significant Rotation: severe, leading to structure distress (kinking of metal culvert, cracking of concrete culvert, cracking of mortar, displacement of masonry units)
	Settlement/ Rotation	Movement: none from installed condition	Movement: exists within tolerable limits (if known) Vertical offset: none at cracking	Movement: exceeds tolerable limits (structure-dependent) Vertical offset: less than or equal to 0.25 inches at cracking Distress/distortion of structure: none	Movement: exceeds tolerable limits (structure-dependent) Vertical offset: greater than 0.25 inches at cracking Distress/distortion of structure: present (wrinkling of metal culvert; cracking of concrete culvert)

3.5 Culvert Barrel

The culvert barrel refers to the passageway through which the water flows. Barrel in this context does not imply roundness since box culverts or other rectangular-shaped culverts would still be described as a culvert barrel. A culvert may have multiple barrels or may have one barrel that has been divided into multiple cells.

When inspecting a culvert barrel for distress, first consider the material of the barrel; types of distress will vary depending on the material. Also, be aware that a concrete or metal culvert may have a coating or lining made of another material. The inspection should be done based on the culvert material and not the lining material.

3.5.1 Plastic Barrel Condition Descriptions

Figure 8 Plastic barrels may show signs of deformation such as sags, humps, or changes to the barrel's cross section. These changes can sometimes be observed by looking for irregularities in the way that water is flowing through the culvert.

Component Description

Plastic-barrel culverts are flexible structures that rely on soil-structure interaction by design. The backfill around the outside of the culvert provides the support for the barrel. More information about flexible and rigid culverts can be found in the AASHTO guide. These culverts are pipe structures and are typically constructed of high-density polyethylene (HDPE), polyvinyl chloride (PVC), polypropylene (PP) or fiberglass-reinforced plastic (FRP).

What to Look For

Plastic barrels are rated by considering six characteristics: shape; surface damage; local buckling, splits, and cracking; joint separation, offset, and rotation; barrel alignment; and infiltration and exfiltration.

- **Shape** should be monitored over time for changes in comparison to the original shape of the culvert. Because flexible culverts rely on soil-structure interaction, changes in the culvert's cross-sectional shape may be indicative of instability of the supporting soil or loads greater than design.
- **Surface damage** can cause loss of structural capacity or lead to infiltration of backfill. Surface damage can be caused by abrasion, splitting (generally at welded seams or abrupt changes in geometry), and photodegradation (at culvert ends due to ultraviolet light).
- **Local buckling, splits, and cracking** may be found in the barrel wall. Local buckling appears as rippling around the circumference of the barrel. It is important to note that the culvert shape will remain round under local buckling although the capacity will be significantly reduced.
- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration. Offset and rotation can be an indication of embankment instability.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert to verify straightness. Sagging traps water and debris, which can reduce flow capacity.
- **Infiltration and exfiltration** occur when there are perforations in the barrel. Infiltration occurs when groundwater is flowing into the culvert through joints. It can happen if the groundwater rises above the elevation of the culvert barrel. Exfiltration occurs when water flows out of the culvert barrel through joints. It can occur when the groundwater table is at a lower elevation than the culvert barrel. Both infiltration and exfiltration can move soil and result in voids around the outside of the culvert barrel. These voids can cause settlement of the culvert or of the roadway above the culvert. Since these voids may be within the embankment, they can be difficult to identify, but probing or checking for hollow sounds at joint locations can help to detect them.

Table 3-5 Plastic Barrel Condition Michigan Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape	Shape: round Wall flattening: none Vertical deformation: less than 5% of original diameter	 Wall flattening: minor Vertical deformation: 5% to 7.5% of original diameter	Shape: visible out-of-roundness Wall flattening: significant OR increased wall curvature Vertical deformation: 7.5% to 10% of original diameter	Shape: significant visible out-of-roundness Wall flattening: extreme with reversal of curvature (global buckling) and/or kinks Vertical deformation: greater than 10% of original diameter
Surface Damage	Wear and/or abrasion: none Impact damage: none UV degradation or staining: none	Wear and/or abrasion: minor, less than 10% of wall thickness UV degradation or staining: minor Blistering: less than 25% of barrel inner surface (FRP)	Wear and/or abrasion: equal to or greater than 10% of wall thickness UV degradation or staining: degradation of barrel ends, discoloration Blistering: equal to or greater than 25% of barrel inner surface (FRP)	Wear/abrasion: greater than 25% of wall thickness UV degradation or staining: degradation of barrel ends, cracked or broken barrel wall

Condition Rating	Good	Fair	Poor	Severe
Local Buckling, Splits, and Cracking	Local buckling: smooth interior wall Splits: none in welded seams Wall cracking: none in wall	Local buckling: buckling indicated by rippling in wall Splits: less than 25% of circumference Infiltration: none Wall cracking: less than 25% of circumference Longitudinal cracking: none	Local buckling: advanced and widespread indicated by extensive rippling of interior surface Splits: 25% to 50% of circumference Infiltration: minor water infiltration but no soil infiltration Wall cracking: 25% to 50% of circumference Longitudinal cracking: less than or equal to 12 inches in length	Local buckling: inward, kinks through the full wall thickness Splits: greater than 50% of circumference Infiltration: water infiltration through cracks with indication of soil infiltration Wall cracking: greater than 50% of circumference Longitudinal cracking: greater than 12 inches in length
Joint Separation, Offset, and Rotation	Joints: tightly installed Offset: proper alignment Functioning well	Joints: separation, no distress Offset: exists but with no distress Rotation: present but with no distress Gaskets: not exposed	Joints: separation in one or more joints Offset: exists in one or more joints Rotation: present in one or more joints Gaskets: materials exposed or missing	Joints: separation with exposed backfill material Offset: exists with exposed backfill material Rotation: present with exposed backfill material Gaskets: gasket materials exposed or missing in multiple locations
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: distress in barrel or at joints with barrel section offsets Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints with barrel section offsets Flow capacity: indication of significant flow restriction
Infiltration and Exfiltration	Infiltration or exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near seam/joint indicating loss of backfill support

3.5.2 Concrete Barrel Condition Descriptions

Figure 9 Concrete barrels should be checked for abrasion along the waterline as well as for signs of infiltration of exfiltration around joints. Performing visual inspections and checking for hollow sounds near joints can help to identify voids that may form as soil around the culvert is carried away. (Photo: Lake County Road Commission)

Component Description

Concrete-barrel culverts are rigid structures that do not deform under heavy loads. They may be either precast or cast-in-place concrete structures. These culverts may be pipes or may be single-cell or multi-cell box shapes.

What to Look For

Since concrete culverts do not deform under heavy loads, shape is not evaluated. Concrete culverts are evaluated by considering six characteristics: cracking; slabbing, spalling, delamination, and patches; deterioration; joint separation, offset, and rotation; barrel alignment; and infiltration and exfiltration.

- **Slabbing, spalling, delamination, and patches** indicate section loss of the original concrete material. Slabbing is a radial failure of the concrete from inadequate concrete cover and involves large slabs of concrete peeling away from the barrel walls. Spalling occurs when concrete separates along a fracture that is parallel to the concrete surface. Delamination is a separation of the concrete parallel to its surface prior to the section loss that occurs with spalling. Patched areas from previous maintenance on spalled sections should be monitored for delamination and/or continued spalling. These characteristics may be identified visually or by sounding with a hammer.
- **Cracking** is important to monitor. Longitudinal cracks in the crown and invert can develop due to tensile stress from circumferential bending. Small hairline cracks are typical and expected. They should be noted and monitored over time for deterioration but are not indicative of distress by themselves. Larger cracks or cracks with increasing thicknesses over time need to be investigated

further as this is indicative of overloading or poor backfill support. Transverse or circumferential cracks are indicative of poor backfill and a lack of support beneath the culvert barrel.

- **Deterioration** of concrete can occur for many reasons. Causes of deterioration include freeze-thaw cycles, chemical attack, and abrasion. Deterioration is generally identified by exposure of aggregate, scaling, or crumbling of the concrete.
- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration.
- **Joint cracking** may occur as a result of mis-handling during shipping/installation or movement/settlement of the pipe due to poor compaction.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert and noting any differential displacement between sections of the barrel. Sagging traps water and debris, and can reduce flow capacity. Trapped water can also cause saturation of supporting soil through leaking joints.
- **Infiltration and exfiltration** occur when there are perforations in the barrel. Infiltration occurs when groundwater is flowing into the culvert through joints. It can happen if the groundwater rises above the elevation of the culvert barrel. Exfiltration occurs when water flows out of the culvert barrel through joints. It can occur when the groundwater table is at a lower elevation than the culvert barrel. Both infiltration and exfiltration can move soil and result in voids around the outside of the culvert barrel. These voids can cause settlement of the culvert or of the roadway above the culvert. Since these voids may be within the embankment, they can be difficult to identify, but probing or checking for hollow sounds at joint locations can help to detect them.

