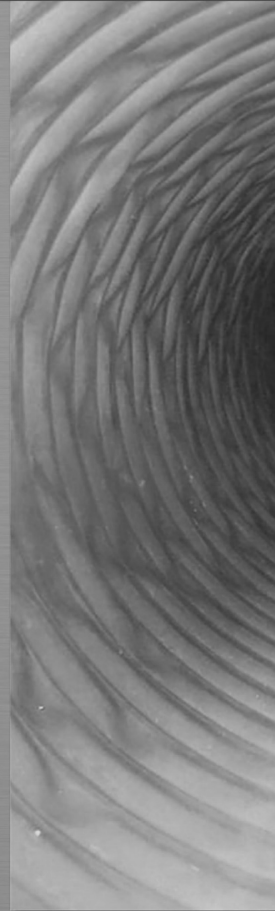


AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO

Culvert & Storm Drain System Inspection Guide



CSDIM-1
ISBN: 978-1-56051-720-7

2020
First Edition

ABBREVIATED TABLE OF CONTENTS

SECTION 1: INTRODUCTION

SECTION 2: DESIGN AND PERFORMANCE CHARACTERISTICS

SECTION 3: INSPECTION PROCEDURE

SECTION 4: CONDITION RATING SYSTEM

SECTION 5: ASSET MANAGEMENT

APPENDIX A: STRUCTURAL SHAPES, MATERIALS, AND SYSTEM COMPONENTS

APPENDIX B: CATALOG OF DISTRESSED CONDITIONS

GLOSSARY

REFERENCES

SECTION 1: INTRODUCTION

TABLE OF CONTENTS

1.1 GENERAL 1-1

1.2 NEED FOR STANDARDIZED INSPECTION 1-1

 1.2.1—Structural Integrity 1-3

 1.2.2—Hydraulic Performance 1-3

 1.2.3—Roadside Compatibility 1-4

1.3 OBJECTIVES, AUDIENCE, AND ORGANIZATION OF THE GUIDE 1-4

 1.3.1—Objectives 1-4

 1.3.2—Audience 1-4

 1.3.3—Organization of the Guide 1-4

SECTION 1

INTRODUCTION TO THE GUIDE

In 1986, the Federal Highway Administration (FHWA) published the *Culvert Inspection Manual* as a supplement to the *Bridge Inspector's Training Manual 70*. This Guide updates the 1986 manual to address the need to inventory, quantify, and rate the condition of in-service culverts and to update the inspection and rating criteria to incorporate over 30 years of change since the original publication.

1.1 General

Culvert and storm drain systems are vital infrastructure assets that require periodic maintenance to achieve their design service life and proper function. Culverts are buried structures designed to allow passage of water under roadways, railways, or embankments. Culverts can be structurally similar to bridges, but are distinguished in terms of span length (diameter for round pipes). The Federal Highway Administration *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* defines a culvert as "a structure designed hydraulically to take advantage of submergence to increase hydraulic capacity." Culverts, as distinguished from bridges, are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert. Culverts may qualify to be considered "bridge length." Structures defined as such and of "bridge length" are to be inspected following National Bridge Inventory (NBI) specifications and the *AASHTO Manual for Bridge Evaluation* (MBE) and, where necessary, the *AASHTO Manual for Bridge Element Inspection* (MBEI). Storm drain systems are closed-end conduits with inlet and outlet structures and in-line junction boxes that convey storm water runoff from roofs, parking lots, roads, walkways, and other impervious surfaces to collection and discharge points. Together, these drainage and conveyance systems protect our transportation assets from the destructive forces of water and help meet environmental requirements.

Many states have required the inspection of structures less than 20-ft span to follow the NBI specifications and AASHTO MBE and MBEI. The implementation of this *AASHTO Culvert and Storm Drainage System Inspection Guide* is not intended to preclude states from using the NBI specification or the AASHTO MBE and MBEI or other culvert inspection guides for the inspection of their culverts. Further, any reference to inspection frequency of culverts or inspector qualifications within this Guide is intended for guidance for asset management only and is at the discretion of the culvert or storm drain owner, and is not suggested to be implemented in a regulatory sense.

