Structure Design Process

Hydrology

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Site Assessment

↓

Alignment and Profile

↓

Bed and Banks

↓

Structure

↓

Sediment Mobility & Stability

Structure design steps

- Choose a structure width based on:
  - Bankfull width
  - Minimum bank width
  - Floodplain requirements
  - Other passage requirements
- Add LVAP & road surface to:
  - Cross-section graph
  - Profile graph
- Select an initial structure:
  - Type and size
  - Id min & max cover requirements

Structure design steps

- Select an elevation for the invert or bottom of footer
- Verify cover requirements & embedment depth
- Determine structure length taking into account:
  - side-slope
  - end treatments
- Check
  - hydraulic capacity (HW/D<0.8 for Q_{100}),
  - bed mobility
  - key piece stability
- Repeat as needed

Structure type and size

The structure must wrap around a design channel that is bankfull width, has stable banks and is capable of handling vertical adjustments, flood flows, debris, sediment transport and floodplain conveyance!

Culvert size & type factors based on project objectives

- Bankfull width minimum
- Capacity for the Q_{100} with HW/D<0.8 plus debris
- Self-sustaining bed with stable key pieces
- Minimize maintenance needs
- Passage of non-aquatic species
- Maintain floodplain processes

Culvert size & type factors based on site conditions and engineering constraints

- Alignment of channel to road
- Ice plugging in severe cold climate
- Large bed material relative to culvert width
- High water level stage during floods
- Soft foundations or shallow bedrock
- High conveyance across flood plain
- Height of road and load requirements
- Access for equipment and materials
- Utilities

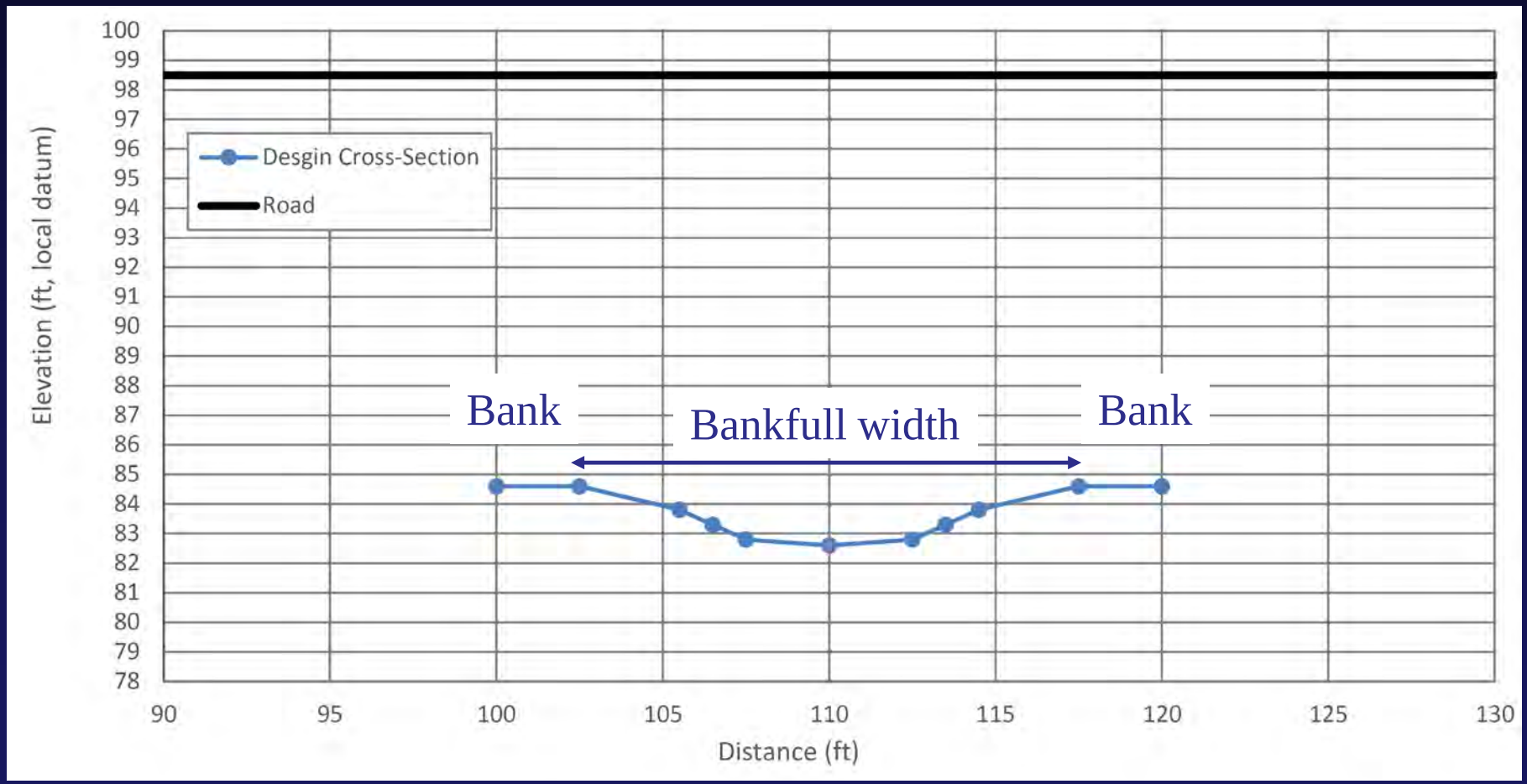
Stream simulation culvert width

Benefits of structures wider than bankfull width:

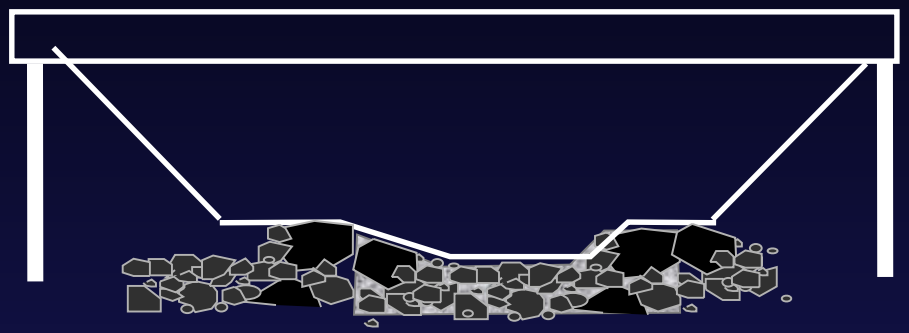
- Banks match reference channel
- Minimize inlet contraction during high flow events
- Can create dry habitat conditions for passage of additional organisms—increases “openness”
- More important on high volume traffic roads

Stream simulation culvert width

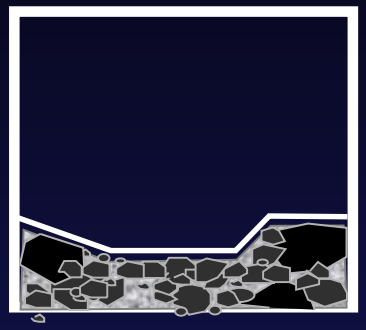
- First estimate: Span BF channel and banks



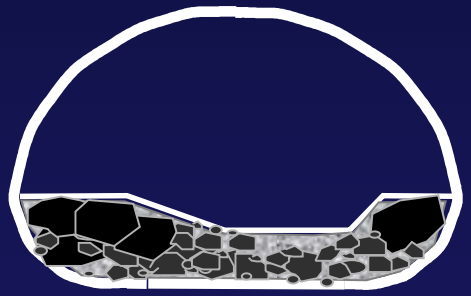
Structure types



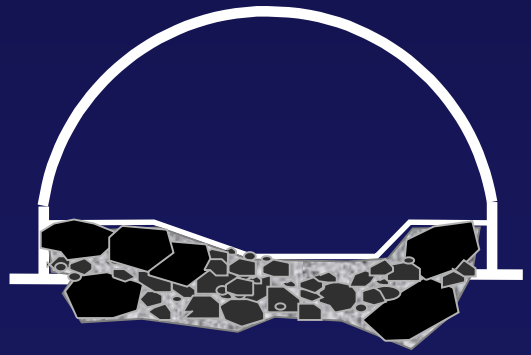
Bridge



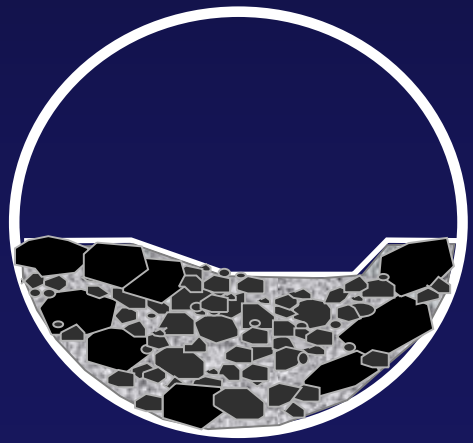
Box



Pipe Arch



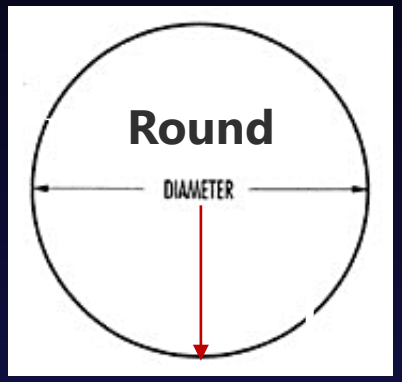
Bottomless Arch



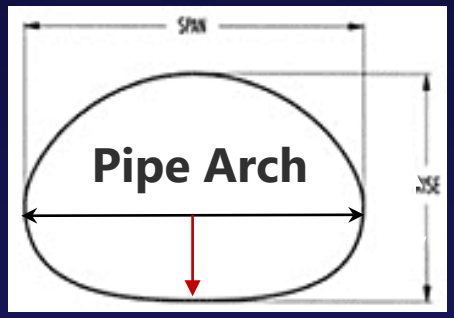
Embedded Round

Pipes

- Max embedment = max pipe width
- embedment depth can be a limitation
- Up to 37’ wide (horizontal ellipse)



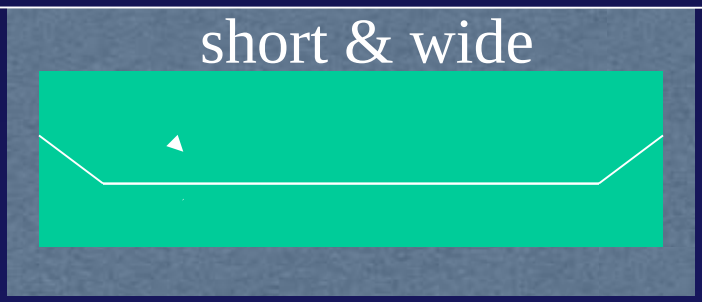
50% of width



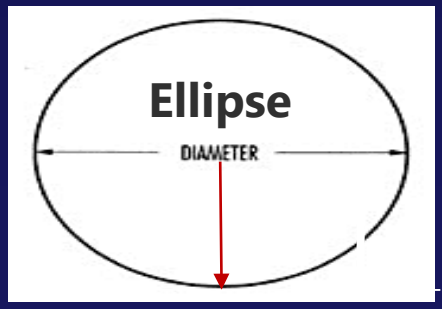
20-35% of width

Box Culverts

short & wide

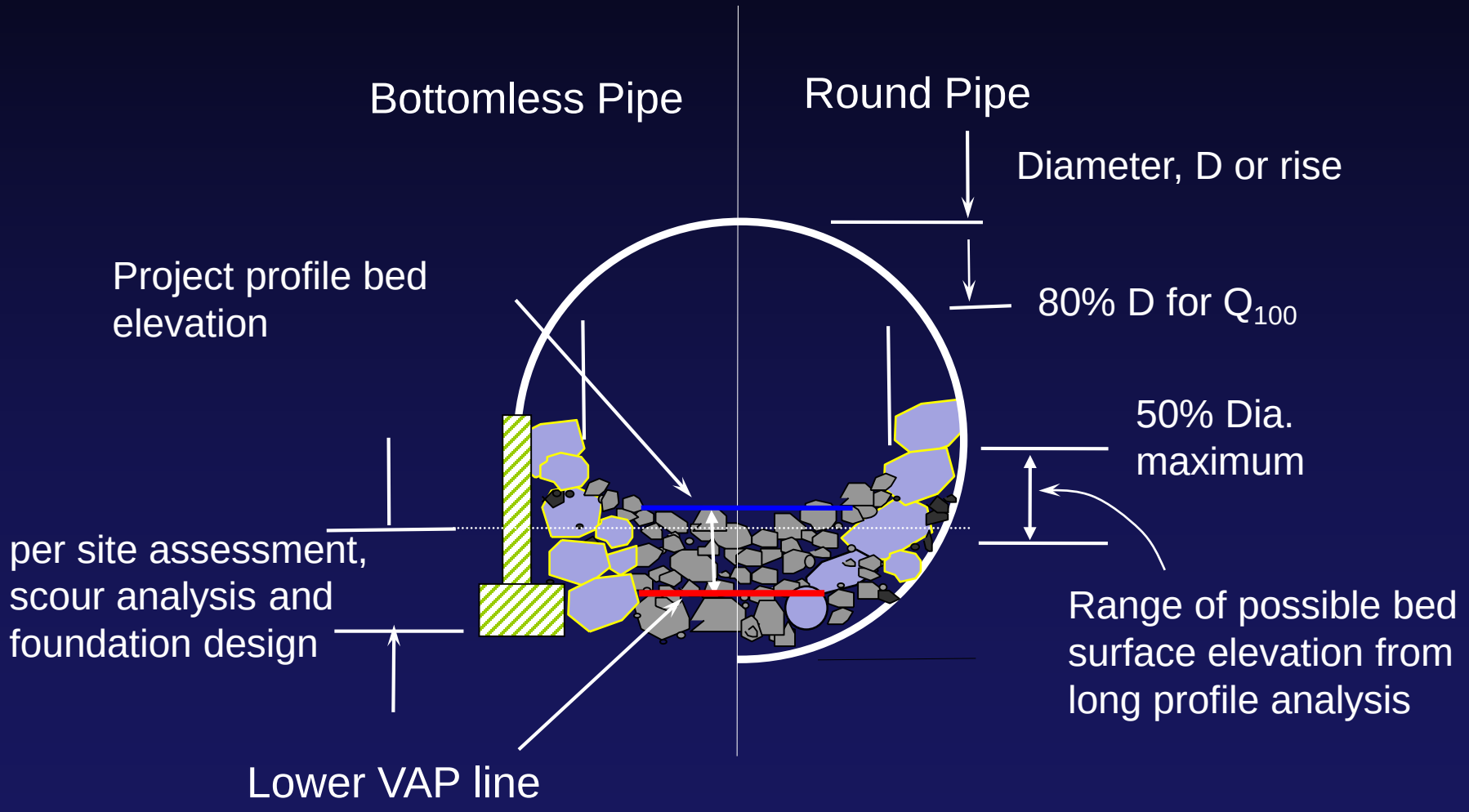


Embedment depth varies, designer has a choice



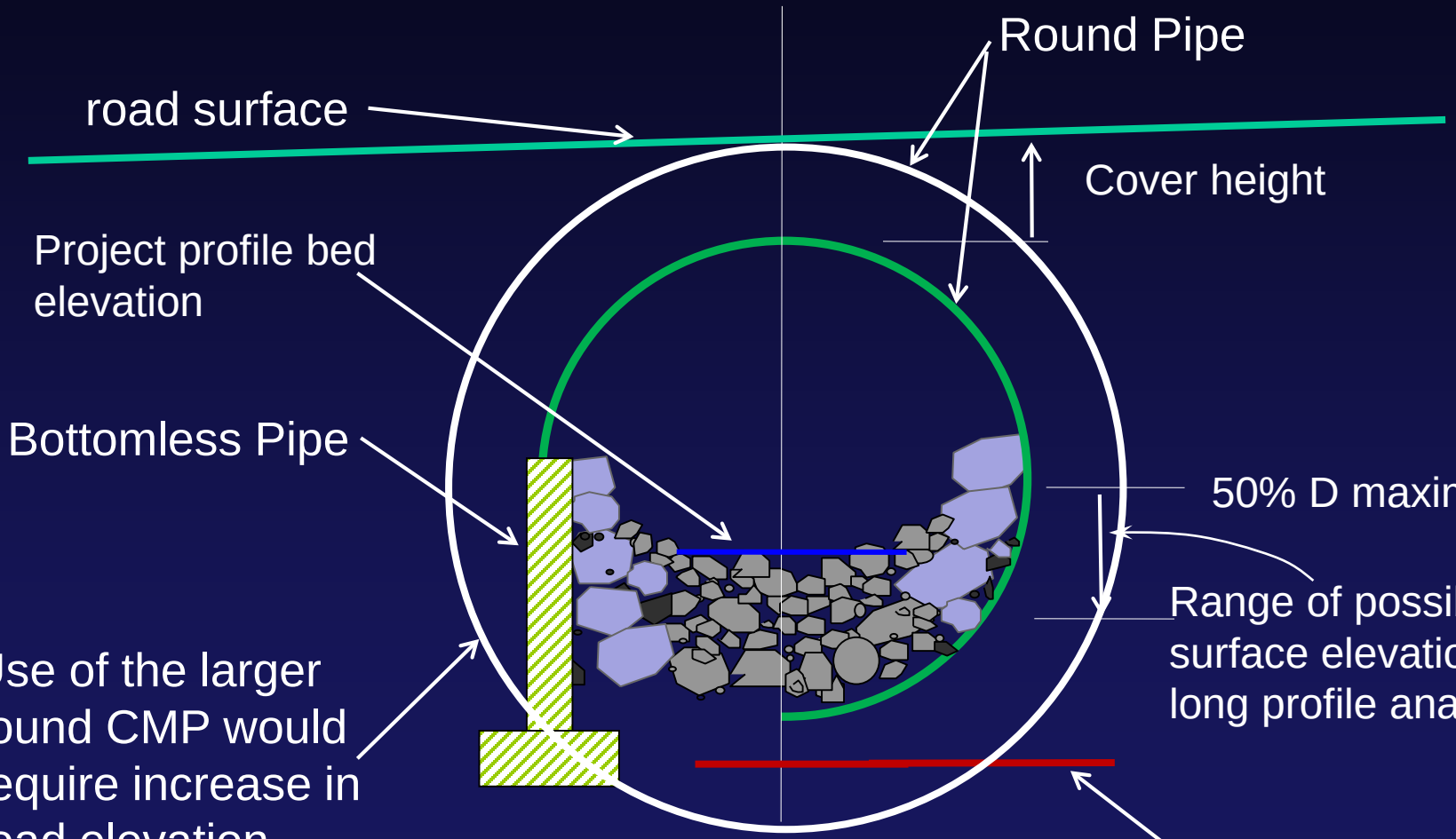
50% of width

Culvert size and elevation



LVAP = max residual pool depth x 1-2 depending on bed material size

