Culvert Data Collection Guide

Dan Baker, MSCE

Dr. Joel Cahoon, PhD, PE

Jodi Carson, PhD

Civil Engineering Department

Montana State University

Bozeman, MT 59717

INTRODUCTION

A joint effort between the Montana Department of Transportation (MDT) and the Western Transportation Institute (WTI) at Montana State University (MSU) developed a formalized rating system that proactively addresses the repair and maintenance needs of culverts. In developing such a rating system, the first step was to record both an overall culvert condition rating and various culvert and site specific characteristics (i.e., shape, size, sedimentation, etc.) for a small sample of culverts throughout the state. This data was be used to determine the specific culvert and site characteristics that lead to a decline in culvert condition. Once these initial relationships were established, an overall condition rating could be predicted for any culvert in the state using only its respective culvert and site characteristics. This overall condition rating could ultimately be used to prioritize culvert repair and maintenance activities. This guide documents the data collection guidelines used in the project, and would serve as a good resources for any agency that is interested in developing a database of culvert conditions and specifics.

BACKGROUND

Culverts are an important supplement to the visible network of roads and structures that convey vehicles providing effective and inexpensive passage over small streams and rivers. As such, culverts are widely used by state, county, local, park, and forest service agencies. The Montana Department of Transportation (MDT) alone utilizes over 30,000 culverts as part of the state roadway system. Similar to bridges, culverts should be inspected periodically to assess the need for maintenance, repair or replacement. Should culverts go unchecked and be allowed to fail and result in road closure, mobility for travelers is compromised, particularly in rural or remote areas where alternate routes are often unavailable. Further, maintenance costs are predictably higher for failed culvert repair as compared to routine or preventative culvert maintenance. Cost savings can be significant; MDT estimates spending $500,000 per year on culvert-related maintenance.

Water flow through culverts is typically divided into two classes: inlet controlled and outlet controlled. Figures 1 and 2, on the following page, provide general culvert cross sections and respective terminology used throughout this guide. **Inlet control** conditions result when the culvert barrel permits more flow than the inlet allows. **Outlet control** conditions result when conditions downstream of the culvert control flow rates or the culvert barrel controls the flow limit. Hence, the inlet and outlet condition are critical in determining its capacity.

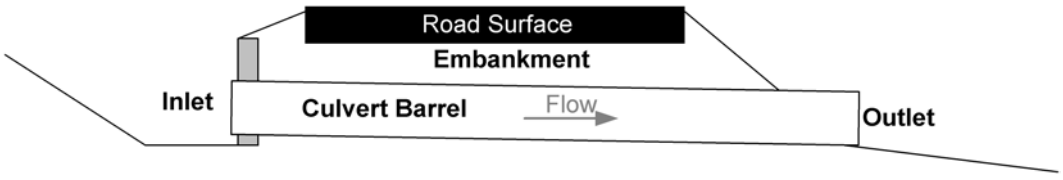


Figure 1.

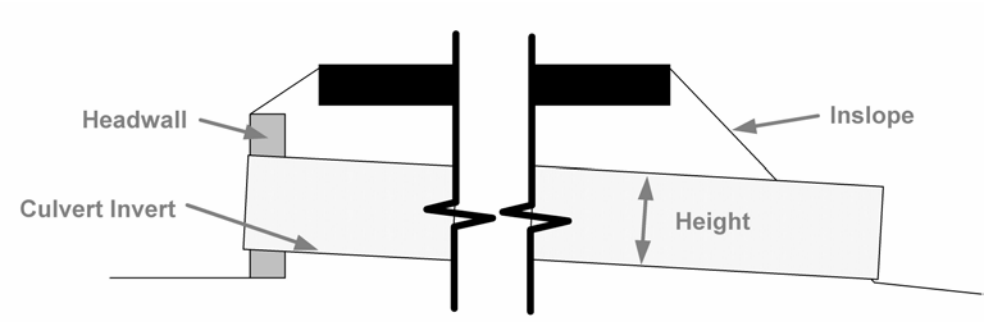


Figure 2.

DATA COLLECTION PROCEDURES

STEP 1. Designate a team of individuals to participate.

Only a two-person team should be responsible for the collection of all data from each division. If possible they should be experienced in culvert maintenance and repair. This will limit potential subjectivity and variability in the data collected.

STEP 2. Select a sample of no less than 40 culverts to inspect.

