Stream Smart Road Crossings

Designing roads for fish, floods and foxes

Maine Audubon

Department of Conservation Maine Forest Service

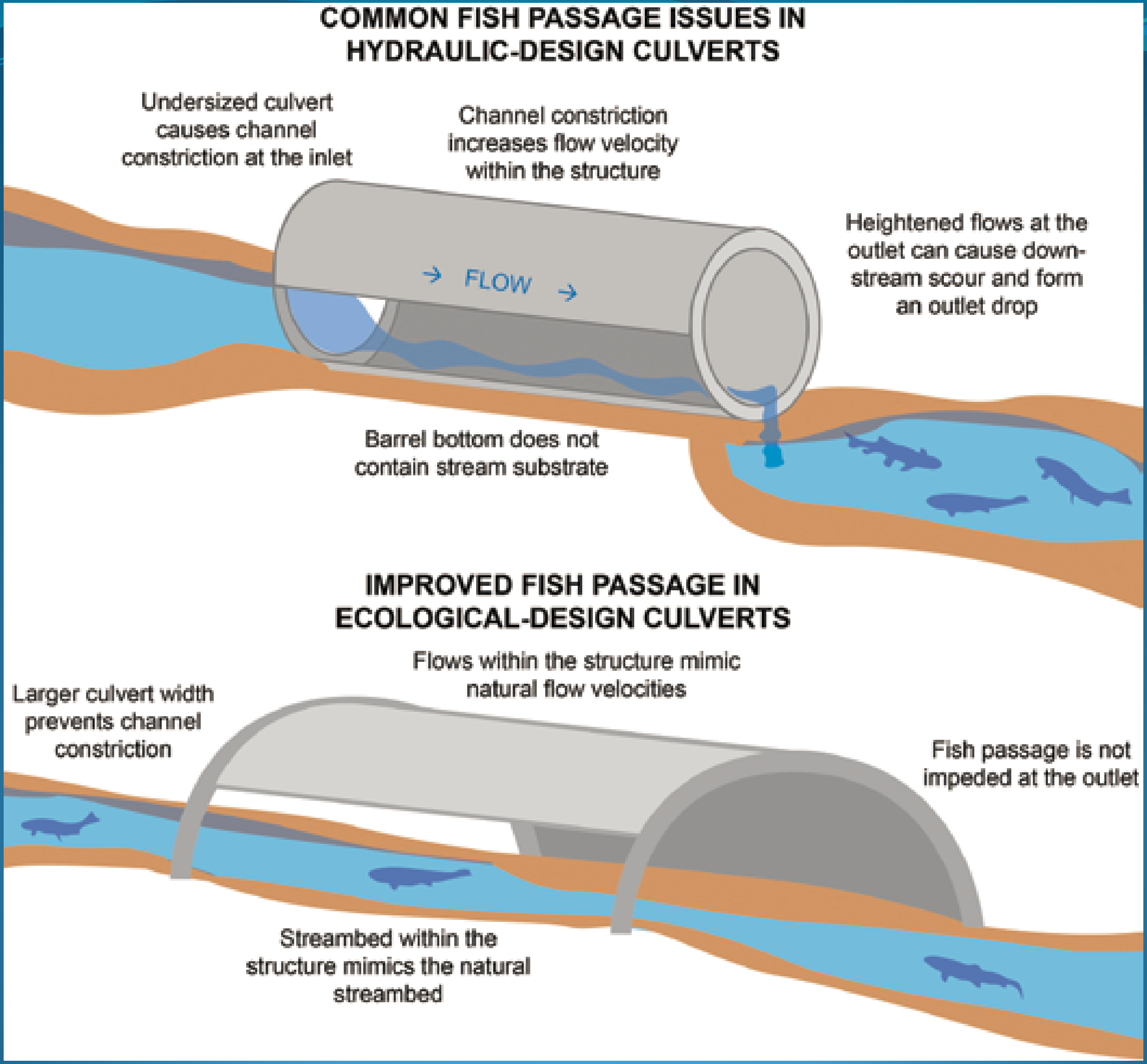
NRCS Natural Resources Conservation Service

The Nature Conservancy
Protecting nature. Preserving life.™

Maine Dept of Inland Fisheries and Wildlife

U.S. Fish & Wildlife Service Department of the Interior

SHARE



COMMON FISH PASSAGE ISSUES IN HYDRAULIC-DESIGN CULVERTS
Undersized culvert causes channel constriction at the inlet
Channel constriction increases flow velocity within the structure
FLOW
Heightened flows at the outlet can cause down-stream scour and form an outlet drop
Barrel bottom does not contain stream substrate
IMPROVED FISH PASSAGE IN ECOLOGICAL-DESIGN CULVERTS
Flows within the structure mimic natural flow velocities
Larger culvert width prevents channel constriction
Fish passage is not impeded at the outlet
Streambed within the structure mimics the natural streambed

Swimming

Occupied Velocity > Prolonged Capability

Yes

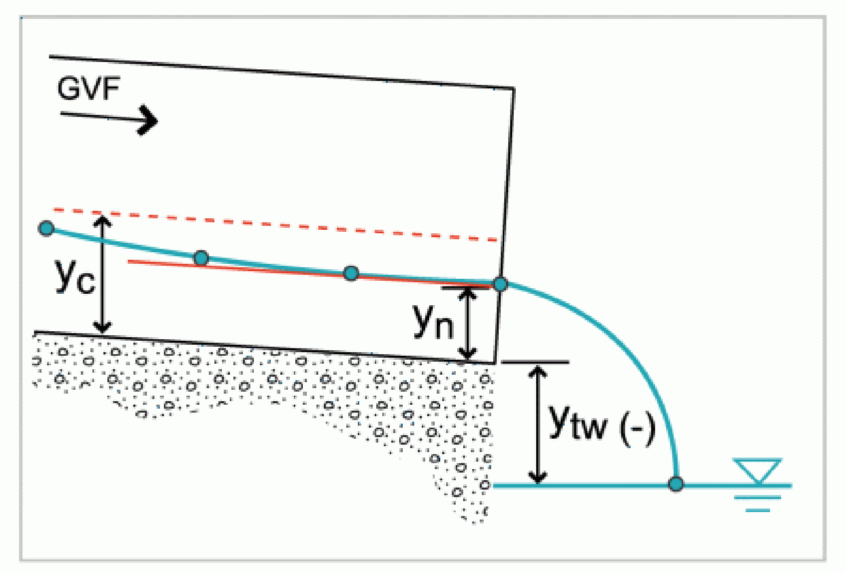
Swim in Burst

Total Time in Burst > Time to Exhaustion

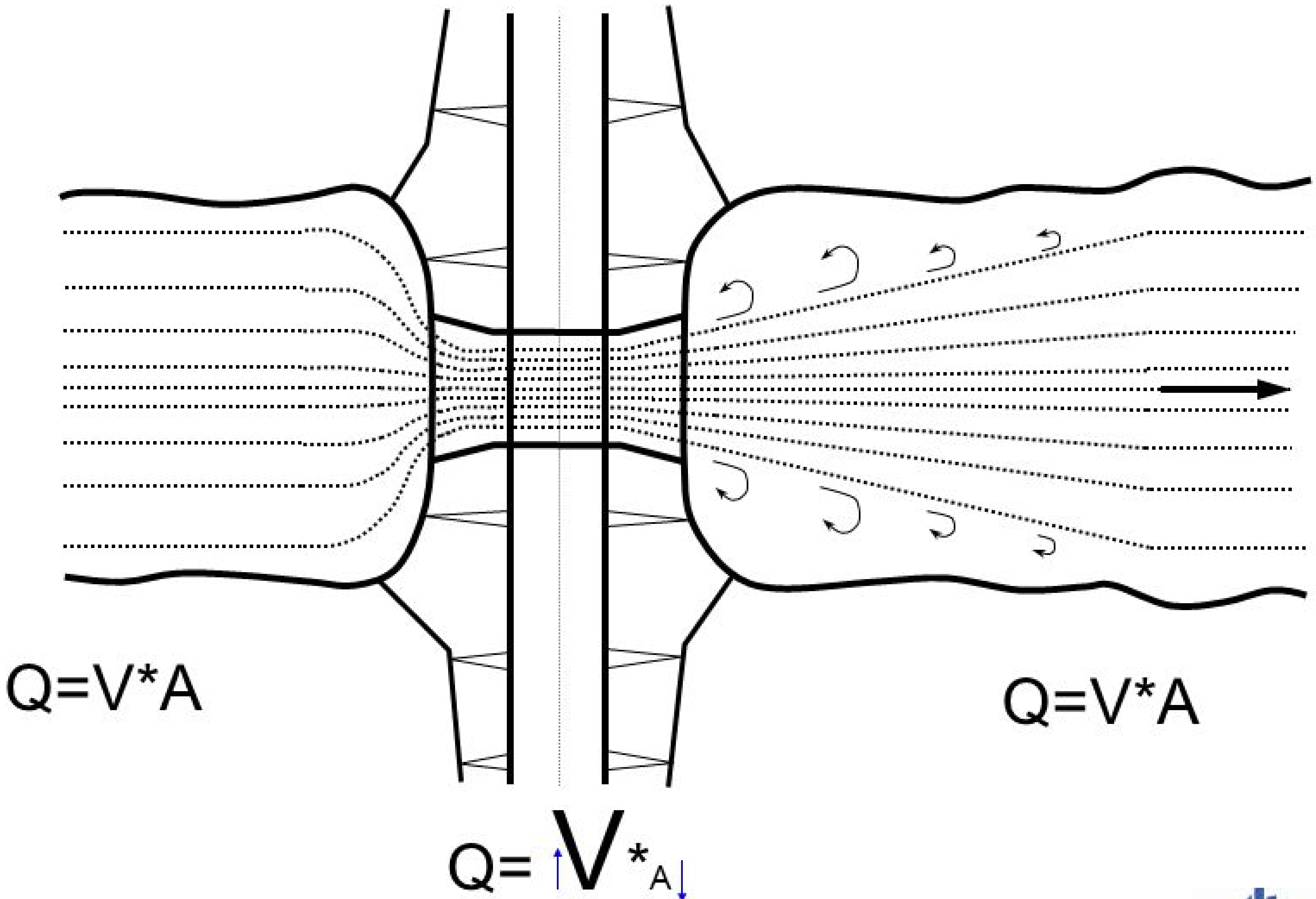
Yes

Barrier
(Exhausted Burst)

Plunging Flow & Leaping



Flowlines - After Constriction



BIM

Alberta INFRASTRUCTURE AND TRANSPORTATION

Hydraulically Efficient culverts can have unintended and adverse consequences:

- Crossing narrower than natural channel
- Upstream sediment deposition
- Increased water velocity and downstream scour
- Risks of plugging from wood and debris

Site 7588 – Before Restoration

Site 7588 – After Restoration *

Inlet

Outlet

* Bridge composed of timber on steel beams. Revegetation to follow.

