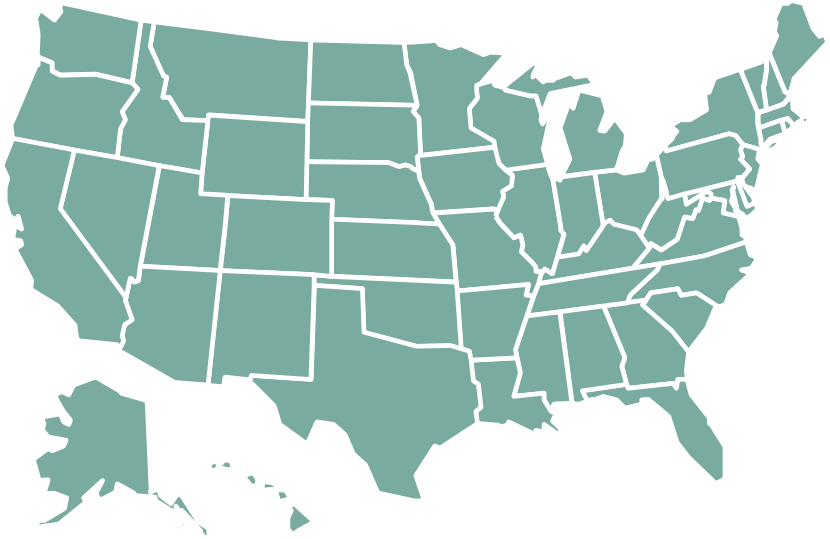
Introduction of the New Culvert and Storm Drain Inspection Manual

NCHRP Project 14-26

NCHRP is a State-Driven Program

- Sponsored by individual state DOTs who
  - Suggest research of national interest
  - Serve on oversight panels that guide the research.



- Administered by TRB in cooperation with the Federal Highway Administration.

Practical, ready-to-use results

- Applied research aimed at state DOT practitioners
- Often become AASHTO standards, specifications, guides, syntheses
- Can be applied in planning, design, construction, operations, maintenance, safety, environment

Additional NCHRP Publications Available on this Topic

- NCHRP Report 750: Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report
- NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices
- NCHRP Report 802: Volume Reduction of Highway Runoff in Urban Areas: Guidance Manual
- NCHRP Synthesis 474: Service Life of Culverts

You can learn more about these publications by visiting www.trb.org

Today's Speakers

- *Jesse Beaver, Simpson, Gumpertz & Heger, Inc.*
- *Matthew Richie, Simpson, Gumpertz & Heger, Inc.*
- *Moderator: Ray Trujillo, New Mexico DOT*

Introduction of the Culvert and Storm Drain System Inspection Manual

NCHRP Project 14-26

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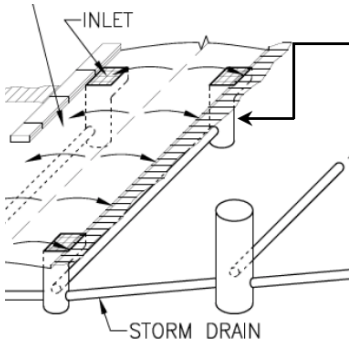
Matthew C. Richie, P.E., Project Manager

Simpson Gumpertz & Heger

30 January 2017

Background

- Culverts
  - Buried structures.
  - Pass water under roadways, railways, or embankments.
  - Structurally similar to bridges, but with span less than 20 ft.
- Storm Drains
  - Low-head or gravity flow.
  - Closed-end conduits, inlet/outlet structures, in-line junction boxes.
  - Convey stormwater to collection and discharge points.
- Highway bridges
  - Includes culverts with spans greater than 20 ft.
  - Federally mandated (and funded) inspection every 2 yrs.
- Culverts & storm drains outnumber bridges approximately 10 to 1
  - No federally mandated (or funded) inspection cycle.
  - Many are not tracked and go uninspected for years until failure.



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Agency Inspection Programs

- Some jurisdictions have developed specifications and hired consultants for culvert inspections.
  - Colorado
- Many jurisdictions have developed their own manuals (or used bridge inspection manuals to inspect culverts).
  - Minnesota, Federal Lands Highways, New York State, Connecticut, New Jersey, Ohio
- Some states have developed training and/or certification courses for their culvert inspection programs.
  - Ohio, California

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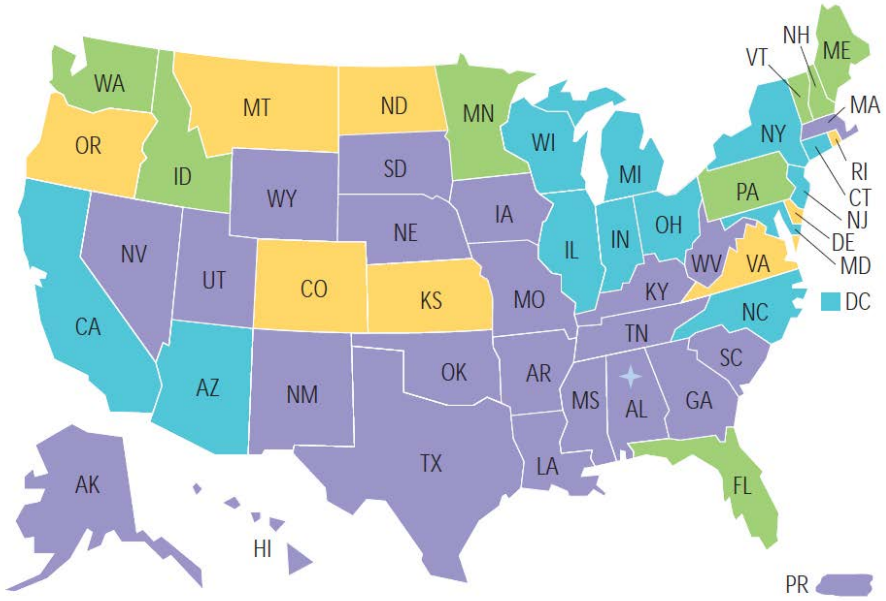
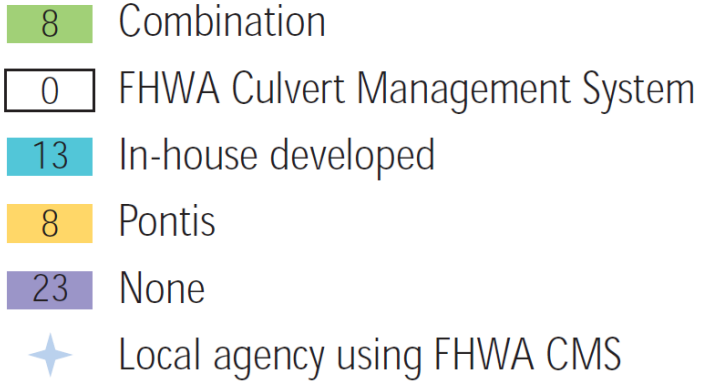
How do States Manage Culvert Inventories?

- Inventory Management Systems
  - Catalog and track infrastructure assets.
  - Identify the infrastructure asset value.
  - Effective systems include: inventory, inspection, management/documentation, planning, budgeting, decision-making.





Based on January 2007 questionnaire sent to state bridge engineers.

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NCHRP Project 14-26

- Completed: May 2016.
- Objective: Develop an inspection manual for assessing the condition of in-service culvert and storm drain systems to ensure system safety and performance and the economical use of owner resources.
- Final Deliverable: *Culvert and Storm Drain System Inspection Manual.*
  - Targeting publication as AASHTO Manual, late summer 2017.
  - Replaces 1986 FHWA Culvert Inspection Manual.
- Oversight Panel: DOT, FHWA, Manufacturers, Industry, Engineers, Academia.

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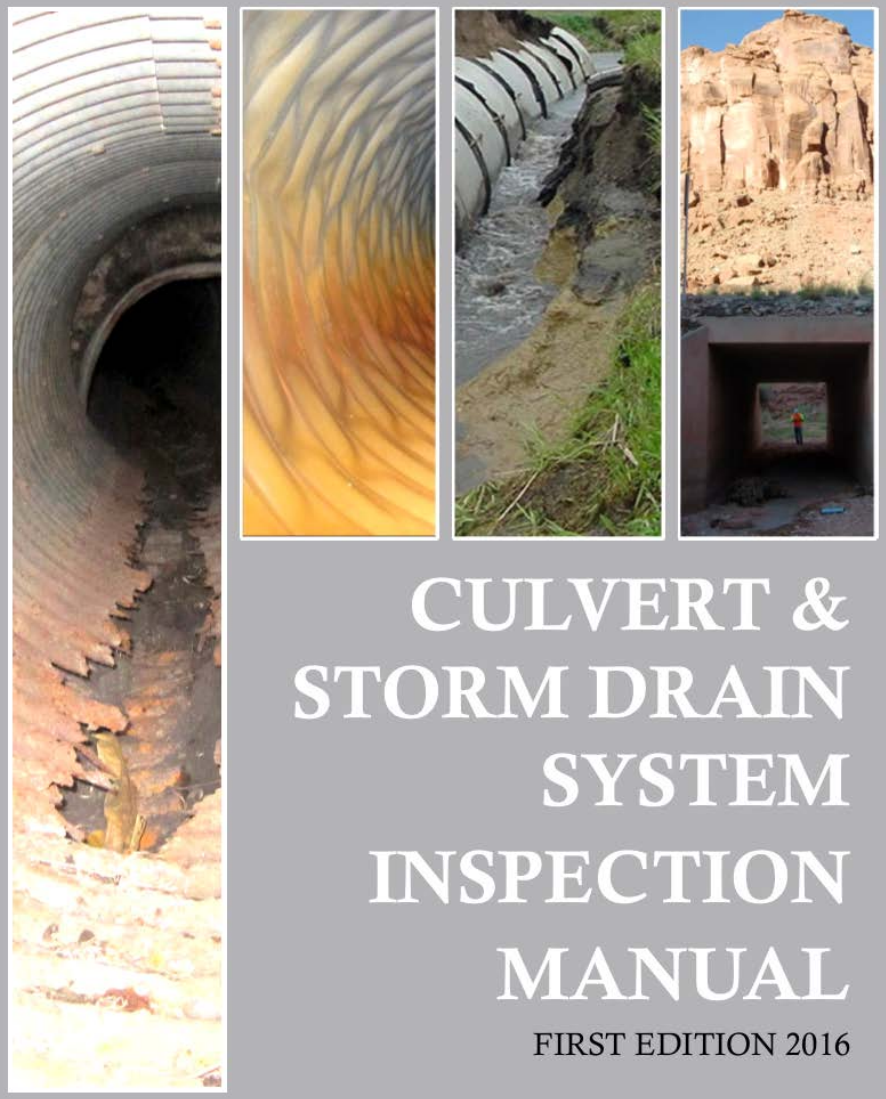

CULVERT & STORM DRAIN SYSTEM INSPECTION MANUAL

FIRST EDITION 2016

CULVERT AND STORM DRAIN SYSTEM INSPECTION MANUAL

FINAL REPORT

Prepared for
NCHRP 14-26 Culvert and Storm Drain System Inspection Manual

Transportation Research Board
of
The National Academies

TRANSPORTATION RESEARCH BOARD
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PRIVILEDGED DOCUMENT

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Jesse L. Beaver
Matthew C. Richie
Simpson, Gumpertz & Heger, Inc.
Waltham, MA
May 2016

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Overview of the New Culvert and Storm Drain System Inspection Manual

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Culvert and Storm Drain System Inspection Manual: Objectives of the Manual

- Quantitative and consistent condition rating criteria based on engineering principles and existing best practices.
- Enable culvert and storm drain inspectors to:
  - Identify structural distress for culvert or storm drain system components,
  - Rate the condition of the system components,
  - Document findings of an inspection, and
  - Recommend corrective actions or further in-depth inspection, as appropriate.
- Provide methods and data for owners to justify repair funding requests and to prioritize rehabilitation programs.

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Culvert and Storm Drain System Inspection Manual: Goals

- Evaluate structural integrity, hydraulic performance, and roadside compatibility.
- Identify minor issues that can be addressed through maintenance before they become safety hazards.
- Mitigate repair costs.
- Reduce risk of failure.
- Provide input to prioritize rehabilitation and maintenance.
- Allow for short- and long-term planning and budgeting for repairs and rehabilitation.
- Provide a method to meet state and federal requirements to quantify the value of highway infrastructure assets.

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Culvert and Storm Drain System Inspection Manual: Organization of the Manual

- Section 1 – Introduction
- Section 2 – Design and Performance Characteristics
  - Appendix A – Structural Shapes, Materials, and System Components
- Section 3 – Inspection Procedure
- Section 4 – Condition Rating System
  - Appendix B – Catalog of Distressed Conditions
- Section 5 – Asset Management

Figure 1.2-1 – Roadway Collapse Due to Piping along Culvert and Loss of Backfill

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Culvert and Storm Drain System Inspection Manual:

Section 1 – Introduction

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Culvert and Storm Drain System Inspection Manual: Section 1 – Introduction

- Introduces culvert and storm drain system inspection.
- Outlines need for standardized inspection program.
- Provides the manual objectives.
- Identifies the intended audience.
- Instructs users on the manual organization and use for inspections.

