Massachusetts
Rivers & Roads Training

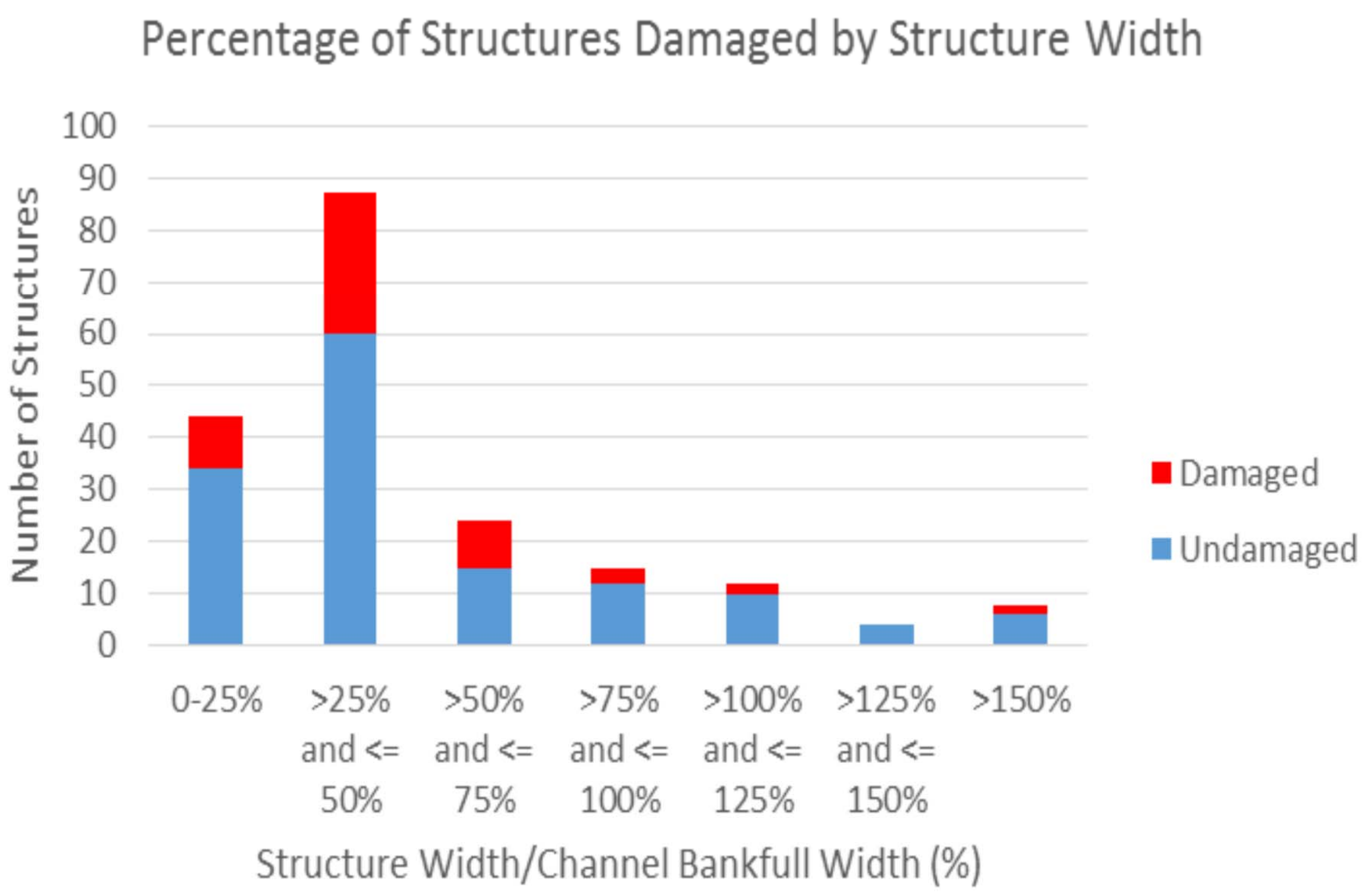
Tier 2A: Bridges, Culverts and Geomorphic Compatibility

Topics

- Undersized structures
- Channel and floodplain impacts
- Geomorphic compatibility
- MassDOT Stream Crossing Handbook

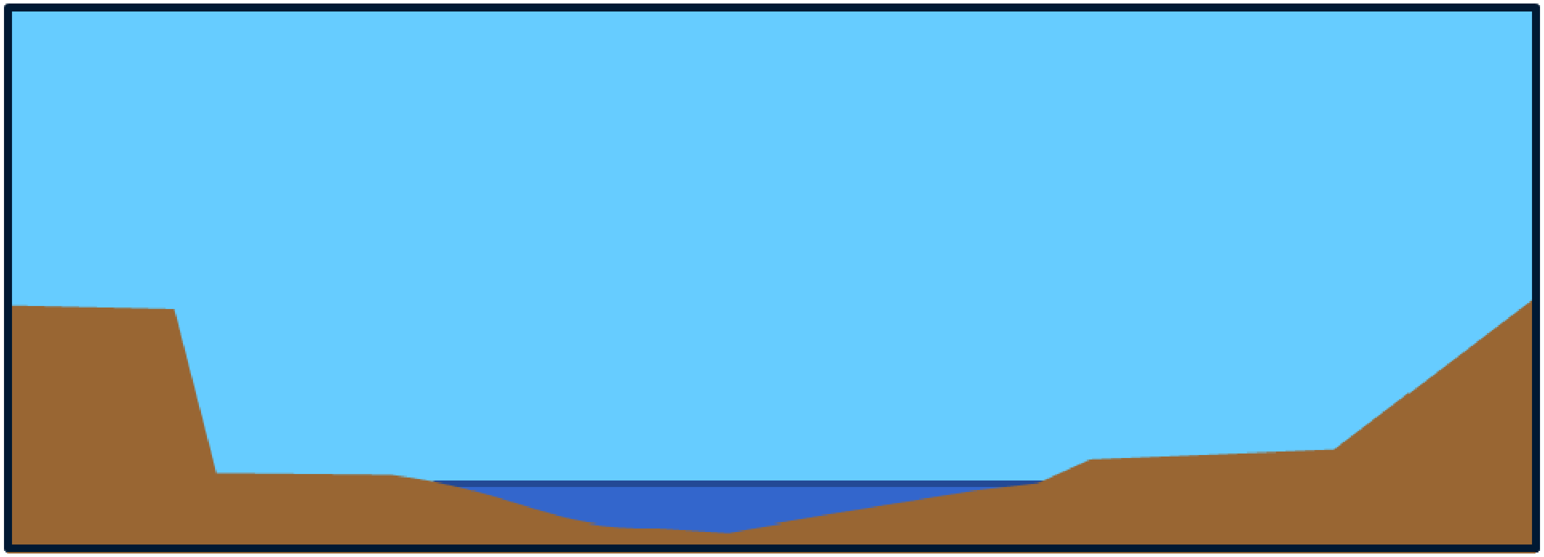
Culvert Damages

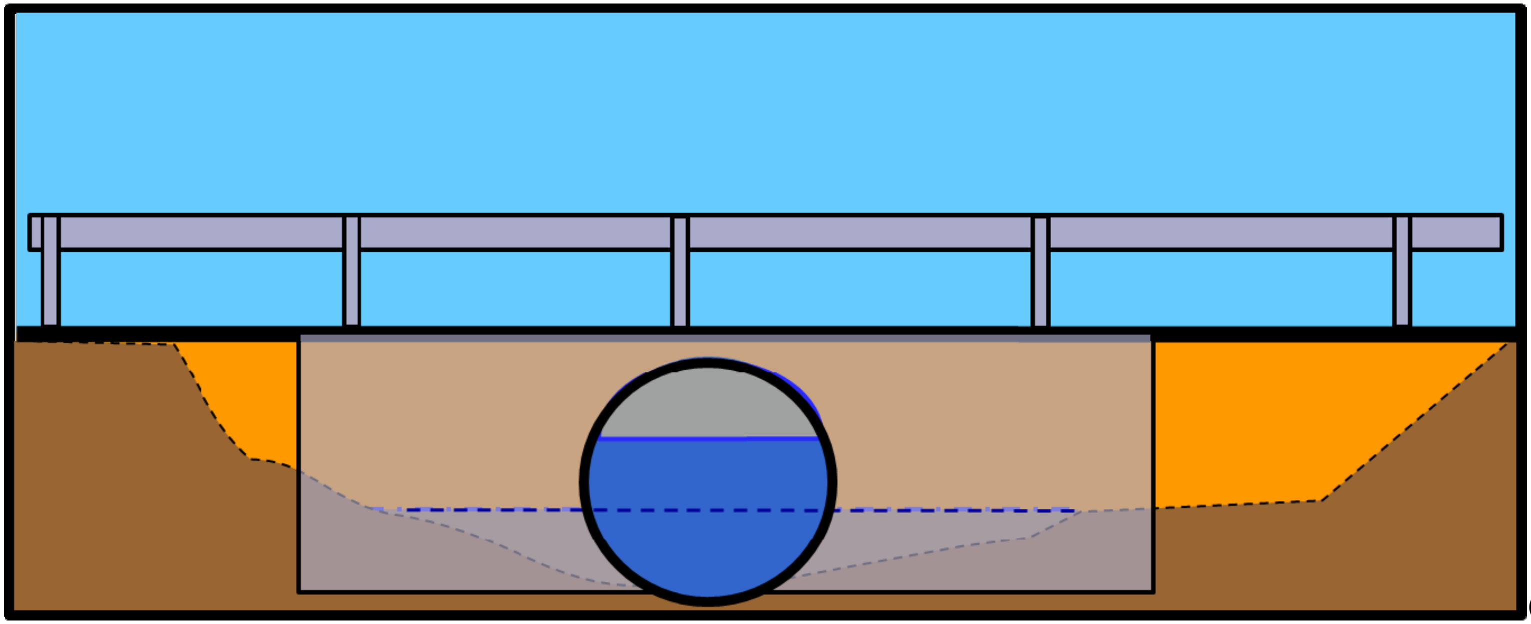
Deerfield River Watershed Pilot Study



(MMI, 2017)

