2021 Summer County Engineer's Conference

Erik Brenna | Assistant State Hydraulics Engineer | MnDOT

June 17th, 2021

DEPARTMENT OF TRANSPORTATION

2021 Summer County Engineer's Conference

State Aid - Bridge Hydraulics Engineer

Position formerly held by Petra DeWall

- Available for assisting local partners with unusual hydraulic issues
- Work closely with State Aid Bridge, State Aid Hydraulics,

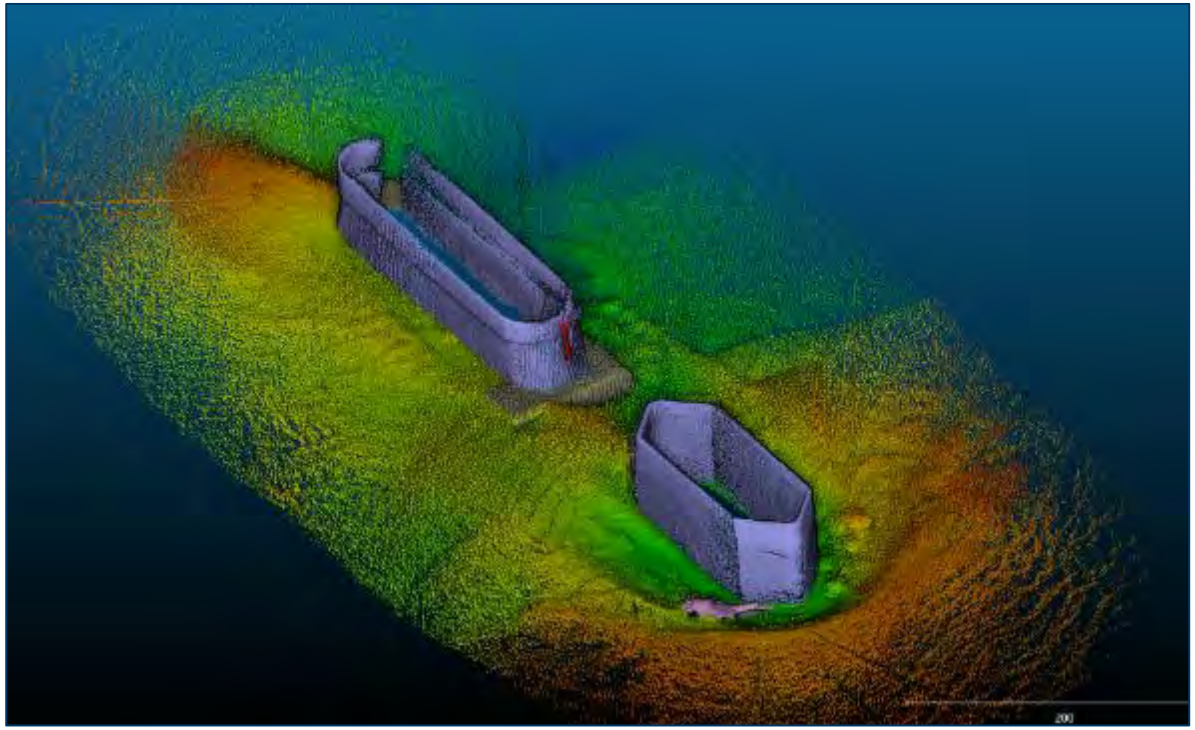
and Waterway units

Scour Plans of Action (POAs)

The Waterway Unit can assist with these

- POAs need to be reviewed every 5-10 years
- These should be substantially complete by now
- Biggest issues are knowing when to start monitoring and being able to monitor as indicated in POAs

Other Services We Can Provide:



3D scanning of scour critical bridges

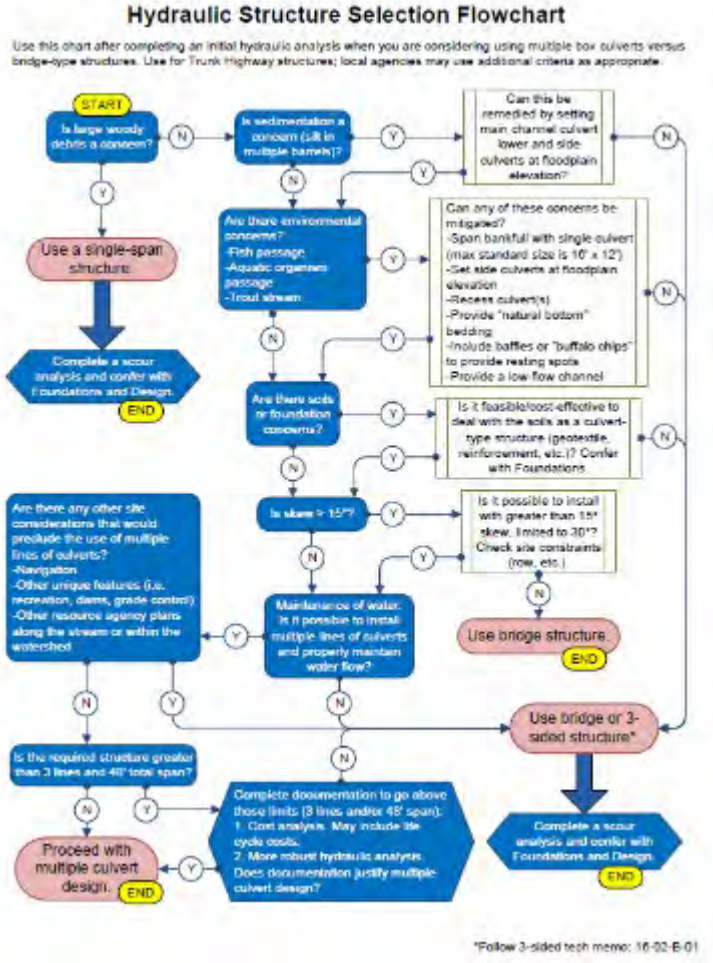
- Based on availability of our unit

Hydraulic design of waterway crossings

- On very limited basis
- Nothing time sensitive at this time
- We bill the local agency directly for this work

Multiple Lines of Culvert

- How many culverts will the site support?
- Multiple culverts vs. bridge structure



http://www.dot.state.mn.us/bridge/hydraulics/Waterways/CulvertBridgeSelection_final.pdf

DNR - Floodplain Culverts

- Site-specific requirements
- DNR looking to fund pilot projects

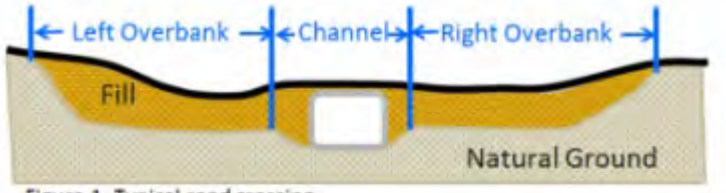


Figure 1. Typical road crossing

Figure 2. Typical Blow-out at low spot in road

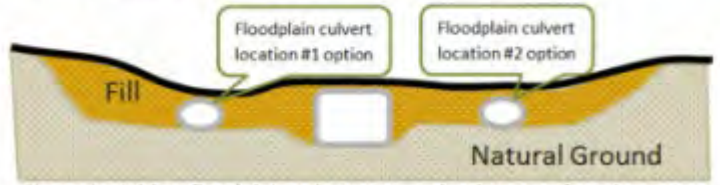


Figure 3. Adding floodplain culverts in overbank areas of road crossing

Minnesota Guide for Stream Connectivity and Aquatic Organism Passage Through Culverts

Nicki Bartelt | Minnesota Department of Transportation
Peter Leete| Transportation Hydrologist | DNR-MnDOT Liaison
Jessica Kozarek and Matt Hernick | UMN Saint Anthony Falls Laboratory

DEPARTMENT OF TRANSPORTATION

DEPARTMENT OF NATURAL RESOURCES

What we are moving towards…

The structure must be comprehensively designed to convey surface water, sediment, debris, and resident aquatic organisms.

Topics addressed in the guide

- Design Approaches. Written is regulatory context for both DNR and MnDOT.
- Design Methods. Provides multiple methods and best practices that incorporate AOP and waterway connectivity.
- Site Assessment and Analysis tools. Consistent tools for gathering characteristics, energy dissipation needs, hydraulic analysis, AOP, and sediment transport.
- Options. Selection charts and corresponding information.
- More Options. Multiple barrels, floodplain culverts, grade control, retrofits and other considerations (such as cost).

https://www.dot.state.mn.us/research/reports/2019/201902.pdf

When and where to use the guide?

When will it be used?

For MnDOT projects, expect it to be referred to in upcoming Early Notification Memo (ENM) comments, the next iteration of the DNR General Permit to MnDOT for Bridge and Culvert work (GP2004-0001), and its accompanying Best Practices Manual

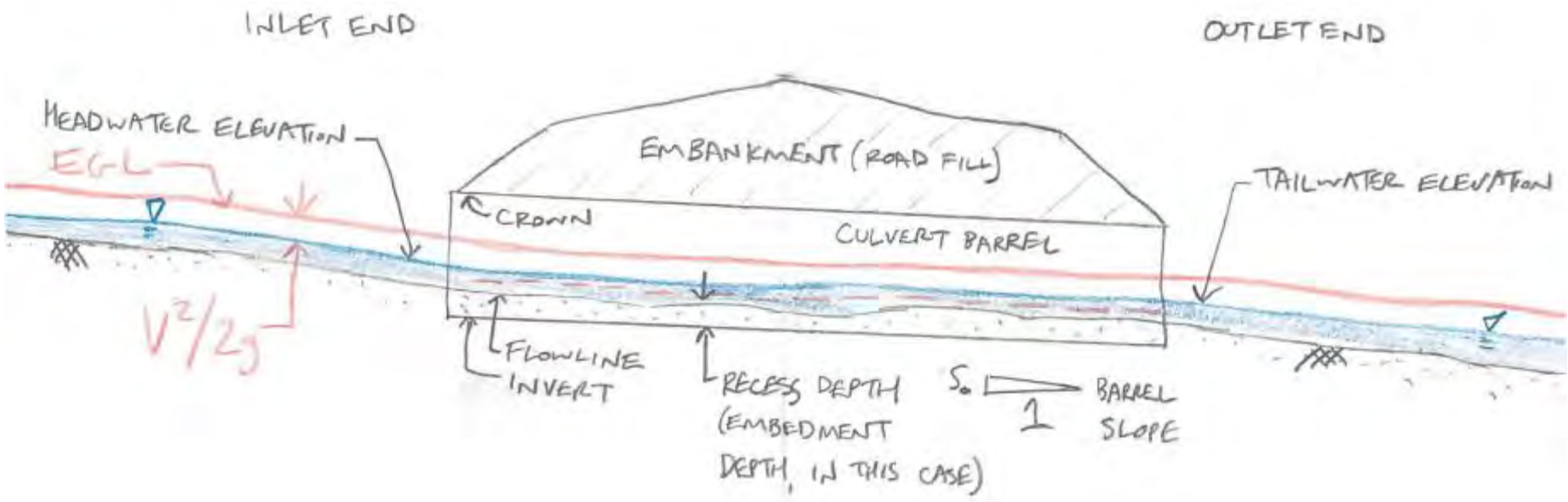
DNR Area Managers and County Engineers may also refer to it on county and local road systems.

Where will it be utilized?

Statewide. The guide is applicable for culvert proposals on Public Waters in regards to game fish passage and/or rare species movement.

How to use the guide

- We've had the "Why" for 2 decades, this guide provides the "How"
- Training provided efficient and consistent culvert design with respect to AOP and stream connectivity – All working from the same playbook
- Give designers the resource in an easy to digest, practical format



Thank you again!

Erik Brenna

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http://www.dot.state.mn.us/bridge/hydraulics/resources.html

Why do we need to design for AOP?

DNR Public Waters

Mn Statute: 103G.245 (Work in Public Water)

Effect on Environment and Mitigation

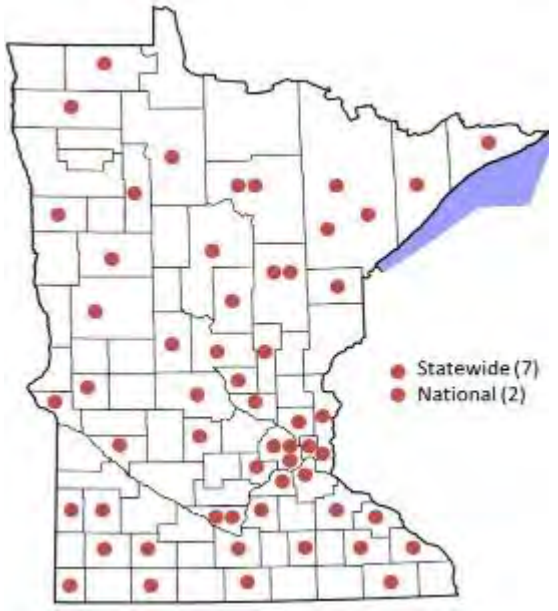
- A public-waters-work permit may be issued only if the project will involve a minimum encroachment, change, or damage to the environment, particularly the ecology of the waterway.
- If a major change in the resource is justified, public waters work permits must include provisions to compensate for the detrimental aspects of the change

Mn Rules: 6115.0230: (Bridge and Culvert criteria)

- The structure provides for game fish movement, unless the structure is
- intended to impede rough fish movement or the stream has negligible fisheries value

Minnesota Guide for Stream Connectivity and Aquatic Organism Passage though Culverts

- This is a GUIDE synthesizing a lot of information on culvert design for aquatic organism passage, tailored to Minnesota.
- Supplement culvert design practices (not replace)
- Informed by Technical Advisory Panel, External Experts Panel, and 67 survey respondents
- Appropriate approaches will differ based on site characteristics, project goals.
- In revision: Best Practices for Meeting DNR General Public Waters Work Permit 2004-0001



Past AOP designs and guidance

"The structure provides for game fish movement, unless the structure is intended to impede rough fish movement or the stream has negligible fisheries value."

Easier said than done....

- Design for 2 fps for 2yr event (fish swimming ability)
- MESBOAC (principles of fluvial geomorphology)

MESBOAC stands for:

Match culvert width to bankfull stream width.

Extend culvert length through the side slope toe of the road.

Set culvert slope the same as stream slope

Bury the culvert

Offset multiple culverts.

Align the culvert with the stream channel.

Consider headcuts and cutoffs.

Seven best practices

Seven best practices (design elements) based on stream characteristics can be summarized as follows:

- Design the culvert to be similar to the stream channel (reference reach)
  Matching bankfull width, alignment, flow depth, and slope

- Provide a continuous sediment bed
  Roughness similar to the channel and maintain sediment transport and debris passage

- Design for public safety, longevity, and resilience.

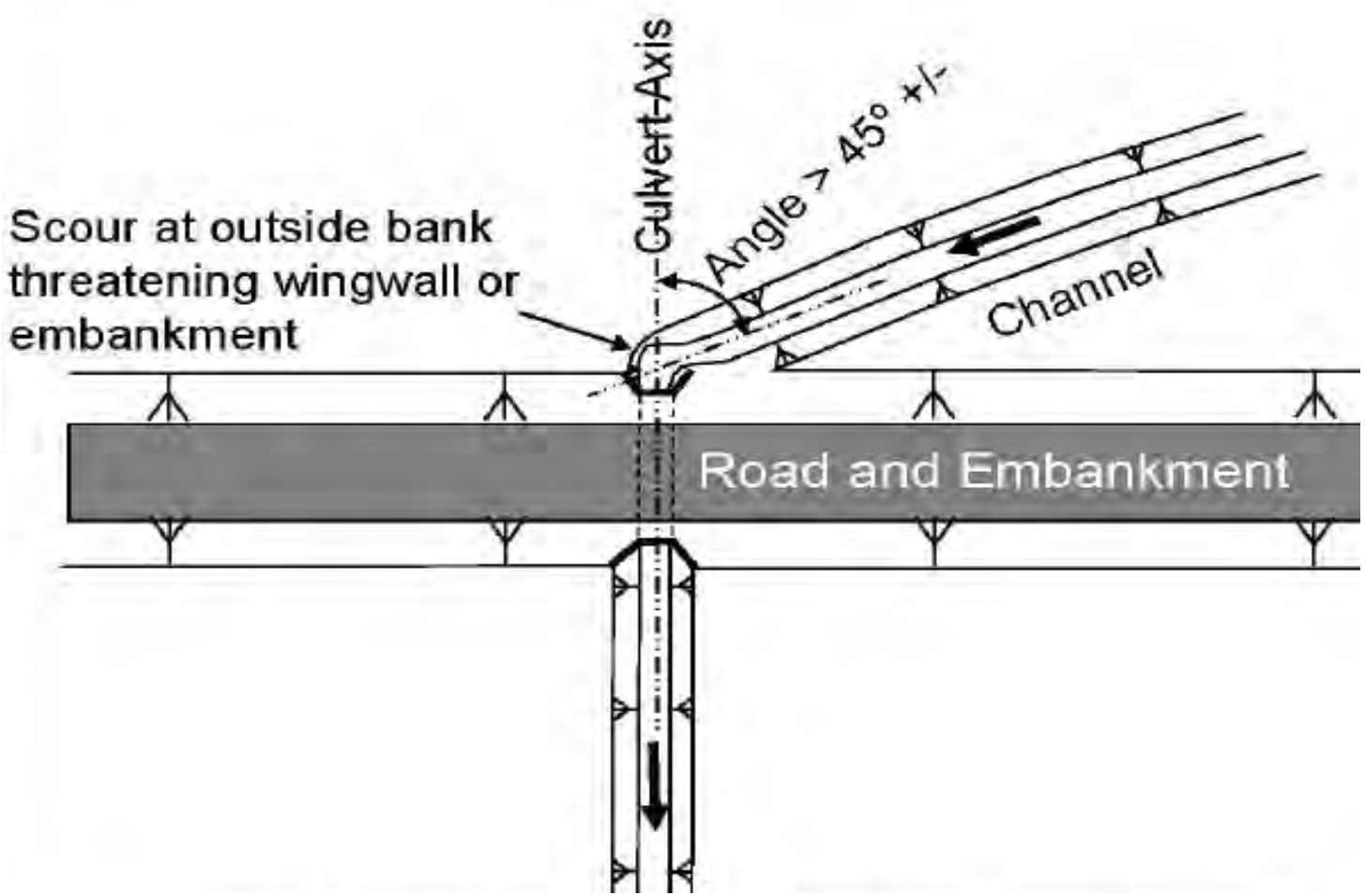
1. Design the culvert slope to match stream slope

- Channel slope is related to energy dissipation in a stream
  - Water depth and velocity
  - Sediment transport
- Abrupt changes in slope can lead to:
  - Barrier to fish movement
  - Sediment scour/deposition
- Very low slope -> special case of no slope culvert
- Grade controls may be necessary
- No more than 25% steeper than stream slope (USFS)

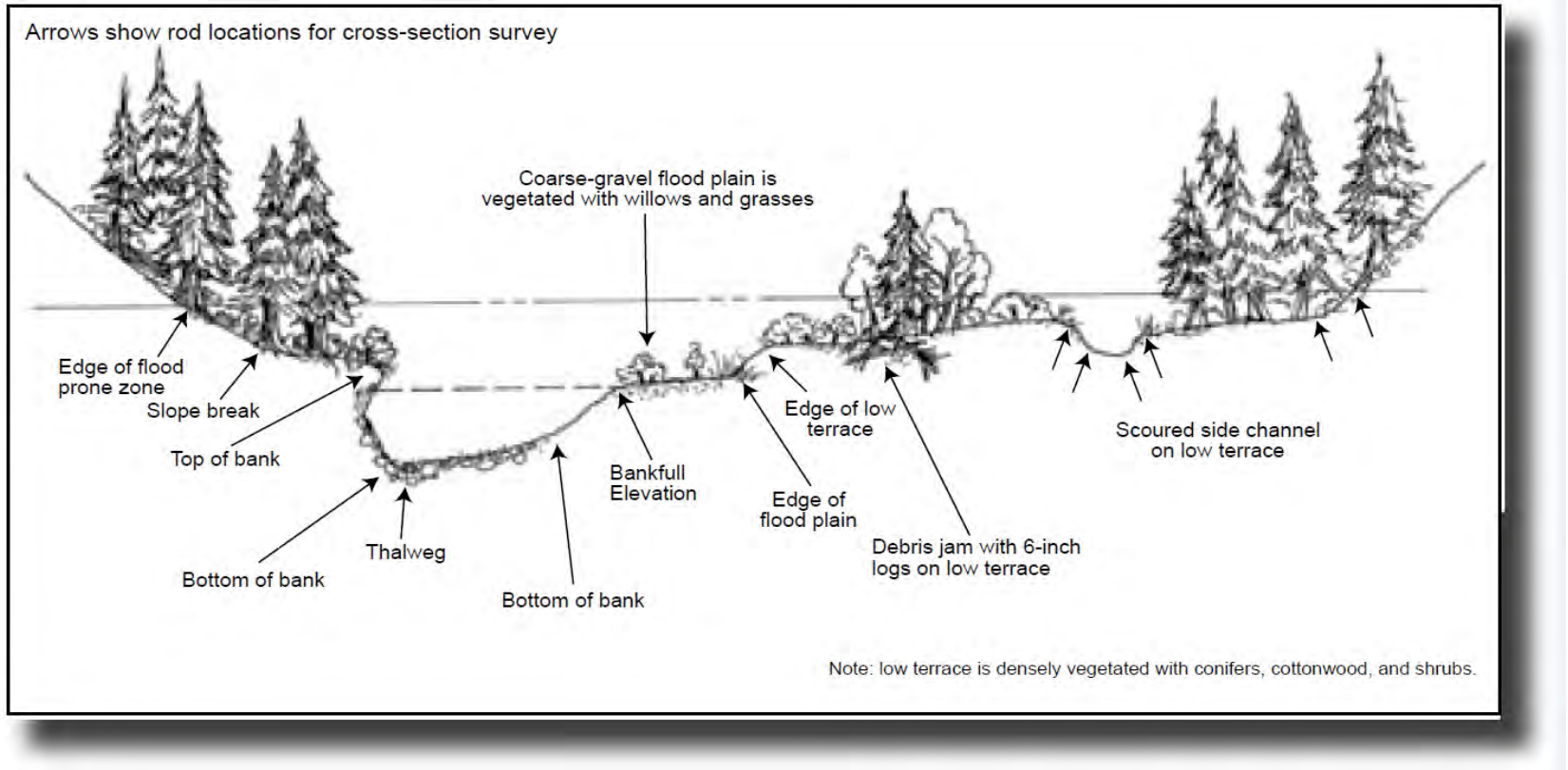
2. Place the culvert to best match stream alignment.

- Avoid scour
- Erosion of road embankment
- Debris issues

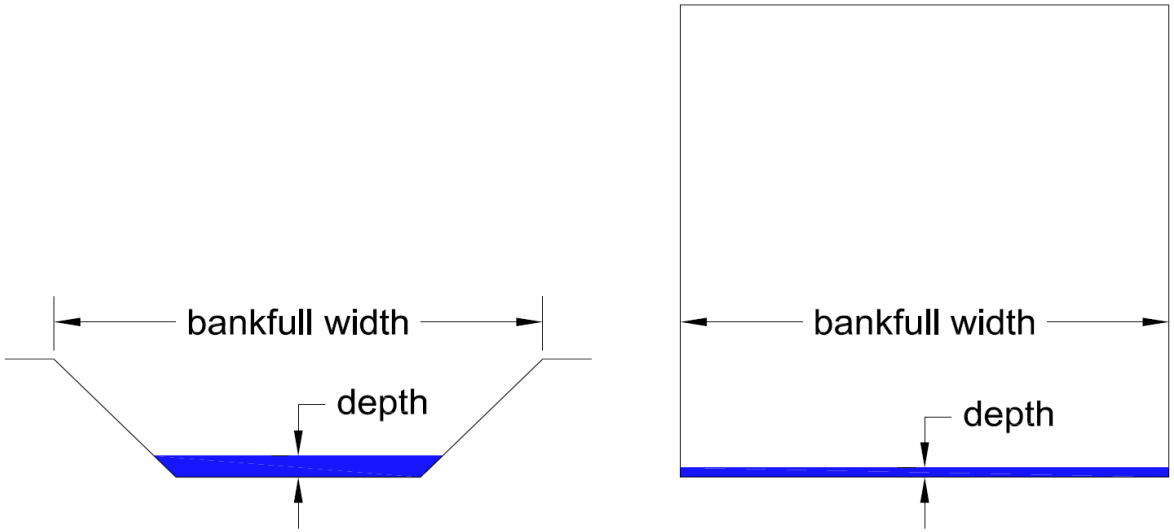
- In practice, will need to balance
  - Stream alignment
  - Culvert length and cost
  - Roadway safety
- Changes in stream length affect slope


Scour at outside bank
threatening wingwall or
embankment
Culvert-Axis
Angle > 45° +/-
Channel
Road and Embankment