Figure 1.2-3 – Roadway Collapse Due to Structural Failure of Culvert
(Photo courtesy of Iowa Department of Transportation)

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Culvert and Storm Drain System Inspection Manual: Section 1 – Introduction

- Target audience
  - Highway departments
    - State highway agencies (Departments of Transportation).
    - County Highway Divisions.
    - Other local agencies.
  - Personnel
    - Agency culvert and storm drain system inspectors.
    - Agency bridge inspectors.
    - Consultants to highway agencies responsible for culvert and storm drain system inspection.
    - Personnel responsible for performing scheduled maintenance on culvert and storm drain systems.

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Culvert and Storm Drain System Inspection Manual:

Section 2 – Design and Performance Characteristics

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Subsections Include:
  - Design Characteristics
    - Hydraulic Requirements
    - Structural Behavior – Flexible vs. Rigid Materials
    - Loads on Culverts and Storm Drains
    - Construction and Installation Requirements
  - Performance Characteristics
    - Durability
  - Culvert and Storm Drain Shapes and System Components
    - Refer to Appendix A for additional details

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Hydraulic Requirements

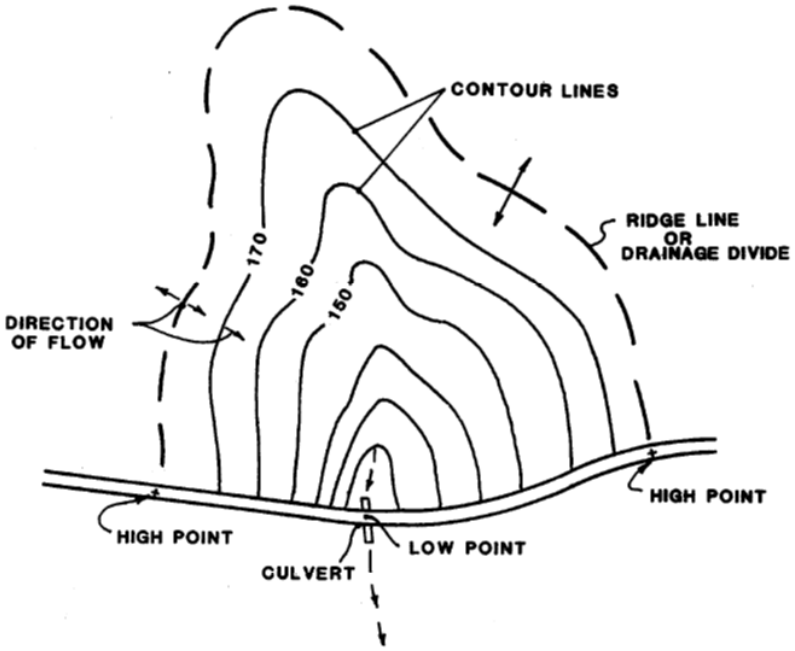

Figure 2.2-1 – Example Drainage Area (Estimate Runoff)

(Outlet Protection)

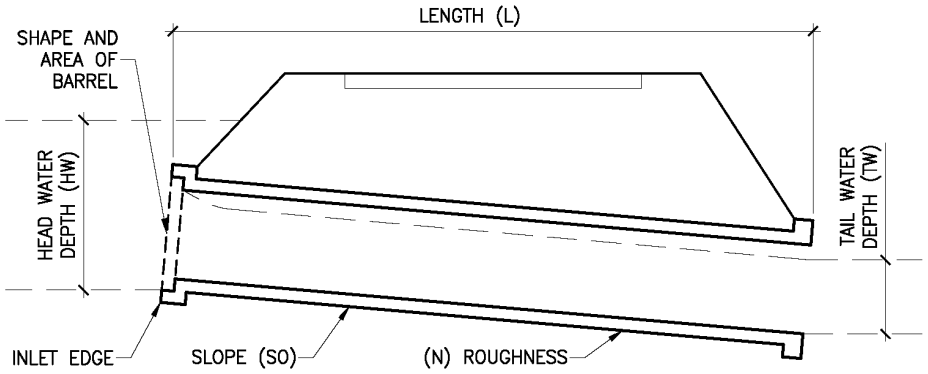

Figure 2.2-2 – Factors Affecting Hydraulic Capacity (Hydraulic Design)

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Structural Behavior and Materials – Flexible Pipe vs. Rigid

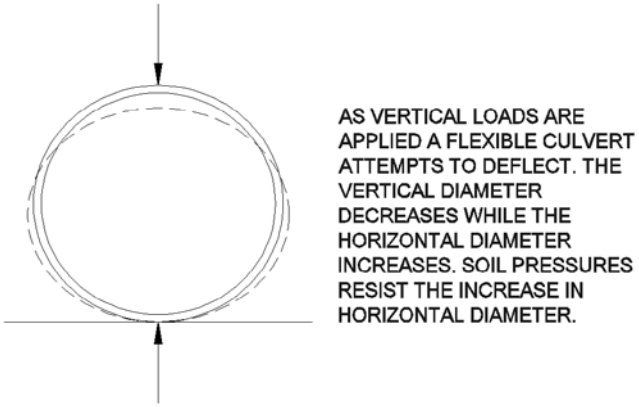

Figure 2.2-3 – Deflection of Flexible Culverts

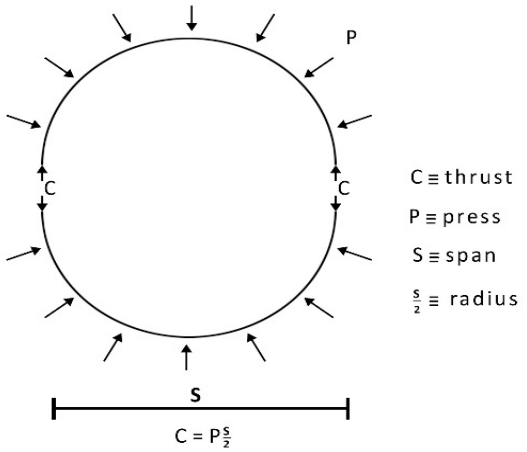

Figure 2.2-4 – Load in Flexible Culverts

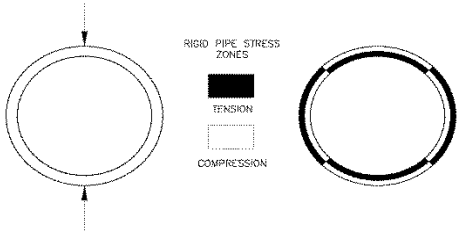

Figure 2.2-6 – Zones of Tension and Compression in Rigid Pipes Develop to Resist Vertical Load in the Three Edge Bearing Test

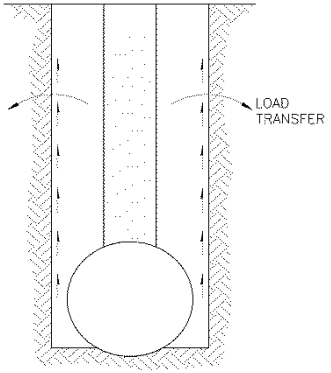

Figure 2.2-7 – Trench Installation (friction on trench sides reduces the width of the column of fill carried by the pipe)

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Loads on Culverts and Storm Drains

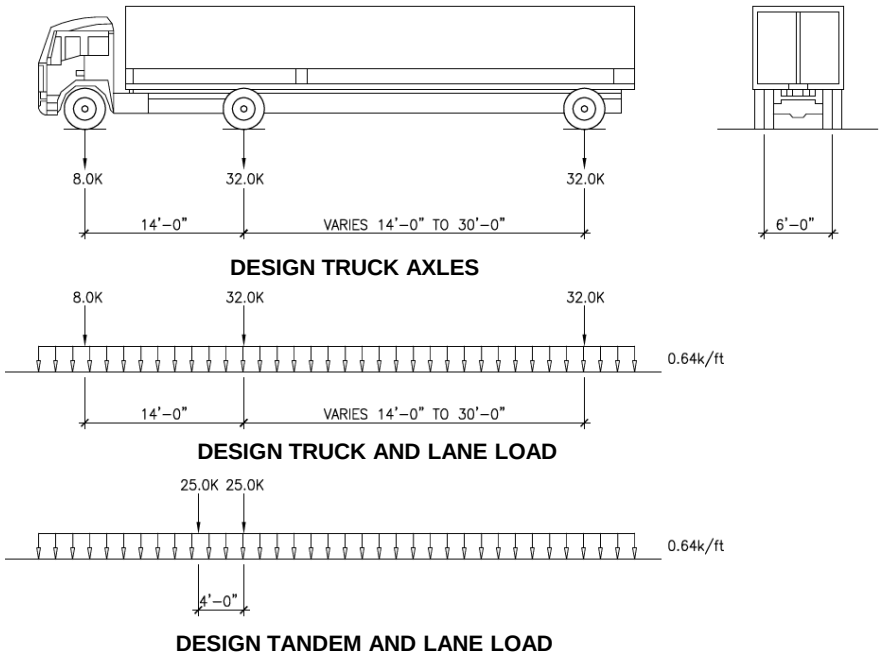

Figure 2.2-8 – AASHTO HL-93 Live Load

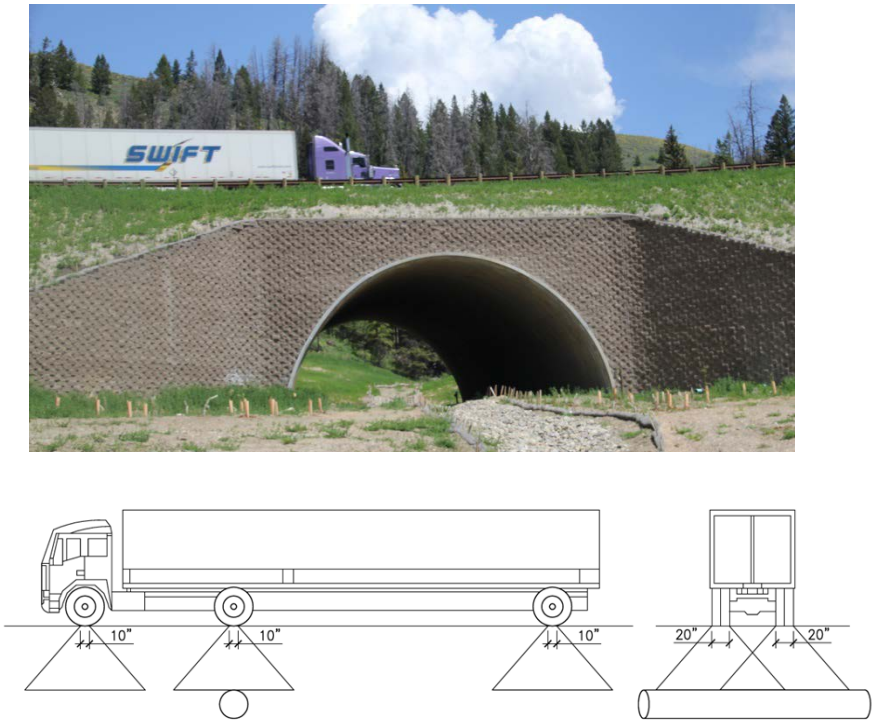

Figure 2.2-9 – Live Load Distribution Through Fill
(Note: Pipe orientation may vary for storm drains)

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Loads on Culverts and Storm Drains – AREMA Cooper E-80

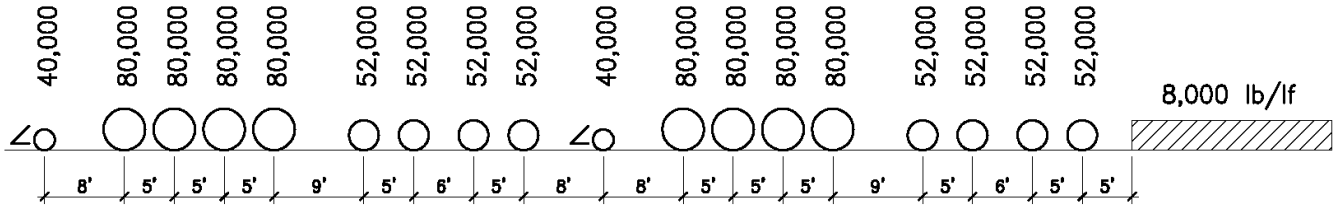

Figure 2.2-10 – AREMA Cooper E80 Railway Loading

TTCI FAST Test Installation of HDPE below RR
(https://www.dot.state.oh.us/engineering/OTEC/2015_OTEC_Presentations/Wednesday_Oct.28/72/Babcanec_72.pdf)

Corrugated Metal below RR

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Construction and Installation Terminology - Trench