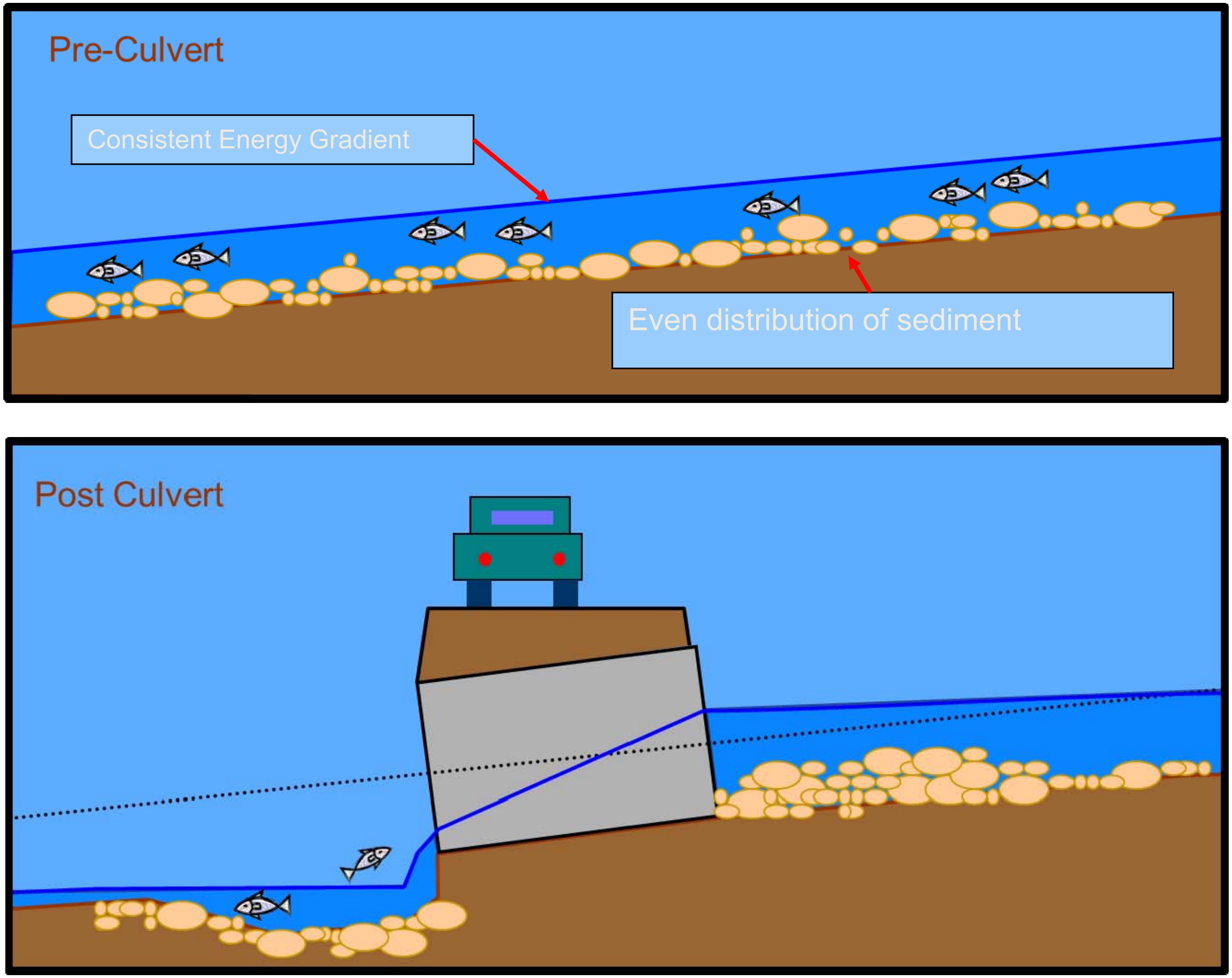
Altering the Cross Section





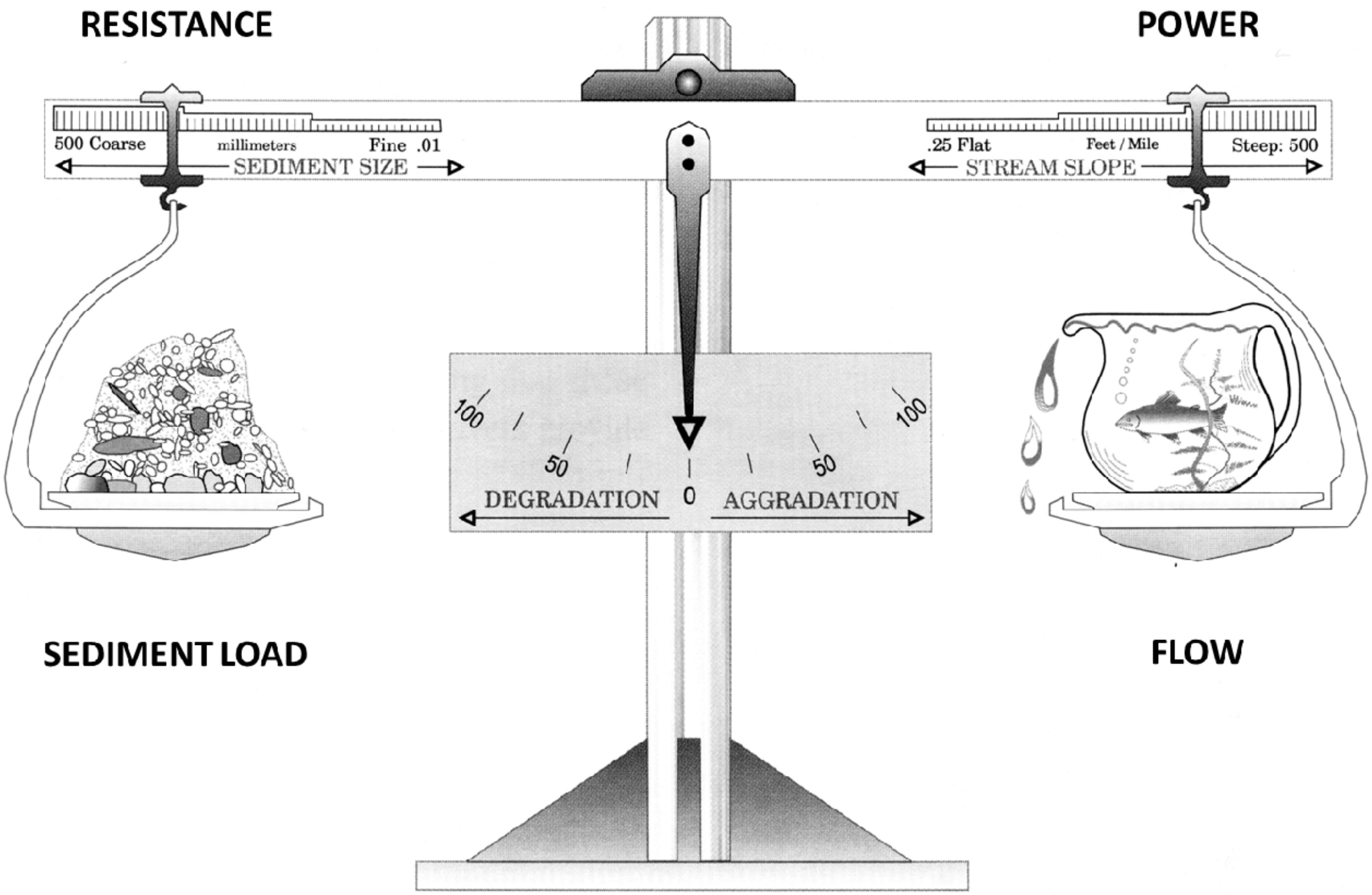
(ANR, 2015)

Altering the Profile



(ANR, 2015)

Dynamic Equilibrium



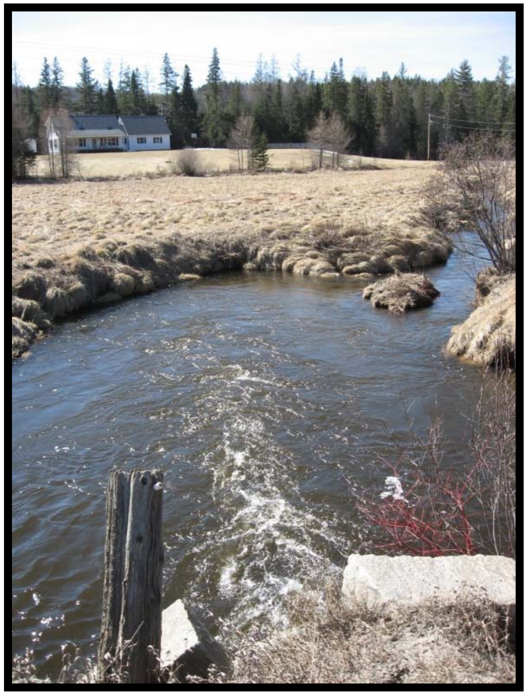
(Sediment LOAD) x (Sediment SIZE) $\propto$ (Stream SLOPE) x (Stream DISCHARGE)

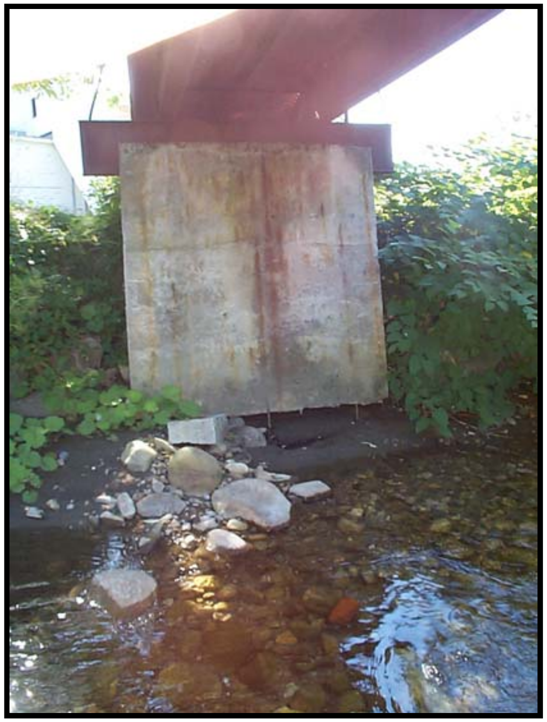
(Lane, 1955; Rosgen and Silvey, 1996)

Excessive Upstream Sedimentation

(ANR, 2015)

Excessive Downstream Scour





(ANR, 2015)

Geomorphic Compatibility

Score	% Bankfull Width	Sediment Continuity	Slope	Approach Angle	Erosion and Armoring
5	%BFW $\geq$ 120	No upstream deposition or downstream bed scour	Structure slope equal to channel slope, and no break in valley slope	Naturally straight	No erosion or armoring
4	100 $\leq$ %BFW < 120	**Either** upstream deposition or downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	No erosion **and** intact armoring, **or** low upstream or downstream erosion **without** armoring
3	75 $\leq$ %BFW < 100	**Either** upstream deposition or downstream bed scour, **with either** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope equal channel slope, with local break in valley slope	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	50 $\leq$ %BFW < 75	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope higher or lower than channel slope, and no break in valley slope	Channelized straight	Low upstream **and** downstream erosion
1	30 $\leq$ %BFW < 50	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	Severe upstream **or** downstream erosion
0	%BFW < 30	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Structure slope higher or lower than channel slope, with local break in valley slope	Sharp bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

(MMI, 2008)