3. Design the culvert opening to bankfull channel width or slightly greater.



4. Provide culvert flow depth comparable to channel flow depth for aquatic organism

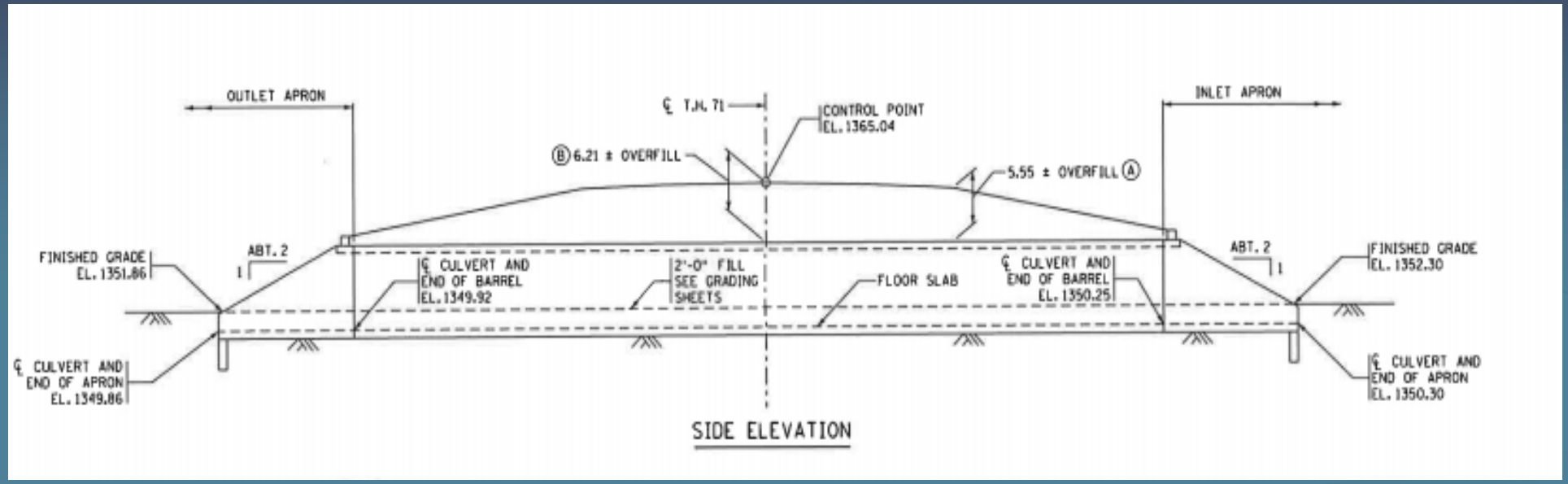


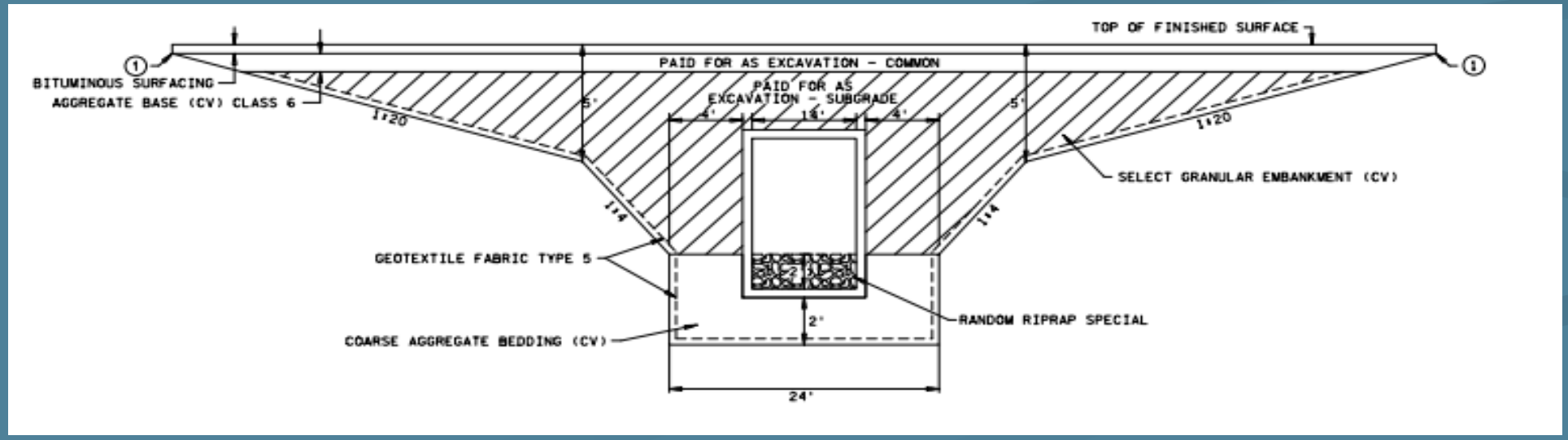
Beware of overwide culverts resulting in shallow flows/ excess sedimentation.

5. Provide a continuous sediment bed with roughness similar to the channel

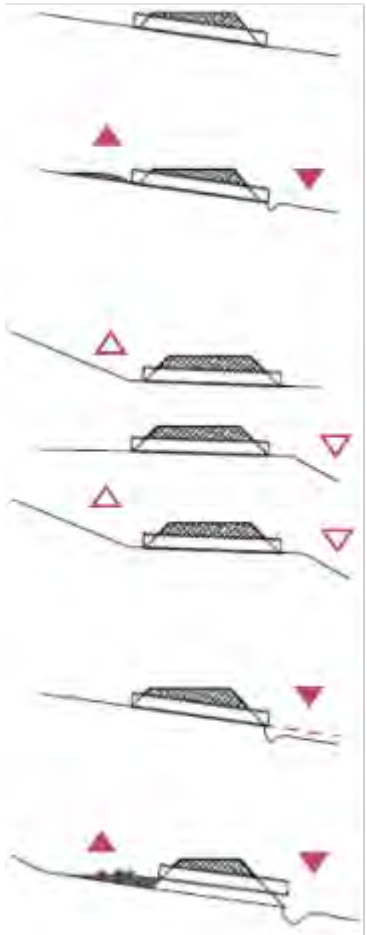
- Higher surface roughness (often estimated by Manning's n), hence lower near-bed velocity, than most culvert materials. Lower near-bed velocity helps smaller organisms to navigate upstream.
- Decreased effects of a behavioral barrier to passage, such as may occur at the transition between a natural and artificial channel bottom.
- Better continuity of sediment movement, helping to avoid excessive aggradation and erosion.

Provide a continuous sediment bed





6. Maintain continuity of sediment transport and debris passage, similar to adjoining reaches



a. Uniform

b. Uniform with sediment wedge at inlet of undersized culvert

c. Concave

d. Convex

e. Complex

f. Incised channel downstream of culvert (dashed line shows streambed elevation before incision)

g. Road impounded wetland

Symbol key

- ▲ Deposition
- △ Potential deposition zone
- ▽ Potential incision zone
- ▼ Head cut / vertical offset / perch

7. Design for safety to the general public, longevity and resilience

Recessed culverts have greater upfront costs, but may be more resilient if designed correctly.

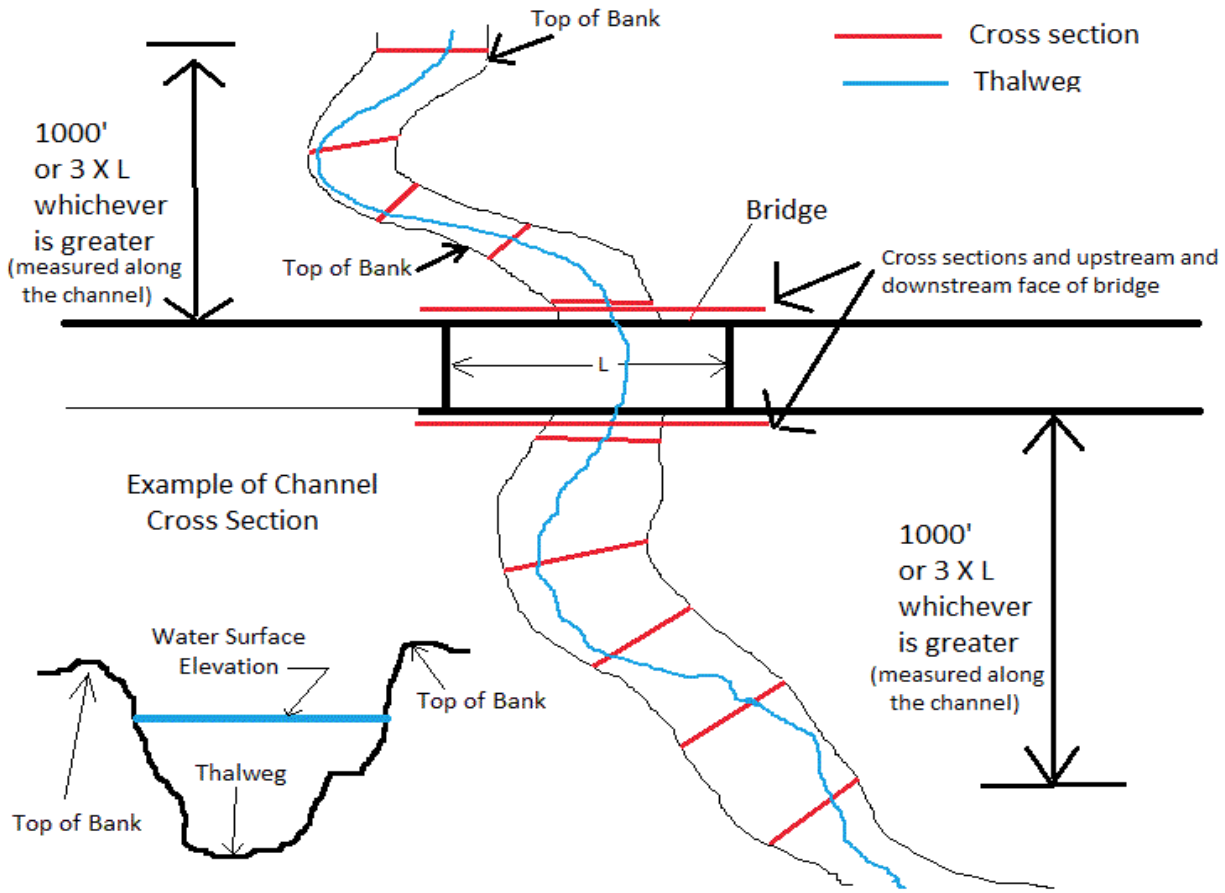
- USFS stream simulation culverts survived 2011 Hurricane Irene in Vermont (Gillespie et al. 2014)
  - ~9-22% more expensive
- Cost-benefit analysis indicates lifetime net fiscal benefits (O'Shaughnessy et al. 2016; Christiansen et al. 2014)
- UMN is leading a new modeling study to evaluate culvert resiliency

