HIGH DEFNITION STREAM SURVEY

Documenting Stream Corridor Condition and Trout Habitat on the Upper Delaware River and Tributary Streams

Prepared by James Parham, Ph.D.
Trutta Environmental Solutions

Water Water Everywhere – Oct 2022

Thanks to:

- National Fish and Wildlife Foundation in collaboration with:
- Friends of the Upper Delaware River,
- Division of Fish and Wildlife, New York Department of Environmental Conservation & Pennsylvania Fish and Boat Commission
  - As Part of the 3-year Upper Delaware River Joint Fisheries Investigation Plan
- Embrace a Stream Program of Trout Unlimited and the Shehawken Chapter of Trout Unlimited
- Upper Delaware Scenic and Recreational River, National Park Service

Stream/River Management & Restoration

The goal of ecological stream management and restoration is to restore the stream ecosystem's physical, chemical, and biological composition as close as possible to the native state given the permanent watershed alterations[1]

The five most common goals

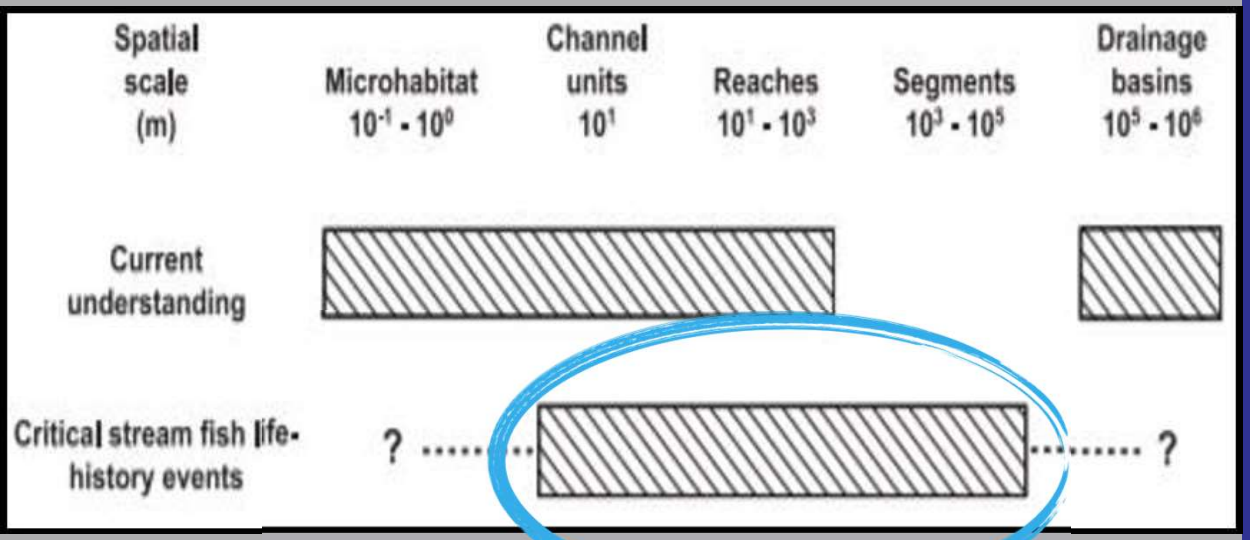
- improve water quality;
- manage riparian zones;
- improve in-stream habitat;
- allow for fish passage and
- stabilize stream banks[2]

Where? Why? How?