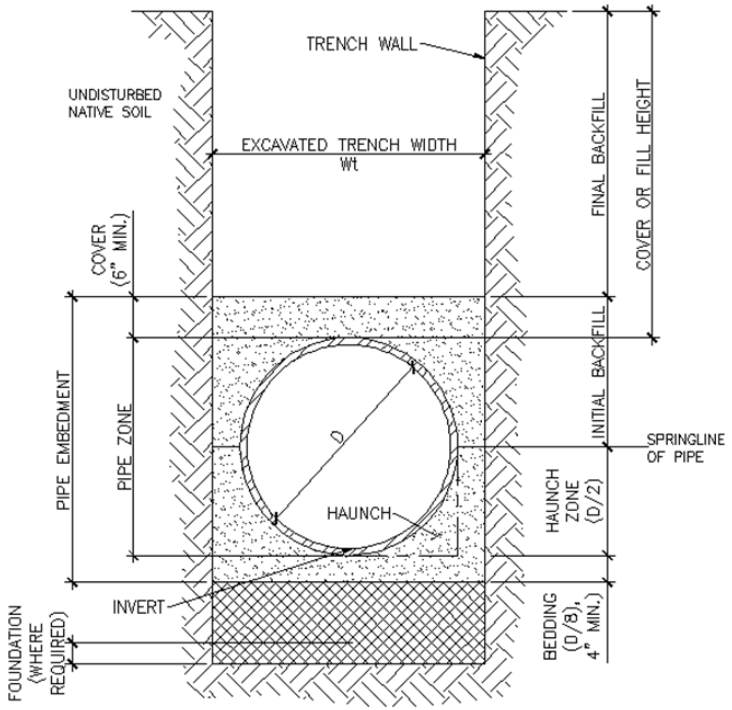

Figure 2.2-11 – Trench Installation for Buried Culvert or Storm Drain

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Construction and Installation Terminology - Embankments

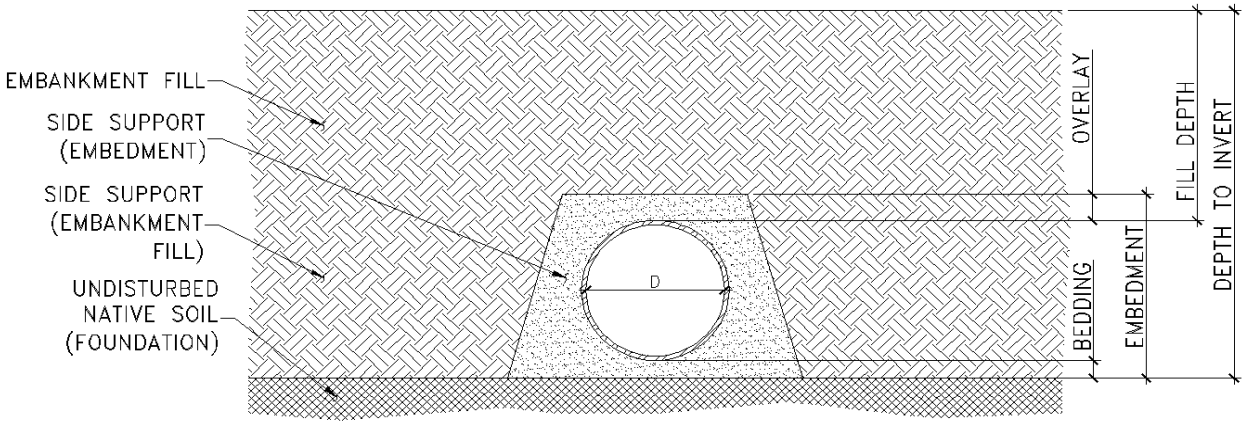

Figure 2.2-12 – Embankment Installation for Buried Culvert or Storm Drain

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Construction and Installation Considerations
  - Compaction and Side Support
  - Trench Width
  - Foundations and Bedding
  - Minimum Depth of Fill
  - Camber
  - High Groundwater (flotation)

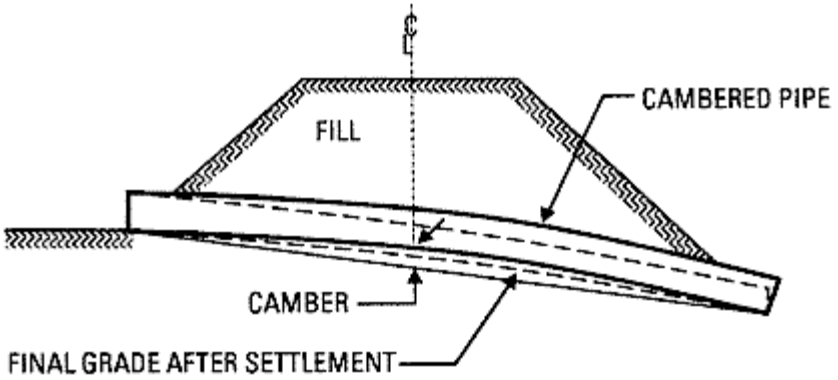

Figure 2.2-13 – Camber in Pipe to Allow for Settlement under High Fill

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Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Performance Characteristics – Durability
  - Corrosion of Metals
  - Degradation of Concrete
  - Degradation of Plastic
  - Abrasion of barrel materials

Figure 2.3-1 – Severe Corrosion of Corrugated Steel Pipe

Figure 2.3-3 – Corrosion of Reinforcing Steel in Concrete Pipe

Degradation and Cracking of HDPE Pipe

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Shapes
  - Materials
  - Culvert Systems and Components
  - Storm Drain Systems and Components
  - Pipe Coatings and Linings

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Shapes

Circular

Pipe Arch

Box

Arch

Three-Sided

Multi-Cell / Multi-Barrel

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Materials – Descriptions and Shapes
    - Corrugated Steel and Aluminum
      - Factory-Made Pipe
      - Structural Plate Steel
      - Corrugated Box Culvert
      - Long-Span Corrugated Structures
    - Plastic
      - Thermoplastic vs. Thermoset Resins
      - HDPE, PVC, PP
      - FRP
      - SRPE
    - Concrete
      - Precast Shapes
      - Cast-In-Place
      - Fiber Reinforced Concrete Pipe

SHAPE	RANGE OF SIZES	COMMON USES
Round	6 in. – 51 ft	Culverts, subdrains, sewers, service tunnels, etc. All plates same radius. For medium and high fills (or trenches).
Vertically-elongated (ellipse) 5% is common	4 – 21 ft nominal; before elongating	Culverts, sewers, service tunnels, recovery tunnels. Plates of varying radii; shop fabrication. For appearance and where backfill compaction is only moderate.
Pipe-arch	Span x Rise 17 in. x 13 in. to 20 ft 7 in. x 13 ft 2 in.	Where headroom is limited. Has hydraulic advantages at low flows. Corner plate radius. 18 inches or 31 inches for structural plate.
Underpass*	Span x Rise 5 ft 8 in. x 5 ft 9 in. to 20 ft 4 in. x 17 ft 9 in.	For pedestrians, livestock or vehicles (structural plate).
Arch	Span x Rise 5 ft x 1 ft 9½ in. to 82 ft x 42 ft	For low clearance large waterway opening, and aesthetics (structural plate).
Horizontal Ellipse	Span 7 – 40 ft	Culverts, grade separations, storm sewers, tunnels.
Pear	Span 25 – 30 ft	Grade separations, culverts, storm sewers, tunnels.
High Profile Arch	Span 20 – 83 ft	Culverts, grade separations, storm sewers, tunnels. Ammo ammunition magazines, earth covered storage.
Low Profile Arch	Span 20 – 83 ft	Low-wide waterway enclosures, culverts, storm sewers.
Box Culverts	Span 10 – 53 ft	Low-wide waterway enclosures, culverts, storm sewers.
Specials	Various	For lining old structures or other special purposes. Special fabrication.

*For equal area or clearance, the round shape is generally more economical and simpler to assemble.

(Corrugated Metal Shapes)

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Other materials
    - Solid Wall Steel Casing
    - Cast and Ductile Iron
    - Masonry
    - Timber

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Culvert Systems and Components

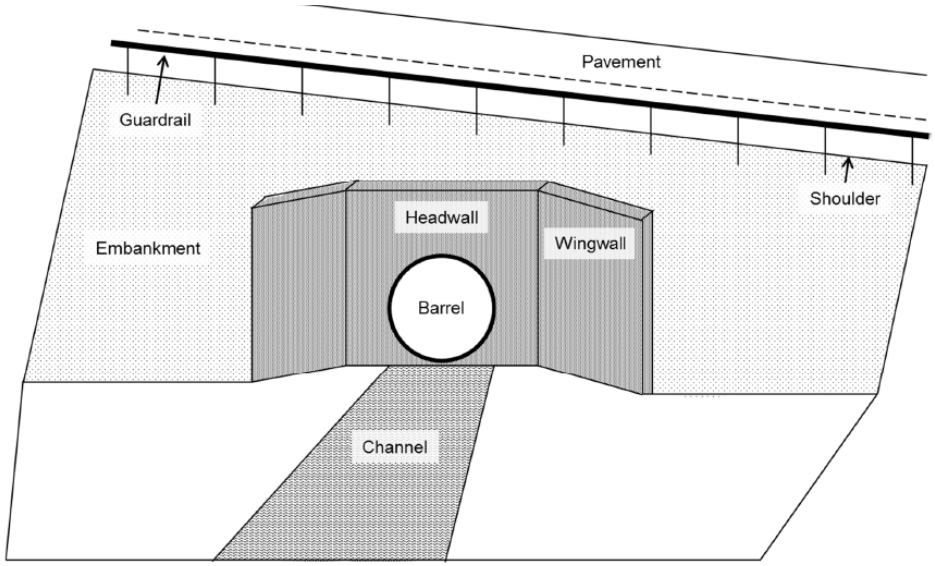

Figure A.3-1 – Culvert System Components

Figure A.3-6 – Headwall (Arrow 1) and Wingwall (Arrow 2) on Concrete Box

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Culvert Systems and Components
    - Inlet and Outlet End Treatments

Figure A.3-5 – Apron (also called Flared End Section) on Corrugated Metal Pipe

Energy Dissipator

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Culvert Systems and Components
    - Foundations

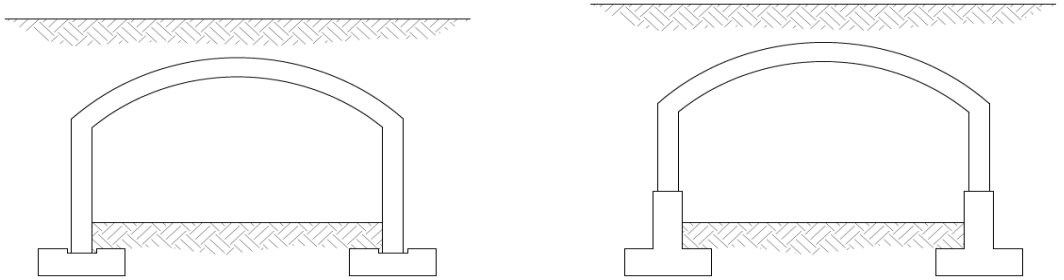

Figure A.3-8 – Typical Reinforced Concrete Spread Footing Foundations (Left: Spread Footing, Right: Pedestal Footing)

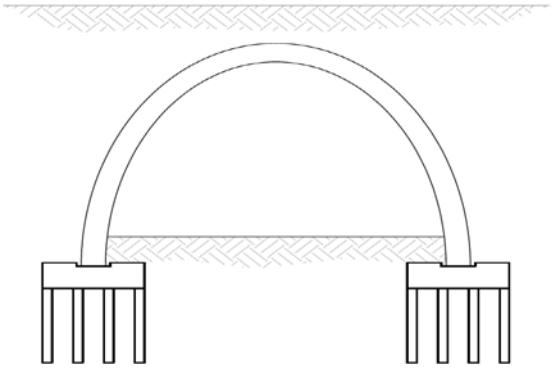

Figure A.3-10 – Typical Pile Foundation

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components – Appendix A
  - Storm Drain Systems and Components

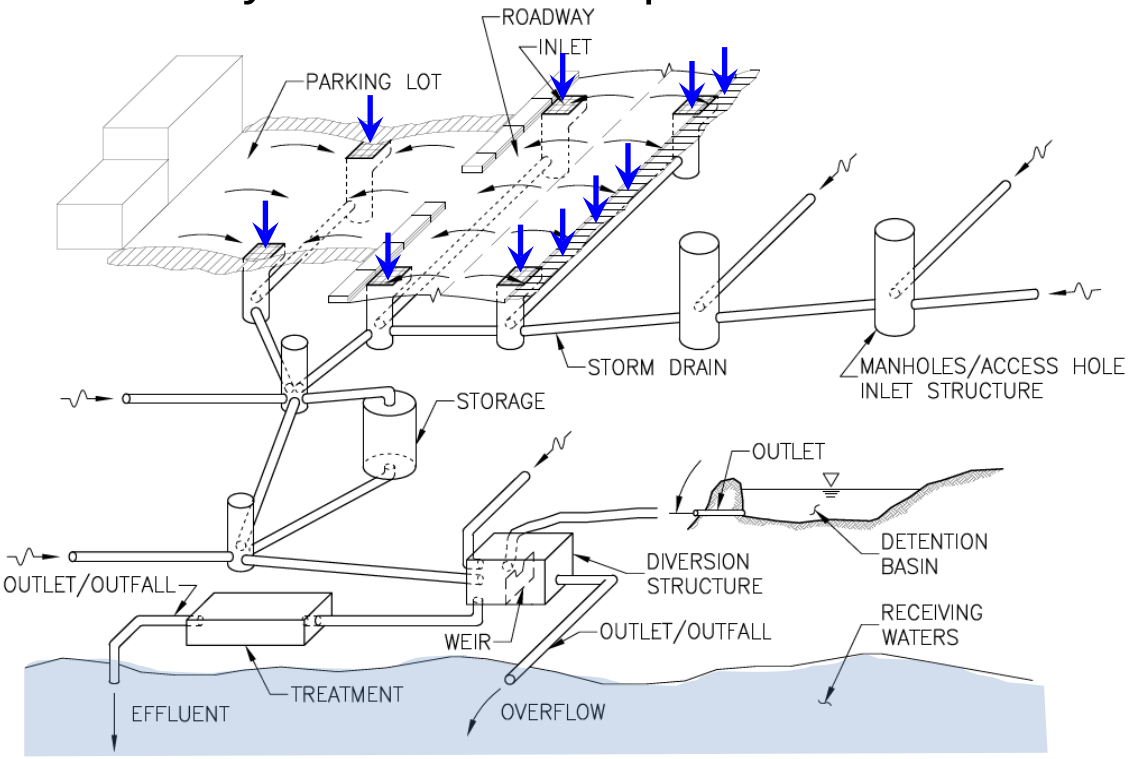

Figure A.4-1 – Storm Drain System Components

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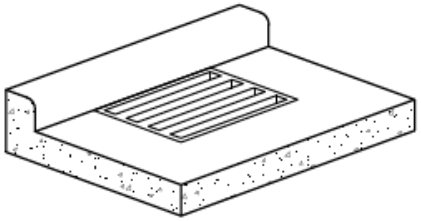
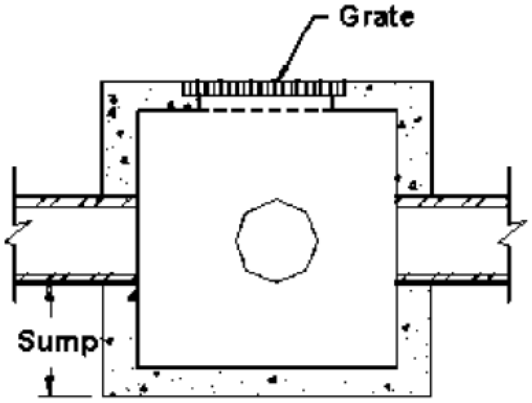
Culvert and Storm Drain System Inspection Manual:
Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components
  - Storm Drain Systems and Components
    - Stormwater Collection
    - Stormwater Conveyance
    - Stormwater Best Management Practices (BMPs)

Curb and Gutter



Grate Inlet



Catch Basin Inlet Structure

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Culvert and Storm Drain System Inspection Manual: Section 2 – Design and Performance Characteristics

- Culvert and Storm Drain Shapes and System Components
  - Pipe Coatings and Linings
    - Nonstructural Pipe Coatings and Linings
      - Cement Mortar, Bituminous, Epoxy, Galvanized, Polymer, Invert Paving, Internal Joint Bands
    - Structural Pipe Linings
      - Sliplining, Multi-Plate or Structural Plate, Fold-and-Form PVC, Cured-in-Place Pipe (CIPP), Spray-Applied, Spiral Wound, Swagelining and Rolldown, Pipe Bursting and Splitting

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Culvert and Storm Drain System Inspection Manual:

Section 3 – Inspection Procedure

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Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Subsections Include:
  - General
  - Purpose and Scope of Inspections
  - Inspection Frequency
  - Preparation and Planning
  - Types of Inspections
  - Types of Entry
  - Inspection Team Role and Qualifications
  - Inspection Equipment
  - Recording the Inspection
  - Safety
  - Inspection Quality Control and Quality Assurance

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Culvert and Storm Drain System Inspection Manual: Section 3 – Inspection Procedure

- Purpose
  - Assess the condition of the entire culvert or storm drain system
    - Structural issues
    - Materials issues
    - Service performance
  - Make accurate ratings that are repeatable by other inspectors
  - Collect data to be included in an agency's asset management system
    - Used for maintenance, repair, and rehabilitation decisions/budgets
  - Collect data that assess roadway safety for the traveling public

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Culvert and Storm Drain System Inspection Manual: Section 3 – Inspection Procedure

- Scope of Inspections
  - All culverts and storm drains in an agency's inventory
  - All systems should be inventoried upon installation or when creating an asset management system
  - Many culverts may not require routine inspection
    - Small diameter pipes, low traffic areas
  - Each agency should define its inspection program in terms of:
    - Inspection frequency
    - Characteristics of culverts to be inventoried and inspected (importance)
    - The information to be collected

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Culvert and Storm Drain System Inspection Manual: Section 3 – Inspection Procedure

- Inspection Frequency
  - Culverts with spans > 20 ft are bridges (NBIS inspection every 2 years)
  - This manual recommends similar frequency for spans > 10 ft
    - Similar to bridges, but less data collected
  - Recommended minimum frequency by barrel span and condition rating

Table 3.3-1 – Inspection Frequency for Routine Inspections

Barrel Size (S)	Inspection Frequency (Ratings ≤ 2)	Inspection Frequency (Ratings ≥ 3)
New Installation (S > 1 ft)	Inspect annually for the first 2 years after construction.	N/A
S ≤ 1 ft	No routine inspection required. Inspect during roadway maintenance activities.	No routine inspection required. Inspect during roadway maintenance activities.
1 ft < S ≤ 4 ft	Every 10 years or prior to routine roadway maintenance activities, whichever is less.	At least every 5 years and with routine roadway maintenance activities.
4 ft < S ≤ 10 ft	Every 5 years or prior to routine roadway maintenance activities, whichever is less.	At least every 2 years and with routine roadway maintenance activities.
S > 10 ft	Every 2 years	At least every 2 years and with routine roadway maintenance activities.

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Culvert and Storm Drain System Inspection Manual: Section 3 – Inspection Procedure

- Types of Inspections
  - Initial (Inventory) Inspection
    - Detailed first inspection establishes agency inventory record
    - Baseline for future comparison
    - Provide data required for agency asset management decisions
  - **Routine Inspection**
    - On defined frequency, visual and non-destructive measurements to assess condition and assign ratings
    - Note changes to inventory baseline
    - Track how components are functioning and aging
  - Special Inspection
    - Triggered by critical or failed rating in a routine inspection
    - Research to monitor new materials, special detailing, etc
  - Damage Inspection
    - Not scheduled
    - Event-driven emergency inspection - flooding, fires, roadway sinkholes, traffic accidents
    - Determine if emergency restrictions/closures/critical repairs are required

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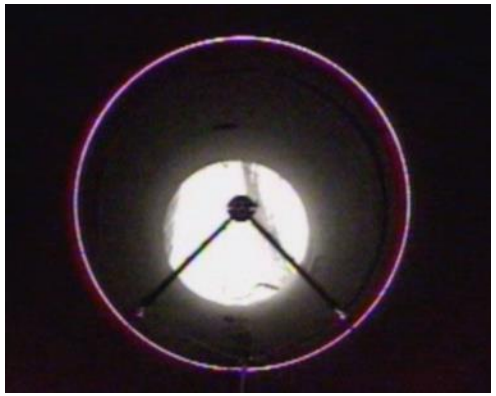
Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Types of Entry
  - Person-Entry Internal Inspection
    - Preferred
    - Component ratings require close-up inspection
    - Must follow OSHA and local confined space entry procedures
  - Non-Entry Internal Inspection
    - Visually examine structure from both ends
    - Not as thorough as person-entry
    - Useful for high flows, deep sedimentation, smaller diameters
    - Identifies significant problems (not detailed problems) in barrel, etc
    - Outlet observations may be representative of worst-case abrasion, etc
  - Remote-Entry Internal Inspection
    - When internal inspection is necessary but person-entry is not practical
      - Small diameter, deep sedimentation, deep water, closed-end conduits
    - Preferred to have video plus other specialized measurement equipment



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Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Inspection Team Roles & Qualifications
  - Roles and qualifications for culvert and storm drain inspection are based on National Bridge Inspection Standards
    - *Program Manager* supervises multiple inspection teams
    - *Inspector* is responsible signatory for each inspection
    - *Assistant Inspector* performs day-to-day routine inspections

  - Training by the manual and on-the-job experience
    - Understanding of design, soil-structure-interaction, failure modes, system function, and hydraulic performance
    - Working knowledge of the manual condition rating system
    - Ability to read plans and construction documents
    - Basic hand-drafting (sketching) abilities
    - Working knowledge of inspection tools, application, limitations
    - Competency for highway and site safety including confined spaced
  - Physical Ability

    - Be prepared to work in demanding conditions including cramped spaces, rugged terrain, steep embankments, in and around water
    - Able to carry tools and equipment

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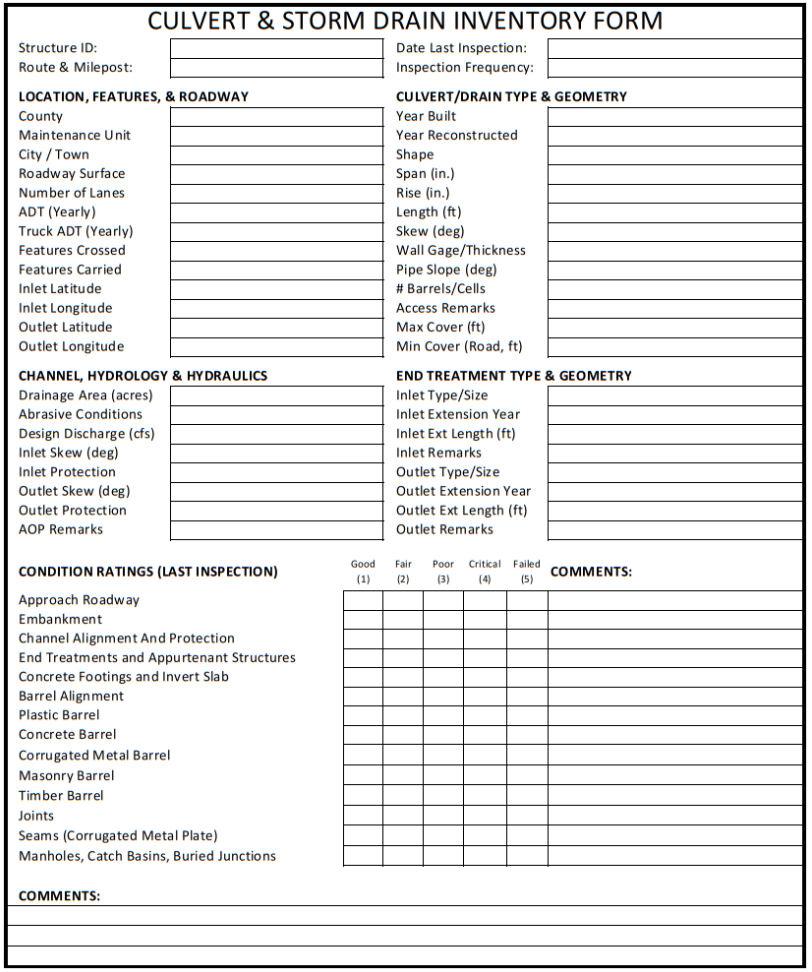
Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Recording the Inspection
  - Inventory Record
    - Location, type, span, etc
    - Road and stream/feature crossed by the structure
    - Assigned structure identification number
    - Design and installation records
  - If no inventory data is available on existing culverts, establish guidelines to prioritize collection methods for maintenance and construction staff



CULVERT & STORM DRAIN INVENTORY FORM

Structure ID:		Date Last Inspection:	
Route & Milepost:		Inspection Frequency:	

LOCATION, FEATURES, & ROADWAY		CULVERT/DRAIN TYPE & GEOMETRY	
County		Year Built	
Maintenance Unit		Year Reconstructed	
City / Town		Shape	
Roadway Surface		Span (in.)	
Number of Lanes		Rise (in.)	
ADT (Yearly)		Length (ft)	
Truck ADT (Yearly)		Skew (deg)	
Features Crossed		Wall Gage/Thickness	
Features Carried		Pipe Slope (deg)	
Inlet Latitude		# Barrels/Cells	
Inlet Longitude		Access Remarks	
Outlet Latitude		Max Cover (ft)	
Outlet Longitude		Min Cover (Road, ft)	

CHANNEL, HYDROLOGY & HYDRAULICS		END TREATMENT TYPE & GEOMETRY	
Drainage Area (acres)		Inlet Type/Size	
Abrasive Conditions		Inlet Extension Year	
Design Discharge (cfs)		Inlet Ext Length (ft)	
Inlet Skew (deg)		Inlet Remarks	
Inlet Protection		Outlet Type/Size	
Outlet Skew (deg)		Outlet Extension Year	
Outlet Protection		Outlet Ext Length (ft)	
AOP Remarks		Outlet Remarks	

CONDITION RATINGS (LAST INSPECTION)	Good (1)	Fair (2)	Poor (3)	Critical (4)	Failed (5)	COMMENTS:
Approach Roadway						
Embankment						
Channel Alignment And Protection						
End Treatments and Appurtenant Structures						
Concrete Footings and Invert Slab						
Barrel Alignment						
Plastic Barrel						
Concrete Barrel						
Corrugated Metal Barrel						
Masonry Barrel						
Timber Barrel						
Joints						
Seams (Corrugated Metal Plate)						
Manholes, Catch Basins, Buried Junctions						

COMMENTS:

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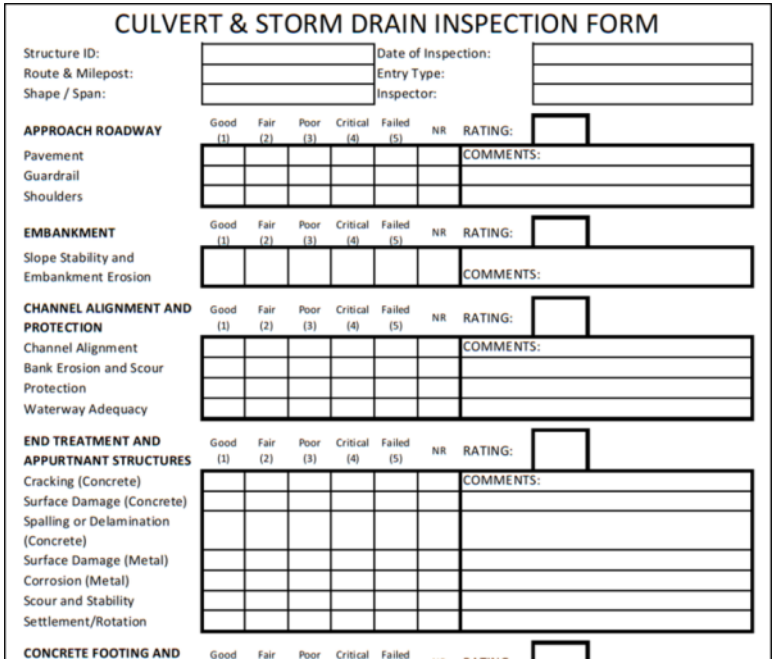
Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Recording the Inspection
  - Inspection Record
    - Standardization is important
    - Agencies should have standard forms to suit their asset management needs
    - Forms should include space for:
      - Relevant data from previous inspections (identify components that may need particular attention)
      - Fields for different features
      - Sketches and narrative description
      - Photos/photo references
      - Condition ratings/comments



CULVERT & STORM DRAIN INSPECTION FORM

Structure ID: | Date of Inspection:
Route & Milepost: | Entry Type:
Shape / Span: | Inspector:

	Good (1)	Fair (2)	Poor (3)	Critical (4)	Failed (5)	NR	RATING:
APPROACH ROADWAY							
Pavement							COMMENTS:
Guardrail							
Shoulders							
EMBANKMENT							RATING:
Slope Stability and Embankment Erosion							COMMENTS:
CHANNEL ALIGNMENT AND PROTECTION							RATING:
Channel Alignment							COMMENTS:
Bank Erosion and Scour Protection							
Waterway Adequacy							
END TREATMENT AND APPURTNANT STRUCTURES							RATING:
Cracking (Concrete)							COMMENTS:
Surface Damage (Concrete)							
Spalling or Delamination (Concrete)							
Surface Damage (Metal)							
Corrosion (Metal)							
Scour and Stability							
Settlement/Rotation							
CONCRETE FOOTING AND	Good	Fair	Poor	Critical	Failed		

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Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Preparation and Planning
  - Organize and schedule inspections while considering:
  - Review Data from Previous Inspections
  - Develop an Inspection Sequence
  - Use a Checklist or Developed Procedure

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Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Safety
  - Requires a thorough safety plan and training
    - OSHA and state- or jurisdiction-specific
    - 22 states currently have their own OSHA-approved plans
  - Topics include:
    - Confined space entry (permit, non-permit)
    - Traffic hazards
    - Drowning hazards
    - Rugged terrain
    - Animals and insects
    - Poisonous plants
    - Equipment safety
    - Miscellaneous hazards (fire, floods, chemical spills, quicksand, etc)

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Culvert and Storm Drain System Inspection Manual:
Section 3 – Inspection Procedure

- Inspection Quality Control/Quality Assurance
  - Program purpose:
    - Maintain a minimum level of consistent quality
    - Accurate and repeatable across teams and across the agency inventory is critical for asset management
  - Framework for a QA/QC Program

  - PLAN, DO, CHECK, ACT
    - Basis of ISO 9001 quality management system
    - PLAN: annual meeting prior to inspections, review QA/QC program and update accordingly
    - DO: perform inspections in accordance with QA/QC program
    - CHECK/STUDY: study the results, plan for improved performance, reevaluate PLAN phase
    - ACT: follow up on all changes and issues, make corrective actions to address deficiencies

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Culvert and Storm Drain System Inspection Manual:

Section 4 – Condition Rating System

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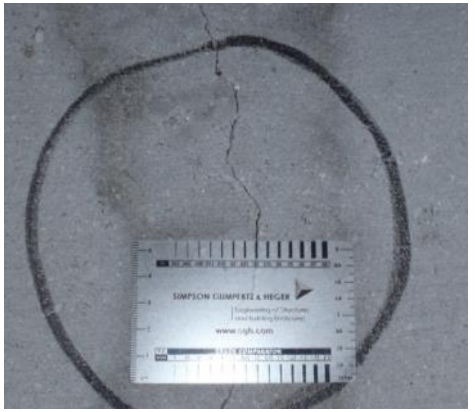
Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Subsections Include:
  - Use of the Condition Rating System
  - Approach Roadway
  - Embankment
  - Channel
  - End Treatments and Appurtenant Structures
  - Concrete Footing and Invert Slab
  - Barrel Alignment
  - Plastic, Concrete, Corrugated Metal, Masonry, and Timber Barrels
  - Joints and Seams
  - Storm Drain System Components
  - Manholes, Catch Basins, Buried Junctions
  - Aquatic Organism Passage



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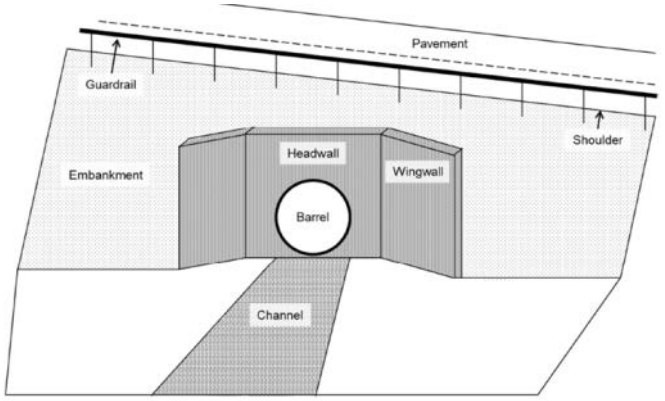
Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System



- Use of the Condition Rating System
  - Scale of 1 to 5
    - 1 (Good) is like new, little or no deterioration, structurally sound, functionally adequate
    - 5 (Failed) indicates component failure
  - Ratings based on comparison of the existing condition with the as-designed condition and are assigned before leaving the site
  - Each component gets a rating
    - The poorest characteristic rating (highest number) determines the component rating
    - Where quantified criteria are provided, measurements may be required
    - If the provided table criteria are not adequate, judgement and experience may be used to assign a rating
  - Appendix B Catalog of Distressed Conditions shows photographs of varying levels of distress severity to allow assignment of consistent ratings

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Use of the Condition Rating System
  - Ratings are tied to specific actions

	RATING SCALE AND ASSOCIATED ACTION				
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
CONDITION	Like new, with little or no deterioration, structurally sound and functionally adequate.	Some deterioration, but structurally sound and functionally adequate.	Significant deterioration and/or functional inadequacy, requiring maintenance or repair.	Very poor conditions that indicate possible imminent failure which could threaten public safety.	Failed or non-functional condition.
ACTION INDICATED	**No action** is recommended. Note in inspection report only.	**No immediate action** is recommended, but more frequent inspection may be warranted. Maintenance should be informed.	Team Leader (Inspector) **evaluates need for corrective action** and makes recommendation in inspection report.	**Corrective action is required** and urgent. Engineering evaluation is recommended to specify appropriate repair.	**Emergency action is required** to address public safety hazard. Roadway closure is typical.

Rating No.	Condition	Action
1	Good	No Action
2	Fair	No Immediate Action, More Frequent Inspection, Inform Maintenance
3	Poor	**Evaluate the Need for Corrective Action**
4	Critical	**Corrective Action is Required**, Engineering Evaluation Recommended
5	Failed	**Emergency Action is Required**

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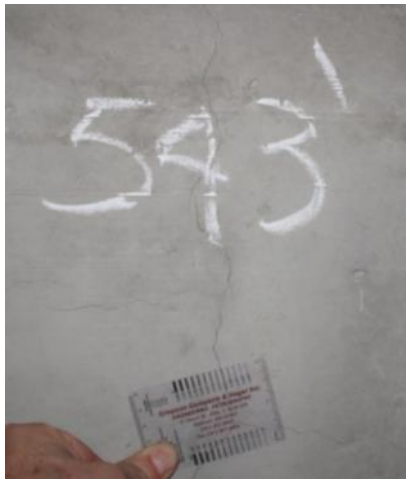
Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Use of the Condition Rating System
  - Documentation Convention
    - Distress Severity
      - Document severity, extent, and location of significant and typical distress
      - Include photos and sketches as necessary
      - Adequate for follow-up inspections
    - Distress Location
      - Use offsets (stationing) from outlet end
      - Use clock positions looking upstream from outlet or offsets from corners of box culvert, etc
    - Joint Distress
      - Identify offset/stationing rather than counting joint numbers to allow for location identification after lining, barrel extensions, etc



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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Component Condition Rating Tables provided for :
  - Approach Roadway
  - Embankment
  - Channel Alignment and Protection
  - End Treatments and Appurtenant Structures
  - Concrete Footings and Invert Slab
  - Barrel Alignment
  - Barrel Material
    - Plastic Barrel
    - Concrete Barrel
    - Corrugated Metal Barrel
    - Masonry Barrel
    - Timber Barrel
  - Joints
  - Seams
  - Manholes, Catch Basins, Buried Junctions

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Approach Roadway
  - Purpose
    - Identify distress indicators in roadway for the structure below
    - Alerts inspector to possible issues with culvert or storm drain below
  - Distress indicators:
    - cracking, humps or sags, patches, settlement

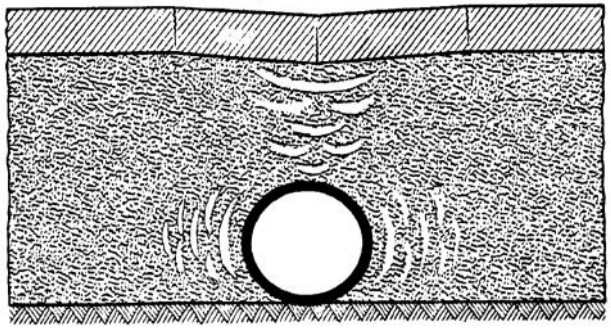

Figure 4.3-2 – Pavement Failure Due to Inadequate Embedment Soil Compaction or Low-Quality Embedment Soil Adjacent to Flexible Pipe

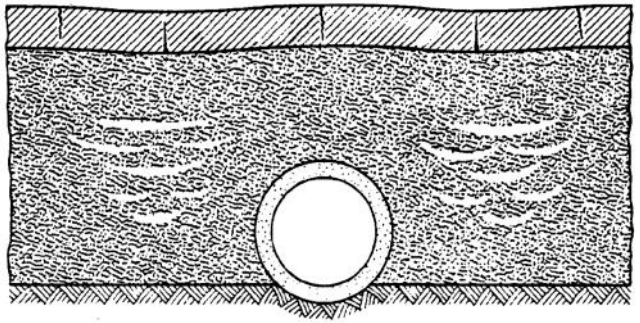

Figure 4.3-3 – Pavement Failure Due to Inadequate Compaction or Low-Quality Fill Soil Adjacent to Rigid Pipe