This Guide provides Inspectors with guidelines for routine condition assessment of culverts or storm drains, including all components in their systems. The criteria herein provide a reliable and reproducible method to rate the condition of system components. The component-based rating system enables a qualified Inspector to assess common distress types, evaluate their severity, understand their significance, and assign a numerical condition rating that is associated with recommendations for further action, if necessary. This Guide is a useful resource to agencies developing and conducting culvert and storm drain inspection programs. The Guide also provides guidance for developing a transportation asset management plan for culvert and storm drain system inventories.

1.2 Need for Standardized Inspection

Culverts have traditionally received less attention than bridges, leading to large numbers of structures with deferred maintenance and varying levels of distress that are not contained in any formal inventory database. Individual culvert and storm drain systems are significantly smaller investments than bridges; however, the total inventory of culverts and storm drains greatly outnumber bridges. Taken in total, the large inventory brings the asset value and the need for maintenance more in line with bridges.

Age, physical damage, changing land use, larger loads, and environmental exposure can lead to system deterioration. Lack of maintenance is a primary cause of improper functioning in culvert and storm drain systems. Scheduled routine inspections allow minor problems to be spotted and corrected before they become serious. Failure can lead to roadway collapse or washout, area flooding,

embankment erosion, or blockage to fish passage. These failures can be a heavy cost burden to transportation agencies, local businesses, and the traveling public. Figure 1.2-1 illustrates roadway failure due to progressive piping of soils from around the buried culvert.



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

(Photo courtesy of FEMA)

The *National Bridge Inspection Standards* (NBIS) define a bridge as “[a] structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the centerline of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.” Federal regulations mandate that all bridges, including culvert-like structures with spans greater than 20 ft, are to be inspected on a two-year cycle. Figure 1.2-2 illustrates the NBIS method for determination of the bridge length for multiple barrel culvert installations.

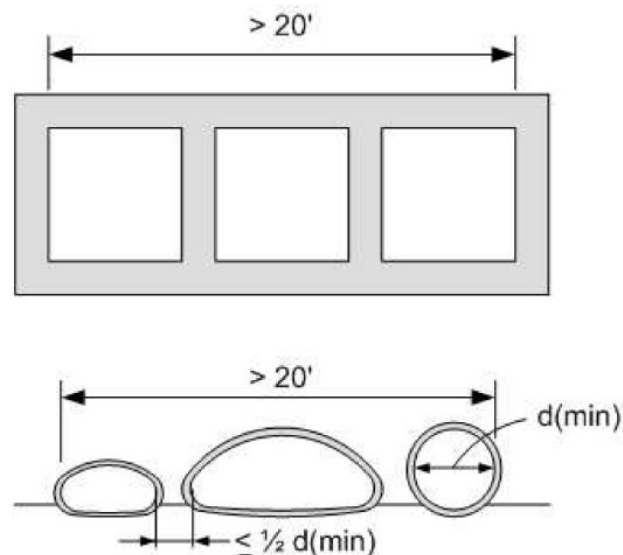


Figure 1.2-2—Culverts Meeting Definition of Bridge Length in the NBIS

(Extract from Figure 3.1.2, *Bridge Inspector's Reference Manual*)

In contrast, culverts and storm drains under 20-ft spans have no federally mandated (or funded) minimum inspection cycle. An inspection and condition monitoring program for these numerous smaller systems provides the following benefits:

- Identification of minor issues that can be addressed through maintenance before they become safety hazards.
- Mitigation of repair costs.
- Reduction in the risk of failure.
- Allowance for short- and long-term planning and budgeting for repairs and rehabilitation.
- Provision of a method to meet state and federal requirements to quantify the value of highway infrastructure assets.

Agencies in charge of culvert and storm drain inventories have a responsibility to assess the condition of these infrastructure assets in sufficient detail to maintain safe roadways and to meet environmental regulations. Inspection data also provide a strong basis to justify repair funding requests and to prioritize rehabilitation programs. The usefulness of the inspection data for these important functions hinges on the type and accuracy of the recorded data and the consistency of condition ratings between Inspectors. Information must be recorded in a manner that is easy to understand, provides an accurate assessment of condition, provides for cross-disciplinary access and sharing, and is easily verified and updated.

