Culvert Sizing and Installation
Stream Simulation

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• Most culverts were placed and designed with the objective of moving water across a road alignment

• Little consideration given to ecosystem processes (hydrology, sediment transport, fish and wildlife passage or movement of woody debris)

• Not surprising then - that many culverts significantly disrupt movement of aquatic organisms and normal stream function

Washington Department of Fish and Wildlife Culvert Inventory
2003
9746 culverts on fish bearing streams

33% Passable
56% Barriers
Slope >1%
Outfall drop >0.8 ft
No bed material in pipe
Culvert width <75% of channel toe width

11% Barrier status unknown

Barriers are estimated to block 7600 miles of stream

Implications

- Independent groups
  - Less robust gene pool
  - Susceptible to disasters
- Excellent habitat may be blocked!

Figure 3.1 in Synthesis Report, page 3-2
Proper sizing is just as important in small headwater streams:

- Accumulatively provide much more habitat for aquatic organisms than large rivers

- Highly productive due to their relationship with adjacent upland habitat

- Provide cooler water temperatures due to shading and groundwater inputs

- Account for most of the total stream miles

Road Hydro Intersections = 67,511
Culverts = 60,700
Bridges = 6,811
Clean Water Act

- If aquatic life is a designated use, culvert installation, operation and maintenance should not cause physical, chemical or biological degradation or otherwise alter fish species composition and demographics, and habitat. The discharge should not impede fish movements, the movements of prey and forage, or symbiotic and commensal species.

US Army Corps of Engineers
Nationwide Permits

- Issued 2002 and renewed 2007

2. Aquatic Life Movements. No activity may substantially disrupt the necessary life cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity’s primary purpose is to impound water. Culverts placed in streams must be installed to maintain low flow conditions.
FWHA Guidance

“The design of crossing structures has traditionally used hydraulic conveyance and flood capacity as the main design parameters. Design for hydraulic efficiency overlooks the impact of a roadway-stream crossing on the stream-channel aquatic ecosystem…. to provide stream reach connectivity for all wildlife, removal of road barriers or the installation of a bridge spanning the floodplain are ideal; however, this report presumes that a narrower, fish-friendly, installation is both permitted and desirable for economical or logistical reasons. This Guidance covers the topics of fish biology, culverts as barriers, fish passage hydrology, and design considerations aid in the selection of appropriate design techniques based on hydraulic, biologic, and geomorphic considerations”.

General DEQ Criteria

• Try to span the bottomlands
• Avoid multiple culverts
• Correct for scour and erosion problems
• Proper alignment
• Bury 6-12 inches
• Avoid increases in upstream flooding
Michigan Department of Natural Resources and Michigan Department of Environmental Quality
2007 Culvert Application Inventory

2007 Culvert applications reviewed 240

- > Stream Width (40%)
- = Stream Width (12%)
- < Stream Width (48%)

Michigan Department of Natural Resources and Michigan Department of Environmental Quality
2007 Culvert Application Inventory

2007 Culvert applications reviewed 224

- Buried (27%)
- Not Buried (73%)
We need to do a better job of sizing our culverts to *simulate streams*.

Strive to maintain or create an un-fragmented stream bottom and bank edge habitat through the culvert.

This will address both fish passage as well as other wildlife that may use the stream corridor.

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**Sizing & Placement of Stream Culverts**

*The Stream Will Tell You!*

- **Match** Culvert Width to Bankfull Stream Width
- **Extend** Culvert Length through side slope toe
- **Set** Culvert Slope same as Stream Slope
- **Bury** Culvert 1/6th Bankfull Stream Width
- **Offset** Multiple Culverts (floodplain ~ splits lower buried one) (higher one ~ 1 ft. higher)
- **Align** Culvert with Stream (or dig with stream sinuosity)
- **Consider** Headcuts and Cut-Offs
Mesboac Culvert Design –

• Match Bankfull width
Fundamental Stream and Culvert Interactions

• Fish and other aquatic organisms live and travel primarily along the channel margins. This is the environment under which they evolved and developed their swimming capabilities: 0 - 3 feet/sec

• When culverts less than the bankfull width restrict flow at a road prism, exit velocities from the culvert easily reach 5 feet/sec

• I have measured some up to 11½ feet/sec

Bankfull Flow Shapes the Channel:

• Bankfull flow is the flow responsible for moving the most sediment and maintaining channel form (Dunne and Leopold 1978).