Structure size and shape is an integration of the project objectives, site conditions and engineering constraints



Structure examples


12’ wide ellipse


25’ wide alum box


24’ wide conc arch

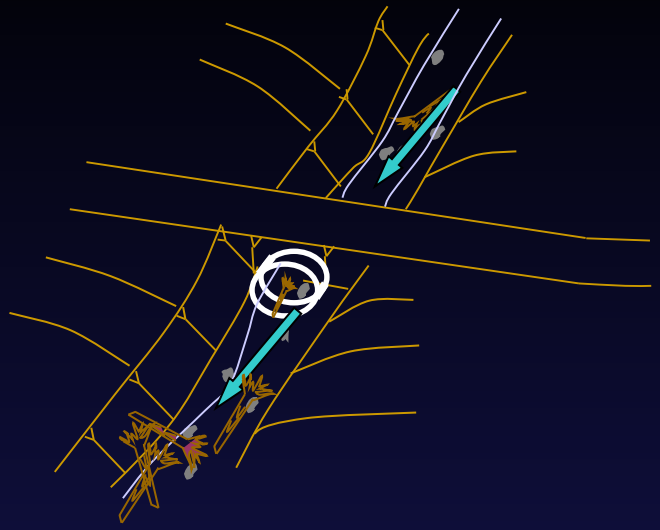

12’ wide pipe-arch


30’ wide bridge

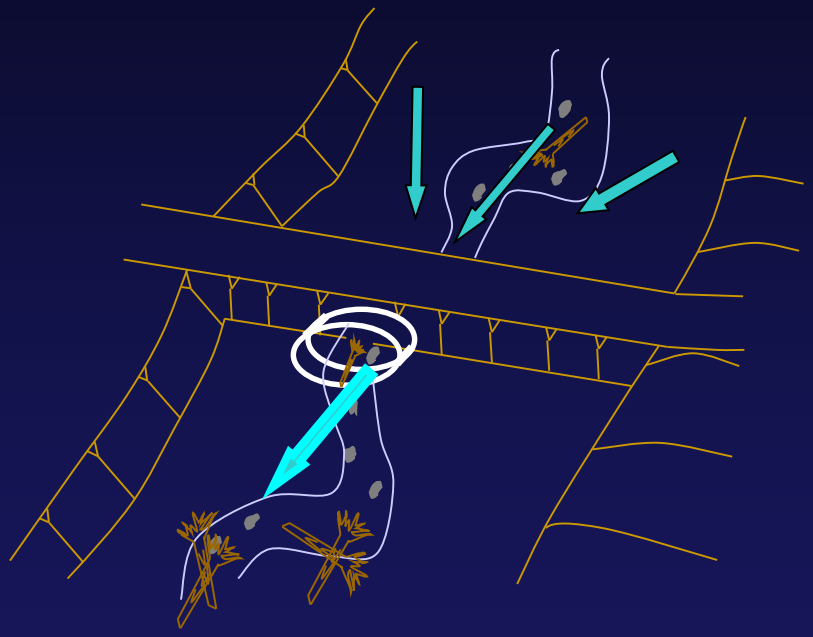

20’ wide conc box

The ellipse, pipe-arch and alum box have bottoms, the other structures do not.

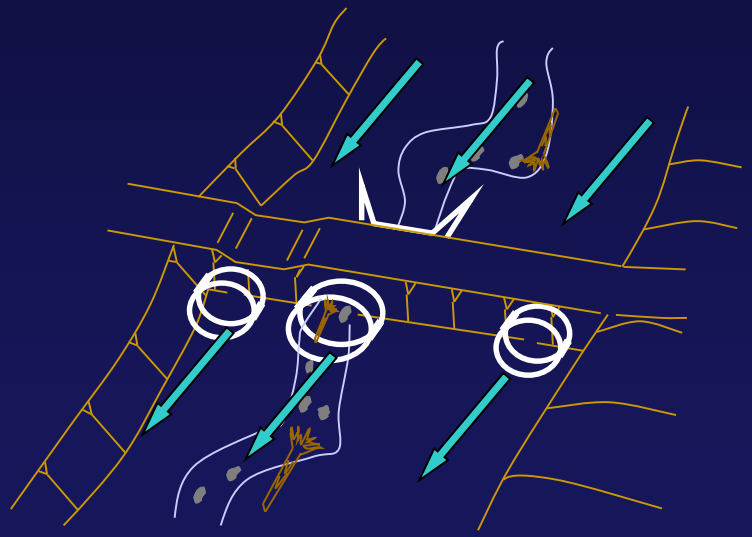
Floodplain considerations flood conveyance



