CHAPTER 2 – CULVERT ASSESSMENT TOOL

SUMMARY OF ASSESSMENT TOOL

The purpose of this assessment tool is to provide FHWA Federal Lands Highway personnel with project-level guidelines for assessing the condition and performance of existing roadway culverts within the extents of a planned roadway project. This procedure applies to culverts with a span of less than 20 feet. The procedure identifies the minimum set of parameters necessary to effectively and efficiently evaluate both existing condition and performance for a broad range of culvert structure types, materials, and applications that may be encountered. The procedure also describes the defining criteria for each parameter, provides a rating system, and suggests methods and tools for measuring and recording the parameters. Safe and efficient assessment practices are outlined in the field inspection protocol and culvert entry guide sections of the procedure.

The culvert assessment tool, herein referred to as a Level 1 assessment, is intended for rapid assessment of a culvert's condition and performance. Culvert condition refers to the level of physical deterioration of the culvert barrel and appurtenances, while performance refers to the functionality of the structure as a water conveyance device, apart from the physical condition of the structures. The Level 1 assessment procedure may identify the need for a more in-depth investigation, termed a Level 2 assessment. Level 2 assessments require the involvement of technical discipline specialists in hydraulic, geotechnical, structural or materials engineering, and may also require special equipment for access and inspection. The Level 1 assessment procedure should lead to one of the following recommendations, for each culvert assessed: (1) the condition and performance appear to be acceptable, and no further action is needed with respect to the project being undertaken; (2) Level 1 maintenance (e.g. cleaning/clearing) is needed to remedy an observed performance problem and/or facilitate completing the Level 1 assessment; (3) Level 1 action is needed to repair or replace the culvert or appurtenances, with assistance from the decision-making tool portion of this procedure; or (4) an in-depth Level 2 assessment is required due to indicators identified by the Level 1 assessment.

FIELD ASSESSMENT PROTOCOL

The following is a recommended field assessment protocol for efficiently conducting Level 1 assessments of culverts. This protocol assumes that the following recommended approach is followed; however, this may not always be the case, depending upon project constraints. The recommended approach is to deploy a two-person assessment team from a motor vehicle staged at regular intervals along the project route, with the team walking from one culvert to the next. This approach allows the assessors to carry the minimum essential inspection and communication gear on their persons, while storing and having intermittent access to specialty and emergency gear that may be required in the vehicle at staging areas. It is also assumed for the purposes of providing this generalized protocol that each culvert is inspected on an individual basis, rather than sampling by groups of similar structures. By following the recommended methodology outlined in this field inspection protocol, the typical Level 1 assessment should take approximately 15 minutes to perform once at the structure, including Tasks B and C below.

Task A: Preparation and Planning

Step 1: Assure all recommended equipment is mobilized with the inspection vehicle by checking the list of Recommended Equipment for Level 1 Culvert Assessments. Make sure that critical specialty equipment that is not easily replaceable in the field, such as personal air monitors and snake bite kits, are included. Prepare individual tool belts, vests or back packs with the recommended "on-person" equipment, so they are ready to grab and go. Check that there are enough assessment forms for all culverts, plus extras for unanticipated structures and mistakes/lost forms. Assessment forms should be tailored for the specific project as much as possible to maximize efficiency and reduce redundant entries required in the field.

Step 2: Locate and plan ahead of time the most efficient course of travel to visit each structure within the project limits. Check and plan for the weather.

Step 3: Consult with environmental and cultural resource specialists to identify possible aquatic organism/fish passage (AOP) or historic structures, and special environmental permitting issues. Check available topographic maps in order to plan for environmental conditions such as remote locations, steep terrain or thick vegetation.

Step 4: Test electronic equipment, such as the GPS device, digital camera and air monitors, to ensure they are working properly. Charge all batteries as needed.

Task B: Arrival and Site Safety/Access

Step 1: Upon arrival at the culvert, if GPS positioning is to be used, pause briefly on the approximate centerline of the culvert and acquire and/or record the GPS coordinates. Doing so will enable the team to leave the GPS equipment in the vehicle rather than carrying it through the assessment, and provide a good approximation of location within the typical 3-meter accuracy of the device. Note that newer technology currently in use by FLH personnel integrates GPS mapping and camera capabilities in a compact hand-held device that provides time-stamping and geo-coordinates of photographs, is portable enough to carry on foot throughout the assessment and helpful for navigation.

Step 2: Stage the vehicle in a safe place on the shoulder or off the roadway, but close enough to be easily reached in an emergency. The distance between staging areas should not exceed twice the distance that either assessor is comfortable with traversing in an emergency, i.e. two miles at the most. Set out safety cones and don safety vests and/or hard hats as needed.

Step 3: Perform a quick safety assessment of the site for challenging conditions that may require extra gear beyond the on-person standard inspection equipment, or possibly dangerous scenarios that may lead to aborting the assessment. Also be aware of the potential for poisonous vegetation and dangerous animal life.

Step 4: Once it has been determined that the culvert may be approached safely, don the necessary equipment and move to assess the accessibility of the structure. Follow the FLH Culvert Entry Diagram to determine whether the culvert may be entered with no special requirements, accessed in accordance with OSHA confined space entry guidelines, inspected at the ends only, or deferred to a Level 2 assessment due to access restrictions. For safety, it is recommended that the culvert entrant wear a hard hat and personal atmospheric monitoring device, regardless of whether the culvert is classified as a confined space, and the other assessor standby at the end of the culvert.

Task C: Conducting Culvert Assessment

Notes: For efficiency, the lead assessor should direct the sequence of the inspection and fill out the assessment form, while the assistant assessor collects the measurements and data and calls it out to the lead. In steep terrain, location and inspection of the outlet of the pipe can be more time consuming; therefore, it is recommended that the assistant assessor inspect and photograph the outlet while the lead assessor handles the inlet, takes roadway photographs, collects GPS data and fills out the form.

Although the assessment guide occasionally refers to quantitative measurements of characteristics and deterioration levels, effective qualitative descriptions are adequate in most cases.

If the culvert is not entered and an end-only inspection is performed, it is important to use a flashlight and/or mirror to examine as much of the culvert length and circumference as possible and from both ends if accessible. Even though many of the joints may not be observed closely in an end-only inspection, serious problems can be inferred by the appearance of cross-section offsets or the presence of piles of backfill soil that has infiltrated at the joint locations. Additionally, serious joint problems can be detected by the presence of holes or depressions in the road embankment above the culvert. Abrasion problems are often worst in the downstream-most sections of pipe. Assessors can be reasonably confident, therefore, that abrasion conditions are no worse elsewhere in the pipe than at the outlet end.

Step 1: The lead assessor should fill out the Location and Route Information section of the Assessment Form, and begin the Culvert Characteristics section, while the assistant assessor takes any desired site photographs. If basic, inventory-type photographs are to be taken, the following is recommended. Ensure that the time stamp on the digital camera is functioning and accurate. In general, the basic photographs that should be taken include a view of the inlet, outlet, upstream and downstream channel, and roadway surface. For culverts rated Poor or Critical, additional photographs documenting the deterioration are highly suggested. Photographs of small cracks can often be improved by wetting the surface and allowing it to dry while the crack remains wet. Set the photograph size to approximately 240 Kb, as applicable.

