Hydraulic Modeling with HY-8
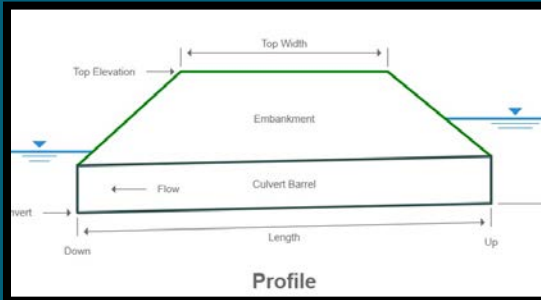

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Today's Outline

- What is HY-8?
- Best Applications & Limitations
- Input Data and Resources
- Example Project - Culvert Replacement
- Calculations & Output Considerations
- Advanced Modeling Options
- Web Resources & DEQ Contact Info

What is HY-8?

- Hydraulic computation model for roadway stream crossings (culverts)
- It is FREE
- Created & Provided Online by FHWA:
  https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
- Current Version is HY-8 7.50 (Build Date 7/28/16)
- It enables users to:
  - ✓ Analyze the performance of culverts (velocities, water depths, flow profiles)
  - ✓ Allows for multi-barrel crossings and multiple crossings in 1 project*
  - ✓ Analyze roadway overtopping (weir flow over road)
  - ✓ Develop report tables and graphs

Best Applications & Limitations

- <u>SIMPLE & BASIC PROJECTS</u>
  - ✓ **Single stream crossings with one or more pipes**
  - ✓ **Simple bridges (modeled as 3-sided box culvert)**
  - ✓ Not appropriate for bridges with piers
  - ✓ Where NO OTHER pipes, structures or floodplain/stream encroachments exist within the area of influence of the crossing being analyzed
  - ✓ *CANNOT compute multiple "In-Line" pipes (Ex: N-Bound and S-Bound HWY crossings)

Can include multiple culverts in 1 Project (i.e. 1 file) – but will not process culverts "In Line"

Yes

No
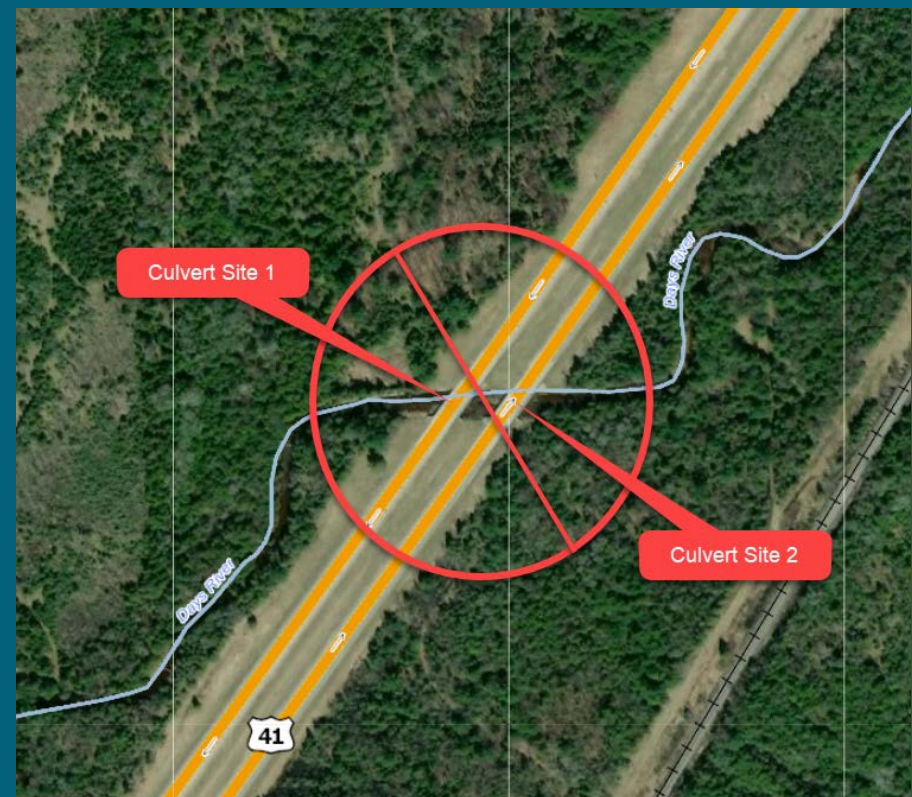
Can use HY-8 to Compare Various Culvert Designs for 1 Replacement Site

