Fish Passage and Habitat Connectivity Design at MaineDOT

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MaineDOT / ENV

Maine Water Conference
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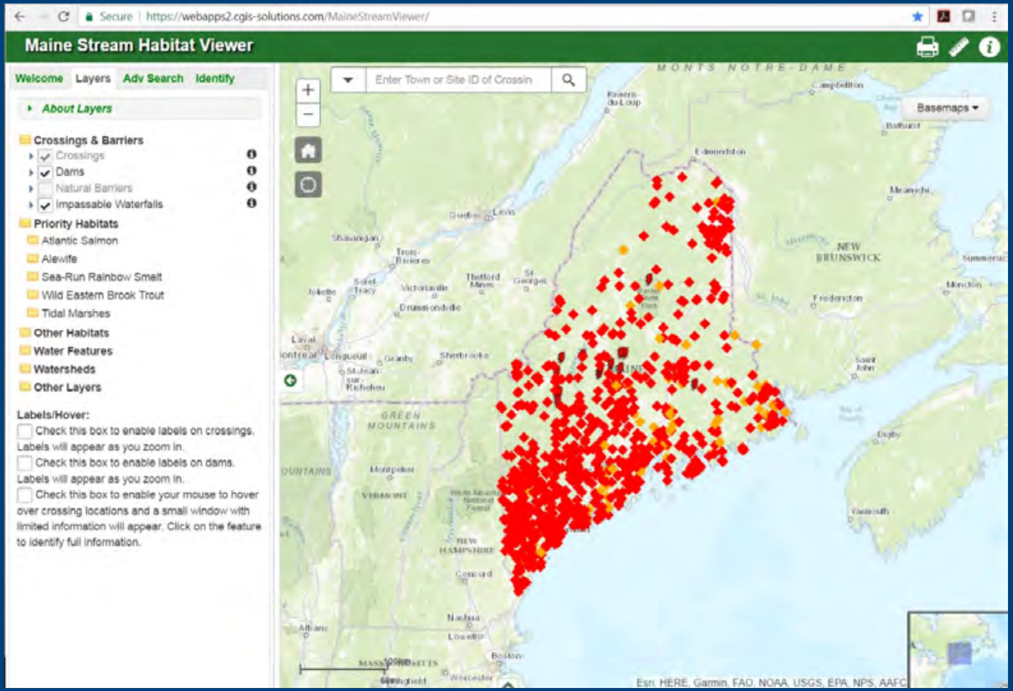
Outline

- Introduction
- Problem
- Solution - MAP
- Habitat Connectivity Design (HCD) v. Stream Simulation
- HCD in practice
- 2017 Experience
- Questions

Traditional Culverts – size for “design” storm …maybe?

Culverts as Barriers

- Depth, velocity criteria
- > 40% are barriers
- > 40% are partial barriers



Source: Maine Stream Habitat Viewer

Previous FP Approaches at MaineDOT

- Engineered: Weir / baffle
- "Bathtub"
- Hydraulic Design: Target species only
  - Velocity, depth
- Embed & Backfill – a hint of Stream Simulation

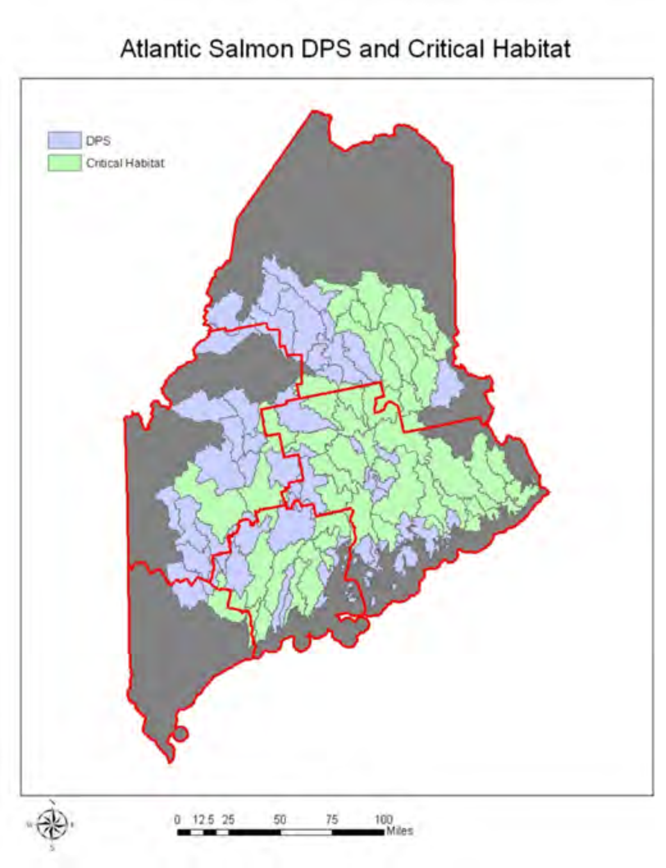
Not just about fish anymore…

- Other species, juveniles
- Aquatic invertebrates
- Terrestrial organisms
- Geomorphic processes

Pierce Pond Stream, Carrying Place Twp.