Step 2: The assistant assessor should collect the remaining Culvert Characteristics section measurements/data, assign ratings to deterioration and report to the lead assessor who records the information. The lead and assistant assessors should discuss and agree upon the various element condition and performance ratings.

Step 3: The lead and assistant should complete the assessment form at the culvert site before departing. Comments such as access issues, photo logs, and recommendations such as maintenance activities, preliminary repair/replace suggestions, and Level 2 escalations should be recorded. Finally, an overall rating for the culvert should be assigned that is generally dictated by the lowest element ranking, but subject to the assessors' judgment.

Note: Variations of this methodology may increase efficiency, depending upon team members' capabilities, the nature of the culverts and environment, and refinements/modifications adopted by the team in the course of conducting assessments.

Task D: Assessment Follow-Up Activities

Step 1: Upon completing assessments of all culverts within project limits, assessment forms should be reviewed for completeness and edits made as necessary before leaving the project site.

Step 2: A summary report should be written for the engineer/designer that briefly describes the findings and highlights any repair/replace and maintenance actions that are recommended. The summary report may be prepared offsite. Copies of assessments that are to be brought to the engineer/designer's attention, including repair/replace, maintenance, and Level 2 recommendations, should be attached to the report as an Appendix. Photographs of the affected culverts, both baseline and problem-specific, should be effectively labeled and attached to the summary report as an appendix. All photographs should be copied to disk and submitted along with the report.

Step 3: The original assessment forms, digital photographs, and summary report should be provided to the owner and archived in a project file folder. For possible future inventory and research purposes, it is best to electronically scan the forms for archival; however, this is optional since the summary report is likely to be in electronic format and include copies of the culverts assessments of interest. Enter information into the inventory database as applicable.

CULVERT ENTRY DIAGRAM

The FLH culvert entry diagram provides general guidance to the assessor regarding when culvert entry by personnel is permissible, and what alternatives to man-entry are recommended when it is not. OSHA regulations concerning confined space entry, as contained in 29 CFR 1910.146, take precedence over these guidelines, and neither should preclude the exercise of good judgment on the part of the assessor with regard to personal safety. A culvert should not be entered if there is any history, sign, or potential of dangerous conditions in the culvert such as hazardous atmosphere or flash flooding.

Barring site specific dangers that may exist and preclude culvert entry, assessors may generally enter a culvert if the rise exceeds 4 feet, barrel length is less than or equal to 200 feet, both ends are open to entry and exit, flow depth is less than 2 ft and velocity is less than 1 foot per second, slope is less than or equal to 20%, and there are no bends in the culvert that prevent both ends from remaining visible to the assessor at all times. Note that culverts traversing under 4-lane highways are typically 200 feet or less in barrel length, except in cases of very high fills. It is recommended that any culvert entrant wear a personal air monitoring device that has been calibrated and tested successfully within 24 hours of the entry. It is also recommended that only one assessor enter the culvert and the other stand by at the entrance in the event of an emergency.

Culverts larger than 4 feet in rise that do not meet the criteria for safe entry by FLH Level 1 assessor teams should be deferred to special inspection teams equipped and trained to conduct underwater or permit-required confined space entries in potentially adverse conditions. Culverts that are less than or equal to 4 feet in rise, precluding entry of Level 1 assessors, will typically be handled with end-only inspections, provided the condition of the full culvert barrel can be confidently assessed or inferred by the conditions observed at the end. In both cases, maintenance may be called for in order to facilitate completing the Level 1 assessment, as well as specialty inspection equipment such as robotic camera crawlers and Remotely Operated Vehicles (ROV's). The FLH culvert entry diagram is presented in the following Figure 1.

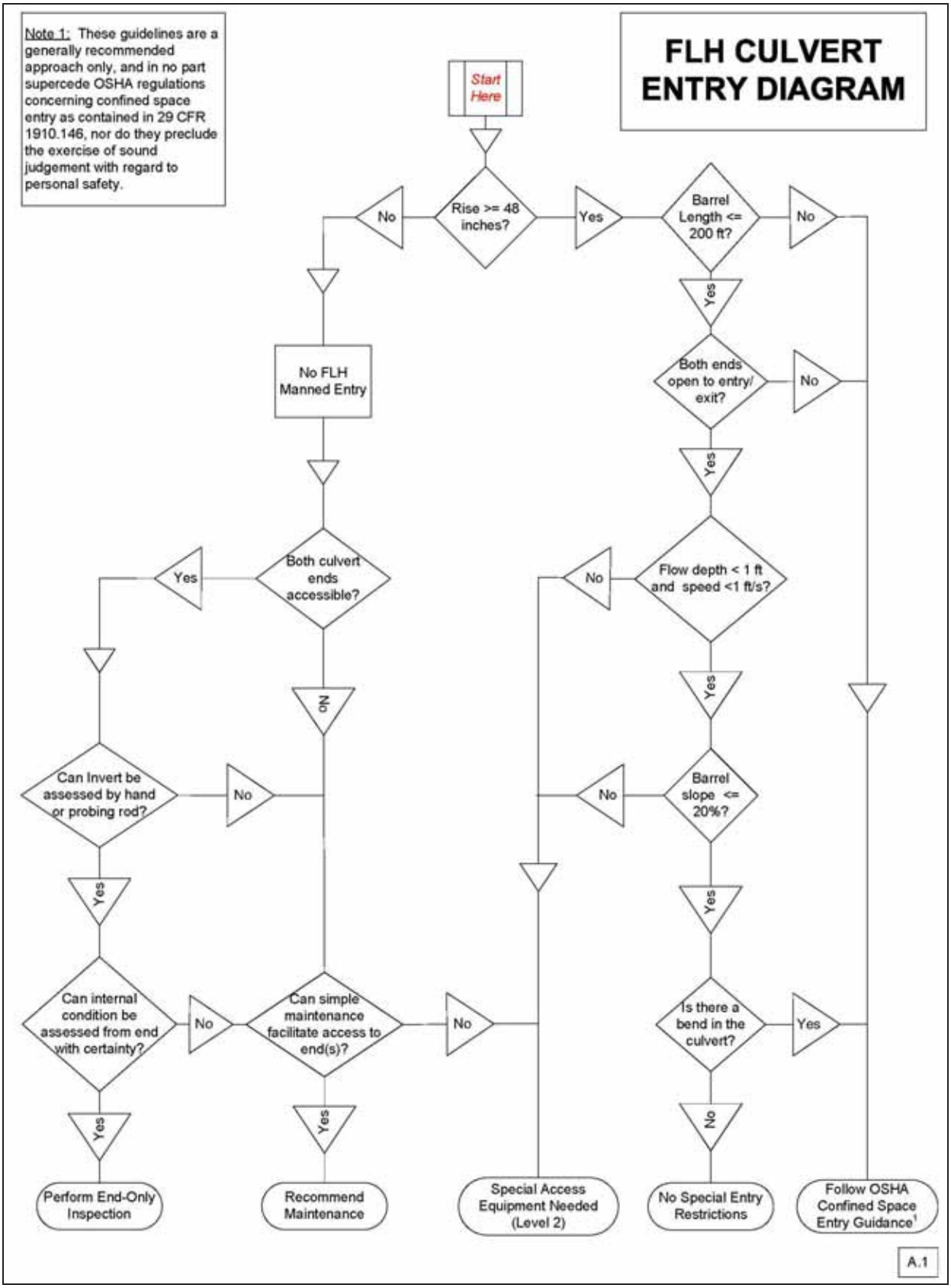


Figure 1. Flowchart. FLH Culvert Entry Diagram (see Appendix A for full size form).