Table 3-6 Concrete Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Slabbing, Spalling, Delamination, Patches	Slabbing: none as indicated by wall visual appearance	Slabbing: none	Slabbing: none	Slabbing: slabbing of concrete
	Spalling: none, as indicated by wall visual appearance	Spalling: localized, less than 0.25 inches in depth and less than 6 inches in diameter; rebar not exposed	Spalling: 0.5 to 0.75 inches in depth and greater than 6 inches in diameter; rebar not exposed, some rust staining; structure stable	Spalling: widespread, greater than 0.75 inches in depth; rebar exposed, structure unstable
	Delamination: none	Delamination: small, indicated by hollow sounds at patches	Delamination: greater than 6 inches in diameter and 0.5 to 0.75 inches in depth; rebar not exposed, some rust staining; structure stable	Delamination: present with rebar exposed; structure unstable
	Patches: areas remain sound	Patches: areas remain stable	Patches: areas are deteriorating and delaminated	

Condition Rating	Good	Fair	Poor	Severe
Cracking	Cracking: none greater than hairline (maximum 0.01 inch)	Longitudinal cracking: 0.01 to 0.05 inches in width (thickness of dime), spacing is equal to or greater than 3 feet Circumferential cracking: some Water infiltration: none	Cracking: no increase from previous inspection Longitudinal cracking: 0.05 to 0.1 inches in width, spacing is 1 to 3 feet; rebar not exposed Circumferential cracking: present Cracking with vertical offset: none Water infiltration: through circumferential cracks Efflorescence: present, rust staining emanating from cracks	Longitudinal cracking: greater than 0.1 inches in width; rebar exposed Cracking with vertical offset: present Water infiltration: significant Soil migration: significant Efflorescence: present, large areas of rust staining emanating from cracks
Deterioration	Scaling: none Abrasion: none Other damage: no surface damage	Scaling: light or moderate (less than 0.25 inches exposed aggregate) Abrasion: less than 0.25 inches in depth over less than 20% of barrel surface Other damage: impact damage localized and superficial (less than 0.25 inches) Rebar: not exposed Weep holes: multiple plugged	Scaling: moderate to severe (aggregate exposed) Abrasion: 0.25 to 0.5 inches in depth over greater than 30% of barrel surface Other damage: impact damage Rebar: exposed	Scaling: extensive Abrasion: extensive Other damage: extensive surface damage and aggregate pop-out Rebar: exposed and/or corroded Complete invert deterioration and loss of barrel wall section
Joint Separation, Offset, and Rotation	Joints: tightly installed Alignment: proper Functioning well	Joints: separation, no distress Alignment: offset with no distress Rotation: present but with no distress Gaskets: not exposed	Joints: separation in one or more joints Alignment: offset in one or more joints Rotation: present in one or more joints Gaskets: exposed or missing gasket materials	Joints: separation with exposed backfill material Alignment: offset with exposed backfill material Rotation: present with exposed backfill material Gaskets: exposed or missing gasket materials in multiple locations

Condition Rating	Good	Fair	Poor	Severe
Joint Cracking	Joint cracking: none	Longitudinal cracking: 0.01 to 0.05 inches in width (thickness of dime) emanating from joint Spalling: none or small spalls along edge of spigot and reinforcing or joint sealant not exposed	Longitudinal cracking: 0.05 to 0.1 inches in width emanating from joint Spalling: moderate spalls along edge of spigot end, reinforcing or joint sealant possibly exposed	Longitudinal cracking: greater than 0.1 inches in width emanating from joint Spalling: large spalls along edge of spigot end with associated structural cracking
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging or heaving with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: misalignment causing distress in barrel or at joints due to barrel section offsets Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints due to barrel section offsets Flow capacity: indication of significant flow restriction
Infiltration and Exfiltration	Infiltration/exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near joints/seams indicating loss of backfill support

3.5.3 Corrugated Metal Barrel Condition Descriptions

Figure 10 Corrugated metal barrels distresses like abrasion or corrosion may only apply to a small portion of the culvert's surface area. However, if even a few inches of a culvert's bottom along the entire length of the culvert barrel has been completely abraded or corroded, that abrasion or corrosion can lead to a culvert failure. The severity, the total area affected, and the location of the distress should be considered during culvert assessment.

Component Description

Corrugated metal pipe (CMP) and corrugated metal plate culverts are flexible structures that depend on soil-structure interaction for their structural stability. These culverts are constructed of aluminum or steel.

What to Look For

CMP and corrugated plate barrels are rated by considering ten characteristics: shape; surface damage; corrosion; abrasion; joint separation, offset, and rotation; seam alignment; seam bolts and fasteners; seam bolt holes; barrel alignment; and infiltration and exfiltration.

- **Shape** should be monitored over time for changes in comparison to the as-designed shape of the culvert. Because flexible culverts rely on soil-structure interaction to provide strength, shape is an important characteristic.
- **Surface damage** includes dents or other small localized damage generally caused by impact.
- **Corrosion** is deterioration of metal due to electrochemical or chemical reactions with the surrounding environment. For example, steel corrodes in the presence of salts and acidic soils, and aluminum corrodes in the presence of alkaline soils.
- **Abrasion** is caused by erosion of the culvert material by sediments within the stream.
- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration.
- **Seam alignment** issues are visibly apparent as cocked or cusped plates, which generally occurs during fabrication from misalignment between the bolt holes in the connection. When bolts are

inserted and tightened, the plates can shift and produce a cocked seam. The cusp effect occurs when the end of one plate bears directly against the surface of the other plate, causing the free end to curl away from the culvert wall, leading to loss of backfill and reduction in ring compression strength.

- **Seam bolts and fasteners** should be inspected for loose or missing fasteners. Tightness may be checked by tapping lightly with a hammer and looking for movement. Seams in aluminum structural plates should be checked with a torque wrench and verified against values provided by the manufacturer.
- **Seam bolt holes** should be checked for signs of bolt tipping and cracking. Bolt tipping is a rotation of the bolts with subsequent elongation of the bolt hole due to bearing against the shank of the bolt, caused by slipping of the plates. Deflection of the culvert can cause longitudinal cracking along the bolt holes.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert to verify straightness. Sagging traps water and debris, and can reduce flow capacity.
- **Infiltration and exfiltration** occur when there are perforations in the barrel. Infiltration occurs when groundwater is flowing into the culvert through joints. It can happen if the groundwater rises above the elevation of the culvert barrel. Exfiltration occurs when water flows out of the culvert barrel through joints. It can occur when the groundwater table is at a lower elevation than the culvert barrel. Both infiltration and exfiltration can move soil and result in voids around the outside of the culvert barrel. These voids can cause settlement of the culvert or of the roadway above the culvert. Since these voids may be within the embankment, they can be difficult to identify, but probing or checking for hollow sounds at joint locations can help to detect them.

Table 3-7 Corrugated Metal Pipe Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape	Curvature: no distortion in barrel Rise measurement: within tolerance Span measurement: within tolerance Deformation: less than 5% of original diameter	Curvature: no distortion in top half Bulges/kinks: minor bulges or flattening of bottom Deformation: 5% to 10% of original diameter	Curvature: significant distortion or flattening Bulges/kinks: lower third may be kinked Deformation: greater than 10% to 15% of original diameter Out-of-roundness: visible	Curvature: extreme distortion throughout barrel, local areas of reverse curvature Bulges/kinks: local area of kinks Deformation: greater than 15% of original diameter Out-of-roundness: significant
Surface Damage	Dents or localized damage: none	Dents or localized damage: small dents or impact damage to barrel wall or end section Wall breaches: none	Dents or localized damage: large dents or impact damage to barrel wall or end section Wall breaches: localized, no more than one	Dents or damage: warrants engineering evaluation Wall breaches: through-wall holes, more than one corrugation over greater

Condition Rating	Good	Fair	Poor	Severe
			corrugation over 6 inches in circumferential length	than 6 inches in circumferential length allowing unimpeded soil infiltration
Abrasion	Abrasion: none	Abrasion: small or local abrasion of wall or coating Wall breaches: none in the coating exposing structural wall Corrosion: none	Abrasion: widespread abrasion of protective coating Wall breaches: breaches exposing the barrel wall material Penetration: through-wall penetration when probing with a pick	Abrasion: significant, large holes through the metal barrel more than one corrugation for greater than 6 inches in circumferential length
Corrosion	Rust: isolated areas of freckled rust	Rust: freckled rust, corrosion of barrel wall material Section loss: none Penetration: no through-wall penetration	Rust: corrosion of barrel material Section loss: widespread, less than 10% of wall thickness. Pitting: localized and deep Holes: less than or equal to 1 inch in diameter, several Penetration: possible with hammer pick strike	Section loss: invert missing localized sections Holes: greater than 1 inch in diameter OR many smaller, closely-grouped holes Penetration: widespread through-wall penetration
Joint Separation, Offset, and Rotation	Joints: tightly installed Alignment: proper Functioning well	Joints: separation Offset or rotation: exists but with no distress Gasket: not exposed	Joints: separation Offset or rotation: exists in one or more joints Gaskets: exposed or missing gasket materials	Joints: separation Offset or rotation: exists with exposed backfill material Gaskets: multiple locations of exposed or missing gasket materials
Seam Alignment	Alignment: no visible misalignment	Alignment: slight cocked seams Cusp effect: none Shape: cross section not affected	Alignment: cocked seams Cusp effect: present with local wall bending Shape: cross section affected	Alignment: cocked seams Cusp effect: present with seam cracking Shape: cross section severely affected Seam capacity loss imminent

Condition Rating	Good	Fair	Poor	Severe
Seam Bolts and Fasteners	Bolts/fasteners: none loose or missing	Bolts/fasteners: less than 5% loose or missing in any seam	Bolts/fasteners: 5% to 15% loose or missing in any seam	Bolts/fasteners: greater than 15% loose or missing in any seam
Seam Bolt Holes	Bolt holes: no yielding or deformation Wall prying: none due to bolt tipping	Bolt holes: localized minor yielding of steel and/or cracking or splitting less than 1 inch in length Corrosion: minor corrosion around bolt holes or on bolts	Bolt holes: localized yielding of steel and/or cracking or splitting 1 to 3 inches in length Corrosion: corrosion with section loss around bolt holes or on bolts	Bolt holes: localized significant yielding of steel and cracking/splitting of greater than 3 inches in length Corrosion: corrosion with section loss around bolt holes or on bolts
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: misalignment causing distress in barrel or at joints due to barrel section offsets Vertical alignment: misalignment causing ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints, barrel section offsets Flow capacity: indication of significant flow restriction
Infiltration and Exfiltration	Infiltration/exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near joints/seams indicating loss of backfill support

3.5.4 Masonry Barrel Condition Descriptions

Figure 11 Masonry barrels are checked for movement of masonry units, mortar, and efflorescence. Note that new mortar or repairs may appear different from original construction. (Photo: St. Clair County Road Commission)

Component Description

Masonry-barrel culverts are rigid structures. These culvert structures are constructed of stone, brick, or concrete block units generally mortared together.