- Modify pipe cross-section designs (circular, box, ellipse, arch)
- Modify pipe elevations and inlet conditions
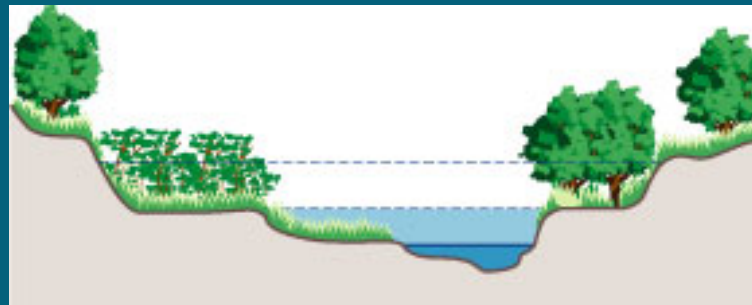- Modify pipe lengths and roadway elevations
- Modify pipe materials

Best Applications (cont'd)

- DEQ Permit Applications
  - ✓ DEQ WRD can require hydraulic models under certain permit application situations, for Part 31 (Floodplain) review
  - ✓ HY-8 is accepted in lieu of HEC-RAS *as long as* culvert site is appropriate per the criteria discussed above
  - ✓ HY-8 Provides Existing and Proposed Headwater Elevations → For 100 year flow yeilds "Existing" and "Proposed" 100 yr Flood Elevations → **Are Flood Stages Increasing or Decreasing going from "Existing" to "Proposed?"**

Input Data & Resources

- Basic Data Required for Input:
  1. <u>Flows</u> (cfs) – 50% (2-year), 10% (10-year), 2% (50-year) 1% (100-year) and 0.2% (500-year) flows are common
  2. <u>Tailwater Cross-section</u> - Stations, Elevations and Mannings 'n' of Channel & Overbank/Floodplain
  3. <u>Slope</u> - Slope of tailwater channel (d/s of x-ing)
  4. <u>Roadway</u> - Shape, Surface Elevations and Surface Type
  5. <u>Culvert Data</u> - Type, Number, Inlet/Outlet Elevations, Length, Inlet Configuration

Input Data & Resources

➢ DEQ Flood or Low-Flow Discharge Request Site

Input Data & Resources

- **Previously Calculated Flows: DEQ Flood Flow Database**
- http://www.deq.state.mi.us/flow/hflowqry.asp

Input Data & Resources

- Manning's "n" (Roughness Coefficient) for Stream Channels and Overbank Areas:
  - ➢ Several references exist for Manning's n for various stream conditions
  - ➢ "Open Channel Hydraulics", Chow 1959 is commonly used: http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Input Data & Resources

- Slope of Tailwater Channel
  - ➢ Channel downstream of road crossing
  - ➢ Obtain from Survey Data (stream bottom elevations measured at <u>riffles</u> – not in pools)
  - ➢ Obtain from Topo Maps (measure <u>stream channel length</u> between known elevation contours)
  - ➢ Rise over Run