A culvert and storm drain system inventory and inspection program should evaluate structural integrity, hydraulic performance, and roadside compatibility. This evaluation requires training and consistent guidance on what to inspect and how to assess inspection findings.

1.2.1—Structural Integrity

Structural failures can be life-threatening to the traveling public, and at a minimum cause roadway closure and traffic delays. Identifying structural and material problems requires a careful evaluation of deterioration and distress of the system components. Figure 1.2.1-1 illustrates roadway failure due to progressive deterioration of a buried culvert system due to deferred maintenance and irregular inspections.



Figure 1.2.1-1—Roadway Collapse Due to Structural Failure of Culvert

(Photo courtesy of Iowa Department of Transportation)

1.2.2—Hydraulic Performance

Inadequate hydraulic performance can result in safety hazards such as flooding of the roadway or adjacent properties, or roadway washout. Aquatic organism passage may also be inhibited when blockage or erosion changes the streambed and flow characteristics.

1.2.3—Roadside Compatibility

Many culverts, like older bridges, present roadside hazards. Headwalls and wing walls higher than the road or embankment surface may constitute a fixed obstacle hazard. Abrupt drop offs over the end of a culvert or steep embankments may represent rollover hazards to vehicles that leave the roadway.

The success of a culvert and storm drain system inspection program hinges on the Inspector's ability to effectively assess the condition of the structure and materials and to make sound evaluations that lead to consistent, accurate ratings. The inspection data collected by the Inspector may be used as an input to an asset management system that allows prioritization of maintenance budgets and to make other decisions that can directly impact public safety. The inspection program thus plays the most critical role in maintaining the large number of systems in a typical agency's culvert and storm drain inventory.

1.3 Objectives, Audience, and Organization of the Guide

1.3.1—Objectives

The objective of this Guide is to provide quantitative and consistent condition rating criteria based on engineering principles and existing best practices. The condition assessment criteria presented in this Guide will enable culvert and storm drain Inspectors to identify structural distress for culvert or storm drain system components, rate the condition of each component, document findings of an inspection, and recommend corrective actions where necessary. To meet this objective, the Guide provides guidelines for conducting culvert or storm drain system inspections and rating system components.

To enable Inspectors to assess the importance of any identified distress, the Guide provides a review of how culvert and storm drain systems function and how buried pipes carry load by soil-structure interaction.

This Guide is not intended to be used as a standard or policy statement. This document is made available to be used as a resource for current information in the area of culvert and storm drain system inspection. Agencies may choose to use this information as one reference on which to build inspection, assessment, and management criteria best suited to their particular agency needs. Knowledgeable inspection, practically and systematically applied, offers the greatest potential for a continually improved transportation system.

1.3.2—Audience

The intended users of the *Culvert and Storm Drain System Inspection Guide* are highway agencies tasked with maintaining culvert and storm drain inventories, including state highway agencies (departments of transportation), city and county highway divisions, and other local agencies. Personnel from these agencies that will benefit from use of the Guide include:

- Culvert and storm drain system Inspectors and bridge inspection personnel.
- Consultants to highway agencies responsible for culvert and storm drain system inspection.
- Maintenance personnel responsible for performing scheduled maintenance on culvert and storm drain systems.

1.3.3—Organization of the Guide

The *Culvert and Storm Drain System Inspection Guide* is organized into five sections with two appendices:

Section 1— Introduction to the Guide	Section 1 introduces the topic of culvert and storm drain system inspections, outlines the need for standardized inspection programs, provides the Guide's objectives, and identifies the intended audience. This section also instructs users on the Guide's organization.
---	---