RECOMMENDED EQUIPMENT LIST

The following is a list of recommended field safety and inspection gear to have available for conducting Level 1 assessments of culverts. It is assumed that a two-person assessment team will typically operate out of a motor vehicle; however, this may not always be possible. The experienced assessor(s) should determine the best equipment arrangement that can be efficiently handled by the team in this case. The most commonly used items are noted as "on-person", while other options are listed as "in-vehicle".

On-Person Equipment

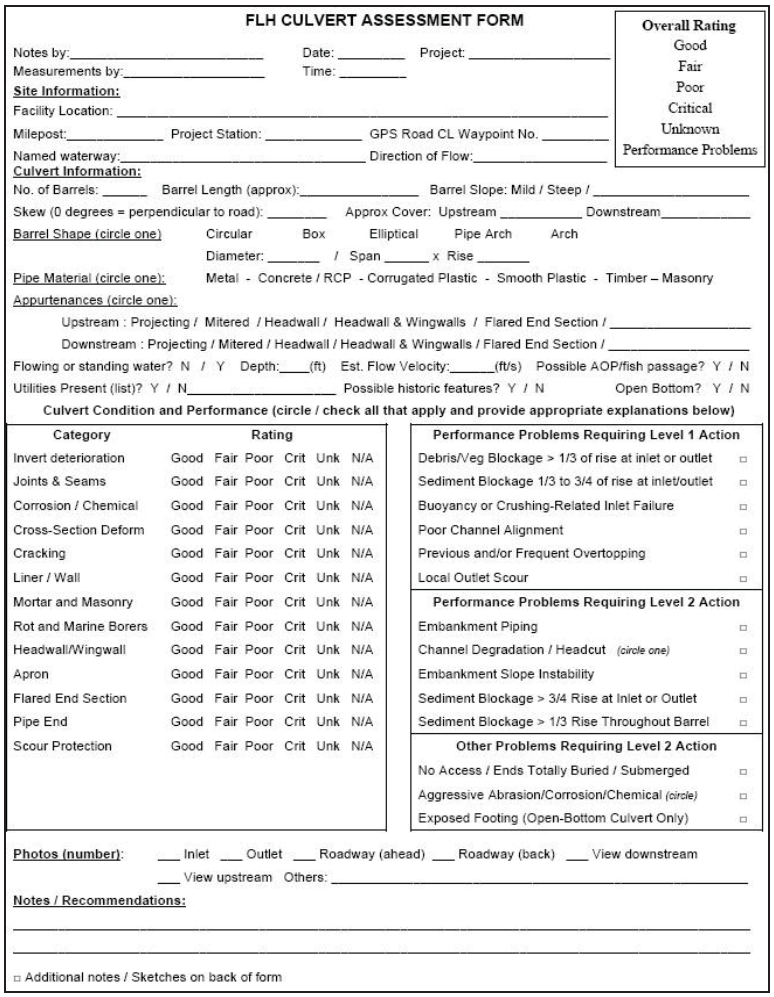
Assessment Form
Clipboard
Geologist Pick Hammer
25-foot Measuring Tape or Folding Carpenters Ruler
Digital Camera (Shock-resistant and Waterproof)
Flashlight (500k to 1M candle) and/or Head Lamp
Handheld Mirror
Probing Rod (Graduated Survey Rod Section)
Personal Air Monitoring Devices
Traffic Safety Vests and Personal Field Safety Gear
Extra Car Keys
Tool Belts for Hands-Free Carrying of Inspection Equipment
Cell phones and/or Field Radios
CTL Crack Comparator Card

In-Vehicle Equipment

GPS Device
Project Files & Maps
Assessment Guide
Culvert Entry Guide
First Aid Kit w/Snake Bite and Poisonous Vegetation Provisions
OSHA Traffic Cones
Extra Batteries, Bulbs and Storage Cards for Camera, GPS and Lights
Waders and Life Jacket
100-foot Tending Line
Hardhats or Climbing Helmets
Crack Gauge or Calipers
Folding Shovel, Machete and Pry-Bar
Emergency Contact Information and Equipment
100-foot Measuring Tape, Distance Wheel, or Range Finder
Inclinometer

CULVERT ASSESSMENT FORM

The FLH Culvert Assessment Form shown in Figure 2 below and included in Appendix A is the master template for conducting Level 1 assessments. The form is designed to closely correlate with the condition and performance issues related to the array of components of the various culvert material types discussed in the assessment guide. Assessment planners are encouraged to custom tailor the master form to their specific projects, and pre-fill out redundant entry fields as much as possible ahead of time, in order to increase efficiency in the field.



FLH CULVERT ASSESSMENT FORM

Overall Rating: Good / Fair / Poor / Critical / Unknown / Performance Problems

Notes by:_____ Date: _____ Project: _____
Measurements by:_____ Time: _____
Site Information:
Facility Location: _____
Milepost:_____ Project Station: _____ GPS Road CL Waypoint No. _____
Named waterway:_____ Direction of Flow:_____
Culvert Information:
No. of Barrels: _____ Barrel Length (approx):_____ Barrel Slope: Mild / Steep / _____
Skew (0 degrees = perpendicular to road): _____ Approx Cover: Upstream _____ Downstream_____
Barrel Shape (circle one) Circular Box Elliptical Pipe Arch Arch
Diameter: _____ / Span _____ x Rise _____
Pipe Material (circle one): Metal - Concrete / RCP - Corrugated Plastic - Smooth Plastic - Timber – Masonry
Appurtenances (circle one):
Upstream : Projecting / Mitered / Headwall / Headwall & Wingwalls / Flared End Section / _____
Downstream : Projecting / Mitered / Headwall / Headwall & Wingwalls / Flared End Section / _____
Flowing or standing water? N / Y Depth:____(ft) Est. Flow Velocity:_____(ft/s) Possible AOP/fish passage? Y / N
Utilities Present (list)? Y / N_____ Possible historic features? Y / N Open Bottom? Y / N

Culvert Condition and Performance (circle / check all that apply and provide appropriate explanations below)

Category	Rating
Invert deterioration	Good Fair Poor Crit Unk N/A
Joints & Seams	Good Fair Poor Crit Unk N/A
Corrosion / Chemical	Good Fair Poor Crit Unk N/A
Cross-Section Deform	Good Fair Poor Crit Unk N/A
Cracking	Good Fair Poor Crit Unk N/A
Liner / Wall	Good Fair Poor Crit Unk N/A
Mortar and Masonry	Good Fair Poor Crit Unk N/A
Rot and Marine Borers	Good Fair Poor Crit Unk N/A
Headwall/Wingwall	Good Fair Poor Crit Unk N/A
Apron	Good Fair Poor Crit Unk N/A
Flared End Section	Good Fair Poor Crit Unk N/A
Pipe End	Good Fair Poor Crit Unk N/A
Scour Protection	Good Fair Poor Crit Unk N/A

