Culvert Design Process

Hydrology
↓
Site Assessment
↓
Alignment and Profile
↓
Bed and Banks
↓
Structure
↓
Sediment Mobility & Stability
Hydraulic modeling to verify capacity

- Select initial culvert size and shape
  - Design flood
  - Bankfull width and channel shape
- Model Culvert
  - Check $Q_{100}$ for $HW/D<1$
  - Check $Q_{1.5}$ or $Q_2$
- Repeat process if needed
Culvert size and bankfull width

- Bankfull Width at Reference Reach
  - Straight segment
  - Narrow
  - Unaffected by road crossing

- Bankfull Width – Brookside Cr Ex
  - Min = 8.3 feet
  - Mean = 9.1 feet
  - Range = 8.3-10.5 feet, n=5

- Select Culvert Width > BF Width

- Compare H&H Width to BF Width
HEC-RAS geometric data
HEC-RAS geometric data
HEC-RAS x-sec editor
HEC-RAS bridge/culvert editor
HEC-RAS culvert editor

![Culvert Data Editor](image)

- **Shape:** Circular
- **Diameter:** 3
- **Chart #:** 2 - Corrugated Metal Pipe Culvert
- **Scale #:** 3 - Pipe projecting from fill
- **Distance to Upstr XS:** 15
- **Culvert Length:** 54
- **Entrance Loss Coeff:** 0.3
- **Exit Loss Coeff:** 1
- **Manning’s n for Top:** 0.019
- **Manning’s n for Bottom:** 0.019
- **Depth to use Bottom n:** 0
- **Depth Blocked:** 0

**Solution Criteria:** Highest U.S. EG

**Upstream Invert Elev:** 92.36
**Downstream Invert Elev:** 92.31
**# identical barrels:** 1
HEC-RAS flows and models

[Image of HEC-RAS software interface]

Steady Flow Boundary Conditions
- Set boundary for all profiles
- Set boundary for one profile at a time

Available External Boundary Condition Types
- Known W.S.
- Critical Depth
- Normal Depth
- Rating Curve
- Delete

Selected Boundary Condition Locations and Types
- River: Brookside Crk
- Reach: Reach 1
- Profile: Upstream
- Downstream

Steady Flow Analysis
- Plan: Existing 3-3 Circ CMPs
- Geometry File: Existing 3-3 Circ CMPs
- Steady Flow File: 500-yr, 100-yr, 1.5-yr, Hpf, Uplf

Flow Regime
- Subcritical
- Supercritical
- Mixed

Plan Description:

Flow Regime:
- Subcritical
- Supercritical
- Mixed

Enter to compute water surface profiles
Existing 3-36” circular CMP profile
103”x71” CMP profile
2-103”x71” CMP profile
12’x6’ concrete box
20’x6’ concrete box
16’x6’ aluminum box
### 20’x6’ concrete box, culvert table

<table>
<thead>
<tr>
<th>Reach</th>
<th>River Sta</th>
<th>Profile</th>
<th>E.G. US.</th>
<th>W.S. US.</th>
<th>E.G. IC</th>
<th>E.G. OC</th>
<th>Min El Weir Flow</th>
<th>Q Culv Group</th>
<th>Q Weir</th>
<th>Delta WS</th>
<th>Culv Vel US</th>
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## 20’x6’ Concrete Box, X-sec Table

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<th>E.G. Elev (ft)</th>
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20’x6’ concrete box, x-sec graphs
Brookside Cr. HEC-RAS summary

100-yr flood, 381 cfs

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<th>Culvert</th>
<th>W.S. US (ft)</th>
<th>W.S. DS (ft)</th>
<th>Delta WS (ft)</th>
<th>Culv Vel US (ft/sec)</th>
<th>Culv Vel DS (ft/sec)</th>
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</table>

Note: W.S.=water surface, US=upstream, DS=downstream, Vel=velocity
7.25’x5.25’ CMP – 104% of min BFW

In N WI, many BFW culverts pass the $Q_{100}$ with a minor head increase and headwater below the top of culvert.
Stream simulation structure design
Stream simulation culvert width

- First estimate: Span channel and banks
- Hydraulic capacity
HEC-RAS profile plot
Some benefits of structures wider than bankfull width:

- Banks match reference channel.
- Minimize inlet contraction during high flow events.
- Provides increased variability of hydraulic conditions during high flows.
- Can create dry habitat conditions for passage of additional organisms—increases “openness”.
- More important on high volume traffic roads.
Stream simulation culvert width

a. Confined

b. Unconfined with wider culvert

c. Unconfined with floodplain culverts
Design the channel and floodplain

Design the culvert to fit

Road Fill

Road Dip

Floodplain culvert in flood swale

Reference channel bankfull cross section

Floodplain

Culvert Width
Structure types

Bridge

Box

Pipe Arch

Bottomless Arch

Embedded Round
Elevation

Trout Cr. Longitudinal Profile

Vertical Adjustment Potential

Proposed new structure elev.
Questions?

Credits: Gary Larson, The Far Side