Section 2— Design and Performance Characteristics	Section 2 introduces the general factors that affect structural and functional performance of culvert and storm drain barrels, the structural shapes and materials, the various culvert and storm drain system components, and pipe coatings and linings. This section provides common system characteristics and refers to Appendix A for additional details about system components.
Section 3— Inspection Procedure	Section 3 covers inspection frequency, preparation and planning of inspections, types of inspections, the inspection sequence for routine inspections, type of entry, qualifications of the Inspector, typical equipment and tools for conducting an inspection, and inspection safety.
Section 4— Condition Rating System	Section 4 provides quantitative criteria for rating the condition of culvert and storm drain system components. Tables describe assignment of a condition rating from 1 (Good) to 4 (Severe) using specific criteria obtained by visual inspection or basic measurements.
Section 5— Asset Management	Section 5 introduces culvert and storm drain system inventory asset management with examples of best current practices. This section also provides references for additional information to this large topic.
Appendix A— Structural Shapes, Materials, and System Components	Appendix A augments Sections 2 and 4 to illustrate and describe the various culvert and storm drain barrel shapes, the materials from which they are constructed, and the system components. This appendix provides references for further information.
Appendix B— Catalog of Distressed Conditions	Appendix B provides Inspectors with a photographic guide for assessing the condition of typical culvert and storm drain system component, by distress characteristic, in catalog format. The catalog sequence is organized to match the distress conditions listed in the condition rating tables of Section 4. The catalog includes narrative descriptions of the distress and color-coding for quick reference to distress condition rating tables.
Glossary	The glossary contains definitions for commonly used culvert and storm drain terms.
References	The references section lists documents used in the production of this Guide.