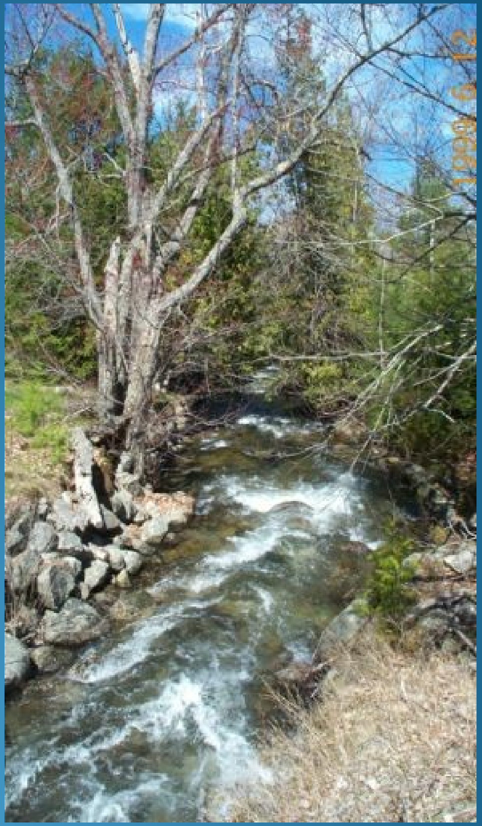
Design Criteria

Span the stream

Set elevation right

Slope matches stream

Substrate in the crossing

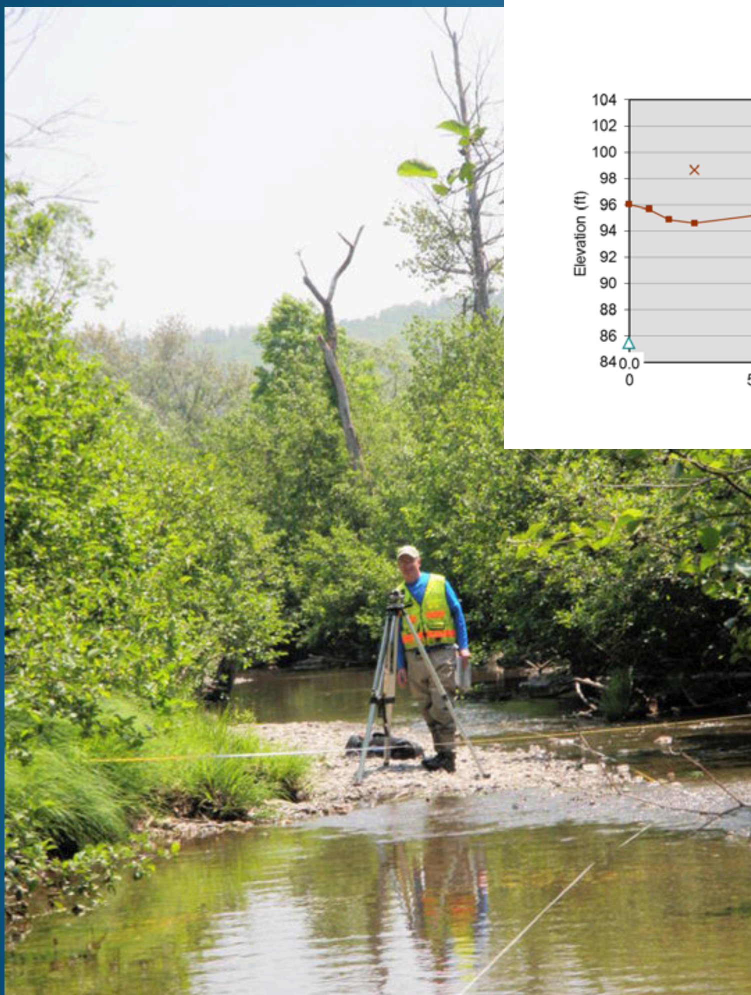


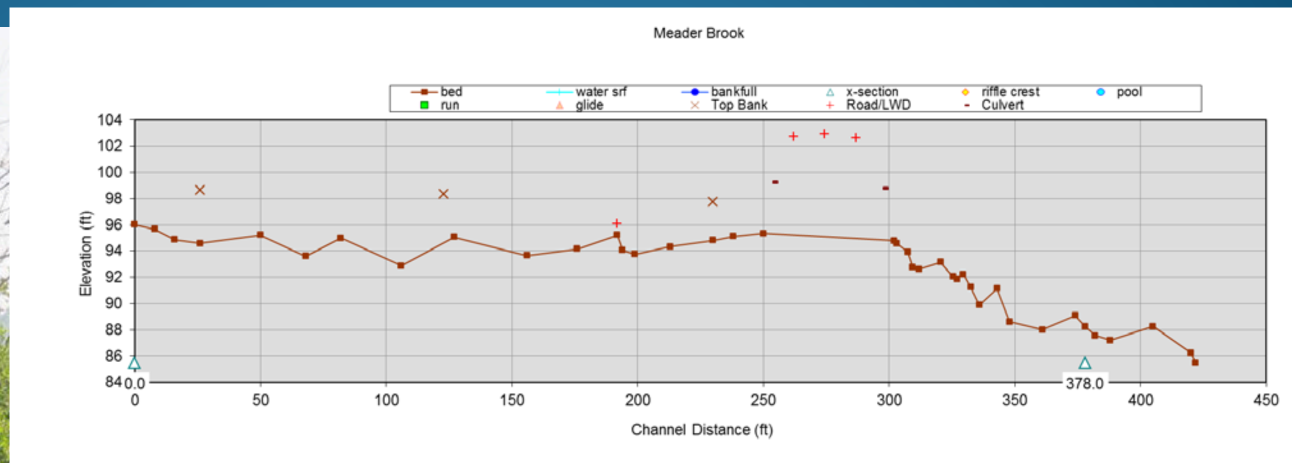
The Golden Rule:
Let the stream act like a stream

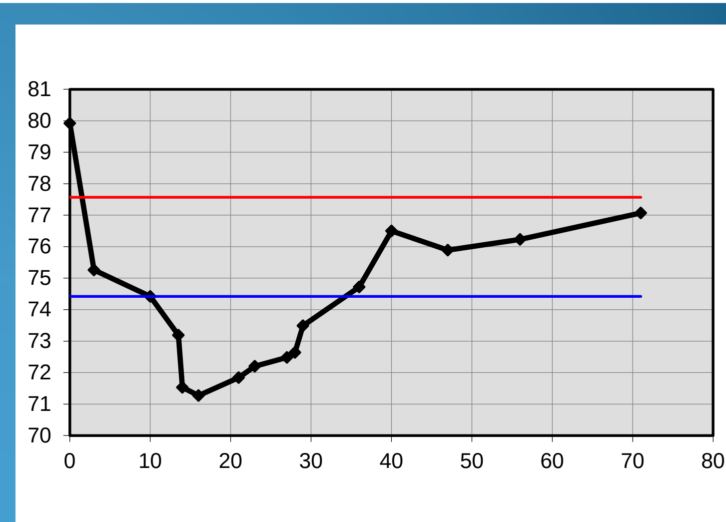
Field Surveys

Getting a good REFERENCE REACH is critical!

Short surveys mean failed culverts!