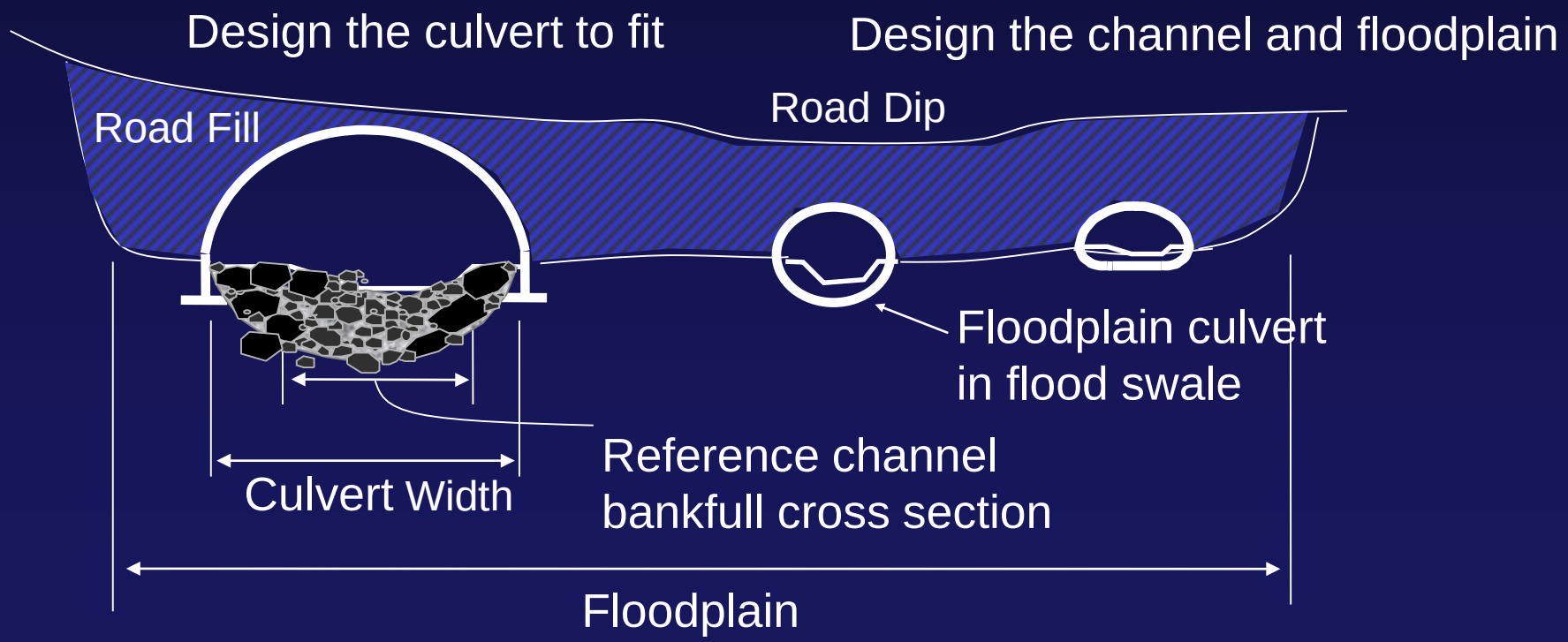
a. Confined



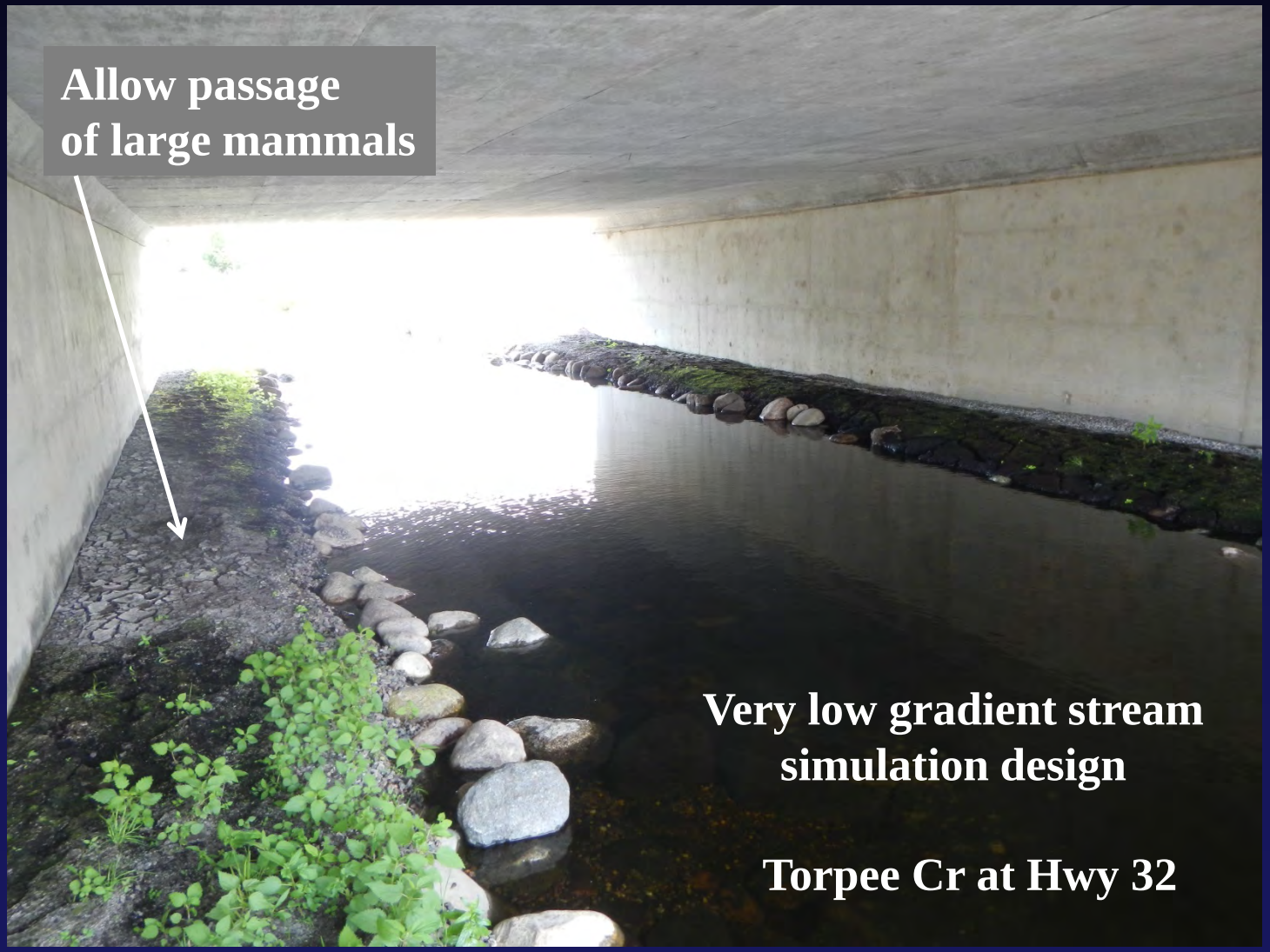
b. Unconfined
with wider culvert



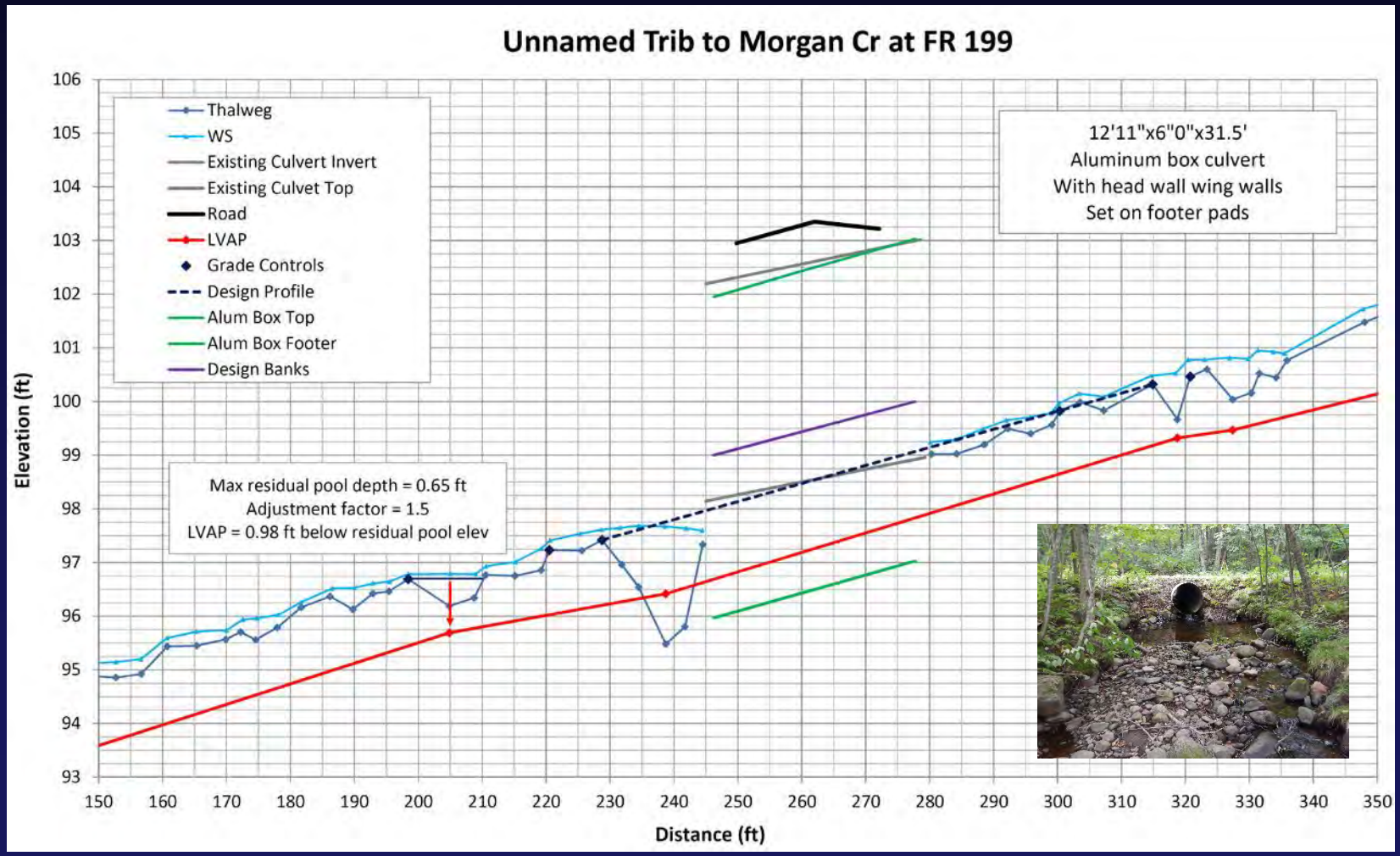
c. Unconfined
with floodplain culverts


Design the culvert to fit
Design the channel and floodplain
Road Fill
Road Dip
Floodplain culvert
in flood swale
Reference channel
bankfull cross section
Culvert Width
Floodplain