What to Look For

Masonry barrels are rated by considering three characteristics: masonry units and movement, mortar, and efflorescence.

- **Masonry units and movements** should both be evaluated. The individual masonry units should be checked for displacement, cracking, and surface deterioration. Movement can occur with an individual unit or a group of units; causes of movement include freeze-thaw cycles, vegetation, deterioration of the mortar, or stress.
- **Mortar** should be checked to ensure its bond to the masonry units. Cracked, deteriorated, or missing mortar should be noted. Presence of dirt can indicate loss of backfill.
- **Efflorescence** is the leachate of salts or chlorides caused by water infiltration through the joints. Efflorescence is generally cosmetic but can lead to spalling and deterioration and, thus, should be noted.

Table 3-8 Masonry Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Masonry Units and Movements	Cracking: none Splitting: none Movement: none displaced Missing: none Surface deterioration: none	Cracking: isolated individual units Movement: none Surface deterioration: weathering or spalling	Cracking: several masonry units Splitting: split masonry units Movement: pronounced movement or dislocation, does not warrant engineering evaluation Surface deterioration: large areas of moderate spalling, scaling, or weathering .	Cracking: widespread Splitting: widespread Movement: significant movement of individual units Missing: widespread crushed or missing units Surface deterioration: large areas of heavy spalling, scaling, or weathering Structure wall: holes through wall Shape: cross section has visible movement or distortion; structure appears unstable
Mortar	Cracked/missing: none, intact Deterioration: none	Cracked/missing: localized Deterioration: widespread areas of shallow mortar deterioration Infiltration/exfiltration: possible minor water infiltration (no active flow) or exfiltration through joints	Cracked/missing: extensive Deterioration: extensive Infiltration/exfiltration: small water flow but no soil/fines infiltration or exfiltration through joints	Cracked/missing: missing Infiltration/exfiltration: backfill infiltration Voids: possible in roadway
Efflorescence	Efflorescence: localized areas	Efflorescence: widespread areas Rust staining: none	Efflorescence: heavy buildup Rust staining: present	No severe rating

3.5.5 Timber Barrel Condition Descriptions

Figure 12 Timber barrel culverts are often in the form of a multi-cell culvert. The width of each cell can be recorded in addition to the total span of the culvert. (Photo: Fleis & Vandenbrink Engineering)

Component Description

Timber-barrel culverts are rigid structures. They are primary constructed of wood. Timber barrel are generally box-structures but can also be other shapes.

What to Look For

Timber barrels should be inspected for signs of material deterioration and mechanical damage. They are rated by considering seven characteristics: distortion, abrasion and impact damage, structural cracks, checks and shakes, delamination, decay, and connections and missing members.

- **Distortion** is generally identified by warping, sagging, or localized crushing of wood members. Warping is generally caused by uneven shrinkage during the drying process and results in a member that is not flat. Sagging generally occurs due to overloading or through creep caused by constant loading over a period of time. Localized crushing commonly occurs at bearing connections perpendicular to the wood grain.
- **Abrasion and impact damage** are caused by erosion of the culvert material by sediments within the stream.
- **Structural cracks** occur from overloading of a timber member and may originate at knots.
- **Checks and shakes** should be investigated. Checks are cracks that occur along the radius end of the wood member, perpendicular to the growth rings, due to shrinkage as the wood dries. The structure's design typically accounts for checks but, in some cases, checks may affect connections. Shakes occur when the growth rings separate. These extend longitudinally in the timber and can affect the bending strength of the member.
- **Delamination** of glu-lam members (members constructed by gluing smaller members together) affects the structural capacity of the member, particularly if they occur at connections.

- **Decay** is checked visually and through soundings. Visible decay is most apparent during its later stages. Sounding and probing can be used to evaluate the extent of decay. Contributors to decay include fungi, insects, and fire.
- **Connection and missing members** should be checked for distress and deterioration. Metal connections should be checked for corrosion and missing fasteners.

Table 3-9 Timber Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Distortion	Shape: cross section has no change Members: no warping, crushing, or sagging	Members: warping or sagging of single or few members not requiring mitigation or previously mitigated	Shape: cross section has warping, sagging causing distortion Members: crushing	Shape: cross section has significant distortion or widespread warping, crushing, or sagging
Abrasion/ Impact Damage	Abrasion: no section loss	Abrasion: section loss of less than 10% of the member cross section	Abrasion: section loss of 10% to 20% of the member cross section	Abrasion: section loss of greater than 20% of the member cross section
Structural Cracks	Structural cracking: none	Structural cracking: arrested	Structural cracking: exists, but projects less than 5% into the member cross section	Structural cracking: exists with differential movement across crack
Checks and Shakes	Checks or shakes: penetrating less than 5% of member thickness	Checks or shakes: penetrating 5% to 50% of member cross section away from connections and tension zones of bending members	Checks or shakes: penetrating greater than 50% of member cross section OR penetrating less than or equal to 10% near connections or tension zone of bending member	Checks or shakes: penetrating greater than 10% near connections or tension zone of a bending member
Delamination	Delamination: none	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
Decay	Members: no sunken faces, staining, or discoloration of surfaces Fruiting bodies: no signs	Members: decay allowing probe penetration of less than or equal to 10% of the cross section Hollow sounds: localized	Members: decay allowing probe penetration of 10% to 20% of the cross section; away from connections and tension zone of bending member	Members: decay allowing probe penetration of greater than 20% of the cross section or greater than 10% of the cross section near connections or tension zone of a bending member Fruiting bodies: present

Condition Rating	Good	Fair	Poor	Severe
Connection and Missing Members	Bolts: none loose	Bolts: loose bolts	Bolts: missing	Bolts: missing, causing movement in connected elements
	Welds: none broken		Welds: broken	Welds: broken, causing movement in connected elements
	Rivets: none missing		Rivets: missing	Rivets: missing, causing movement in connected elements
	Fasteners: none missing	Fasteners: loose	Fasteners: missing	Fasteners: missing, causing movement in connected elements
	Surface rust: none	Surface rust: freckled rust (no pitting or section loss), rust staining on face of members	Surface rust: present with some pitting, pack rust without distortion	Surface rust: heavy rusting with section loss, and/or pack rust causing distortion
		Connection: functioning as designed	Connection: functioning as designed	Connection: integrity is in question
				Imminent collapse

Appendix A: Definitions

- **Agency**: The group of inspectors, whether private consultant or public owner, that has been assigned inspection responsibility for one or more culverts. Private consultants may perform the inspections for multiple owners.
- **Bridge**: Structures on public highways carrying traffic that span 20 feet or more measured from the center of the roadway. These structures must be inspected per the NBIS and the MiSIM, regardless of the structural configuration.
- **Channel**: The stream bed and adjacent upstream and downstream banks near the culvert barrel
- **Checks**: Cracks that occur along the radius end of the wood member, perpendicular to the growth rings, due to shrinkage as the wood dries. *See also:* Shakes
- **Culvert**: A linear drainage conduit(s) underneath a public roadway that is/(are) not considered a "bridge(s)" by the Federal Highway Administration (FHWA). Culverts are differentiated from storm sewers in that they are straight-line conduits that are open at each end and do not include intermediate drainage structures (e.g., manholes, catch basins).
- **Delamination**: A separation of the concrete parallel to its surface prior to the section loss that occurs with spalling
- **Efflorescence**: Deposits of salts or chlorides caused by water infiltration through the joints; generally pale in color
- **Embankment**: The bank of soil or rock constructed above and around a culvert and usually supporting a roadway surface
- **Erosion**: Wearing away of the streambed or embankment by flowing water. *See also:* Gullying, Piping, Rilling, Sheet erosion