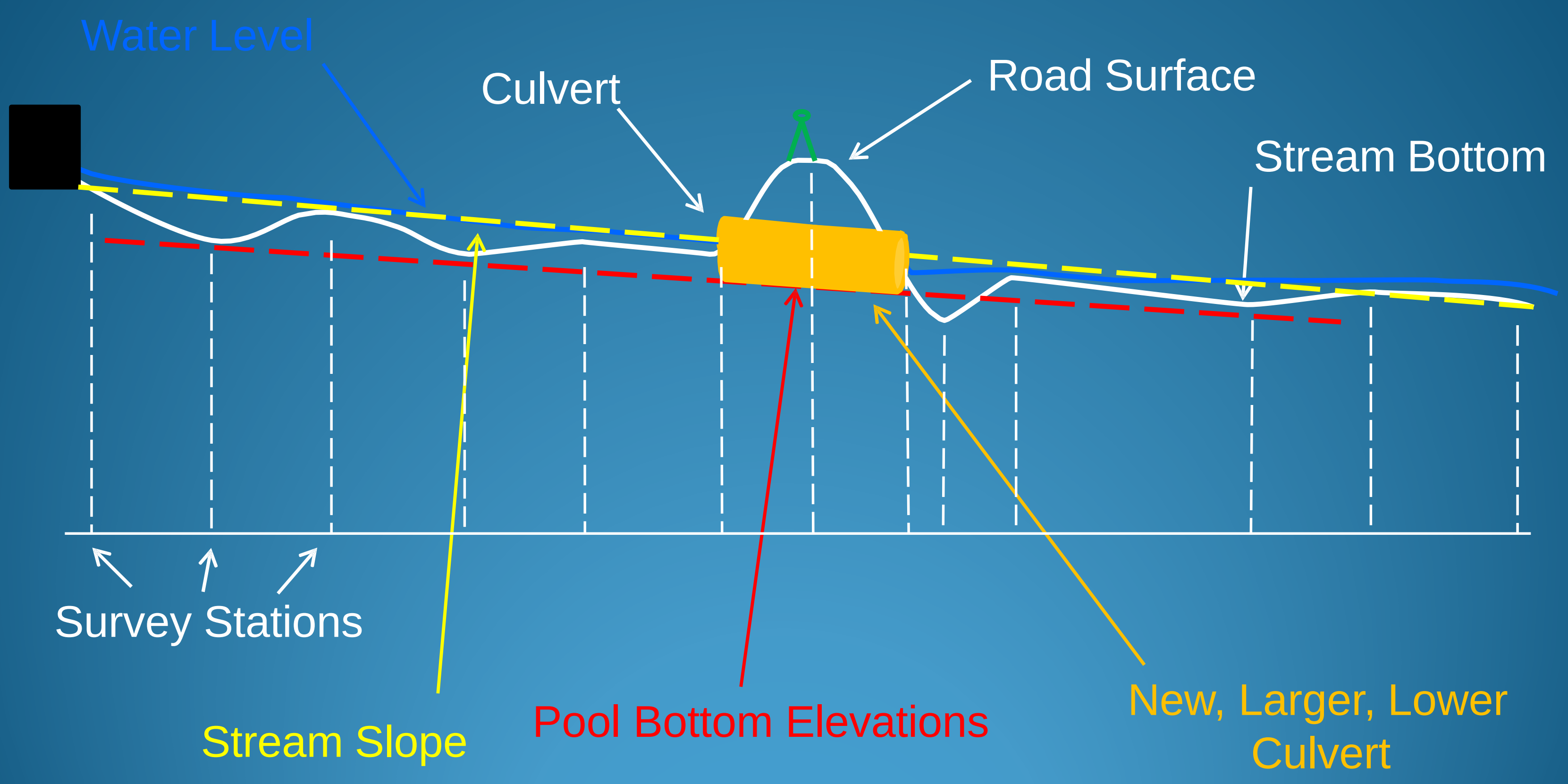




Field Surveys

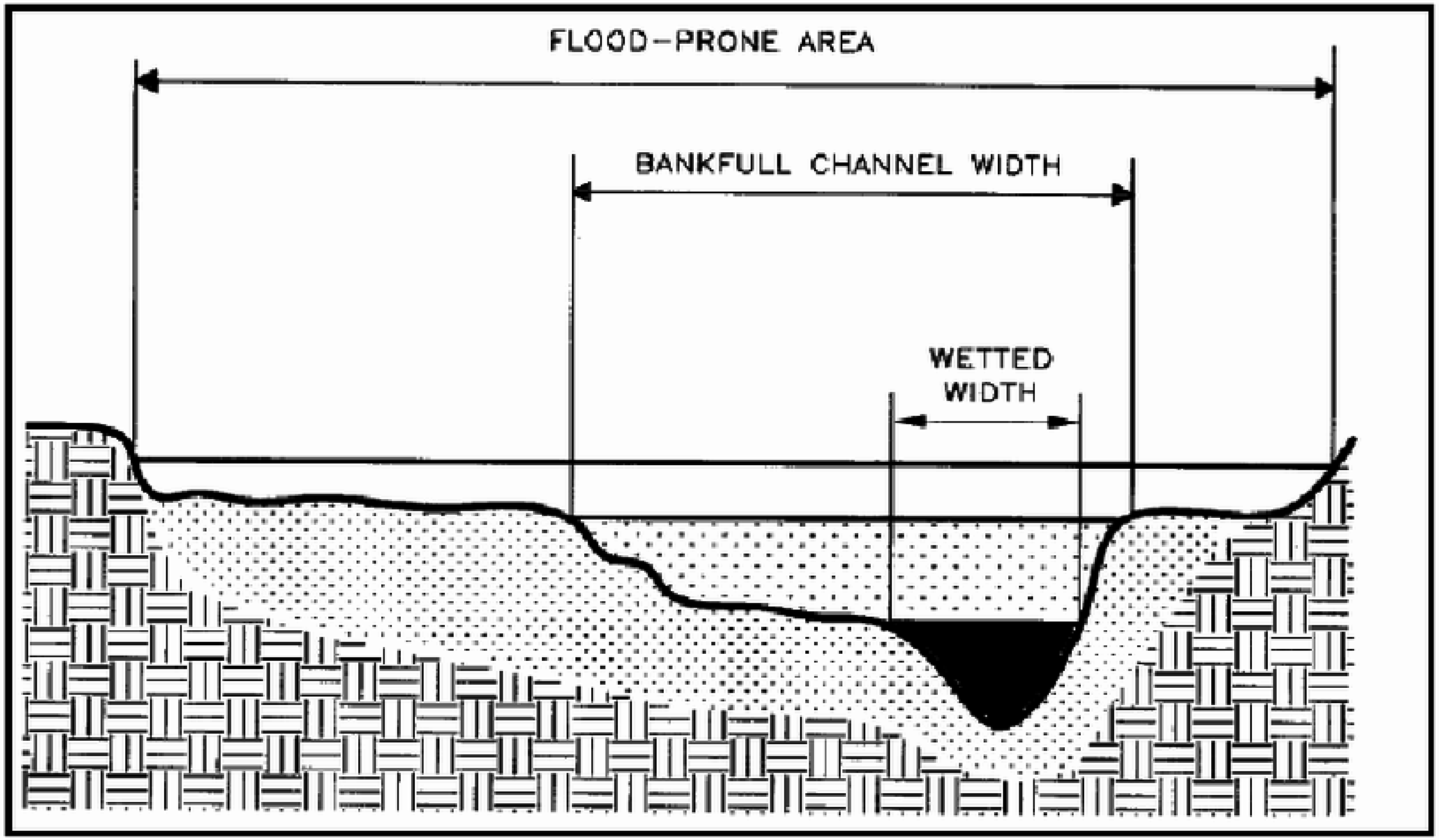
Longitudinal Profile

Used to find correct elevation and slope from a REFERENCE REACH



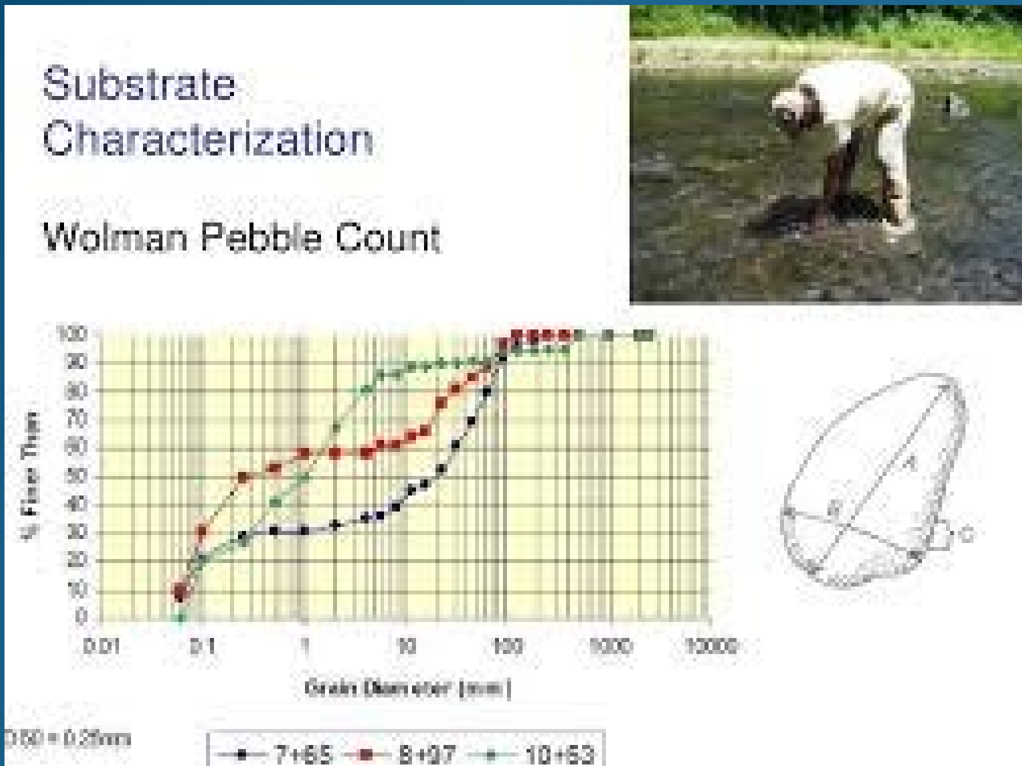
Field Surveys

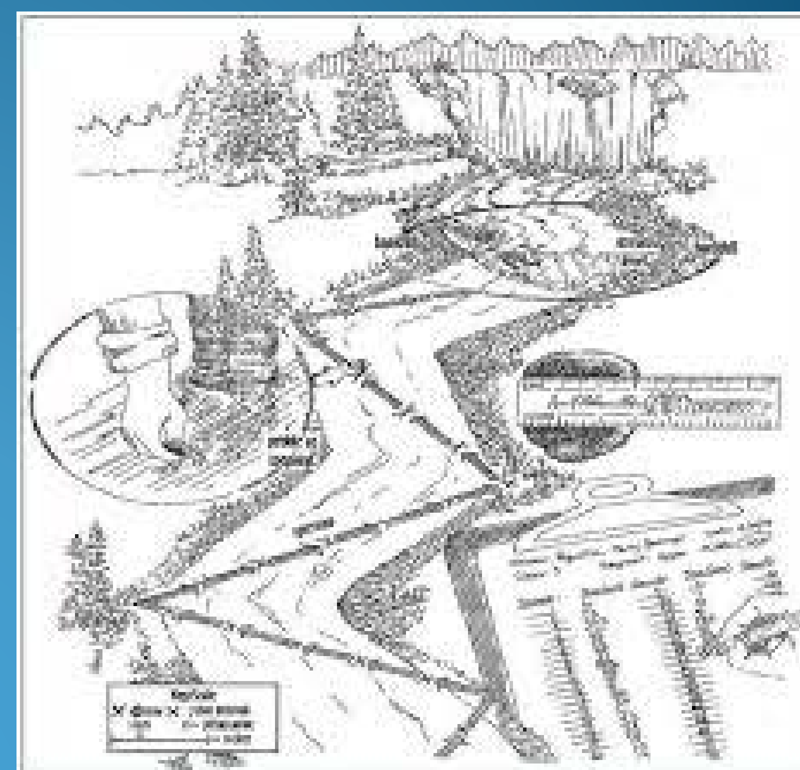
X-Section from REFERENCE REACH



Step 2: Field Surveys

Pebble Count





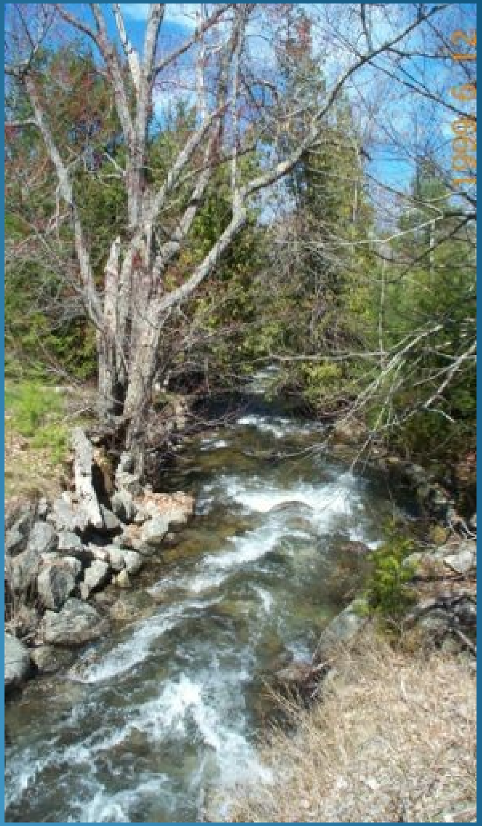
Design Criteria

<u>Span the stream</u>

Set elevation right

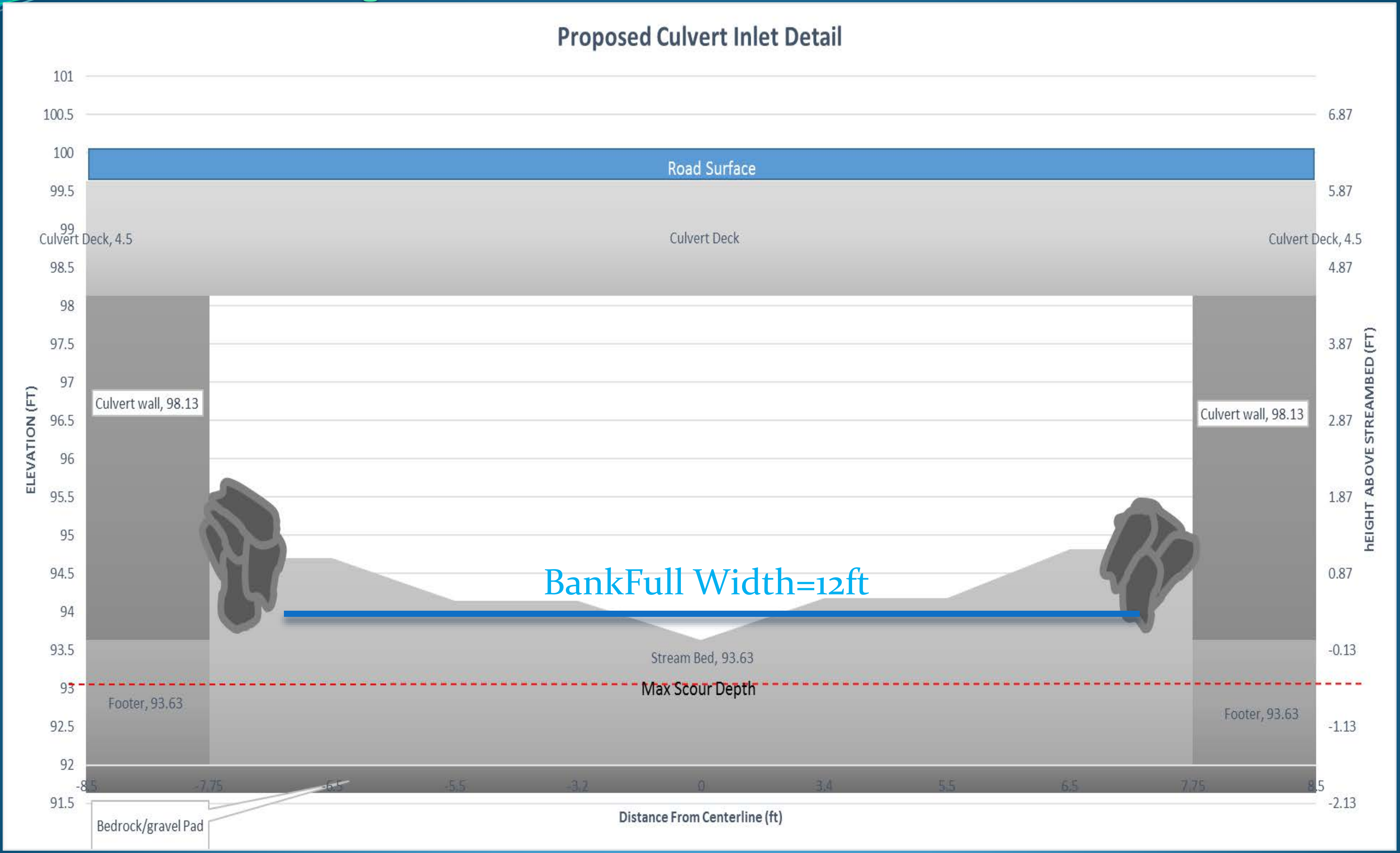
Slope matches stream

Substrate in the crossing

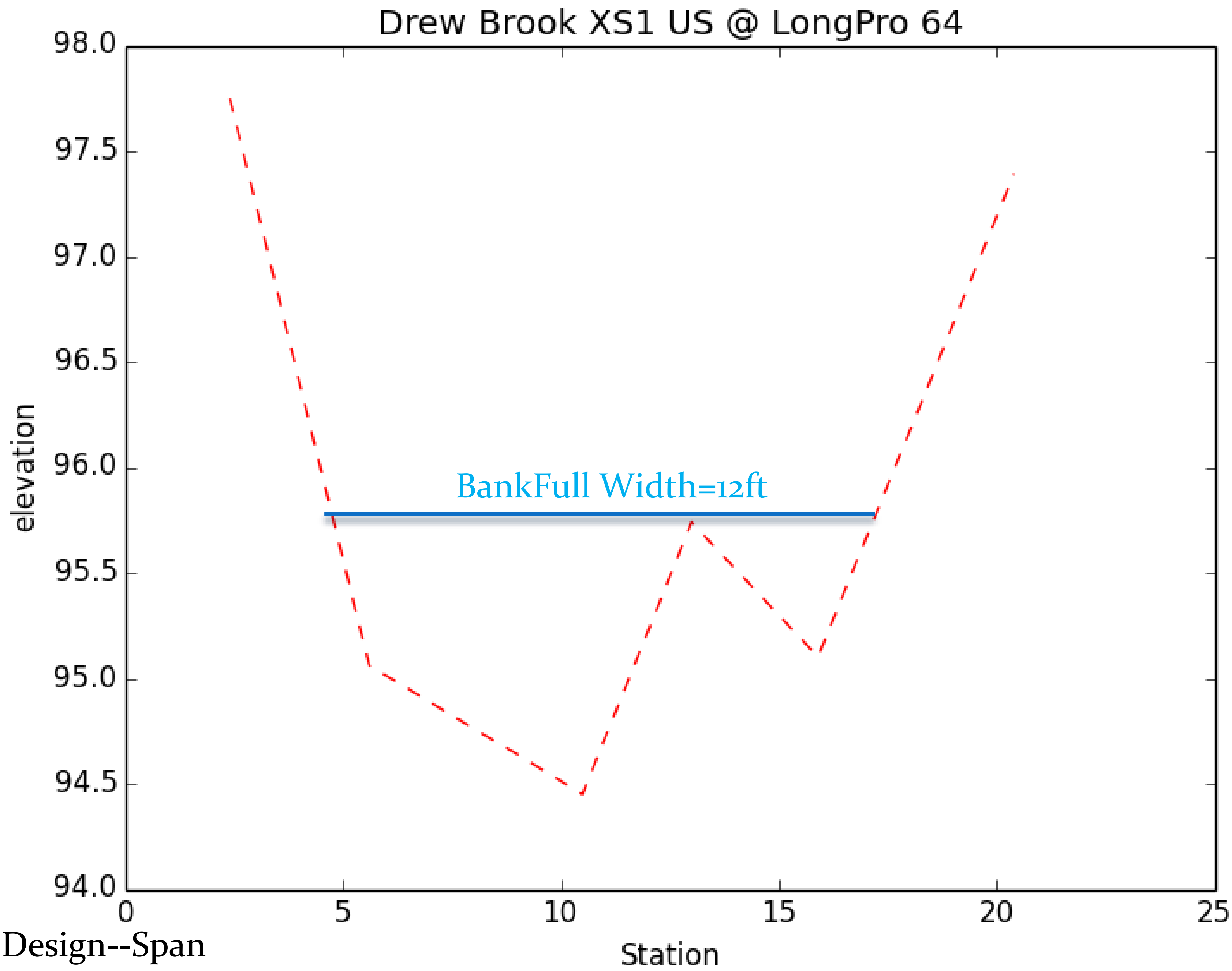


The Golden Rule:
Let the stream act like a stream

Span the stream



Design--Span