[1] Murdock, 2005; [2] Bernhardt et al. 2008

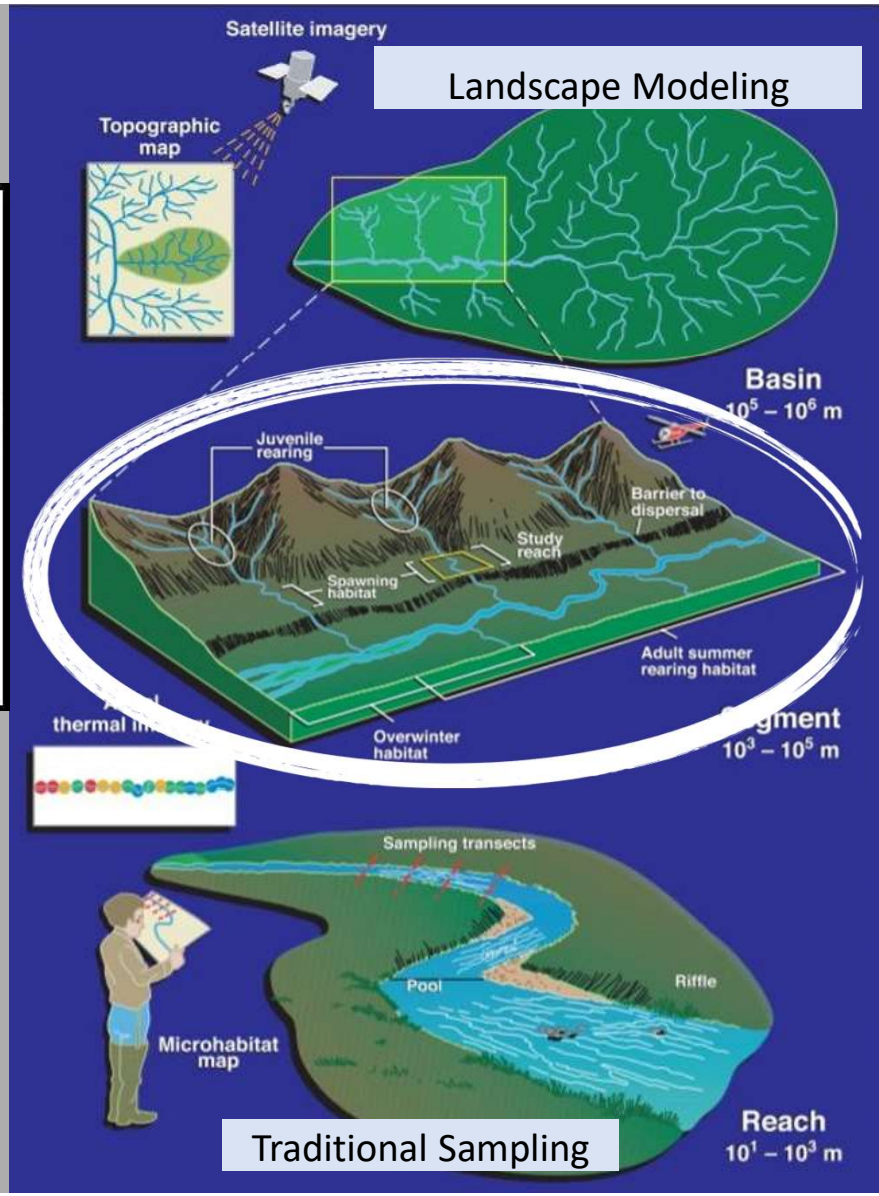
DRAWBACKS TO TRADITIONAL SAMPLING

- ACCESS
- AREA
- TIME
- FLOW/DEPTH LIMITS
- Stream Walks Only Documents Bad Areas



Fausch et al. 2002. Landscapes to Riverscapes: Bridging the [illegible] between Research and Conservation [illegible]stream Fishes. BioScience

Intermediate scale = 1 to 100 km



Hydropower

Stormwater
MS4

Transportation

Water Quality
- Longitudinal Profile
- Tributary input
- Sediment TMDLs
- Point & Non-Point Source Impacts

Water Quantity
- Channel Profiles
- Channel Capacity
- Flood Risk Models
- Drought impacts
- Instream Flow

Habitat
- Riffle, Run, Pool Delineation
- Substrate Types
- Embeddedness
- Instream Cover
- Riparian Condition

HDSS
Cross-sectional Transects and Longitudinal Surveys

Infrastructure
Location, Extent & Condition of:
- Bridges
- Intakes & Outfalls
- Bank Stabilization
- Dams, etc.

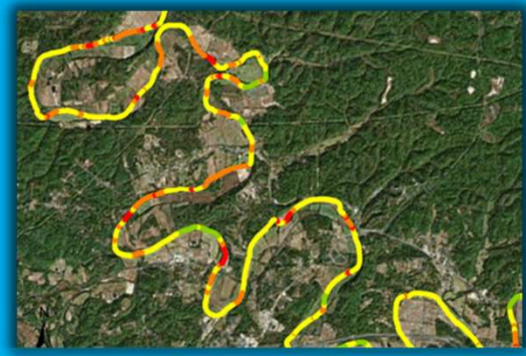
Outreach
- Virtual Stream Tours
- Integrates with Aerial Imagery
- StreamView Dashboards show data and stream conditions

Stream Corridor Assessment
- Current Conditions Archive
- Restoration Prioritization
- Mitigation Potential

Integrated Planning Framework
HDSS supports integrated planning by providing high-quality, multi-attribute, geo-referenced data of the entire stream channel

Wildlife

Environmental
& Non-Profits



How do we collect data?