- **Gullying**: Erosion in the form of channels over 1 foot deep that are cut into a slope by flowing water. *See also:* Rilling
- **In-depth inspection**: An inspection triggered by the observation of structural deterioration of a culvert or vicinity or appurtenant structure that is done to determine a design solution
- **Initial inspection**: The first inspection of a culvert that is used to collect inventory data or both inventory data and an initial condition rating. This inspection might occur when a culvert is newly constructed or when it is identified and discovered by an agency.
- **Invert**: The bottom or the lowest point of the inside surface of a culvert barrel
- **Inlet**: The upstream end of a culvert barrel
- **Longitudinal pavement cracking**: Cracking that is parallel to the centerline of the pavement
- **Outlet**: The downstream (discharge) end of a culvert barrel
- **Owner**: The public entity responsible for the highway carried by the culvert
- **Perched culvert barrel**: Culvert barrel that has had the soil around the end of the culvert eroded and has been left the culvert unsupported and at a higher elevation than the channel. Water flowing out of the culvert barrel cascades or falls to the level of the stream.
- **Piping**: Erosion occurring at the sides or underneath of a culvert when water flows along the outside of the culvert and soil is carried away
- **Rilling**: Erosion in the form of shallow channels (less than 1 foot deep) that are cut into a slope by flowing water. *See also:* Gullying
- **Roadway**: Travelling surface for vehicle or pedestrian traffic that is located above the culvert
- **Routine inspection**: A regularly-scheduled inspection of a culvert, vicinity, and appurtenant structures that is used to observe the condition, identify and record any changes to the structures, and note any deterioration that might affect functionality and would require further investigation.
- **Scaling**: Deterioration of the concrete surface resulting in peeling or flaking of the cement paste; often due to environmental factors such as freeze/thaw cycles or chemical attack
- **Seepage**: Water flowing out of the embankment soil instead of through the culvert barrel
- **Shakes**: Cracks that extend longitudinally in the timber and occur when the growth rings separate. *See also:* Checks
- **Sheet erosion**: A shallow flow of water over a ground surface that removes a uniform layer of soil
- **Slabbing**: Large slabs of concrete peeling away from the sides of a concrete pipe and a straightening of the reinforcing steel
- **Spalling**: Concrete separation along a fracture that is parallel to the concrete surface

- **Tension crack**: Longitudinal cracks appearing along the top of a slope or embankment; they may be set back from the edge of the embankment
- **Transverse pavement cracking**: Cracking that is perpendicular to the centerline of the pavement
- **Weep holes**: A small opening in a concrete or masonry structure that allows water to drain

Appendix B: Comparisons between Culvert Condition Assessment Systems

Tables B.1, B.2, B.3, and B.4 may be used to provide a general understanding of how previous culvert ratings used by agencies involved in the Michigan TAMC pilot culvert data collection effort compare to the rating system outlined in this guide. This comparison may be useful for understanding how a historically-rated culvert may have rated for the pilot; however, this comparison should not be construed as a means for directly converting historical data since rating criteria may not directly relate or fully encompass the current components and characteristics rating system.

	Table B.1: Culvert Structure Inspection Guide Inventory Fields and Valid Entries Compared to the TAMC Pilot			
	Inventory Field	**TAMC Guide Description**	**Valid Entries**	**TAMC Pilot**
VICINITY & APPURTENANT STRUCTURES	Roadway	The approach roadway is the length of roadway, shoulder and guardrail above the culvert and the embankment below that is influenced directly by the performance of the buried system and should encompass a minimum length of 20 feet either side of the culvert plus the culvert span or the full width of any wingwall structure, whichever is greater.	Good, Fair, Poor or Severe, Not Rated	Not rated
	Channel scour and blockage	The channel consists of the stream or river, its bed, and the adjacent banks.	Good, Fair, Poor or Severe, Not Rated	Channel blockage and scour – minimum of two ratings
	End treatments and appurtenant structures	The components 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.	Good, Fair, Poor or Severe, Not Rated	Not rated
CULVERT BARREL	Barrel	Condition tables are given for plastic, concrete, corrugated metal, masonry and timber barrel type which contain descriptions for individual characteristics that are rated. Barrel alignment, applicable to plastic, metal, and concrete culverts is a measure of horizontal and vertical deviation from the design profile Joints and seams consider the transverse transitions between barrel sections (joints) and the longitudinal or helical transitions between barrel sections (seams)	Good, Fair, Poor or Severe, Not Rated	Structural deterioration – straight conversion Invert deterioration-straight conversion Section deformation – straight conversion Joint/seam condition – straight conversion
	Overall rating	**Minimum of evaluated components**		**Minimum of all available ratings**
	General Descriptions			
	Good	No action is recommended. Note in inspection report only.		Ratings 10-8
	Fair	No immediate action is recommended, but more frequent inspection may be warranted. Maintenance personnel should be informed.		Ratings 7-6
	Poor	Inspector evaluates need for corrective action and makes recommendation in inspection report		Ratings 5-4
	Severe	Corrective action is required and urgent. Engineering evaluation is required to specify appropriate repair		Ratings 3-1

Table B.2: NBI Culvert (CSIR #1) Comparison to TAMC Culvert Barrel Evaluation

NBI Rating Guidelines	Ratings		Michigan Non-NBI Culvert Structure Inspection Guide
Culvert (CSIR #1)	NBI	TAMC	Culvert Barrel (Tables 3-6, 3-7, 3-9), General Condition Rating (Table 3-1), and Scour and Blockage (Table 3-3)
New condition	9	Good	Like new. Little to no deterioration. Structurally sound. Functionally adequate. Concrete: No slabbing, spalling, or delamination. No cracks greater than hairline. Tight joints. Metal: Deformation less than 5% original. Isolated areas of freckled rust. Tight joints and proper alignment. Timber: Checks or shakes penetrate less than 5% member thickness.
No settlement or misalignment. Members retain full section properties and function as designed with limited deterioration.	8		
No settlement or misalignment. Members retain full section properties and function as designed with limited deterioration. Concrete: Shrinkage cracks, light scaling, and insignificant spalling which does not expose reinforcing steel. Steel: Metal culverts have a smooth symmetrical curvature with superficial corrosion and no pitting. No problems with joints or seams. Timber: Checks or shakes penetrate less than 5% of the member thickness.	7		
Local minor scouring at curtain walls, wingwalls, or pipes. Concrete: Minor chloride contamination, cracking with some leaching, or spalls on concrete or masonry walls and slabs. Steel: Metal culverts have a smooth curvature, non-symmetrical shape, significant corrosion or moderate pitting. Timber: Decay or section loss affecting less than 5% of the member section. Splits arrested and concerns mitigated.	6	Fair	Some deterioration. Structurally sound. Functionally adequate. Local scour near inlet or outlet. Concrete: Localized spalling less than 0.25 inch deep, small delaminations. Some cracking, 0.01 to 0.05 inch width. Light or moderate scaling and abrasion less than 0.25 inches. No distress at joints. Metal: Smooth top half, minor bulges, deformation 5% to 10% original. Small or local abrasion. No section loss. Joint separation, minor water no soil infiltration. Timber: Decay less than 10% of cross section. Checks or shakes penetrating 5% to 50% of cross section away from connections and tension zones of bending members.
Moderate to major deterioration or disintegration. Noticeable scouring or erosion at curtain walls, wingwalls, or pipes. Concrete: Extensive cracking and leaching, or spalls on concrete or masonry walls and slabs. Steel: Metal culverts have significant distortion and deflection in one section, significant corrosion or deep pitting. Timber: Decay or section loss affecting 5% to 10% of the member section. Checks, shakes, and splits have no effect on capacity.	5		
Opened joint or seam permitting loss of backfill. Considerable settlement or misalignment. Considerable scouring or erosion at curtain walls, wingwalls or pipes. Concrete: Large spalls, heavy scaling, wide cracks, considerable efflorescence. Steel: Metal culverts have significant distortion and deflection throughout, extensive corrosion or deep pitting. Timber: Extensive decay, section loss, checks, shakes, or splits that do not warrant structural review.	4	Poor	Significant deterioration. Functionally inadequate. Requires maintenance or repair. Local scour or headcutting near outlet or signs of downstream scour. Concrete: Spalling 0.5 to 0.75 inch deep. Delamination greater than 6 in diameter. Cracks 0.05 to 0.1 inch width. Water infiltration through cracks. Rust staining. Scaling with aggregate exposed. Separation in one or more joints. Alignment deviation. Metal: Significant deformation 10% to 15% of original. Section loss widespread, less than 10% thickness. Holes less than 1 inch. Joint separation with water and fine soil infiltration. Timber: Decay of 10% to 20% or checks/shakes greater than 50% cross section away from connections and tension zone of bending member. Checks or shakes less than 10% near connections or tension zone of bending member.
Severe movement or differential settlement of the segments, or loss of fill. Severe scour or erosion at curtain walls, wingwalls or pipes. Concrete: Considerable areas of spalling, exposed reinforcement with section loss, or heavy rust staining. Steel: Metal culverts have extreme distortion and deflection in one section, extensive corrosion, or deep pitting with scattered perforations. Timber: Decay or section loss that affects more than 10% of the member section. Checks, shakes, splits may warrant action.	3		
Integral wingwalls have collapsed, severe settlement of roadway due to loss of fill. Section of culvert may have failed and can no longer support embankment. Complete undermining at walls & pipes. Corrective action required to maintain traffic. Metal culverts have extreme distortion/deflection throughout with extensive perforations due to corrosion.	2	Severe	Severe deterioration. Structurally unsound. Functionally inadequate. Possible imminent failure or threat to public safety. Scour causing (or leading to) weakening of bank, culvert, end treatment structure, and/or roadway. Concrete: Spalling widespread and greater than 0.75 in depth, exposed rebar. Longitudinal cracking greater than 0.1 inch width. Extensive scaling and abrasion. Joint separation with exposed backfill. Misalignment causing distress. Metal: Extreme distortion, greater than 15% original. Large holes. Invert missing in localized sections. Holes greater than 1 inch. Joints separated with water and coarse soil infiltration. Timber: Decay greater than 20% or greater than 10% near connections or tension zone of bending member. Checks and shakes greater than 10% cross section near connections or tension zone of bending member.
Culvert is closed, but corrective action may put it back in service.	1		
Culvert is closed and replacement is necessary. Coordinate with SI&A Item 41 and notify Bridge Field Services.	0		