Each division is asked to collect data for no less than 40 culverts. All culverts must be MDT-owned and maintained. Do not include private culverts. Though not truly randomly sampled, please select a good mix of culvert size, shape, and material for inspection. However, do not include culverts constructed of masonry, wood or stone and do not include culverts in excess of 20 feet in diameter.

STEP 3. Read the information contained in this Guide fully.

It is essential to read this guide carefully prior to starting your data collection efforts. Because several different individuals from around the state will be collecting information to be entered in a common database, its important that you all use the same terminology and follow the same procedures for collecting and recording data.

STEP 4. Per culvert, record an overall condition rating of 1 through 5.

Overall condition ratings are defined as follows:

CONDITION INDEX	GENERAL DESCRIPTION	DESCRIPTION
1	**Poor**	Culvert is in dire need of prompt repair or full replacement. Its deficiencies threaten to disrupt or are hindering traffic flow. Damage needs to be repaired as soon as possible.
2	**Below Average**	Culvert condition indicates need for repair. While it is still in operating condition, its condition shows potential for additional deterioration.
3	**Fair**	Culvert is still operating, but could use some maintenance to restore it to full potential. Adverse conditions could cause major problems.
4	**Good**	Culvert shows minor deficiencies, with continued periodic maintenance culvert should be trouble free.
5	**Excellent**	Culvert shows no signs of problems. Water is flowing, or could flow at full capacity with no chance of interrupting traffic flow.

Once initial relationships are developed between the overall condition rating and various culvert and site characteristics for this sample of culverts, an overall condition rating can be predicted for any culvert statewide using only its culvert and site characteristics.

STEP 5. Record the various culvert and site characteristics for each culvert.

A predefined list of culvert and site characteristics is solicited on the data collection forms contained within this guide. Data is entered either as short answers, YES or NO, or qualitative ratings that are described in the pages to follow. Note the completed example data collection form on the next page. By general estimate it should take no more than 30 minutes per culvert to collect all data. As described previously you are asked to provide an overall condition rating for each of the 40 culverts in your division. The only materials required for data collection will be this manual, the attached forms, and a tape measure.

In these measurements, we are looking at the worst case scenario. For example if the data input requires rating of the degree of siltation, and the upstream end is completely covered, but the downstream end is open, we will rate the upstream end.

Overall Condition Rating

Poor 1 2 3 (4) Excellent 5

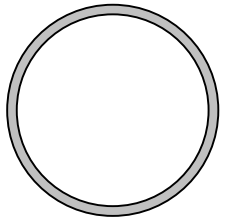
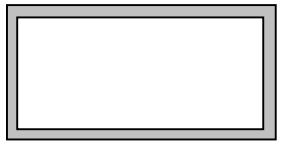
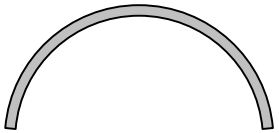
Culvert and Site Characteristics

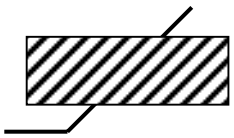
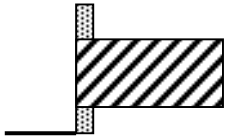
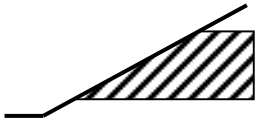
1	**Date of Inspection**	09 18 2000	
2	**Culvert Installation Date**	10 1975	
3	**Name of Inspector**	Baker, D	
4	**Cross Dimensional Shape**	(Circular)	Pipe Arch
		Rectangular	Arch (Open Bottom)
5	**Culvert Material**	(Galvanized Corrugated Steel Pipe)	Ribbed High Density Polyethylene (HDPE)
		Reinforced Concrete Pipe (RCP)	Other:
		Corregated Aluminum Pipe (CAP)	
6	**Interior or Invert Treatment**	(No Invert Treatment)	Concrete Lined
		Spray on Bituminous Asphalt	Natural Bed Material
		Asphalt Cement Pavement	Other:
7	**Type of Inlet Structure**	Projecting	Mitered
		(Flush)	
8	**System & Route**	P-50	
9	**Reference Point**	115.3	
10	**Height of Culvert**	3.5	feet
11	**Width of Culvert**	3.5	feet
12	**Length of Culvert**	59	feet
13	**Cover Height**	7	feet
14	**Culvert Use**	(Stream Passage)	Stock Passage
		Periodic Drainage	Road Underpass