Key to future success of the guide

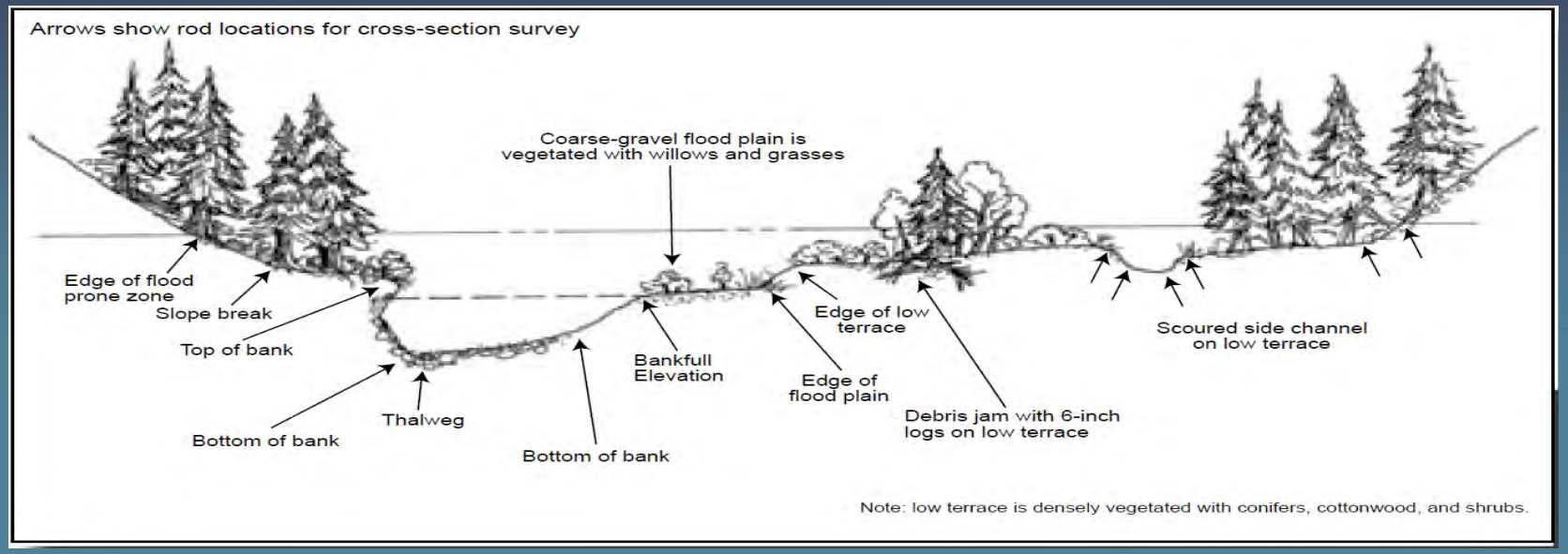
Common Terminology

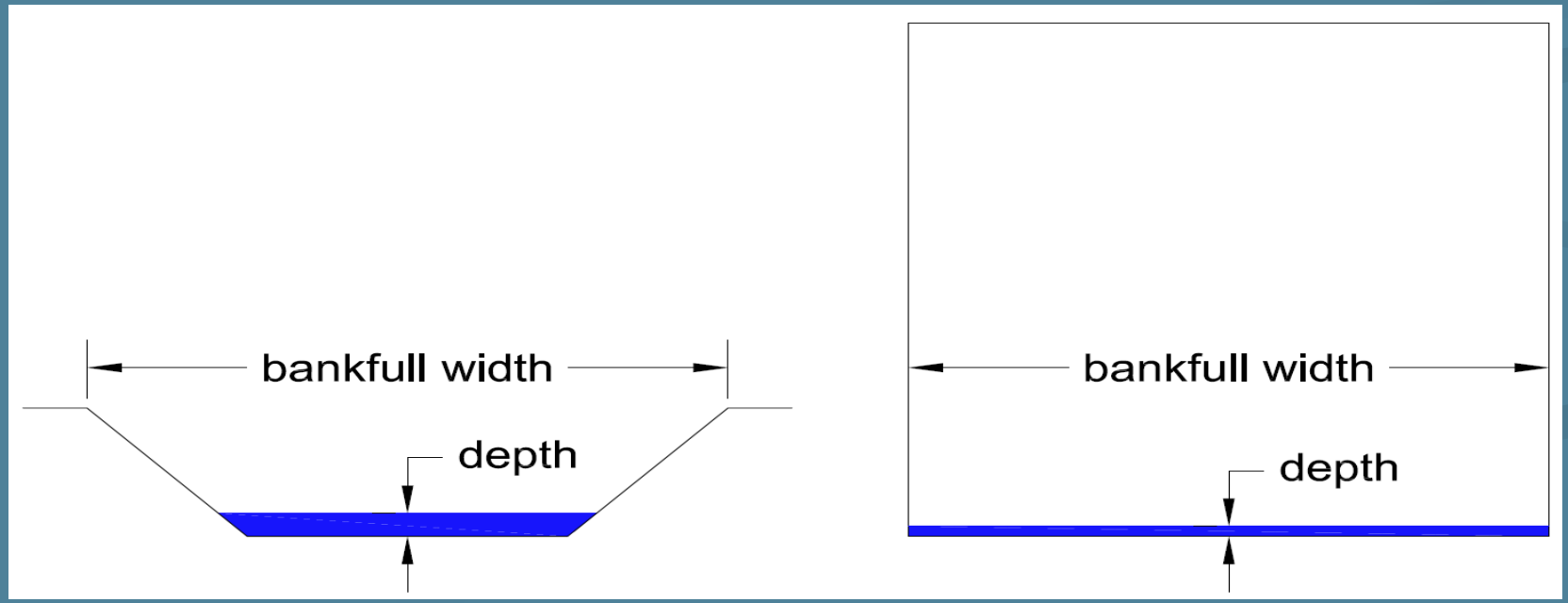
- Recessed culvert
- Embedded culvert
- Offset culvert
- Floodplain culvert
- Bankfull width, etc