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Approach Roadway

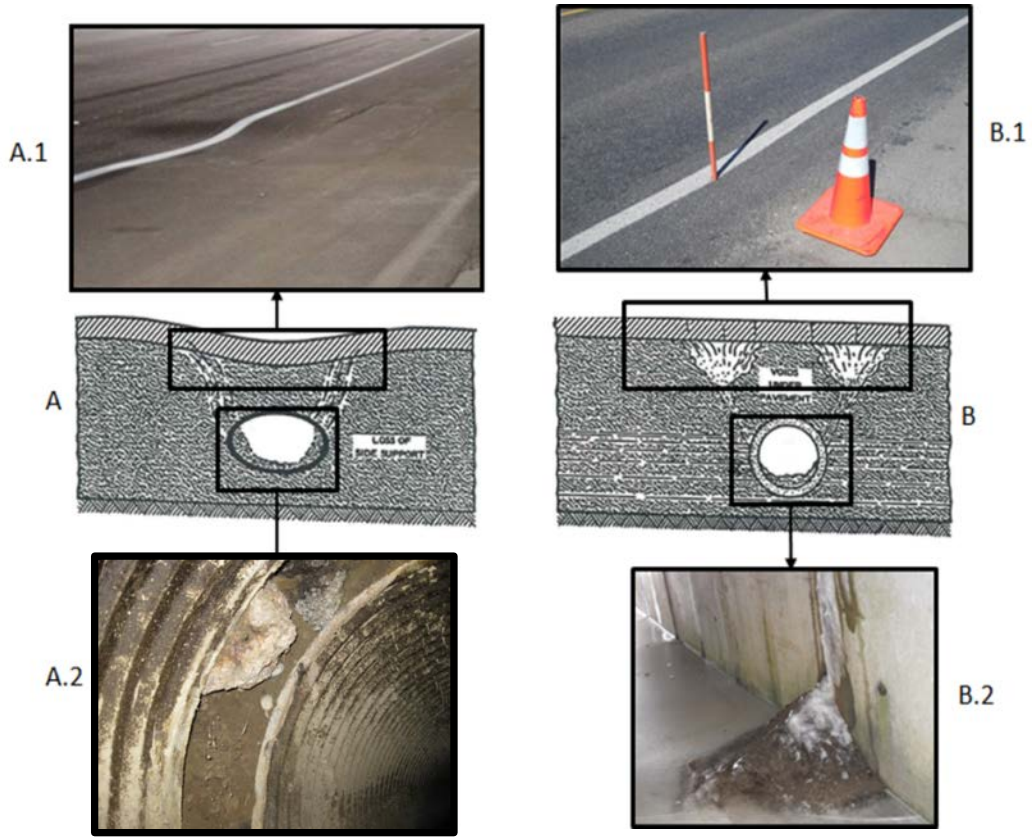

Figure 4.3-4 – (A) Backfill Loss Beneath Pavement Causing Sag in the Approach Roadway (A.1). (B) Large Void Beneath Pavement Due to Backfill Loss, Discovered by Probing Small Hole (B.1). These distress indicators should alert the inspector to check for evidence of backfill infiltration inside barrel (A.2 and B.2)

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Approach Roadway

Figure 4.3-5 - Bridging in Flexible Pavements

Figure 4.3-6 – Failure Due to Piping (Water flowing along outside of pipe and washing away backfill)

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Approach Roadway

Figure 4.3-7 - Left: High Severity Transverse Pavement Cracks, Right: High Severity Longitudinal Pavement Cracks

Figure 4.3-8 – Alligator Cracking in Pavement

Figure 4.3-9 - Misalignment of Guardrail at Culvert Outlet (Note also patching of pavement, cracking and sagging at same location)

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Approach Roadway

APPROACH ROADWAY					
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
PAVEMENT	All areas of potential distress to paving, guardrail, and shoulders are in good condition for a minimum length of 20 ft either side of crossing culvert or full length of storm drains. Sags or humps less than 1/8 in. over 10 ft. Guardrail generally aligned and plumb. No displacement of posts due to settlement or sliding of shoulder.	Low severity transverse pavement cracks (less than ¼ in. wide). Low severity sags or humps less than 2 in. over 10 ft over culvert barrel.	Rutting in wheel paths localized over culvert/storm drain. Evidence of repeated patching. Medium severity transverse pavement cracks greater than ½ in. wide. Medium severity sags or humps (up to 4 in. over 10 ft) over culvert barrel.	High severity transverse or longitudinal cracks greater than ½ in. wide. with raveling of pavement over the culvert or storm drain. High severity sags or ruts with voids beneath pavement.	Collapsed pavement over culvert or storm drain (complete or partial).
GUARDRAIL		Slight misalignment of posts due to settlement or sliding of shoulder.	Misalignment and medium severity settlement/sag or rotation of posts due to ground movement (not due to impact damage).	High severity settlement/sags or rotation of posts due to ground movement (not due to impact damage). Guardrail may be ineffective.	Collapsed guardrail (complete or partial).
SHOULDERS		Low severity sag over culvert/storm drain. Low severity cracking local to shoulder.	Settlement around catch basins. Evidence of repeated patching. Moderate severity cracking (transverse or longitudinal)	High severity transverse or longitudinal cracking and/or sags over culvert/storm drain. Voids in roadway in vicinity of culvert (piping or infiltration). Soil cracking or slope movement in shoulder area.	Loss of shoulder pavement; shoulder soil movement presents immediate safety hazard to traffic.
			Evaluate Need for Action	Corrective Action Required	Emergency Action Required

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Embankment
  - Purpose
    - Identify distress indicators in roadway for the structure below
    - Alerts inspector to possible issues with culvert or storm drain below
  - Look for sloughing, erosion, rill, gullying, etc

Figure 4.4-1 - Embankment Sloughing

Figure 4.4-2 – Moderate Sheet Erosion on Steep Embankment

Figure 4.4-3 – Minor Rill from Roadway Runoff

Figure 4.4-4 – Severe Gullying with Severe Sheet Erosion

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Channel
  - Purpose
    - Identify channel-related problems that may affect performance or structural stability of the culvert
    - Identify issues that may affect ability to handle design flow

Figure 4.5-2 – Bank erosion adjacent to culvert

  - Look for alignment changes, bank erosion/scour, issues with channel protection, issues with water adequacy (non-AOP)

Figure 4.5-1 – Change in stream alignment causing flow to be directed into wingwall

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- End Treatments and Appurtenances
  - Purpose
    - Identify conditions that may relate to their structural stability, hydraulic performance, and traffic safety characteristics
  - Look for projecting ends, changes to prefabricated end treatments, issues with headwalls/spandrel walls/wingwalls, issues with aprons and flumes, debris accumulations, and issues with weep holes, etc

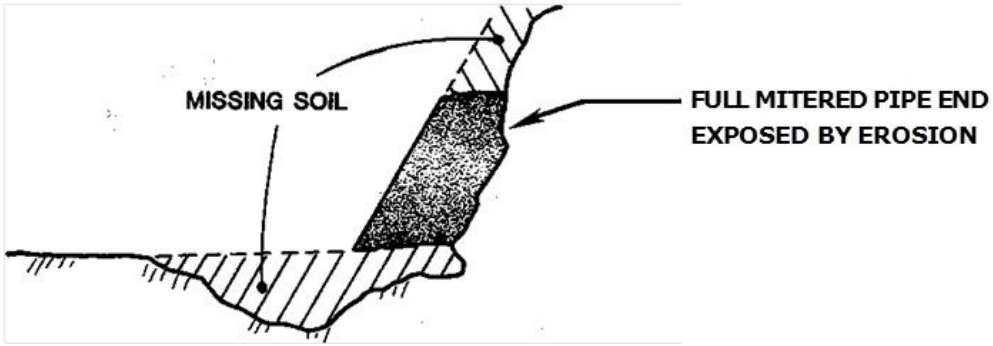

Figure 4.6-2 – Erosion Around Mitered End Section (Photo shows erosion on sides and below mitered end section)

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- End Treatments and Appurtenances

Figure 4.6-3 – End section drop-off due to erosion under projecting end

Figure 4.6-5 – Separation of Headwall and Culvert Pipe

Figure 4.6-4 – Deformation of Prefabricated End Sections

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Concrete Footing and Invert Slab
  - Purpose
    - Identify distress and distress indicators that result in foundation problems for three-sided and other structures.
  - Look for differential settlement, scour, concrete deterioration, etc.

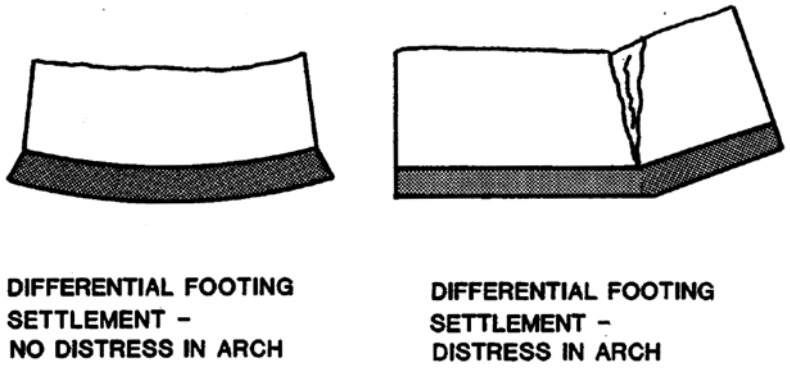

Figure 4.7-1 – Differential Footing Settlement

Figure 4.7-2 – Differential Settlement of Footing Supporting Corrugated Metal Arch

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Concrete Footing and Invert Slab

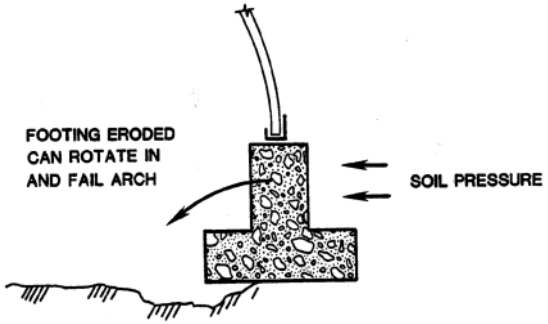

Figure 4.7-3 – Footing Rotation

Figure 4.7-2 – Differential Settlement of Footing Supporting Corrugated Metal Arch

Figure 4.7-5 – Severe scour undermining wing wall foundation

Figure 4.7-6 – Invert slab in critical condition due to severe degradation of concrete

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Barrel Alignment
  - Purpose
    - Identify misalignment of pipe segments and may reduce hydraulic performance or lead to structural problems.
  - Look for vertical misalignments (sag, pooled water), sheared joints, etc.

Figure 4.8-1 – Severe visible sag in vertical alignment causing ponding

Figure 4.8-2 – Severe vertical misalignment has dislodged pipe segment resulting in joint offset and loss of support to embedment soil

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Barrel Alignment

BARREL ALIGNMENT					
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
BARREL ALIGNMENT	Horizontal alignment shows no signs of movement from installed condition (straight or smooth bends). Vertical alignment shows no sagging or heaving.	Horizontal alignment shows small visible deviations from installed condition that does not affect joints or barrel. Vertical alignment has minor sagging or heaving.	Horizontal alignment with deviations from installed condition that may affect joints or barrel (refer to joint inspection). Vertical misalignment causing ponding / sediment accumulation at sags between 10% and 30% of diameter.	Distress at joints or in barrel due to vertical or horizontal misalignment with pipe section offsets. Vertical misalignment has caused ponding/sediment accumulation of more than 30% of diameter. Indication of significant flow restriction.	Cannot cause failed rating.
			Evaluate Need for Action	Corrective Action Required	N/A

- Barrel structure ratings evaluated separately

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System

- Concrete Barrel
  - What to look for:
    - Cracking
      - Longitudinal
      - Circumferential
      - Radial Offsets
    - Spalling
    - Delamination
    - Slabbing
    - Deterioration
    - Clogged Weep Holes

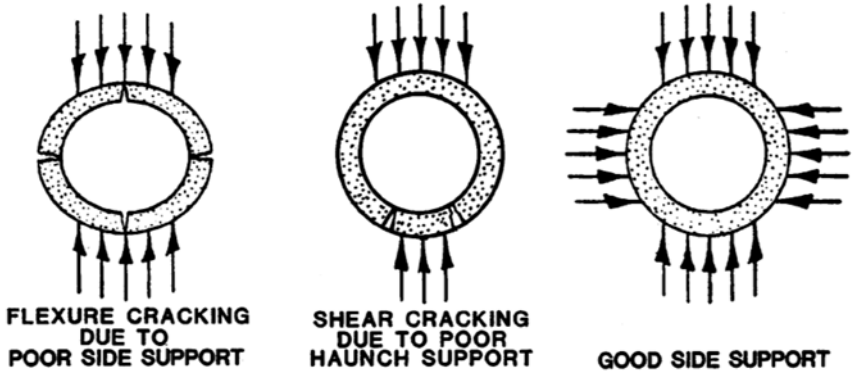

Figure 4.10-1 – Results of Poor and Good Side Support in Rigid Pipe

Figure 4.10-2 – Pipe with Critical Longitudinal Cracks with Rust Staining and Efflorescence