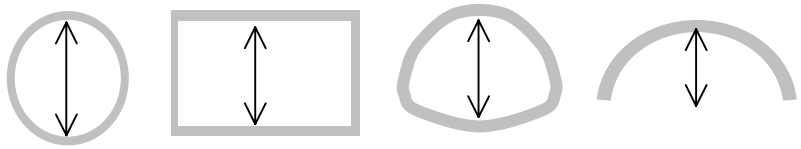
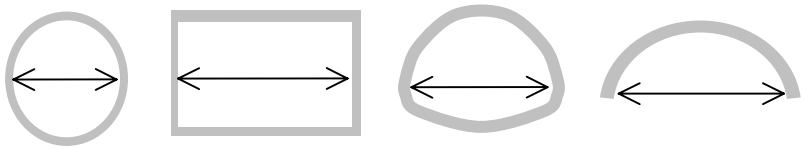
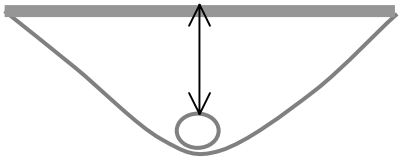
Notes:

Culvert and Site Characteristics

15	**Crossing or Stream Name**	Big Creek		
16	**Detour Length**	0 to 1.0 miles		10.1 to 50.0 miles
		1.1 to 3.0 miles		over 50.1 miles
		(3.1 to 10.0 miles)		
17	**Channel Material/Surface Description**	(Grass)		Gravel
		Brush and/or Trees		Dirt
		Cobbles		Lined (Concrete or AC)
18	**Scour at Outlet**	(0) No Damage	1	2 Serious
19	**Evidence of Major Failure**	YES		(NO)
20	**Evidence of Culvert Settlement**	(0)	1	2
21	**Degree of corrosion**	0	(1)	2
22	**Coating of Culvert Invert Worn Away**	0	(1)	2
23	**Holes in Culvert Invert**	YES		(NO)
24	**Sedimentation of Cross Section**	10 %		
25	**Physical Blockage**	0 %		
26	**Perched Outlet**	YES		(NO)
27	**Joint Separation**	YES		(NO)
28	**Damage to Roadway**	(0)	1	2
29	**Erosion or Failure of Side Slope**	(0)	1	2
30	**Physical Damage to Culvert**	0	(1)	2
31	**Evidence of Piping**	(0)	1	2
32	**Presence of Backwater Pool**	YES		(NO)

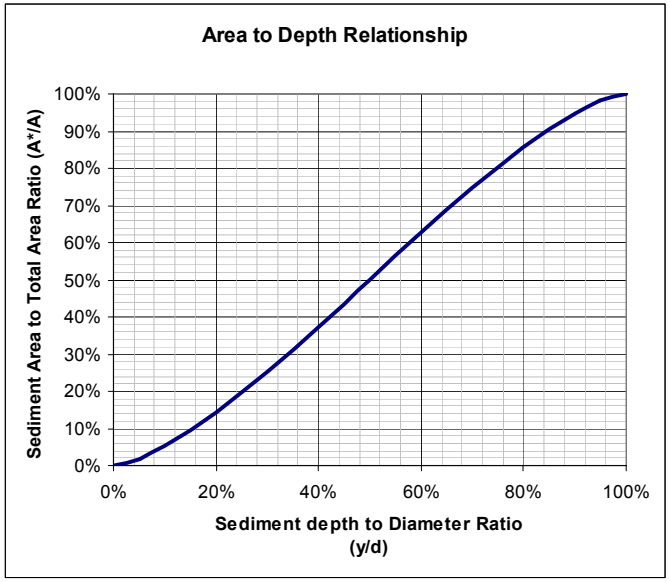
Culvert and Site Characteristics				
	Input Name	**Description**	**Notes:**	
1	**Date of Inspection**	Date in form: MM-DD-YYYY		
2	**Culvert Installation Date**	Date in form: MM-YYYY	This data may be impossible to gather in the field. Culverts are typically evaluated for repair or replacement every time a road is resurfaced or reconstructed. Most culverts along the same route should have approximately the same installation date. *Approximations only allowed when impossible to determine installation date.*	
3	**Name of Inspector**	Last Name, First Initial	This information allows others to review who made the measurements.	
4	**Cross Dimensional Shape**	<u>Select one of following:</u> • Circular • Rectangular • Pipe Arch • Arch (Open Bottom)	Circular 	Pipe Arch 
			Rectangular 	Arch (open bottom) 