SECTION 2: DESIGN AND PERFORMANCE CHARACTERISTICS

TABLE OF CONTENTS

2.1 GENERAL2-1

2.2 DESIGN CHARACTERISTICS2-1

2.2.1—Hydraulic Requirements.....2-1

2.2.1.1—Sedimentation.....2-1

2.2.1.1.1—Inlet and Outlet Protection.....2-2

2.2.1.1.2—Protection against Piping2-2

2.2.2—Structural Behavior (Flexible vs. Rigid)2-2

2.2.2.1—Flexible Culvert Behavior2-2

2.2.2.2—Rigid Culvert Behavior.....2-4

2.2.3—Loads on Culverts and Storm Drains.....2-6

2.2.3.1—Dead Loads2-6

2.2.3.2—Live Loads2-7

2.2.3.2.1—Highway Loads.....2-7

2.2.4—Construction and Installation Requirements2-8

2.2.4.1—Installation Conditions2-9

2.2.4.2—Compaction and Side Support2-10

2.2.4.3—Trench Width2-10

2.2.4.4—Foundations and Bedding2-10

2.2.4.5—Minimum Fill Depth.....2-10

2.2.4.6—Camber.....2-10

2.2.4.7—High Groundwater2-11

2.3 PERFORMANCE CHARACTERISTICS OF CULVERTS AND STORM DRAINS.....2-11

2.3.1—Durability2-11

2.3.1.1—Corrosion of Metals2-11

2.3.1.2—Degradation of Concrete2-14

2.3.1.2.1—Acid Attack2-15

2.3.1.2.2—Alkali–Aggregate Reactivity (AAR)2-15

2.3.1.2.3—Sulfate Attack2-15

2.3.1.2.4—Hydrogen Sulfide Attack.....2-15

2.3.1.2.5—Freeze–Thaw Damage.....2-15

2.3.1.2.6—Impact Damage.....2-15

2.3.1.2.7—Corrosion of Reinforcing Steel2-15

2.3.1.3—Degradation of Plastics2-16

2.3.1.3.1—Oxidation Degradation2-16

2.3.1.3.2—Environmental Stress Cracking (ESC).....2-16

2.3.1.3.3—Photo-Induced Degradation (UV Degradation).....2-16

2.3.1.3.4—Thermal Degradation2-16

2.3.1.3.5—Chlorine-Induced Degradation2-17

2.3.1.4—Abrasion2-17

SECTION 3: INSPECTION PROCEDURE

TABLE OF CONTENTS

3.1 GENERAL 3-1

3.2 PURPOSE AND SCOPE OF INSPECTIONS 3-1

3.3 INSPECTION FREQUENCY 3-2

 3.3.1—Size 3-2

 3.3.2—Condition Rating..... 3-2

 3.3.3—Structure Age 3-3

 3.3.4—Average Daily Traffic (ADT)..... 3-3

 3.3.5—Environmental Conditions..... 3-3

 3.3.6—Special Function 3-3

3.4 PREPARATION AND PLANNING 3-3

 3.4.1—Organizing and Scheduling Inspections 3-3

 3.4.2—Review of Inventory and Data from Previous Inspections..... 3-4

 3.4.3—Gaining Access through Locked Access Points 3-5

 3.4.4—Inspection Sequence 3-5

3.5 TYPES OF INSPECTIONS 3-5

 3.5.1—Initial (Inventory) Inspection..... 3-5

 3.5.2—Routine Inspection 3-6

 3.5.3—Special Inspection..... 3-6

 3.5.4—Damage Inspection..... 3-6

3.6 TYPES OF ENTRY 3-6

 3.6.1—Person-Entry Internal Inspection 3-6

 3.6.2—Non-Entry Internal Inspection 3-7

 3.6.2.1—Remote-Entry Internal Inspection 3-8

3.7 INSPECTOR ROLE AND TRAINING 3-8

 3.7.1—Inspector 3-8

 3.7.2—Training 3-9

 3.7.3—Physical Ability 3-9

3.8 INSPECTION EQUIPMENT 3-9

 3.8.1—Standard Inspection Tools and Equipment 3-10

 3.8.2—Nondestructive Inspection (NDI) Equipment 3-15

 3.8.3—Remote-Entry Inspection Equipment..... 3-18

3.9 RECORDING THE INSPECTION 3-19

 3.9.1—Inventory Record 3-20

 3.9.2—Inspection Record..... 3-23

3.10 SAFETY..... 3-30

 3.10.1—Common Hazards..... 3-30

3.11 INSPECTION QUALITY CONTROL AND QUALITY ASSURANCE (QC/QA) 3-34

SECTION 4: CONDITION RATING SYSTEM

TABLE OF CONTENTS

4.1 GENERAL 4-1

4.2 USE OF THE CONDITION RATING SYSTEM 4-1

4.2.1—Guidelines for Using the Rating System 4-1

4.2.2—Inspection of Large- vs. Small-Diameter Culverts and Storm Drains 4-3

4.2.3—Documentation Conventions 4-3

4.2.4—Inspection and Condition Rating Flow Chart 4-4

4.3 APPROACH ROADWAY 4-5

4.3.1—Purpose 4-5

4.3.2—What to Look For 4-5

4.4 EMBANKMENT 4-12

4.4.1—Purpose 4-12

4.4.2—What to Look For 4-12

4.5 CHANNEL 4-15

4.5.1—Purpose 4-15

4.5.2—What to Look For 4-15

4.6 END TREATMENTS AND APPURTENANT STRUCTURES 4-23

4.6.1—Purpose 4-23

4.6.2—What to Look For 4-23

4.7 CONCRETE FOOTING AND INVERT SLAB 4-30

4.7.1—Purpose 4-30

4.7.2—What to Look For 4-30

4.8 BARREL ALIGNMENT 4-35

4.8.1—Purpose 4-35

4.8.2—What to Look For 4-35

4.9 PLASTIC BARREL (HDPE, PVC, PP, FRP) 4-37

4.9.1—Purpose 4-37

4.9.2—What to Look For 4-37

4.10 CONCRETE BARREL 4-40

4.10.1—Purpose 4-40

4.10.2—What to Look For 4-41

4.11 CORRUGATED METAL BARREL 4-50

4.11.1—Purpose 4-50

4.11.2—What to Look For 4-50

4.12 MASONRY BARREL 4-68

4.12.1—Purpose 4-68

4.12.2—What to Look For 4-68

4.13 TIMBER BARRELS 4-72

4.13.1—Purpose 4-72

4.13.2—What to Look For 4-72

4.14 JOINTS	4-79
4.14.1—What to Look For	4-83
4.15 SEAMS OF CORRUGATED METAL PLATE	4-87
4.15.1—What to Look For	4-87
4.16 STORM DRAIN SYSTEM COMPONENTS	4-90
4.16.1—What to Look For	4-90
4.17 MANHOLES, CATCH BASINS, AND BURIED JUNCTIONS	4-91
4.17.1—What to Look For	4-92
4.18 AQUATIC ORGANISM PASSAGE	4-94