Floodplain considerations animal passage



Structure elevation and length



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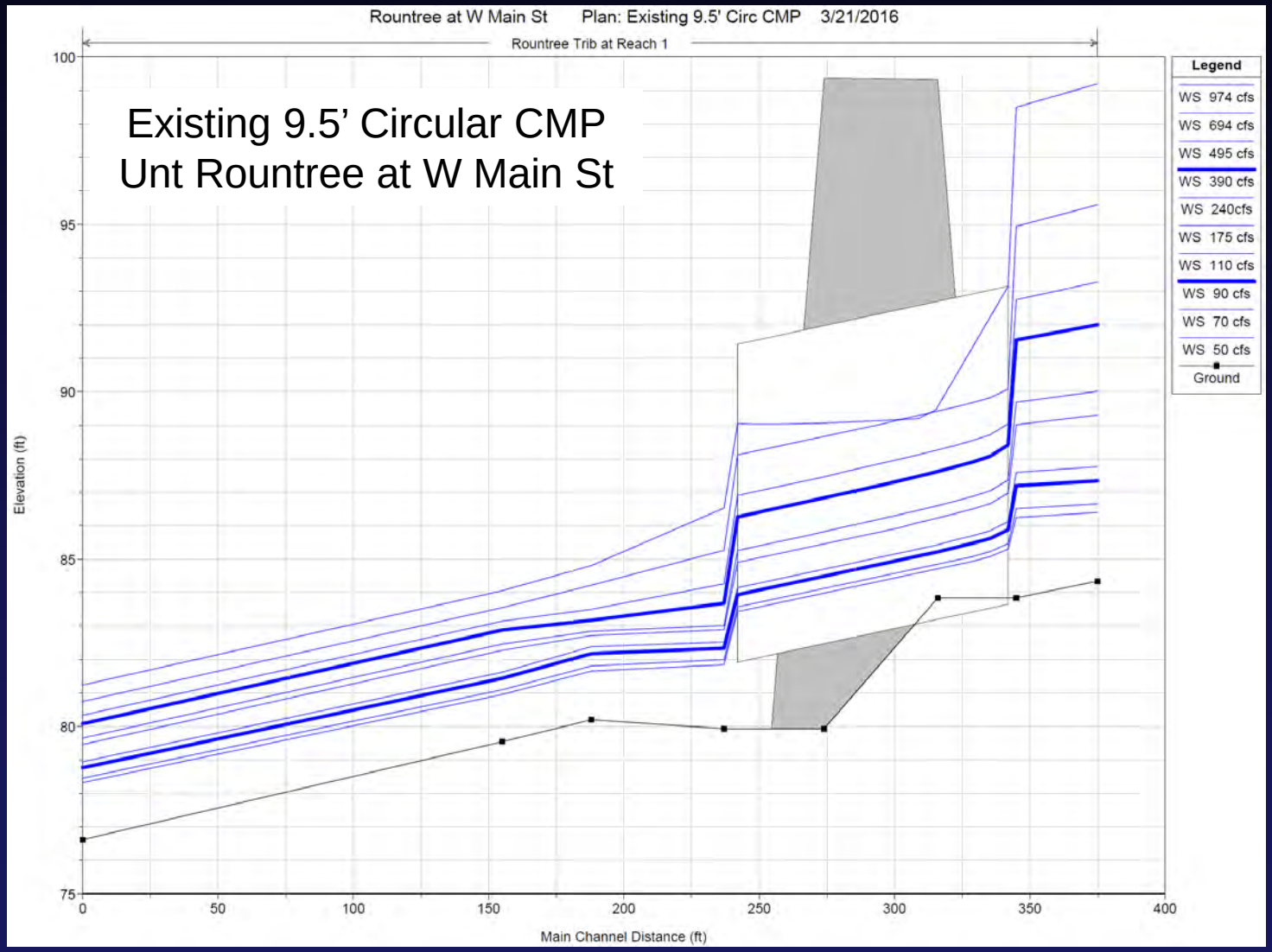
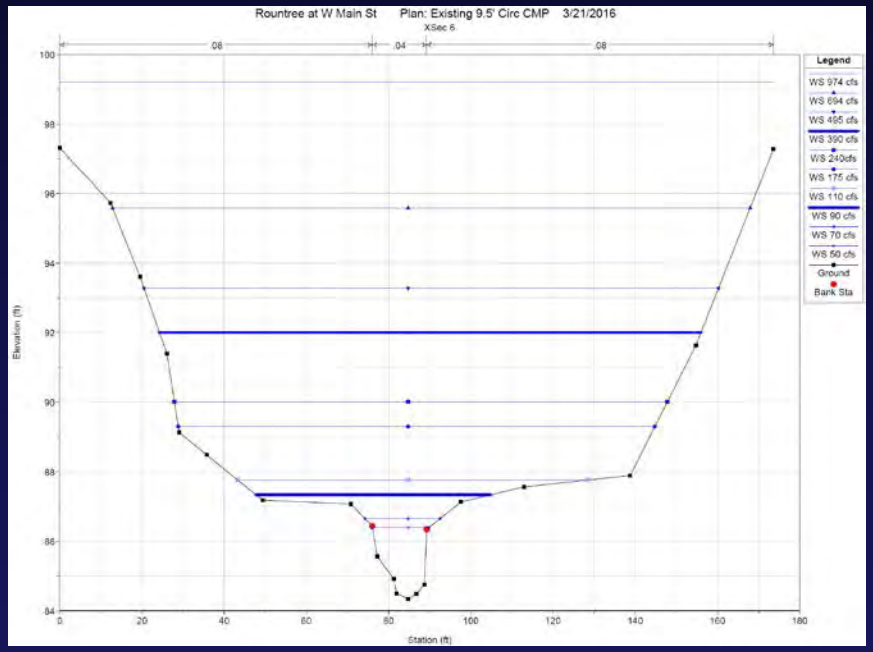
Stream simulation structure shape and size, and substrate volume exercises