The Problem: Unpredictability of schedule and project design in Atlantic Salmon (ATS) Distinct Population Segment (DPS) watersheds protected by the Endangered Species Act (ESA)

- Individual "consultations"
- Project Delivery: Blown schedules & budgets
- Projects needed for customer service and safety were not being completed
- Unhappy management



The Solution: The <u>**M**</u>aine <u>**A**</u>tlantic Salmon <u>**P**</u>rogramamtic Agreement

Programmatic Biological Assessment
for Transportation Projects for the
Gulf of Maine Distinct Population Segment of
Atlantic Salmon and Designated Critical Habitat

U.S. Fish and Wildlife Service Jurisdiction

June 2016

Submitted by:

Maine Department of Transportation

Federal Highway Administration

US Army Corps of Engineers

http://maine.gov/mdot/maspc/

Pros and Pros?

MaineDOT gets:

- Streamlined consultation process
  - << 30 days vs. 180 – 360 days previously
- Predictable avoidance and minimization measures
- Predictable design criteria = ***Habitat Connectivity Design***
- Some element of prioritization
- *Bonus*: increased hydraulic capacity for potential climate change impacts

** **NO FREE LUNCH**: HCD designs **generally bigger, more complex** than traditional capacity design => cost more; special project concerns and/or site issues may preclude MAP*

Pros and Pros?

Atlantic salmon get:

- Geomorphic-based culvert & bridge designs
- Projects helping aid in species recovery

“Scope Creep”:

- General HCD methods used statewide as appropriate
- Species, streams outside DPS also benefit
- Cannot maintain a double standard

Approximate predicted numbers of projects process with the MAP - 5 Years

Project Activity	Number
Stream Crossing Replacements:	--
Culverts (Spans ≤20 feet)	50
Bridges (Spans > 20 feet)	45
Bridge and Culvert Removal	3
Scour Countermeasures	15
Culvert End Resets and Extensions	50
Bridge Maintenance	16
Temporary Work Access and Temporary Bridges	15*
Invert Line and Slipline Culvert Rehabilitation	15
Pre-project Geotechnical Drilling	15*
ESTIMATED TOTAL	194*

Projects processed to date

- 23 projects processed in 2017
- *Time: 3 - 7 days average processing*
- 30 projects anticipated in 2018

Stream Simulation *(from USFS 2008 manual)*

*Recreate – **Simulate** – Natural Stream in Culvert*

- Method for designing and building road-stream crossings intended to *permit free and unrestricted movements* of any aquatic species
- *Premise*: physical characteristics very similar to natural channel, aquatic species should experience no greater difficulty moving through it
- Continuous streambed that *mimics* the slope, structure, and dimensions of the *natural streambed*.
- *Water depths and velocities as diverse* as those in natural channel, providing passageways for all swimming or crawling aquatic species.

Habitat Connectivity Design (HCD)

- Umbrella term to capture Stream Sim and related techniques on the geomorphic / nature-like / engineered spectrum as acceptable design methodologies under the MAP
- Stream Sim is not always appropriate or meaningful
  - Use the other geomorphic methods
  - Still get a nature-like streambed with hydraulic variability

Habitat Connectivity Design (HCD)