Performance Problems Requiring Level 1 Action
- Debris/Veg Blockage > 1/3 of rise at inlet or outlet □
- Sediment Blockage 1/3 to 3/4 of rise at inlet/outlet □
- Buoyancy or Crushing-Related Inlet Failure □
- Poor Channel Alignment □
- Previous and/or Frequent Overtopping □
- Local Outlet Scour □

Performance Problems Requiring Level 2 Action
- Embankment Piping □
- Channel Degradation / Headcut *(circle one)* □
- Embankment Slope Instability □
- Sediment Blockage > 3/4 Rise at Inlet or Outlet □
- Sediment Blockage > 1/3 Rise Throughout Barrel □

Other Problems Requiring Level 2 Action
- No Access / Ends Totally Buried / Submerged □
- Aggressive Abrasion/Corrosion/Chemical *(circle)* □
- Exposed Footing (Open-Bottom Culvert Only) □

Photos (number): ___ Inlet ___ Outlet ___ Roadway (ahead) ___ Roadway (back) ___ View downstream
___ View upstream Others: _____

Notes / Recommendations:
_____
_____

□ Additional notes / Sketches on back of form

Figure 2. Form. FLH Culvert Assessment Form (see Appendix A for full size form).

General project information that can sometimes be filled out before going into the field appears at the top of the form. The overall rating for the culvert, which is generally governed by the lowest rating of the individual elements, appears in the upper right-hand corner to easily facilitate paging through a group of forms to locate problematic culverts. Specific culvert type and characteristic information such as barrel shape and appurtenance types present is entered in the fields in the middle of the form. Near the bottom of the form are the condition and performance categories and ratings, as well as automatic Level 1 and Level 2 Action triggers. The last fields of the form provide entries for the standard photograph numbers, as well as notes and recommendations. A check box at the footer allows the assessor to indicate if there are additional notes or sketches on the back of the form.

CULVERT ASSESSMENT GUIDE

The culvert assessment guide is a tool to assist assessors in assigning the appropriate condition rating codes to the various culvert material types based on deterioration levels. The guide consists of eleven tables, the first of which describes the five possible rating codes in the left-hand column and their general meanings in the right-hand column. The remaining tables describe each major culvert material type and common appurtenances, with typical modes of deterioration for that material type listed in the left hand column and rating codes appearing in the top row. By cross-referencing the deterioration mode and rating code, the assessor correlates within the body of the Table 1 detailed description for rating each category of deterioration for the culvert.

Important notes for consideration when using the assessment guide appear in the bottom-most row of each table, including special conditions that might trigger in-depth Level 2 investigations above and beyond this initial Level 1 assessment. There is also a reference at the top of each table to the photographic guide for further assistance in assigning rating codes. The Photographic Guide for Culvert Assessment appears as Appendix B of this procedure manual, and provides a sample image of each condition level and appropriate rating code for every deterioration mode and material that is described in this guide and might commonly be encountered in the field.

FHWA FLH CULVERT ASSESSMENT GUIDE

CONDITION ASSESSMENT RATING CODES

Good	Like new, with little or no deterioration, structurally sound and functionally adequate.
Fair	Some deterioration, but structurally sound and functionally adequate.
Poor	Significant deterioration and/or functional inadequacy, requiring repair action that should, if possible, be incorporated into the planned roadway project.
Critical	Very poor conditions that indicate possible imminent failure that could threaten public safety, requiring immediate repair action.
Unknown	All or part of the culvert is inaccessible for assessment or a rating cannot be assigned.

Notes:

- In general, the lowest elemental rating for the culvert determines the overall rating.
- Culvert conditions are assigned the above ratings, while failing culvert performance parameters are indicated by a check box if present.
- This guide is used for the rating of culverts with spans less than 20 feet as measured along the centerline of the roadway, as defined by NBIS. (1)
- Due to the varied background and experience of the assessors, and variety of structures and deterioration modes, there is some inherent subjectivity to assigning the ratings in this guide.

FHWA FLH CULVERT ASSESSMENT GUIDE

CONCRETE & RCP CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Invert Deterioration	Little or no abrasion, with light scaling and exposed aggregate	Moderate abrasion and scaling with minor aggregate loss but no exposure of steel reinforcement	Heavy abrasion and scaling with exposed steel reinforcement	Holes or section loss with extensive voids beneath and embankment or roadway damage
Joints	Smooth, tight joints with minor chips, cracks	Open or displaced with minor infil/exfil of water and/or soil	Open or displaced with significant infil/exfil of soil and/or water and voids visible	Broken open or separated > 4" gap with extensive voids and embankment or roadway damage
Cross-Section Deformation	None observed	Cracks present, but no perceptible cross-section deformation	Longitudinal cracks in crown, invert and/or haunches, with perceptible cross-section deformation	Deformation and cracking has led to extensive infiltration of backfill soil, structural failure or embankment and/or roadway damage
Cracking	Boxes and Arches: Minor hairline or map cracks due to shrinkage <=1/8" wide at isolated areas, not at the crown or spring lines, with <25% cross-section coverage RCP: No cracks	Boxes and Arches: Minor cracks <= 1/4" wide, with minor spalls and infil/exfil of water or soil, along crown or haunches, <50% cross-section coverage any size RCP: Few hairline cracks, not at crown or haunches	Boxes and Arches: Open cracks >1/4" wide with significant infil/exfil and voids, or >50% cross-section coverage any size RCP: Cracks >1/8" wide, or any along crown or haunches, or >25% cross-section coverage any size	Resultant displacement at cracks has led to extensive infiltration of backfill soil, structural failure and/or resultant embankment and/or roadway damage
Corrosion/ Chemical	Boxes and Arches: Efflorescence present for boxes & arches RCP: No efflorescence	Boxes and Arches: Rust staining at cracks and spalls RCP: No rust staining	Boxes and Arches: Exposed steel reinforcement RCP: Rust staining or exposed steel reinforcement	Significant section loss of steel reinforcement that causes pipe deformation, holes in pipe walls and embankment and/or roadway damage

Notes:

- If the structure is open-bottomed and the side of a footing is exposed, a Level 2 assessment is required.
- If the structure is open-bottomed and rated in Poor or Critical condition, a Level 2 assessment is required.
- If the structure is known to have deteriorated from New/Good condition to Poor or Critical due to invert abrasion or corrosion/chemical attack in 5 years or less, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for guidance on Level 2 assessments.