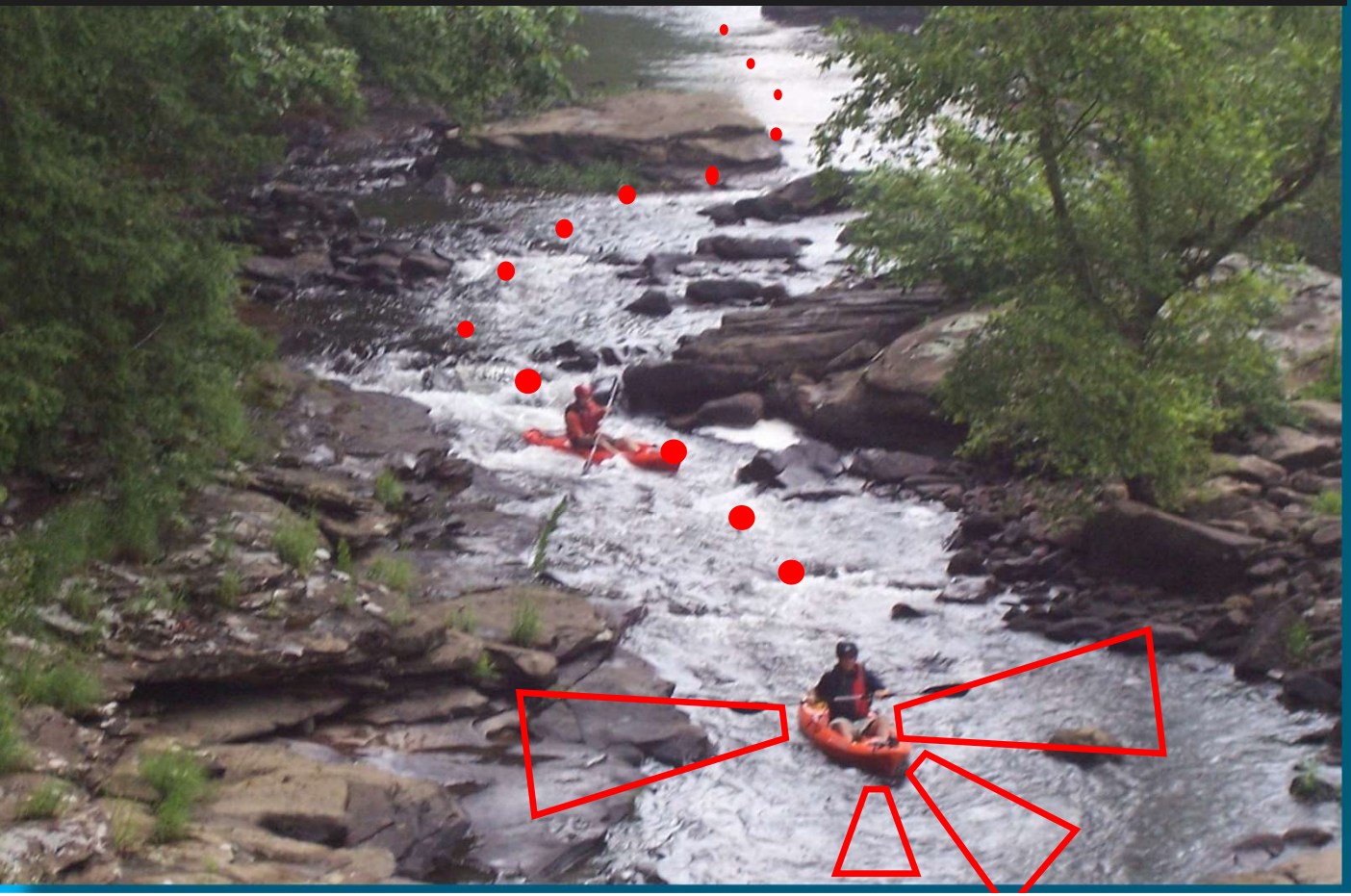
BACKPACK

KAYAK

INFLATABLE BOAT

In select places:
DRONES

What data do we collect?