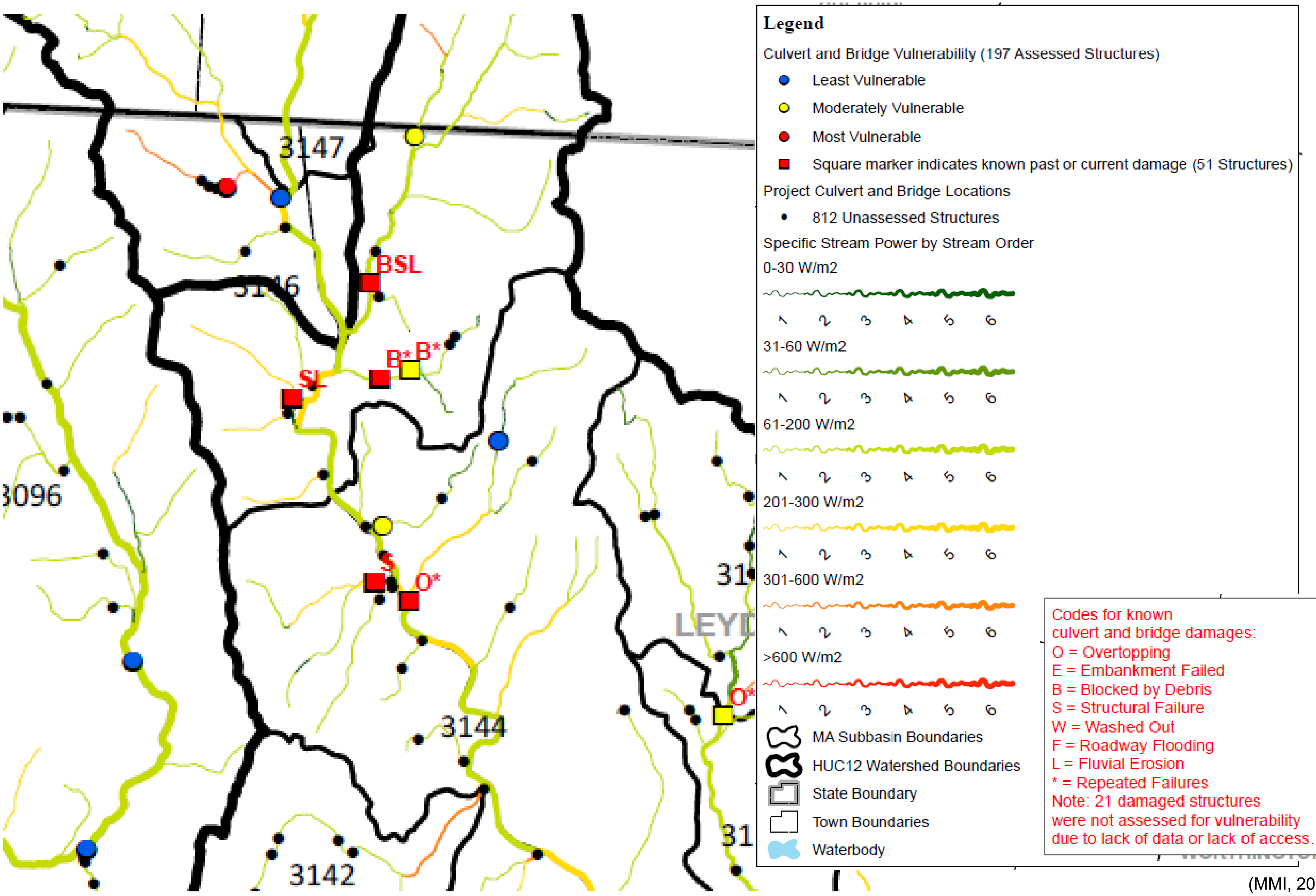
Geomorphic Compatibility

Category Name	Screen Score	Threshold Conditions	Description of structure-channel geomorphic compatibility
Fully compatible	20<GC≤25	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly compatible	15<GC≤20	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially compatible	10<GC≤15	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly incompatible	5<GC≤10	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully incompatible	0≤GC≤5	% Bankfull Width + Approach Angle scores ≤ 2 AND Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

(MMI, 2008)

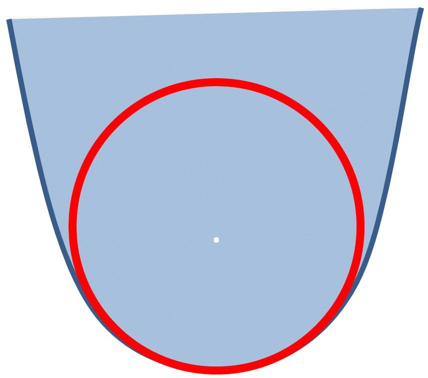
Undersized culverts
Bell Rock Road over Middle Brook
Fall River, MA

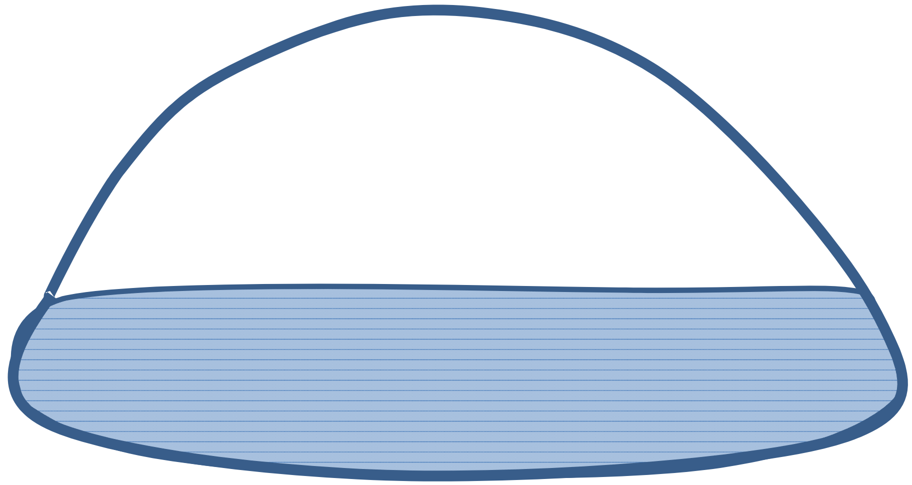
SSP Mapping for Asset Resiliency



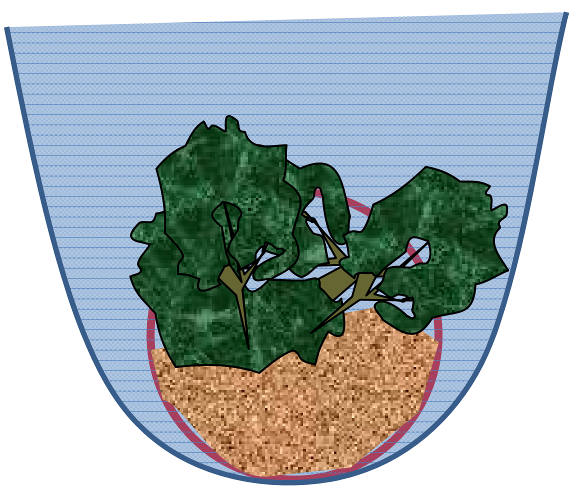
(MMI, 2016)