5	**Culvert Material**	Select one of following: • Galvanized Corrugated Steel Pipe • Reinforced Concrete Pipe (RCP) • Corrugated Aluminum Pipe (CAP) • Ribbed High Density Polyethylene (HDPE) • Other (Please List)	Culvert materials listed are typical of those used by MDT. Please list if other material was used.
6	**Interior or Invert Treatment**	Select one of following: • No Invert treatment • Spray on Bituminous Asphalt • Asphalt Cement Pavement • Concrete Lined • Natural Bed Material • Other (Please Describe)	In order to increase abrasion and corrosion resistance in some culverts they receive interior treatments, mainly concentrated on the invert. Indicate which treatment the culvert is supposed to have. *Only select "Natural Bed Material" if culvert is designed to contain natural material.*
7	**Type of Inlet Structure**	Select one of following: • Projecting (Culvert Inlet Projects Into Channel • Flush (Culvert Inlet Is Flush With Vertical Headwall) • Mitered (Culvert Is Mitered Flush With Embankment)	If inlet is different from those listed, select most similar type. Projecting  Flush  Mitered 

8	**System and Route Number**	MDT System Route #	Do NOT use common designation (ex. Do not use US 191, but P-50 instead)
9	**Reference Point**	Number in miles. *Accuracy to 0.1 mile or greater if possible.*	This is the primary means of identifying each culvert. The distance between reference points (commonly known as mile markers) may be measured by automobile.
10	**Height of Culvert**	Maximum inside height of culvert barrel. *Accuracy to 0.1 feet.*	
11	**Width of Culvert**	Maximum inside width of culvert barrel. *Accuracy to 0.1 feet.*	
12	**Length of Culvert**	Culvert length from inlet to outlet invert. *Accuracy to 0.1 feet.*	Measure as accurately as possible. Some situations and placements may require approximate methods.
13	**Cover Height**	Average Height from top of culvert to road surface. *Accuracy to 0.1 feet.*	
14	**Primary Culvert Use**	<u>Select from the following:</u> • Stream or other waterway passage • Periodic Drainage • Stock Passage	Culverts are installed for a wide variety of reasons. Please indicate the primary use only.

		• Road Underpass	
15	**Crossing or Stream Name**	Simple name of crossing (cross road or waterway).	Name location (if any) of crossing. If crossing name unknown leave blank.
16	**Detour Length**	Select from range below: • 0 to 1.0 miles • 1.1 to 3.0 miles • 3.1 to 10.0 miles • 10.1 to 50.0 miles • over 50.1 miles	This is the distance in miles a vehicle would be required to travel to reach the other side of the crossing, if the culvert crossing were closed or had failed. Use area maps to accurately estimate the distance.
17	**Channel Material/Surface Description**	Select one of following: • Grass • Brush and/or Trees • Cobbles • Gravel • Dirt • Lined (Concrete or AC)	Select predominant channel description of upstream and downstream channels.
18	**Scour at Outlet**	Qualitative rating of degree of scour of channel material at outlet. *(0, 1, or 2)*	High velocity water exiting a culvert may erode non-protected channel material. Rate as follows: **0.** No indication of scouring at outlet. **1.** Moderate scour. Limited amount has occurred but does not appear to continue. **2.** Major scour concerns, problem continues to wash away bed material.

19	**Evidence of Major Failure**	Indicate evidence of former major hydraulic failure. *(Yes or No)*	Failures may include: • **Overtopping**: Backwater of culvert increases beyond height of roadbed. Water flows over road and may result in erosion of the road surface or shoulders. • **Buoyancy Failure**: Uplift forces in culvert due to trapped air either bend ends of culvert up, or displace entire culvert. • **Structural Collapse of Barrel**: Culvert barrels must support the weight of the above roadway. And major deformation can be considered collapse as the culvert's strength is primarily attributed to its shape. During major flow events drainage may overwhelm the capacity of the culvert and a hydraulic failure results. Typically one failure can lead to another.
20	**Evidence of Culvert Settlement**	Indicate qualitative level of settlement problems. *(0, 1, or 2)*	Settlement can be localized (just the culvert itself settling), or the culvert may settle as the entire roadbed subsides. Settlement typically is caused by the consolidation of unfit building materials over time. <u>Rate settlement as follows:</u> **0.** No apparent settlement. **1.** Minor localized settlement of culvert, culvert still functional. **2.** Settlement of roadbed or major settlement of culvert, resulting in reduced hydraulic capacity of culvert.
21	**Degree of Corrosion**	Indicate degree of soil side or water side corrosion. *(0, 1, or 2)*	<u>Rate degree of corrosion:</u> **0.** No corrosion visible. **1.** Minor corrosion problems. **2.** Major corrosion damage.