Side Video/LiDAR
- Left & Right Streambank
- Riparian
- Floodplain Access
- Infrastructure

Front Video
- Habitat Type
- Canopy Cover

Down Video & Sonar
- Depth
- Side-scan imagery
- Substrate Type
- Embeddedness

Water Quality Sensor
- DO, pH, Temp, etc.

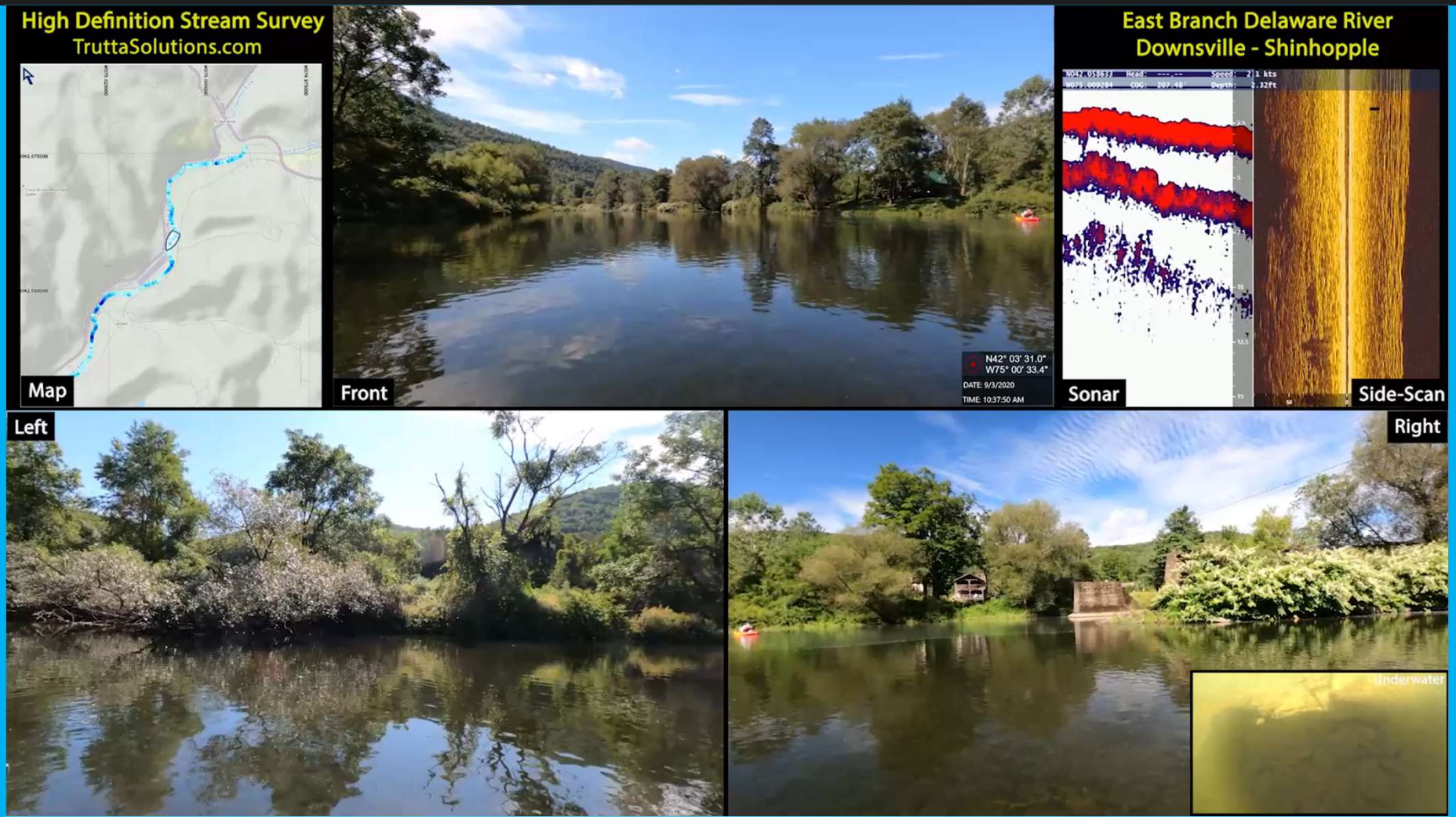
Acoustic Doppler Current Profiler
- Bathymetry
- Discharge
- Transects