FHWA FLH CULVERT ASSESSMENT GUIDE

CORRUGATED METAL PIPE CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Corrosion (Above Invert)	Little or no surface rust above the invert Little or no coating loss if coated above the invert	Minor surface rust and limited pitting above the invert Connection hardware corroded but intact	Perforations visible or easily made by hammer test strike above the invert Connection hardware failing	Significant section loss resulting in extensive infiltration of backfill soil, voids and embankment and/or roadway damage
Cross-section Deformation	None	Slight perceptible deformation at worst section, or local bulging	Deformation with accompanying longitudinal cracking or crushing in crown, invert and/or spring lines	Excessive deformation resulting in extensive infiltration of backfill soil, voids and piping with resultant embankment and/or roadway damage
Invert Deterioration	Little or no coating loss, and/or light rust staining, but no metal section loss	General corrosion, scaling or pitting with coating loss, but significant remaining metal section	Perforations visible or easily made by hammer test strike in invert area	Significant section loss in invert beyond perforations resulting in extensive voids beneath invert and/or embankment and/or roadway damage
Joints & Seams	Minor damage with no separation gaps	Open or displaced with minor infil/exfil of water and/or soil	Open or displaced with significant infil/exfil of soil and/or water and voids visible	Open or displaced with significant infiltration of backfill soil, and accompanying embankment and/or roadway damage

Notes:

- If the structure is open-bottomed and the side of a footing is exposed, a Level 2 assessment is required.
- If the structure is open-bottomed and rated in Poor or Critical condition, a Level 2 assessment is required.
- If the structure in known to have deteriorated from New/Good condition to Poor or Critical due to abrasion or corrosion in 5 years or less, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for guidance on Level 2 assessments.

FHWA FLH CULVERT ASSESSMENT GUIDE

PLASTIC PIPE CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Liner/ Corrugation Wall Condition	Liner is smooth with no signs of re-corrugation (rippling in smooth liner) No splits, tears, cracking or localized bulging	Slight re-corrugation of inner liner or wall buckling Splits, tears, and cracks <=6" long at limited locations	Significant re-corrugation of inner liner or wall buckling Splits, tears and cracks at several locations >6" long	Excessive tears, splits and/or bulges resulting in extensive infiltration of backfill soil, voids and piping with resultant embankment and/or roadway damage
Invert Deterioration	None	Minor wear or abrasion	Significant wear and perforations	Significant section loss in invert through outer wall of pipe resulting in voids beneath invert and/or embankment and/or roadway damage
Joints	Minor damage with no separation gaps	Open or displaced with minor infil/exfil of water and/or soil	Open or displaced with significant infil/exfil of soil and/or water and voids visible	Open or displaced with significant infiltration of backfill soil, and accompanying settlement of, or sinkholes in, embankment and/or roadway damage
Cross-section Deformation	No cross-section deformation	Slight perceptible deformation and/or few bulges	Significant perceptible deformation	Excessive deformation resulting in embankment and/or roadway damage and/or significant loss of conveyance

Notes:

- If the structure is known to have deteriorated from New/Good condition to Poor or Critical due to abrasion in 5 years or less, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for guidance on Level 2 assessments.

FHWA FLH CULVERT ASSESSMENT GUIDE

TIMBER CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Invert Deterioration	None	Minor section loss with no perforations	Significant section loss and/or perforations present with accompanying infiltration and voids	Complete loss of section at invert resulting in extensive voids beneath invert and/or embankment and/or roadway damage
Joints & Seams	Minor damage with no separation gaps Surface rusting of connection hardware	Displaced or separated with minor infil/exfil, but no visible voids Connection hardware corroded but intact Perceptible deformation and/or warping, with minor cracks	Displaced or separated with significant infil/exfil and visible voids Connection hardware failing Significant warping and cracking/breaking	Excessive deformation, displacement or separated with accompanying embankment and/or roadway settlement/ sinkholes Connection hardware failure resulting in joint and seam damage and infiltration of backfill soil and roadway damage
Rot and Borer Attack	None	Minor, local damage or section loss	Significant section loss, crushing and/or cracks and holes with significant infil/exfil of soil and water with voids visible	Severe deformation due to section losses and/or crushing, with embankment and/or roadway damage

Notes:

- If the structure is open-bottomed and the side of a footing is exposed, a Level 2 assessment is required.
- If the structure is open-bottomed and rated in Poor or Critical condition, a Level 2 assessment is required.
- If the structure has deteriorated from New/Good condition to Poor or Critical in 5 years or less, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for guidance on Level 2 assessments.

FHWA FLH CULVERT ASSESSMENT GUIDE

MASONRY CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Cross-section Deformation	None	Minor cracking visible, but no perceptible deformation	Perceptible deformation, and longitudinal cracks in crown, invert and/or spring lines	Holes and gaps have led to extensive infiltration of backfill soil and resultant embankment and/or roadway damage
Invert Deterioration	Minor scaling of joint material or blocks in invert area	Significant scaling with loose mortar and/or blocks in invert area	Displaced mortar and/or blocks, holes in invert area	Significant holes and section loss at invert resulting in extensive voids beneath invert and/or embankment and/or roadway damage
Mortar and Masonry	Isolated, minor mortar deterioration All blocks in place and stable No infil/exfil of soil	Mortar/block crushing and loss, loose blocks Minor infil/exfil of soil	Missing and/or displaced blocks Infiltration and voids	Widespread holes have led to extensive infiltration of backfill soil, voids, and piping with resultant embankment and/or roadway damage

Notes:

- If the structure is open-bottomed and the side of a footing is exposed, a Level 2 assessment is required.
- If the structure is open-bottomed and rated in Poor or Critical condition, a Level 2 assessment is required.
- If the structure has deteriorated from New/Good condition to Poor or Critical in 5 years or less, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for further guidance on Level 2 assessments.

FHWA FLH CULVERT ASSESSMENT GUIDE

APPURTENANCES CONDITIONS

Refer to Photographic Guide for further assistance with rating assignments.

	Good	Fair	Poor	Critical
Headwall/ Wingwall	Little or no cracking, rotation, or displacement Light concrete scaling, timber rot, metal corrosion or other surface deterioration No footing exposed	Minor cracks and spalls in concrete Minor rotation and/or displacement with gap in barrel seam Minor footing exposure	Area affected by cracking and spalling is >50% and/or rebar exposed Significant displacement at cracks or wall rotation causing a gap at the wall-to-barrel interface >4". Footing exposed and undermined	Partially or totally collapsed, with resultant damage to embankment and/or roadway damage
Apron	No cracking, piping or undermining	Minor cracking but no visible piping or undermining	Significant cracking affects >50% of apron Significant piping or undermining	Partially or totally collapsed, significantly effecting performance and/or causing embankment and/or roadway damage
Flared End Section or Pipe End	Little or no visible cracking, deterioration, or deformation No undermining	Minor cracking, deterioration, or deformation Minor undermining	Significant cracks, piping or undermining affects >50% of appurtenance End crushed or separated from barrel	Deterioration is significantly effecting performance and/or causing embankment and/or roadway damage
Scour Protection	Little or no displacement or undermining of individual rip rap or armor units Tight interface with culvert structure	Localized displacement of individual rip rap or armor units, undermining or deterioration Slight separation at culvert interface	Significant displacements, undermining or deterioration effecting the performance of the counter measure and culvert structure	Partially or totally failed, significantly effecting performance and/or causing embankment and/or roadway damage

Notes:

- If the apron has deteriorated from New/Good condition to Poor or Critical in 5 years or less due to aggressive abrasion, a Level 2 assessment is required.
- See Level 2 Disciplines Matrix in Decision-Making Tool for guidance on Level 2 assessments.