Figure 4.10-3 – Cracks with Radial Offset

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Barrels

- Concrete Barrel

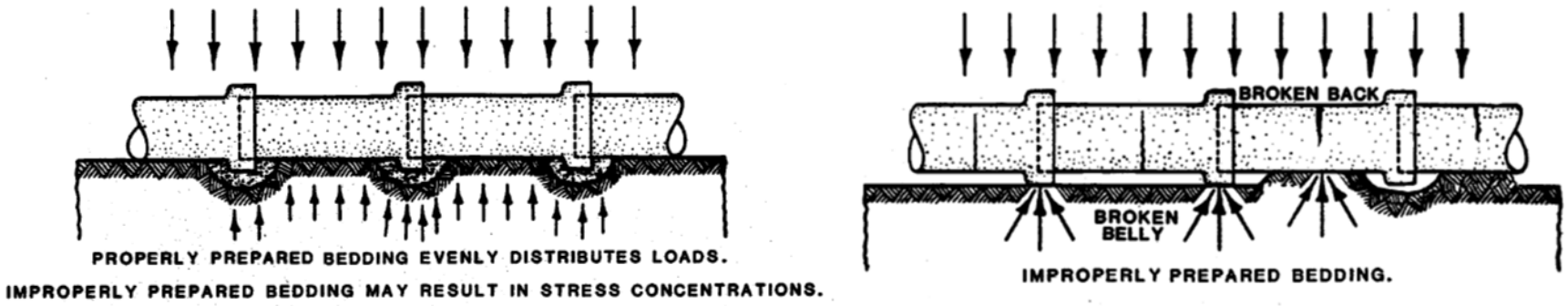

Figure 4.10-4 – Transverse or Circumferential Cracking due to Poor Bedding Conditions

Figure 4.10-4 – Left: Small Spall along Crack, Right: Large Spall with Exposed/Corroded Rebar

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Barrels

- Concrete Barrel

Figure 4.10-5 – Delaminated Area Marked on Pipe Wall, Located by Sounding with Hammer

Figure 4.10-6 – Slabbing in concrete pipe

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Barrels

- Concrete Barrel

Figure 4.10-7 – Severe Freeze-Thaw Deterioration with Stand-Out Aggregate and Pop Outs

Figure 4.10-8 – Moderate Deterioration (Probable Chemical Attack) with Exposed Aggregate and Loss of Surface Mortar

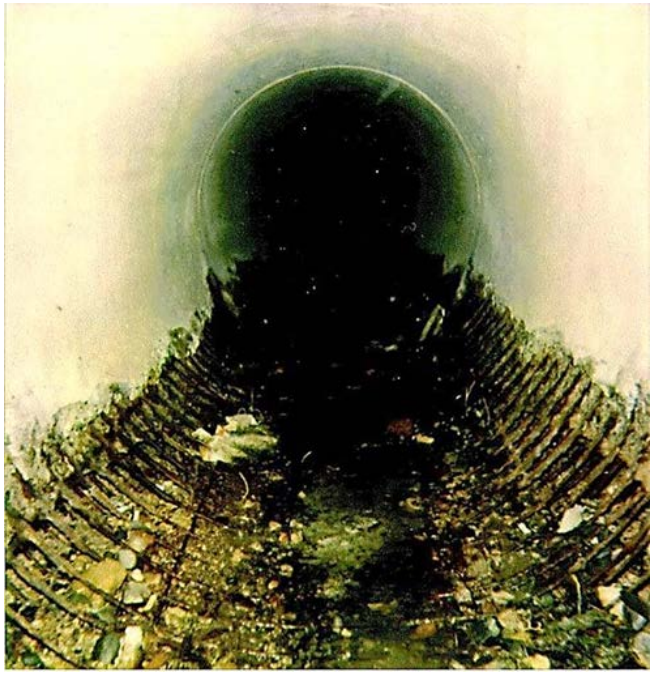

Figure 4.10-9 – Severe Deterioration (Probable Chemical Attack) with Complete Loss of Invert

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Barrels

- Concrete Barrel Rating Table – Overview

Appendix B Example

CONCRETE BARREL					
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
CRACKING	No measurable crack width greater than hairline (maximum 0.01 in.).	Longitudinal cracks 0.01 in. to 0.05 in. wide (thickness of dime) with spacing of 3.0 ft or more. Some circumferential cracks with no infiltration. Efflorescence but no rust staining emanating from cracks.	Longitudinal cracks between 0.05 in. and 0.1 in. wide, no exposed rebar with spacing 1.0 – 3.0 ft. Water infiltration through circumferential cracks. Efflorescence and/or rust staining emanating from cracks. No cracks with vertical offset. No increase in cracking from previous inspection.	Longitudinal cracks greater than 0.1 in. wide, exposed rebar, significant water infiltration and/or soil migration. Cracks with vertical offset. Large areas of rust staining emanating from cracks.	Collapse (complete or partial) or imminent collapse of culvert barrel.
SLABBING, SPALLING, DELAMINATION, PATCHES	No spalling or slabbing, as indicated by wall visual appearance. No delamination. Patched areas that are sound.	Localized spalls less than ½ in. depth and less than 6 in. in diameter. No exposed rebar. No slabbing. Small delaminations indicated by hollow sounds at patches but patch remains stable.	Spalling and/or delaminations larger than ¾ in. in depth and larger than 6 in. in diameter. No exposed rebar. Some rust staining from spalled areas, structure stable. No slabbing. Patched areas that are delaminated or deteriorating.	Widespread spalling greater than ¾ in. in depth or delamination with exposed rebar, structure unstable. Slabbing of concrete.	Cannot cause failed rating.
DETERIORATION	No scaling, abrasion, or other surface damage.	Light or moderate scaling (less than 0.25 in. exposed aggregate). Abrasion less than 0.25 in. deep over less than 20% of pipe surface. Localized superficial (less than 0.25 in.) impact damage No rebar exposed. Multiple plugged weep holes.	Moderate to severe scaling (aggregate clearly exposed). Abrasion between 0.25 in. and 0.5 in. deep over more than 30% of pipe surface. Impact damage with exposed rebar.	Extensive surface damage and aggregate pop-out. Includes exposed and/or corroded rebar. Complete invert deterioration and loss of pipe wall section.	Collapse (complete or partial) or imminent collapse of culvert barrel.

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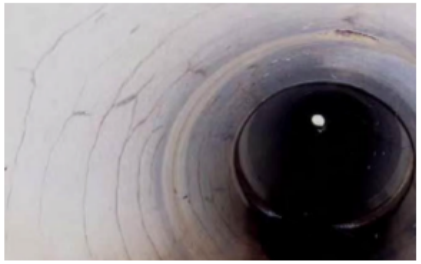
Culvert and Storm Drain System Inspection Manual:
Appendix B – Catalog of Distressed Conditions

2
FAIR
Longitudinal cracks 0.01 in. to 0.05 in. wide (thickness of dime) with spacing of 3.0 ft or more. Some circumferential cracks with no infiltration. Efflorescence but no rust staining emanating from cracks.

CONCRETE BARREL

Cracking

Fair: Longitudinal cracks 0.01 in. to 0.05 in. wide (thickness of dime) with spacing of 3.0 ft or more. Some circumferential cracks with no infiltration. Efflorescence but no rust staining emanating from cracks.



Courtesy of Delaware Department of Transportation

Longitudinal cracks less than 0.01 in. Some circumferential cracks with no infiltration.

Courtesy of Simpson Gumpertz & Heger

Crack width less than 0.05 in. with spacing greater than 3.0 ft.

Courtesy of Simpson Gumpertz & Heger

Efflorescence through cracks less than 0.05 in.

3
POOR
Longitudinal cracks between 0.05 in. and 0.1 in. wide, no exposed rebar with spacing 1.0 – 3.0 ft. Water infiltration through circumferential cracks. Efflorescence and/or rust staining emanating from cracks. No cracks with vertical offset. No increase in cracking from previous inspection.

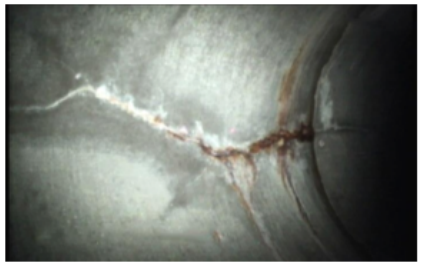
Poor: Longitudinal cracks between 0.05 in. and 0.1 in. wide, no exposed rebar with spacing 1.0 – 3.0 ft. Water infiltration through circumferential cracks. Efflorescence and/or rust staining emanating from cracks. No cracks with vertical offset. No increase in cracking from previous inspection.

Courtesy of Kentucky Transportation Center

Longitudinal cracks between 0.05 in. and 0.1 in., no exposed rebar. Minor water infiltration through cracks.

Courtesy of Kentucky Transportation Center

Longitudinal cracks at crown and springline up to 0.1 in.



Courtesy of Kentucky Transportation Center

Cracks up to 0.1 in. with efflorescence and rust staining.

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Culvert and Storm Drain System Inspection Manual:
Appendix B – Catalog of Distressed Conditions

4
CRITICAL
Longitudinal cracks greater than 0.1 in. wide, exposed rebar, significant water infiltration and/or soil migration. Cracks with vertical offset. Large areas of rust staining emanating from cracks.

CONCRETE BARREL

Cracking

Critical: Longitudinal cracks greater than 0.1 in. wide, exposed rebar, significant water infiltration and/or soil migration. Cracks with vertical offset. Large areas of rust staining emanating from cracks.

Courtesy of Delaware Department of Transportation

Longitudinal cracks greater than 0.1 in., exposed rebar, significant soil migration.

Courtesy of Kentucky Transportation Center

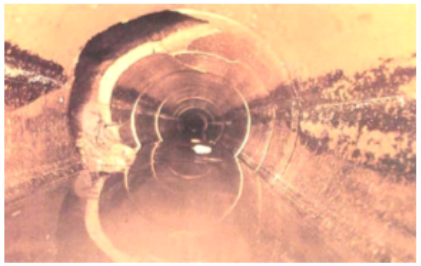
Longitudinal cracks greater than 0.1 in. with vertical offset.

Courtesy of Kentucky Transportation Center

Longitudinal cracks greater than 0.1 in., exposed rebar, significant water infiltration.

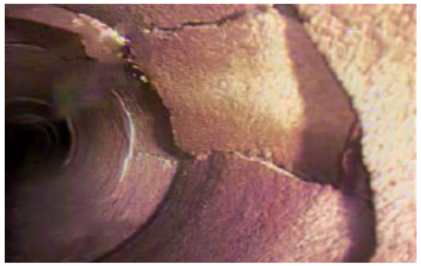
5
FAILED
Collapse (complete or partial) or imminent collapse of culvert barrel.

Failed: Collapse (complete or partial) or imminent collapse of culvert barrel.



Courtesy of Delaware Department of Transportation

Partial failure of concrete pipe.



Courtesy of Delaware Department of Transportation

Imminent collapse of barrel.

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Joints & Seams

- Joints and Seams
  - Joint Types
    - Plastic Pipe:
      - Bell and spigot, split couplers
    - Concrete Pipe:
      - Tongue and groove, bell and spigot
    - Corrugated Metal:
      - Connecting bands, bell and spigot

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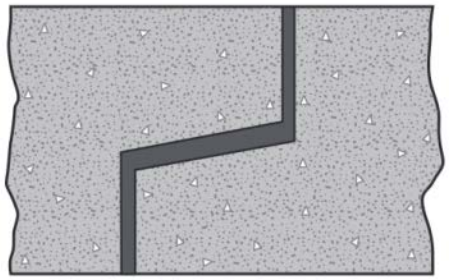
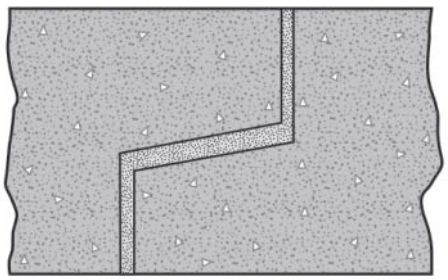
http://5oakswildlifeservices.com/?page_id=6

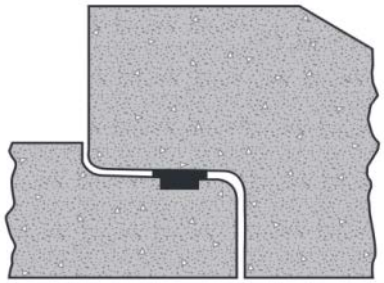


Typical cross-section of tongue and groove joint with flexible mastic sealant.

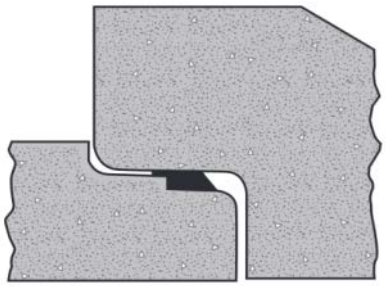


Typical cross-section of tongue and groove joint with mortar packing.