22	**Coating of Culvert Invert Worn Away**	Indicate degree of culvert lining material being washed or worn away. *(0, 1, or 2)*	Culverts may be lined as described in item #7. These linings are subject to wear and tear, mainly on the invert of the culvert. Include in this rating the galvanized coating on typical CSP. <u>Rate the condition of the lining as follows:</u> **0.** No damage to culvert lining. **1.** Minor damage to invert material. **2.** Majority of coating worn away.
23	**Holes in Culvert Invert**	Observe presence of holes through the culvert barrel. *(YES or NO)*	Holes are typically caused by abrasion and/or corrosion in the invert of the culvert.
24	**Sedimentation or sod blockage as percentage of cross section**	Estimate maximum cross sectional blocked by sediment or sod as a percentage of flow area. *(0% to 100%)*	As height of blockage to area of blockage is not a linear relationship, refer to graph below. 

25	**Physical Blockage**	Estimate Maximum cross sectional blocked by large debris as a percentage of flow area. *(0% to 100%)*	When possible remove obstructions during inspection. Only include physical blockage that is impossible to remove during inspection.
26	**Perched Outlet**	Determine if invert of outlet lies notably above downstream channel *(YES or NO)*	Perched outlets inhibit fish passage and also contribute to scour effects. Example photo of extreme case: 
27	**Joint Separation**	Indicate presence of joint separation *(YES or NO)*	Joint separation is the physical separation of different sections of culvert along the barrel. It typically is cause by differential settlement or improper construction. This separation can lead to a variety of problems such as infiltration.
28	**Damage to Roadway Immediately Above Culvert**	Degree of damage to roadway due to culvert. *(0, 1, or 2)*	Damage to the roadway above the culvert is of major concern to the safety of road users. It also is a primary indicator of several failure mechanisms that would otherwise go unnoticed. Damage can include sagging of the guardrail and pavement, and transverse or alligator cracking of the pavement. Worst cases could include potholes in the pavement. <u>Rate the degree of damage as follows:</u> **0.** No evidence of damage caused by culvert failure. **1.** Minor or possible damage caused by culvert. **2.** Major roadway damage caused by culvert.

29	**Erosion or failure of Side Slope**	Degree of damage to road inslopes adjacent to culvert location. *(0, 1, or 2)*	Side slopes that are improperly protected are easily eroded by backwater pools at the upstream end of culverts or by scour effects or backwater at the downstream end. This erosion may propagate into sloughing of the road cut or fill slopes. <u>Rate degree of damage as follows:</u> **0.** No damage to slopes adjacent to or above culvert. **1.** Minor damage to slopes adjacent or above culvert. **2.** Major damage to side slopes adjacent or above culvert.
30	**Physical damage to culvert**	Degree of physical damage to end treatments or culvert barrel *(0, 1, or 2)*	Physical damage is typically caused by large debris attempting to flow through the culvert, by cars leaving the roadway, or improper road and ditch maintenance activities. Severity of the damage can be limited to simple bent or broken outlet or inlet, or as major as complete collapse of the damaged sections. If the disrepair may be corrected on site no major repair will be merited. <u>Rate physical damage as follows:</u> **0.** No physical damage to culvert. **1.** Minor physical damage to culvert, unlikely to inhibit flow. **2.** Major physical damage to culvert, requires repair or replacement.

31	**Evidence of Piping**	Degree of piping in culvert. *(0, 1, or 2)*	Piping is the flow of water around (instead of through) the culvert barrel. The two primary reasons for piping are deficient end treatments or poorly compacted fill immediately around the culvert. As water is piped around the culvert, it begins to carry away the fine fill around the culvert barrel. This creates instability and structural problems around the culvert, and for the road surface. Piping can be diagnosed at the ends of the culvert by the undermining of the culvert invert, or material loss around the culvert barrel. The easiest indicator would be notable water flowing around the culvert barrel. <u>Rate piping as follows:</u> **0.** No evidence of piping **1.** Minor or possible evidence of piping. **2.** Major piping problems.
32	**Presence of Backwater Pool During Normal Flows**	Presence of backwater pool at outlet end of culvert. *(YES or NO)*	Backwater pools create problems with sedimentation, corrosion and piping. Indicate if backwater pool is present, or is usually (>75% of the time) at this location. Example of backwater pool: