Right-Size That Culvert!

A Practical Overview of Right-Sizing Considerations

Today's To-Do List

1) Why do we care about undersized crossings?
2) How do we identify undersized crossings and AOP barriers?
3) What do we do about them?
4) Case Studies in the Beaver River Watershed:
    a) Brewery
    b) Long Pond

QUESTION: HOW MANY CULVERTS DO YOU DRIVE OVER EVERY DAY?

I cross a total of NINE culverts on the 5-mile drive to school drop off!

- Barrier to organism passage
- Public safety issue with scour of banks

Most of us probably don't notice a culvert until it fails…

Upstream:
- Acts like a dam,
- Can cause the road to flood.

Downstream:
- Acts like a firehose,
- Creates scour;
- Undermines even large armor.

Prioritization

Multiple Objectives to *Prioritize* Sites

Municipal Priorities

- Maintenance Issues: (Wood, boulders)
- Public Safety Concerns
  - Flooding
  - Failing structure (corrosion, collapsing headwalls, wingwalls, road damage)
  - Lengthy Detours

Ecological Priorities

- Aquatic Org. Passage
- Priority Watershed
- Miles reconnected
- Habitat Quality
- Brook trout value
- Freshwater Type
- WQ Standard

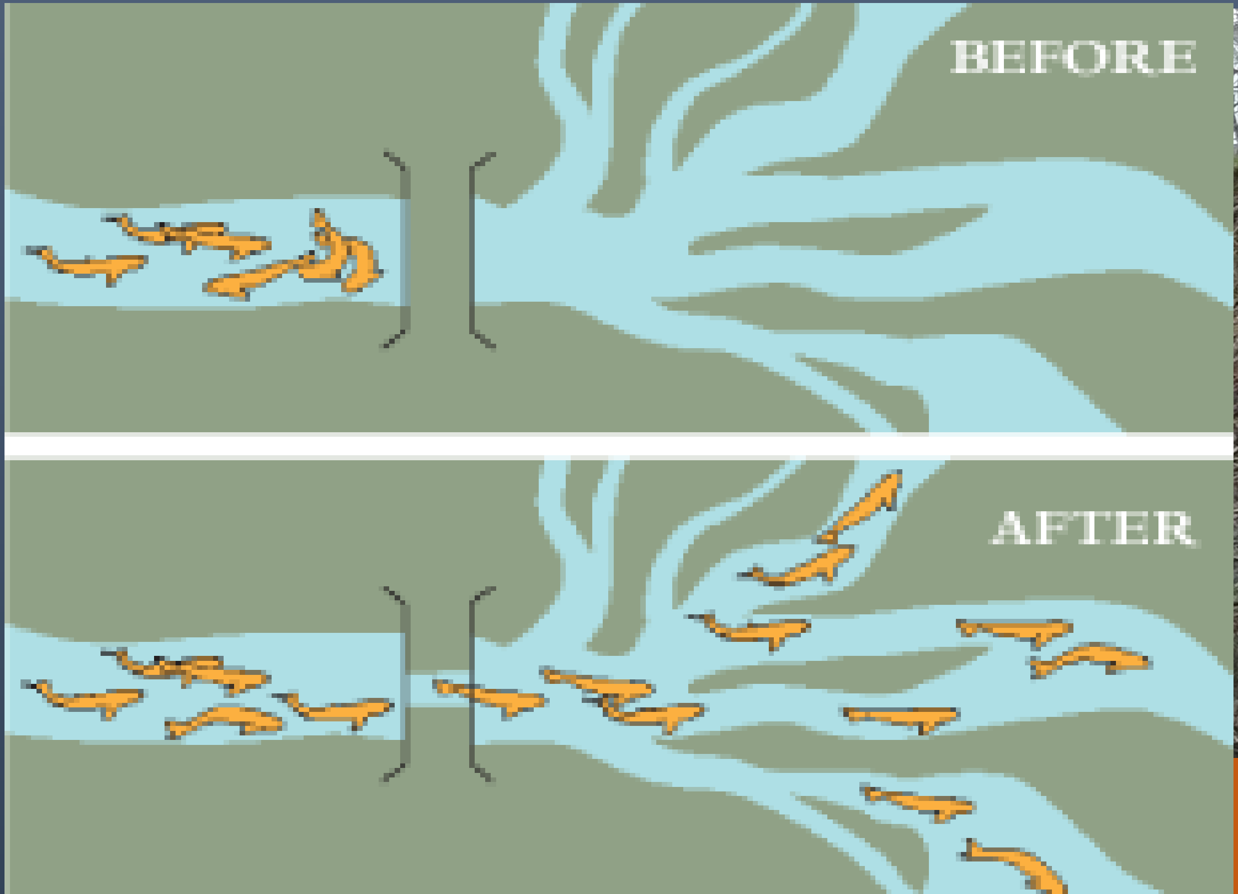
Community Priorities

Safety
Flood Risk

Municipal Concerns

- Structural Issues:
  - Road Closure
  - Corrosion
  - Collapsing headwalls
  - Road damage
  - Scour of abutments

Ecological concerns:
Barriers affect thousands of organisms that rely on the health of the stream…



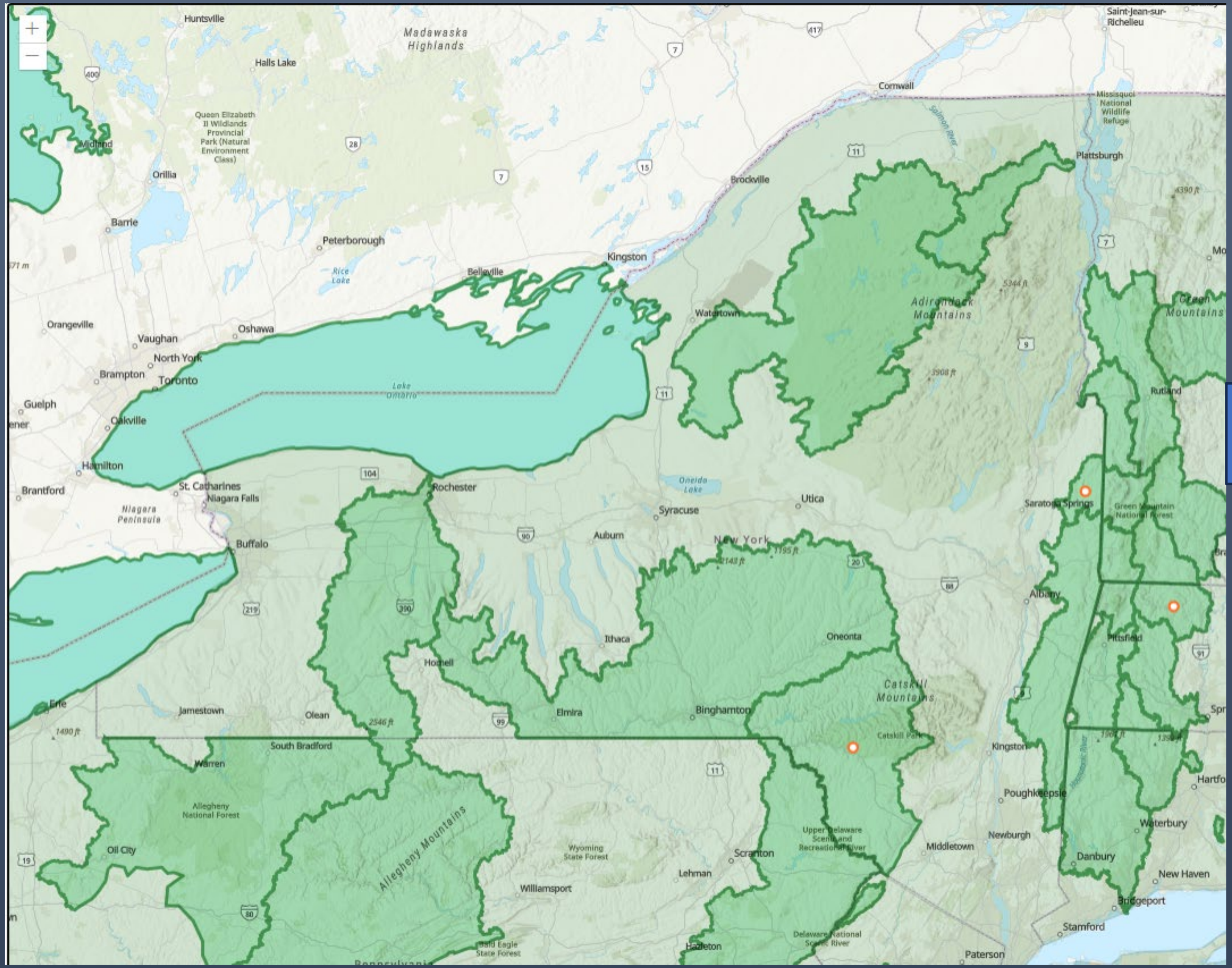
How does TU decide where to work?

TROUT UNLIMITED

Priority Waters (TU)

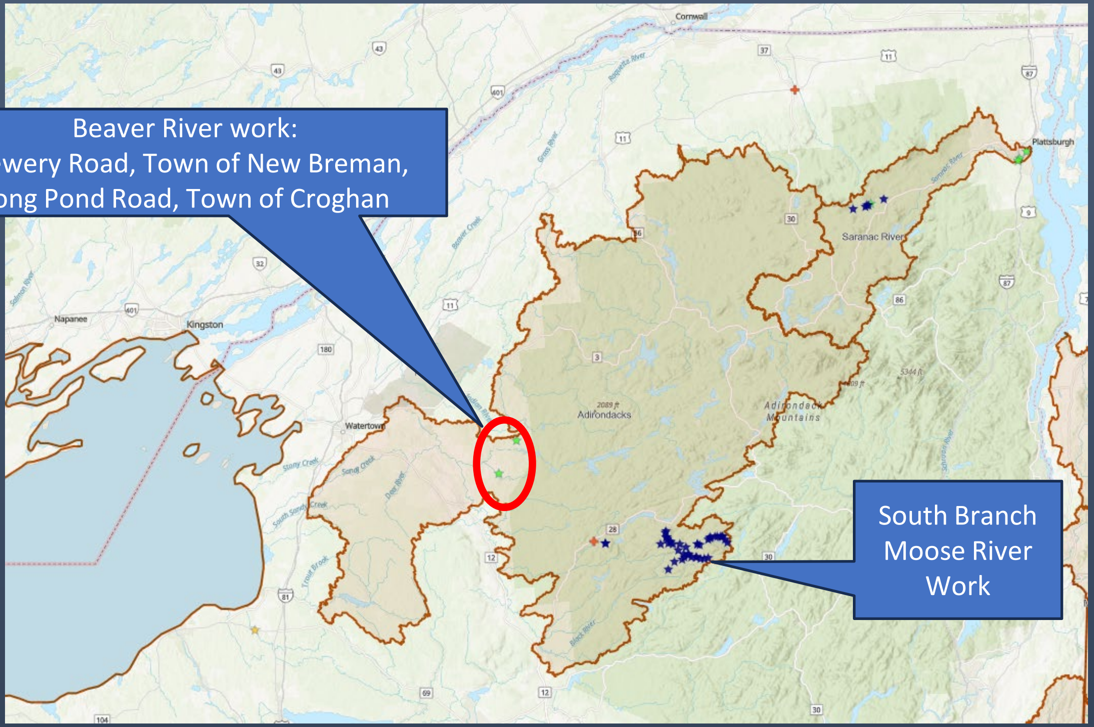
What Are Priority Waters?

Rooted in science and developed in collaboration with TU volunteers and trusted partners, our shared Priority Waters are the foundation of a strategic blueprint to protect, restore and reconnect America's wild and native trout and salmon watersheds.



Adirondack Priority Waters:

- Reconnect streams and watersheds
- Understand current conditions
- Partnership establishment and engagement
- Assess/Reconnect/Restore/Engagement



TROUT UNLIMITED

NORTHEAST

STAY UP TO DATE WITH TROUT UNLIMITED CONSERVATION WORK AND VOLUNTEER OPPORTUNITIES IN NEW YORK AND CONNECTICUT.

@TU_NORTHEAST

How to Identify Barriers?

Step 1: NAACC Road Stream Crossing Assessments

- Methodology to Identify and Assess Road Stream Crossings.
- Conducted by trained observers (SWCDs, DEC, Nonprofits: TU, TNC)
- Record features of crossings, ie:
  - Location,
  - Size,
  - Type,
  - Condition,
  - Alignment
  - Constriction
- Rate the passage capability of the crossing.
- Serves as Level 1 Prioritization for future work.
- https://naacc.org/naacc_data_center_home.cfm

SCAN ME

North Atlantic Aquatic Connectivity Collaborative

NAACC

North Atlantic Aquatic Connectivity Collaborative
NAACC

NAACC Data Center

Search Crossings LogIn

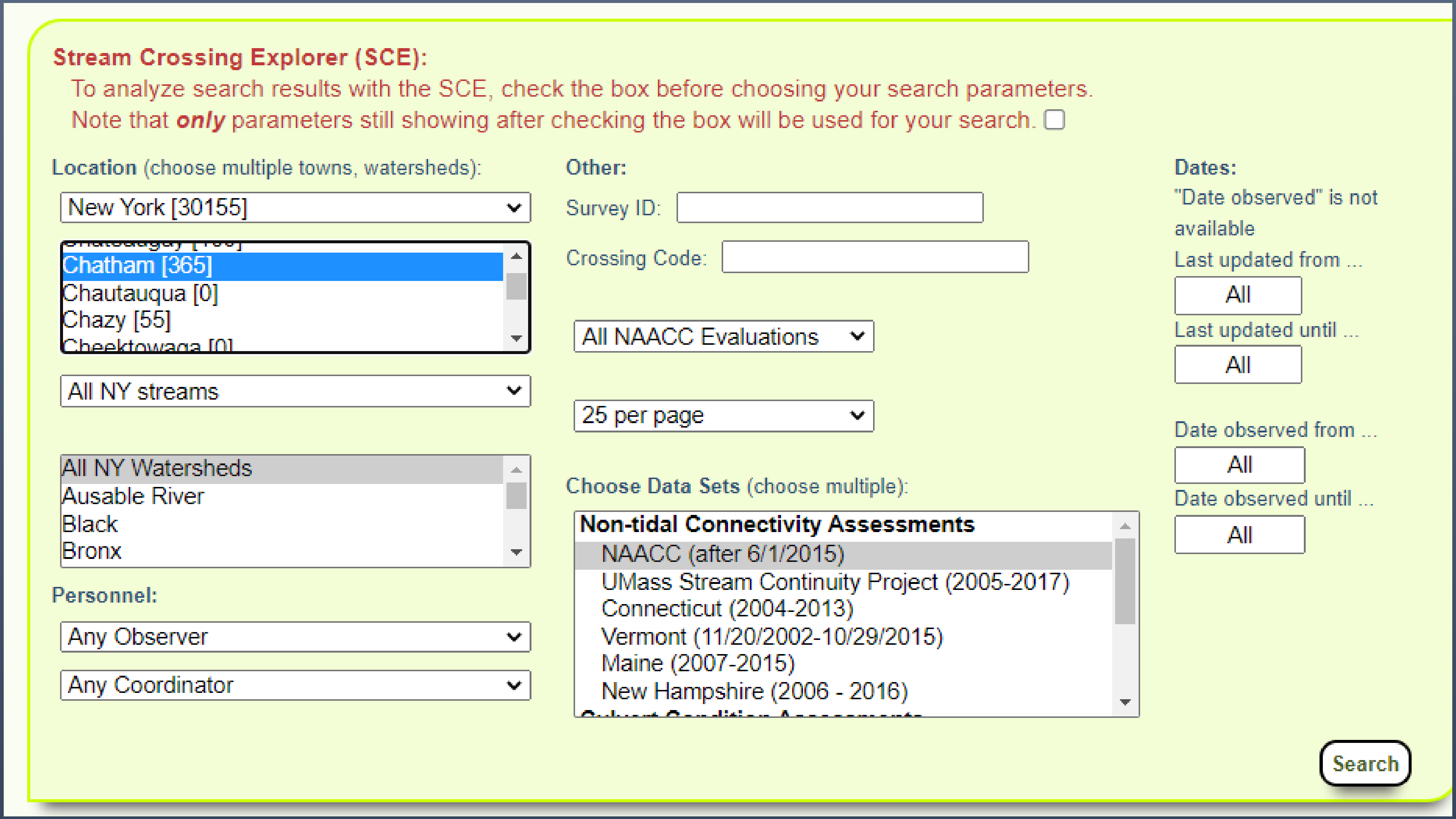
Welcome to the NAACC Data Center!

This website stores all the North Atlantic Aquatic Connectivity Collaborative (NAACC) data for road-stream crossings assessments. You may search, view, map and download most of the data in Excel or Shapefile format without logging on. If you are logged on, pages accessed from the navigation bar allow for entering and correcting crossing records. If logged on, you may also manage user data and download the Offline Data Manager. Only certified NAACC lead observers and coordinators can log on. To return to this page, click the "NAACC Data Center" title at the top of any page.

About the NAACC

The NAACC is a network of individuals from agencies and organizations focused on improving aquatic connectivity across a thirteen-state region. The NAACC provides protocols for road-stream crossings (culverts and bridges) to assess and score crossings for fish and wildlife passability, as well as culvert condition and other data useful for evaluating risk of failure.

How to use the online NAACC Tool



How to use the online NAACC Tool

Lat/Long of crossing

Showing 400 Records , 25 per page.

Sort by any field Except Evaluation

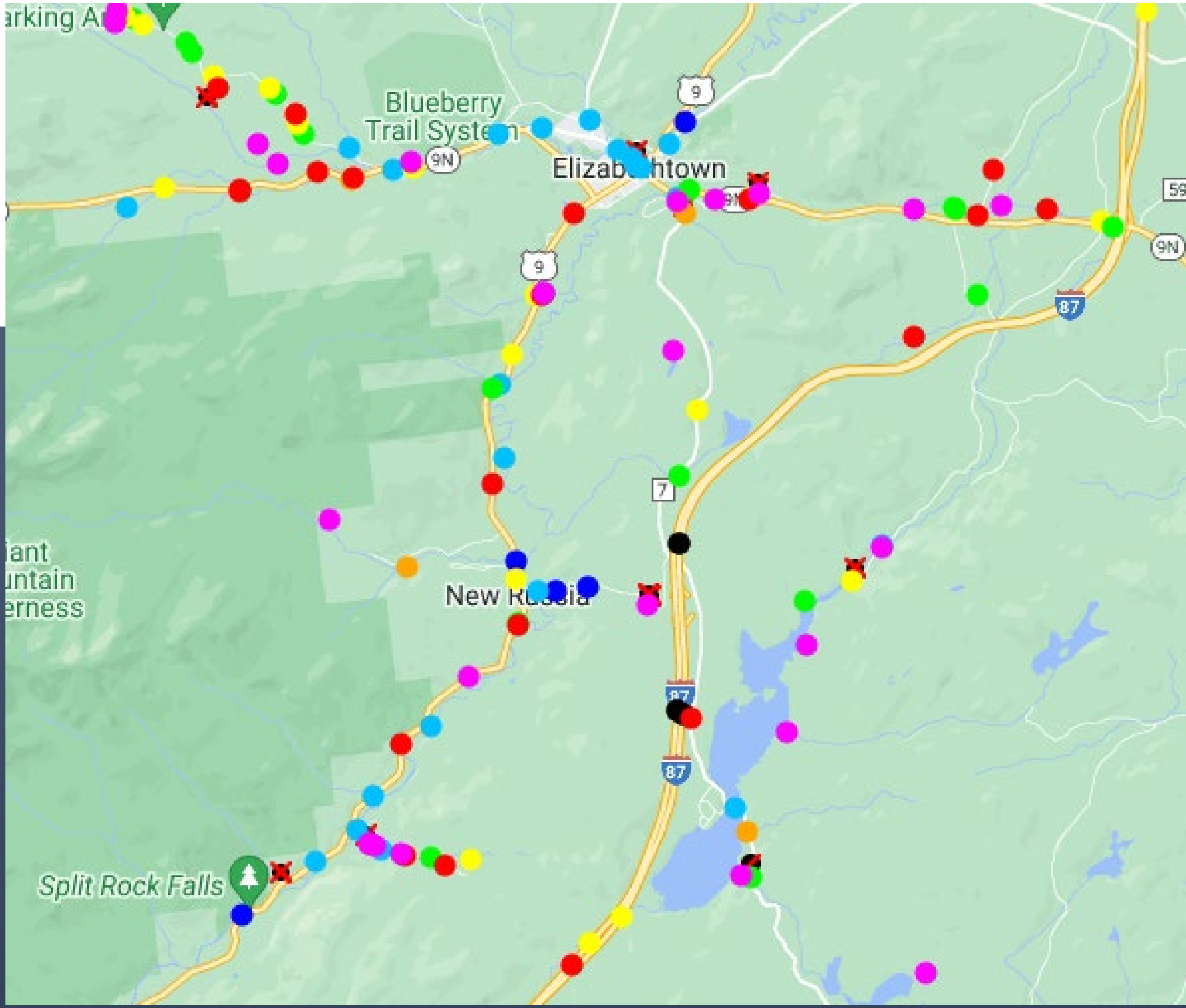
Next [375]

Survey ID	Crossing Code	Date Observed	Last Updated	Town	Stream	Road	Evaluation	Culvert
30188	xy4248665773558329	2016/05/03	2016/05/09	Chatham NY	unnamed	ny 66	Significant barrier	1
30189	xy4248586873559350	2016/05/03	2016/05/09	Chatham NY	unnamed	ny 66	Severe barrier	1
30190	xy4248570873560038	2016/05/03	2016/05/09	Chatham NY	unnamed	ny 66	Severe barrier	1
30191	xy4248053573566544	2016/05/03	2017/12/05	Chatham NY	Green Brook	ny 66	Insignificant barrier	1
30204	xy4247573173580307	2016/05/05	2016/05/09	Chatham NY	unnamed	Pratt Rd	Severe barrier	1
30205	xy4247130673589800	2016/05/05	2016/05/09	Chatham NY	Unnamed	Hoes Rd	Insignificant barrier	1
30206	xy4247546973591246	2016/05/05	2016/05/09	Chatham NY	unnamed	Albany Turnpike Rd	Severe barrier	1
30207	xy4248208473573541	2016/05/05	2016/05/09	Chatham NY	unnamed	Bachus Rd	Severe barrier	1
30208	xy4248251573575342	2016/05/05	2016/05/09	Chatham NY	unnamed	Pratt Rd	Severe barrier	1
30209	xy4248085273572944	2016/05/05	2016/05/09	Chatham NY	unnamed	driveway off Bachus Rd	Significant barrier	1
30210	xy4248110573573150	2016/05/05	2016/05/09	Chatham NY	unnamed	driveway off Bachus	Moderate barrier	1
30211	xy4248419973575398	2016/05/05	2016/05/09	Chatham NY	unnamed	Fredenberg Rd	Moderate barrier	1
30212	xy4247739773578641	2016/05/05	2016/05/09	Chatham NY	unnamed	Pratt Rd	Severe barrier	1
30213	xy4248460173574853	2016/05/05	2016/05/09	Chatham NY	unnamed	Pratt Rd	Severe barrier	1
30215	xy4248064873575619	2016/05/05	2016/05/09	Chatham NY	unnamed	Pratt Rd	Moderate barrier	1
30396	xy4246992573532314	2016/05/13	2016/05/18	Chatham NY	unnamed	County Rd 13	Severe barrier	1
30397	xy4246961273529636	2016/05/13	2016/05/18	Chatham NY	unnamed	County Rd 13	Significant barrier	1
30398	xy4246981873527374	2016/05/13	2016/05/18	Chatham NY	Green Brook	County Rd 13	Severe barrier	1
30399	xy4247429273523312	2016/05/13	2016/05/18	Chatham NY	unnamed	County Rd 13	Significant barrier	1
30400	xy4247450973523392	2016/05/13	2016/07/26	Chatham NY	unnamed	private driveway off county rd 13	no score - missing data	0
30401	xy4247921373521869	2016/05/13	2016/05/18	Chatham NY	unnamed	County Rd 13	Significant barrier	1
30402	xy4247170673525317	2016/05/13	2016/05/18	Chatham NY	unnamed	County Rd 13	Minor barrier	1
30403	xy4248307973539440	2016/05/13	2016/05/18	Chatham NY	unnamed	Ashley Hill Rd	Moderate barrier	1
30404	xy4248180973540082	2016/05/13	2016/05/18	Chatham NY	unnamed	Ashley Hill Rd	Severe barrier	1
30428	xy4244483873565854	2016/05/20	2016/05/20	Chatham NY	unnamed	Albany Turnpike Rd	Severe barrier	1

Next [375]

Understanding the NAACC Map

1. The colored circles on the map represent surveyed NAACC crossings (Non-tidal Aquatic Connectivity, Terrestrial Connectivity, Tidal Aquatic Connectivity or Culvert Condition Assessments) and colored squares represent UMass Stream Continuity Project crossings color coded as follows:
   - **No barrier:** blue ● ■
   - **Insignificant barrier:** blue green ● ■
   - **Minor barrier:** green ● ■
   - **Moderate barrier:** yellow ● ■
   - **Significant barrier:** orange ● ■
   - **Severe barrier:** red ● ■
   - **Missing data:** magenta ● ■
   - **No crossing:** black circle with bold red x
   - **New crossing pending approval:** black circle with red slash



- NAACC map: quickly see where the Significant and Severe barriers are located.
- Black dots are crossings that were not accessible.

Stream Continuity

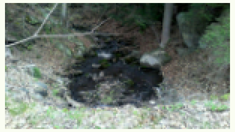
streamcontinuity.org/naacc

Survey Id: 30206 **Crossing Code:** xy4247546973591246
AOP Coarse Screen: No AOP **NAACC Aquatic Passability Score:** 0.11
Data checked and accurate by Josh Thiel on 07-20-2016

xy4247546973591246(downstream)5-5-16.jpg

xy4247546973591246(inlet)5-5-16.jpg

xy4247546973591246(outlet)5-5-16.jpg



xy4247546973591246(upstream)5-5-16.jpg

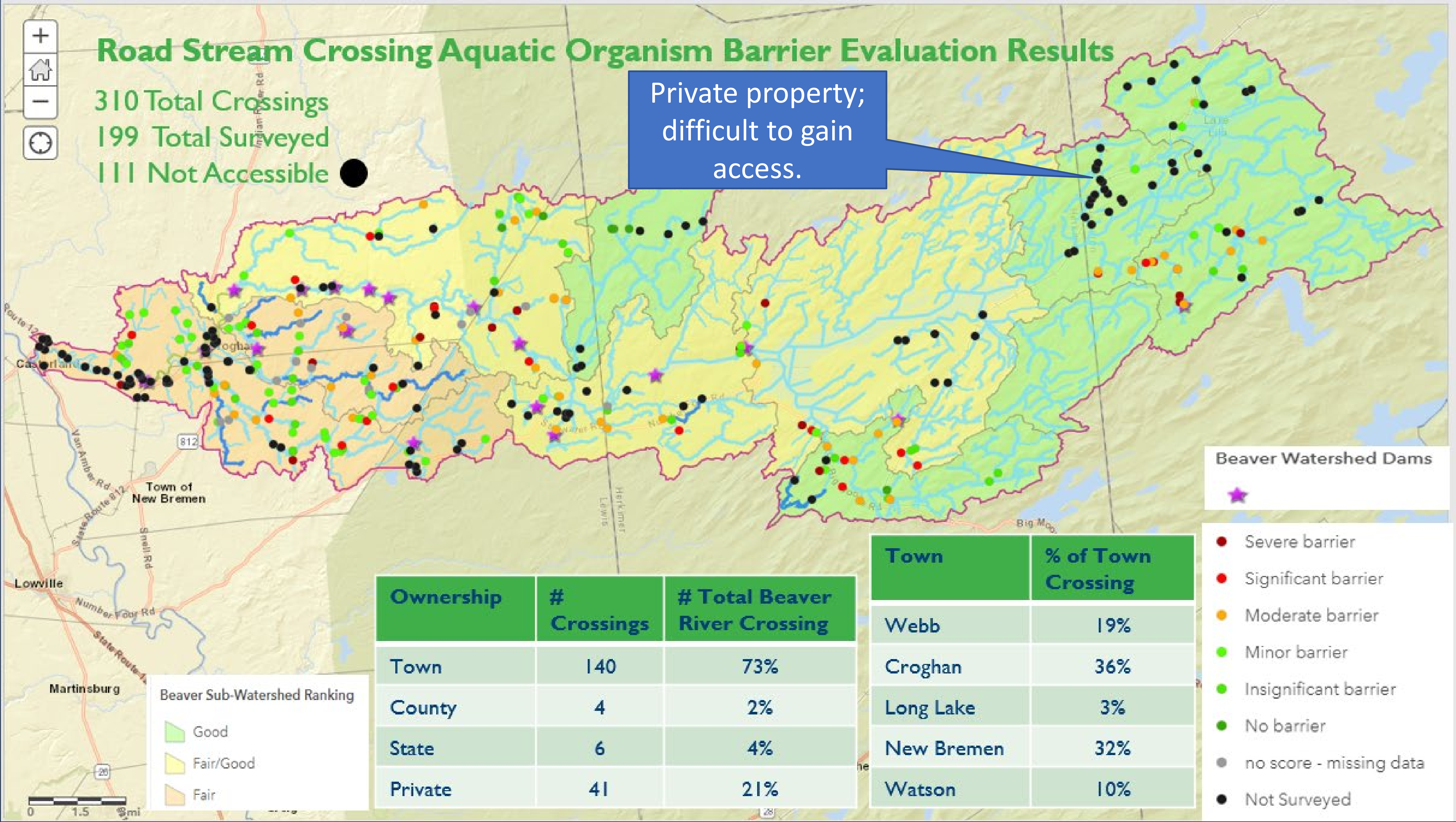
Database Entry By: No data	**Entry Date:** 05-09-2016
Coordinator: Josh Thiel	**Last Updated:** 05-09-2016
GPS to Crossing Distance (meters): 0.0	**NHD-HUC8 Watershed:** Middle Hudson
Crossing Code: xy4247546973591246	**Local ID:** No data
Date Observed: 05-05-2016	**Lead Observer:** Erica Capuana
Town/County: Chatham, NY	**Stream/River:** unnamed
Road: Albany Turnpike Rd	**Type:** Paved
GPS: Lat: 42.47547, Long: -73.59125	
Location Description: intersect albany turnpike rd and syring rd	
Crossing Type: Culvert	**Number of Culverts/Bridge Cells:** 1
Flow Condition: Moderate	**Crossing Condition:** OK
Tidal Site: No	**Alignment:** Flow-Aligned
Road Fill Height (feet) : 3	**Bankfull Width (feet):** No data
Bankfull Width Confidence: No data	**Constriction:** Severe
Tailwater Scour Pool: Large	
Crossing Comments: stream takes 90 degree turn left downstream	

Evaluation of this stream crossing is estimated as: SEVERE BARRIER

- Great baseline information.
- Identifies priorities.
- **Next steps**:
  - Connect with highway supers,
  - Assess from a design/build standpoint.
  - Funding & Access are critical.
  - Work together to find $$ for priorities (Fed, State, Local)

SCAN ME

Priority Waters + NAACC Watershed Results

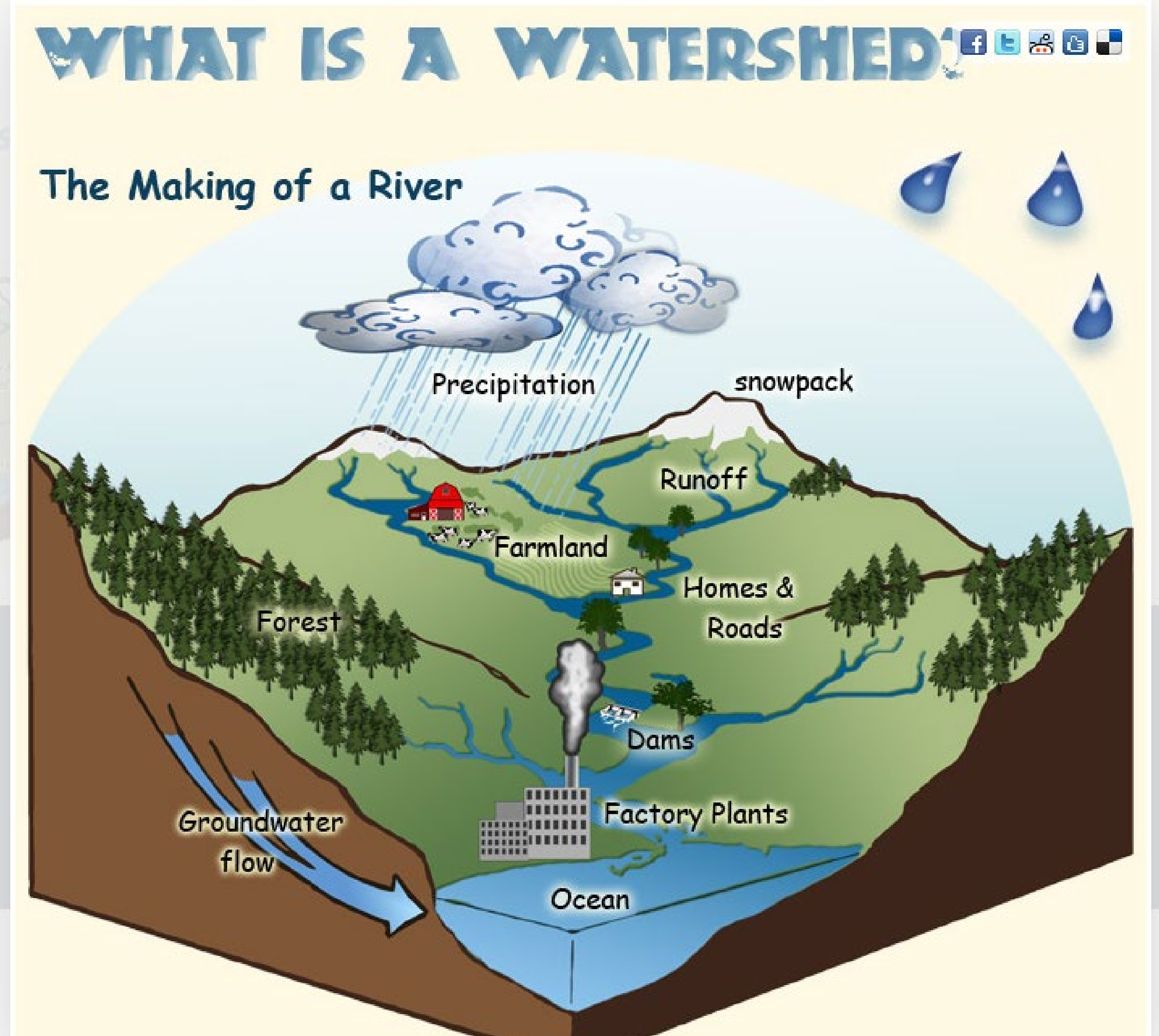


Ownership	# Crossings	# Total Beaver River Crossing
Town	140	73%
County	4	2%
State	6	4%
Private	41	21%

Town	% of Town Crossing
Webb	19%
Croghan	36%
Long Lake	3%
New Bremen	32%
Watson	10%

Watershed and Stream Science

Stream Basics: What is a Watershed?



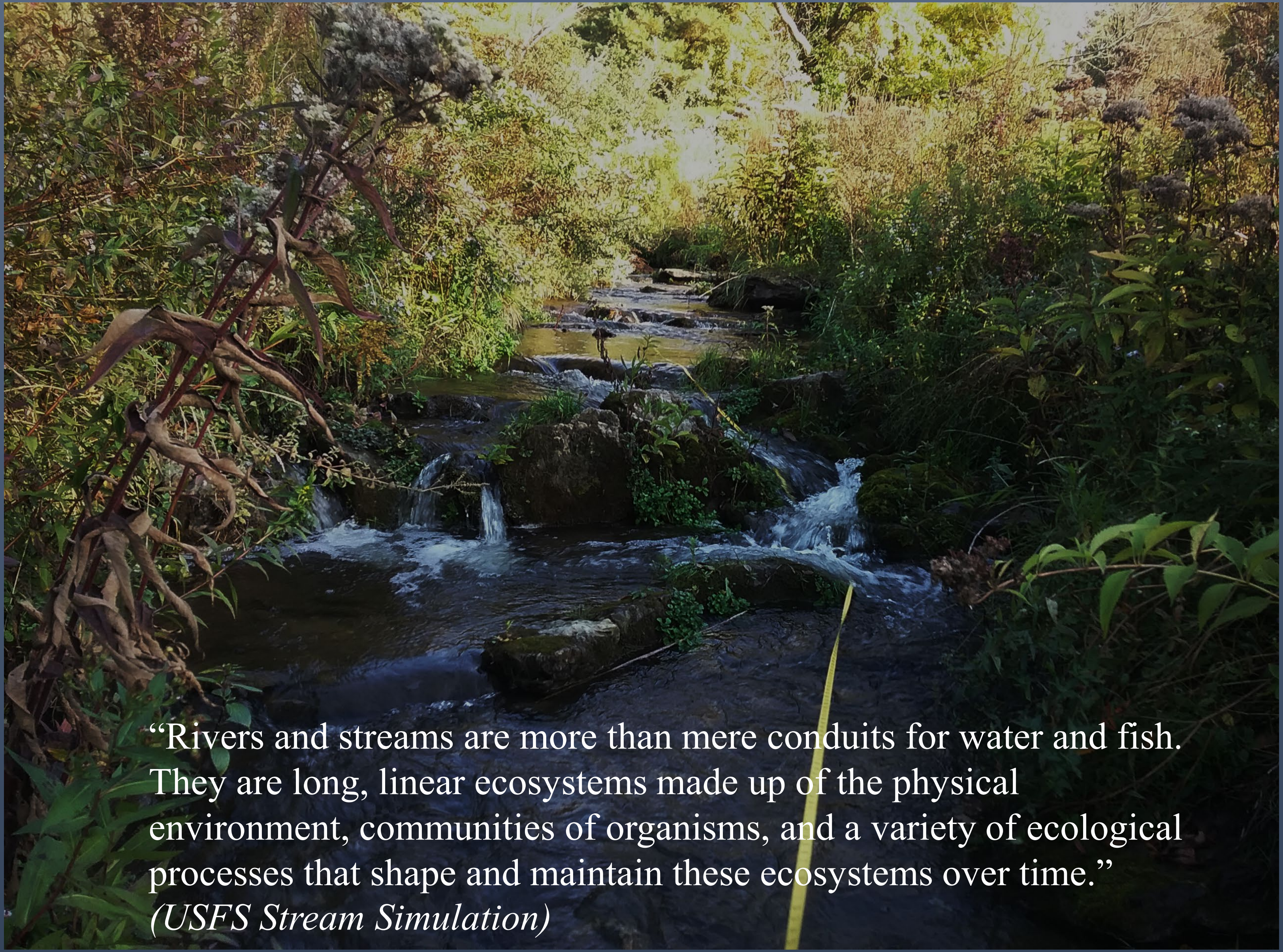
Center for Watershed Protection

The stream is a product of its watershed.

All the land that drains to a design point.
Stream appearance is a partly a function of watershed properties:

- LAND USE: ie, % forested, % developed, % ag
- SOILS
- TOPOGRAPHY: Mountains? Rolling Hills? Flat?
- SHAPE
- PRECIPITATION: Geographic

Streams are dynamic, living systems!



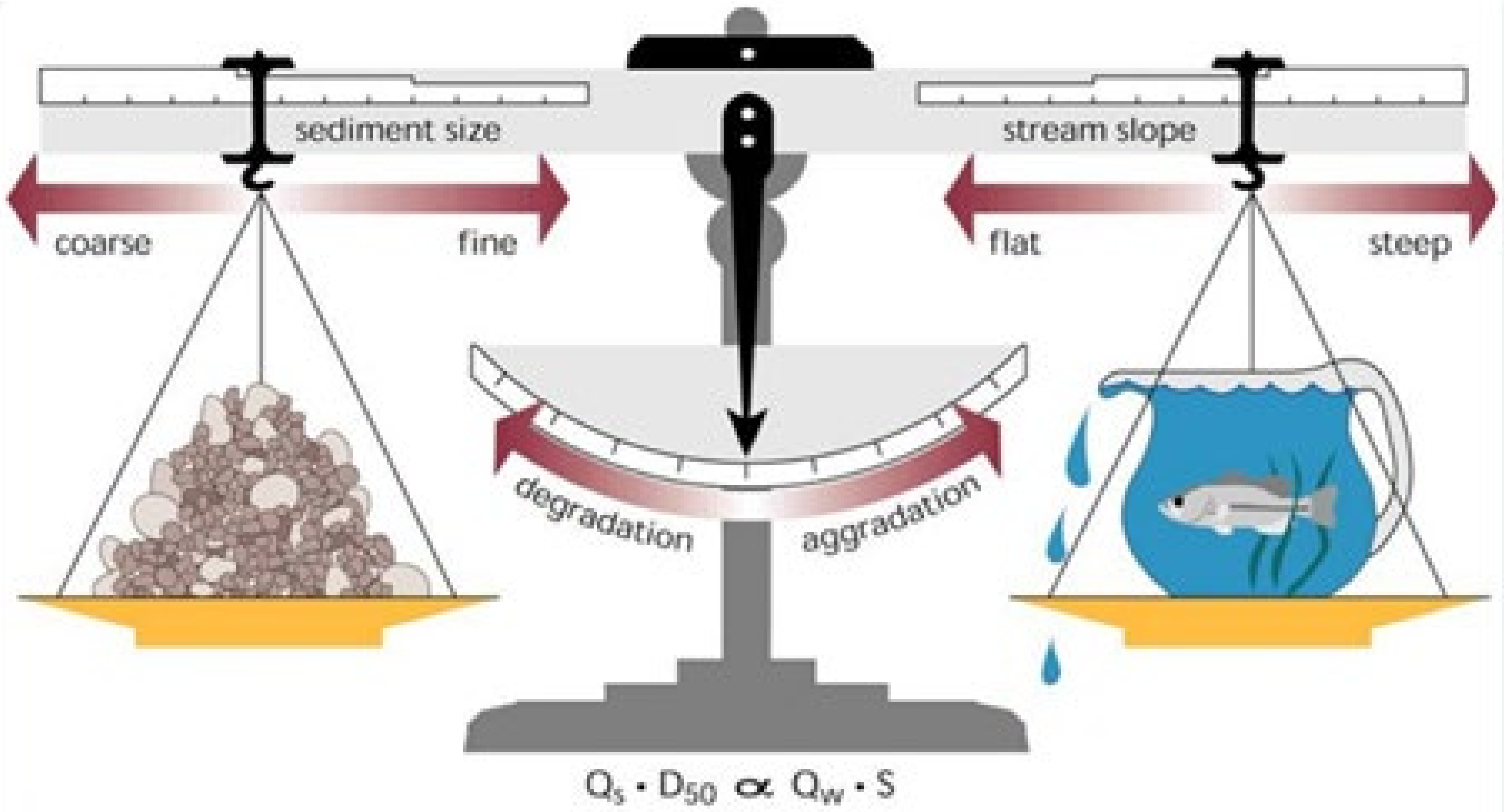
"Rivers and streams are more than mere conduits for water and fish. They are long, linear ecosystems made up of the physical environment, communities of organisms, and a variety of ecological processes that shape and maintain these ecosystems over time."
(USFS Stream Simulation)

Stable streams convey flows and transport sediment without excessive erosion or deposition.

They are stable for **both** the human community and the aquatic and terrestrial organisms that reside there.

Remember! Streams Move Water AND Sediment

<u>Sediment Sources</u>:
Streambank erosion
Streambed incision
Landslides
Surface erosion
DEPOSITION



From Rosgen (1996), from Lane, Proceedings, 1955.
Published with the permission of American Society of Civil Engineers.

Fig. 1.13 – Factors affecting channel degradation and aggradation: Concept of "Stream Balance.".
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (15 Federal Agencies of the US).

<u>Water</u>:
Rainfall
Snowmelt
Stormwater
Drainage
Loss of Greenspace
EROSION OF BED AND BANKS!

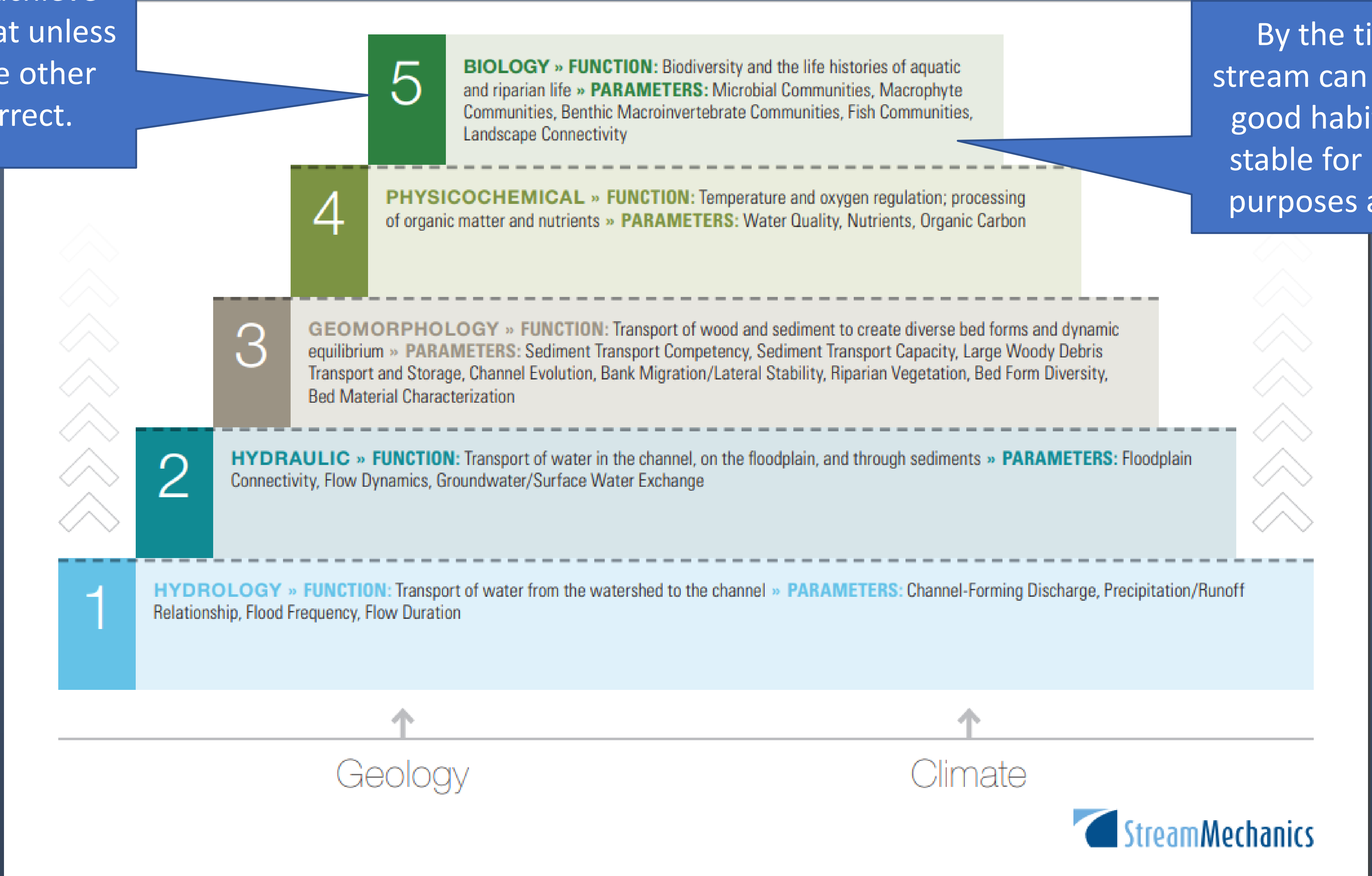
“Why do you only care about the fish??”

Stream Functions Pyramid

A Guide for Assessing & Restoring Stream Functions

We can’t achieve good habitat unless we get the other steps correct.

By the time a stream can support good habitat, it’s stable for human purposes as well.



U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

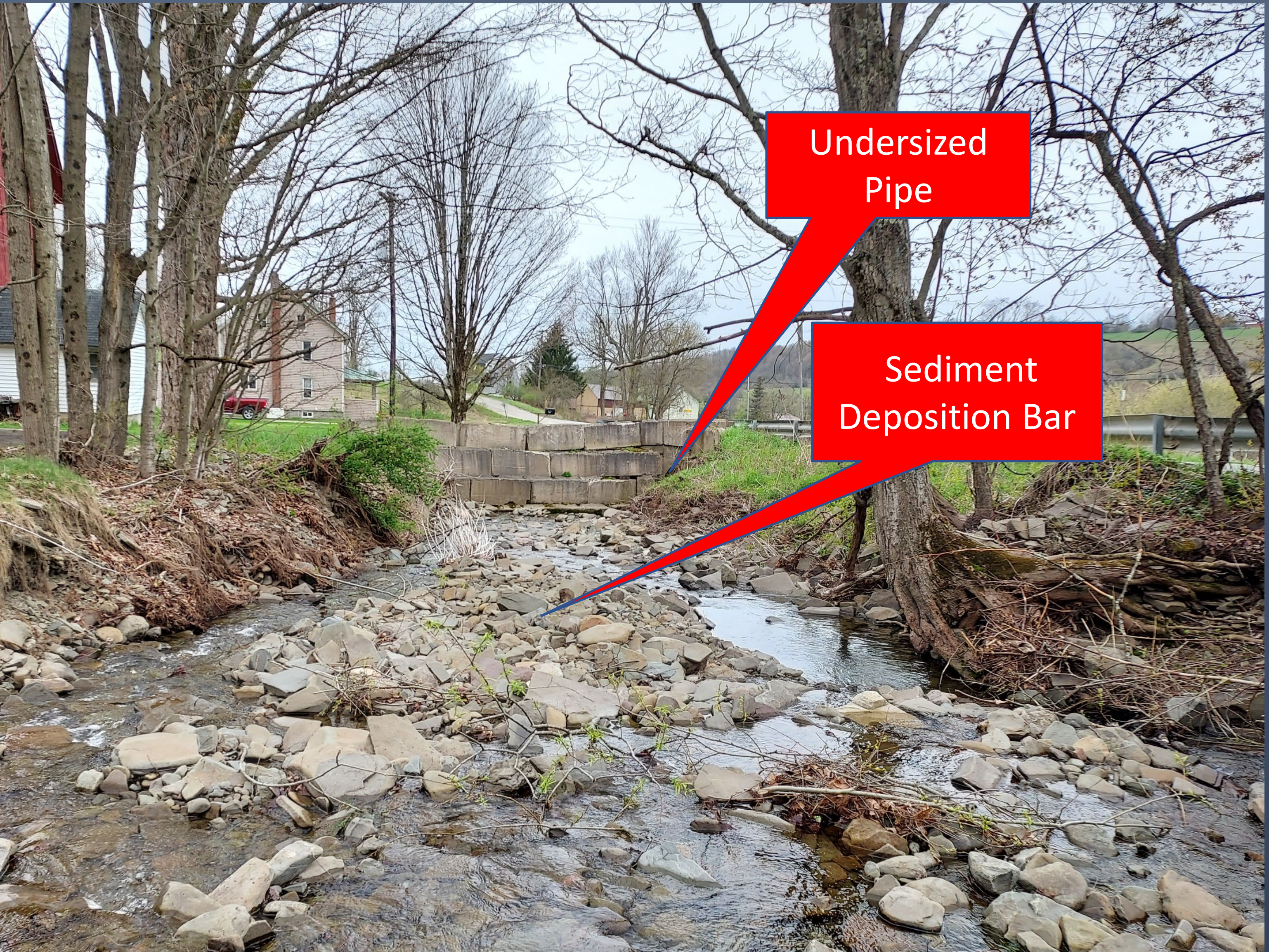
What Does a **Stable Stream** Look Like?

- Balances flows and sediment transport.
- Maintains dimensions and pattern in multiple storms.
- Has access to a vegetated floodplain.
- Vegetation creates roughness to slow flow.
- Bridge doesn’t squeeze channel.

- Floodplains spread out and slow down flows and trap sediment.
- **No Excessive Erosion or Deposition Present!**
- Stable Streams are good for everyone!

What Does an UNstable Stream Look Like?

Deposition – Sediment Transport Problems



Unstable: Over-wide

- Upstream erosion or bed failure.
- Crossing acts like a dam.
- Center Bar Deposition upstream of crossing where energy is low.
- Center bar splits channel
- Both banks become unstable.
- More sediment delivered downstream.

What Does an UNstable Stream Look Like?

Incision *(Bed Scour)* - Erosion Mobilizes Sediment

Unstable: Incision

- Bed Scour (Incision) caused by undersized culvert.
- Stream is overly narrow, no floodplain, digs deeper.
- Wing Wall is collapsing.
- When the bed fails, the banks fail.
- Driveway and Road are at the top of the bank!
- Sediment delivered downstream.

Prioritize Reconnection of Floodplains!

<u>Floodplain Function:</u> Slow it down! Spread it out!

- Vegetation creates roughness.
  Roughness **<u>slows down</u>** the water and traps sediment.
- Slow water is less erosive!
- Floodwater **<u>spreads out</u>** and absorbs into the soil.
- No floodplain = more energy stays in the stream = more erosion = more sediment bars.
- **If this was bermed, the flow and sediment would be forced downstream**.

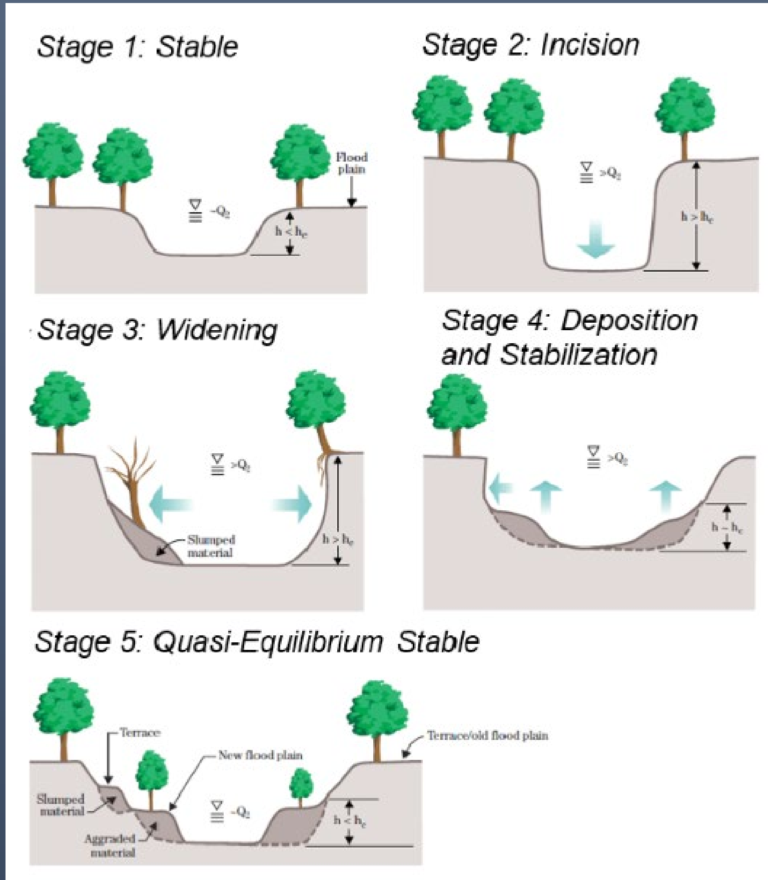
What Does an UNstable Stream Look Like?
No Flood Plain

No Floodplain:

- Channelized,
- Moved to make room for a parking lot,
- No flood prone area,
- Undersized culvert
- Road floods,
- Downstream home incurs flood damages.

TROUT UNLIMITED

What Does an UNstable Stream Look Like?
No Flood Plain



Channel evolution model, with channel cross sections illustrating the 5 channel stages (modified from NRCS 2007, Ch3).

No Floodplain:
- Incised channel
- Flows cannot reach a floodplain;
- Banks undermined.
- Property Damage
- Deposition above crossing.
- <u>**Can be caused by flood response efforts!**</u>

Understanding Headcutting

Headcuts happen when:

- Excavation of gravel in the bed.
- Overly narrow channel.

River Geomorphology – Headcut Migration

Video courtesy of Emriver Inc.

Examples of Headcutting & Incision

Removal of beaver dam triggered a headcut that moved upstream into the tributary. Approx. 2’-3’.

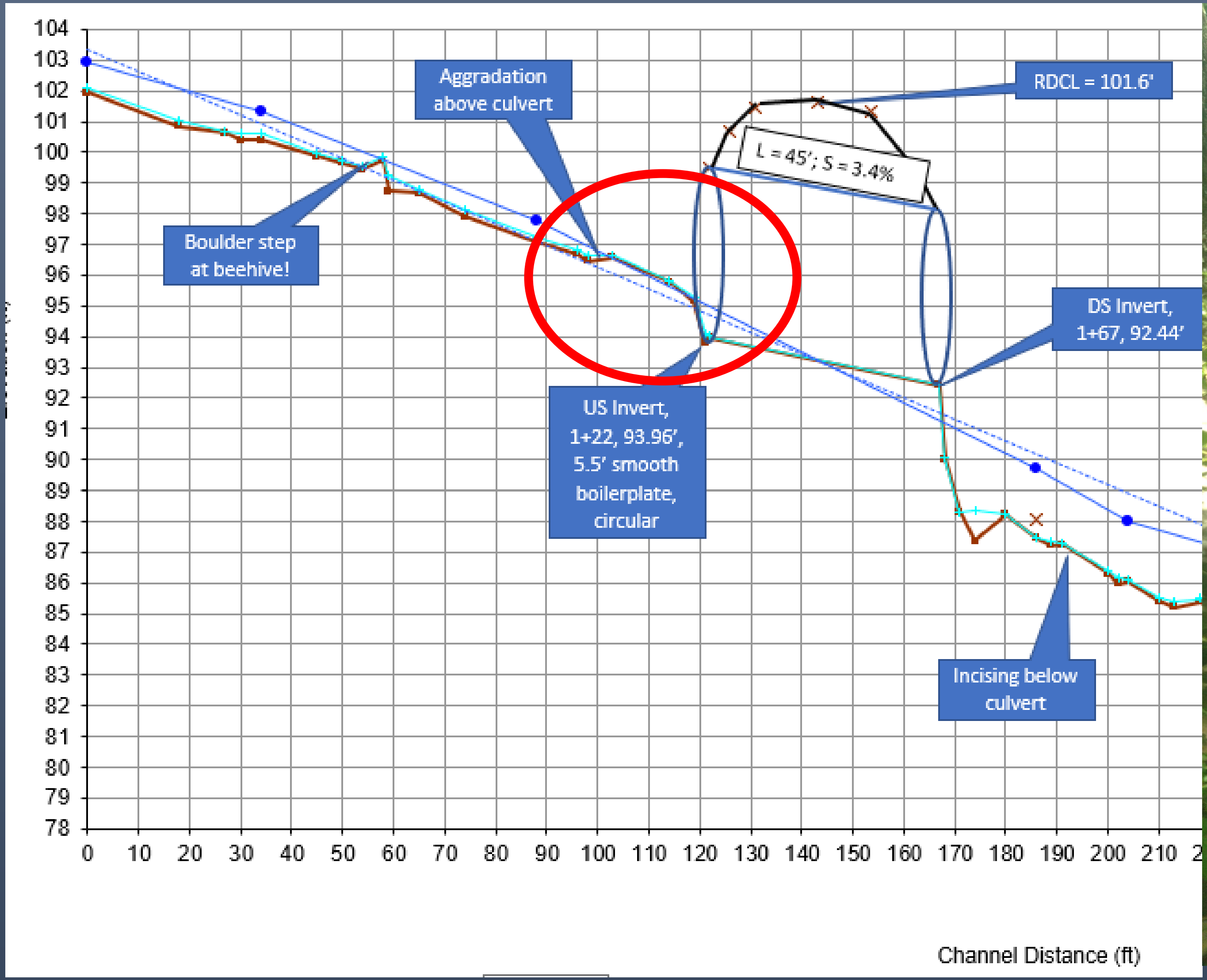
Undermining rip rap

How Can You Tell if a Crossing is Undersized?

Crossing is narrower than channel width:
Channel width here is ~13’, but the pipe is 6’ diameter…
Channel forming flow = Bankfull ~ Ordinary High Water
Mean High Water: Terrestrial vegetation

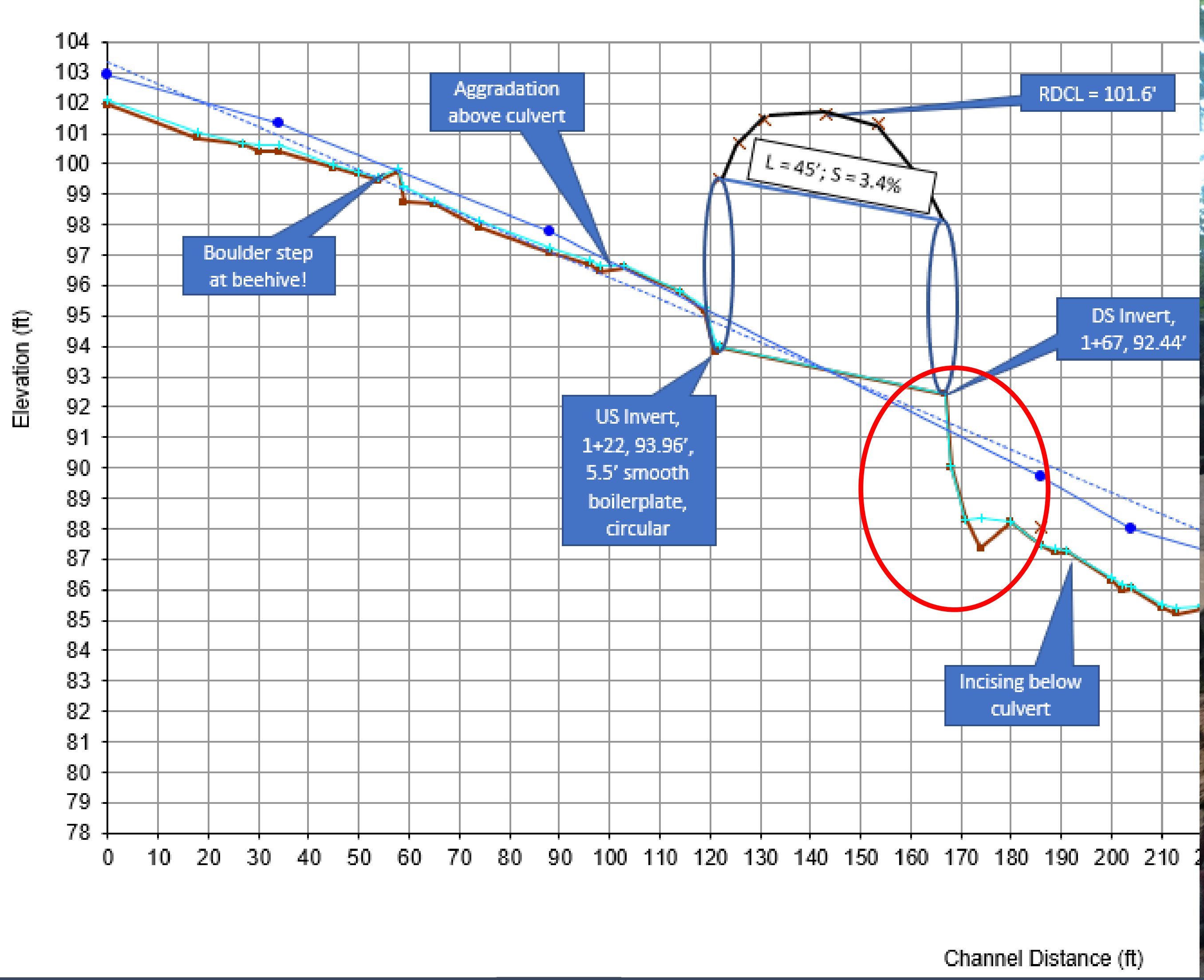
NEW YORK STATE:
New Crossing = 1.25x Channel Width!

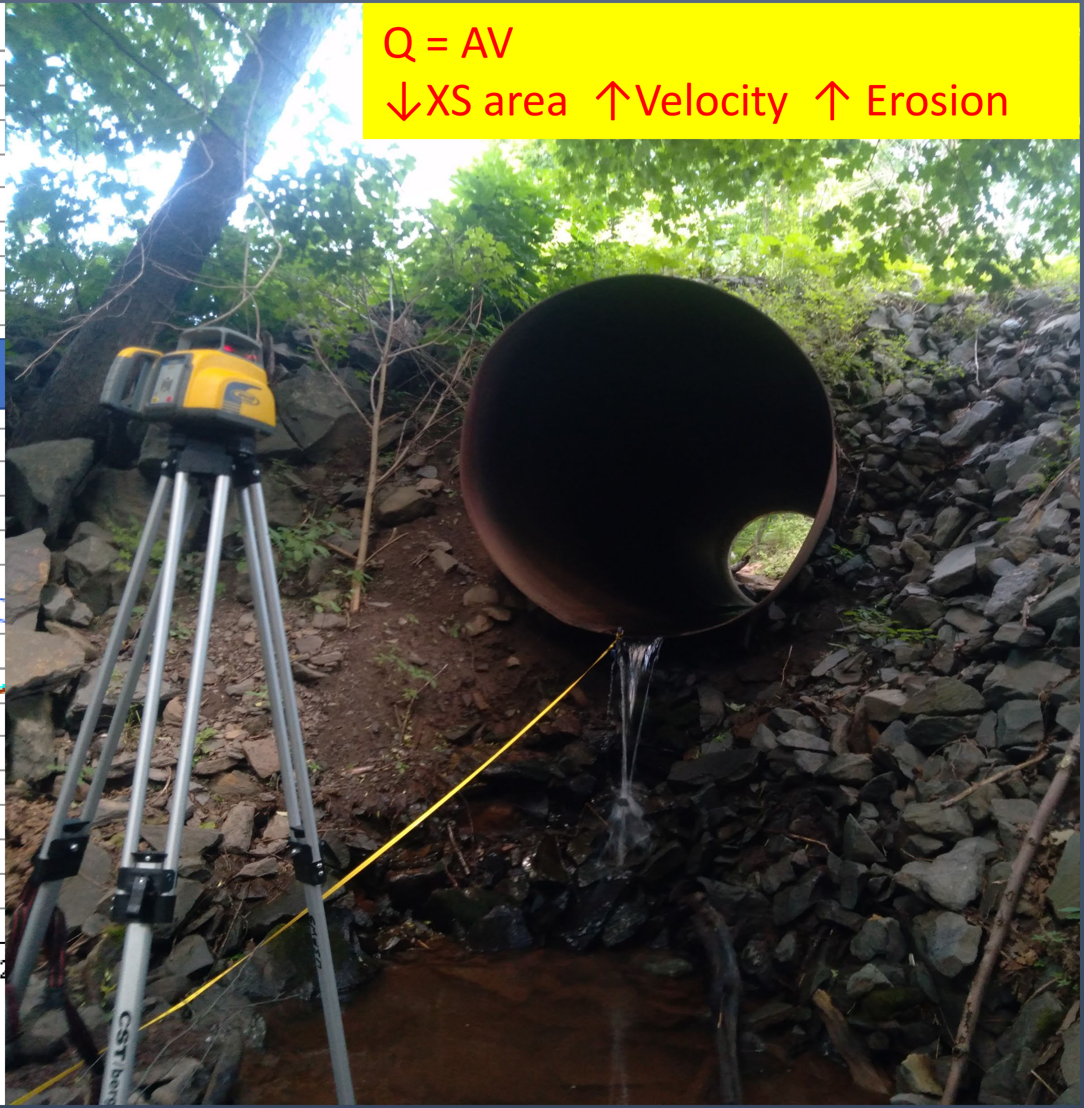
How Can You Tell if a Crossing is Undersized?



Undersized Crossing: Acts like a dam on upstream side. Deposition at the inlet leads to post storm dredging.

Undersized Crossings Continued





Q = AV
↓XS area ↑Velocity ↑ Erosion

Perched Culvert: High Velocity at outlet = High Scour.

Signs of an Undersized Crossing

Oversized Pool at Outlet

Not a Barrier…yet – Important to work toward ensuring that the **Replacement** doesn't become a Barrier!

Even if it’s not a barrier…

While not a barrier, this is undersized and corroding; if the municipality replaces it, it should be right sized.

Is the crossing needed? This private road is not used so, can the crossing be removed?

Aquatic Organism Passage Barriers

- Perched culverts: Free fall >0.7 feet is not passable for most native trout.
- High Velocity: Less than 3 feet/second is ideal.
- High Turbulence
- Shallow Depth: Low flow channel in natural bed is ideal.
- Long Distance (ie, length of pipe): The longer the pipe, the more difficult to make it through the barrel.

Functional AOP Upgrades

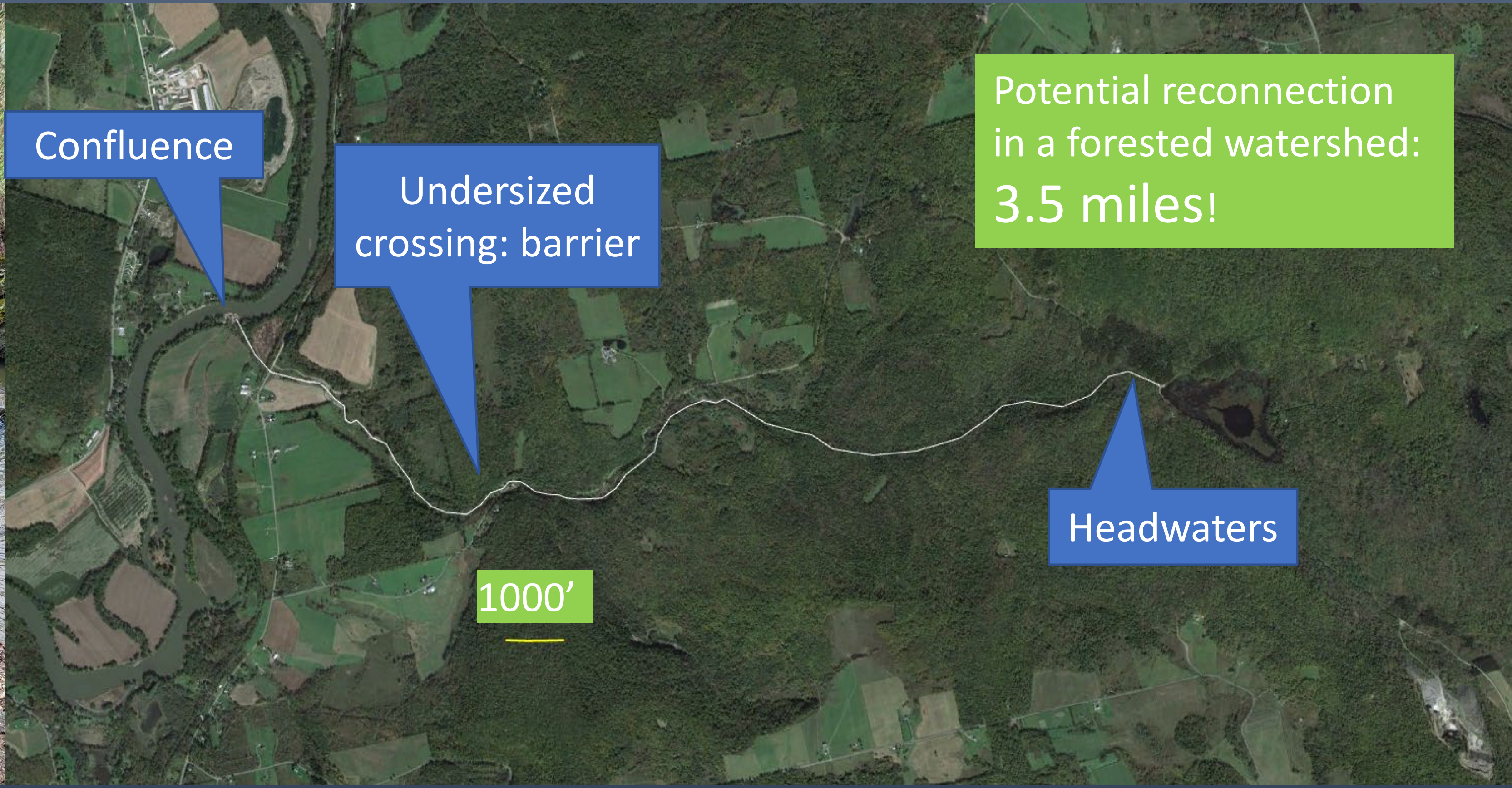
Photos Courtesy of Steve Swenson, NYSDEC

Eliminated perched conditions

Restored natural bed

Ecological Considerations

HOW MANY MILES OF RECONNECTION ARE POSSIBLE?



Common Goals for a Right Sized Crossing

- Safe structure for the public.
- Provide capacity for future events.
    - 20% more than the 2% storm
- Reconnected habitat for native species.
- Limited maintenance needs.
- <u>Affordable installation</u>.
- Minimal disruption in road access.

- Stable stream reach.
    - Make the crossing invisible to the stream.
    - Natural, stable bed with ample span to convey flows and debris.
    - Diverse bed features

Considerations for a Right Sized Crossing

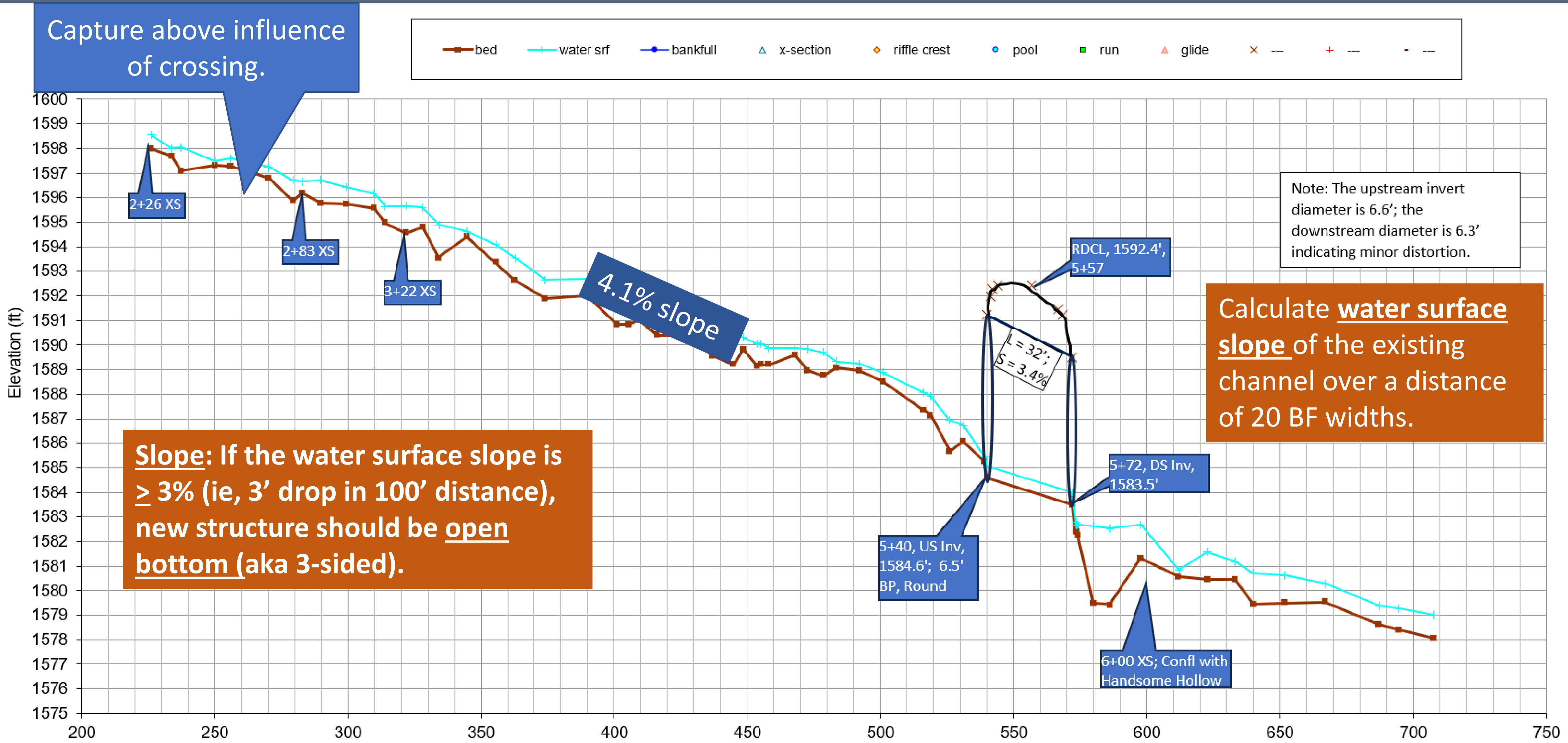
- **Cost**: Ensure that proposed budget makes sense for the setting.
  - ~$700-$1000/foot of work if hired out.
- **Channel Dimensions**
- **Capacity: Flow, Sediment, Wood**
- Alignment
- Cover
- Utilities
- Access:
  - Municipal ROW
  - Landowner permission
- Time
- PERMITTING!

16’x7’1” SRA Pipe was $16,836,
$400/ft PIPE,
Project ~$185K
170 lf
14 grade controls

Information to Collect: Site History

- Drainage Area
- Property Ownership
- Road ROW
- Wood
- Ice
- Flooding
- Road Closure
- Property damage (private and public)

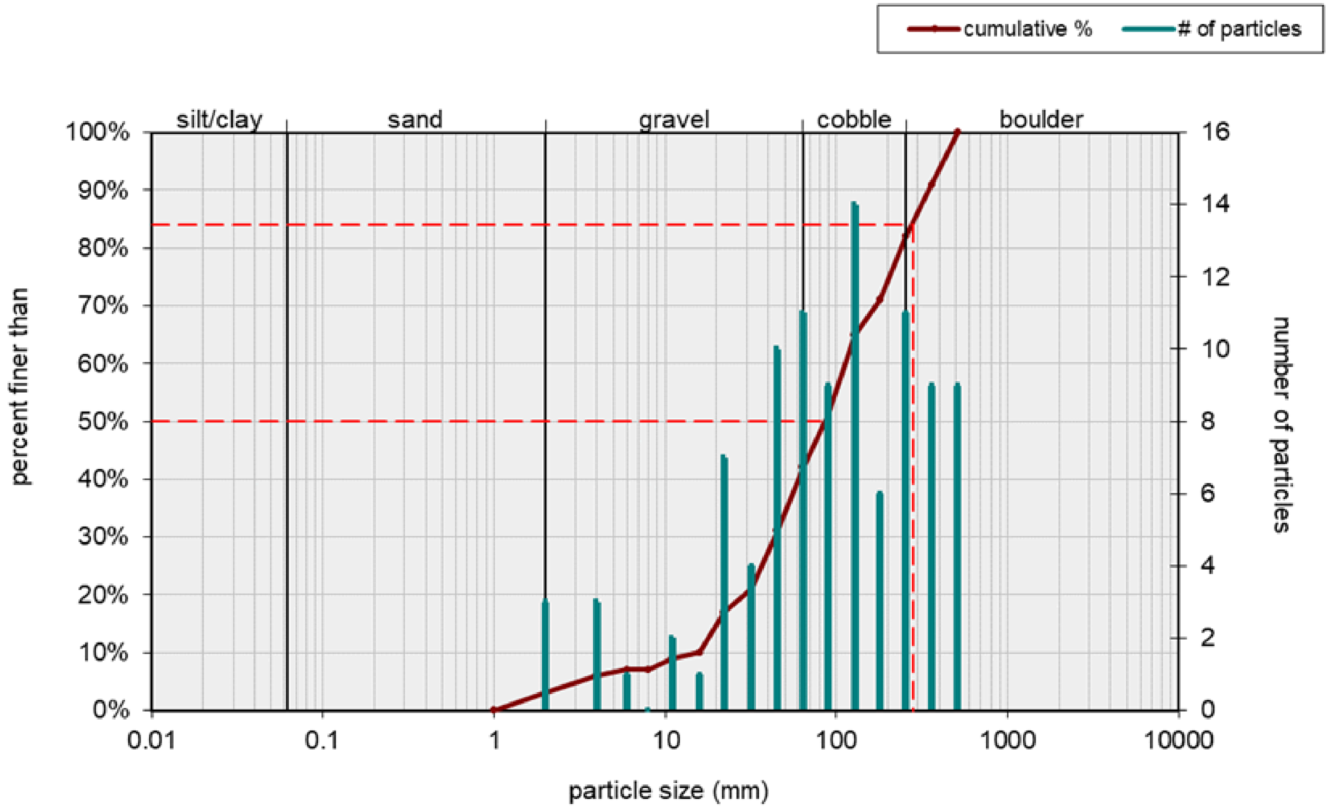
Information to Collect: Longitudinal Profile



Calculate **water surface slope** of the existing channel over a distance of 20 BF widths.

Slope: If the water surface slope is ≥ 3% (ie, 3' drop in 100' distance), new structure should be open bottom (aka 3-sided).

Information to Collect: Pebble Count

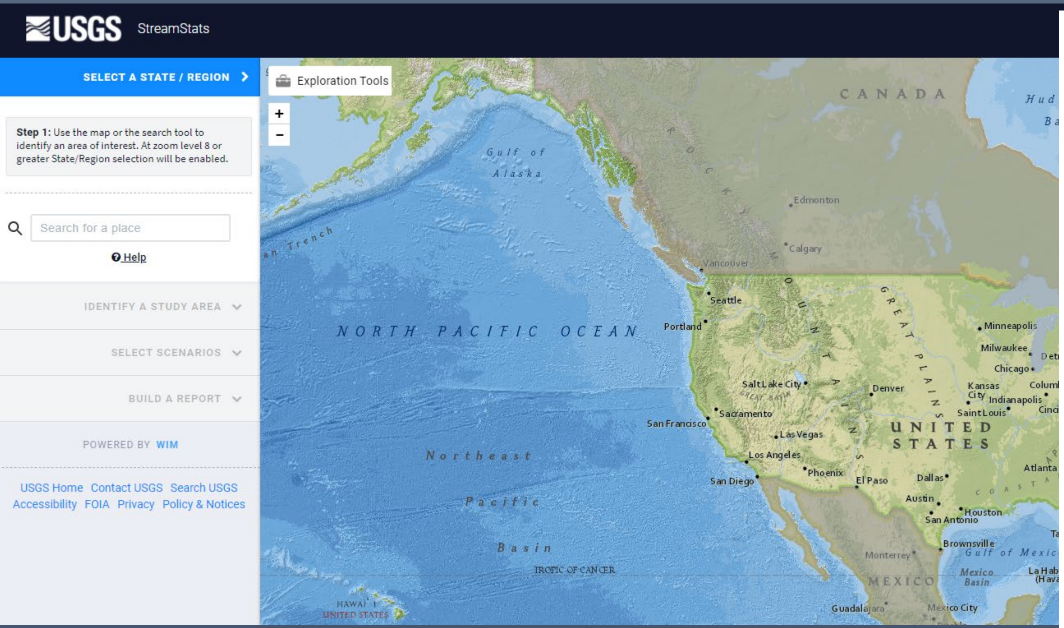


	Size (mm)
D16	21
D35	51
D50	87
D65	130
D84	280
D95	420

- What size moves in which event?
- Helps calculate Shear Stress and Stream Power
- Helps determine what size rock to use for grade controls.

Information to Collect: Stream Dimensions

https://streamstats.usgs.gov/ss/



StreamStats Report: Federal Hill #2

Region ID: NY
Workspace ID: NY20191015195337950000
Clicked Point (Latitude, Longitude): 42.26261, -74.87371
Time: 2019-10-15 15:53:53 -0400

Bankfull Dimensions:

- Difficult to identify bankfull in a degraded reach!
- Identify bankfull based on veg, sed, capacity, etc.

<u>State and Federal Permits: 1.25x BF Width!</u>

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu
Bankfull Area	12.1	ft^2	5.22	28.1
Bankfull Depth	0.864	ft	0.382	1.95
Bankfull Streamflow	51.1	ft^3/s	7.5	348
Bankfull Width	14.4	ft	6.06	34.1

USGS StreamStats:

- Free tool,
- Good starting point,
- **<u>Drainage Area</u>**,
- Est. Bankfull dimensions,
- Peak flows.
- **Field Truthing is needed!**

Information to Collect: Channel Dimensions

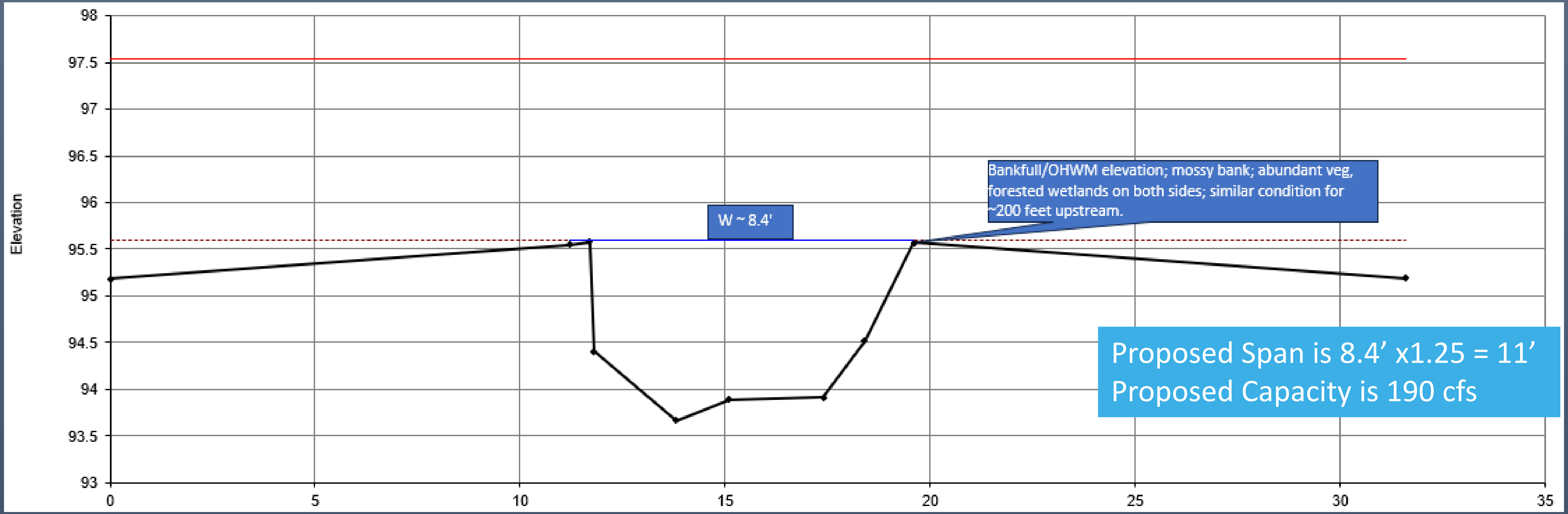
Brewery Road site: Proposed Span 10-11 feet.

Bankfull/Ord. High Water Mark Dimensions:

Very hard to id in incised reach!!

- Incipient point of flooding.
- **NOT WETTED WIDTH!**
- Depositional
- Look for stable reach
- Ideally **above the influence** of the crossing unless slope is too flat.
- If channel width is 20’ or more, a bridge is best option;

Example of Cross Section for Stream Dimensions



Put Profile, Pebble Count and Cross Section information together to calculate Forces and Power.

Bankfull Dimensions		Flood Dimensions		Materials	
11.5	x-section area (ft.sq.)	50.0	W flood prone area (ft)	9.1	D50 Riffle (mm)
8.4	width (ft)	6.0	entrenchment ratio	27	D84 Riffle (mm)
1.4	mean depth (ft)	1.9	low bank height (ft)	35	threshold grain size (mm):
1.9	max depth (ft)	1.0	low bank height ratio		
10.2	wetted parimeter (ft)				
1.1	hyd radi (ft)				
6.1	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
5.8	velocity (ft/s)	0.028	Manning's roughness	1	channel slope (%)
67.3	discharge rate (cfs)	0.09	D'Arcy-Weisbach fric.	0.71	shear stress (lb/sq.ft.)
0.97	Froude number	9.7	resistance factor u/u*	0.60	shear velocity (ft/s)
		15.5	relative roughness	5	unit strm power (lb/ft/s)

TROUT UNLIMITED

StreamStats Flow Data: Estimates

Peak-Flow Statistics Flow Report [2006 Full Region 1]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Up ard Error of Prediction, SE: Standard Error (other -- see report)

Standard Error

Statistic	Value	Unit	SE	ASEp	Equiv. Yrs.
80-percent AEP flood	36.4	ft^3/s	31.6	31.6	2.2
66.7-percent AEP flood	44	ft^3/s	30.3	30.3	2
50-percent AEP flood	54.4	ft^3/s	29	29	2.1
20-percent AEP flood	83.2	ft^3/s	27.3	27.3	3.6
10-percent AEP flood	105	ft^3/s	27.2	27.2	5.1
4-percent AEP flood	135	ft^3/s	28.2	28.2	6.9
2-percent AEP flood	158	ft^3/s	29.4	29.4	8
1-percent AEP flood	183	ft^3/s	30.8	30.8	8.8
0.5-percent AEP flood	208	ft^3/s	32.5	32.5	9.4
0.2-percent AEP flood	245	ft^3/s	35.1	35.1	9.8

66.7% ~ BF Flow

USACE allows span to equal width at 50% Flow

2% = "50 year"

New DEC Capacity Reg: Adjust 2% by 20% and provide 2' of freeboard, ie, 158 cfs adjusted to 190 cfs..

Information to Collect: Culvert and Road Data

HY-8 Program
(Federal Highway Admin)
Inputs for Existing Crossing
Est. Capacity at Road
Design for Proposed Structures.

Name: Brewery Road existing

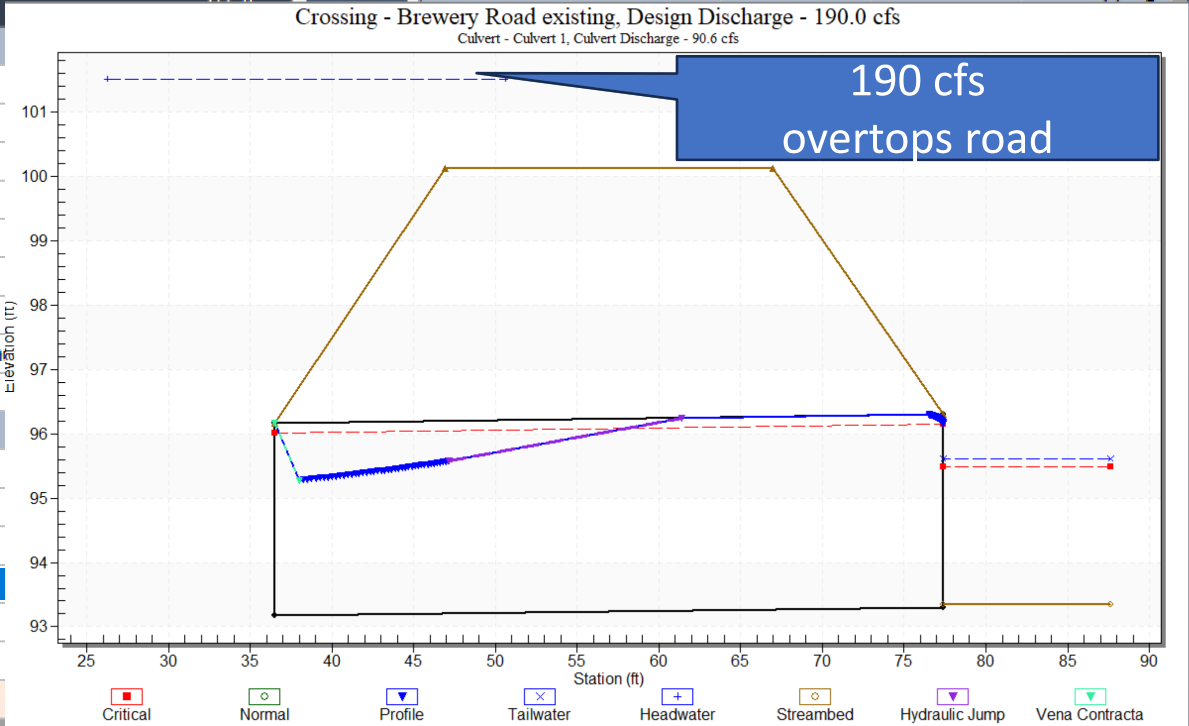
Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	41.000	cfs
Design Flow	190.000	cfs
Maximum Flow	250.000	cfs
TAILWATER DATA		
Channel Type	Trapezoidal Channel	
Bottom Width	8.000	ft
Side Slope (H:V)	2.000	_:1
Channel Slope	0.0100	ft/ft
Manning's n (channel)	0.030	
Channel Invert Elevation	93.340	ft
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	40.000	ft
Crest Length	20.000	ft
Crest Elevation	100.130	ft
Roadway Surface	Paved	
Top Width	20.000	ft

Culvert 1

Add Culvert
Duplicate Culvert
Delete Culvert

Parameter	Value
CULVERT DATA	
Name	Culvert 1
Shape	Circular
Material	Corrugated Steel
Diameter	3.000
Embedment Depth	0.000
Manning's n	0.024
Culvert Type	Straight
Inlet Configuration	Square Edge with Hea
Inlet Depression?	No
SITE DATA	
Site Data Input Option	Culvert Invert Data
Inlet Station	36.500
Inlet Elevation	93.170
Outlet Station	77.400
Outlet Elevation	93.300
Number of Barrels	1
Computed Culvert Slope	-0.003178

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
96.95	41.00	41.00	0.00	1
98.16	61.90	61.90	0.00	1
100.23	82.80	80.87	1.90	10
100.61	103.70	83.82	19.87	6
100.87	124.60	85.84	38.76	6
101.10	145.50	87.54	57.95	5
101.31	166.40	89.05	77.35	5
101.52	190.00	90.58	99.41	5
101.68	208.20	91.68	116.52	5
101.84	229.10	92.87	136.23	5
102.01	250.00	93.98	156.01	4
100.13	80.05	80.05	0.00	Overtopping



Let’s Talk About: Capacity

On paper, this culvert can take the 50 year storm (2% storm)…but only if it isn’t blocked with trees. Sediment and wood transport are essential considerations in culvert replacements.

Capacity: Published Data From USGS StreamStats

What are the peak flows in the channel?

What is the existing capacity?

What is the proposed capacity?

Statistic	Value	Unit	SE	SEp	Equiv. Yrs.
2 Year Peak Flood	86.9	ft^3/s	27.9	27.9	2.5
5 Year Peak Flood	139	ft^3/s	24.7	24.7	4.2
10 Year Peak Flood	179	ft^3/s	23.1	23.1	6.5
25 Year Peak Flood	233	ft^3/s	22	22	9.9
50 Year Peak Flood	277	ft^3/s	21.6	21.6	12.6
100 Year Peak Flood	323	ft^3/s	21.6	21.6	15
200 Year Peak Flood	371	ft^3/s	21.7	21.7	17.1
500 Year Peak Flood	437	ft^3/s	22.4	22.4	19.4

Let's Talk About: Wood

- Wood is a natural part of a healthy stream;
- Build a crossing that prevents wood from blocking the entrance

Stream Simulation

Table 4.1—Qualitative criteria for assessing the risk of plugging by woody debris at a road-stream crossing structure

Woody Debris Risk	Description
LOW	Debris mostly absent or well anchored on banks and in channel.
	Debris dispersed uniformly along the reach (i.e., it has not moved).
	Available wood is much larger than the stream's ability to move it (i.e., large trees in small streams).
	Little or no wood available for local recruitment.
	Bed material not anchored by debris.
	Woody debris likely to remain at or near source area.
MODERATE	Most wood pieces anchored in the channel bed or channel banks.
	Potential for local recruitment of wood.
	History of occasional maintenance to remove wood at the crossing.
	Small translational slides or undercut slopes adjacent to channel.
HIGH	Unstable accumulations of woody debris present along banks, gravel bars, and channel constrictions.
	Most wood pieces not anchored to bed or banks.
	Considerable wood available for local recruitment.
	History of frequent maintenance to remove wood at the crossing.
	Upstream watershed susceptible to debris flows.

Is wood transport an issue at the crossing?

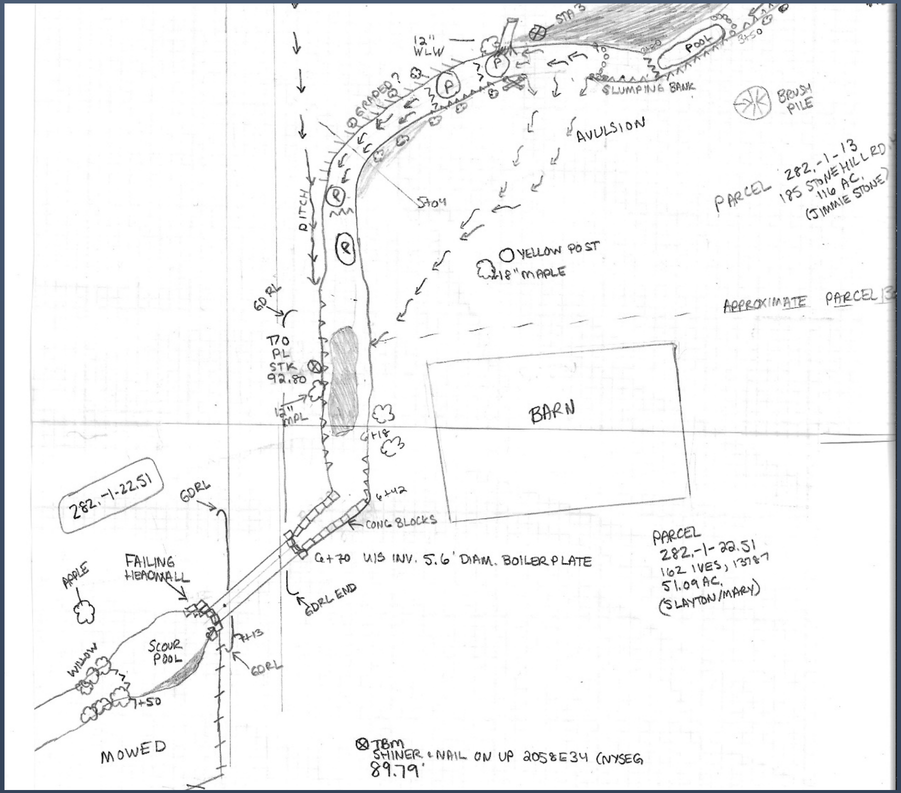
Trees deposited in high water event.

Existing Crossing is undersized for Wood and Flows!
Consider a floodplain culvert to help with overflows.

Let’s Talk About: Cover

- Minimal cover is a common concern:
- Options include
  - Concrete box (or arch),
  - prefab bridge,
  - or raising road.
- Most metal pipes require at least 1.5’ cover with strongest gage for HL93 loading.

Poor Alignment Issues



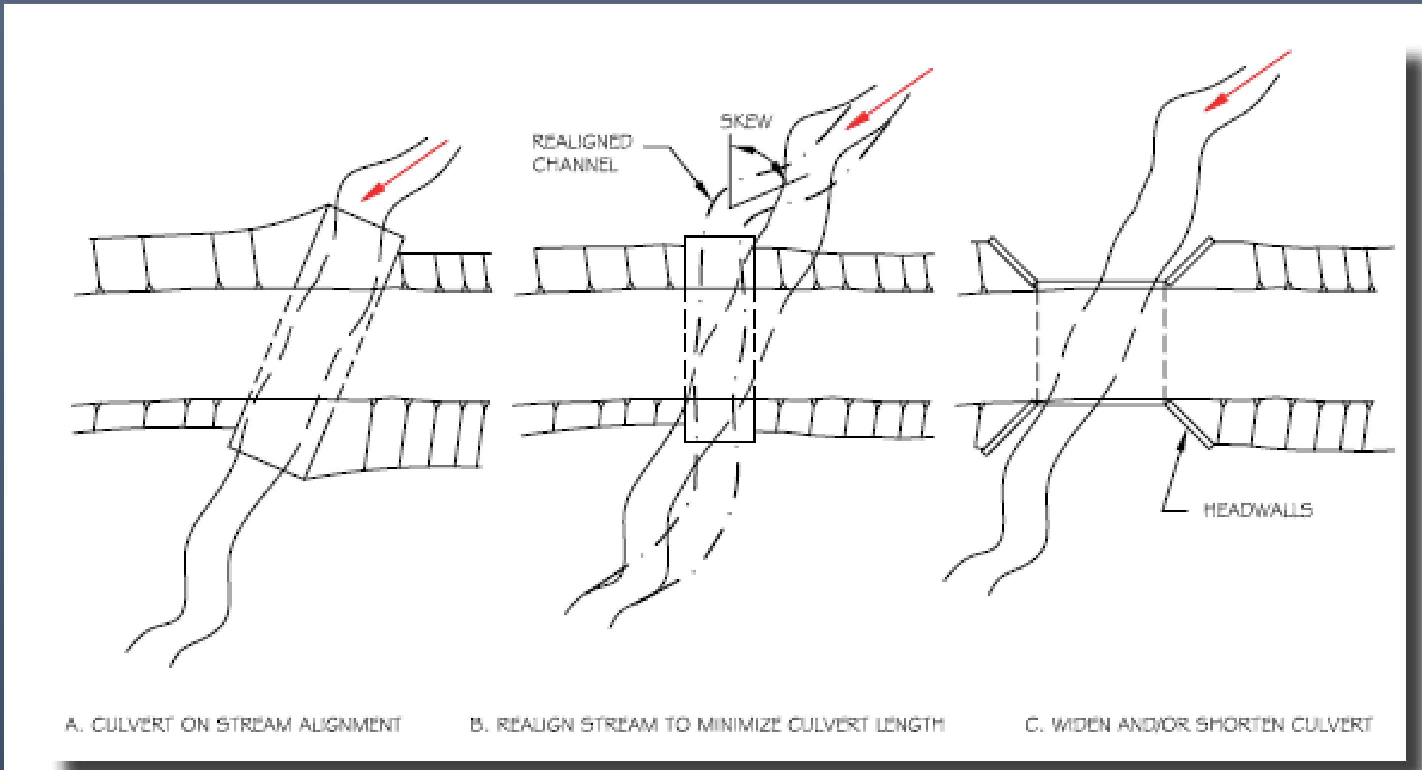


Figure 6.3—Three alignment options for a culvert where the road crosses the stream at an acute angle (high road-to-channel skew).

How to address skewed alignment?

A wider span helps with alignment **and** wood transport.

A longer pipe may be needed.

Geotech: Essential for footer designs

What is bearing capacity of foundation (4000 psf)?
Depth and type of bedrock? Silt?
Can Town provide backhoe and operator?
Is drilling needed?

In-Stream Structures

Grade Controls

- Grade controls prevent headcutting.
- Project USUALLY REQUIRES GC UPSTREAM AND DOWNSTREAM
    - MUNICIPAL ROW
    - LANDOWNER PERMISSION
- Place inside the new structure
- Construct with Rock or Logs
- Tie in critical to avoid outflanking
- Vertical spacing of GC is 0.5’-0.7’.
- Horizontal spacing is guided by the slope of the proposed bed.
- Steeper beds need more structures.
- When slope is <8%, each structure consists of a step and a pool.
- Provides bed diversity and cover.
- Can be used to retrofit a crossing.

In-Stream Structures

CAUTION:
Crossings without Grade Controls can scour.

- **K**ey-in, especially on downstream structure, is really important to prevent scour.
- **Right of Way** limitations can affect the placement of grade controls.
- Grade controls are an investment to protect the lifespan of the new structure.

In-Stream Structures

Headcutting in tributary in pasture

Corrected with Constructed Cascade due to steep slope. Approx. 6 weeks post-construction.

ADDITIONAL CONSIDERATIONS

Tree Removal (minimize)

Construction Duration:

Utilities

Staging areas

Permitting: Federal (USACE) & State (NYSDEC)

Stream Crossings

3 parts to SEQR

PRINT SHARE TRANSLATE

Home > Regulations and Enforcement > Permits, Licenses, and Regi... > Waterways, Coastlines & Wet... > Protection of Waters Program > Stream Crossings

Protection of Waters Program

- Constructing Recreational And Farm Ponds
- Shoreline Stabilization Techniques
- Shoreline Stabilization
- Stream Crossings

Important Links

Environmental Resource Mapper

Protection of Waters

NYSDEC developed the stream crossings guidelines to promote natural stream conditions and to allow animals to move unrestricted while balancing transportation demands. Special considerations for the life requirements of invertebrates, fish, amphibians, reptiles, mammals, and birds have been considered while developing these guidelines. Depending on the project, additional engineering design may be necessary to ensure structural integrity and appropriate hydraulic capacity.

Draft 2024 Bridge and Culvert Guidance

- DEC has announced new draft Guidance for the Review of Bridge and Culvert Projects in Nontidal Waters Requiring a Protection of Waters Permit and a Water Quality Certificate (PDF) which is now available for public review and comment.
  NOTE: The period for public review and comment has been extended until February 23, 2024.
- This guidance describes minimum design requirements and other considerations of the New York State Department of Environmental Conservation (NYSDEC), Division of Fish and Wildlife during review of bridge and culvert projects requiring Protection of Waters permits. This new guidance has been developed to:
  - Clarify DEC's stream crossing guidelines described on this webpage and clarify permit issuance standards used by staff;
  - Incorporate climate change considerations into issuance of DEC permits as required by CRRA and CP-49; and
  - Promote and encourage statewide consistency and efficiency with both DEC staff and the regulated community.
- Written comments on the draft Guidance will now accepted by email until February 23, 2024. The comments shall be submitted to the contact below. Please include "Comments on the 2024 Draft Bridge and Culvert Guidance" in the subject line.
  - **Contact Information:**
    Corbin Gosier
    518-402-8872
    Corbin.gosier@dec.ny.gov

Short Environmental Assessment Form

Part 1 - Project Information

Instructions for Completing

Part 1 – Project Information. The applicant or project sponsor is responsible for the completion of Part 1. Responses become part of the application for approval or funding, are subject to public review, and may be subject to further verification. Complete Part 1 based on information currently available. If additional research or investigation would be needed to fully respond to any item, please answer as thoroughly as possible based on current information.

NEW YORK STATE | Department of Environmental Conservation | Office of General Services | Department of State | US Army Corps of Engineers

JOINT APPLICATION FORM

For Permits for activities activities affecting streams, waterways, waterbodies, wetlands, coastal areas, sources of water, and endangered and threatened species.

You must separately apply for and obtain Permits from each involved agency before starting work. Please read all instructions.

1. Applications To:

>NYS Department of Environmental Conservation ☐ Check here to confirm you sent this form to NYSDEC.

Check all permits that apply:
- ☑ Stream Disturbance
- ☑ Excavation and Fill in Navigable Waters
- ☐ Docks, Moorings or Platforms
- ☐ Dams and Impoundment Structures
- ☑ 401 Water Quality Certification *
- ☐ Freshwater Wetlands
- ☐ Tidal Wetlands
- ☐ Wild, Scenic and Recreational Rivers
- ☐ Coastal Erosion Management
- ☐ Water Withdrawal
- ☐ Long Island Well
- ☐ Incidental Take of Endangered / Threatened Species

* See Instructions Page 3

>US Army Corps of Engineers ☑ Check here to confirm you sent this form to USACE.

Check all permits that apply: ☐ Section 404 Clean Water Act ☐ Section 10 Rivers and Harbors Act

Is the project Federally funded? Yes No

If yes, name of Federal Agency:

General Permit Type(s), if known:

Preconstruction Notification: Yes No

>NYS Office of General Services ☐ Check here to confirm you sent this form to NYSOGS.

Check all permits that apply:
- ☐ State Owned Lands Under Water
- ☐ Utility Easement (pipelines, conduits, cables, etc.)
- ☐ Docks, Moorings or Platforms

>NYS Department of State ☐ Check here to confirm you sent this form to NYSDOS.

Check if this applies: ☐ Coastal Consistency Concurrence

2. Name of Applicant | Taxpayer ID (if applicant is NOT an individual)

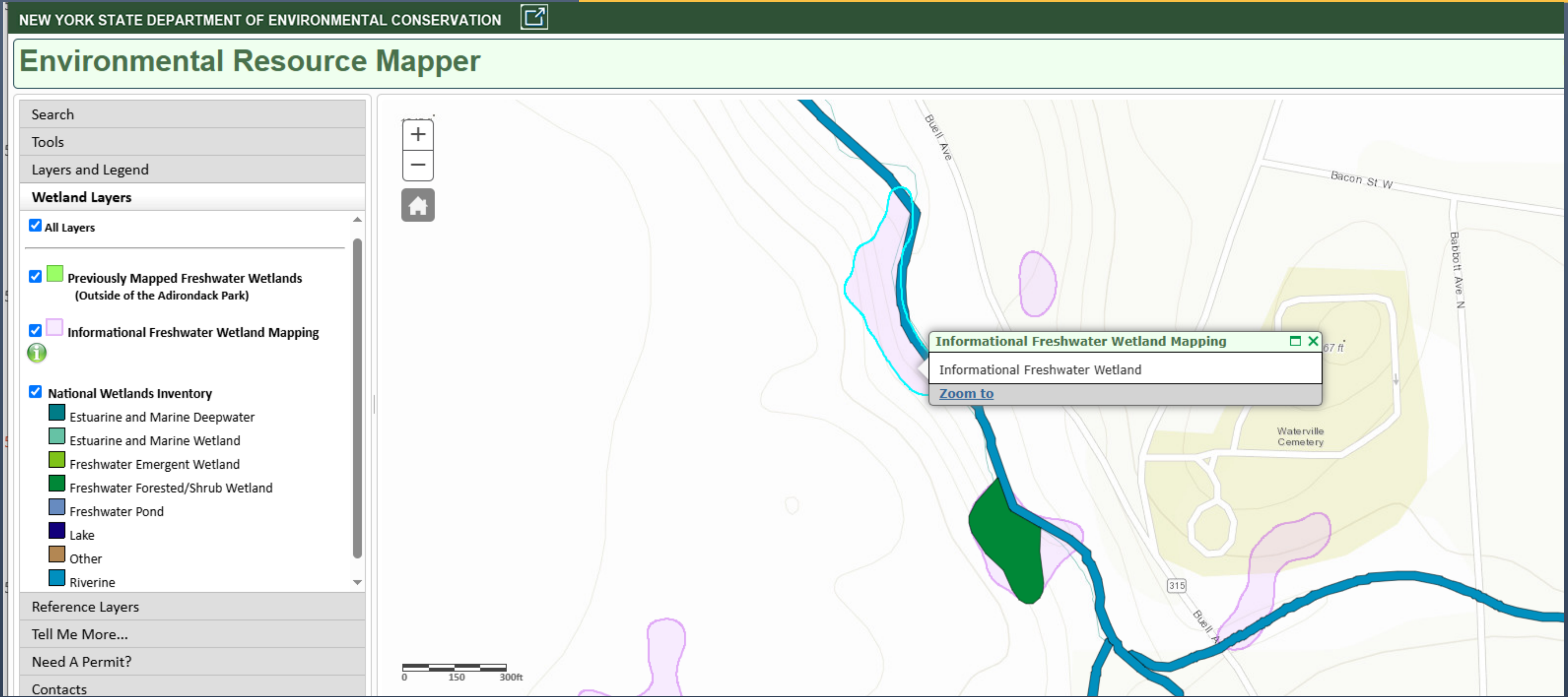
ACTIVITIES AUTHORIZED BY 2017 NATIONWIDE PERMIT WITHIN THE STATE OF NEW YORK

Expiration March 18, 2022

B. Nationwide Permits

Permitting!

- Even if Class C, need a DEC Water Quality Cert and USACE permit.
- Stream Classification
- Wetlands
- Natural Communities/Rare Plants or Animals
- Regulated Flood Hazard Areas may require HEC-RAS analysis.
- Cultural Resources
- Dam(s) in watershed; Hazard Level
- Dewatering Regs vary by Region and Watershed!



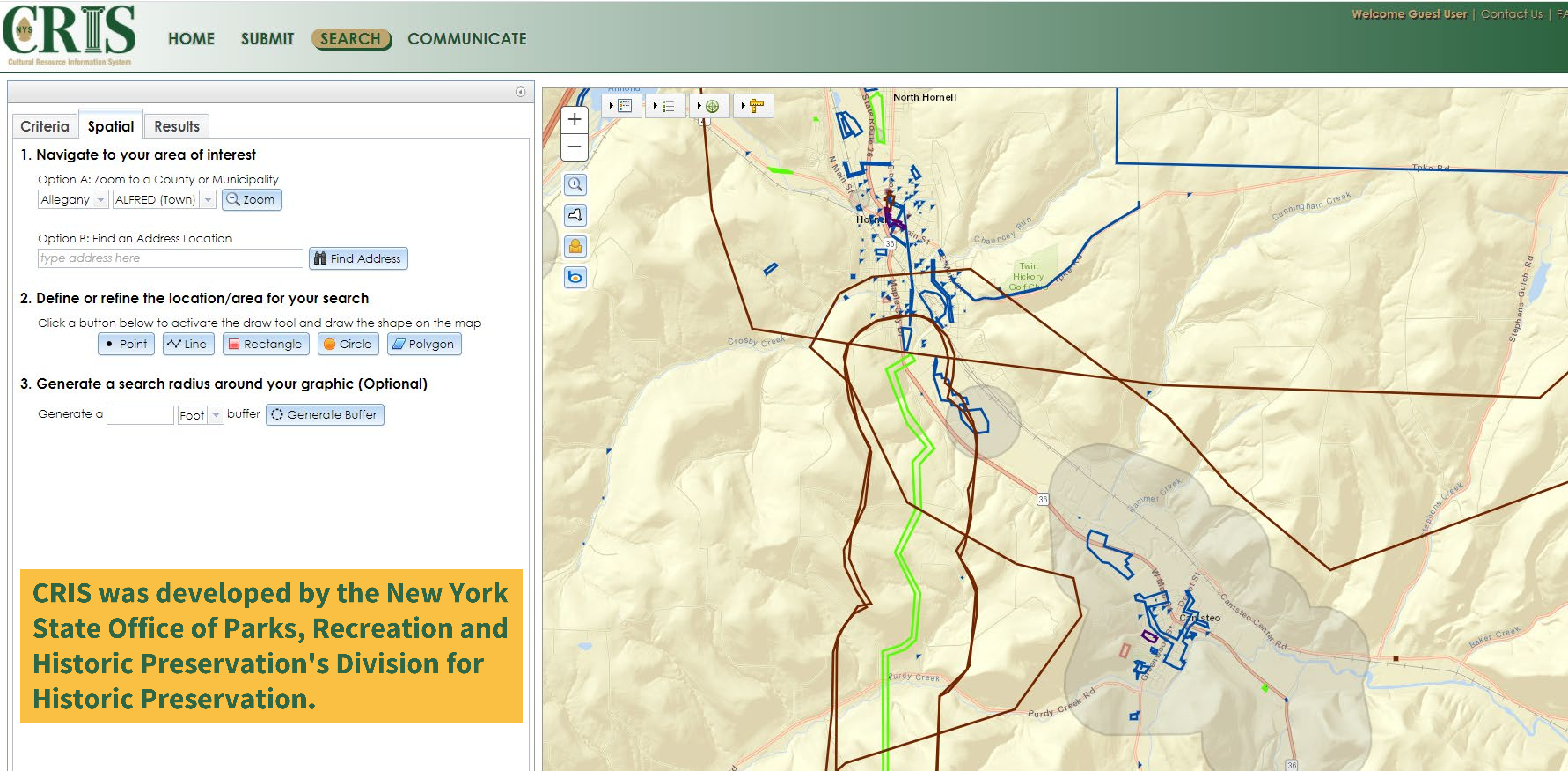
DEWATERING

Pump around is often required for the duration of the project.
Pump around must remain active during curing time.

DEWATERING


Dirty water gets pumped to a stable filtration site nearby with good vegetation.
Clean water gets pumped around and back into the creek to a stable section to prevent scour.

Permitting: Cultural Resources

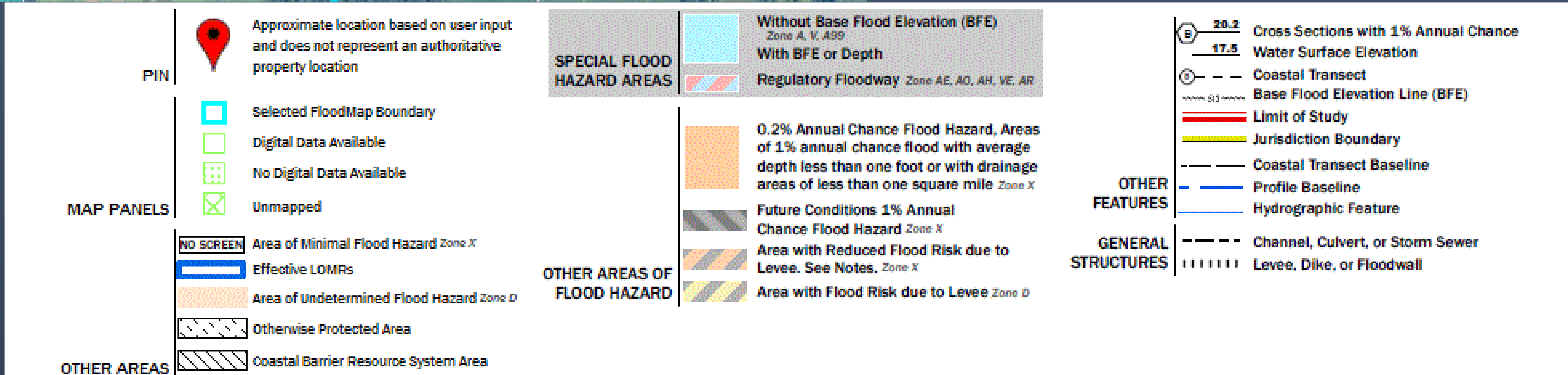


CRIS was developed by the New York State Office of Parks, Recreation and Historic Preservation's Division for Historic Preservation.

Permitting: Flood Zones

Work in regulated Flood Hazard Area may require HEC RAS to prove No Rise to meet local FP Regs

Quick check on Floodplains: FEMA Flood Map Service Center: Search By Address



USDA NRCS Web Soil Survey:

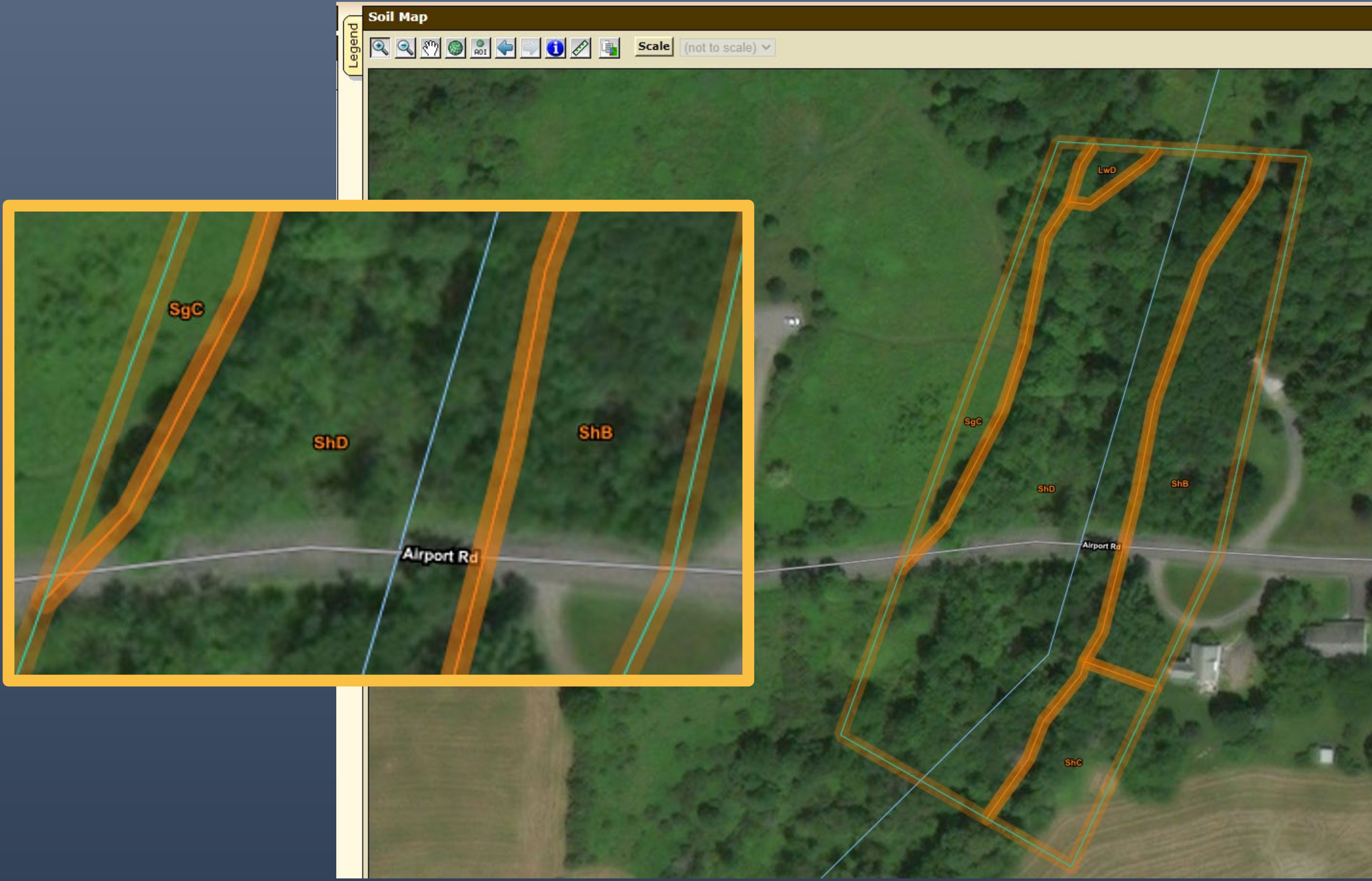
First step in Soil Bearing Capacity for structures.

Map Unit Legend

Madison County, New York (NY053)

Madison County, New York (NY053)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
LwD	Lordstown channery silt loam, 15 to 25 percent slopes	0.1	1.5%
SgC	Stockbridge channery silt loam, 8 to 15 percent slopes	0.3	7.2%
ShB	Stockbridge-Howard gravelly silt loams, 3 to 8 percent slopes	1.1	23.0%
ShC	Stockbridge-Howard gravelly silt loams, 8 to 15 percent slopes	0.4	8.7%
ShD	Stockbridge-Howard gravelly silt loams, 15 to 25 percent slopes	2.8	59.6%
Totals for Area of Interest		**4.7**	**100.0%**

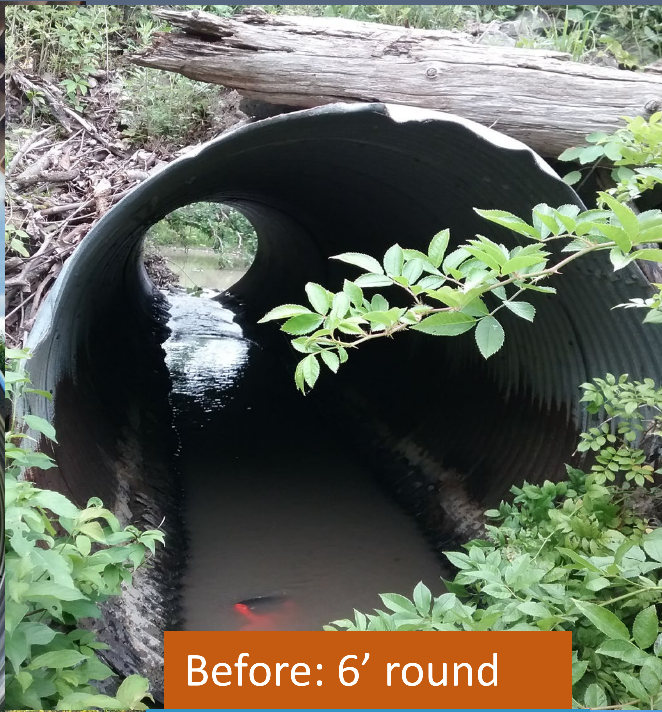


Replacement Options: Pipe Arch (Steel or Aluminum)

Pipe Arch:

- Gradient should be nearly flat (Avoid if >3% slope).
- Use when channel width is 13’ or less;
- Bury the pipe to create natural bed;
  - <40% at inlet; 20% at outlet
- Install with an excavator;
- Requires 18-30” of cover depending on span.
- Relatively low price: ~$600/foot; depends on span;
- Relatively quick install
- No Footers needed; use gravel for base below pipe.
- Rises are **high** so not ideal for sites with minimal cover.
- NOT FOR STEEP SITES!!

T/O Ghent built :
2 crossings
1 50’ & 1 20’
17’ x 10’ PA
70’ Pipe: $49,028



Before: 6’ round

After: 17’ pipe arch

Replacement Options: SRA

Single Radius Arch: Steel or Aluminum

If stream gradient is 3% or greater, open bottom required.

- Good for creating wide span with natural bed.
- Requires **concrete footers**
- Cast In Place requires curing time (~$500/cy).
- Extends duration of road closure.
- Low price for structure (~$500/ft) relative to ABC and Concrete. Depends on span.
- But, Footer costs vary based on local contractors.
- Footer design usually based on **Geotech**.
- Requires 18”-30” cover depending on span.
- EXTENSIVE DE-WATERING REQUIREMENTS UNTIL CURE TIME COMPLETED.

Replacement Options

Aluminum Box Culvert

- Ideal for wide-span low rise scenarios.
- Can be installed with 1.4’ cover minimum.
- Can be installed with full invert which reduces construction duration.
- STATE REGS: NO BOTTOMS ON SLOPES >3%
- If full invert is used (buried for natural bed): Max Cover is 4’
- Not good for sites with more than 4.5’ cover!
- MATERIAL More costly than SRA and PA; LABOR is easier.
- Place with an excavator.
- Concerns with durability voiced by some partners.
- Shell only: ~ $1200/ft (depends on span)
- Shell + Invert: ~$2000/ft or more (depends on span)

AVOID INSTALLATION HALF AT A TIME.

Replacement Options

Concrete :

- Ideal for wide span and minimal cover.
- Requires a crane for installation.
- Durable structure
- Most costly up front (>$3000/ft).
- 3 sided on footers or 4 sided box allow for natural bed.
- **BURY THE BOX** FOR A NATURAL BED!
- Use grade controls to hold bed material in place.

19’x8’x32’ Box
$75,442

Replacement Options

Pre-Fab Bridge (can be less than 20’ span)

- Ideal for wide span, low cover.
- Pre-fab components can be installed quickly (~$200/sf)
- Competitive pricing with ABCs depending on required span. (26’ between rails, 20’ length, ~$52,000, ($2600/ft)
- Cover not an issue
- Good for sites with alignment issues.

Bridges:

- Any span >20’ is a “bridge” (NYS).
- If Bankfull width is over 17 feet, then the 1.25x rule can result in a bridge.
- USACE allows span to equal width at 50% flow.
- If Drainage Area is ~ 0.75 square miles (~450 acres), a bridge may be recommended.
- Bridges usually require more stringent design
- Bridges require annual inspection to conform with NYSDOT requirements.
- **Cost:Benefit important especially on low traffic crossings.**

Laurel Creek
Single lane bridge
~$22,000
and prefab blocks:
~$12,000

A Cautionary Tale

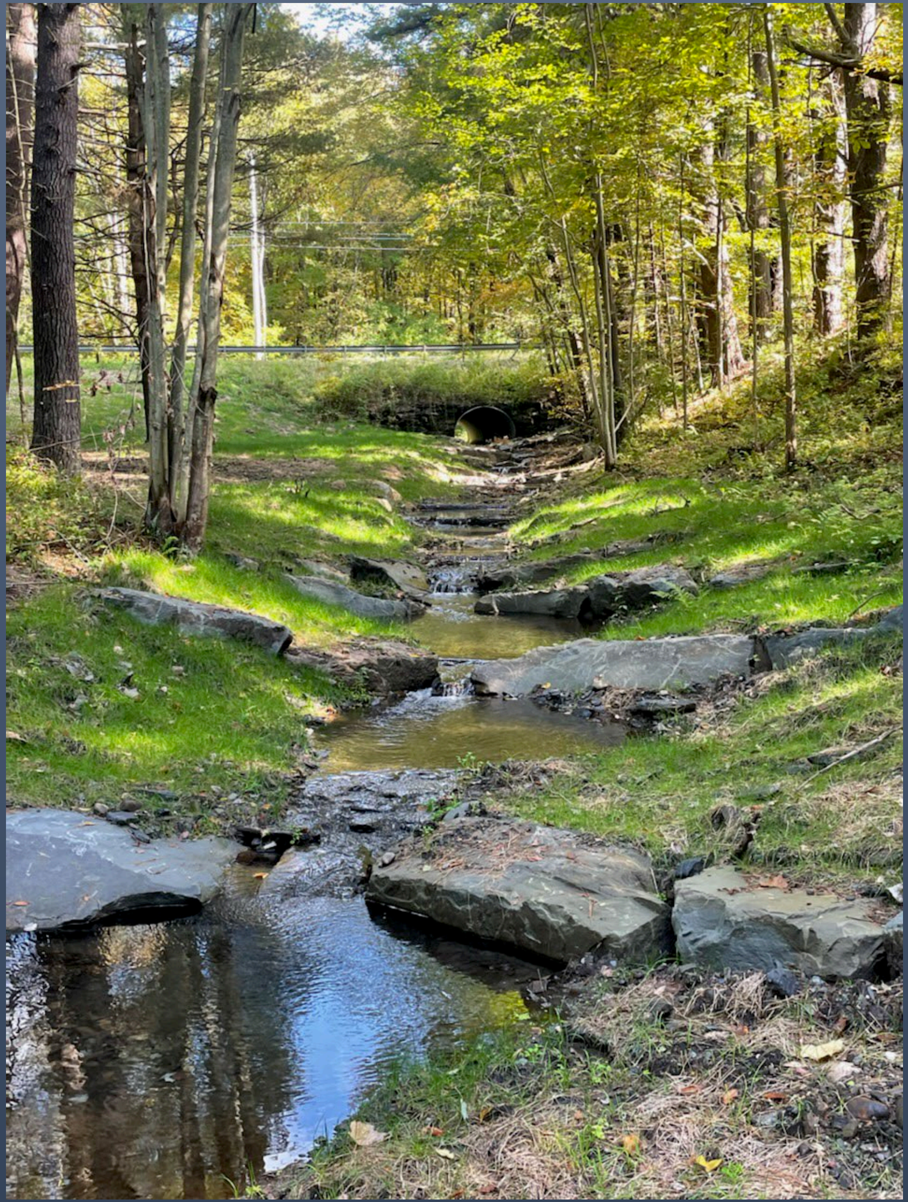
Each site is different with different challenges and constraints!

Avoid Multiple Pipes – prone to blockage.

Smooth, round pipes set at-grade are common culprits in failures and barriers.

Retrofitting:

Restoring Connectivity in Existing Structure



TROUT UNLIMITED

Consider Downstream Grade Controls to restore a natural bed and reconnect the stream.

11 grade controls + private dam removal, $37,000

Cost

Replacement is Expensive but there is help!

- PLEASE DON'T REPLACE A CULVERT BASED SOLELY ON COST!
- ALMOST ALWAYS THE DRIVING FACTOR IN PERMANENTLY UNDERSIZED INFRASTRUCTURE!
- FEDERAL/STATE/NONPROFIT ASSISTANCE LIKELY AVAILABLE.

	Option 1	Option 2
Size	16'8"x7'6"x50'	16'x8'4"x50'
Flow (cfs)	900	800
Type	ABC	SRA
Lifespan (yrs)	50	50
Constructability	ABC with invert can reduce constrution duration	SRA requires footers to cure which prolongs construction time and road closure duration.
Maintenance	Minimal	Minimal
Road Closure	1 week	1 month
Costs		
Structure	$ 47,350.00	$ 13,200.00
Footer	$ 11,313.00	$ 11,378.00
Grade Control	$ 2,333.00	$ 2,333.00
Headwall/Wingwall	$ 7,038.00	$ 7,038.00
Dewatering	$ 5,000.00	$ 5,000.00
E&S/Restoration	$ 1,000.00	$ 1,000.00
Labor	$ 26,250.00	$ 33,250.00
Road Resurfacing	$ 10,000.00	$ 10,000.00
Sub-Total	**$ 110,284.00**	**$ 83,199.00**
15% Contingency	$ 16,542.60	$ 12,479.85
Total Estimated	$ 126,826.60	$ 95,678.85

Municipal Match: Range of Opportunities

Trucking
Road Restoration
Guard Rail
Installation
Project Installation

Case Studies: Brewery and Long Pond
WQIP Round 18 (C01898GG)

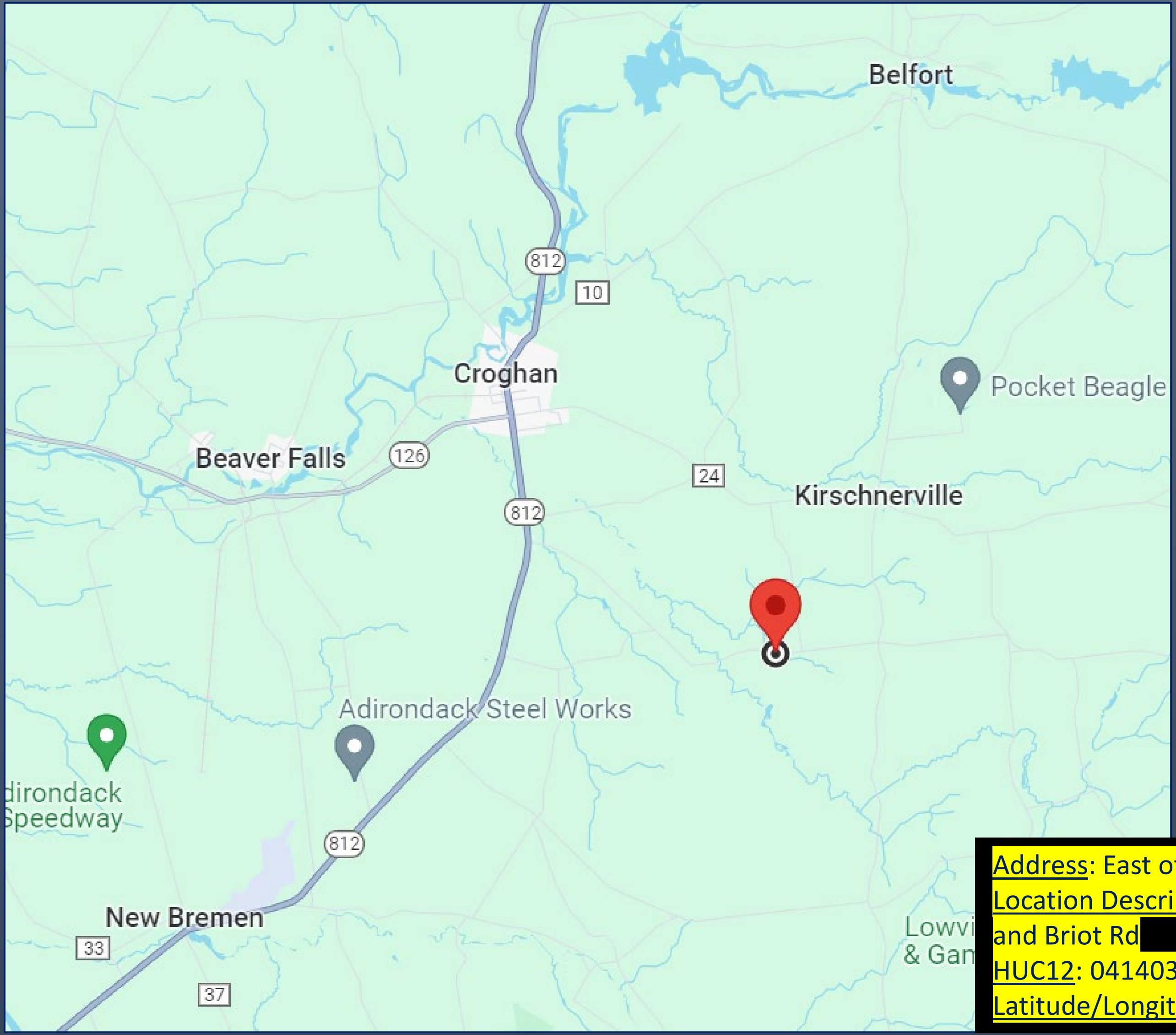
<u>Brewery</u>: <u>Class C(T) Un-named Tributary to Black Creek</u>
Reconnection: ~ 3 miles
DA: 0.98 sm
NAACC Significant Barrier, 3’ corrug metal.
8’ Bankfull Width
Capacity increased from ~ 50 cfs to ~ 400 cfs.
11’9”x7’2” Embedded Pipe Arch
Completed in 2 days by Hodge Creek Excavating
Hydroseeded by SWCD.

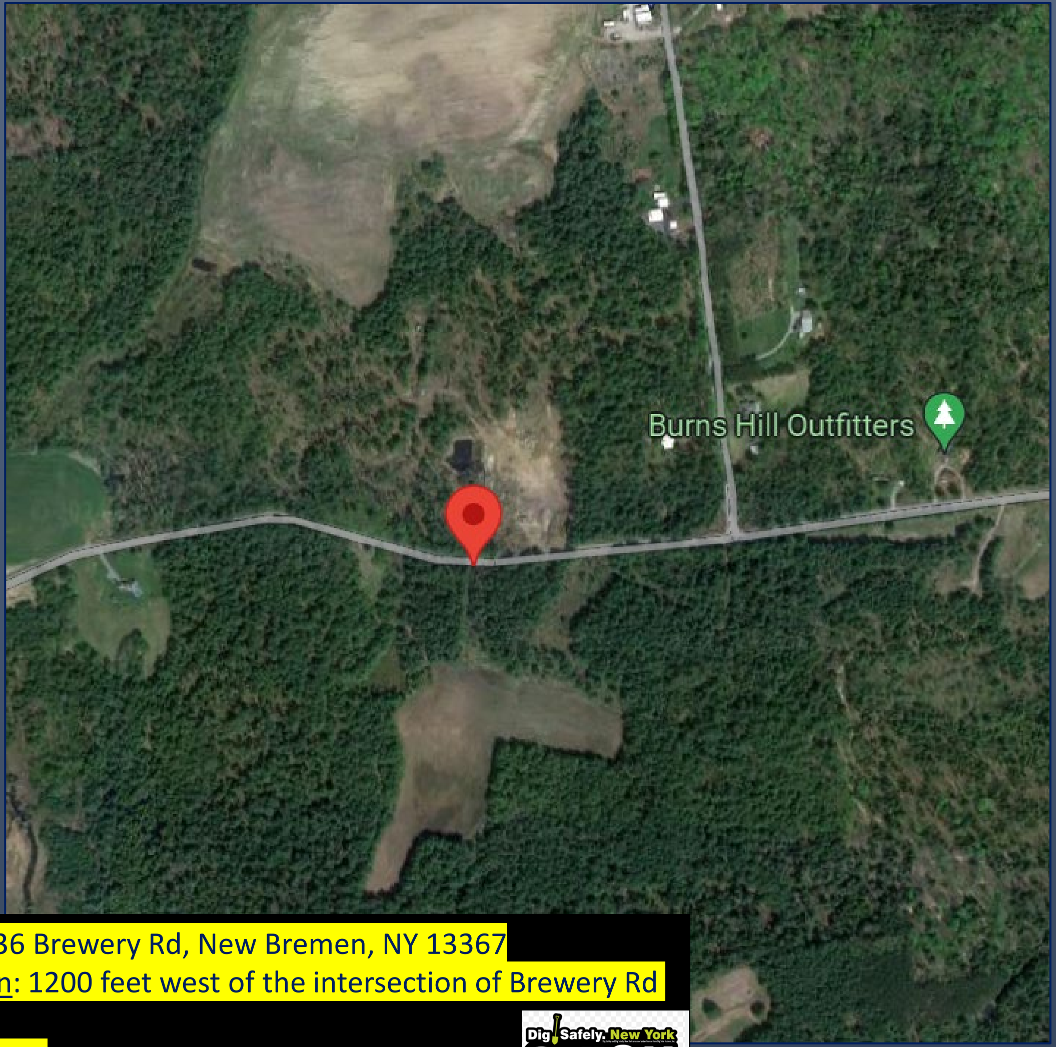
<u>Long Pond: Warner Brook, trib to Balsam Creek</u>
Reconnection: up to 10.7 miles
DA ~ 3 sm
NAACC Significant Barrier, 3’ corrug metal.
10’ BFw,
Capacity increased from ~ 70 cfs to ~ 400 cfs
13’3” span x 6’9” embedded ABC.
Completed in 3 days by Hodge Creek.
Hydroseeded by SWCD
EXTREMELY CHALLENGING SITE: Traffic, utilities, wetlands, schedule, soils, pipe fittings.

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY

Permit Designs Version 1

June 6, 2025





Address: East of 7236 Brewery Rd, New Bremen, NY 13367

Location Description: 1200 feet west of the intersection of Brewery Rd and Briot Rd

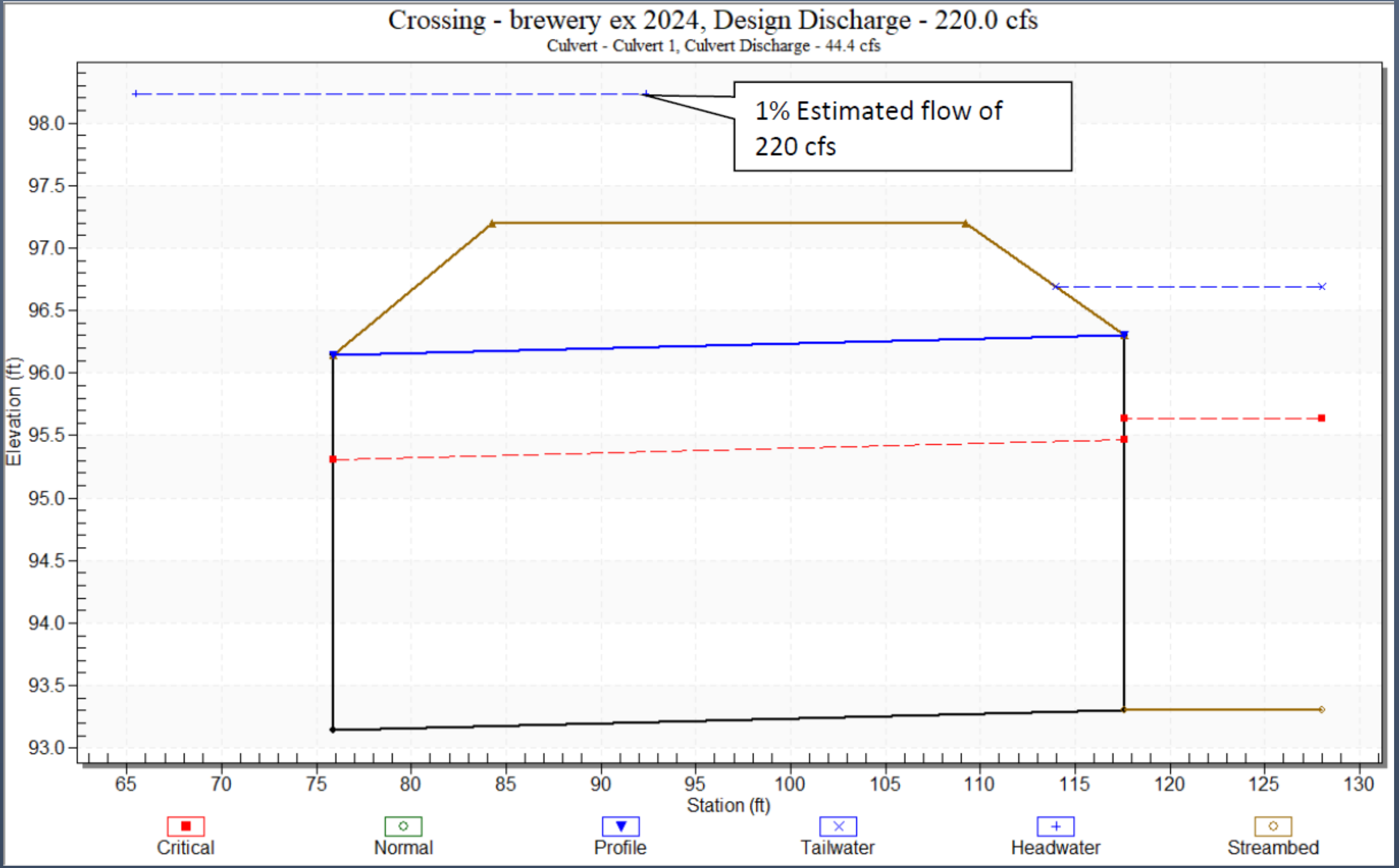
HUC12: 041403011105

Latitude/Longitude: 43.866000, -75.352210

Dig Safely. New York Call 811 before you dig

Last Updated 6/6/2025

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY

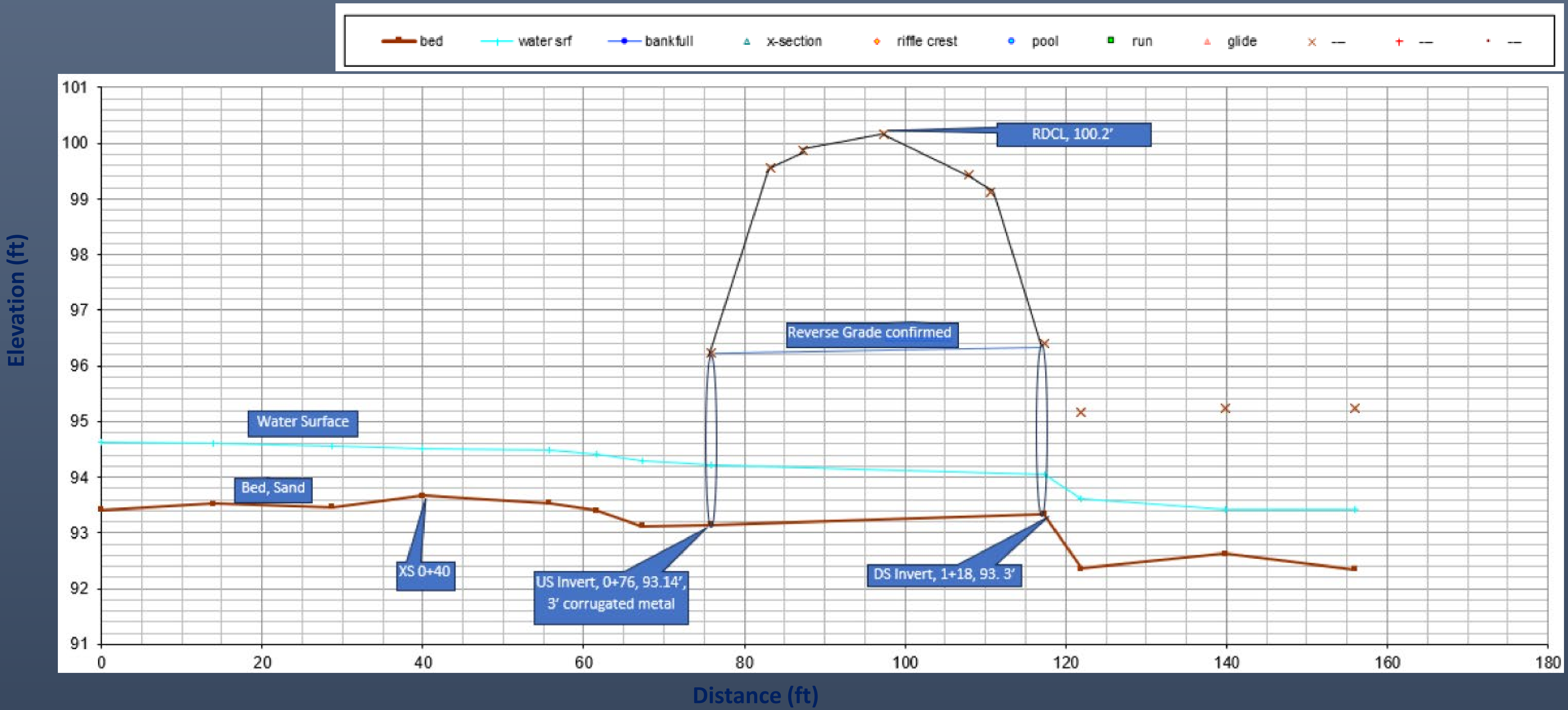


Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
97.61	100.00	56.09	43.86	7
97.72	120.00	57.36	62.62	6
97.82	140.00	58.49	81.46	5
97.91	160.00	59.53	100.44	5
98.06	180.00	46.55	133.45	6
98.15	200.00	45.45	154.55	5
98.23	220.00	44.39	175.59	4
98.32	240.00	43.38	196.61	4
98.39	260.00	42.40	217.59	4
98.47	280.00	41.45	238.54	4
98.54	300.00	40.53	259.47	4
97.20	47.65	47.65	0.00	Overtopping

HY-8 Analysis showing existing conditions.

HY-8 Analysis (Existing Conditions)

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY

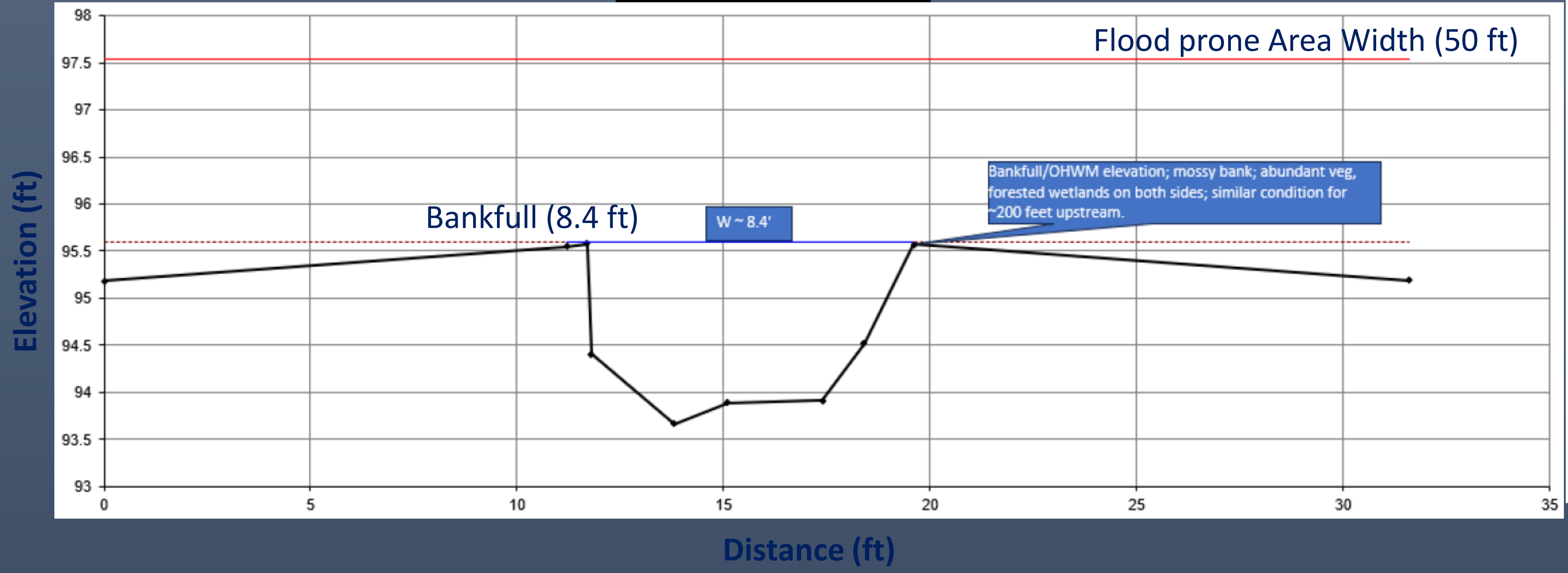


Current Conditions – Longitudinal Profile

Last Updated 6/6/2025

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY

X 0+40 Riffle



Bankfull Dimensions	
11.5	x-section area (ft.sq.)
8.4	width (ft)
1.4	mean depth (ft)
1.9	max depth (ft)
10.2	wetted parimeter (ft)
1.1	hyd radi (ft)
6.1	width-depth ratio

Flood Dimensions	
50.0	W flood prone area (ft)
6.0	entrenchment ratio
1.9	low bank height (ft)
1.0	low bank height ratio

Bankfull Flow	
5.8	velocity (ft/s)
67.3	discharge rate (cfs)
0.97	Froude number

Flow Resistance	
0.028	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.7	resistance factor u/u*
15.5	relative roughness

Materials	
9.1	D50 Riffle (mm)
27	D84 Riffle (mm)
35	threshold grain size (mm):

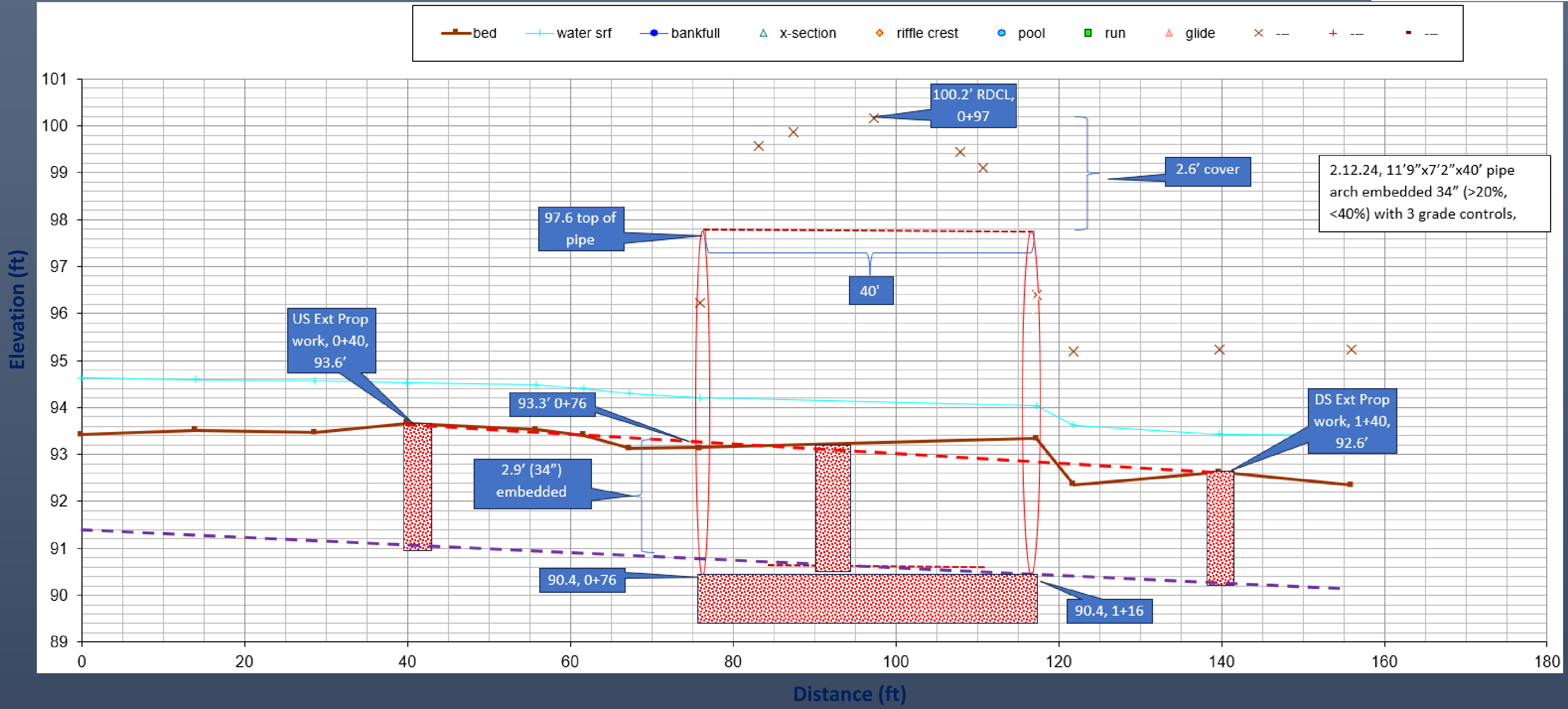
Forces & Power	
1	channel slope (%)
0.71	shear stress (lb/sq.ft.)
0.60	shear velocity (ft/s)
5	unit strm power (lb/ft/s)

Current Conditions – Cross-sections

Cross Section Notes:
1) All cross sections are facing downstream.
2) River left and river right are facing downstream
3) All dimensions in feet unless otherwise noted.
4) WFPA is the Width of the Flood prone Area drawn at 2x the maximum Bankfull depth.
5) Bankfull elevations shown are based on features identified in the field.
6) In scenarios where bankfull features are not discernable in the field we use active channel indicators such as vegetation.

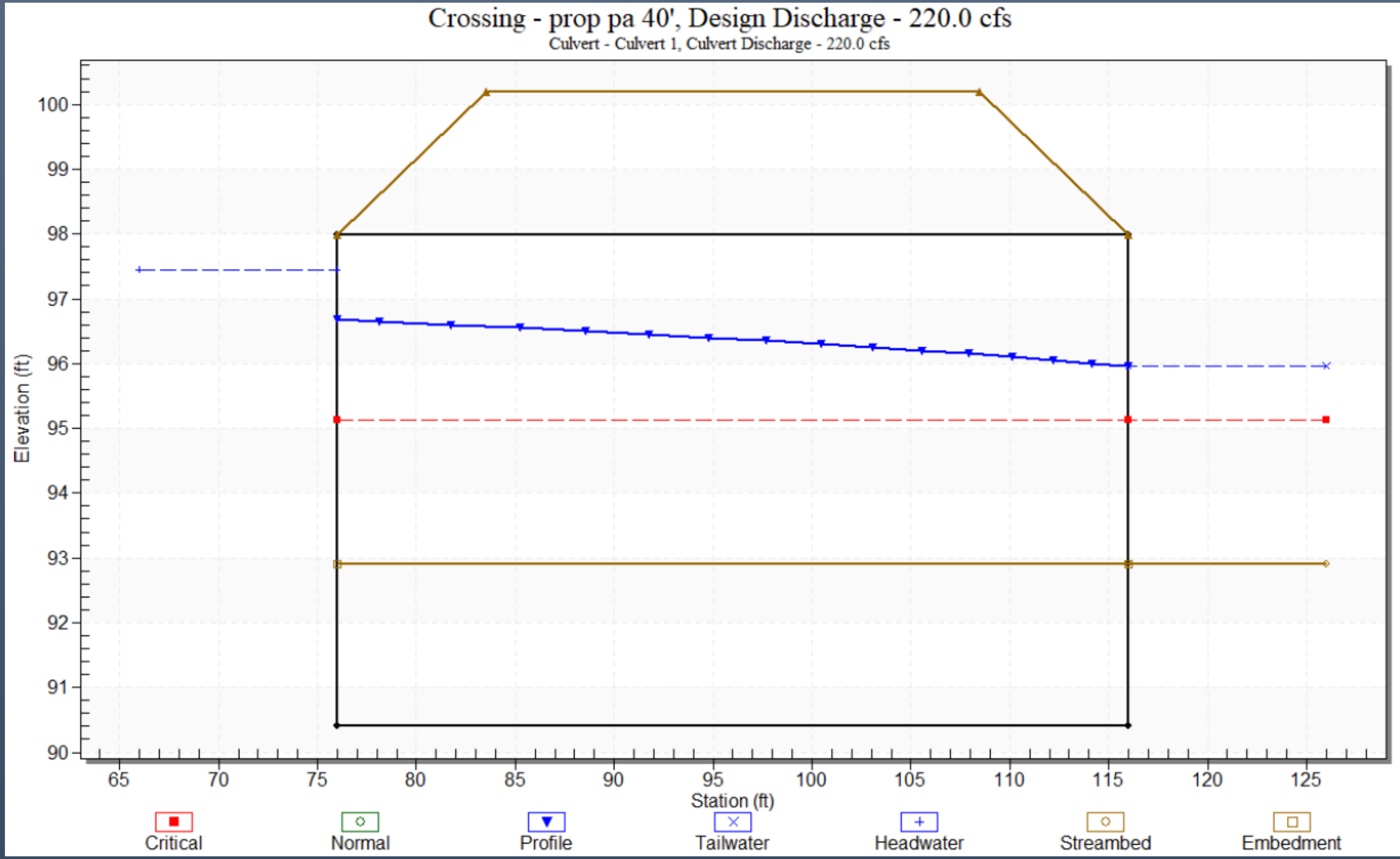
Last Updated 6/6/2025

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY



Proposed Conditions – Longitudinal Profile

Trout Unlimited Brewery Rd Culvert Replacement Project – Town of New Bremen, NY



Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
97.02	190.00	190.00	0.00	1
97.17	201.00	201.00	0.00	1
97.33	212.00	212.00	0.00	1
97.44	220.00	220.00	0.00	1
97.64	234.00	234.00	0.00	1
97.79	245.00	245.00	0.00	1
97.94	256.00	256.00	0.00	1
98.10	267.00	267.00	0.00	1
98.25	278.00	278.00	0.00	1
98.41	289.00	289.00	0.00	1
98.57	300.00	300.00	0.00	1
100.20	438.86	438.86	0.00	Overtopping

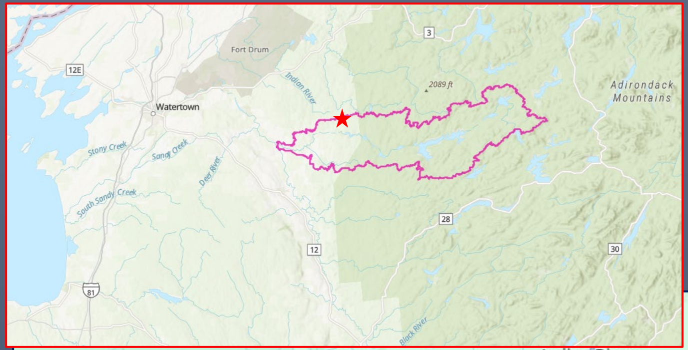
HY-8 Analysis showing proposed conditions.

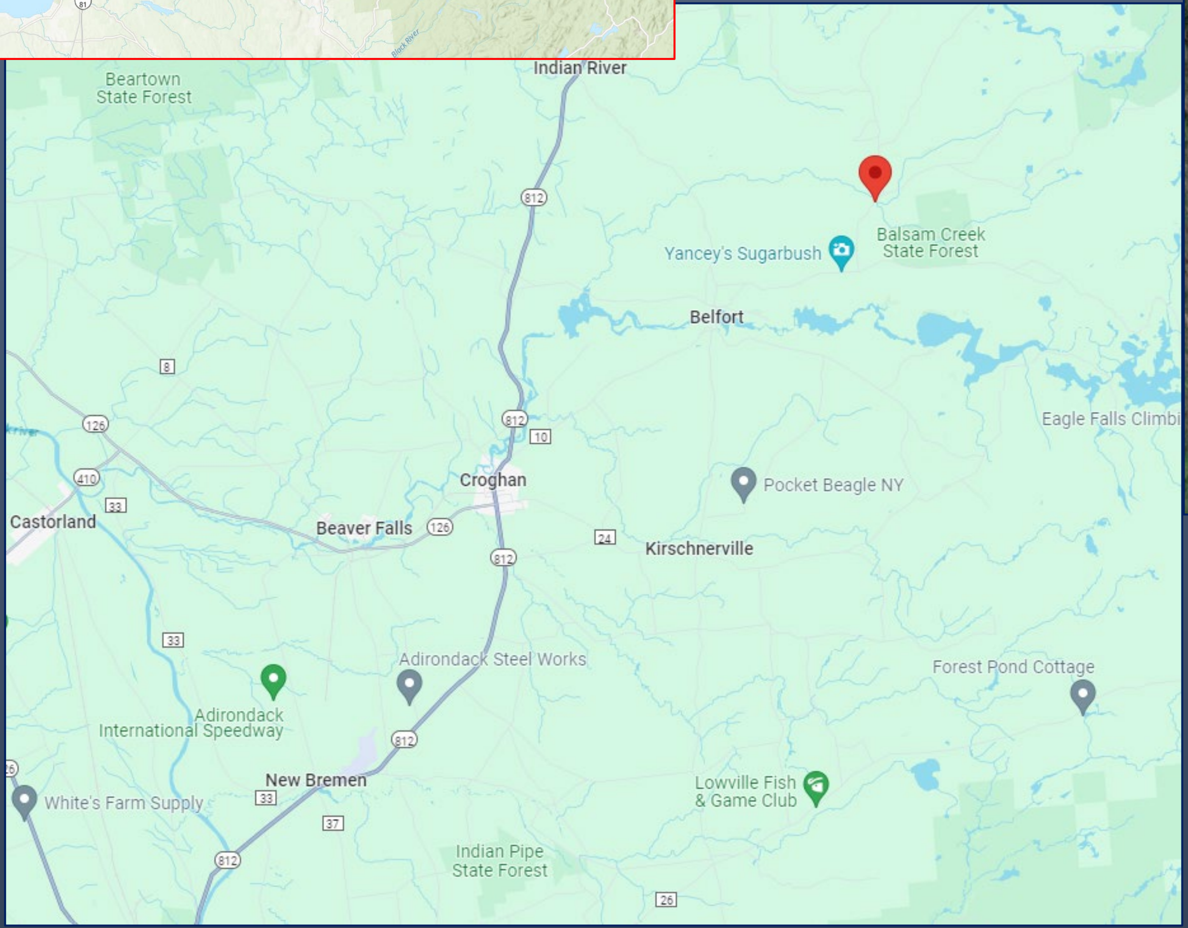
HY-8 Analysis (Proposed Conditions)

Brewery Road: Before and After

TU Long Pond Road Over Warner Creek Culvert Replacement Project
Town of Croghan NY

Permit Designs Version 1
June 6, 2025





<u>Address</u>: Near 8235 Long Pond Rd., Croghan, NY 13327

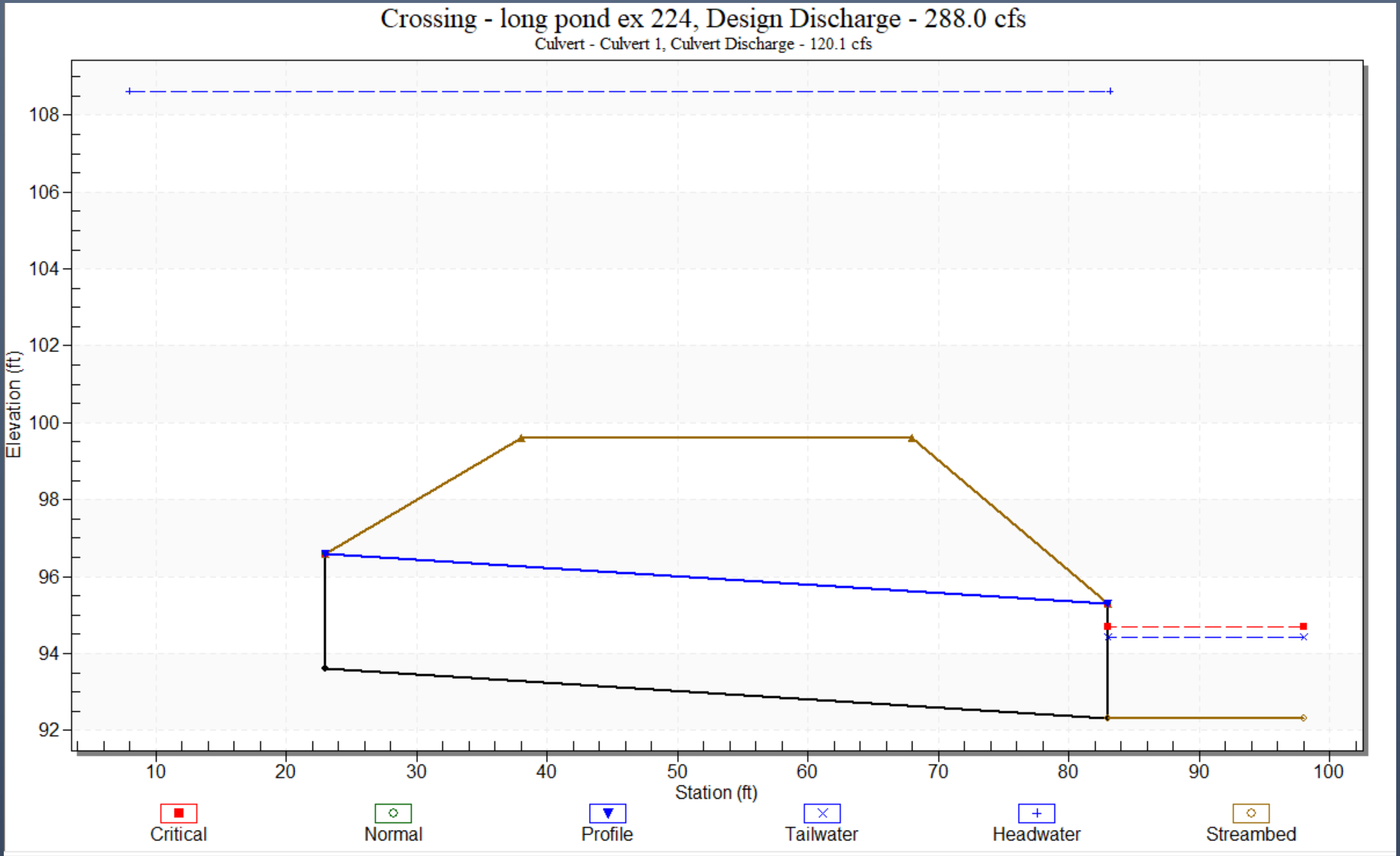
<u>Location Description</u>: The Warner Creek crossing is located on Long Pond Road feet ~500' south/southwest of the intersection of Long Pond Road and Bisha (or Kilbourn) Road in the Town of Croghan in Lewis County (Figure 1).

<u>HUC12</u>: 041403011103

<u>Latitude/Longitude</u>: <u>43.95102, -75.28877</u>

Updated 6/6/2025

TU Long Pond Road Over Warner Creek Culvert Replacement – Town of Croghan, NY

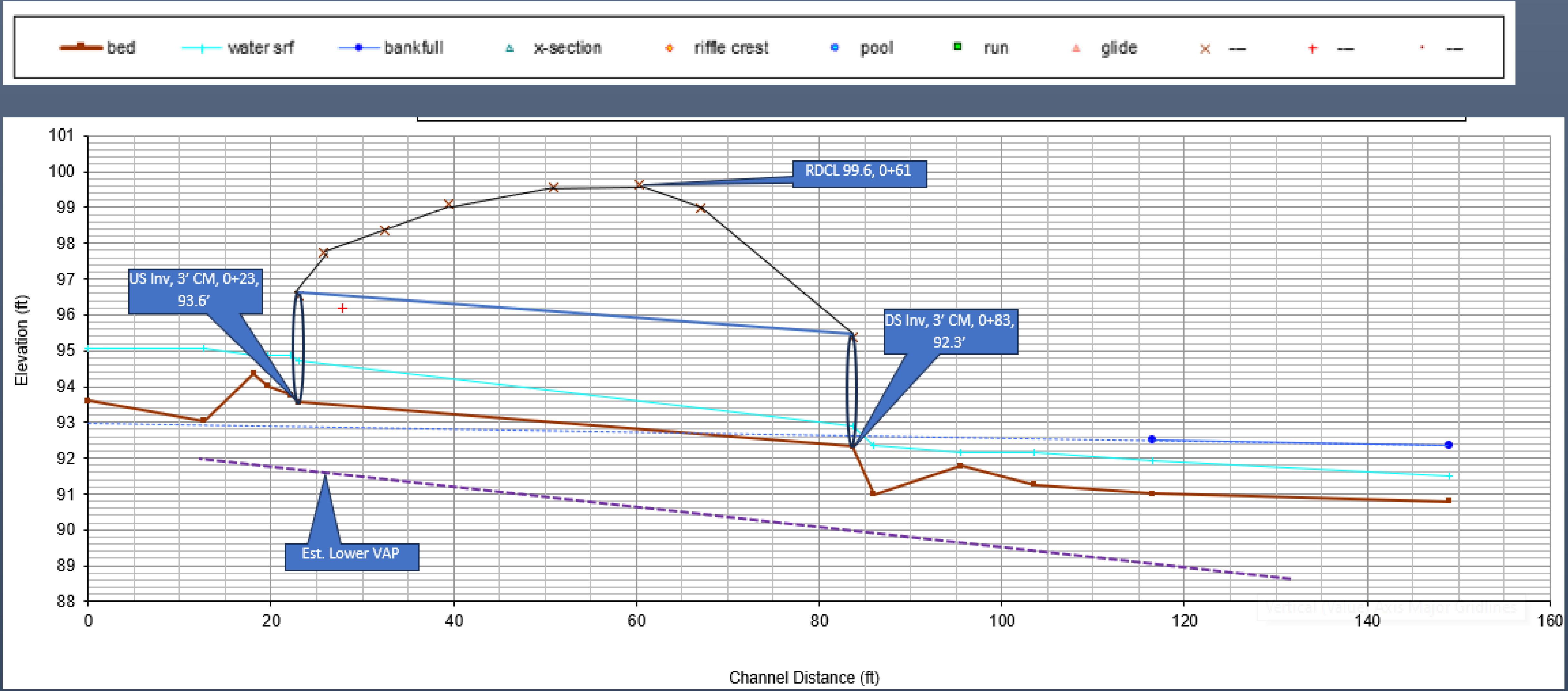


HY-8 Analysis showing existing conditions

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
107.59	255.00	115.39	139.61	17
107.74	259.50	116.06	143.44	3
107.88	264.00	116.73	147.27	3
108.02	268.50	117.39	151.11	3
108.16	273.00	118.03	154.97	3
108.30	277.50	118.67	158.83	3
108.44	282.00	119.30	162.70	3
108.63	288.00	120.13	167.87	3
108.72	291.00	120.55	170.45	3
108.86	295.50	121.17	174.33	3
108.99	300.00	121.78	178.22	3
99.60	69.57	69.57	0.00	Overtopping

HY-8 Analysis

TU Long Pond Road Over Warner Creek Culvert Replacement – Town of Croghan, NY

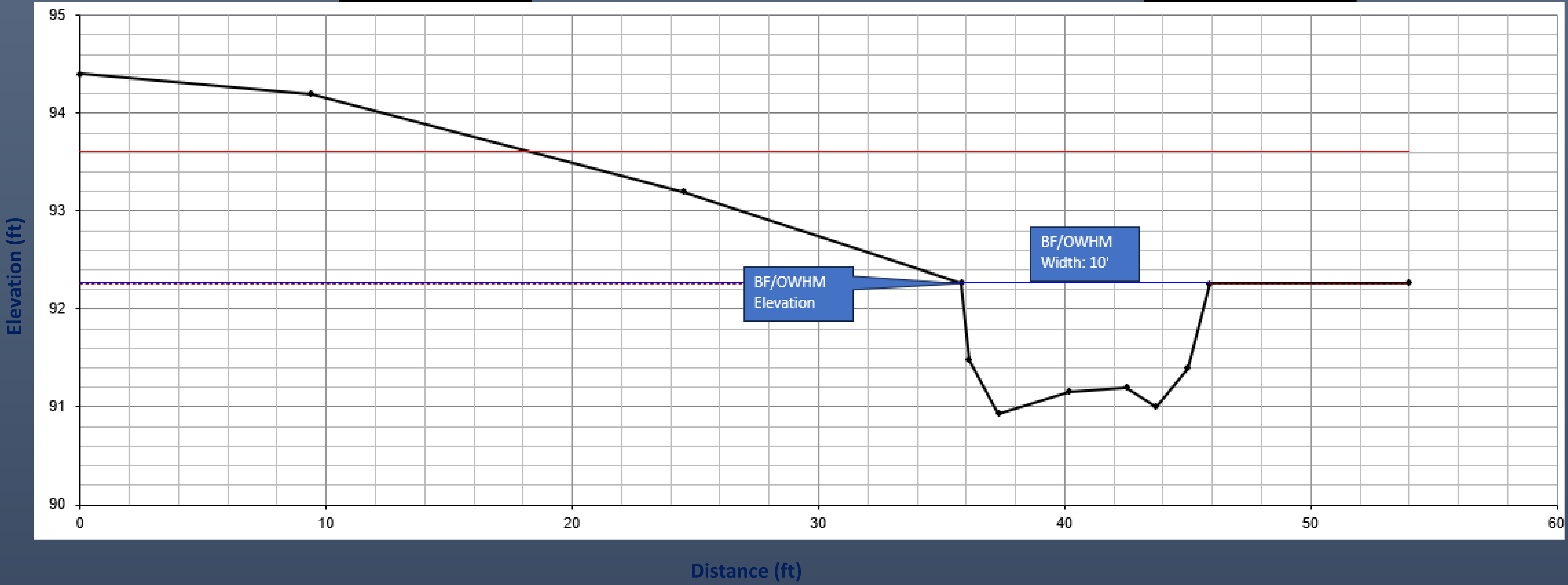


Current Conditions – Longitudinal Profile

Last Updated 6/6/2025

TU Long Pond Road Over Warner Creek Culvert Replacement – Town of Croghan, NY

[redacted] [redacted]



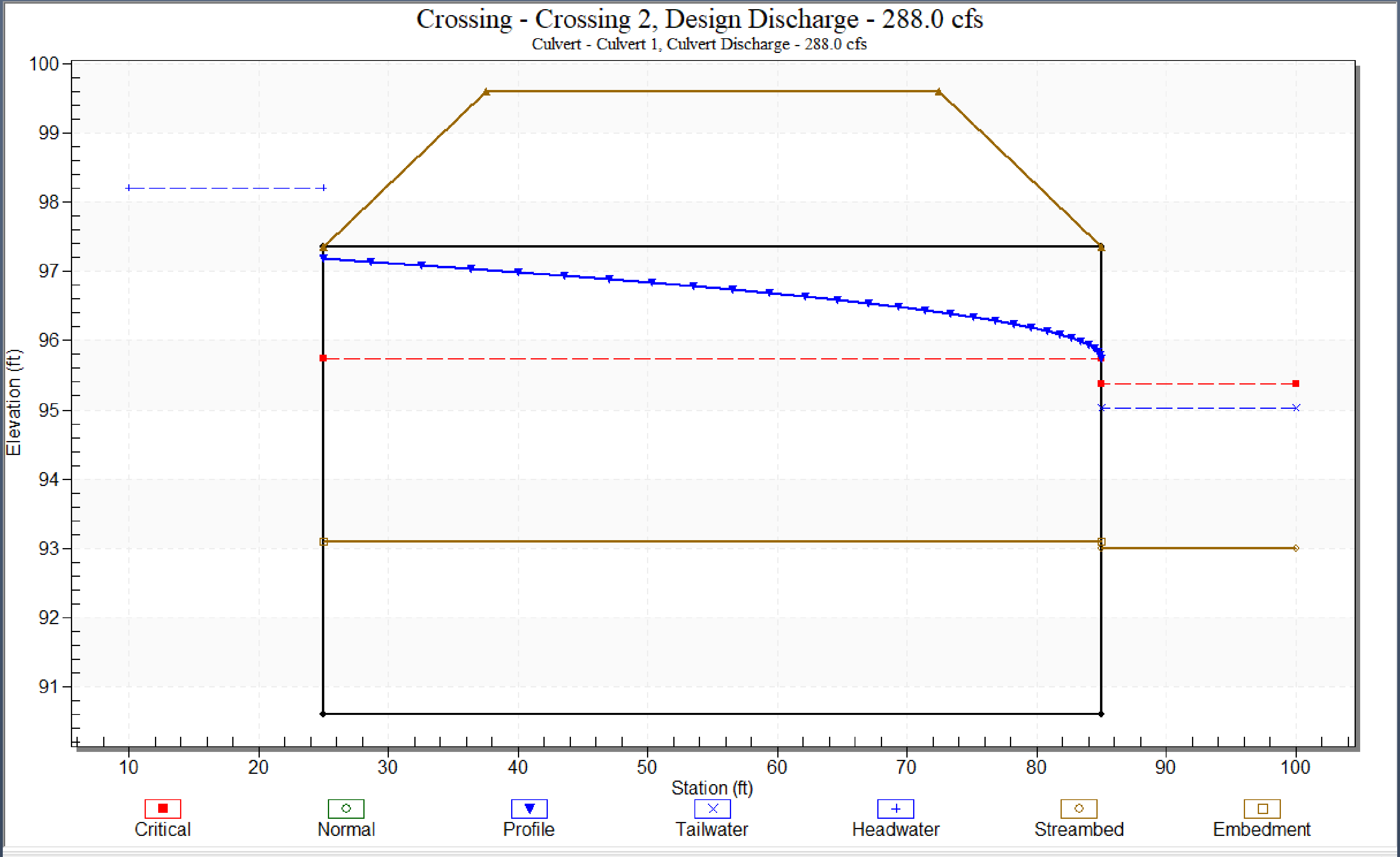
Current Conditions – Cross-sections

Cross Section Notes:

1) All cross sections are facing downstream.
2) River left and river right are facing downstream
3) All dimensions in feet unless otherwise noted.
4) WFPA is the Width of the Flood prone Area drawn at 2x the maximum Bankfull depth.
5) Bankfull elevations shown are based on features identified in the field.
6) In scenarios where bankfull features are not discernable in the field we use active channel indicators such as vegetation.

Last Updated 6/6/2025

TU Long Pond Road Over Warner Creek Culvert Replacement – Town of Croghan, NY

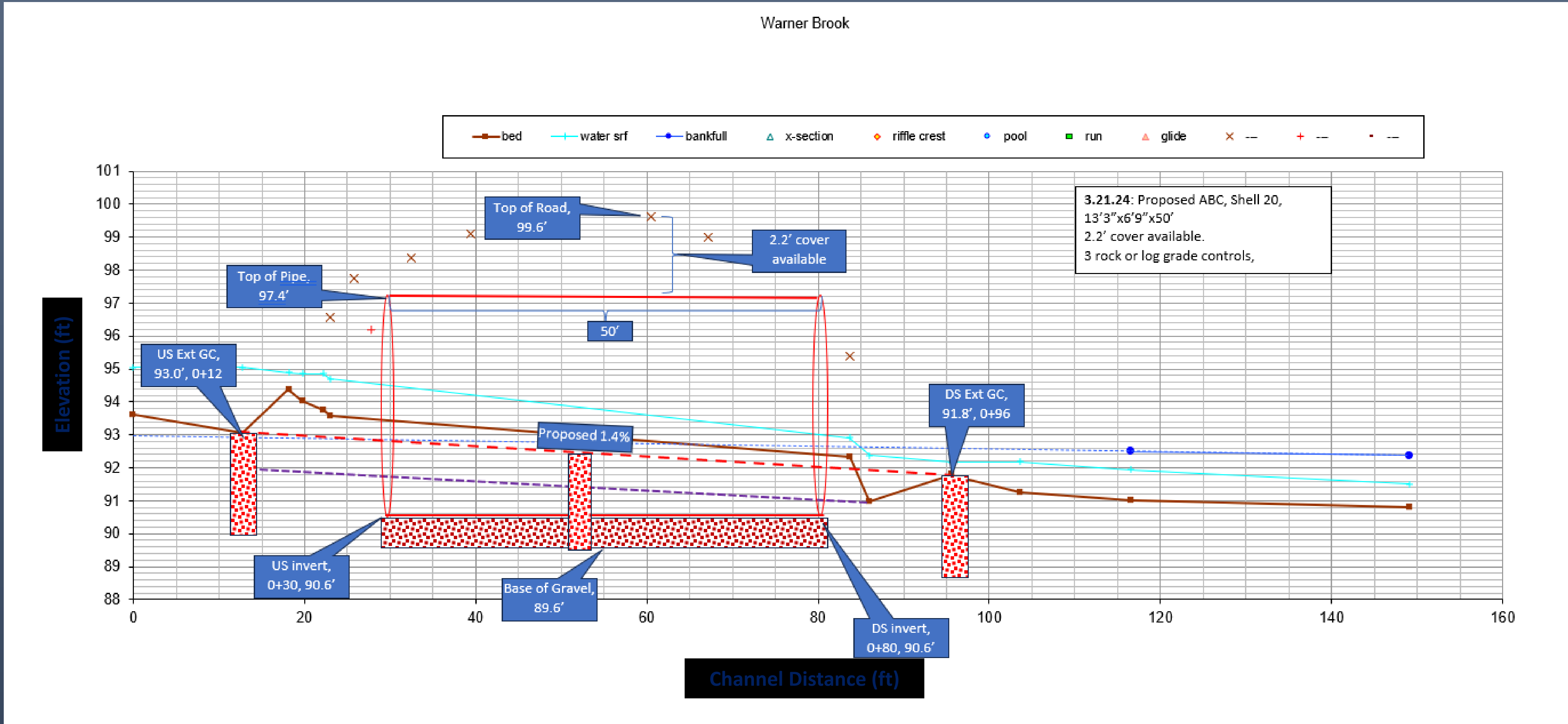


HY-8 Analysis showing estimated capacity of proposed ABC structure

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
95.64	100.00	100.00	0.00	1
95.95	120.00	120.00	0.00	1
96.24	140.00	140.00	0.00	1
96.51	160.00	160.00	0.00	1
96.78	180.00	180.00	0.00	1
97.05	200.00	200.00	0.00	1
97.31	220.00	220.00	0.00	1
97.56	240.00	240.00	0.00	1
97.82	260.00	260.00	0.00	1
98.19	288.00	288.00	0.00	1
98.37	300.00	300.00	0.00	1
99.60	435.96	435.96	0.00	Overtopping

HY-8 Analysis

TU Long Pond Road Over Warner Creek Culvert Replacement – Town of Croghan, NY



Proposed Conditions – Longitudinal Profile

Long Pond Road: Before and After

Helpful References


U.S. Department
of Agriculture

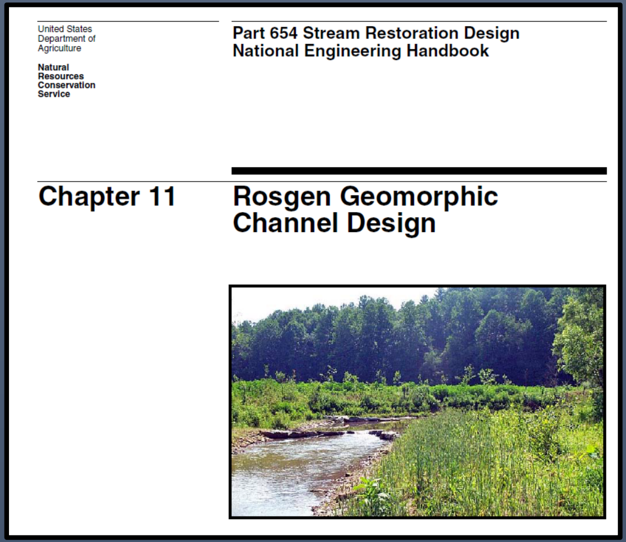
Forest Service

National Technology
and Development
Program

7700—Transportation Mgmt
0877 1801—SDTDC
August 2008

STREAM SIMULATION:
An Ecological Approach
to Providing Passage for
Aquatic Organisms at
Road-Stream Crossings

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054564.pdf


United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Part 654 Stream Restoration Design
National Engineering Handbook

Chapter 11

Rosgen Geomorphic
Channel Design


Natural Channel Design
REVIEW CHECKLIST

StreamMechanics

Questions ?

Jo-Anne Humphreys
Joanne.Humphreys@tu.org