CULVERT AND CHANNEL PERFORMANCE INDICATORS

In addition to assessing the condition of each culvert and its appurtenances, the Level 1 assessment includes observations of the performance of the culvert and associated channel. The following pages describe various indicators and potential causes of performance problems. The assessor is expected to indicate whether these problems are present at each culvert. The presence of one or more performance problems may lead to action recommendations such as maintenance, culvert replacement or appurtenance repair, or may indicate the need for a Level 2 investigation. The presence of performance problems would trigger action even in the case of a "Good" or "Fair" condition rating for the structure itself. The relationships between various causes and indicators for level 1 and 2 activities are presented in Tables 1 and 2 at the end of this section. The performance problems are described below. Examples of some common performance problems encountered in the field are included the Appendix A Photographic Guide for Culvert Assessment.

PERFORMANCE PROBLEMS LEADING TO LEVEL 1 ACTIONS

The following Table 1 outlines the Level 1 performance problems that might commonly be encountered by assessors, and the field indicators that are typical of each. The problems listed in the left-hand column coincide with the entry fields on the right-hand side of the FLH Culvert Assessment Form entitled Performance Problems Requiring Level 1 Actions. The field indicators listed on the right-hand side of Table 1 are the most common symptoms of the problems the typical assessor will observe in the field.

Table 1. Performance Problems Leading to a Level 1 Action.

Problem	Field Indicator(s)
Debris/Vegetation Blockage	• Debris / Vegetation blocks 1/3 or more of inlet opening
Sediment Blockage at Inlet or Outlet	• Sediment blocks 1/3 to 3/4 of rise, localized at the inlet or outlet only
Buoyancy-Related Inlet Failure	• Inlet barrel raised above streambed
Poor Channel Alignment	• Barrel skewed > 45-degrees to upstream channel with associated damage to embankment or end treatment
Previous and/or Frequent Overtopping	• Drift on guardrail • Erosion on downstream side of embankment • Loss of pavement structure • Maintenance history / testimony
Local Scour at Outlet	• Undermined culvert, end treatment, or embankment slope

Debris/Vegetation Blockage

The culvert will fail to perform as designed if the entrance is blocked by a combination of vegetation, trash, sediment and other debris, as shown in Figure 3 below. This problem should be noted as present if a significant blockage exists, reducing the opening area by roughly 33% or more. This element is distinct from chronic sediment, explained later in this document. If this problem is present, a Level 1 recommendation for maintenance to clear the culvert is appropriate, considering and combined with any other recommendations arising from the Level 1 condition assessment. If the blockage prevents an adequate Level 1 condition assessment, the assessor should mark the condition parameters as "unknown", collect what data that can be safely acquired while on-site, and then reattempt the assessment after the required maintenance has occurred.

Figure 3. Photo. Example of severe debris blockage.[(2)]

Sediment Blockage at Inlet or Outlet

An accumulation of pure sediment, generally devoid of vegetation debris, that is local to either the inlet or outlet and greater than or equal to 1/3 but less than or equal to 3/4 of the rise of the barrel may be considered a Level 1 maintenance issue. The localized blockage should not extend more than a few feet into the barrel from the culvert end, which would be indicative of greater channel aggradation problems and trigger Level 2 action. In most cases, a minor accumulation is due to minor embankment sloughing around the pipe end, or settling out of sediment loads conveyed by the flow. In cases where the blockage is less than 1/3 of the rise, with sufficient invert slope periodic flows, the culvert will likely blow out the blockage as a self-cleaning mechanism. If the blockage is 1/3 to 3/4 of the rise, self-cleaning may not occur and the culvert should be a candidate for maintenance to clear the sediment.

Buoyancy-Related Inlet Failure

Buoyancy can cause damage to the inlets of a large corrugated metal culvert with a projecting inlet (the pipe projects out from the road embankment). This problem should be noted as present if the projecting segment of a CMP has noticeably lifted above the streambed. The problem should lead to a Level 1 recommendation for repair of the culvert via the decision-making tool (e.g. repair damage and add headwall, slope pavement anchor or terminal end section as appropriate). The following Figure 4 shows an example of extreme buoyancy uplift.

Figure 4. Photo. Example of severe buoyancy uplift (FHWA/NHI training materials). [2]

Poor Channel Alignment

This problem should be noted as present if the channel approaching the culvert from upstream or exiting the culvert downstream is highly skewed (say more than roughly 45 degrees) from the axis of the culvert barrel, and there is scour at the outside channel bank that is causing damage to the culvert, headwall, wing walls or road embankment. The following Figure 5 is an idealized example sketch of poor channel alignment. If present, this problem should lead to a Level 1 recommendation for remediation.