Table B.3: NBI Culvert Superstructure (BSIR #9/SI&A Item 59) Comparison to TAMC Culvert General Condition Rating			
NBI Rating Guidelines	**Ratings**		**Michigan Non-NBI Culvert Structure Inspection Guide**
Superstructure (BSIR #9/SI&A Item 59)	**NBI**	**TAMC**	**General Condition Rating (Table 3-1)**
No deficiencies in any of the structural components that will affect long term performance	9	Good	Like new. Deterioration none to little. Structurally sound. Functionally adequate.
All protective coatings are sound and functioning but with minor weathering of the coating	8		
Members retain full section properties and function as designed with limited deterioration. Concrete: Hairline cracks in CIP concrete or sealed cracks spaced at more than 3' with no other defects present. Steel: Very limited partial protective coating failures that do not expose bare steel. Timber: Checks or shakes penetrate less than 5% of the member thickness.	7		
Members retain full section properties and function as designed with minor deterioration. Superficial impact damage. Concrete: Cracks in CIP concrete 1/16" wide or less or hairline cracks in PS concrete spaced at more than 3'. Minor delamination and spalling with exposed mild steel reinforcement without section loss or rust staining. Steel: Protective coating failures present with no section loss. Timber: Decay or section loss affecting less than 5% of the member section. Splits arrested and concerns mitigated.	6	Fair	Some deterioration. Structurally sound. Functionally adequate
Members continue to function as designed with moderate deterioration affecting structural members and minor section loss in low or no stress areas. Moderate impact damage that does not require mitigation. Concrete: Cracks in CIP concrete 1/16" wide or less or hairline cracks in PS concrete spaced at 1' to 3'. Moderate delamination, spalling, or exposed prestressing reinforcement without section loss. Minor efflorescence present. Steel: protective coating failures with minor loss of section. Cracks are arrested. All connections functioning as intended. Timber: Decay or section loss affecting 5% to 10% of the member section. Checks, shakes, and splits have no effect on capacity.	5		
All members continue to function as designed with considerable deterioration affecting structural members and up to 10% section loss in scattered and isolated areas. Substantial impact damage may be present. Concrete: Cracks in CIP 1/16" wide or greater or hairline cracks in PS concrete spaced at less than 1'. Moderate delamination and spalling or exposed prestressed reinforcement without section loss. Steel: Significant protective coating failure and limited loss of section, Cracks not arrested or missing fasteners are present. Timber: Decay, section loss, checks, shakes, or splits that do not warrant structural review.	4	Poor	Significant deterioration. Functionally inadequate. Requires maintenance or repair.
Considerable deterioration affecting structural members with section loss up to 25% in scattered and isolated areas. Structural evaluation or load analysis may be necessary to determine if the structure can continue to function without restricted loading. Concrete: Structural cracking or reinforcement section loss that may affect load capacity. Steel: Protective coating failed with measurable loss of section. Cracks or missing fasteners may affect design capacity. Timber: Decay or section loss that affects more than 10% of the member section. Checks, shakes, splits, may warrant action.	3		
The superstructure will not support design loads. Posting, emergency repairs installed or temporary shoring is required.	2	Severe	Very poor. Severe deterioration. Structurally unsound. Functionally inadequate. Possible imminent failure or threat to public safety.
The bridge is closed to traffic due to the potential for superstructure failure, but corrective action may put it back in service.	1		
Bridge is closed due to condition. Coordinate with SI&A Item 41 and notify Bridge Field Services.	0		

Table B.4: NBI Culvert Abutments (BSIR #13/SI&A Item 60) Comparison to TAMC Culvert General Condition Rating and End Treatments

NBI Rating Guidelines	Ratings		Michigan Non-NBI Culvert Structure Inspection Guide
Abutments (BSIR #13/SI&A Item 60)	NBI	TAMC	General Condition Rating (Table 3-1), End Treatments (Table 3-4)
No deficiencies in any of the structural components that will affect long term performance.	9	Good	Like new. Deterioration none to little. Structurally sound. Functionally adequate. Concrete: No cracking greater than hairline (maximum 0.01 inches). No spalling. No movement from installed condition. No scour.
All structural components are sound and functioning as designed. There may be superficial cracking or weathering of protective components and/or dirt contamination of structural components.	8		
All components retain full section properties and function as designed. Concrete: Insignificant cracks or moderate cracks that are sealed. MSE: Minor uniform tilting of walls that does not require structural review. Structural cracking limited to 5% or less of the area. Timber: Decay or section loss affecting less than 5% of the member thickness.	7		
Minor deterioration affecting structural components. Scour effects have been arrested with countermeasures. Concrete: Unsealed moderate-width or map cracks. Minor delamination, spalling, or efflorescence without built-up or rust staining. MSE: Minor uniform tilting of walls that does not require structural review. Structural cracking limited to 5% or less of the area. Timber: Decay or section loss affecting less than 5% of the member section. Splits arrested and concerns mitigated.	6	Fair	Some deterioration. Structurally sound. Functionally adequate. Concrete: cracking between 0.01 to 0.05 inches (thickness of dime). No infiltration. Moderate Efflorescence and no rust staining emanating from cracks. Localized spalling, less than or equal to 6 inches in diameter. Movement exists within tolerable limits (if known). Scour exposing buried footings/structures: any surface. No undermining of footing.
Moderate deterioration affecting structural components including minor settlement, shallow scour, or impact damage. All members continue to function as designed. Concrete: Moderate delamination, spalling, or efflorescence. Reinforcement exposure without section loss. MSE: Connections visible at isolated locations where panels are bowing. Joint width between panels is substantially uniform. Timber: Decay or section loss affecting 5% to 10% of the member section. Checks, shakes, and splits have no effect on capacity.	5		
Considerable deterioration affecting structural members including partial settlement or scour. All members continue to function as designed. Concrete: Considerable cracking, spalling, and efflorescence with heavy built-up or rust staining. MSE: Moderate uniform tilting of walls that does not require structural review. Structural cracking limited to between 10% and 25% of the area. Erosion has exposed the wall base without undermining. Timber: Extensive decay, section loss, checks, shakes, or splits that do not warrant structural review.	4	Poor	Significant deterioration. Functionally inadequate. Requires maintenance or repair. Cracking 0.05 to 0.1 inches. Local areas of exposed rebar. Minor water infiltration through cracks. Moderate efflorescence and/or rust staining emanating from cracks. Spalling greater than 6 inches in diameter. Rust staining from spalled areas. Movement exceeds tolerable limits (structure dependent). Scour exposing buried footings/structures: vertical face. No undermining of footing.
Considerable deterioration or damage 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 or immediate repairs. Concrete: Considerable areas of spalling, exposed reinforcement with section loss, or heavy rust staining. MSE: Structural cracking occurring on greater than 25% of area. Exposed geotextile fabric or loss of backfill. Timber: Decay or section loss that affects more than 10% of the member section. Checks, shakes, splits may warrant action.	3		
Deterioration has progressed to the point where the structure will not support design loads and posting, emergency repairs, or shoring with structurally engineered temporary supports is required.	2	Severe	Very poor. Severe deterioration. Structurally unsound. Functionally inadequate. Possible imminent failure or threat to public safety. Concrete: Cracking greater than 0.1 inches. Widespread exposed rebar with significant corrosion. Soil infiltration through cracks. Efflorescence widespread and rust staining emanating from cracks. Widespread spalling or delamination. Rebar exposed and corroded. Structure unstable. Movement exceeds tolerable limits (structure dependent). Scour exposing buried footings/structures: scour present. Significant undermining of footing.
Bridge is closed to traffic due to abutment failure, but corrective action may put it back in service.	1		
Bridge is closed due to abutment condition. Coordinate with SI&A Item 41 and notify Bridge Field Services.	0		

Appendix C: Rating Cards

The rating cards are summaries of the tables included in this guide. They are intended for quick reference while working in the field and are not intended to stand in the place of the unabridged versions of the tables in this guide. Note that these cards are designed to be printed double sided, flipped on the short-edge; the card for Table 3.8 is blank on the back side.