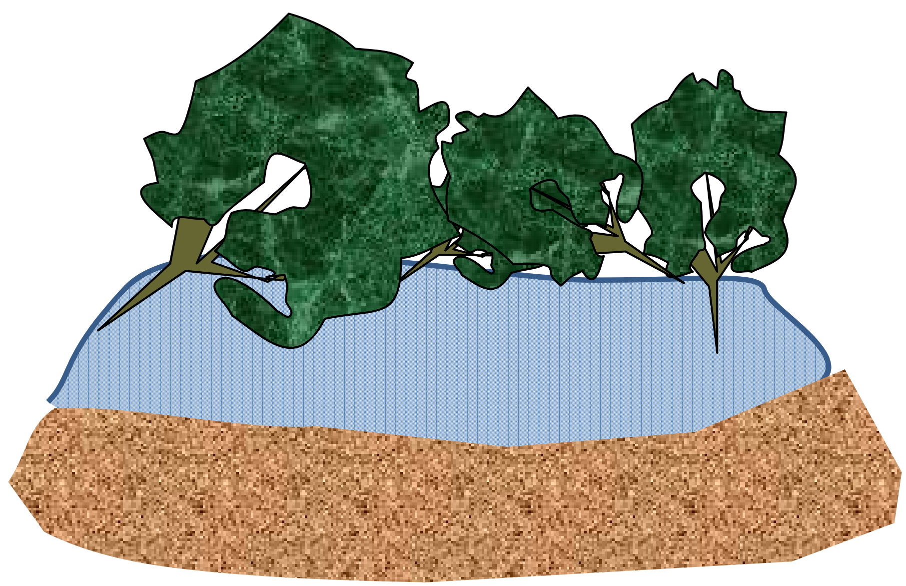
The Clear Flow Fairy Tale



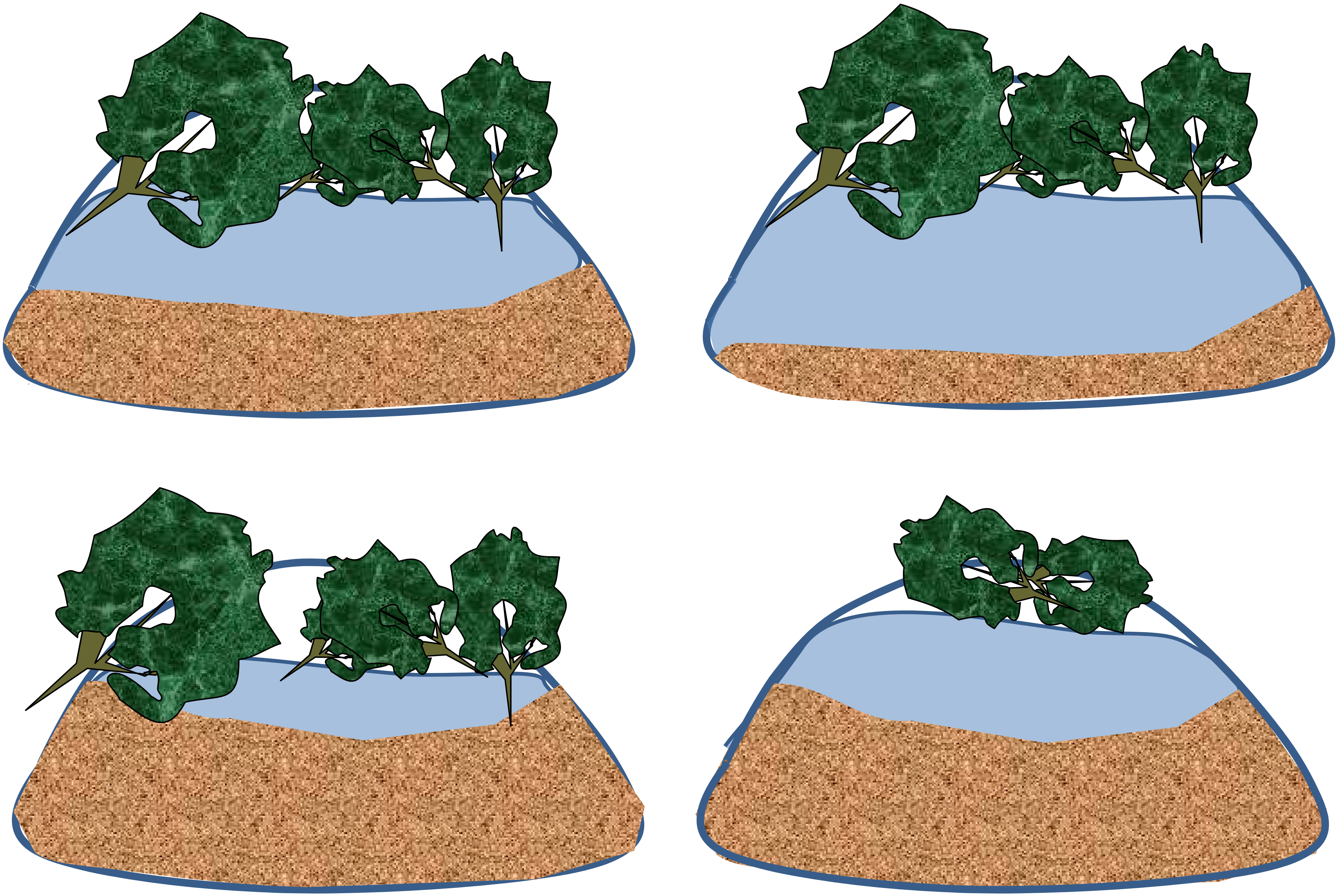


The Large Wood and Sediment Reality

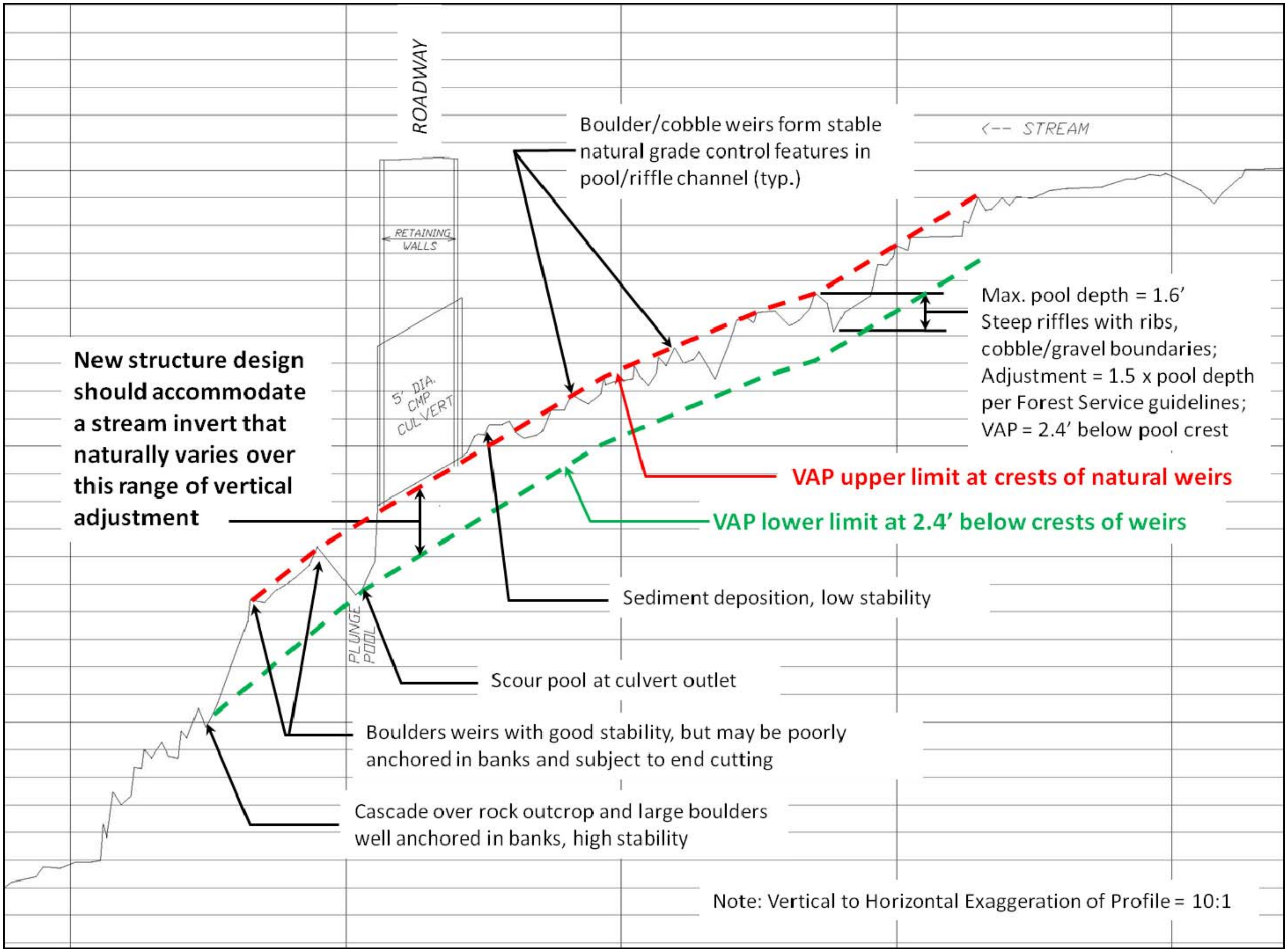




The Scary Part of Reality



Range of Vertical Adjustment



(Nyman and MassDOT, 2018 (Draft))

Questions

Structures should be designed to pass what?

Click For Answer

Click For Answer

Click For Answer

Click For Answer

What is the MA standard for structure width?

Click For Answer

Regulatory Context – Stream Crossing Standards

1. Federal
   - US Army Corps of Engineers General Permit for MA

2. Massachusetts
   - Wetlands Protection Act Regulations
   - 401 Water Quality Certification Regulations

3. MA River and Stream Crossing Standards
   - Full compliance for new structures
   - Maximum extent practicable for replacements

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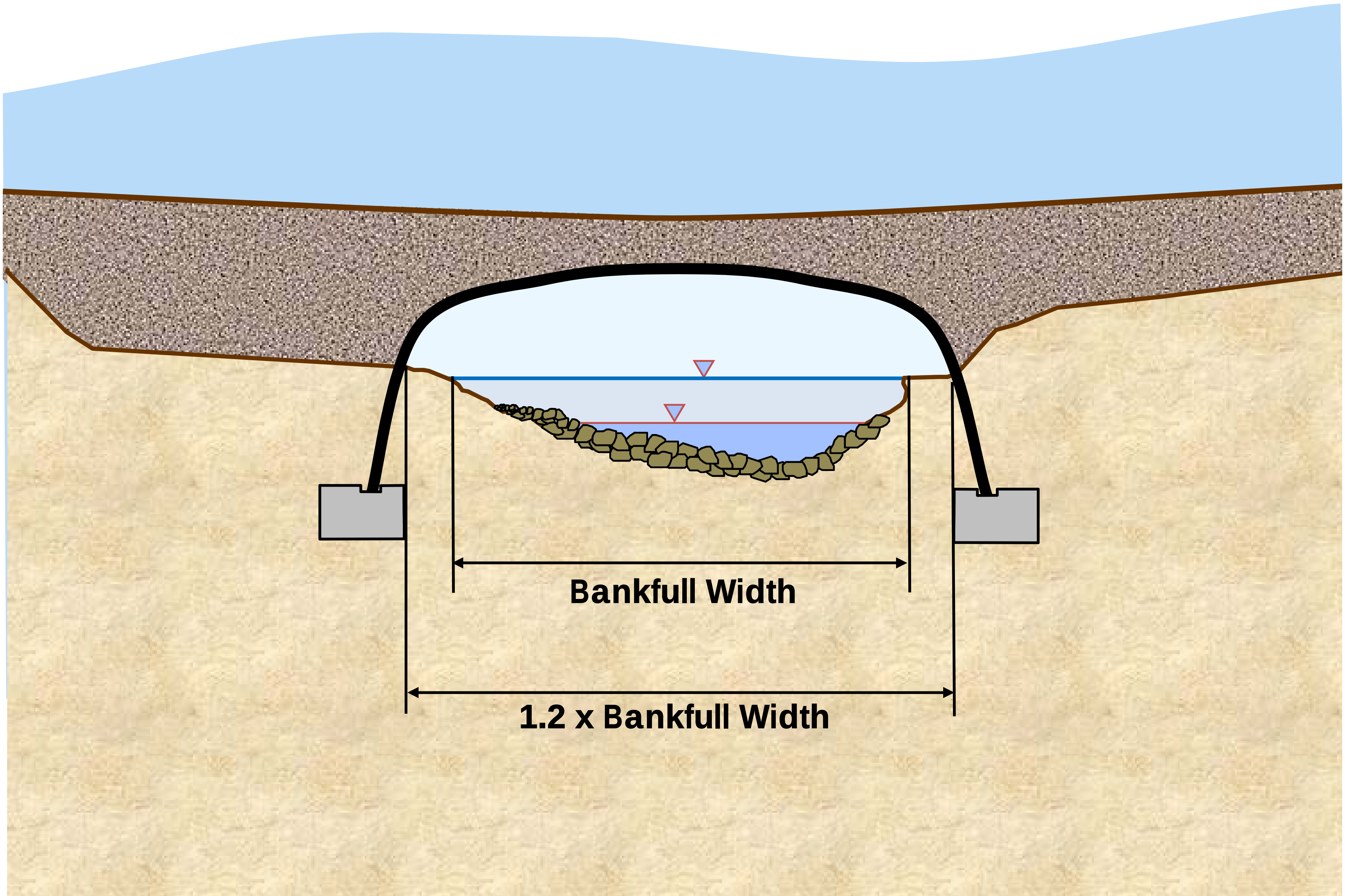
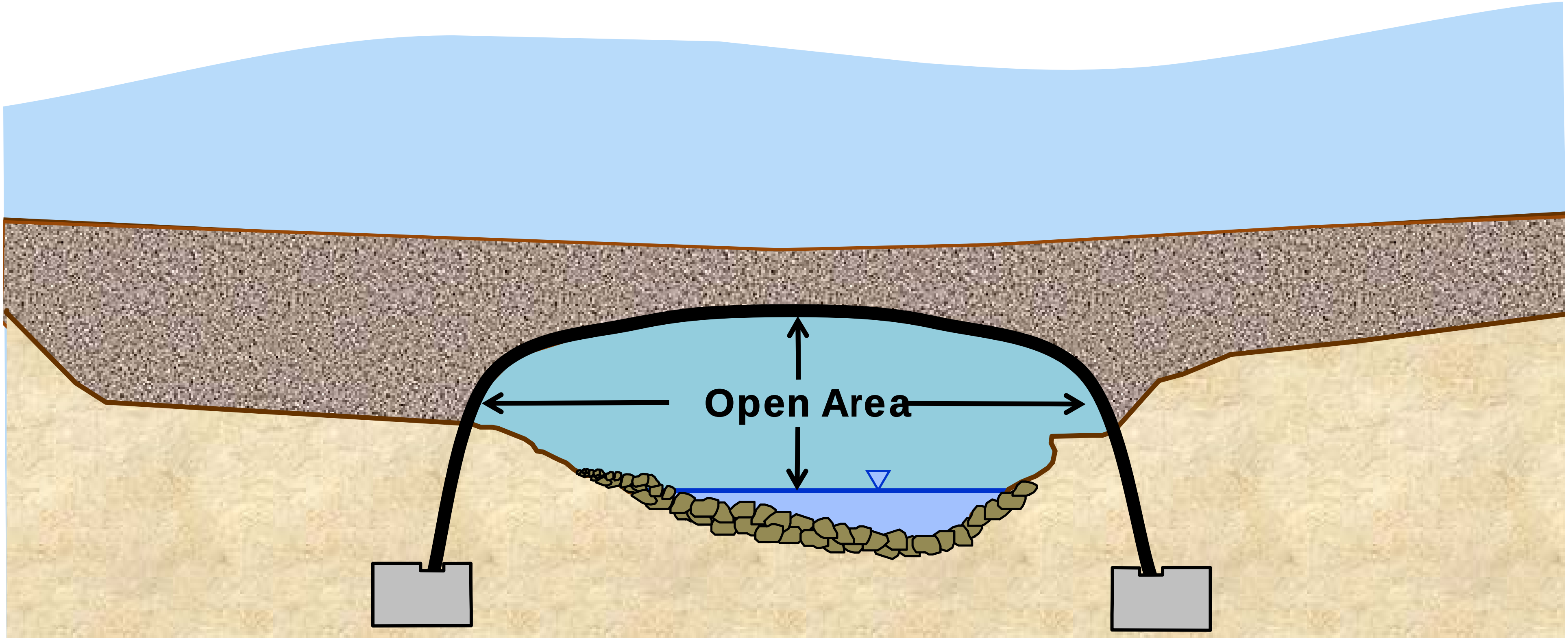
Stream Crossing Standards