• That is why bankfull flow width is the minimum structure width required for simulating and maintaining form and functions through a crossing.

• The Bankfull Discharge (flow) on average is a 1.5 year event

• Average stream velocities at the bankfull stage are 3 – 6 feet/sec
  – Generally 3 ft/sec when channel slopes are less than 1%.
  – The average velocity goes up as channel slope increases above 1%
Avoid Width Measurements at the road on existing sites

Measure at the narrowest point on the channel away from the existing crossing—normally at riffles

Widening due to scour

Widening due to aggradation

Mesboac Culvert Design –

• Set on Channel Slope
Set Slope

Failure to set culverts on the same slope as the stream (and bury them $1/6^{th}$ width\textsubscript{BKF}) is the single reason that many culverts do not allow for fish passage!

**Slope can be measured as:**
- Slope along the bank (wider variation, than thalweg)
- Slope of the water surface (big errors at low flow or in flooded channels, good at moderate to bankfull flows)
- Slope of the thalweg (this, by far, is the best one)

Try as she might, this fish did not make it into the culvert to get where she wanted to go. Neither do most of her peers.

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**Measure a longitudinal profile to allow the precise placement of culverts.**

- **Precision Setting** is the key to a fully functional culvert installation
- Setting the elevation of the culvert invert upstream & downstream assures success!

**Measure** Bankfull elevation, water surface elevation, and major thalweg topographic breaks (riffle top, riffle bottom, pool bottom), at each station, on the longitudinal profile
1. A line connecting the thalweg riffle points from above and below the crossing site is the most accurate estimate of stream bottom.

Mesboac Culvert Design –

- Bury 1/6th of Bankfull stream width

Road Surface

1/6th width bkf
Why Bury? Many streams are naturally degrading

Bed inside culvert is about 1/6th the bankfull stream width
Up to a maximum of 2 feet
Let the bankfull discharge that lifts the stream bottom carry both the water and the sediment through the culvert, mimicking the hydraulics of the channel
1. A line connecting the thalweg riffle points from above and below the crossing site is the most accurate estimate of stream bottom

2. Subtract burying depth from these elevations to find the elevation of the inverts

Mesboac Culvert Design –

- Consider headcut

Qualitatively evaluate bank stability by observing:
- Bank materials and their layering
- Rooting depth, density and root sizes
- Large, stable woody structure on banks
- Live trees and shrubs that may overhang banks
- Evidence of active bank erosion
No culvert

Improperly set culvert

Culvert replaced properly

Aggradation

Scour pool

Note gradient increase

Stream Thalweg  Stream Slope  Culvert

Use cross vanes as grade control to permanently set a channel invert
High floodplain conveyance affects design. When conveyance is high it may be necessary to install floodplain drainage or low areas across the road. Objective being to avoid funneling over-bank flows through the main crossing structure which could destabilize the structure.

Floodplain culvert same size as stream culvert. Set same as floodplain slope.

Stream culvert sized to bankfull width. Set same as thalweg riffle slope.

**Economics?**

- The initial cost of designing for fish passage is higher, because the culvert is bigger. However,
- Failure risks are reduced
- Structural life is optimized
- Maintenance levels are reduced, and
- Replacement frequency declines
- Creating opportunities for work at other sites
Reality Check

• Having the least expensive crossing alternative and still maintaining fish passage, stream function, maximized structural life, and minimum maintenance cost is unrealistic.

• Integrating culverts, streams, and fish passage is a win-win scenario that leads to more viable fish populations, healthier streams, and engineering maintenance budgets that can focus resources elsewhere.

• Do it for the big picture, for the long haul, first.

• With a little luck, you won’t need to come back!

“The difficulty lies not in the new ideas, but in escaping from the old ones.”

John Maynard Keyes 1936