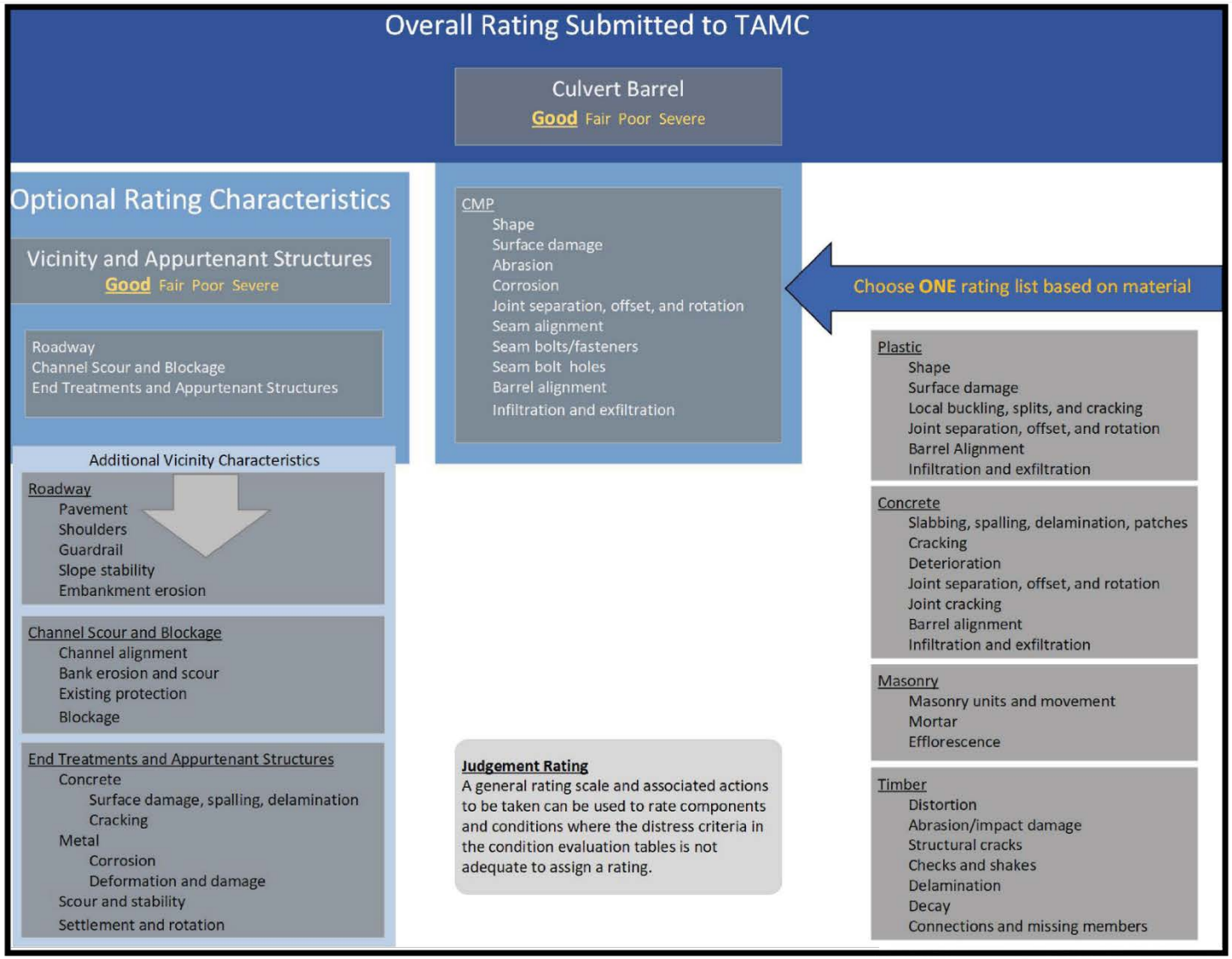
Please refer to the tables in this guide for a complete description of the component or element condition.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.1 General Condition Ratings, Actions, and Descriptions

Condition Rating	Good	Fair	Poor	Severe	Not Rated
Action Indicated	Action: None	Action: None, but more frequent inspection may be warranted	Action: Corrective action based on inspector's evaluation	Action: Corrective action based on engineering evaluation to specify appropriate repair	Action: None
	Note in inspection report only	Inform maintenance personnel	Recommendations made in inspection report	Required action is urgent	
Condition Description	Like new			Very poor	Not part of the culvert design or structure
Deterioration	None to little	Some	Significant	Severe	
Structural soundness	Sound	Sound	*and/or*	Unsound	
Functional adequacy	Adequate	Adequate	Inadequate	Inadequate	Not required
			Requires maintenance or repair	Possible imminent failure or threat to public safety	Not an inspection item at last inspection. Excludes items missing due to vandalism, damage, or deterioration.

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.1 in the guide.


Overall Rating Submitted to TAMC
Culvert Barrel
Good Fair Poor Severe
Optional Rating Characteristics
Vicinity and Appurtenant Structures
Good Fair Poor Severe
Roadway
Channel Scour and Blockage
End Treatments and Appurtenant Structures
Additional Vicinity Characteristics
Roadway
Pavement
Shoulders
Guardrail
Slope stability
Embankment erosion
Channel Scour and Blockage
Channel alignment
Bank erosion and scour
Existing protection
Blockage
End Treatments and Appurtenant Structures
Concrete
Surface damage, spalling, delamination
Cracking
Metal
Corrosion
Deformation and damage
Scour and stability
Settlement and rotation
CMP
Shape
Surface damage
Abrasion
Corrosion
Joint separation, offset, and rotation
Seam alignment
Seam bolts/fasteners
Seam bolt holes
Barrel alignment
Infiltration and exfiltration
Judgement Rating
A general rating scale and associated actions to be taken can be used to rate components and conditions where the distress criteria in the condition evaluation tables is not adequate to assign a rating.
Choose ONE rating list based on material
Plastic
Shape
Surface damage
Local buckling, splits, and cracking
Joint separation, offset, and rotation
Barrel Alignment
Infiltration and exfiltration
Concrete
Slabbing, spalling, delamination, patches
Cracking
Deterioration
Joint separation, offset, and rotation
Joint cracking
Barrel alignment
Infiltration and exfiltration
Masonry
Masonry units and movement
Mortar
Efflorescence
Timber
Distortion
Abrasion/impact damage
Structural cracks
Checks and shakes
Delamination
Decay
Connections and missing members

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.2 Roadway Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Placement				
	No potential distress for 20-ft minimum length on either side of crossing culvert			
Transverse cracking severity		Low (width: <0.25 in.)	Medium (width: 0.25-0.5 in.)	High (width: >0.5 in.) Pavement raveling over culvert
Longitudinal cracking severity				High (width: >0.5 in.) Pavement raveling over culvert
Sag or hump severity		Low (<2 in. over 10 ft) over culvert barrel	Medium (2-4 in. over 10 ft) over culvert barrel	High *and* Voids beneath pavement
Rutting in wheel path			Localized over culvert	
Patching			Evidence of repeated patching	
Shoulders				
	No potential distress for 20-ft minimum length on either side of crossing culvert			
Transverse cracking severity		Low, local to shoulder	Moderate	High
Longitudinal cracking severity		Low, local to shoulder	Moderate	High
Sag severity (over culvert)		Low		High
Settlement			Present	
Patches			Evidence of repeated patching	
Voids				In roadway near culvert (piping or infiltration)
Soil cracking				In shoulder area
Slope mobility				Movement in shoulder area

continued on back →

Guardrail				
	No potential distress for 20-ft minimum length on either side of crossing culvert			
Post alignment (not due to impact damage)		Slight misalignment due to shoulder settlement or sliding	Misalignment due to ground movement	
Settlement or sag severity			Medium, due to ground movement	High
Post rotation (not due to impact damage)			Exists due to ground movement	Exists due to ground movement
				Guardrail may be ineffective
Slope stability				
Slope stability (or movement)	Stable	Stable	Stable with minor sloughing	Failure likely
Soil sloughing	None			Embankment sloughing (causes loss of support to guardrails and/or roadway, and culvert end section joint distress)
Soil tension cracks				Parallel to roadway (indicates shifting or settlement)
Embankment erosion				
Rill erosion/gullying		Rill erosion: Minor	Rill erosion: Moderate Backfill around culverts slightly displaced	Gullying erosion: Severe
Piping (in embankment)	None		Evidence	
Sheet erosion		Minor (≤10% bare ground)	Moderate (11%-≤40% bare ground) Requires protection and investigation	Severe (>40% bare ground)
Embankment soil erosion	None due to runoff	Indication of storm water runoff		Significant
Structure stability (i.e. inlet, barrel, outlet, end treatments)		Not affected		Loss of support
Structure exposure (i.e. inlet, barrel, outlet, end treatments)		Not affected	Early-stage exposure	Fully-exposed barrel ends with rotation of end section or end section drop-off

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.2 in the guide.