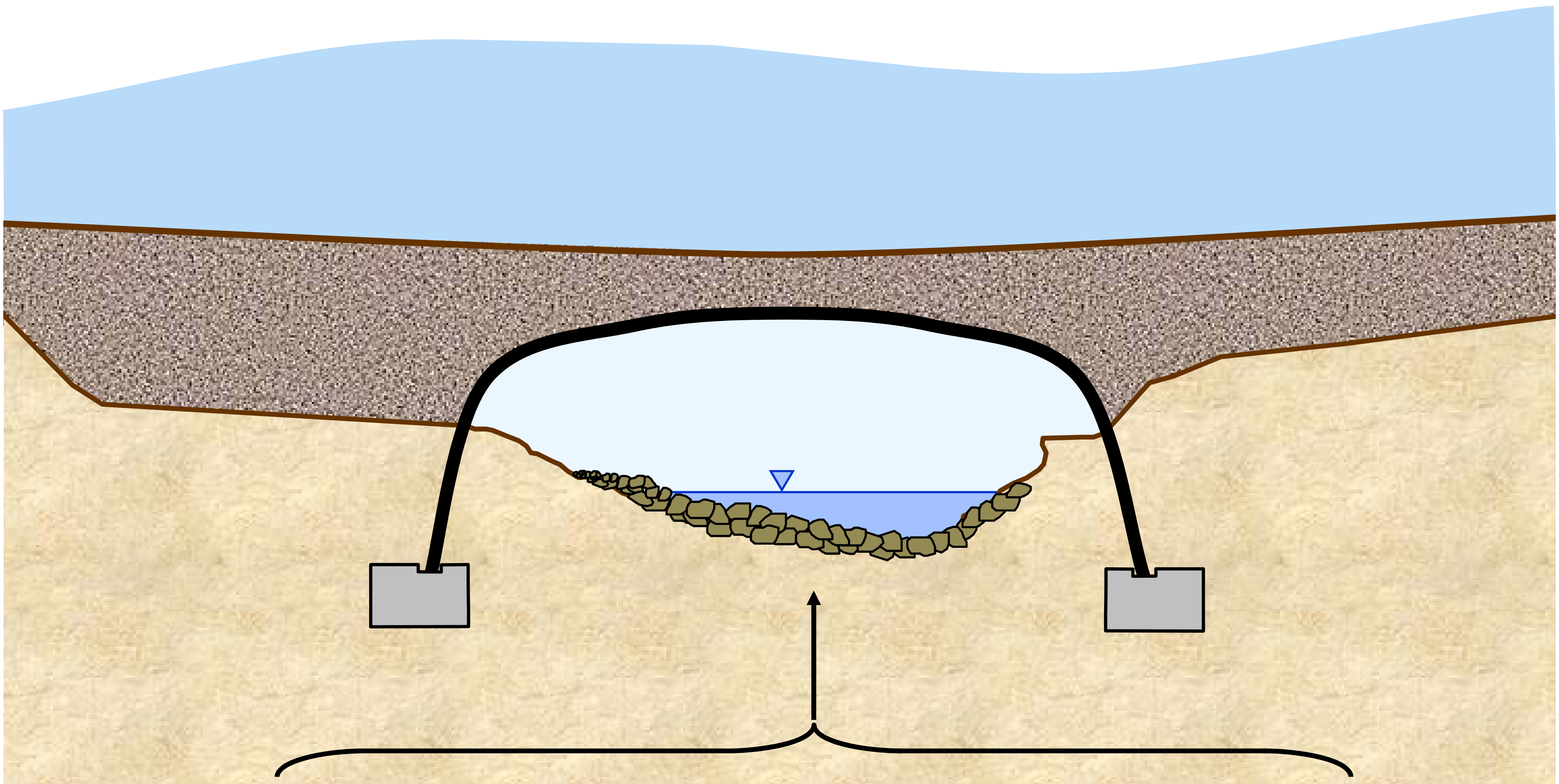
Stream Crossing Standards



$$\frac{\text{Open Area (m}^2\text{)}}{\text{Structure Length (m)}} = \text{Openness Ratio (m)}$$

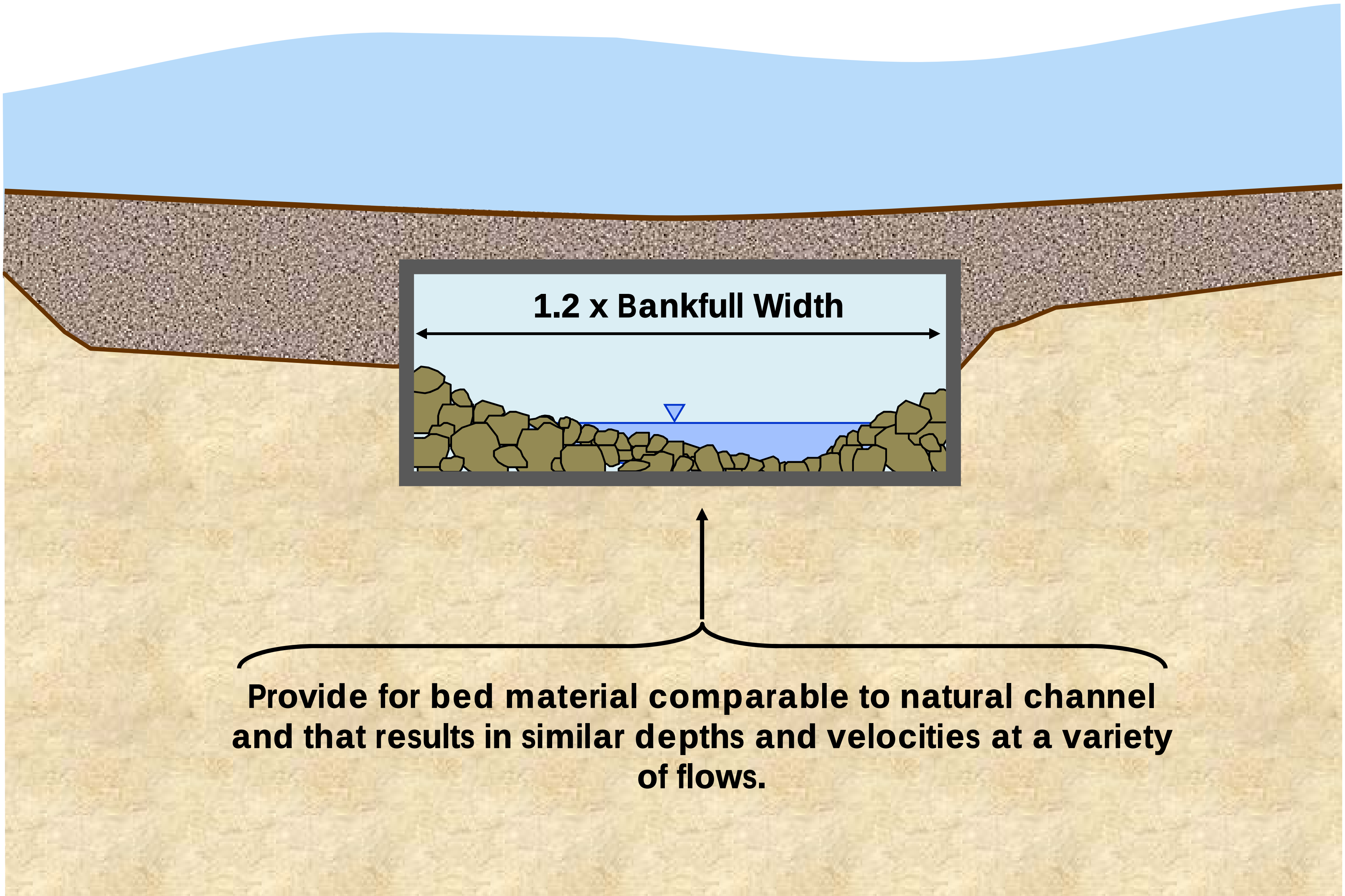
Openness Ratio (m) $\geq$ 0.25m for General Standards
$\geq$ 0.50m to 0.75m for Optimum Standards

Stream Crossing Standards



Preserve existing stream bed (preferred);
or if necessary,
Provide for bed material comparable to natural channel and that results in similar depths and velocities at a variety of flows.

Stream Crossing Standards



Importance of Alternative Analysis

MA WPA 310 CMR 10.53(8):

- The potential for downstream flooding;
- Upstream and downstream habitat (in-stream habitat, wetlands);
- Potential for erosion and head-cutting;
- Stream stability;
- Habitat fragmentation caused by the crossing;
- The amount of stream mileage made accessible by the improvements;
- Storm flow conveyance;
- Engineering design constraints specific to the crossing;
- Hydrologic constraints specific to the crossing;
- Impacts to wetlands that would occur by improving the crossing;
- Potential to affect property and infrastructure; and
- Cost of replacement.