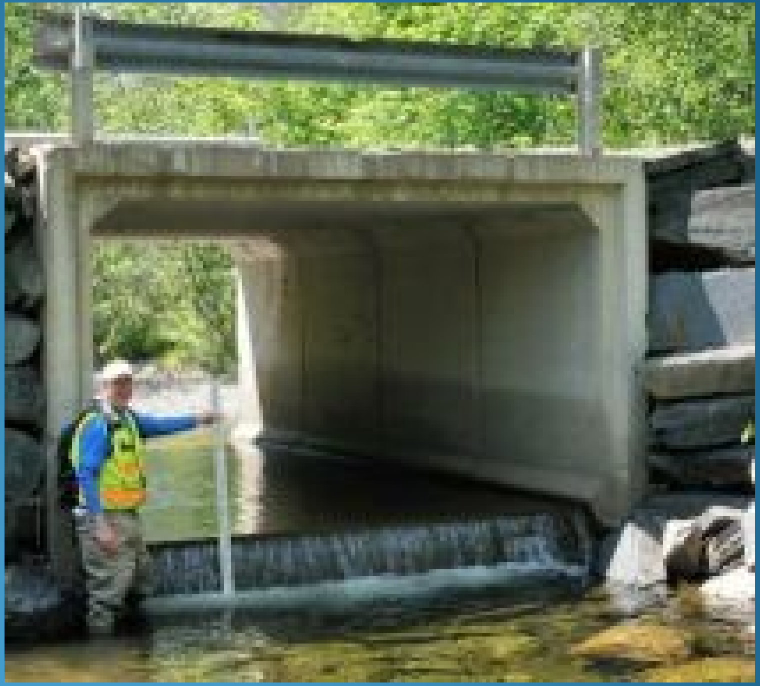
Drew Brook XS1 US @ LongPro 64
98.0
97.5
97.0
96.5
96.0
95.5
95.0
94.5
94.0
elevation
0
5
10
15
20
25
Station
BankFull Width=12ft

Design--Span

Real World – Blanchard Opps!!

2008

2010



Design--Span

Design Rules of Thumb (4 S's)

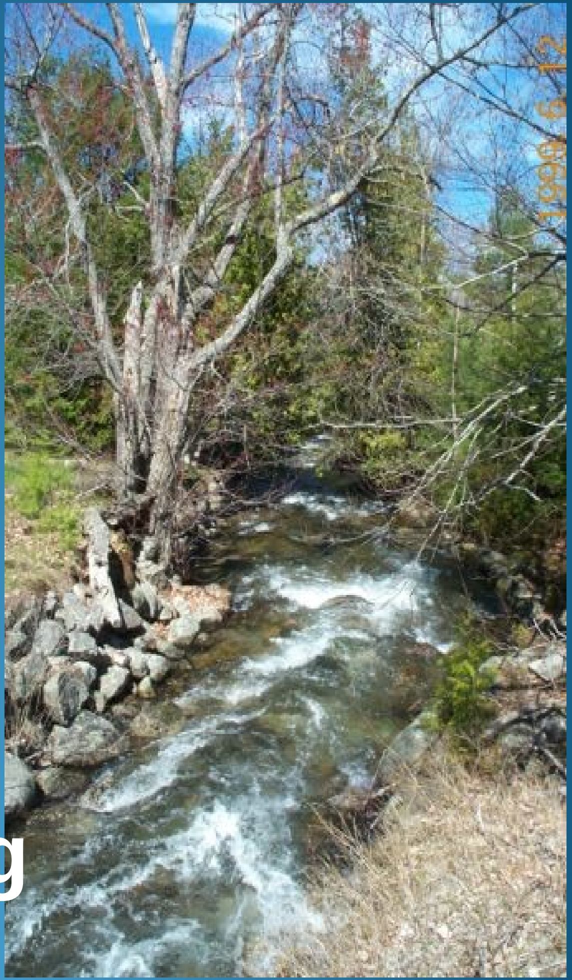
Span the stream

<u>Set elevation right:</u>

- **Use Long Profile to calculate Max Scour Depth and set footer and invert elevations**

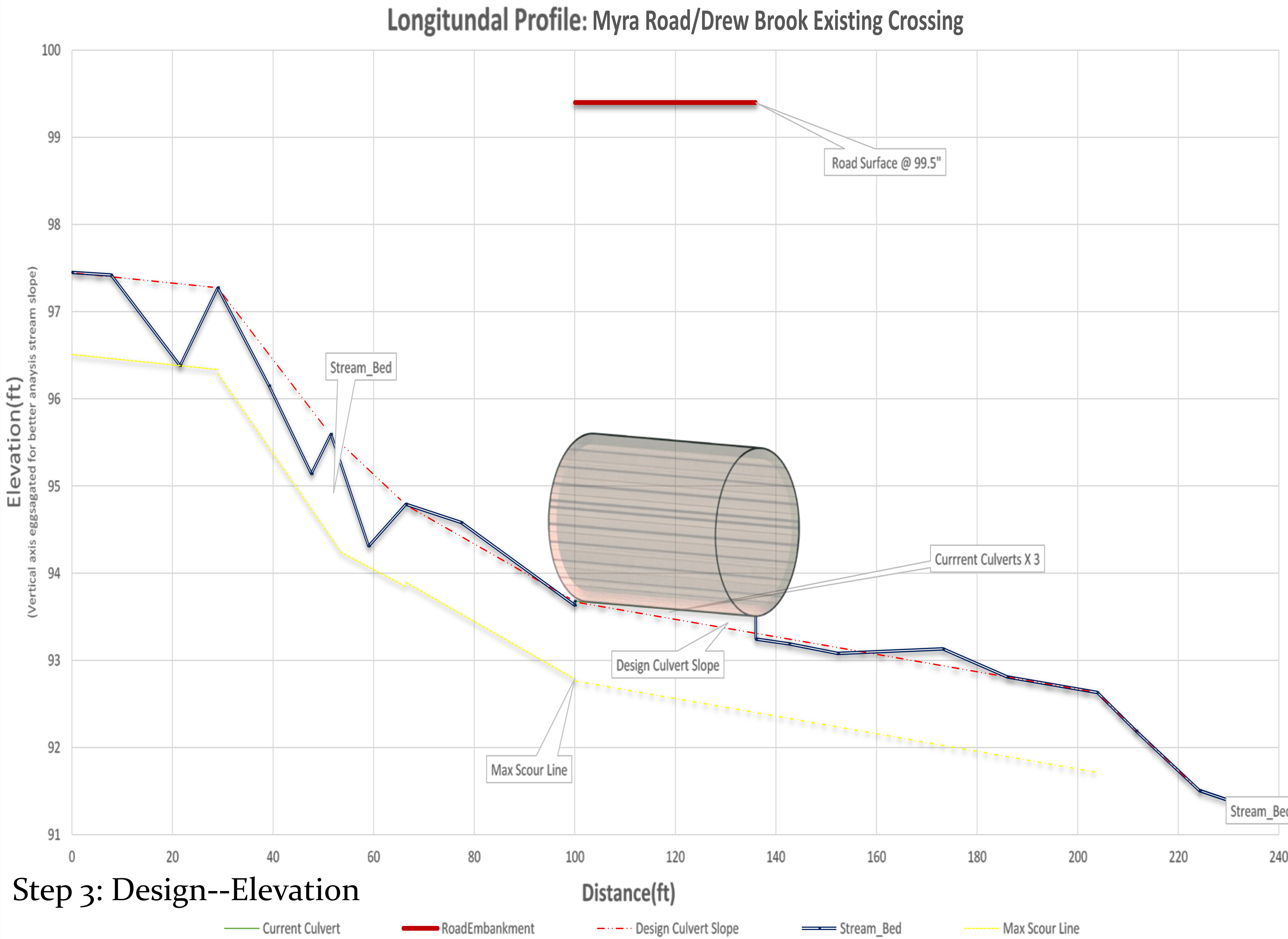
Slope matches stream

Substrate in the crossing



Design--Elevation

Elevation problem indicators



Step 3: Design--Elevation

A stream channel rediscovered!

Design--Elevation

Design Rules of Thumb (4 S's)

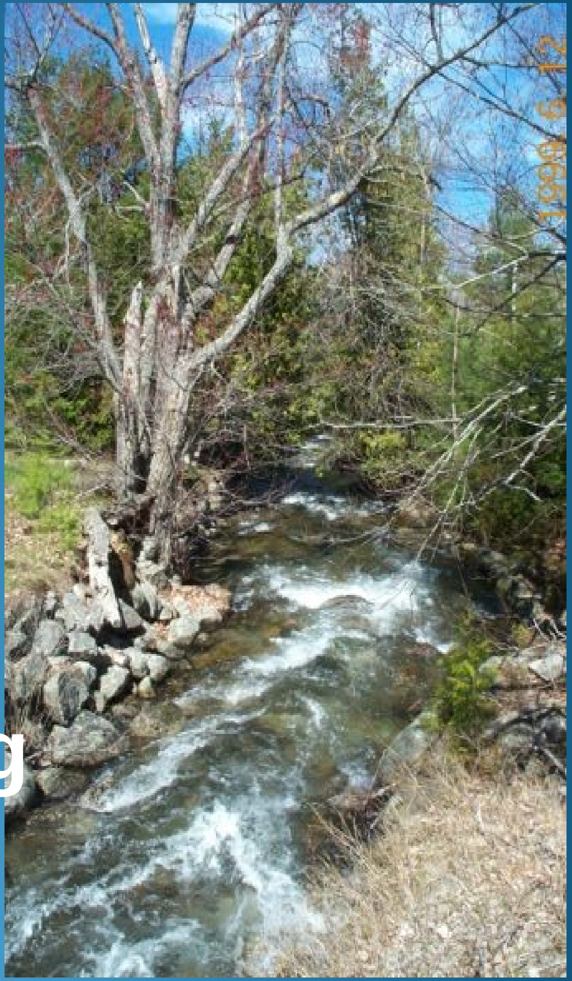
Span the stream

Set elevation right

<u>Slope matches stream</u>

- Use **REFERENCE REACH**
- to calculate slope of new crossing

Substrate in the crossing



Design--Slope

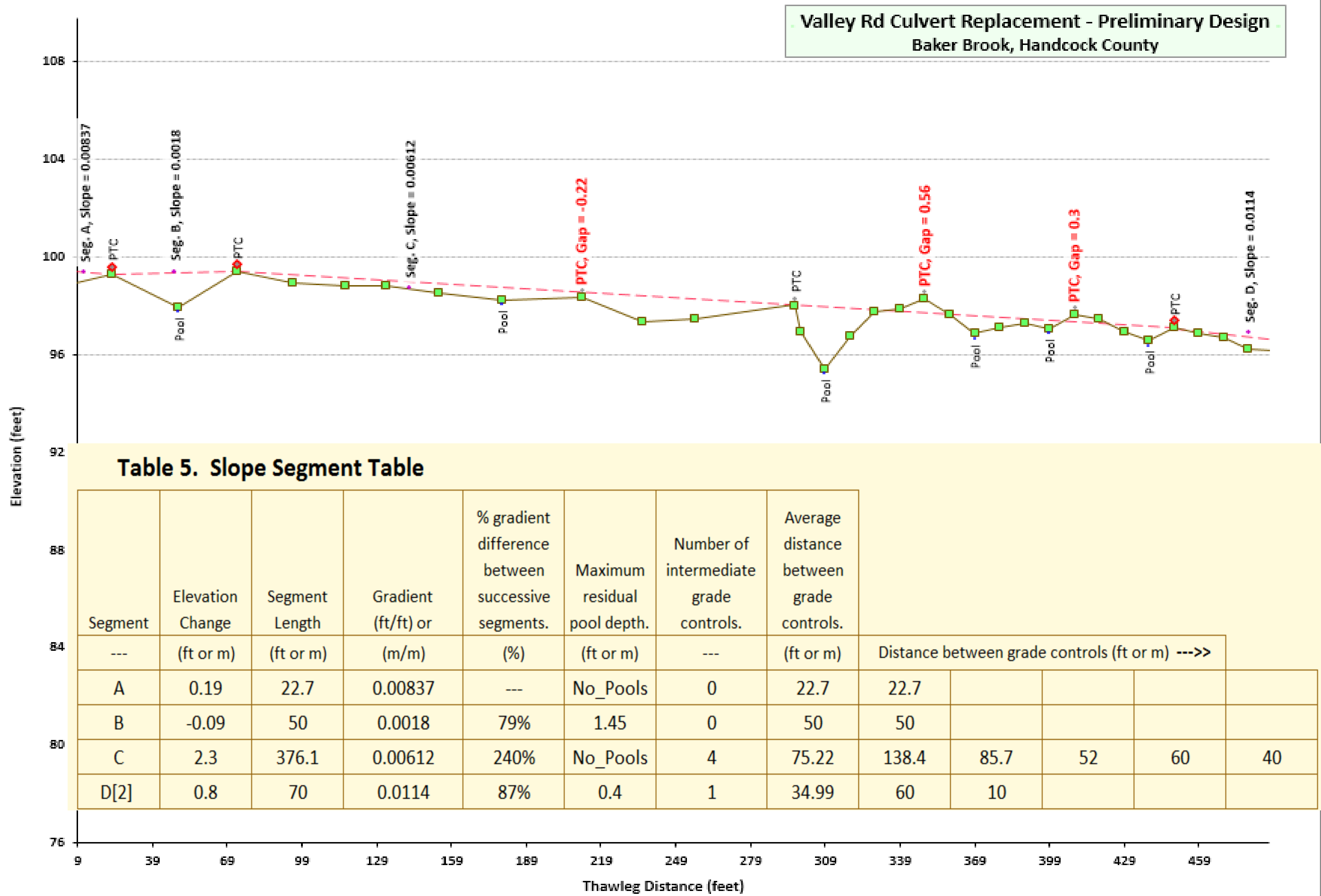


Table 5. Slope Segment Table

Segment	Elevation Change	Segment Length	Gradient (ft/ft) or	% gradient difference between successive segments.	Maximum residual pool depth.	Number of intermediate grade controls.	Average distance between grade controls.	Distance between grade controls (ft or m) --->>				
---	(ft or m)	(ft or m)	(m/m)	(%)	(ft or m)	---	(ft or m)					
A	0.19	22.7	0.00837	---	No_Pools	0	22.7	22.7				
B	-0.09	50	0.0018	79%	1.45	0	50	50				
C	2.3	376.1	0.00612	240%	No_Pools	4	75.22	138.4	85.7	52	60	40
D[2]	0.8	70	0.0114	87%	0.4	1	34.99	60	10			

Design--Slope

Design Rules of Thumb (4 S's)

Span the stream

Set elevation right

Slope matches stream

Substrate in the crossing

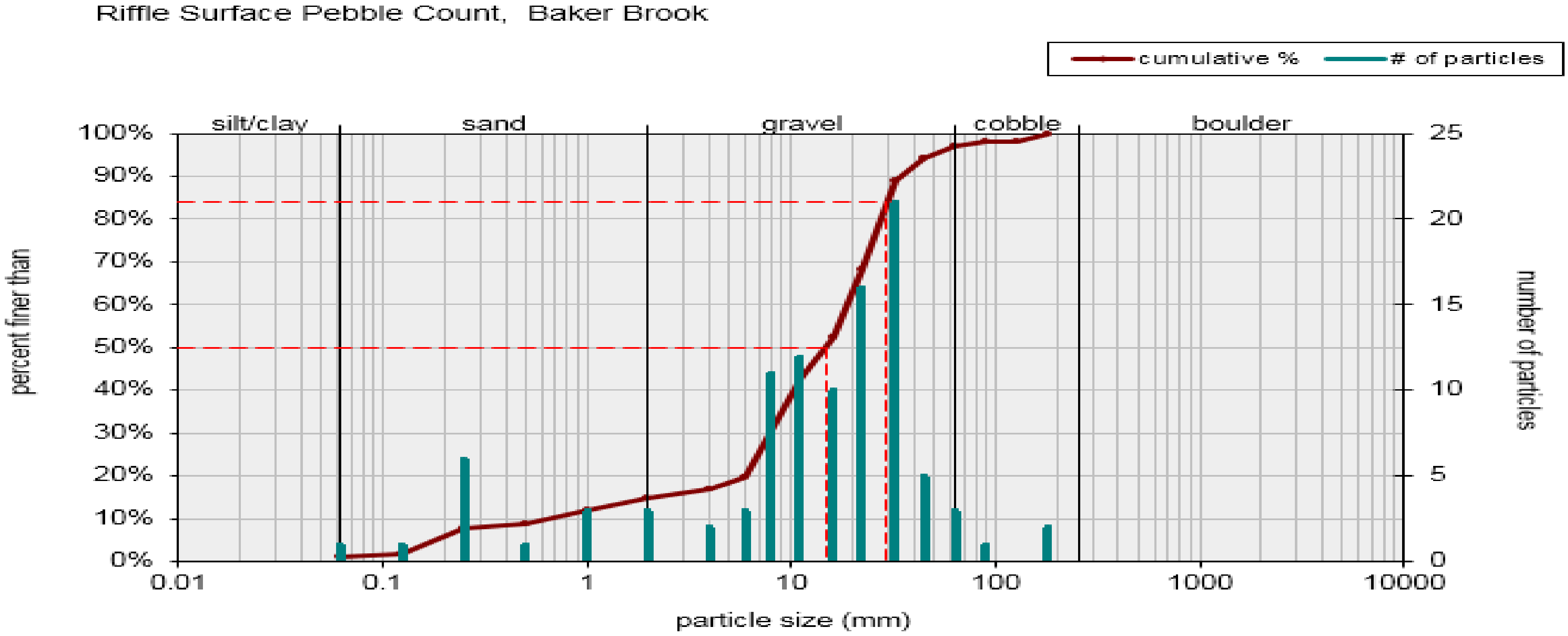
- Use REFERENCE REACH to calculate substrate distribution and develop a stream bed material mix.

Check slope:

Seamless inlets and outlets

Design—Substrate & slope

Substrate in the crossing



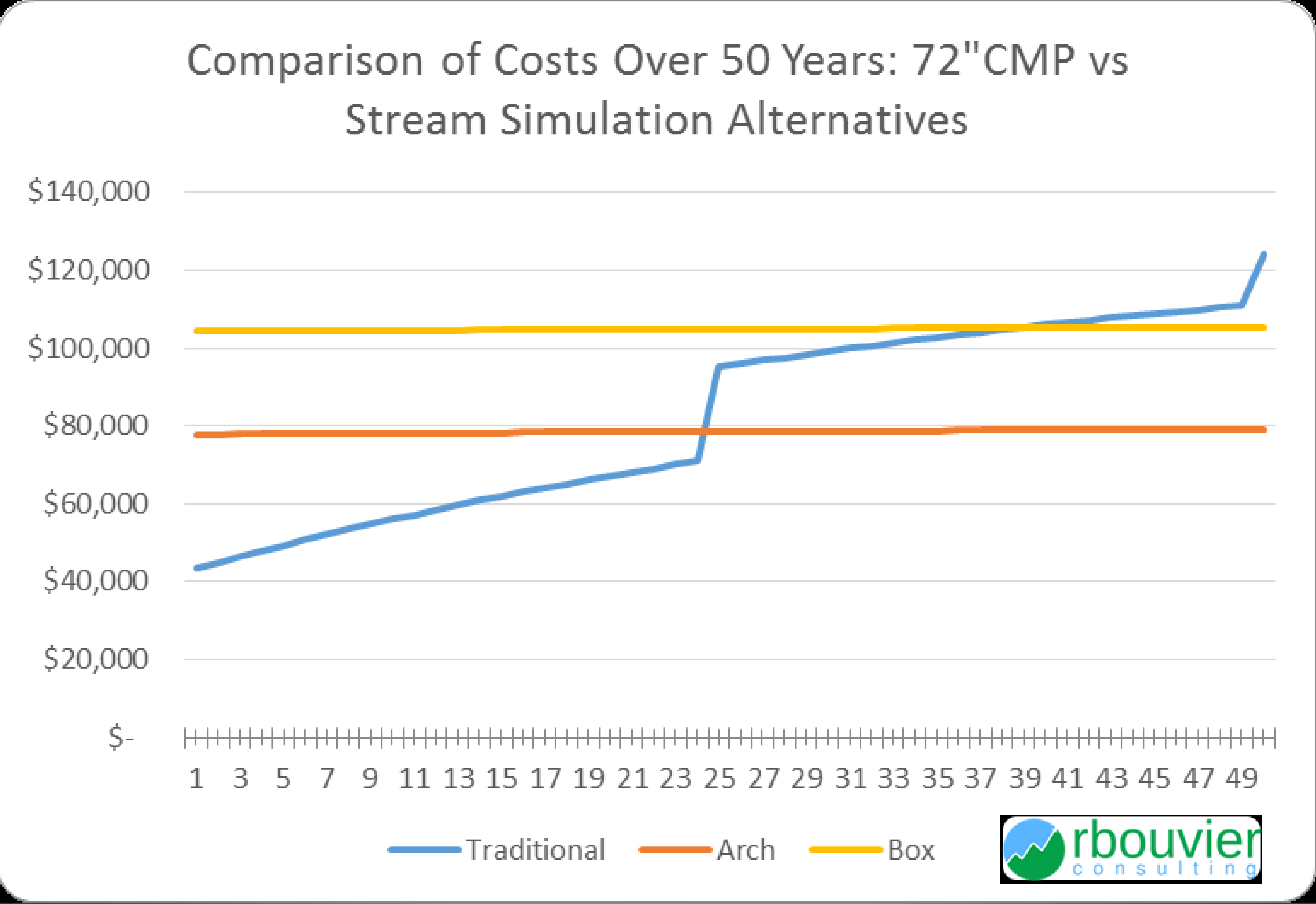
Size (mm)	
D16	3
D35	9
D50	15
D65	21
D84	29
D95	50