Michigan
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Management Council

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.3 Channel Scour and Blockage Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Channel alignment				
Channel stream alignment with culvert	Aligned horizontally and vertically	Slight angle/offset from centerline	Early-stage altered alignment, channel enters/exits at moderate angle	Severe misalignment, channel directed at bank Threat of immediate collapse
Erosion	None		Erosion of embankment	Severe erosion
Flow capacity restriction	None	Not affected		
Undercutting			Barrel or end section	
Ponding		Minor	Occurring at inlet or outlet	
Bank erosion & scour				
Structure stability	Stable	Stable	Undercutting and sod-root overhangs	Danger of collapse with next flood event
Bank erosion	None	Intermittent	General erosion leading to channel widening	
Scour	None	Local to inlet or outlet No exposure of previously-buried features	Local scour or headcutting to outlet *or* Signs of downstream scour	Scour causing/leading to weakening of structures* *bank, culvert, end treatments, and/or roadway
Existing protection				
Protective material (e.g., rip-rap, armor, or other protective measures)	Meets design requirements No noted channel bank distress	Minor degradation	Moderate degradation	Partial failure Culvert, embankment, roadway, or other elements in danger of collapse
Displacement of protective material (e.g., rip-rap, armor, or other protective measures)		Localized displacement or undermining	Significant displacement Undermining or deteriorating performance	

continued on back →

Blockage				
Waterway blockage depth	None, free flowing	<10% of barrel diameter	10%-30% of barrel diameter	>30% of barrel diameter
Sedimentation/debris		Minor accumulation	Accumulation** creating partial blockage ** sedimentation, debris, trees, or shrubs	Accumulation*** creating blockage or severe restriction *** mass drift accumulation
Scour		None		
Ponding		Some evidence	Depth: >10% of diameter	Frequent flooding High water marks indicating roadway overtopped in high flows

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.3 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.4 End Treatments & Appurtenant Structures Condition Descriptions

CONCRETE

Condition Rating	Good	Fair	Poor	Severe
Surface damage, spalling, and delamination				
Surface damage	None	Impact damage: localized superficial (<0.25 in.)	Impact damage	Extensive
Scaling	None	Light or moderate (<0.25 in. exposed aggregate)	Moderate to severe (exposed aggregate)	
Abrasion	None	Depth: <0.25 in. over <20% of surface	Depth: 0.25-0.5 in. over >30% of surface	
Spalling	None	Localized Diameter: ≤6 in.	Diameter: >6 in. Rust staining from spalled areas	Widespread Rebar exposed and corroded Structure unstable
Rebar		Not exposed	Exposed	Significant exposed and/or corroded
Delamination	None			Widespread
Hollow sounds	None	Small areas	Areas >6 in. in diameter	
Patches	Areas remain sound	Edges tightly bonded	Areas are delaminated	
Weep holes			Multiple plugged (water cannot drain from backfill)	
Cracking				
Cracking	None greater than hairline Width: ≤0.01 in. (hairline)	Width: >0.01 - <0.05 in. (dime thickness) No increase from previous inspection	Width: 0.05-0.1 in. Rebar: Local areas exposed	Width: >0.1 in. Rebar: Widespread areas exposed, significant corrosion Soil infiltration through cracks
Infiltration		None	Water: Minor through cracks	
Efflorescence		Moderate *and* Rust staining from cracks: None	Efflorescence *and/or* Rust staining from cracks: Present	Efflorescence *and* Rust staining from cracks: Widespread

continued on back →

METAL	**Corrosion**				
	Corrosion	None	Freckled rust or other signs	Corrosion: Present Penetration: Possible with hammer strike or sharp point	Corrosion: Widespread Penetration: :Local through-thickness
	Section loss		None	<10% of thickness	
	Pitting		None	Deep pronounced thinning	
	Holes			Diameter: ≤ 1 in. *and* Several	Diameter: >1 in. *or* Many small holes, grouped holes allowing soil migration
	Deformation and damage				
	Dents/impact damage/ deformation	None	Small	Large	Restricts flow capacity or results in scour or erosion of embankment
	Abrasion	None	Coating abraded Breaches: None exposing structural wall	Protective coating abraded Breaches: Present, exposing structural wall	
ALL	**Scour and stability**				
	Scour exposing buried footings/structures	None	Surface	Vertical face	Scour present
	Undermining of footing	None	None	None	Significant
	Rotation	Installed condition	Installed condition		Severe, leading to structural distress (concrete culvert: cracking; metal culvert: kinking; masonry culvert: cracking of mortar and displacement of masonry units)
	Settlement/Rotation				
	Movement	None from installed condition	Exists within tolerable limits (if known)	Exceeds tolerable limits (structure-dependent)	Exceeds tolerable limits (structure-dependent)
	Vertical offset at cracking		None	≤0.25 in.	>0.25 in.
	Distress/distortion of structure			None	Present (concrete culvert: cracking; metal culvert: wrinkling)

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.4 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.5 Plastic Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape				
Shape	Round		Visible out-of-roundness	Significant visible out-of-roundness
Wall flattening	None	Minor	Significant *or* Wall curvature: Increased	Extreme *and* Wall curvature: Reversed (global buckling) *and/or* Kinks
Vertical deformation	<5% of original diameter	5%-7.5% of original diameter	7.5%-10% of original diameter	>10% of original diameter
Surface damage				
Wear and/or abrasion of wall thickness	None	Minor, <10%	≥10%	>25%
Impact damage	None			
UV degradation or staining	None	Minor	Degradation of barrel ends, discoloration	Degradation of barrel ends, cracked or broken barrel wall
Blistering of barrel inner surface (FRP)		<25%	≥25%	
Local buckling, splits, and cracking				
Local buckling of interior wall	Smooth	Buckling indicated by rippling	Advanced and widespread indicated by extensive rippling	Inward, kinks through full wall thickness
Splits	None in welded seams	<25% of circumference	25%-50% of circumference	>50% of circumference
Infiltration		None	Water: Minor Soil: None	Water: Through cracks Soil: Indication
Wall cracking	None	<25% of circumference	25%-50% of circumference	>50% of circumference
Longitudinal cracking		None	≤12 in. in length	>12 in. in length
Joint separation, offset, rotation				
Joint separation	Tightly installed	Separation, no distress	Separation in ≥1 joint(s)	Separation with exposed backfill material
Offset	None (proper alignment)	Exists, no distress	Exists in ≥1 joint(s)	Exists with exposed backfill material
Rotation		Present, no distress	Present in ≥1 joint(s)	Present with exposed backfill material
Gaskets/gasket materials		Not exposed	Exposed or missing	Exposed or missing in multiple places
	Functioning well			

continued on back →

Barrel alignment				
Horizontal alignment to installed condition	No signs of movement (straight or smooth bends)	Small visible deviations Barrel or joints not affected	Deviations Barrel or joints may be affected (refer to joint inspection)	Barrel section offsets Barrel or joints are distressed
Vertical alignment	No sagging or heaving	Minor sagging or heaving	Misalignment causing sagging Ponding or sediment accumulation: 10%-30% of diameter	Misalignment causing sagging Ponding or sediment accumulation: >30% of diameter Barrel section offsets Barrel or joints are distressed
Flow capacity/restriction				Indication of significant restriction
Infiltration and exfiltration				
Infiltration and exfiltration	No signs			
Water infiltration through leak-resistant joints/seams		Minor	Significant	
Soil infiltration through joints/seams		None	Fine soils	Coarse soils
Exfiltration				Evidence of piping due to exfiltration
Hollow sounds				Possible, behind structure wall near seam/joint indicating loss of backfill support

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.5 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.6 Concrete Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Slabbing, spalling, delamination, patches				
Slabbing	None (indicated by wall visual appearance)	None	None	Slabbing of concrete
Spalling	None, as indicated by wall visual appearance	Localized Depth: < 0.25 in Diameter: < 6 in Rebar not exposed	Depth: 0.5–0.75 in Diameter: > 6 in Rebar not exposed, some rust staining Structure stable	Widespread Depth: > 0.75 in Rebar exposed Structure unstable
Delamination	None	Small, indicated by hollow sounds at patches	Depth: 0.5–0.75 in Diameter: > 6 in Rebar not exposed, some rust staining Structure stable	Present Rebar exposed Structure unstable
Patch areas	Sound	Stable	Deteriorating and delaminated	
Cracking				
Cracking	None greater than hairline Width: ≤0.01 in. (hairline)		No increase from previous inspection	
Longitudinal cracking		Width: 0.01–0.05 in (dime thickness) Spacing: ≥3 ft	Width: 0.05–0.1 in Spacing: 1–3 ft Rebar not exposed	Width: >0.1 in Rebar exposed
Circumferential cracking		Some	Present	
Cracking w/ vertical offset			None	Present
Water infiltration				Significant
Soil migration		None	Through circumferential cracks	Significant
Efflorescence			Present Rust staining from cracks: Present	Present Rust staining from cracks: Large areas
Deterioration				
Scaling	None	Light or moderate Exposed aggregate: < 0.25 in	Moderate to severe Aggregate exposed	Extensive
Abrasion	None	Depth: <0.25 in. over <20% of barrel surface	Depth: 0.25–0.5 in. over >30% of barrel surface	Extensive
Other damage	No surface damage	Impact damage: localized and superficial (<0.25 in)	Impact damage	Extensive Aggregate pop-out
Rebar		Not exposed	Exposed	Exposed and/or corroded
Weep holes		Multiple plugged		Complete invert deterioration and loss of barrel wall section

continued on back →

Joint separation, offset, rotation				
Joint separation	Tightly installed	Separation, no distress	Separation in ≥1 joint(s)	Separation with exposed backfill material
Offset	Proper alignment	Offset, no distress	Offset in ≥1 joint(s)	Offset with exposed backfill material
Rotation		Present, no distress	Present in ≥1 joint(s)	Present with exposed backfill material
Gaskets/gasket materials		Not exposed	Exposed or missing	Exposed or missing in multiple places
	Functioning well			
Joint cracking				
Joint cracking (longitudinal cracking emanating from joint)	None	Width: 0.01–0.05 in	Width: 0.05–0.1 in	Width: >0.1 in
Joint spalling along edge of spigot		None or small spalls; reinforcing or joint sealant not exposed	Moderate spalls; reinforcing or joint sealant possibly exposed	Large spalls; associated structural cracking
Barrel alignment				
Horizontal alignment to installed condition	No signs of movement (straight or smooth bends)	Small visible deviations Barrel or joints not affected	Deviations Barrel or joints may be affected (refer to joint inspection)	Misalignment/barrel section offsets Barrel or joints are distressed
Vertical alignment	No sagging or heaving	Minor sagging or heaving	Misalignment causing sagging or heaving Ponding or sediment accumulation: 10%-30% of diameter	Misalignment causing sagging Ponding or sediment accumulation: >30% of diameter Barrel section offsets Barrel or joints are distressed
Flow capacity/restriction				Indication of significant restriction
Infiltration and exfiltration				
Infiltration & exfiltration	No signs			
Water infiltration through leak-resistant joints/seams		Minor	Significant	
Soil infiltration through joints/seams		None	Fine soils	Coarse soils
Exfiltration				Evidence of piping due to exfiltration
Hollow sounds				Possible, behind structure wall by joints/ seams due to backfill support loss