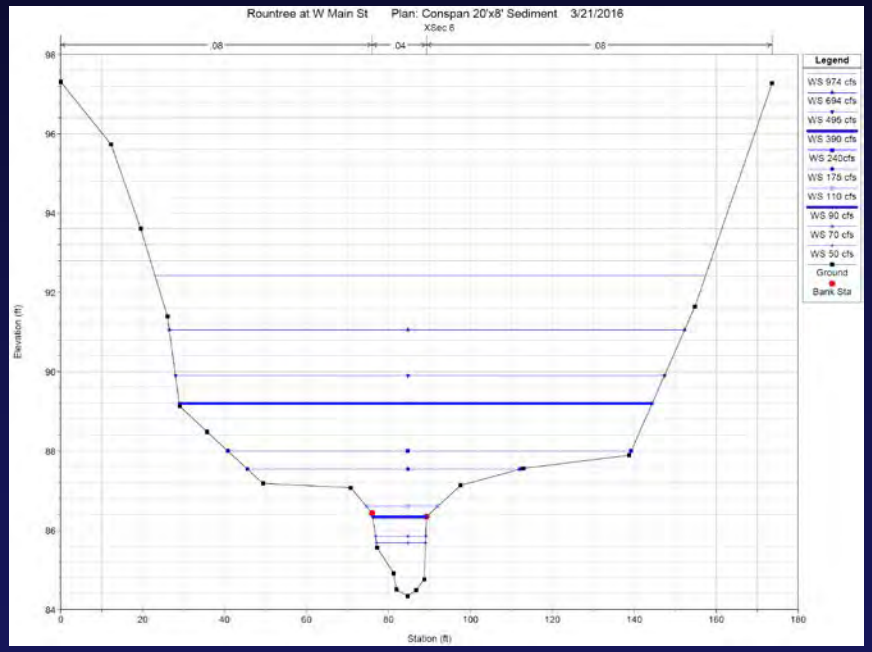
Hydraulic modeling for existing structure



Hydraulic modeling for existing and proposed structure

Cross-section 6 located 33 ft upstream from culvert inlet

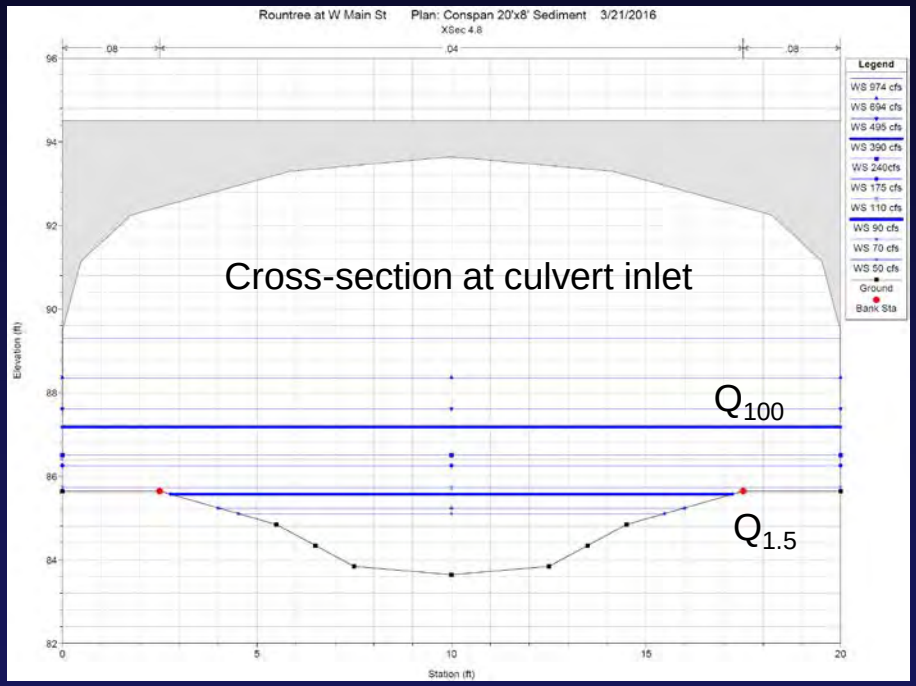


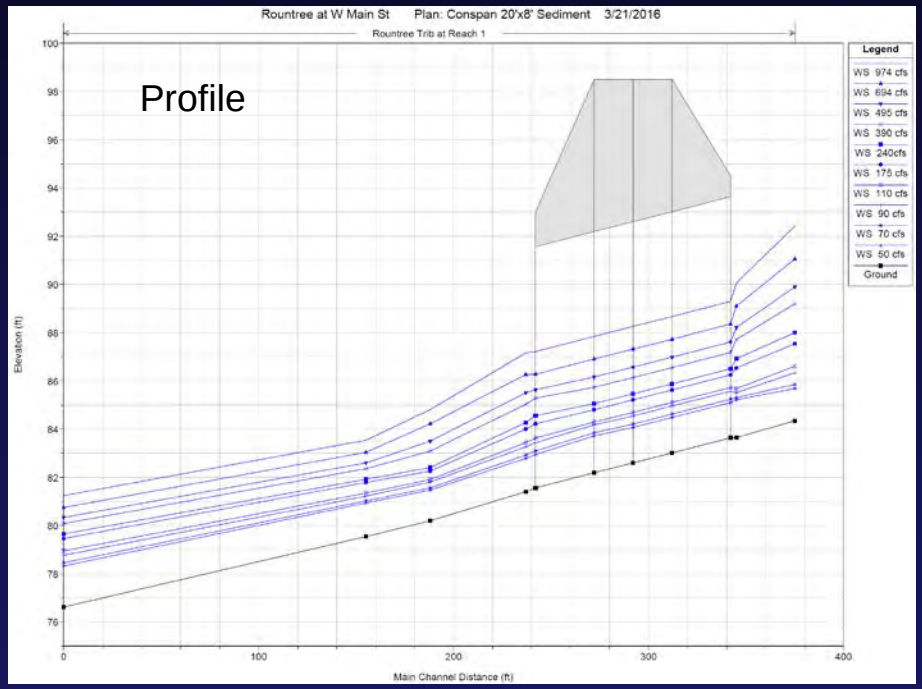


Existing 9.5’ Circular CMP
Unt Rountree at W Main St

Proposed 20’ Arch
Unt Rountree at W Main St

Hydraulic modelling for proposed structure





Proposed 20’x8’ Arch Unnamed Tributary to Rountree at W Main St

Questions?

Credits: Gary Larson, The Far Side