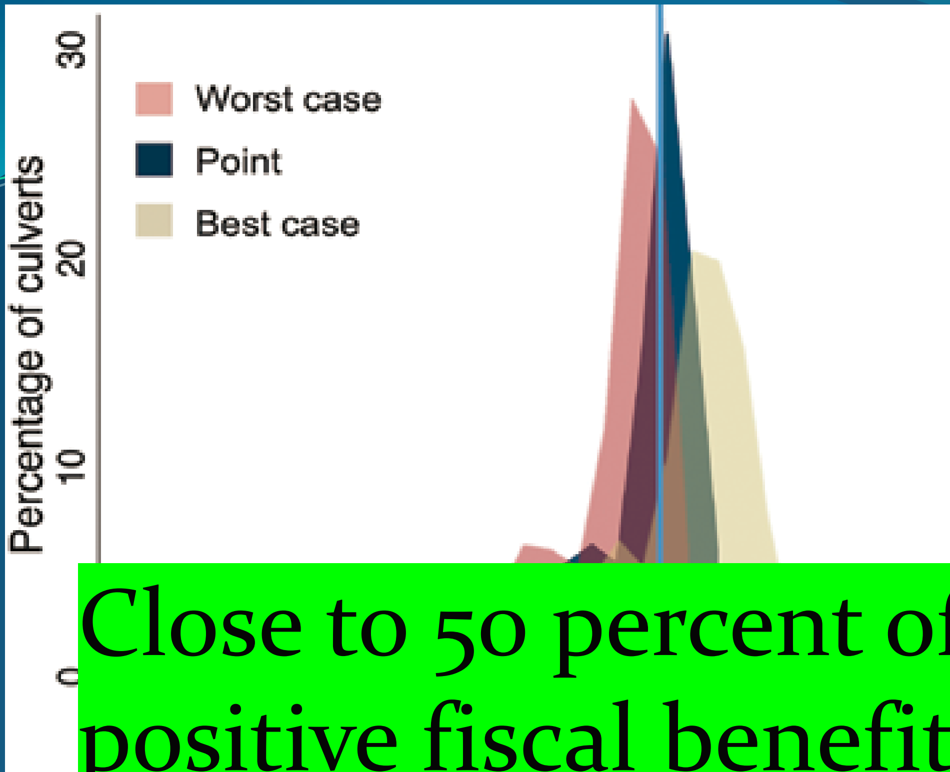
Size Distribution	
mean	9.3
dispersion	3.5
skewness	-0.21

Type	
silt/clay	1%
sand	14%
gravel	82%
cobble	3%
boulder	0%

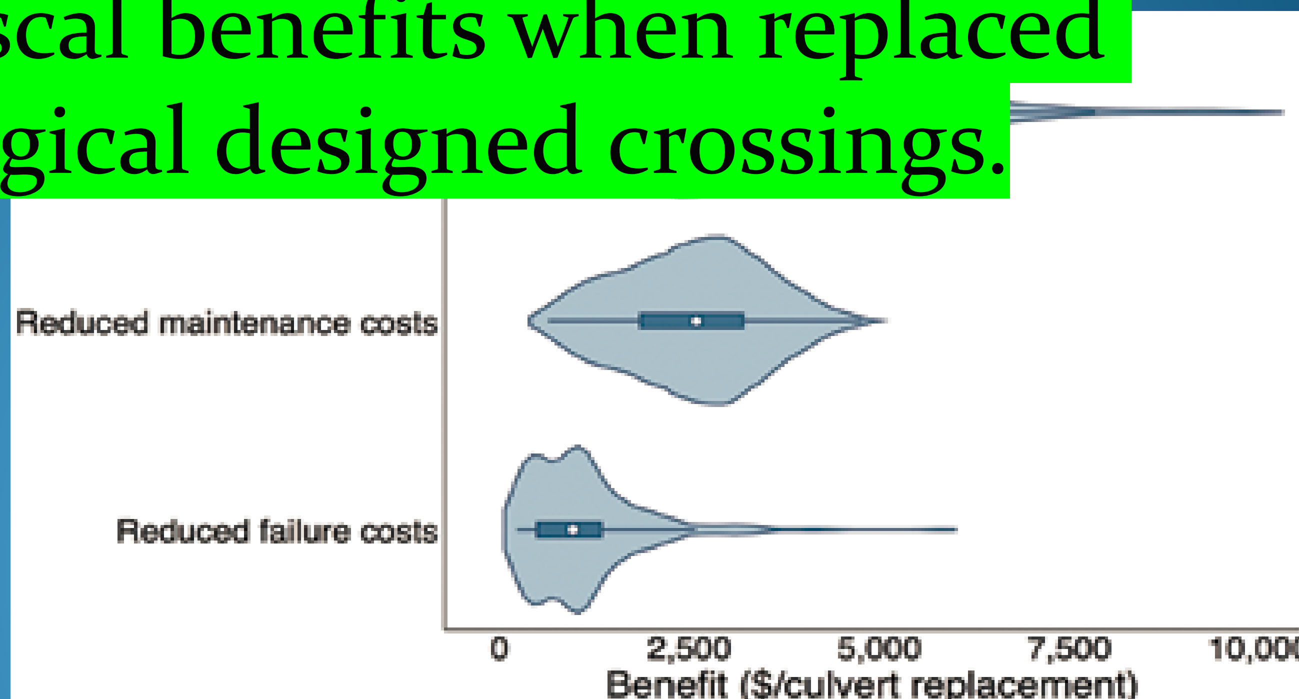
Stream-Smart: Open Arch

This IS what it should look like when your done!

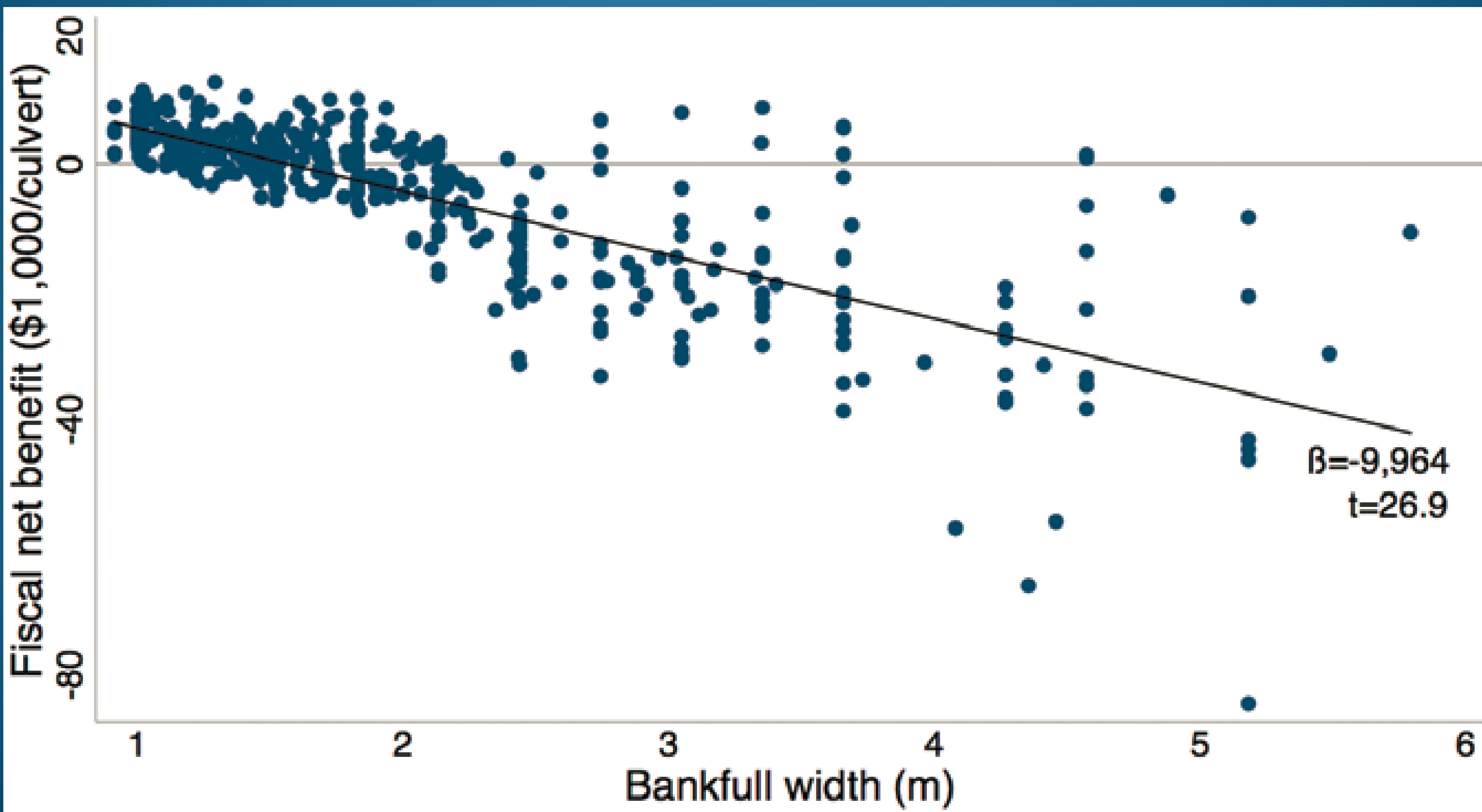

Comparison of Costs Over 50 Years: 72"CMP vs Stream Simulation Alternatives
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Traditional
Arch
Box
rbouvier
consulting



Close to 50 percent of culverts shows positive fiscal benefits when replaced with ecological designed crossings.



Ecological design saves the most money in headwaters!!



Partnerships make the restoration world go round!

THANK YOU!

Federal, State, Tribal, lo… O & … te partner…

Any questions?

Installation

- Permits
- In stream work window (July 15-Sept 30)
- Controlling the water during construction
- Sediment control
- Embedding
- Bedrock/Clay– do you need Geotech borings
- Road Control
- Complicated legacy effects
- When you can’t find channel
- Tidal streams

Setting the structure

Controlling Water

Installation

Hydrology & Hydraulics

Determine Flow Capacity

- What volume of flow are we allowing for?

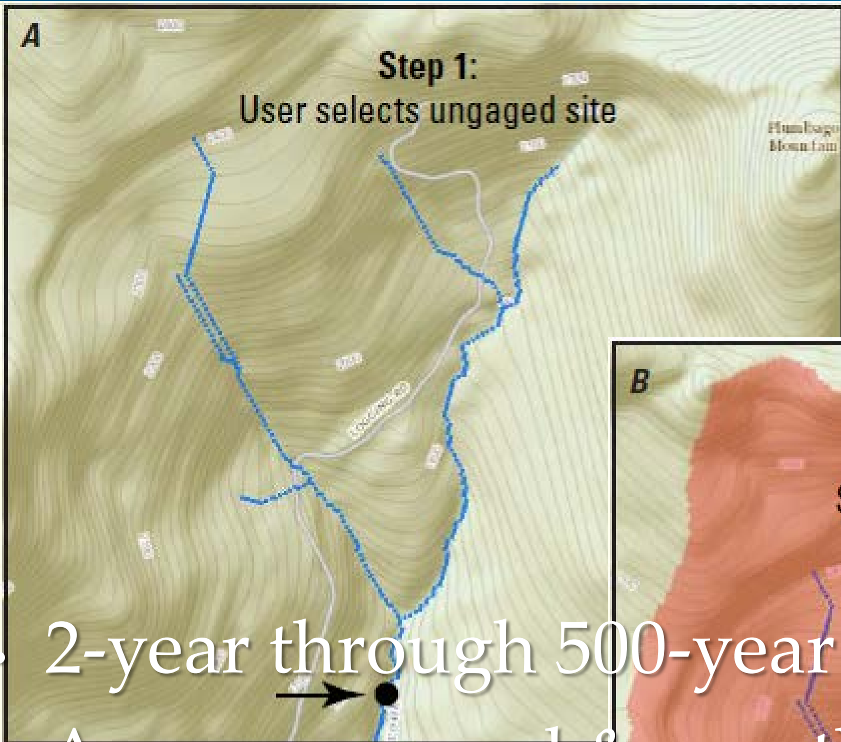
25-, 50-, 100- or 150-year storm event?