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.6 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.7 Corrugated Metal Pipe Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape				
Curvature	No distortion in barrel	No distortion in top half	Significant distortion Flattening	Extreme distortion Local areas of reverse curvature
Rise measurement	Within tolerance			
Span measurement	Within tolerance			
Bulges/kinks		Minor bulges or flattening of bottom	Kinks in lower third	Kinks in local areas
Deformation	<5% of original diameter	5%-10% of original diameter	>10%-15% of original diameter	>15% of original diameter
Out-of-roundness			Visible	Significant
Surface damage				
Dents or damage	None	Dents: Small Damage: Localized, small impact damage to barrel section or end wall	Dents: Large Damage: Localized, large impact damage to barrel section or end wall	Warrants engineering evaluation
Wall breaches		None	Localized, ≤1 corrugation over 6 in. in circumferential length	Through-wall holes, >1 corrugation over >6 in. in circumferential length allowing soil infiltration
Abrasion				
Abrasion	None	Wall or coating: Small or local	Protective coating: Widespread	Metal barrel: Significant Large holes >1 corrugation over >6 in. in circumferential length
Wall breaches		None in coating of structural wall	Breaches exposing wall material	
Corrosion		None		
Penetration			Through-wall when probing with pick	
Corrosion				
Rust	Freckled rust: isolated areas	Freckled rust Corrosion of barrel wall material	Corrosion of barrel material	
Section loss		None	Widespread, <10% of wall thickness	Invert missing localized sections
Pitting			Localized and deep	
Holes			Diameter: ≤1 in. Several	Diameter: >1 in. *or* Many, smaller, closely-grouped
Penetration		None (through-wall)	Possible with hammer strike	Widespread through-wall

continued on back →

Joint separation, offset, or rotation				
Joint separation	Joints tightly installed	Separation	Separation	Separation
Offset or rotation	None (proper alignment)	Exists, no distress	Exists in ≥1 joint(s)	Exists with exposed backfill material
Gaskets/gasket materials		Not exposed	Exposed or missing	Exposed or missing in multiple places
	Functioning well			
Seam alignment				
Seam alignment	No visible misalignment	Slightly cocked seams	Cocked seams	Cocked seams
Cusp effect		None	Present with local wall bending	Present with seam cracking
Shape: cross section		Not affected	Affected	Severely affected
Seam capacity				Loss imminent
Seam bolts and fasteners				
Seam bolts & fasteners	None loose or missing	>5% loose or missing in any seam	5%-15% loose or missing in any seam	>15% loose or missing in any seam
Seam bolt holes				
Seam bolt holes	No yielding or deformation	Yielding of steel: localized, minor *and/or* Cracking/splitting length: <1 in.	Yielding of steel: localized *and/or* Cracking/splitting length: 1-3 in.	Yielding of steel: localized, significant *and/or* Cracking/splitting length: >3 in.
Wall prying	None due to bolt tipping			
Corrosion, around bolt holes or on bolts		Minor	Present with section loss	Present with section loss
Barrel alignment				
Horizontal alignment to installed condition	No signs of movement (straight or smooth bends)	Small visible deviations Barrel or joints not affected	Deviations Barrel or joints may be affected (refer to joint inspection)	Misalignment causing barrel section offsets (causes distress in barrel or at joints)
Barrel alignment—vertical	No sagging or heaving	Minor sagging or heaving	Misalignment causing sagging or heaving Ponding/sediment accumulation: 10%-30% of diameter	Misalignment causing sagging Ponding/sediment accumulation: >30% of diameter Barrel section offsets causing distress in barrel or at joints
Flow capacity/restriction				Indication of significant restriction
Infiltration and exfiltration				
Infiltration & exfiltration	No signs			
Water infiltration through leak-resistant joints/seams		Minor	Significant	
Soil infiltration through joints/seams		None	Fine soils	Coarse soils
Exfiltration				Evidence of piping due to exfiltration
Hollow sounds				Possible, behind structure wall by joints/seams due to backfill support loss

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.7 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.8 Masonry Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Masonry units and movement				
Cracking of units	None	Isolated individual units	Several	Widespread
Splitting of units	None		Split units	Widespread
Movement/dislocation	None	None	Pronounced Does not warrant engineering evaluation	Significant
Missing units	None			Widespread crushed or missing
Surface deterioration	None	Weathering or spalling	Large areas of moderate weathering, spalling, or scaling	Large areas of heavy weathering, spalling, or scaling
Structure wall				Holes through wall
Shape				Cross section has visible movement or distortion; structure appears unstable
Mortar				
Cracked/missing	None (intact)	Localized	Extensive	Missing
Deterioration	None	Widespread areas of shallow mortar deterioration	Extensive	
Infiltration/exfiltration		Water: Possible minor infiltration (no active flow)and exfiltration through joints	Water: Small flow Soil/fines: None through joints	Soil: Backfill infiltration
Voids				Possible in roadway
Efflorescence				
Efflorescence	Localized areas	Widespread areas	Heavy buildup	No severe rating
Rust staining		None	Present	

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.8 in the guide.

Michigan Non-NBI Culvert Structure Inspection Rating Card

3.9 Timber Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Distortion				
Shape of cross section	No change		Warping or sagging causing distortion	Significant distortion *or* Widespread warping, crushing, or sagging
Members	No warping, crushing, or sagging	Warping, crushing, or sagging of single or few members not requiring mitigation or previously mitigated	Crushing	
Abrasion/impact damage				
Abrasion	Section loss: None	Section loss: <10% of member cross section	Section loss: 10%-20% of member cross section	Section loss: >20% of member cross section
Structural cracks				
Structural cracking	None	Arrested	Exists Projects <5% into member cross section	Exists Differential movement across crack
Checks or shakes				
Checks or shakes	Penetration: <5% of member thickness	Penetration: 5%-50% of member cross section Away from connections and tension zones of bending members	Penetration: >50% of member cross section *or* Penetration: ≤10% near connections or tension zone of bending members	Penetration >10% near connections or tension zone of a bending member
Delamination				
Delamination	None	Delamination length < total member depth and away from connections *or* Has been arrested	Delamination length ≥ total member depth and away from connections	Delamination near connections Imminent collapse of member or structure

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Decay				
Members	None (no sunken faces, staining, or discoloration of surface)	Decay Probe penetration: ≤10% of cross section	Decay Probe penetration: 10%-20% of cross section Away from connections and tension zone of bending member	Decay Probe penetration: >20% of cross section *or* >10% of cross section near connections or tension zone of bending member
Fruiting bodies	No signs			Present
Hollow sounds		Localized		
Connection and missing members				
Bolts	None loose	Loose bolts	Missing	Missing, causing movement in connected elements
Welds	None broken		Broken	Broken, causing movement in connected elements
Rivets	None missing		Missing	Missing, causing movement in connected elements
Fasteners	None missing	Loose	Missing	Missing, causing movement in connected elements
Surface rust	None	Freckled rust (no pitting or section loss) Rust staining on face of member	Present with some pitting Pack rust without distortion	Heavy rusting with section loss *and/or* Pack rust causing distortion
Connection		Functioning as designed	Functioning as designed	Integrity is in question
				Imminent collapse

This table is excerpted from the *Michigan Non-NBI Culvert Inspection Guide* by the Michigan Transportation Asset Management Council, 2021. For a more detailed descriptions, please refer the to Table 3.9 in the guide.

Appendix D: Data Dictionary

Table D-1 outlines the fields from the web service class used by the Center for Shared Solutions.

Table D.1 Culvert Fields from the Center for Shared Solutions Web Service Class

Field Name	Data Type	Note
Barrel	string	Good, Fair, Poor, or Severe
ConstributorAgency	string	Zero filled (prefix) jurisdiction code: FIPS for City, FIPS County Code for county
CustodianCode	integer	jurisdiction code: FIPS for City, FIPS County Code for county
DateInstalled	DateTime	
Delete	boolean	Whether the culvert has been marked as deleted
DepthCover	double	in feet
DownstreamElevation	double	in feet
InspectionDate	DateTime	
Latitude	double	Latitude at road centerline crossing
LatitudeEntrance	double	
LatitudeExit	double	
MP	double	Road milepoint at centerline crossing
MaterialType	string	value must match lookup values
NumberOfBarrels	integer	

Table D.1 Culvert Fields from the Center for Shared Solutions Web Service Class		
Field Name	**Data Type**	**Note**
OwnerCode	string	Zero filled (prefix) jurisdiction code: FIPS for City, FIPS County Code for county
PRNo	integer	
Rise	double	in feet
RoadSurfaceType	string	Asphalt, Concrete, Seal Coat, Brick, Gravel, or Earth
Roadname	string	
RoadsoftUID	string	GUID: Unique identifier for the culvert
ShapeType	string	value must match lookup values
SkewAngle	integer	-90 to 90
Span	double	in feet
UpstreamElevation	double	in feet
Width	double	in feet