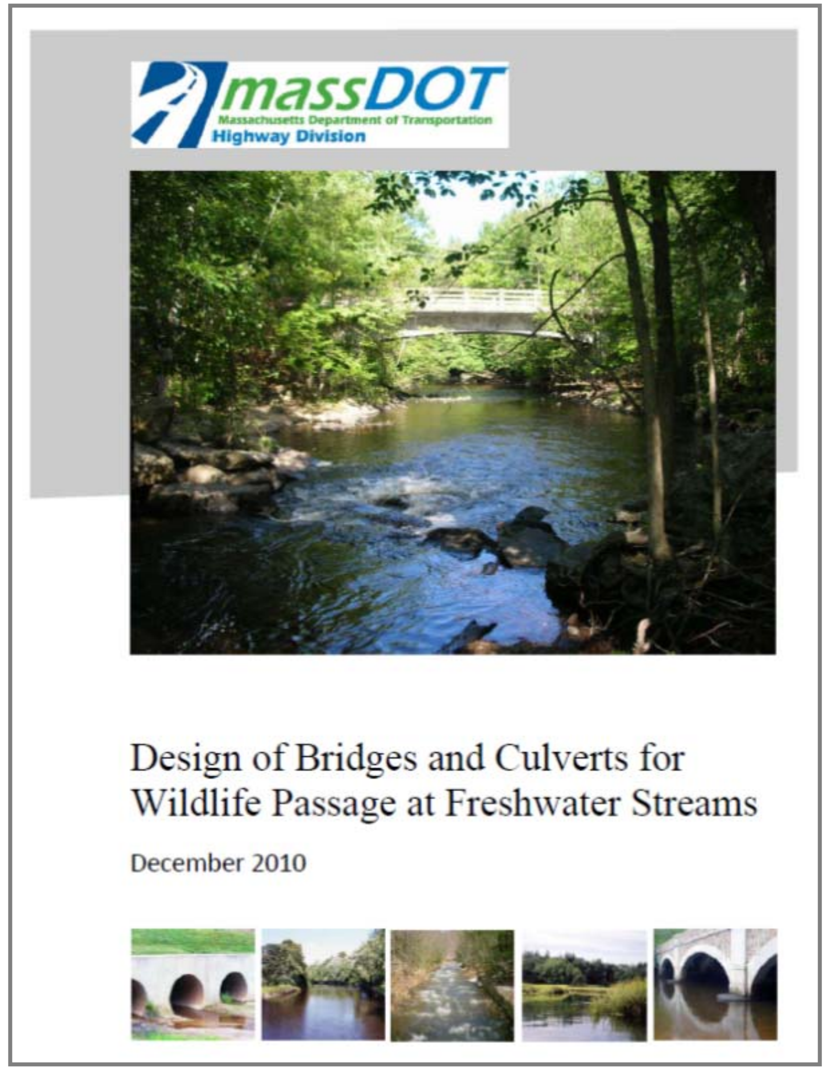
MassDOT Stream Crossing Handbook

Originally published 2010

- Response to unregulated "Stream Crossing Standards"

Since then:

- Stream Crossing Standards codified into regulations
- Municipalities requesting guidance / assistance on culvert & small bridge projects



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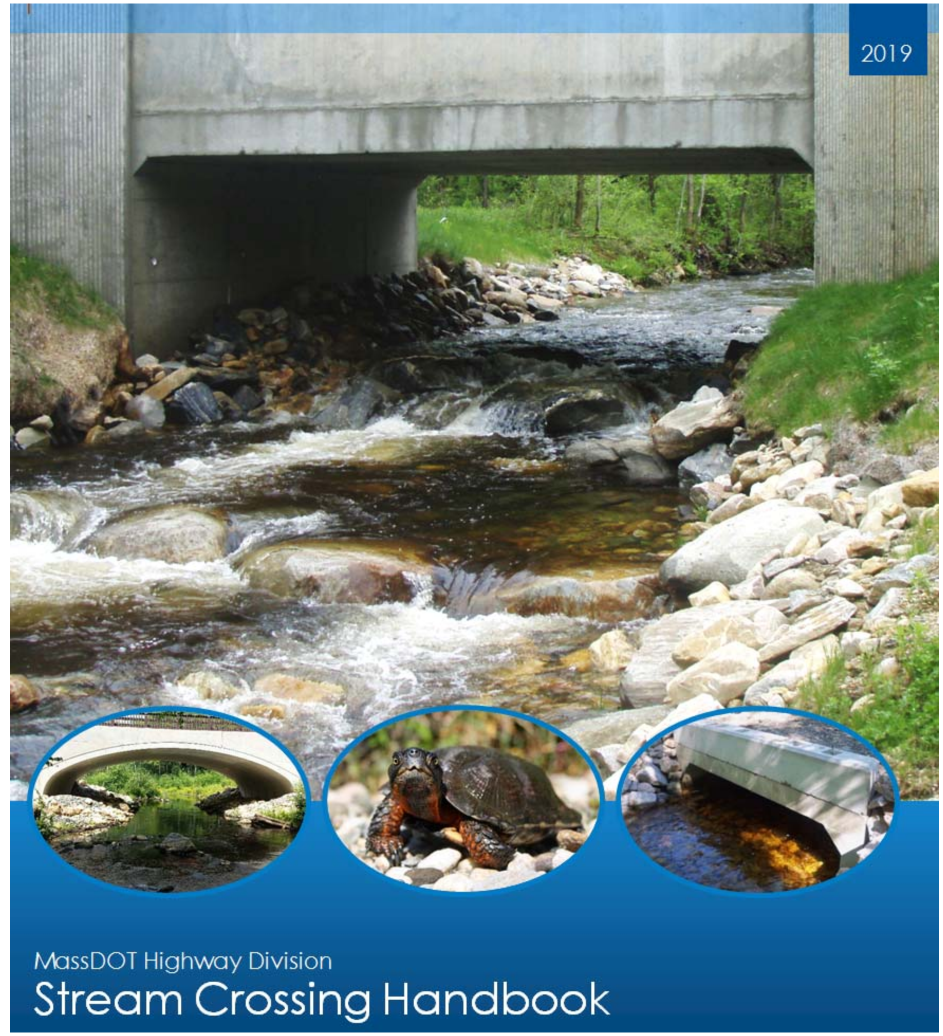
MassDOT Stream Crossing Handbook

<u>Updated Handbook (2019):</u>

- Technical, practical focus
- Current best crossing practices
- Current stream crossing regulations
- Climate resilient design
- Technical guidance for municipalities
- Prototype design templates
- Publication pending



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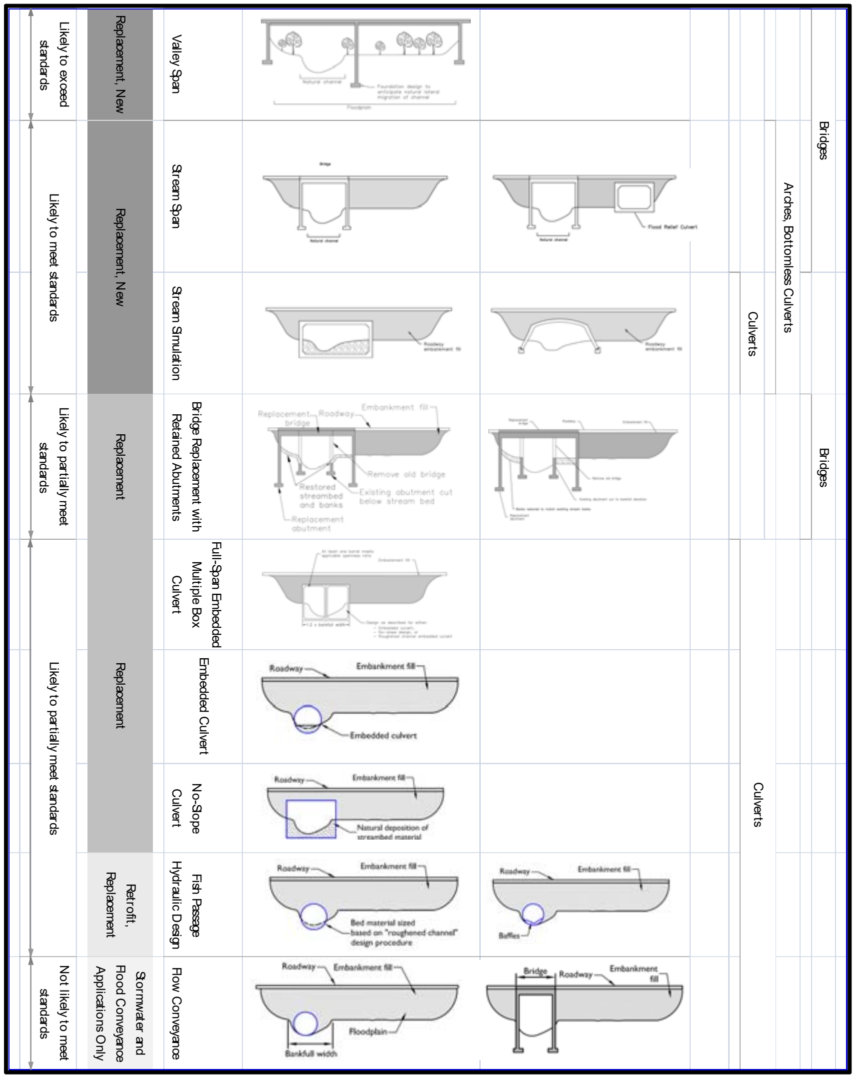
Range of Design Approaches



Valley Span

Stream Span (preserve stream)

Stream Span (simulate stream)

Bridge Replacement – retained abutments

Full Span Embedded Multi-Box Culvert

Embedded Culvert (less than full span)