Water Grab Samples
- eDNA

GPS

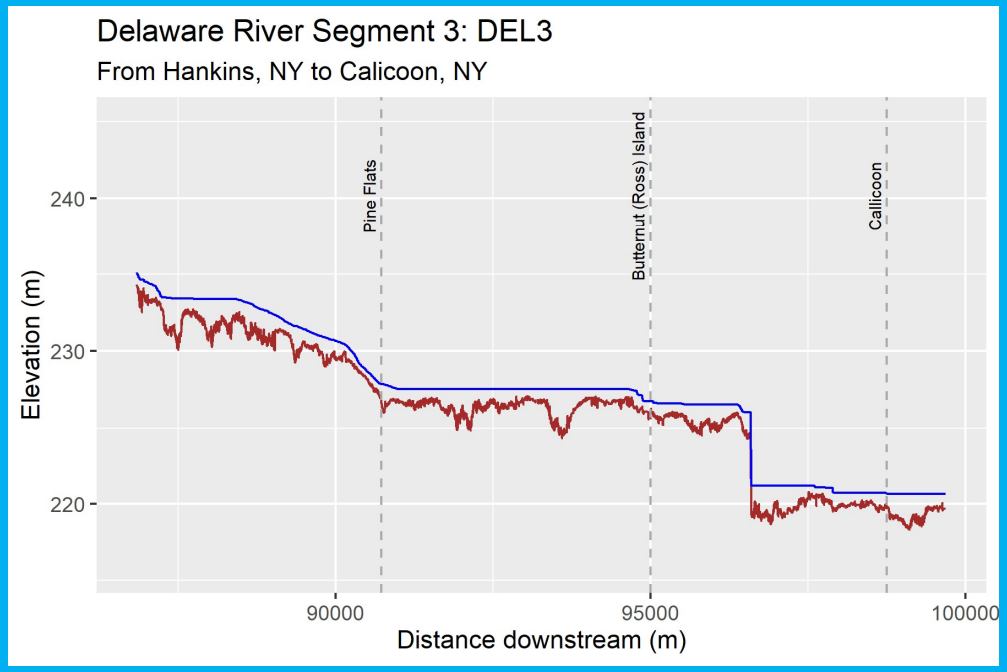
Time
Location
Elevation

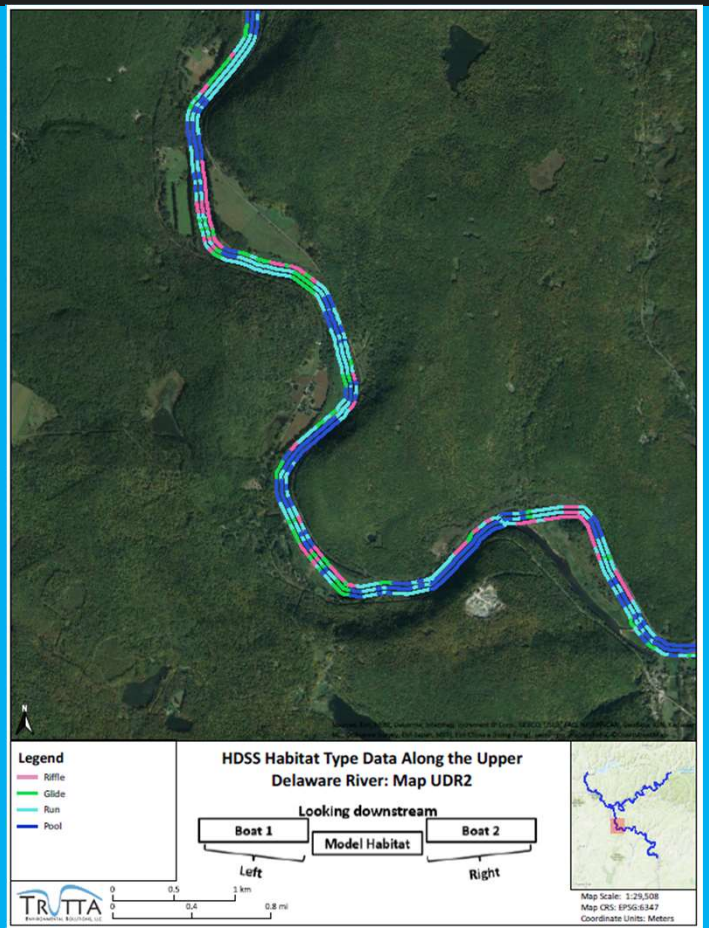
Visual Habitat



Digitally Collected Habitat

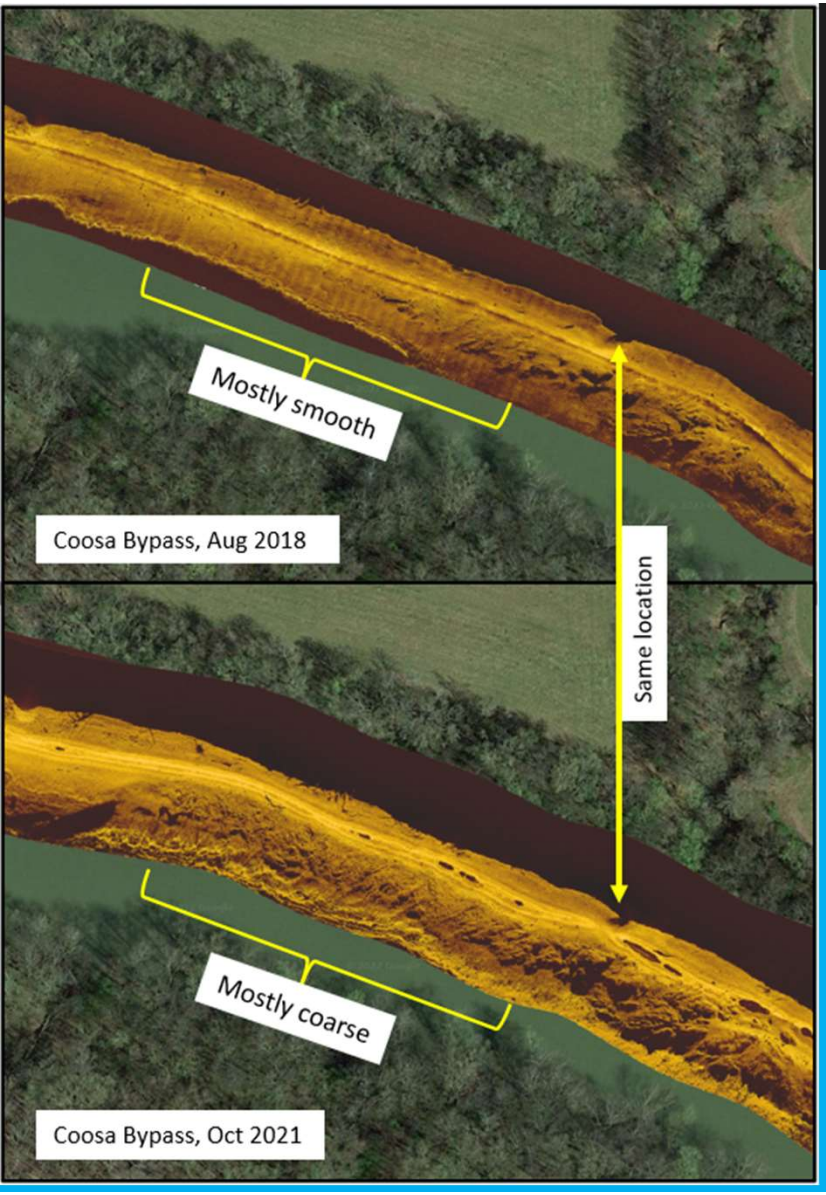
Depth, Elevation, Slope & Habitat Type

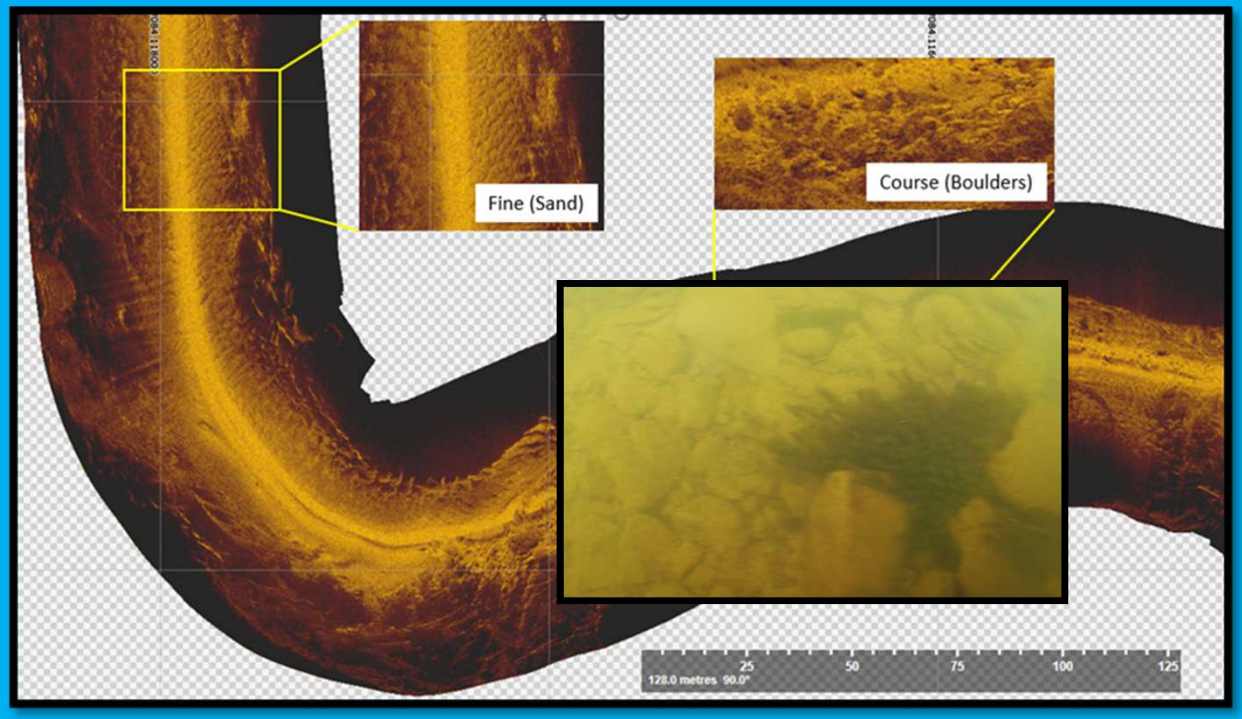