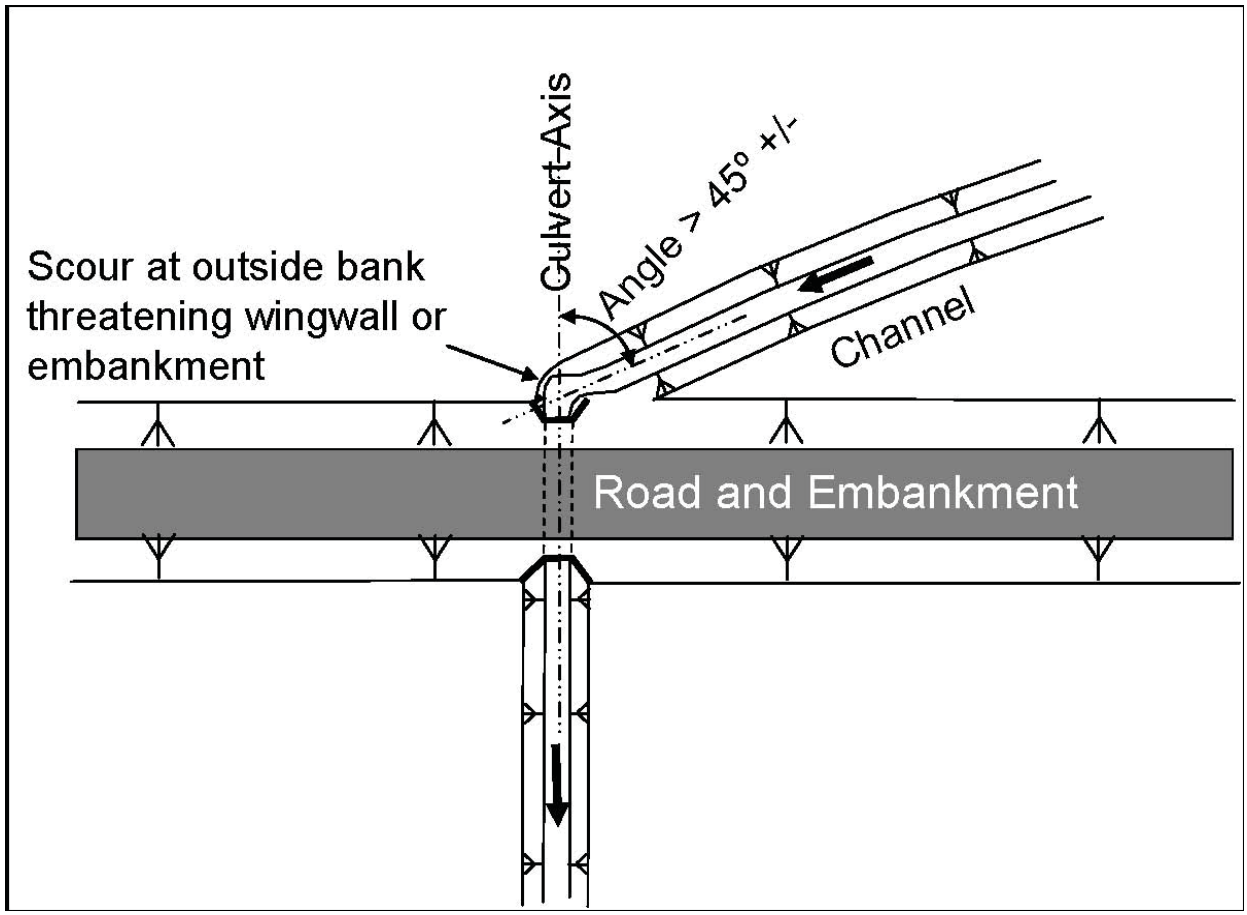


Figure 5. Drawing. Idealized example sketch of Poor channel alignment.

Previous and/or Frequent Overtopping

Embankment damage at the culvert site may be present because of previous overtopping, potentially due to inadequate hydraulic capacity. Indicators of overtopping could include, but are not limited to, drift hanging on guardrail above the culvert, extensive erosion of the downstream embankment, often accompanied by loss of the pavement section along the downstream edge. The most likely location of overtopping is at the low point in the road profile, which may be offset from the culvert crossing location. Overtopping indicators, if present, should lead to a Level 1 recommendation for maintenance (to repair any related erosion damage) and potentially a recommendation to add erosion protection to accommodate future overtopping. If the client reports that overtopping is known to be frequent at the culvert and if the condition rating is poor or critical, then the culvert should be replaced with an adequately sized structure, determined through hydrologic and hydraulic analysis. The following Figure 6 shows an example of erosion damage to the downstream embankment slope and shoulder from previous overtopping.

Figure 6. Photo. Erosion damage to downstream embankment slope and shoulder from previous overtopping.[(3)]

Local Scour at Outlet

Most culverts have some degree of scour at the outlet. This problem should be noted as present if a very large and noticeable scour hole is observable at the inlet or outlet, as illustrated in Figures 7 and 8 below, and it is causing damage to the culvert, headwall, wing walls or road embankment. Such problems should lead to a Level 1 recommendation for installation or repair of outlet protection, as determined in the Decision-Making tool (e.g. line existing scour hole with riprap). A local scour hole is different from a head cut in that the scour hole is a localized depression with excavated bed material often mounded not far downstream from the hole, while the stream bed affected by a headcut extends at a generally uniform slope elevation for a significant distance downstream of the headcut.

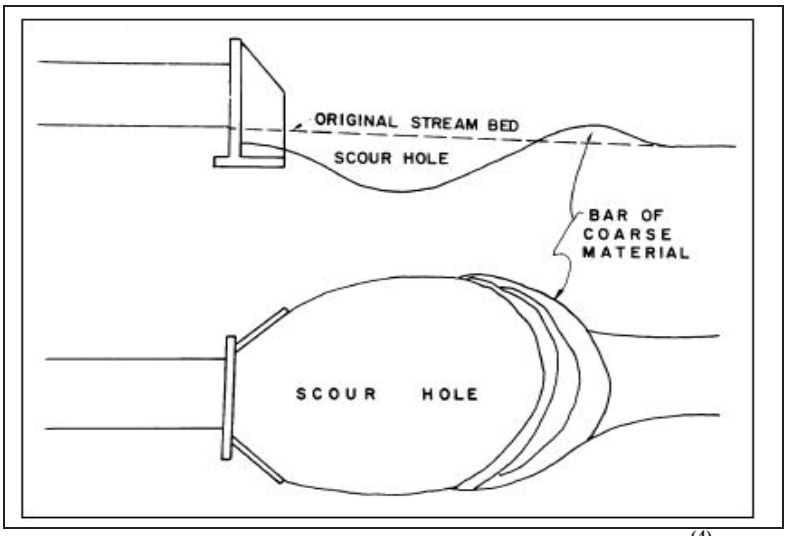


Figure 7. Drawing. Outlet scour: example sketch.[4]

Figure 8. Photo. RCP culvert damaged by scour. [2]

PERFORMANCE AND OTHER PROBLEMS LEADING TO LEVEL 2 INVESTIGATIONS

The following Table 2 outlines the Level 2 performance problems that might commonly be encountered by assessors, and the field indicators that are typical of each. The problems listed in the left-hand column coincide with the entry fields on the bottom-right corner of the FLH Culvert Assessment Form entitled Performance Problems Requiring Level 2 Actions. The field indicators listed on the right-hand side of Table 2 are the most common symptoms of the problems the typical assessor will observe in the field. Table 3 covers other potential problems that may be encountered which are not performance-related, such as limited access, AOP or historical issues.

Table 2. Performance Problems Leading to a Level 2 Action.

Problem	Field Indicator(s)
Embankment Piping	• Settlement or holes in roadway with no significant joint problems identified in culvert • Holes in embankment outside of culvert with no significant joint problems identified in culvert
Channel Degradation	• Perched inlet and/or outlet with adjacent channel banks vertical or unstable (sloughing)
Headcut	• Unstable channel drop of 2 feet or more within sight of the culvert
Embankment Slope Instability	• Failure of upstream embankment with channel approach angle less than 45-degrees to barrel • Failure of downstream embankment beyond that caused by local outlet scour
Sediment Blockage and Channel Aggradation	• Full barrel length blocked 1/3 or more of rise with sediment and culvert not an AOP design • Blockage 3/4 or more of rise local to the inlet or outlet only
Aggressive Abrasion, Corrosion and/or Chemical Environment*	• Poor or Critical condition reached in 5 years or less
Exposed Footing (Open-Bottom Culvert)*	• Side of any footing exposed

* Item also noted in the condition assessment tables

Table 3. Other (Non-Performance) Problems Leading to a Level 2 Action.

Problem	Field Indicator(s)
No Access	• Condition cannot be adequately assessed by an end-only inspection • Access precluded by factors not remedied by routine maintenance (e.g. total submergence in water)
Aquatic Organism Passage Culvert	• Any performance problem
Historical Culvert or Headwalls	• Any performance problem or condition rating of Poor or Critical
Open-Bottom Culvert*	• Any condition rating of Poor or Critical

* Item also noted in the condition assessment tables

Embankment Piping

Piping is the condition of water flowing through the embankment outside of, rather than inside the culvert barrel. It leads to holes in the embankment and if left unchecked will cause failure of the embankment and/or culvert. It can be caused by overly porous or poorly compacted culvert backfill, or by exfiltration from the culvert barrel due to open joints. This problem should be noted as present if holes are visible in the embankment outside the culvert barrel at either end of the culvert, as shown in Figure 9 below. Presence of this problem should trigger a Level 2 geotechnical investigation.