DEQ Wetland Map Viewer Website has Topo + Measuring Tool:
https://www.mcgi.state.mi.us/wetlands/index.html
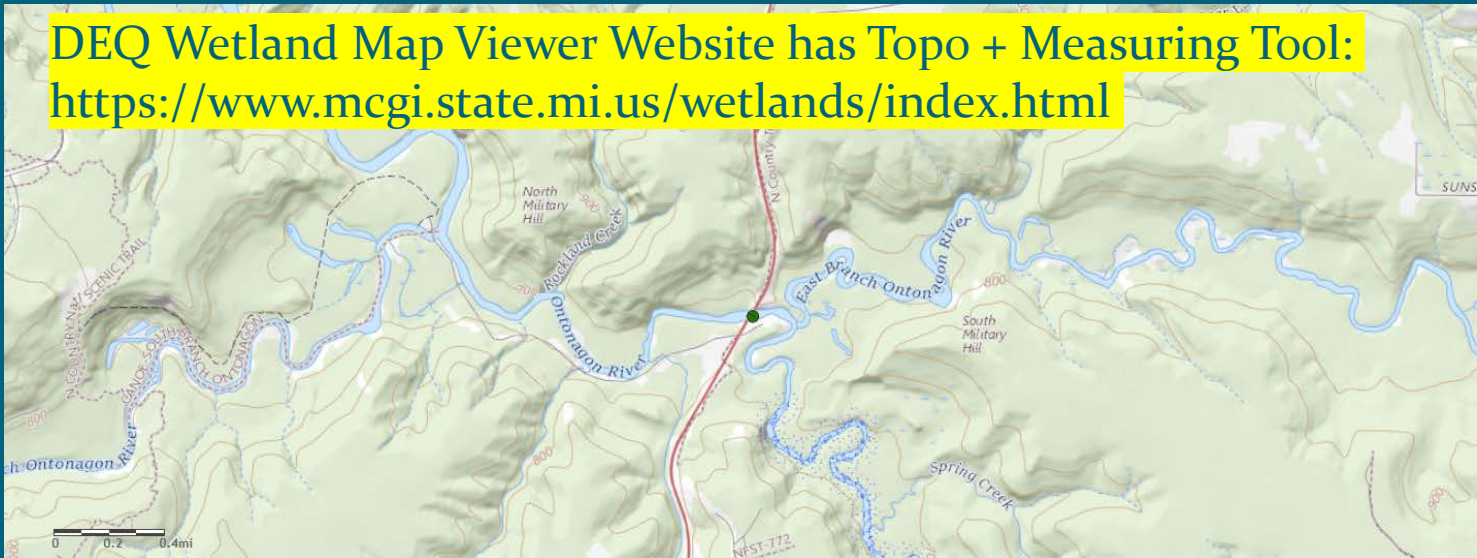
Input Data & Resources

- Project Survey and Design Data
  - Tailwater Cross-section and Roadway Survey Data:
    - Both need to span ENTIRE floodplain of interest*

      If unsure contact local floodplain engineer for elevation estimate
    - Stationing is Left to Right, looking downstream
    - Stationing should be consistent (referenced to same base line), Elevations referenced to local datum or BM
    - Road cover material and width
  - Existing Culvert Data
    - Material, shape & dimensions, invert and crown elevations (inlet & outlet), inlet condition, length
  - Proposed Design Data
    - Proposed Road Grade sta. + elevs., cover material and width

Example Project

- Remove two 4' high x 6' wide x 40' long corrugated metal ellipse culverts (projecting inlets)
- Install one 5' high x 10' wide x 48' long reinforced concrete box culvert (headwall inlet)
- Road is gravel and has a 30' width for both Existing and Proposed

→ Run the model to ensure this design will result in the <u>same or lower 100-year flood stage</u> to meet Part 31 (Floodplain) requirements.

Example Project

Open new Project File:

Input Screen pops up when box is checked:
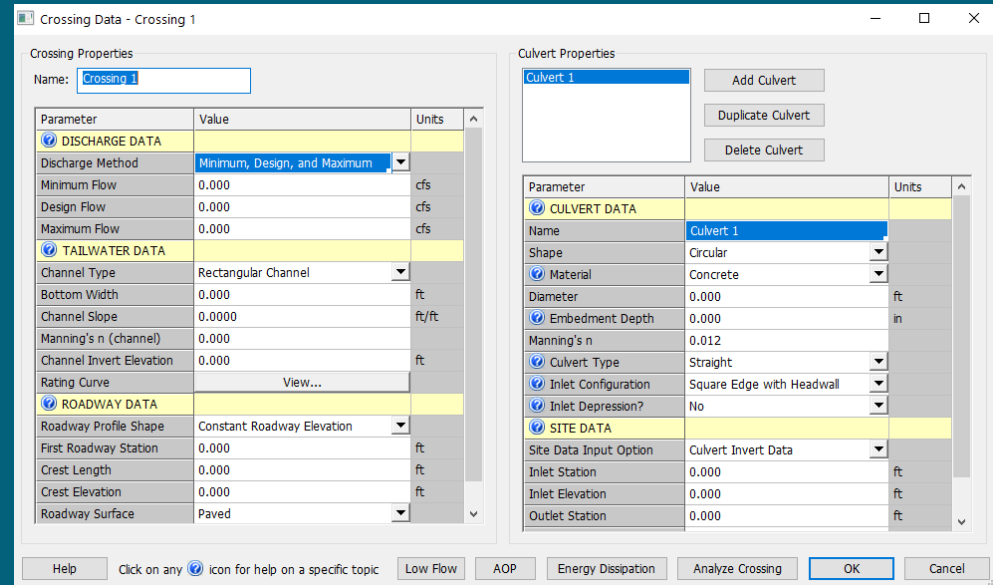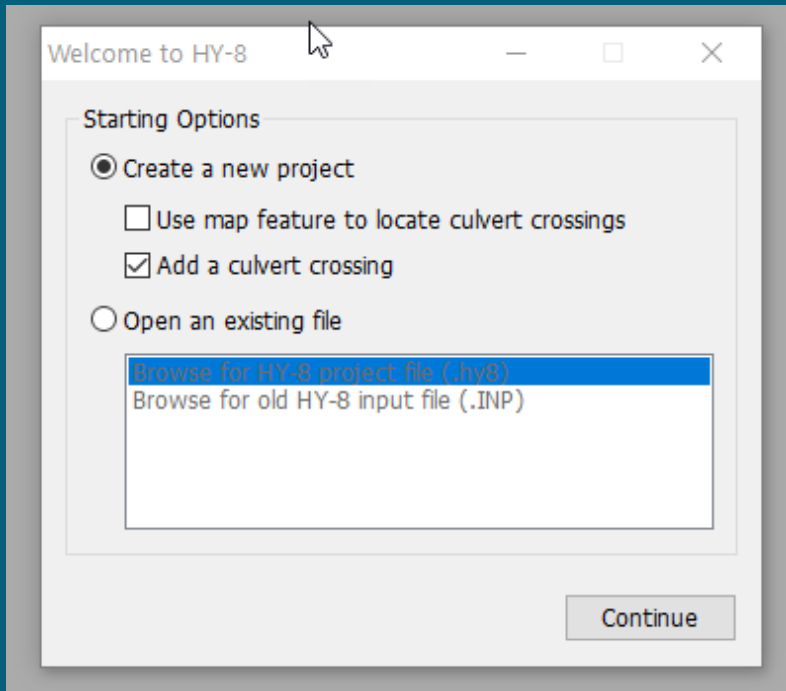
Example Project

Name Crossing & Enter Crossing Properties: Flow, Tailwater & Road Data

Example Project

Enter Culvert Properties: Name, Shape, Material, Dimensions, Embedment Depth, Inlet Configuration, Inlet & Outlet Sta + Elevs., # of Barrels