Figure 4.14-1 – Tongue-and-groove Joint



Typical cross-section of opposing shoulder type bell and spigot joint with a confined o-ring rubber gasket.



Typical cross-section of opposing shoulder type bell and spigot joint with a single offset rubber gasket.

Figure 4.14-2 – Bell-and-Spigot Joint

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Joints & Seams

- Joints and Seams
  - Joint Types
    - Plastic Pipe:
      - Bell and spigot, split couplers
    - Concrete Pipe:
      - Tongue and groove, bell and spigot
    - Corrugated Metal:
      - Connecting bands, bell and spigot, bolted

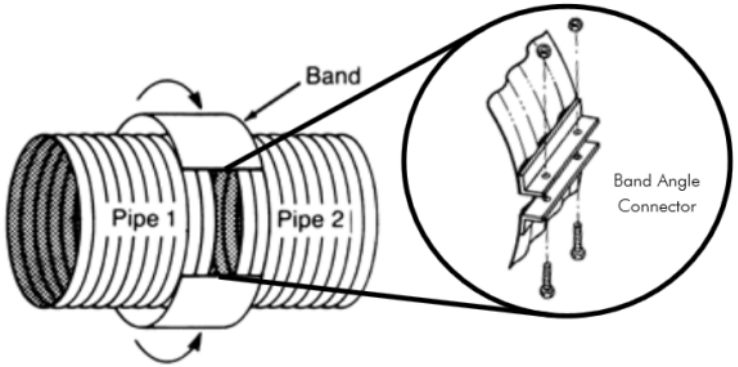

Figure 4.14-3 – Connecting Bands for CMP

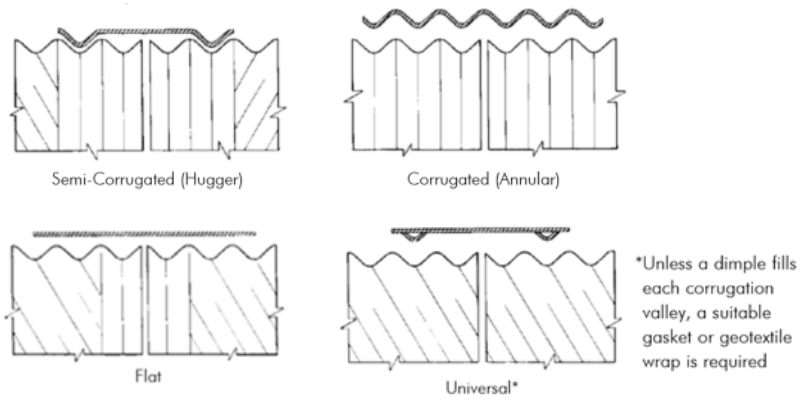

Figure 4.14-4 – Standard Connecting Bands for CMP (without gasket)

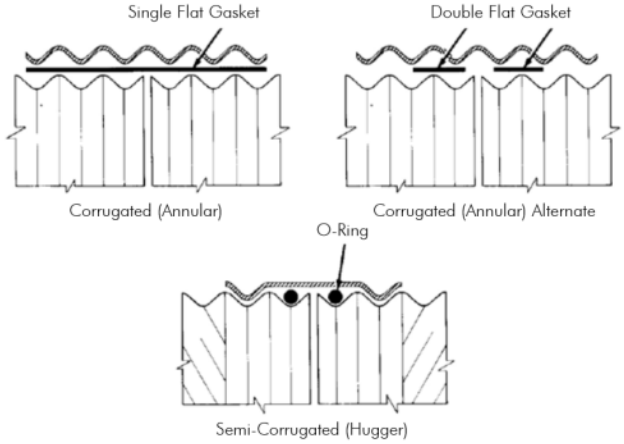

Figure 4.14-5 – Gasketed Connecting Bands for CMP

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Joints & Seams

- Joints and Seams
  - Look for joint separation, offset, rotation, cracking, spalling, infiltration/exfiltration, etc

Figure 4.14-6 – Joint Separation in Corrugated Metal Pipe with Visible Backfill

Figure 4.14-7 – Joint Offset Causing Completely Dislodged Pipe Section

Figure 4.14-9 – Water Infiltration through Joints

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Joints

- Joint Rating Table

JOINTS					
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
JOINT SEPARATION, OFFSET, AND ROTATION	Joints are tightly installed with proper alignment and functioning well.	Joint separation, offset, or rotation with no indication of distress. Gasket not exposed.	Joint separation, offset, or rotation in one or more joints, with exposed or missing gasket materials.	Joint separation, offset, or rotation with exposed backfill material. Multiple locations of exposed or missing gaskets.	Cannot cause failed rating.
JOINT CRACKING (CONCRETE)	No joint cracking.	Longitudinal cracks of 0.01 in.to 0.05 in. wide (thickness of dime) emanating from joint. No spalling.	Between 0.05 in. and 0.1 in. wide longitudinal cracks emanating from joint. Small spalls along edge of spigot end.	Greater than 0.1 in. longitudinal cracks emanating from joint. Large spalls along edge of spigot end.	
INFILTRATION AND EXFILTRATION	Joints are performing as intended with respect to infiltration and exfiltration.	Not applicable. *Joint must meet performance requirement specified in design or will rate as poor.*	Joint distress identified by coarse grained soil infiltration through soil-tight joints. Fines infiltration through silt-tight joints. Any water infiltration/exfiltration through leak resistant or watertight joint.	Joint distress directly causes distress to barrel/end section, roadway/shoulder, or embankment.	
			Evaluate Need for Action	Corrective Action Required	N/A

- Joints cannot cause failed ratings.
- Evaluation of the need for corrective action is required for:
  - Joint separations, offsets, or rotations with exposed or missing gaskets, 0.05 to 0.1 in. wide longitudinal cracks at joint, small spalls, soil or water infiltration if not meeting specified performance criteria.
- Corrective action is required for:
  - Exposed backfill, multiple locations of exposed or missing gaskets, longitudinal cracks greater than 0.1 in. width, large spalls, joint distress causing distress to the barrel or other component.

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Joints & Seams

- Seams

Figure 4.15-1 – Cocked Seam with Cusp Effect

Figure 4.15-2 – Severe Bolt Tipping in Corrugated Metal Plate

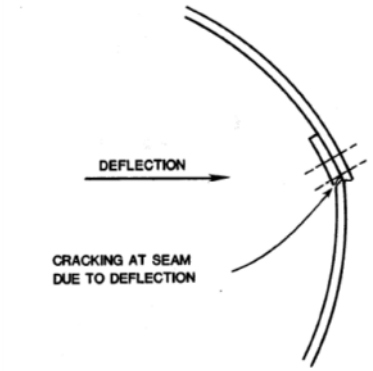

Figure 15-3 - Cracking at bolt holes

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Culvert and Storm Drain System Inspection Manual:
Section 4 – Condition Rating System: Seams

- Seam Rating Table

SEAMS OF CORRUGATED METAL PLATE					
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
INFILTRATION/ EXFILTRATION	No signs of infiltration or exfiltration.	Minor water infiltration through leak resistant seams but no soil infiltration.	Significant water infiltration and evidence of fine soils infiltrating through seams.	Coarse soil infiltration through seam openings. Possible hollow sounds behind structure wall near seams indicating loss of backfill support. Evidence of piping due to exfiltration.	Collapse (complete or partial) or imminent collapse of Structure.
SEAM ALIGNMENT	No visible misalignment.	Slight cocked seams without cusp effect, but does not affect cross section shape.	Cocked seams such that it affects cross-section shape. Cusped effect with local wall bending.	Cocked seams severely affecting cross-section shape. Cusp effect with seam cracking. Seam capacity loss imminent.	Complete separation of pipe segments such that backfill is visible.
SEAM BOLTS/ FASTENERS	No loose or missing bolts/fasteners	Less than 5% loose or missing bolts in any seam.	5% to 15% of loose or missing bolts in any seam.	Greater than 15% loose or missing bolts in any seam.	Collapse (complete or partial) or imminent collapse of Structure.
SEAM BOLT HOLES	No yielding or deformation of bolt holes. No wall prying due to bolt tipping.	Minor yielding of steel and/or cracking/splitting less than 1 in. long local to bolt holes. Minor corrosion developing around bolt holes or on bolts.	Yielding of steel and/or cracking/splitting 1 in.to 3 in. long local to bolt holes. Corrosion with section loss around bolt holes or on bolts.	Significant yielding of steel at bolt holes. Cracking/splitting 3 in. or more local to bolt holes. Corrosion with section loss around bolt holes or on bolts.	Seam has completely failed, possible structural collapse.
			Evaluate Need for Action	Corrective Action Required	Emergency Action Required

- Failed seams can cause failed ratings.
- Evaluation of the need for corrective action is required for:
  - Significant water infiltration with fines, cocked or cusped seams, 5% to 15% loose or missing bolts in a seam, moderate yielding/cracking/splitting at bolt holes.
- Corrective action is required for:
  - Coarse soil infiltration, possible voids behind steel, evidence of piping from exfiltration, severely cocked or cusped seams with potential loss of capacity, greater than 15% loose or missing bolts in a seam, significant yielding/cracking/splitting at bolt holes, corrosion and section loss at bolts/bolt holes.

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Culvert and Storm Drain System Inspection Manual: Section 4 – Condition Rating System

- Aquatic Organism Passage (AOP)
  - Not historically considered in design
  - Culverts can result in barriers and stream fragmentation
  - Common barriers include:
    - Excessive velocity
    - Outlet configuration (drops)
    - Turbulence
    - Insufficient depth
    - Excessive lengths (darkness)
    - Debris and sediment
    - Culvert damage (can prevent fish from passing)

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Culvert and Storm Drain System Inspection Manual:

Section 5 – Asset Management

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Culvert and Storm Drain System Inspection Manual: Section 5 – Asset Management

- Transportation Asset Management
  - Makes an account of inventory and maintenance to prolong the service life of highway assets.
  - Weigh costs and benefits of maintenance with importance of structure and performance goals to prioritize and optimize actions
  - Goals can be over an extended time horizon and draw from both economics and engineering principles
  - Allows for accountability and transparency in public funding

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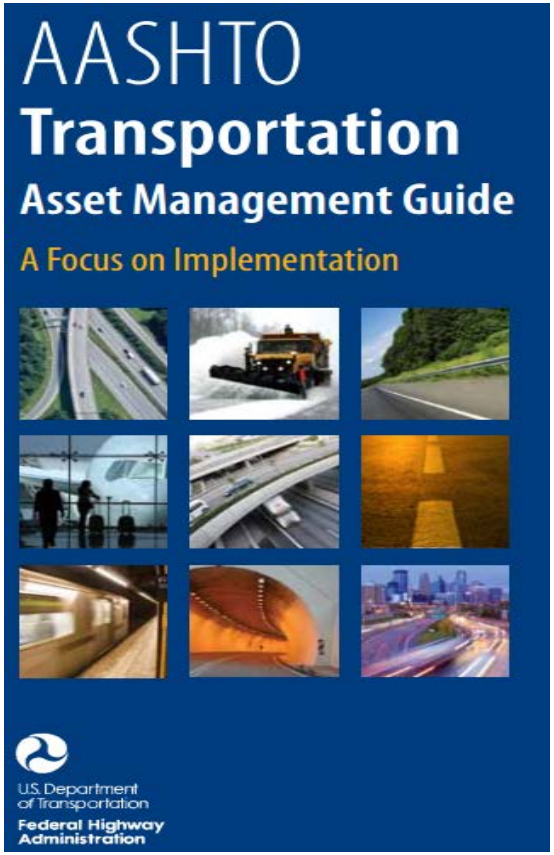
Culvert and Storm Drain System Inspection Manual: Section 5 – Asset Management

- Best Practices for Developing an Asset Management Plan
  - AASHTO Transportation Asset Management Guide
    - Published in response to growing emphasis and requirements for transportation asset management
    - Recommended resource for development of a culvert and storm drain system asset management plan



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Culvert and Storm Drain System Inspection Manual: Section 5 – Asset Management

- Best Practices for Developing an Asset Management Plan
  - FHWA Case Studies
    - FHWA Report No. IF-07-032: Culvert Management Systems
      - Case studies from Alabama, Maryland, and Shelby County Alabama
    - FHWA Report No. FHWA-HIF-14-008: Culvert Management Case Studies
      - Case studies and best practices from Vermont, Oregon, Ohio, Los Angeles County
  - Minnesota DOT Culvert Management System
    - Transportation Asset Management Plan (TAMP)
    - HYDINFRA (HYDraulic INFRAstructure) for spans < 10 ft
  - New Jersey DOT Culvert Information Management System (CIMS)

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Concluding Remarks

- NCHRP 14-26 Final Report available at:
  - http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP14-26_FR.pdf

- Email mcrichie@sgh.com for announcements on:
  - Expected publication date of manual
  - Upcoming presentations
  - Upcoming training and implementation seminars

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Questions and Discussion

Thank you!

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