Figure 9. Photo. Example of piping through an embankment. [2]

Holes or settlement visible in the road or embankment can be indicators of embankment piping and damage, as in Figures 10 and 11 below. A Level 2 investigation should be triggered, which may include conducting a full-length culvert investigation (e.g. with an ROV) for infiltration and a geotechnical investigation to determine the extent of the damage to the embankment.

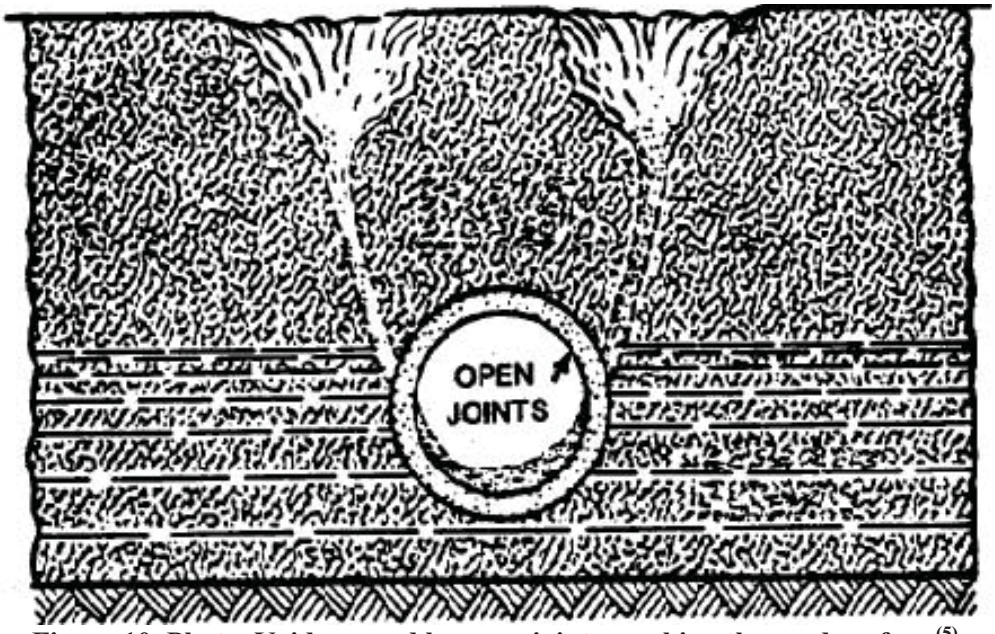


Figure 10. Photo. Voids caused by open joints reaching the road surface.[5]

Figure 11. Photo. Example of roadway settlement caused by voids around a culvert.[3]

Channel Degradation

A perched culvert inlet or outlet that is not associated with a local scour hole is one of several indicators of channel degradation. Another indicator of degradation is visibly unstable channel banks (e.g. vertical or undercut banks) that are not only local to the culvert structure, but extend much further downstream and/or upstream, as shown in the following Figure 12.

Figure 12. Photo. Unstable channel, evidenced by stream bank erosion and vertical bank.[(6)]

Head Cut

A head cut is a vertical or steep drop in the stream bed, as shown in Figure 13 below, and is a mechanism of degradation. A head cut is different from a local scour hole in that a stream bed affected by a head cut extends at a generally uniform slope or elevation for a significant distance downstream, while the scour hole is a localized depression with excavated bed material often mounded not far downstream from the hole. If a head cut with a height of two feet or more is observed within sight of the culvert, and if it is not arrested in its current position by bedrock or a structure, its presence should be indicated. It may eventually migrate over time and threaten to undermine the culvert or embankment.

Figure 13. Photo. Example of head cut that can be expected to move upstream over time.[7]

With the exception of a potentially approaching head cut, only channel degradation that is currently affecting the culvert or embankment should be noted in the assessment. The presence of one or more problems with channel degradation should trigger a Level 2 hydraulic investigation.

Embankment Slope Instability

In cases where the road embankment is exceptionally steep, the intermittent ponding and drawdown of water upstream of a culvert inlet can lead to localized slope failure or sloughing of the embankment neat the inlet. If present, this problem should trigger a Level 2 geotechnical investigation.

Sediment Blockage and Channel Aggradation

Unlike a local blockage by debris or sediment, chronic channel sedimentation indicates long-term channel aggradation. Channel aggradation, or excessive sediment accumulation, is a condition that cannot be addressed by maintenance activities at the culvert, especially if it extends downstream of the culvert exit. Mark this problem as present if the culvert barrel has sediment occupying roughly 33% or more of the barrel depth throughout its length, and if the bed sediment continues on that profile downstream of the culvert barrel. Also mark this problem as present if sediment accumulation at the inlet, absent other debris, causes a blockage of greater than 75% of the rise. In culverts that have been designed for AOP/fish passage, this condition may be an intentional design feature (e.g. the culvert was intentionally countersunk into the streambed to provide a natural streambed for aquatic organisms). If this problem is present in a non-AOP culvert, however, it should trigger a Level 2 hydraulic investigation. Figure 14 below shows a culvert barrel filled to approximately half of its rise with aggraded sediment.

Figure 14. Photo. Culvert barrel filled with sediment up to half its rise, possibly due channel aggradation. [(2)]

Open-Bottom Culvert

Many culverts have natural streambed sediments at the bottom, either because the bottom of the structure is open, or because the bottom of the culvert structure has been intentionally set below channel grade to promote AOP/fish passage. Open-bottom culverts, an example of which appears as Figure 15 below, often have shallow foundations that can be undermined by scour within the culvert barrel. Open-bottom culverts, if they are to be rehabilitated because of a condition rating of Poor or Critical, should receive a Level 2 hydraulic investigation in order to ensure that the rehabilitation does not increase the risk of undermining the foundations. Note that cattle pathways and farm road underpasses can be confused with flood plain relief culverts and may appear as bottomless culverts, although they are not as much of a concern for undermining and scour. A cattle pathway or farm road underpass in Poor or Critical condition should receive a Level 2 hydraulic investigation, unless it is obvious to the assessor that runoff is not conveyed.

Figure 15. Photo. Example of an open-bottom culvert.

Open-Bottom Culvert with Exposed Footing

If an open-bottom culvert has an exposed footing, there is an enhanced risk of culvert failure by scour undermining the footings. Mark this condition as present if the side of any footing is exposed, as shown in Figure 16 below. The presence of this problem should trigger a Level 2 hydraulic investigation to determine the risk of a scour-related failure. A cattle pathway or farm road underpass with an exposed footing should also receive a Level 2 hydraulic investigation, unless it is obvious to the assessor that runoff is not conveyed and that scour is not the cause of the exposure.

Figure 16. Photo. Exposed spread footing condition possible in an open-bottom culvert.

Regulatory Status for AOP or Historic Structure

If the culvert has been designated with regulatory status requiring passage of fish or other aquatic organisms and rehabilitation or replacement action is required, a Level 2 investigation is conducted before making any decision. If one or both headwalls has an historic structure designation and rehabilitation or replacement action is required, a Level 2 investigation is conducted before making any decision. Figure 17 below shows an example of an AOP culvert.

Figure 17. Photo. An aquatic organism passage (AOP) culvert.[8]

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