No-Slope Culvert

Fish Passage Hydraulic Design

Flow Conveyance Design

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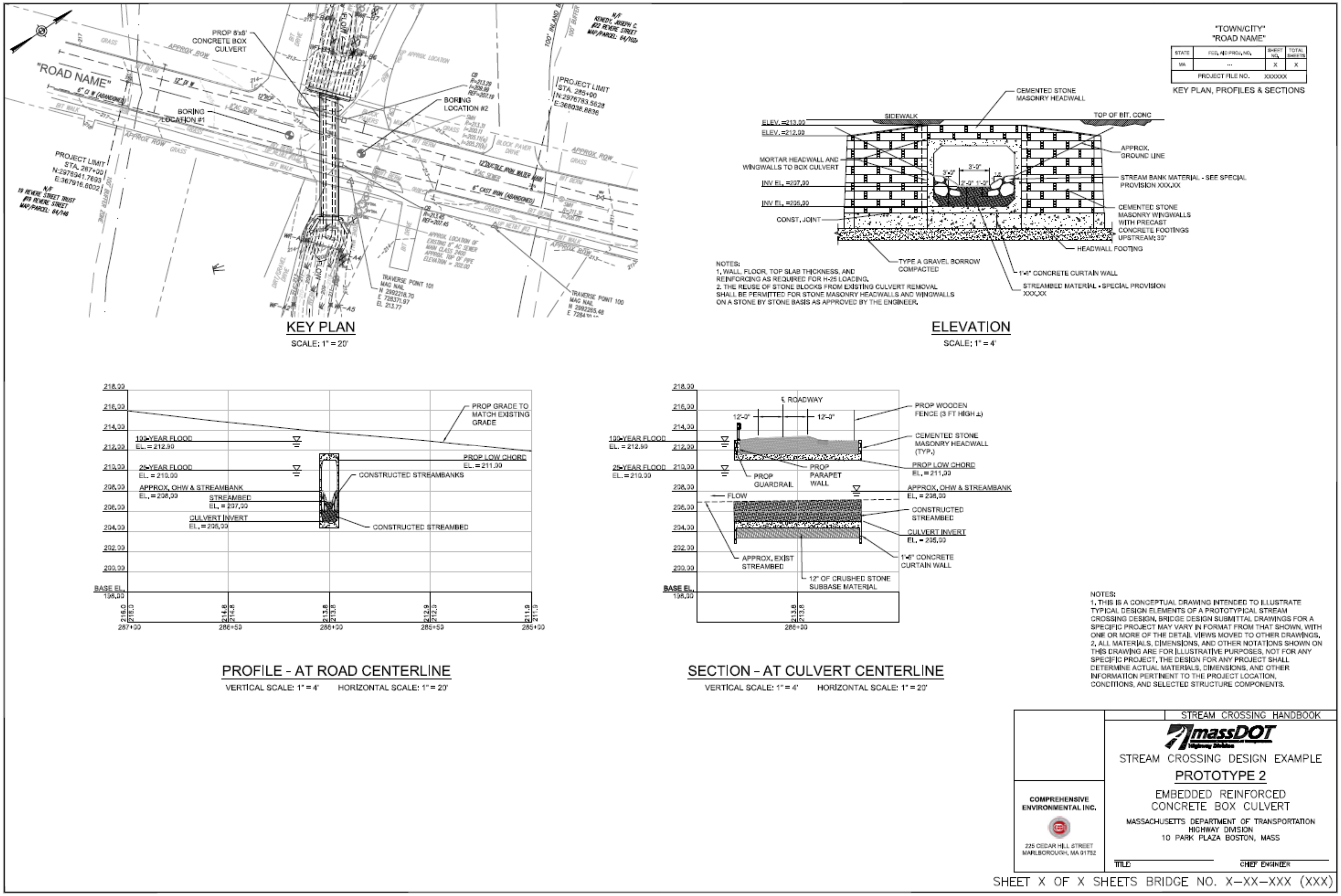
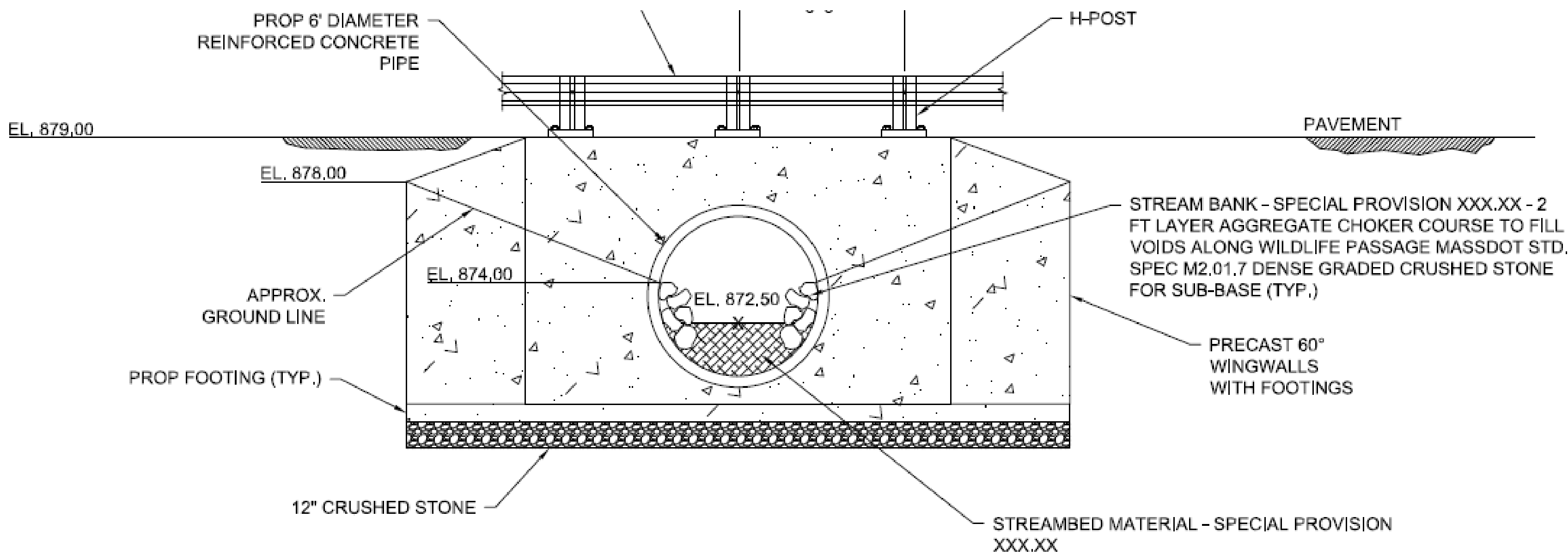
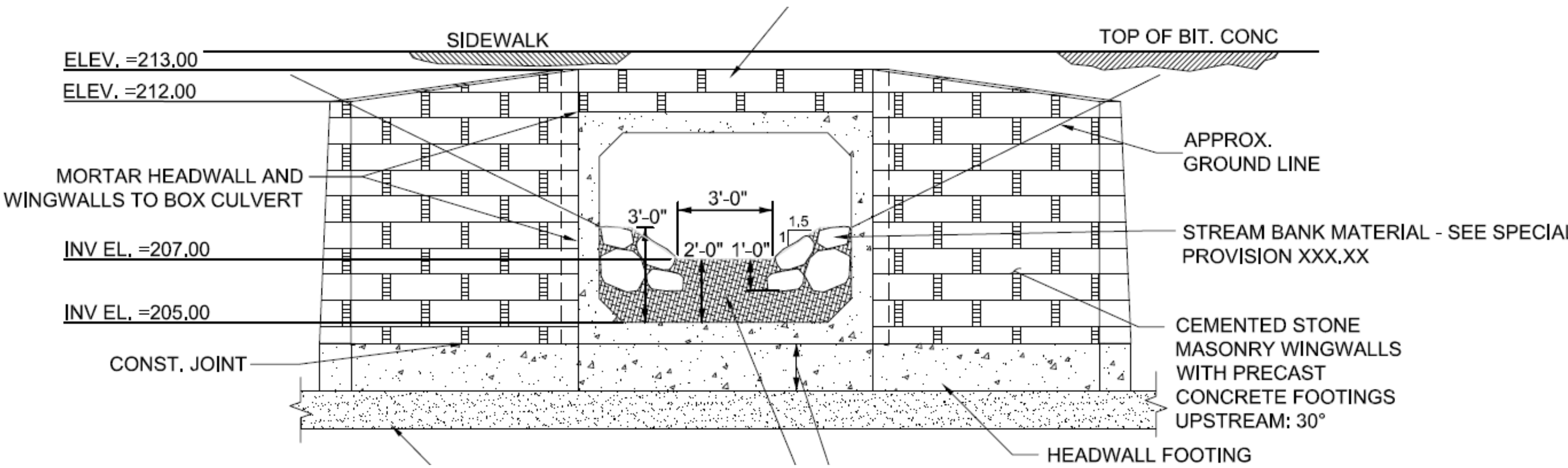
Prototypical Culvert and Small Bridge Plan Templates