Survey methodology



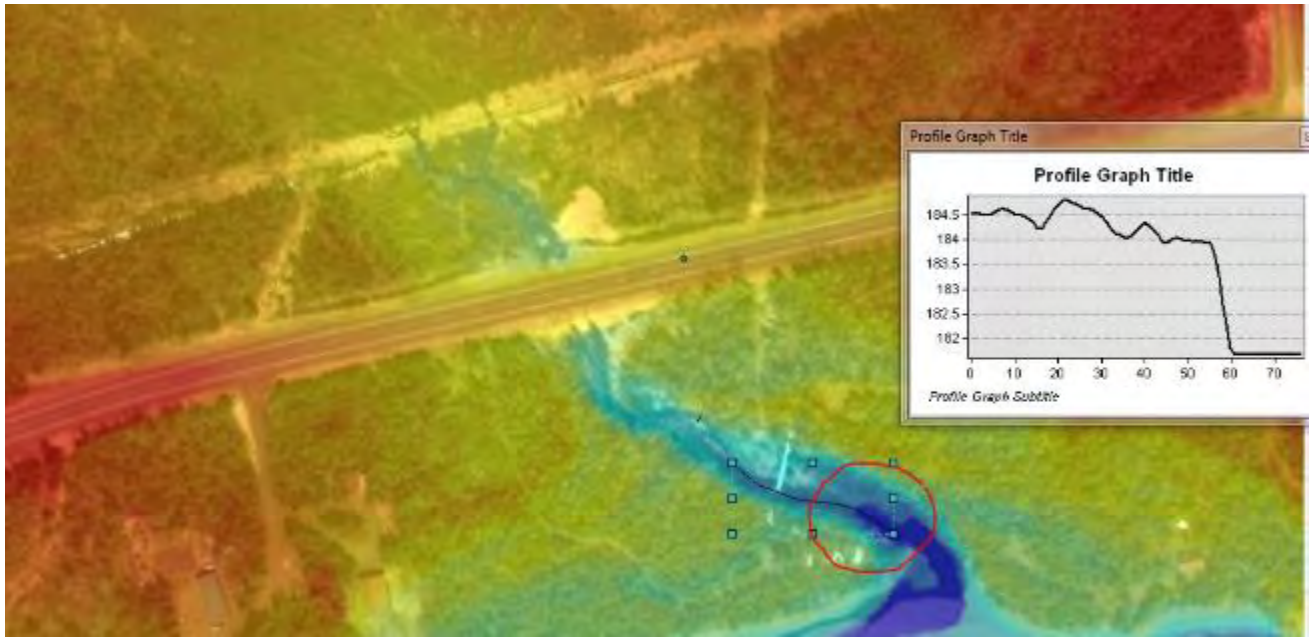
Design the culvert to be similar to the stream channel (bankfull width)





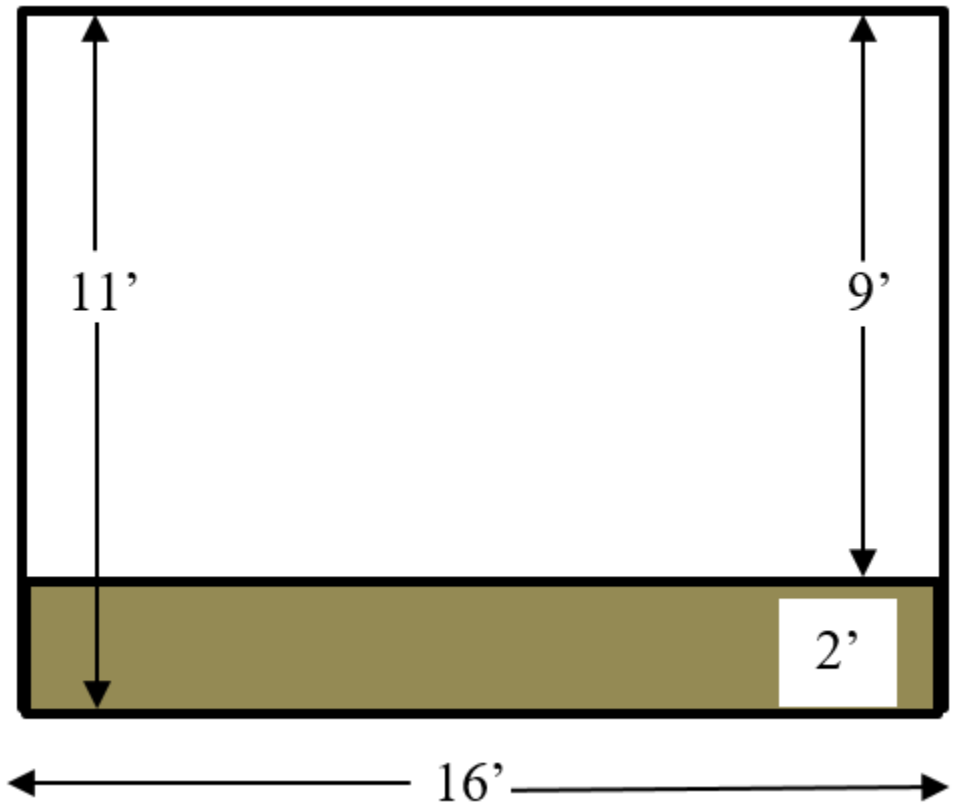
Example

- TH 61 over Red Rock Creek
- Grand Portage Indian Reservation
- Outlets into Lake Superior
- Two culverts inplace:
  - 72” RCPA
  - 98” CMPA
- Estimated bankfull = 14’



Recommended solution

- 16’x11’ concrete box culvert
- Spanned bankfull
- Embedded (buried) 2-ft
- Debris was a consideration
- Box slope to approximately match stream slope



Ongoing or Future Research Efforts

Assessing culverts in Minnesota: fish passage and storm vulnerability

Jessica Kozarek
William Herb

ST. ANTHONY FALLS LABORATORY

UNIVERSITY OF MINNESOTA
Driven to Discover®

Project Goal

Local Road Research Board (LRRB) Knowledge Building Priority KB03: Water Quality

This project addresses:

(i) the scope of aquatic organism passage through culverts in Minnesota

(ii) ways to design road stream crossings to address extreme weather and climate change (including culvert sizing).