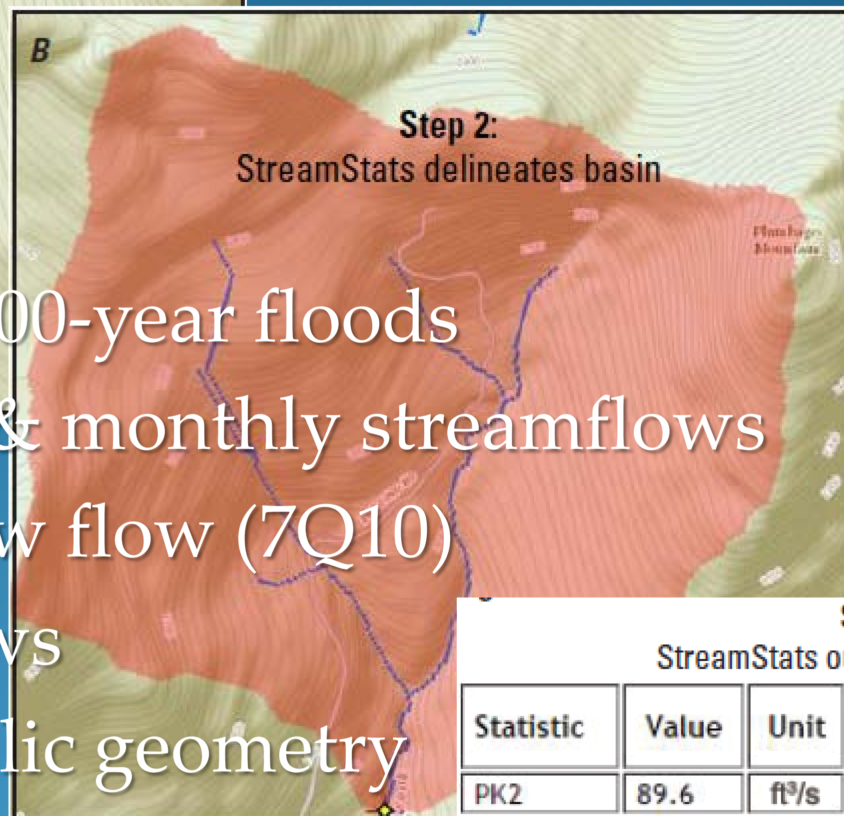
Can our structure pass this flow without creating too much turbulence or overtopping?

What is the Slope, Roughness & Tailwater Geometry?

Streamflow Statistics

http://streamstats.usgs.gov





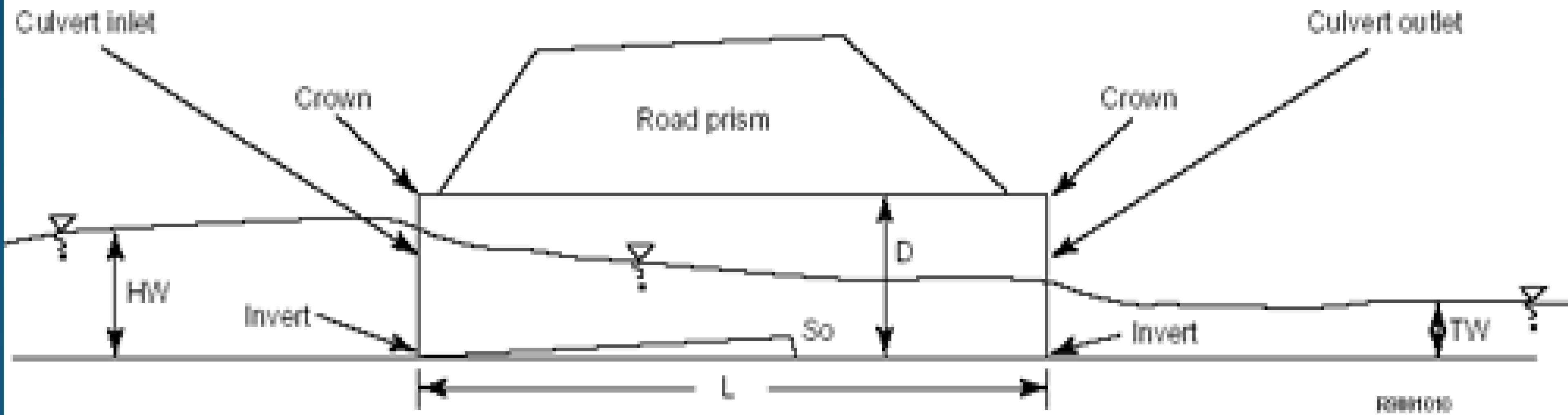
- 2-year through 500-year floods
- Average annual & monthly streamflows
- 7-day, 10-year low flow (7Q10)
- Regional lowflows
- Regional hydraulic geometry

Step 3:
StreamStats outputs flow statistics

Statistic	Value	Unit	Prediction Error (percent)
PK2	89.6	ft^3/s	35
PK5	156	ft^3/s	36
PK10	210	ft^3/s	37
PK25	287	ft^3/s	39
PK50	350	ft^3/s	40
PK100	420	ft^3/s	41
PK500	603	ft^3/s	45

Step 6: Hydraulic Modeling

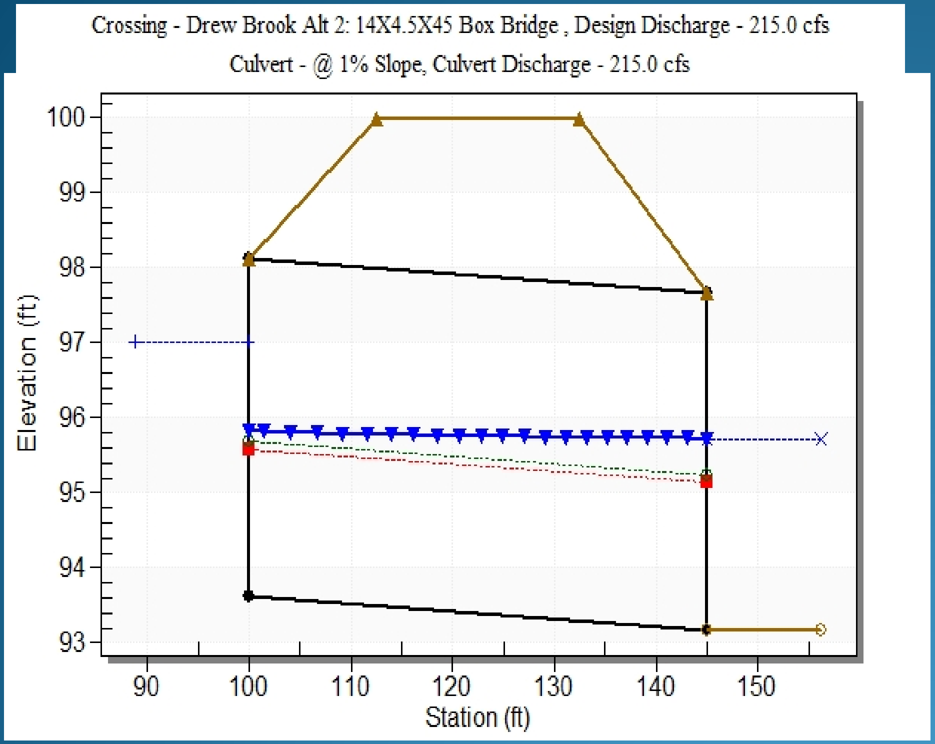
Profile of culvert, inlet control, inlet not submerged, and projecting inlet and outlet

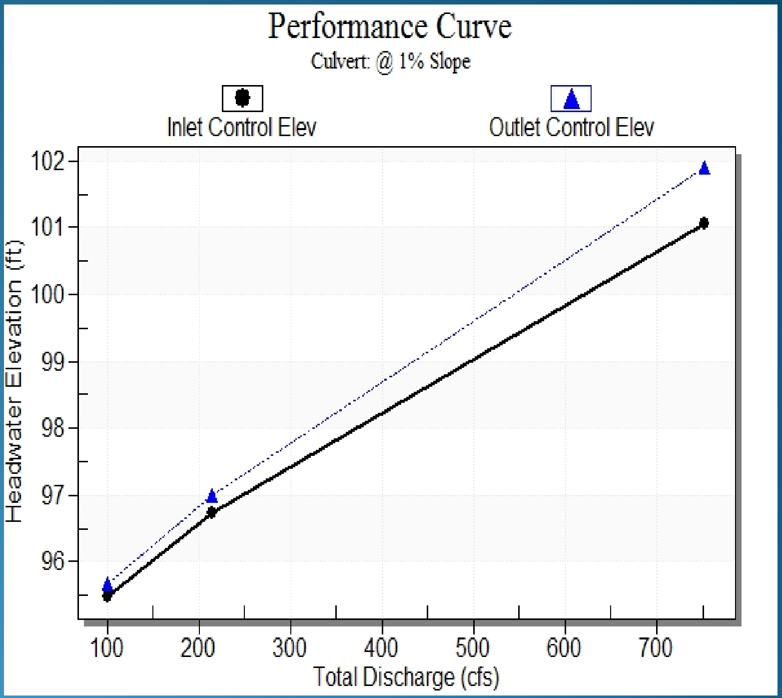


HW - Headwater elevation
TW - Tailwater elevation
L - Barrel length
So - Slope of culvert
D - Diameter of culvert barrel

HY-8 Output

Hydraulic Analysis:





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)
100.00	100.00	95.67	1.847	2.039	3-M1t	1.265	1.177	1.881	1.881	3.855	5.945
215.00	215.00	97.01	3.104	3.377	3-M1t	2.058	1.959	2.545	2.545	6.159	7.172

Restoring River Processes Benefits All

Including our road budgets!

Which can lead to fill failure and large sediment inputs.

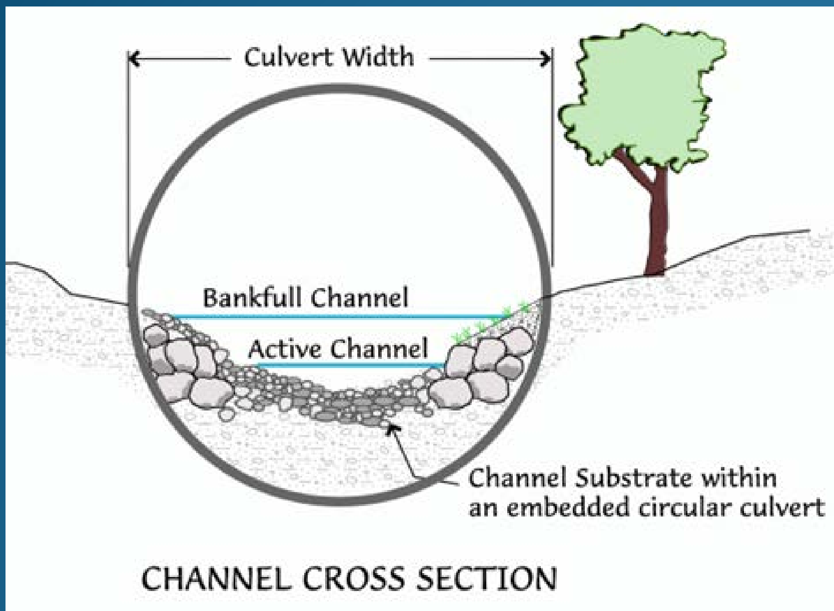
EXHIBIT ES-2. SUMMARY OF CULVERT REPLACEMENT CASE STUDY FINDINGS

CATEGORY		DINGLE ROAD	HILL STREET	DRIFT ROAD
Background on Project	Culvert Owner	Town of Worthington	Town of Raynham	Town of Westport
	Year of Culvert Upgrade	2008	2010	2012
Costs	Upgrade Cost	$370,000	$440,000	$230,000
	Cost to Owner (percent of total costs)	$56,000 (15%)	$72,000 (17%)	$45,000 (20%)
	Other Funding Sources (percent of total costs)	DER: $61,000 (16%) Other Conservation Partners: $160,000 (42%) Other Sources: $98,000 (26%)	Chapter 90: $340,000 (77%) MORE Grant: $27,000 (6%)	FEMA: $180,000 (80%)
	Long-term Cost Savings Relative to Replacement In-Kind	$180,000	$(41,000)	$520,000
	Owner Savings Relative to Costs of Culvert Repair and Maintenance[1]	$500,000	$220,000 to $320,000	$560,000 to $700,000

Massachusetts Department of Fish and Game
Division of Ecological Restoration
Invested in Nature and Community

Application: Stream Simulation Design

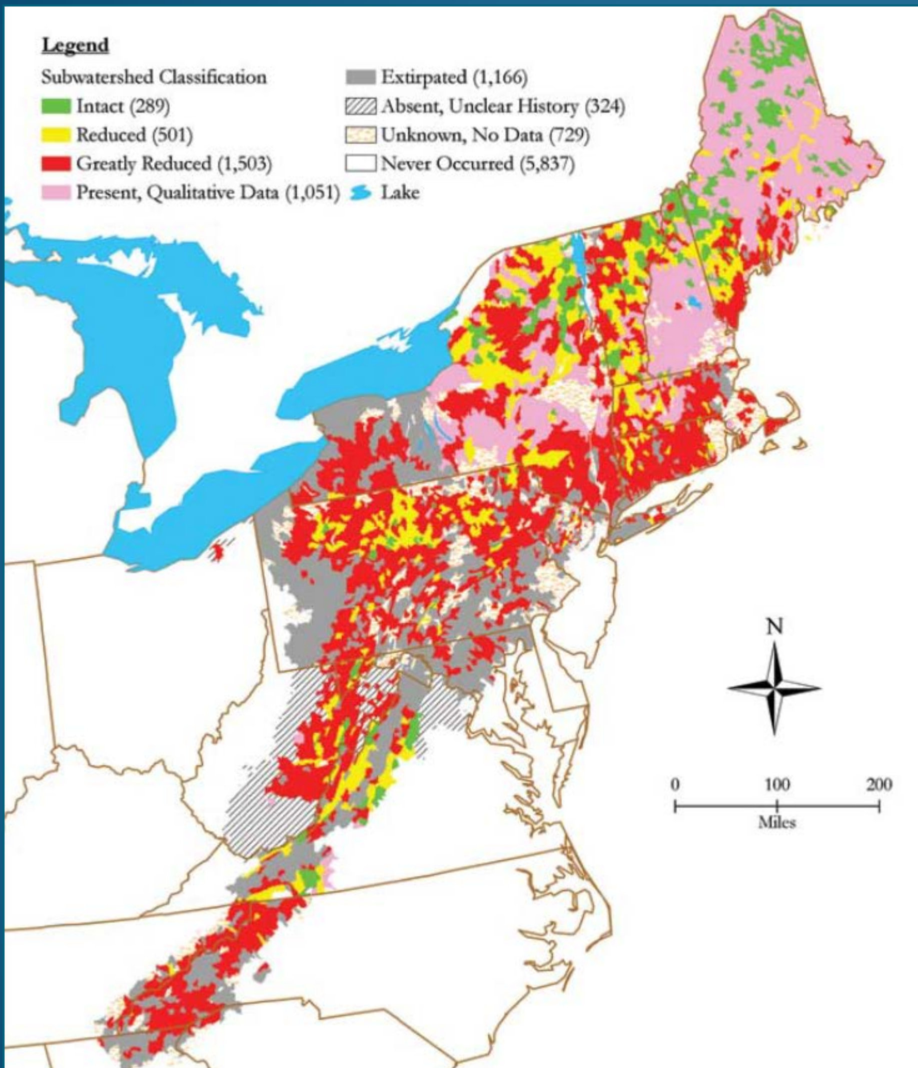
Culvert is wider than adjacent channel with a natural bottom and maintains Ecological Connectivity.



Hydraulic variables used in stream simulation design:

- Channel width
- Shear Stress
- Darcy Friction Factor
- Energy Dissipation Factor
- Stream Power
- Composite Roughness

Eastern brook trout



1. Inventory & Prioritize barriers
2. Assess habitat (presence/absence)
3. Share technical support
4. Implement projects
5. Track and Share Lessons

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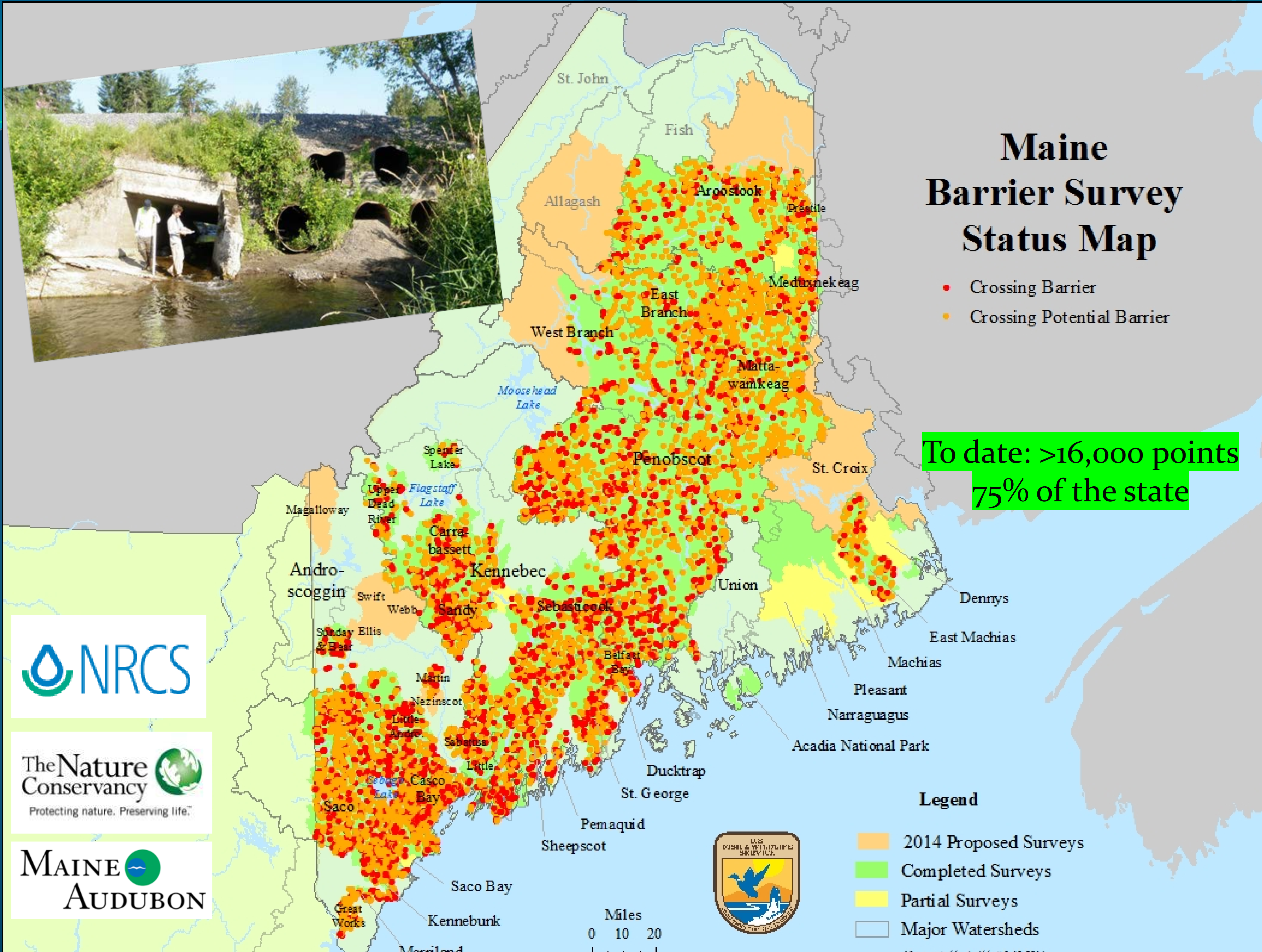
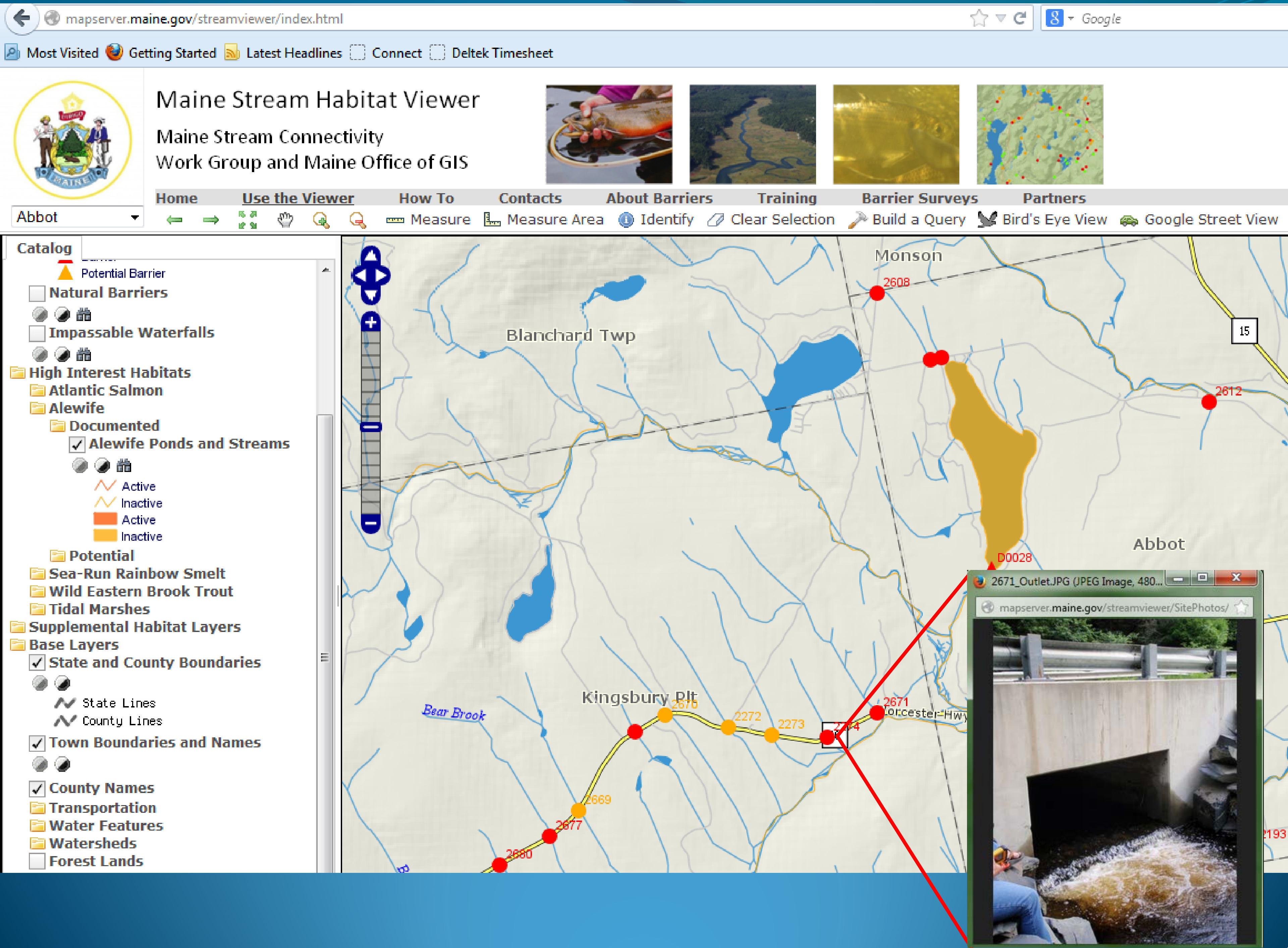


To date: >16,000 points
75% of the state



mapserver.maine.gov/streamviewer/index.html
Most Visited
Getting Started
Latest Headlines
Connect
Deltek Timesheet
Maine Stream Habitat Viewer
Maine Stream Connectivity
Work Group and Maine Office of GIS
Home
Use the Viewer
How To
Contacts
About Barriers
Training
Barrier Surveys
Partners
Abbot
Measure
Measure Area
Identify
Clear Selection
Build a Query
Bird's Eye View
Google Street View
Catalog
Potential Barrier
Natural Barriers
Impassable Waterfalls
High Interest Habitats
Atlantic Salmon
Alewife
Documented
Alewife Ponds and Streams
Active
Inactive
Active
Inactive
Potential
Sea-Run Rainbow Smelt
Wild Eastern Brook Trout
Tidal Marshes
Supplemental Habitat Layers
Base Layers
State and County Boundaries
State Lines
County Lines
Town Boundaries and Names
County Names
Transportation
Water Features
Watersheds
Forest Lands
Monson
2608
15
Blanchard Twp
2612
Abbot
D0028
Kingsbury Plt
Bear Brook
2272
2273
2671
2669
2677
2680
2671_Outlet.JPG (JPEG Image, 480...
mapserver.maine.gov/streamviewer/SitePhotos/

Barriers/Potential Barriers Across Surveyed Watersheds