Note "User Defined" vs. Template

Stationing ALONG culvert defines length

Example Project
Create Proposed Box Culvert & Repeat

Example Project

Hit "Analyze Crossing", View Culvert Profiles, Enter Road Station Location of Culvert(s) + View X-Section
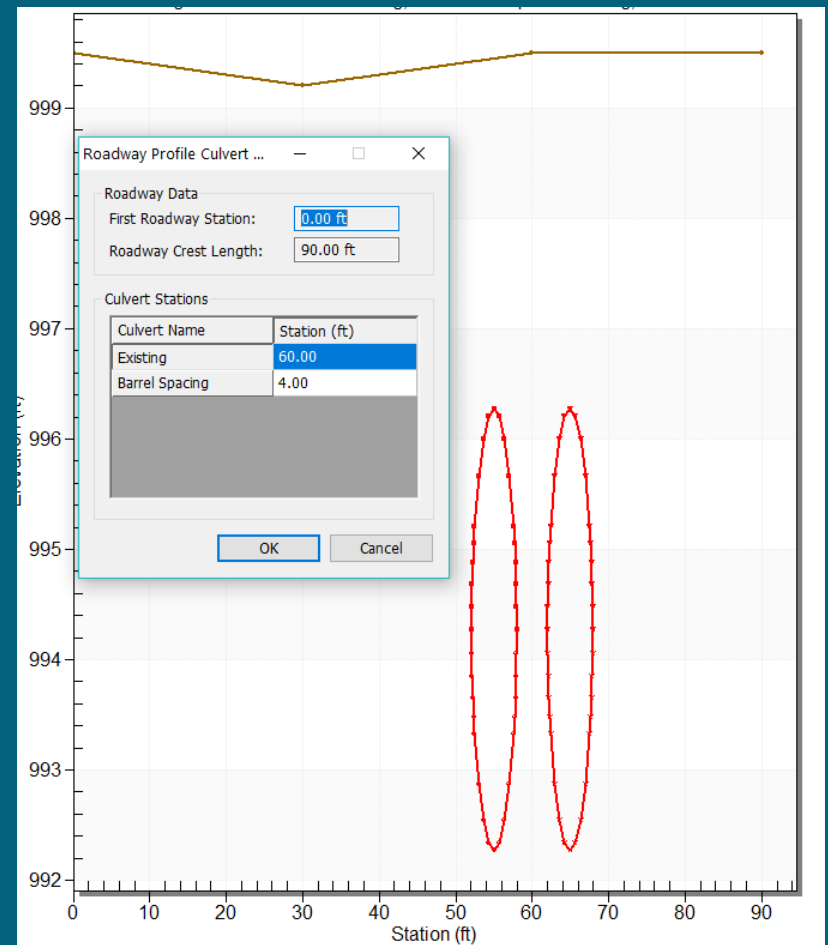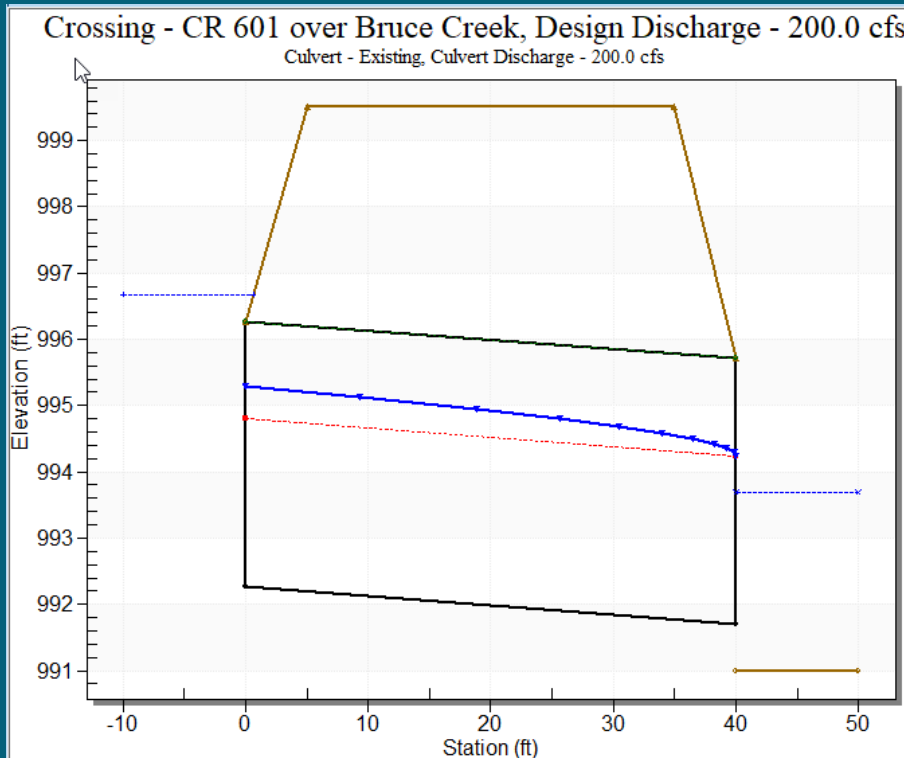
Example Project
Review Results:

Existing 100 yr Elev. = 996.7 ft.

Summary of Flows at Crossing - CR 601 over Bruce Creek

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
993.69	2 year	25.00	25.00	0.00	1
994.69	10 year	70.00	70.00	0.00	1
995.96	50 year	150.00	150.00	0.00	1
996.67	100 year	200.00	200.00	0.00	1
999.20	Overtopping	324.75	0.00	1.00	

→ **RESULT:** The project as proposed is a hydraulic improvement (does not increase flood stages) and can be permitted under Part 31 (Floodplains)

Proposed 100 yr Elev. = 995.4 ft.

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
992.72	2 year	25.00	25.00	0.00	1
993.62	10 year	70.00	70.00	0.00	1
994.75	50 year	150.00	150.00	0.00	1
995.40	100 year	200.00	200.00	0.00	1
999.20	Overtopping	516.54	0.00	1.00	

Example Project
Various Ways to View Results

Crossing Summary Table

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
992.72	2 year	25.00	25.00	0.00	1
993.62	10 year	70.00	70.00	0.00	1
994.75	50 year	150.00	150.00	0.00	1
995.40	100 year	200.00	200.00	0.00	1
999.20	Overtopping	516.54	0.00	1.00	

Water Surface Profiles

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Length Full (ft)	Length Free (ft)
2 year	25.00	25.00	992.72	0.83	1.36	3-M1t	0.00	48.00
10 year	70.00	70.00	993.62	1.66	2.27	3-M1t	0.00	48.00
50 year	150.00	150.00	994.75	2.74	3.39	3-M2t	0.00	48.00
100 year	200.00	200.00	995.40	3.36	4.04	3-M2t	0.00	48.00

Culvert Summary Table

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	25.00	25.00	992.72	0.83	1.36	3-M1t	0.82	0.57	1.58	1.57	1.59	4.04
10 year	70.00	70.00	993.62	1.66	2.27	3-M1t	1.60	1.16	2.19	2.19	3.20	3.65
50 year	150.00	150.00	994.75	2.74	3.39	3-M2t	2.64	1.92	2.54	2.54	5.90	3.26
100 year	200.00	200.00	995.40	3.36	4.04	3-M2t	3.13	2.32	2.69	2.68	7.44	3.28

Total Rating Curve (Performance)
Crossing: CR 601 over Bruce Creek (dup)
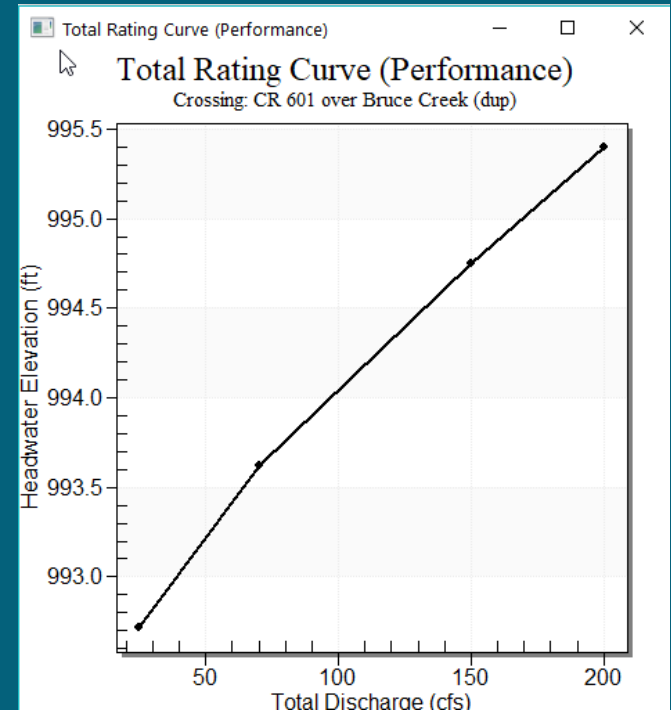
Calculations & Output Considerations