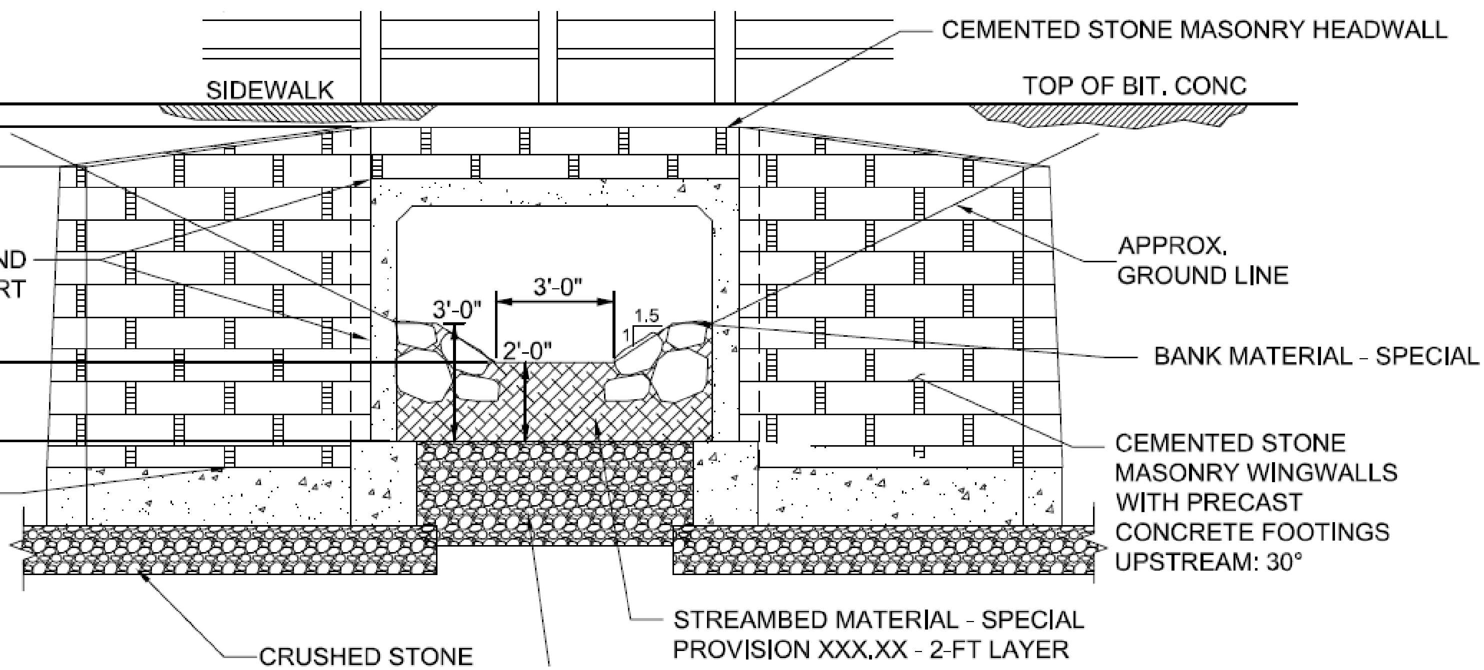
Embedded Precast Concrete Pipe



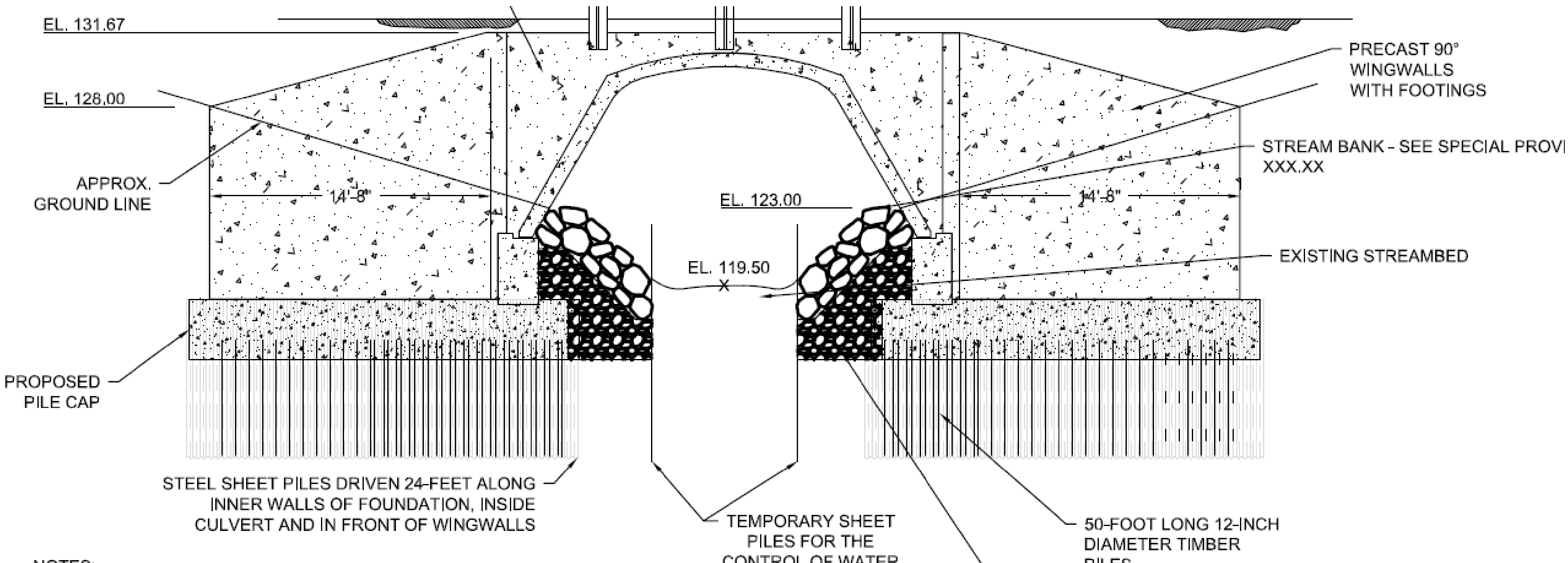
Embedded Reinforced Concrete Box Culvert



Precast Concrete 3-Sided Box Culvert



Precast Concrete Arch



NOTES:
1. PRECAST ARCH AS REQUIRED FOR HS-25 LOADING

ELEVATION

SCALE: 1" = 5'

Chapter 85 Bridge Review

- MassDOT review of new / replacement structures >10'

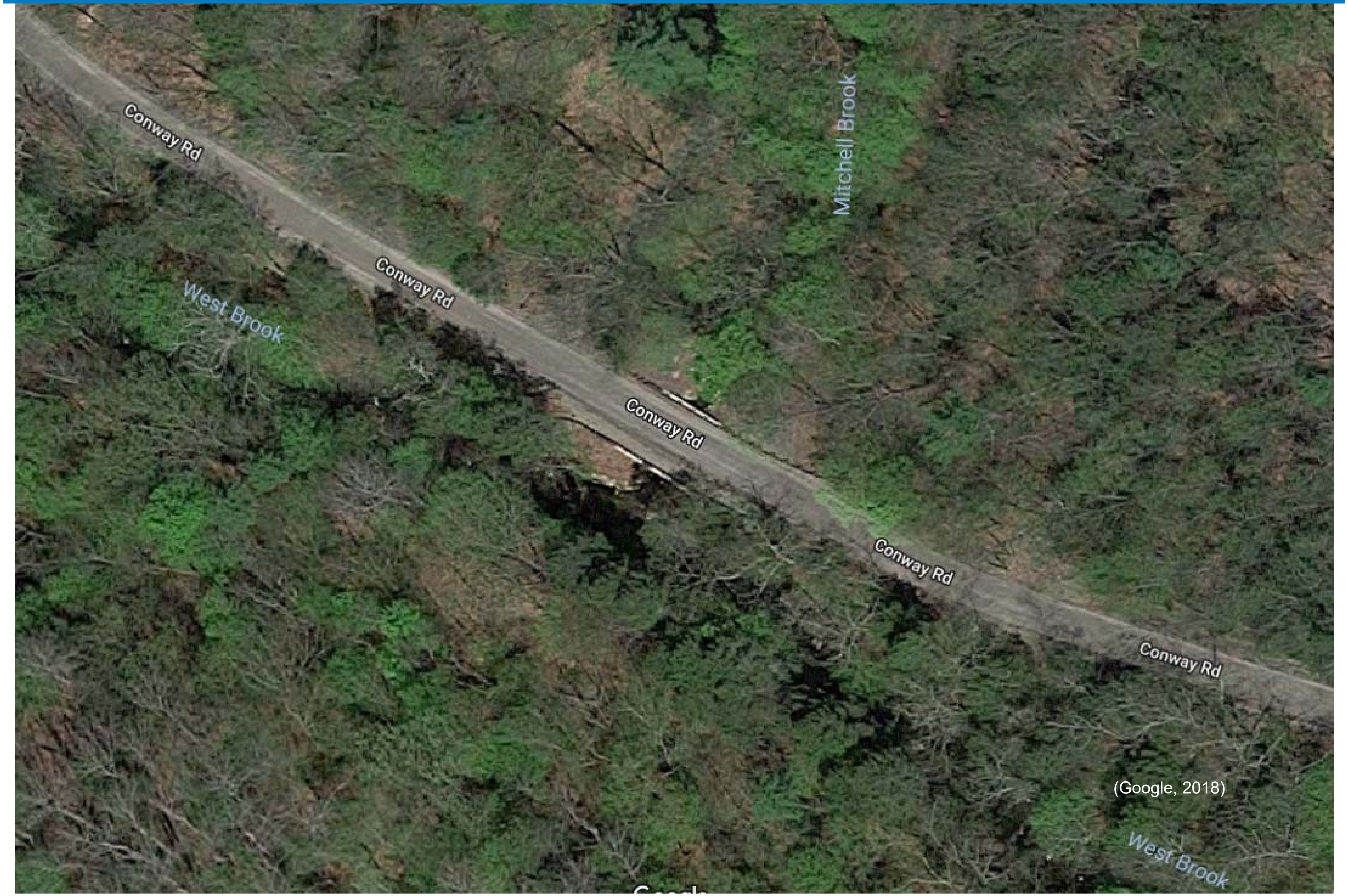
- Design Requirements & Submittals guidance:
  - https://www.mass.gov/files/documents/2017/11/08/SmallBridgeProg_requirements_new_or_replacement.pdf

- Provides requirements, by Roadway Functional Class, for:
  - Hydraulic Design
  - Geotechnical Design
  - Structural Design
  - Construction Details
  - Design Review Submittals
  - Other considerations

Chapter 85 Review

Municipal Bridge Projects MGL Chapter 85 Section 35 Review Process Design Requirements and Submittals for New Bridge and Full Bridge Replacement Projects NOTE: Design Requirements to be used depend on the Category of the Proposed Structure and not on the Category of the Existing Structure						
Note: If the Category of the Proposed Structure is neither BRI nor NBI (i.e., span ≤ 10 feet), a Chapter 85 review is not required						
If the Category of the Proposed Structure is a BRI Bridge (10 feet < span ≤ 20 feet)						
Roadway Functional Class	**Hydraulic Design**	**Geotechnical Design**	**Structural Design**	**Construction Details**	**Design Review Submittals**	**Other Considerations**
Rural Minor Collector **Rural Local Road** **Urban Collector** **Urban Local Road**	Hydraulic report per Bridge Manual (except as noted below) Less than 2 feet of freeboard Flood frequency: 10 year Design Scour freq.: 25 year Check Scour freq.: 50 year Must be scour stable after Design Scour Event but not necessarily available for use.	Geotechnical Report per Bridge Manual (except as noted below) At least one boring to refusal below bottom of footing or pile tip for every 30 feet of abutment or culvert width. If rock is encountered, a 10 foot core is recommended.	Design in accordance with AASHTO LRFD for HL-93 Design Loading. Bridge Manual DL and LL load distribution procedure if applicable. Seismic: AASHTO Guide Specifications for SDC A requirements. If a pre-fabricated structure that is designed by the fabricator: when the Contractor submits the fabricator design calculations and shop drawings, the municipality's Designer of Record shall review and accept the design.	Need not follow MassDOT Bridge Manual construction details. If not using standard MassDOT bridge railings or barriers and transitions, those used must be crash tested to either NCHRP 350 or MASH, Test Level 2 minimum if roadway speed ≤ 45 mph, minimum Test Level 3 if roadway speed > 45 mph. Provide 42" railing height if pedestrians are allowed on bridge.	Hydraulic Report (if over water) Geotechnical Report Complete final set of Construction Plans and one set of design calculations checked by a second engineer for MassDOT review. If a pre-fabricated structure, submit the shop drawings and fabricator design calculations after they have been reviewed and accepted by the municipality's Designer of Record. After MassDOT accepts the design, a complete final set of Construction Plan mylars with the MassDOT Chapter 85 approval stamp printed on each sheet for Bridge Engineer's signature.	Evaluation of structure from a Cultural Resources standpoint. Consider Stream Crossing Standards requirements. Consider "no rise" guidelines for NFIP regulatory floodways. Consider Complete Streets guidelines. Provide for utilities (water, gas, etc.) if it is expected that they will be installed in the future. Environmental permitting may put restrictions on time of year when work can be done in the water.
Rural Major Collector **Urban Minor Arterial**	Hydraulic report per Bridge Manual Provide 2 feet of freeboard Flood frequency: 25 year Design Scour freq.: 50 year Check Scour freq.: 100 year Must be scour stable and available for limited use after the Design Scour Event.	Geotechnical Report per Bridge Manual Perform a Design Boring program in accordance with Bridge Manual Part I, Section 1.2.	Design in accordance with AASHTO LRFD for HL-93 Design Loading Bridge Manual DL and LL load distribution procedure if applicable. Seismic design per Bridge Manual for a 1000 year return period event. If a pre-fabricated structure that is designed by the fabricator: when the Contractor submits the fabricator design calculations and shop drawings, the municipality's Designer of Record shall review and accept the design.	If using MassDOT standard bridge details, follow MassDOT Bridge Manual construction details. Use MassDOT bridge railings and barriers and transitions.	Hydraulic Report (if over water) Geotechnical Report Complete final set of Construction Plans and one set of design calculations checked by a second engineer. If a pre-fabricated structure, submit the shop drawings and fabricator design calculations after they have been reviewed and accepted by the municipality's Designer of Record. After MassDOT accepts the design, a complete final set of Construction Plan mylars with the MassDOT Chapter 85 approval stamp printed on each sheet for Bridge Engineer's signature.	Evaluation of structure from a Cultural Resources standpoint. Consider Stream Crossing Standards requirements. Consider "no rise" guidelines for NFIP regulatory floodways. Consider Complete Streets guidelines. Provide for utilities (water, gas, etc.) if it is expected that they will be installed in the future. Environmental permitting may put restrictions on time of year when work can be done in the water.

Mitchel Brook, Conway Road, Whately, MA



(AR and MADER, 2016)

(AR and MADER, 2016)

(AR and MADER, 2016)

Installing cobble bed/fines

Dry Passage

Dry passage fines

(AR and MADER, 2016)

Installing culvert over bed


(AR and MADER, 2016)

Push dry passage against culvert

Post Construction

(AR and MADER, 2016)


(MMI, 2018)


(MMI, 2018)

(MMI, 2018)


(MMI, 2018)


(MMI, 2018)