SECTION 5: ASSET MANAGEMENT

TABLE OF CONTENTS

5.1 GENERAL 5-1

5.2 TRANSPORTATION ASSET MANAGEMENT 5-1

5.3 BEST PRACTICES FOR DEVELOPING AN ASSET MANAGEMENT PLAN 5-2

 5.3.1—FHWA Culvert Management Case Studies 5-3

TABLE OF CONTENTS

A1. SHAPES	A-1
A1.1—Circular	A-1
A1.2—Pipe Arch and Elliptical.....	A-2
A1.3—Box Culvert.....	A-2
A1.4—Arch	A-3
A1.5—Three-Sided.....	A-4
A1.6—Multiple Barrel/Multicell Barrels.....	A-4
A2. MATERIALS	A-5
A2.1—Corrugated Steel	A-5
A2.2—Corrugated Aluminum	A-8
A2.3—Plastic	A-9
A2.4—Concrete	A-11
A2.5—Solid Wall Steel Casing.....	A-13
A2.6—Cast-Iron and Ductile-Iron	A-13
A2.7—Masonry.....	A-14
A2.8—Timber	A-14
A2.9—Other Materials.....	A-15
A3. CULVERT SYSTEMS AND COMPONENTS	A-15
A3.1—Approach Roadway and Embankment.....	A-15
A3.2—Inlet and Outlet End Treatments	A-17
A3.3—Headwalls, Spandrel Walls, and Wingwalls	A-18
A3.4—Energy Dissipators	A-19
A3.5—Foundations.....	A-22
A3.6—Aquatic Organism Passage (AOP).....	A-23
A4. STORM DRAIN SYSTEMS AND COMPONENTS	A-25
A4.1—Stormwater Collection	A-26
A4.2—Stormwater Conveyance	A-29
A4.3—Stormwater Best Management Practices (BMPs).....	A-30
A5. PIPE COATINGS AND LININGS	A-34
A5.1—Nonstructural Pipe Coatings and Linings.....	A-34
A5.2—Structural Pipe Linings	A-36

TABLE OF CONTENTS

B1. APPROACH ROADWAY	B-1
Pavement	B-1
Guardrail	B-3
Shoulders	B-5
B2. EMBANKMENT	B-7
Slope Stability and Embankment Erosion	B-7
B3. CHANNEL	B-9
Channel Alignment.....	B-9
Bank Erosion and Scour	B-11
Protection	B-13
Waterway Adequacy (Non-AOP)	B-15
B4. END TREATMENTS AND APPURTENANT STRUCTURES	B-17
Cracking (Concrete).....	B-17
Surface Damage, Spalling, Delamination (Concrete).....	B-19
Deformation and Damage (Metal).....	B-21
B5. CONCRETE FOOTING AND INVERT SLAB	B-22
Spalling, Delamination, Patches.....	B-22
B6. PLASTIC BARREL	B-24
Shape	B-24
Local Buckling, Splits, and Cracking.....	B-26
B7. CONCRETE BARREL	B-28
Cracking	B-28
Spalling, Slabbing, Delamination, Patches	B-30
Deterioration.....	B-32
B8. CORRUGATED METAL BARREL	B-34
Surface Damage	B-34
Corrosion.....	B-36
Shape (Closed Shape).....	B-38
B9. MASONRY BARREL	B-40
Masonry Units and Movement	B-40
Mortar	B-42
Efflorescence.....	B-43
B10. TIMBER BARREL	B-44
Connections and Missing Members	B-44
B11. JOINTS	B-45
Joint Separation, Offset, and Rotation	B-45
B12. SEAMS OF CORRUGATED METAL PLATE	B-47
Seam Bolt Holes.....	B-47