- Water Surface Profiles are calculated using the Direct Step Method
  - ➤ Uses Manning's, Continuity Equations
  - ➤ Guesses and iterates until an answer is converged upon
  - ➤ The entered flow data, tailwater cross-section and tailwater slope (which equates to the assumed tailwater depth) are required to begin the iterations
- Weir flow (over road) is calculated using a broad-crested weir equation
  - ➤ Roadway width & surface type inputs
  - ➤ Weir and Pressure flow equations are balanced until they result in the same headwater elevation.

Calculations & Output Considerations

- HY-8 Computes Inlet Control Headwater Elevation:
  - ➤ Headwater elevation is entirely a function of inlet size, geometry and entrance condition
  - ➤ Flow passes through critical depth at the culvert entrance and is supercritical in the barrel
- HY-8 Computes Outlet Control Headwater Elevation:
  - ➤ Headwater elevation is a function of barrel size, material, geometry and tailwater condition
  - ➤ Flow in barrel is subcritical and the energy equation is used to calculate the headwater elevation
- HY-8 uses the higher of the two answers for the water profile solution

Calculations & Output Considerations

- Make sure Output Data makes sense:
  - ➢ Does it make logical sense based on your inputs?
  - ➢ How does it compare to existing data or previous on site observations?
  - ➢ Comparing between existing and proposed – do drastic changes in design result in drastic hydraulic changes? (and vice versa)
  - ➢ Multiple culverts (multi-barrel or floodplain overflow pipes) do flows compared between them make sense?
  - ➢ Weir flow over road - would it really rise that high?
  - ➢ If something looks logically wrong – check your input data!

Advanced Modeling Options of V. 7.50

- Energy Dissipation Evaluation
  - ➢ Estimate Scour Hole Geometry
  - ➢ Design Internal and External Energy Dissipators
- Aquatic Organism Passage (AOP) Design Calculator (FHWA HEC-26)
  - ➢ Enter hydraulic and stream morphology data and determine if the stream is stable (not aggrading or degrading) → Design culvert based on stability
  - ➢ Analysis of flows based on culvert size, alignment, material selection → Compare in-pipe Velocity with u/s and d/s Velocities
- Evaluation of Fish Passage in Large Culverts for Low Flows (FHWA-HRT-14-064)
  - ➢ Evaluates velocities across pipe x-sec
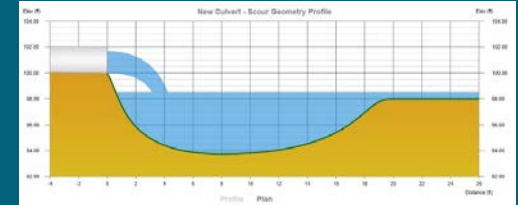
Web Resources & DEQ Contact

- HY-8 Download Page https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
- DEQ Flood Flow Database (and link to Discharge Requests) http://www.deq.state.mi.us/flow/hflowqry.asp
- DEQ Wetland Map Viewer (topo, aerials with measuring tools) https://www.mcgi.state.mi.us/wetlands/index.html
- Manning's 'n' values http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

- DEQ WRD Transportation Staff Map (Contacts Listed by County) https://www.michigan.gov/documents/deq/wrd-trans-hydraulics-staff_402907_7.pdf

Questions?