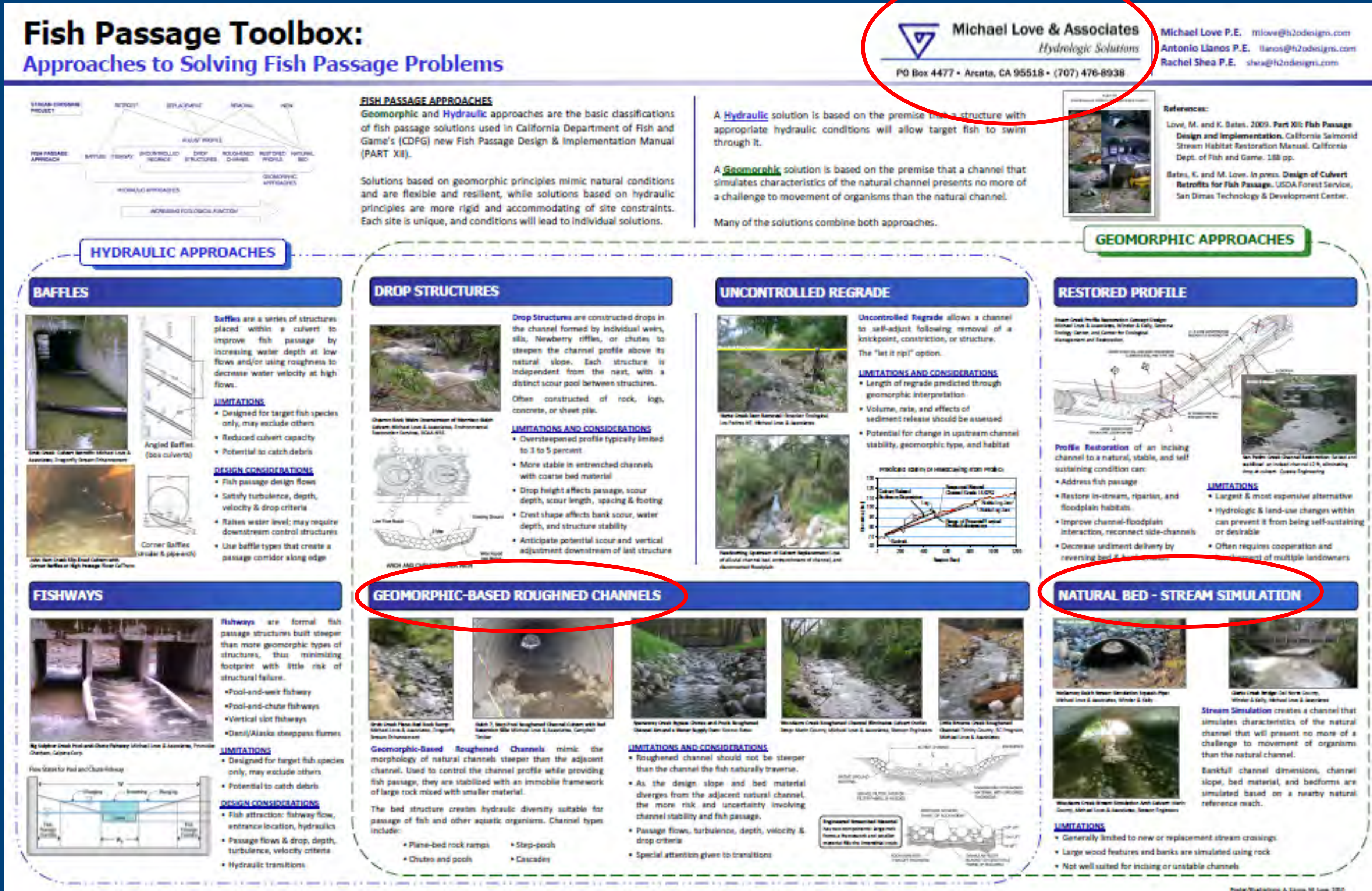
- Design and build for consistency with natural stream dimensions, profiles, and dynamics
- Technical references:

  U.S. Forest Service guide (Forest Service Stream-Simulation Working Group 2008), augmented by documents published by states of:

    - Washington (Barnard et al. 2013)
    - Vermont (Bates and Kirn 2009)
    - California (Love and Bates 2009)

MaineDOT-Sponsored Training

- June 2017 – 4 days
- MaineDOT staff and consultants under General Consulting Agreements
- Sean Smith (UMO)
  - Fluvial geomorphology
- Mike Love (Mike Love Assoc, Arcata, CA)
  - Engineering and design



Fish Passage Toolbox:
Approaches to Solving Fish Passage Problems

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FISH PASSAGE APPROACHES

Geomorphic and **Hydraulic** approaches are the basic classifications of fish passage solutions used in California Department of Fish and Game's (CDFG) new Fish Passage Design & Implementation Manual (PART XII).

Solutions based on geomorphic principles mimic natural conditions and are flexible and resilient, while solutions based on hydraulic principles are more rigid and accommodating of site constraints. Each site is unique, and conditions will lead to individual solutions.

A **Hydraulic** solution is based on the premise that a structure with appropriate hydraulic conditions will allow target fish to swim through it.

A **Geomorphic** solution is based on the premise that a channel that simulates characteristics of the natural channel presents no more of a challenge to movement of organisms than the natural channel.

Many of the solutions combine both approaches.

References:

Love, M. and K. Bates. 2009. **Part XII: Fish Passage Design and Implementation.** California Salmonid Stream Habitat Restoration Manual. California Dept. of Fish and Game. 188 pp.

Bates, K. and M. Love. In press. **Design of Culvert Retrofits for Fish Passage.** USDA Forest Service, San Dimas Technology & Development Center.

HYDRAULIC APPROACHES

GEOMORPHIC APPROACHES

BAFFLES

Baffles are a series of structures placed within a culvert to improve fish passage by increasing water depth at low flows and/or using roughness to decrease water velocity at high flows.

Angled Baffles (box culverts)

Corner Baffles (circular & pipe-arch)

LIMITATIONS
- Designed for target fish species only, may exclude others
- Reduced culvert capacity
- Potential to catch debris

DESIGN CONSIDERATIONS
- Fish passage design flows
- Satisfy turbulence, depth, velocity & drop criteria
- Raises water level; may require downstream control structures
- Use baffle types that create a passage corridor along edge

DROP STRUCTURES

Drop Structures are constructed drops in the channel formed by individual weirs, sills, Newberry riffles, or chutes to steepen the channel profile above its natural slope. Each structure is independent from the next, with a distinct scour pool between structures.

Often constructed of rock, logs, concrete, or sheet pile.

LIMITATIONS AND CONSIDERATIONS
- Oversteepened profile typically limited to 3 to 5 percent
- More stable in entrenched channels with coarse bed material
- Drop height affects passage, scour depth, scour length, spacing & footing
- Crest shape affects bank scour, water depth, and structure stability
- Anticipate potential scour and vertical adjustment downstream of last structure

UNCONTROLLED REGRADE

Uncontrolled Regrade allows a channel to self-adjust following removal of a knickpoint, constriction, or structure.

The "let it rip!" option.

LIMITATIONS AND CONSIDERATIONS
- Length of regrade predicted through geomorphic interpretation
- Volume, rate, and effects of sediment release should be assessed
- Potential for change in upstream channel stability, geomorphic type, and habitat

RESTORED PROFILE

Profile Restoration of an incising channel to a natural, stable, and self sustaining condition can:
- Address fish passage
- Restore in-stream, riparian, and floodplain habitats
- Improve channel-floodplain interaction, reconnect side-channels
- Decrease sediment delivery by reversing bed & bank erosion

LIMITATIONS
- Largest & most expensive alternative
- Hydrologic & land-use changes within can prevent it from being self-sustaining or desirable
- Often requires cooperation and involvement of multiple landowners

FISHWAYS

Fishways are formal fish passage structures built steeper than more geomorphic types of structures, thus minimizing footprint with little risk of structural failure.

- •Pool-and-weir fishway
- •Pool-and-chute fishways
- •Vertical slot fishways
- •Denil/Alaska steeppass flumes

LIMITATIONS
- Designed for target fish species only, may exclude others
- Potential to catch debris

DESIGN CONSIDERATIONS
- Fish attraction: fishway flow, entrance location, hydraulics
- Passage flows & drop, depth, turbulence, velocity criteria
- Hydraulic transitions

GEOMORPHIC-BASED ROUGHNED CHANNELS

Geomorphic-Based Roughened Channels mimic the morphology of natural channels steeper than the adjacent channel. Used to control the channel profile while providing fish passage, they are stabilized with an immobile framework of large rock mixed with smaller material.

The bed structure creates hydraulic diversity suitable for passage of fish and other aquatic organisms. Channel types include:
- Plane-bed rock ramps
- Step-pools
- Chutes and pools
- Cascades

LIMITATIONS AND CONSIDERATIONS
- Roughened channel should not be steeper than the channel the fish naturally traverse.
- As the design slope and bed material diverges from the adjacent natural channel, the more risk and uncertainty involving channel stability and fish passage.
- Passage flows, turbulence, depth, velocity & drop criteria
- Special attention given to transitions

NATURAL BED - STREAM SIMULATION

Stream Simulation creates a channel that simulates characteristics of the natural channel that will present no more of a challenge to movement of organisms than the natural channel.

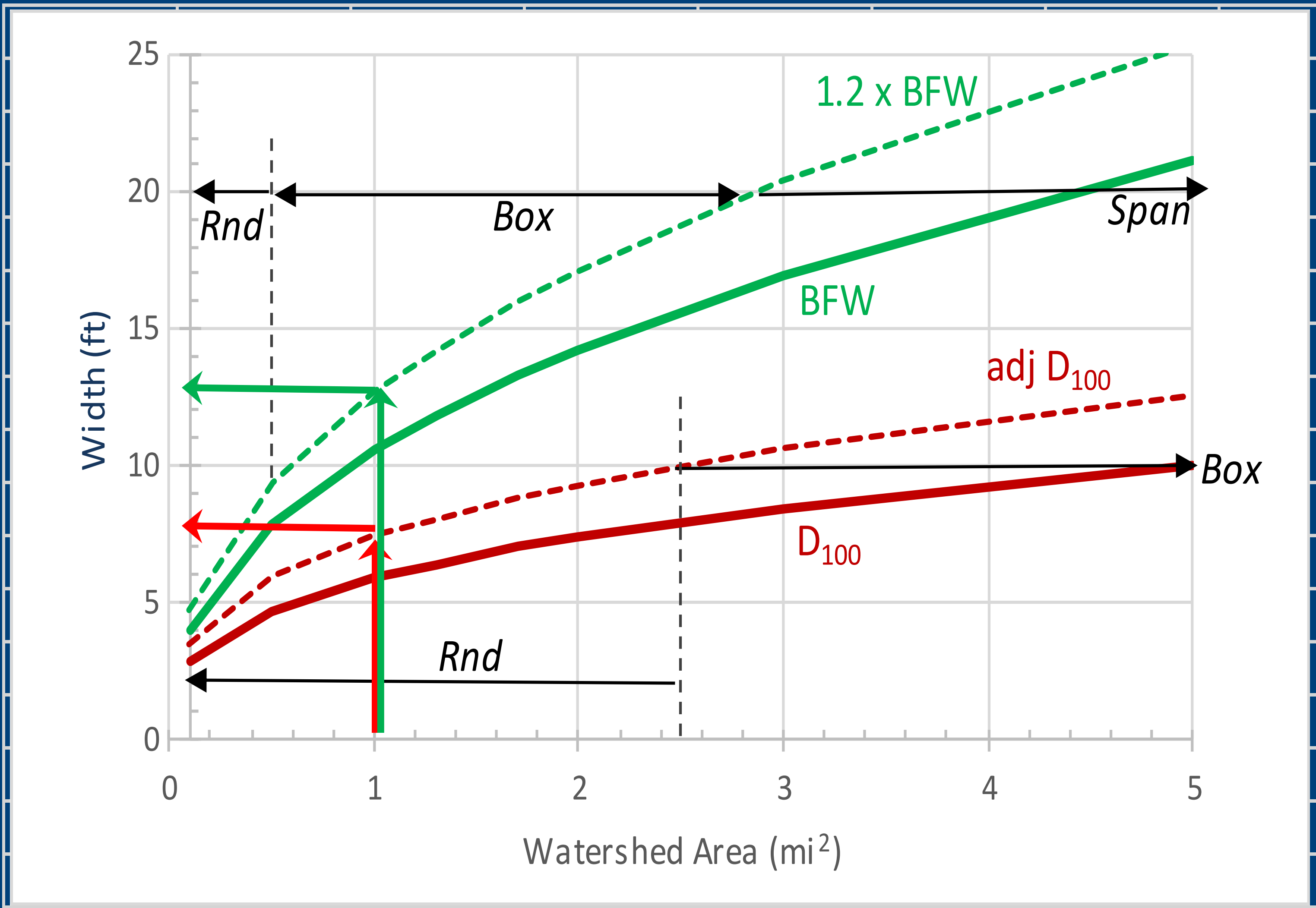
Bankfull channel dimensions, channel slope, bed material, and bedforms are simulated based on a nearby natural reference reach.

LIMITATIONS
- Generally limited to new or replacement stream crossings
- Large wood features and banks are simulated using rock
- Not well suited for incising or unstable channels

Implications for HCD Hydraulic Structures

- 1.2 X BFW in Tier 1 areas
- Open Rise 2' less than structure rise
- Must satisfy $H_w/R_{open} \leq 1$ @ Q100
- Round pipes D $\geq$ 6'
  - For constructability
  - Limits DOT to 6'D & 8'D round pipes
- Box culverts 10' < S < 26' (max)
  - Prefer Rise R $\geq$ 8' for constructability & access
  - Use clamshell for R < 8'
- Sometimes Pipe Arch shape

Culvert Size Increase for HCD



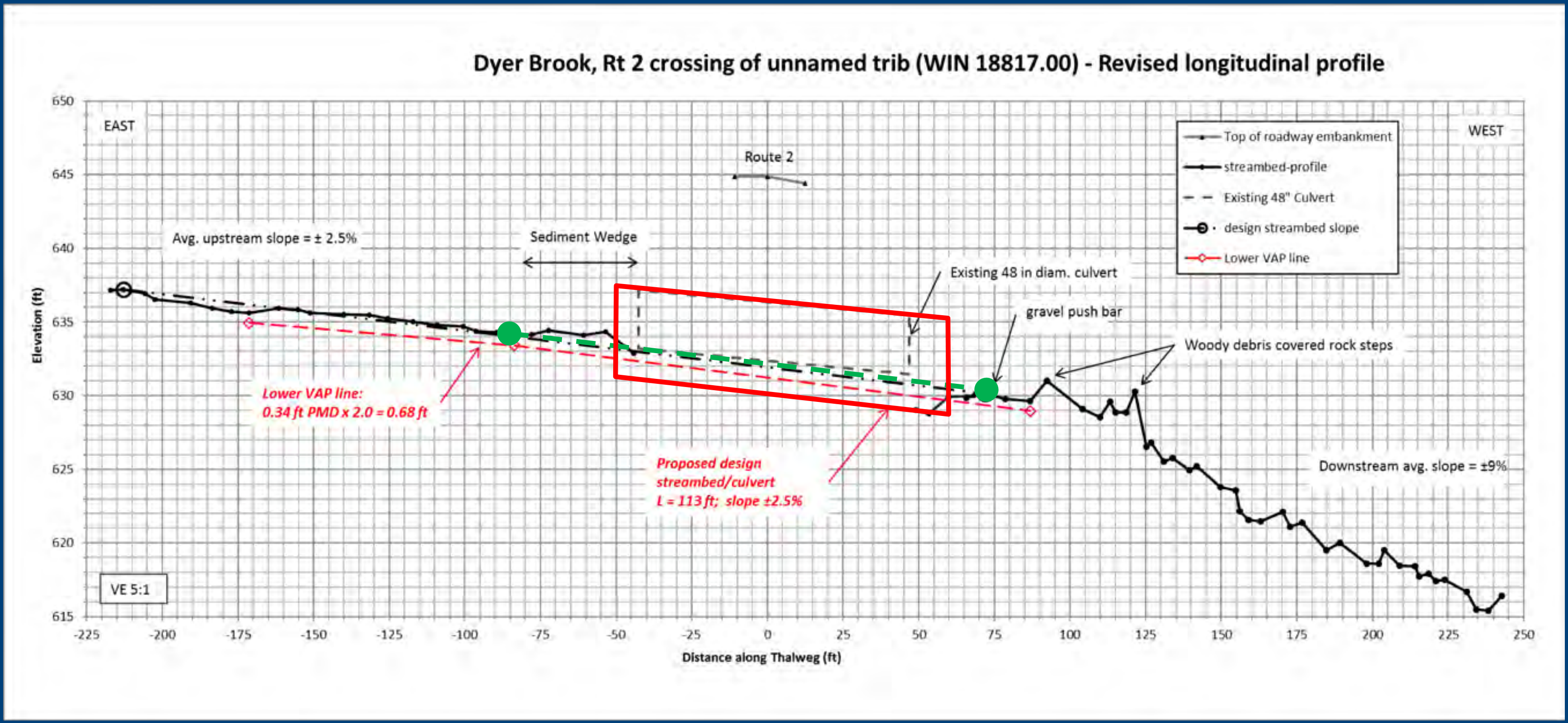
Culvert Size Increase for HCD

Some Critical Pieces in HCD

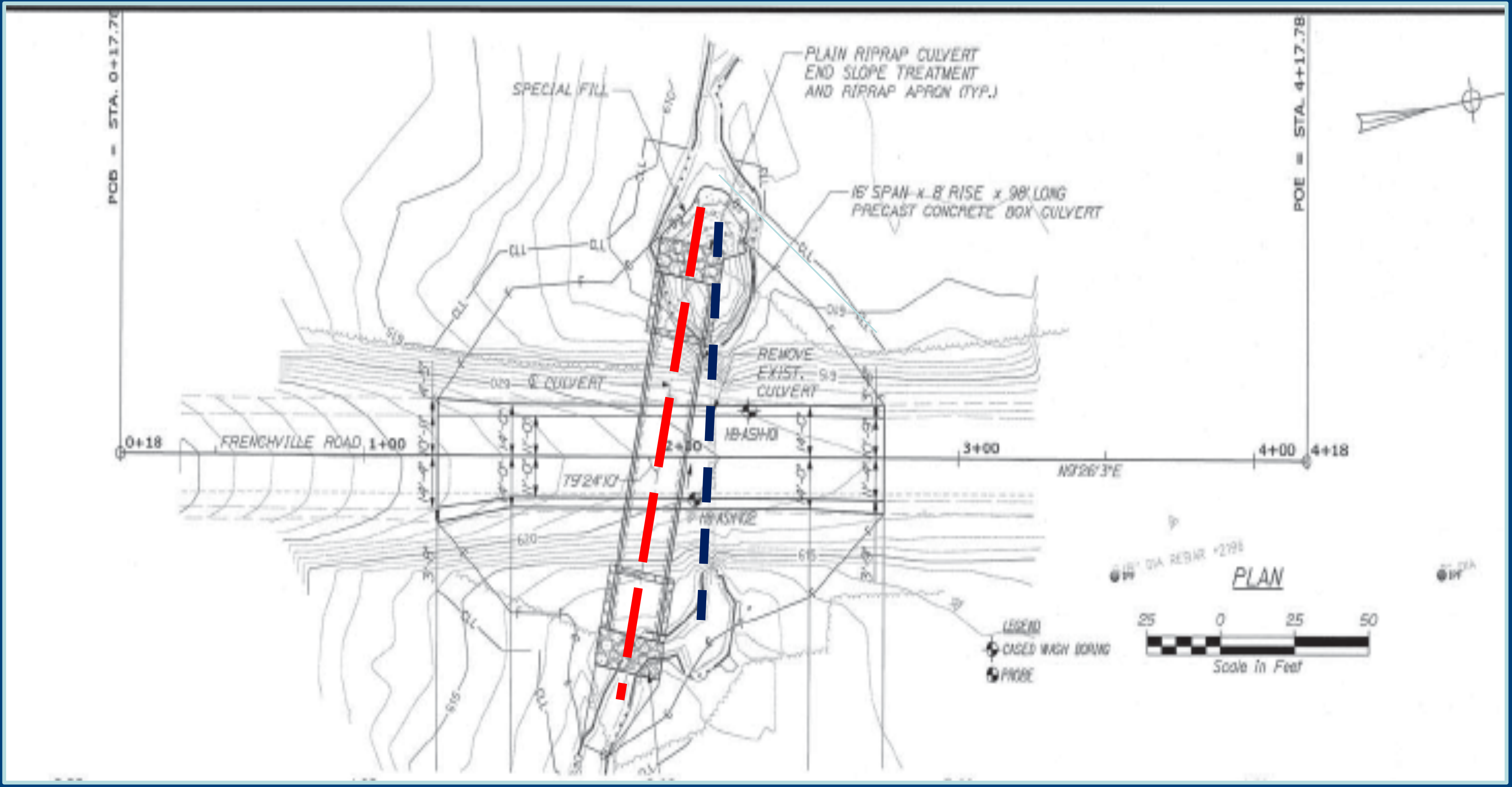
- Channel width measurements
- Stream profile – vertical alignment
- Stream plan view – horizontal alignment
- Streambed Wolman pebble count

BFW determination

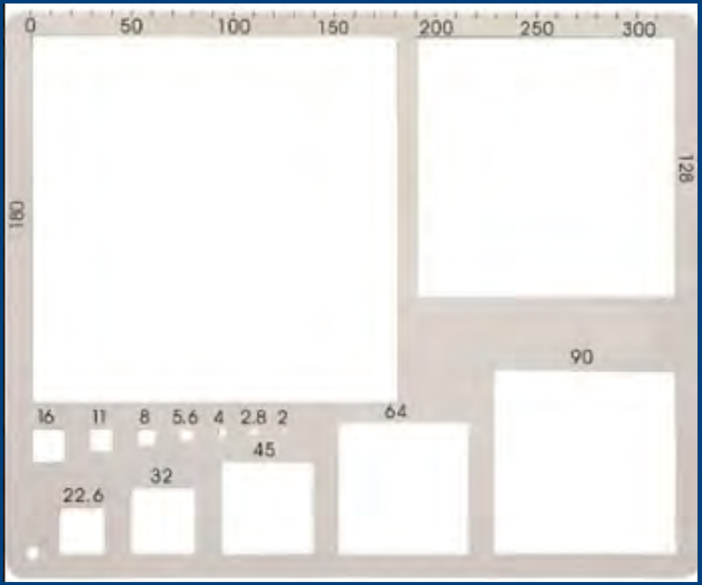
Longitudinal Profile



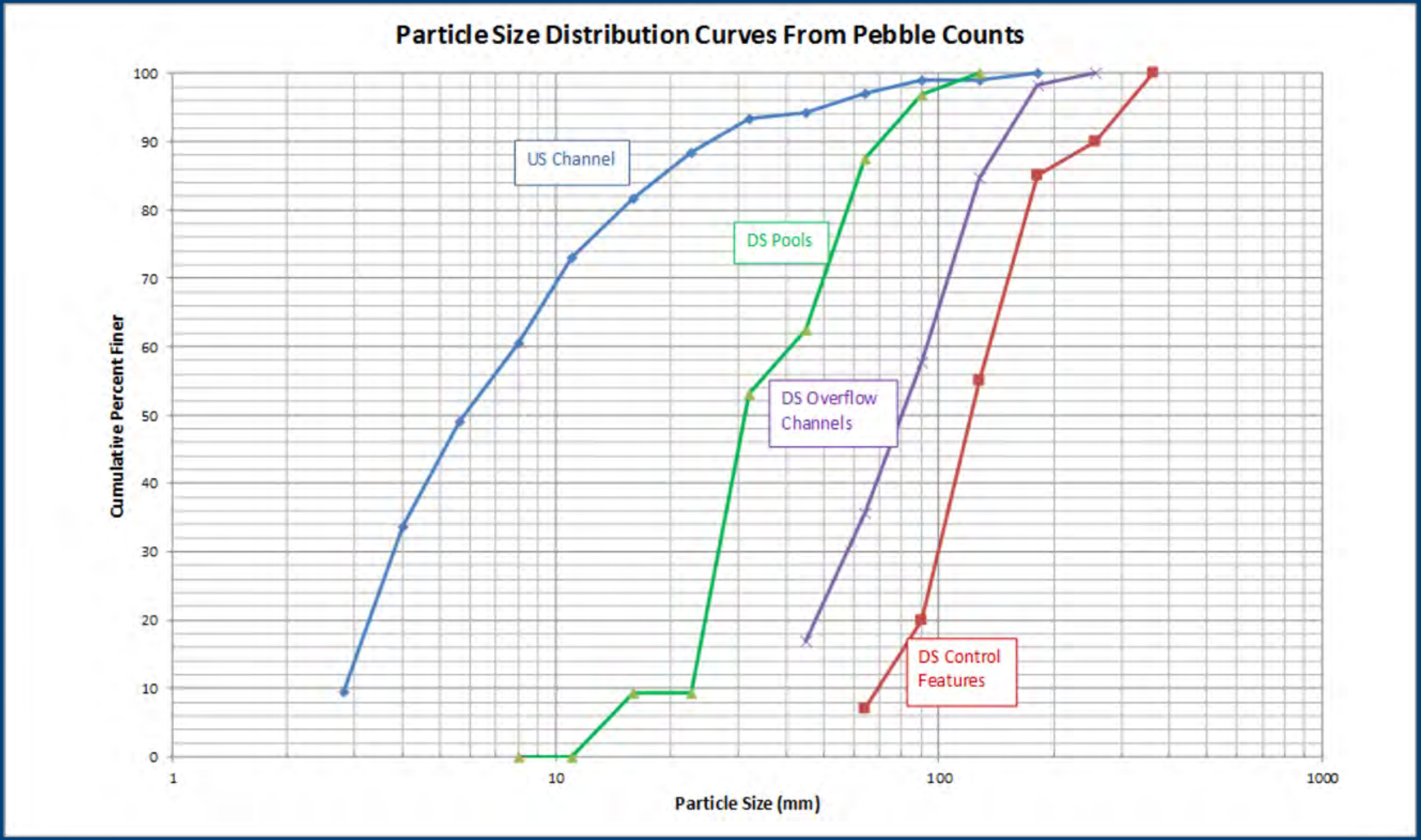
Alignment (Skew)



Streambed -- Pebble Count



Streambed – Pebble Count



Streambed Design

- Generally 2-ft thick
- Based on pebble count and/or stability – incipient motion analysis
- May include stable geomorphic structure
  - Step-pool, rock weirs, cobble bars, rock bands, feature rocks
- Special Provisions for Special Fill and Stream Channel Rock contract items

2017 MAP Large Culvert Projects

- Dyer Brook, Rt 2

  Old: 48” CMP

  BFW = 6.8 ft

  New: 103”S x 71”R PA

  S = 2.5%

2017 MAP Large Culvert Projects

- Windsor ME17

  Old: 4.5' CMP

  BFW = 5.9 ft

  New: 8 ft D RCP

  S = flat

Streambed Materials

- Stockpile materials on/off site
- Reviewed and approved

Streambed Materials

Layout

Equipment

Staging

Construction

- Low Rise = challenging!
- Health & Safety implications

Clam-shell Box

Streambed Compaction

- Water-in each lift to fill voids, compact bed
- Alternative means? – vibration?

Stable Features

- Banklines, rock bands, weirs / steps, bars
- Water-in filler material to fill voids

Banklines

- 1.2 BFW structures

Banklines

- Connect culvert banklines to existing natural banks outside culvert
- Smooth inlet and outlet transitions

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