Investigate the parameters of ***culvert design*** through a modeling study that integrates fish swimming ability for Minnesota fish species with current and future hydrologic scenarios.

Why we needed a Minnesota AOP Design Guide

Goal: Improve culvert design to accommodate fish passage and improve stream connectivity through culverts at road-stream crossings. To balance ecological and transportation needs.

- More efficient culvert design and permitting process.
- Frequency of similar designs will improve contractors familiarity with them (lowering construction costs?).
- Avoidance of detrimental designs to the natural environment and/or roadway.
- Increased ecological connectivity.

In short: Consistency

How the guide came to be – Research efforts

Project Partners:

- Sara Mielke, Matt Hernick, Bill Herb, and many undergraduate researchers, SAFL
- Britney Mosey and Jay Hatch, Fish., Wild. and Con. Bio., CEHR and Bell Museum
- John Nieber, Chris Lenhart, Bioproducts and Biosystems Engineering
- TAP members – Petra DeWall, Bartelt, Peter Leete, and many others
- Bob Gubernick, USFS

University of Minnesota Projects:

1. Design considerations for recessed/embedded culverts
2. Novel boundary roughness retrofits
3. Evaluation of behavioral barriers in dark culverts
4. Development of design guidance
5. Resiliency of fish passage design culvert to extreme events

Funding:

LRRB

DEPARTMENT OF TRANSPORTATION

Synthesize national and Minnesota research into a guidance document tailored to Minnesota

The guide balances: DNR biological concerns & MnDOT engineering methods

Scientific research & accepted methodologies.

Who put the guide together?

UMN Research Team

Matt Hernick & Jessica Kozarek, St. Anthony Falls Laboratory,
Chris Lenhart & John Nieber, Department of Bioproducts & Biosystems Engineering.

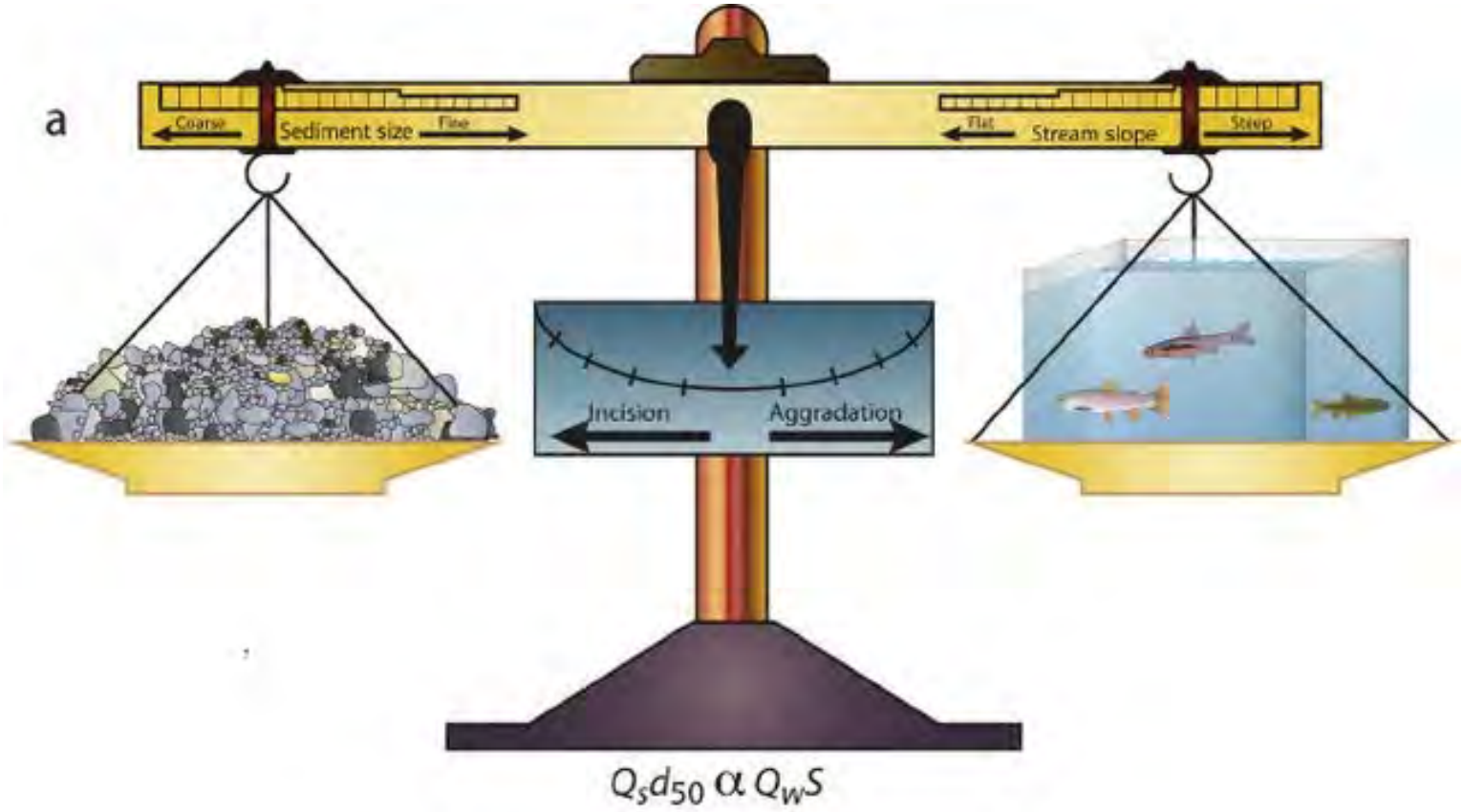
Technical Advisory Team

MnDOT (Petra Dewall & Nicole Bartelt, MnDOT Bridge Hydraulics)
DNR (Brian Nerbonne, Stream Habitat Program, Peter Leete, Hydrologist)
USFS (Bob Gubernick, Watershed Restoration Geologist)

External Review Panel

Tom Wilson, Erickson Engineering
Pete Sarberg, Widseth, Smith & Nolting
Chris Katapodis, Katapodis Ecohydraulics
Luther Aadlund, DNR River Ecologist
Julie Aadlund, DNR Area Hydrologist
Kristian Blann, Freshwater Ecologist, The Nature Conservancy
Scott Jackson, UMass, North Atlantic Connectivity Cooperative
Matt Diebel, WiDNR, Research Scientist

Lane's Balance



Training Specifics

- Implementation project ongoing to develop the training for the guide
- Anticipated delivery in Summer 2020 – Winter 2021
- 6 sessions, spaced throughout the state
- Will include both in-class and field work sessions, anticipated 1.5 day class
- Audience: MnDOT Hydraulic Design Engineers, City and County Engineers, Consultant Engineers, Regulatory staff, other resource agency partners
- FREE for attendees