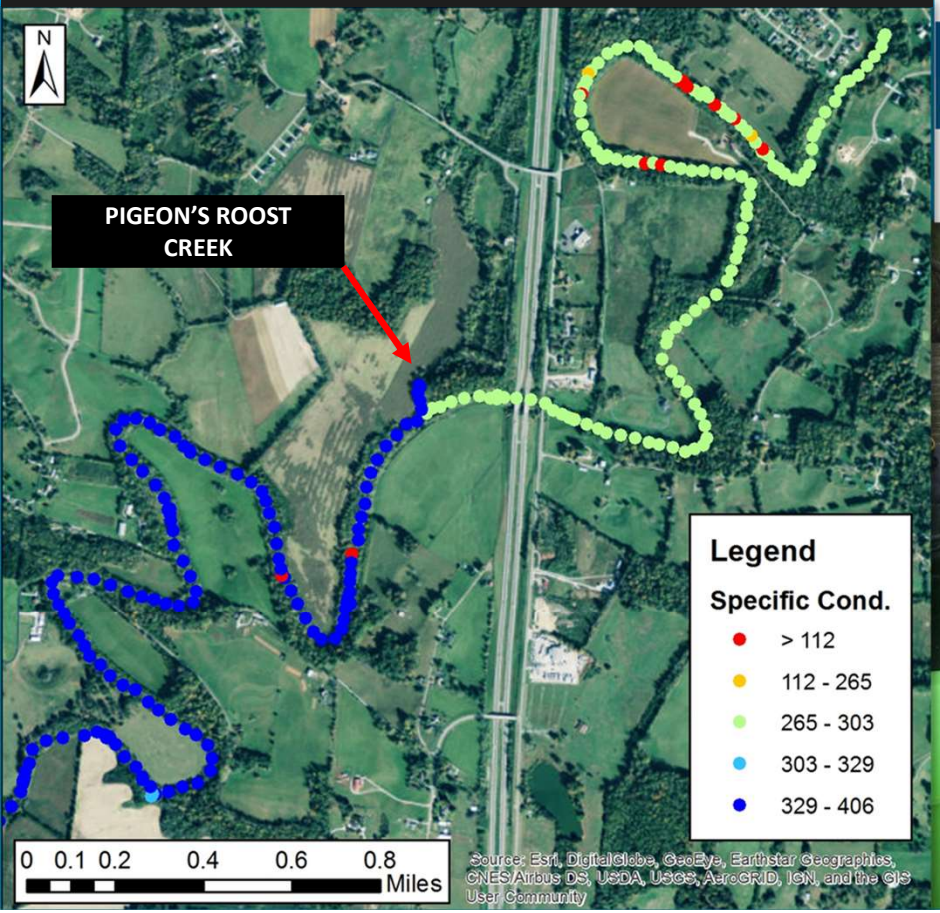
Underwater Habitat

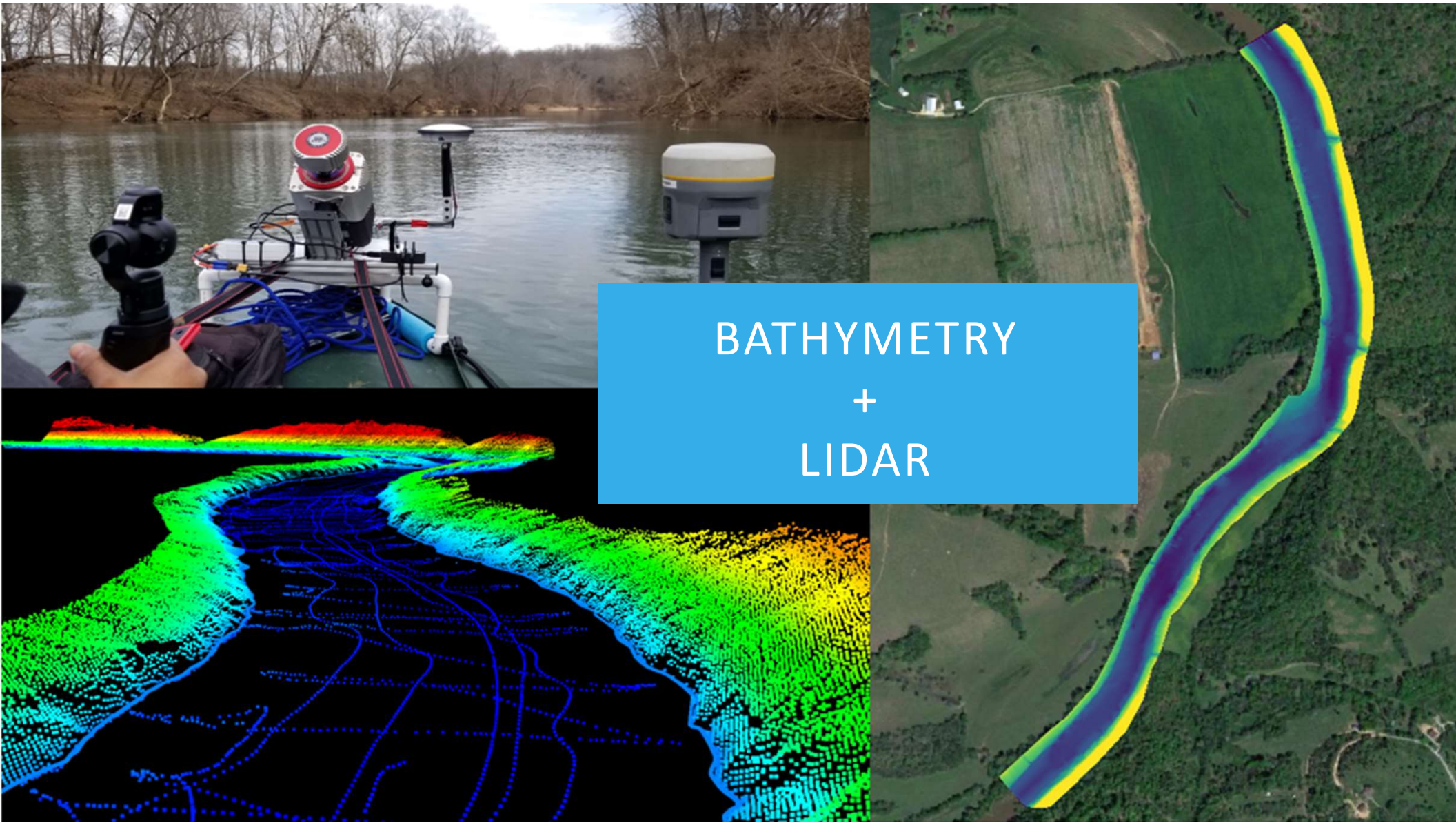
Side-scan Sonar & Video





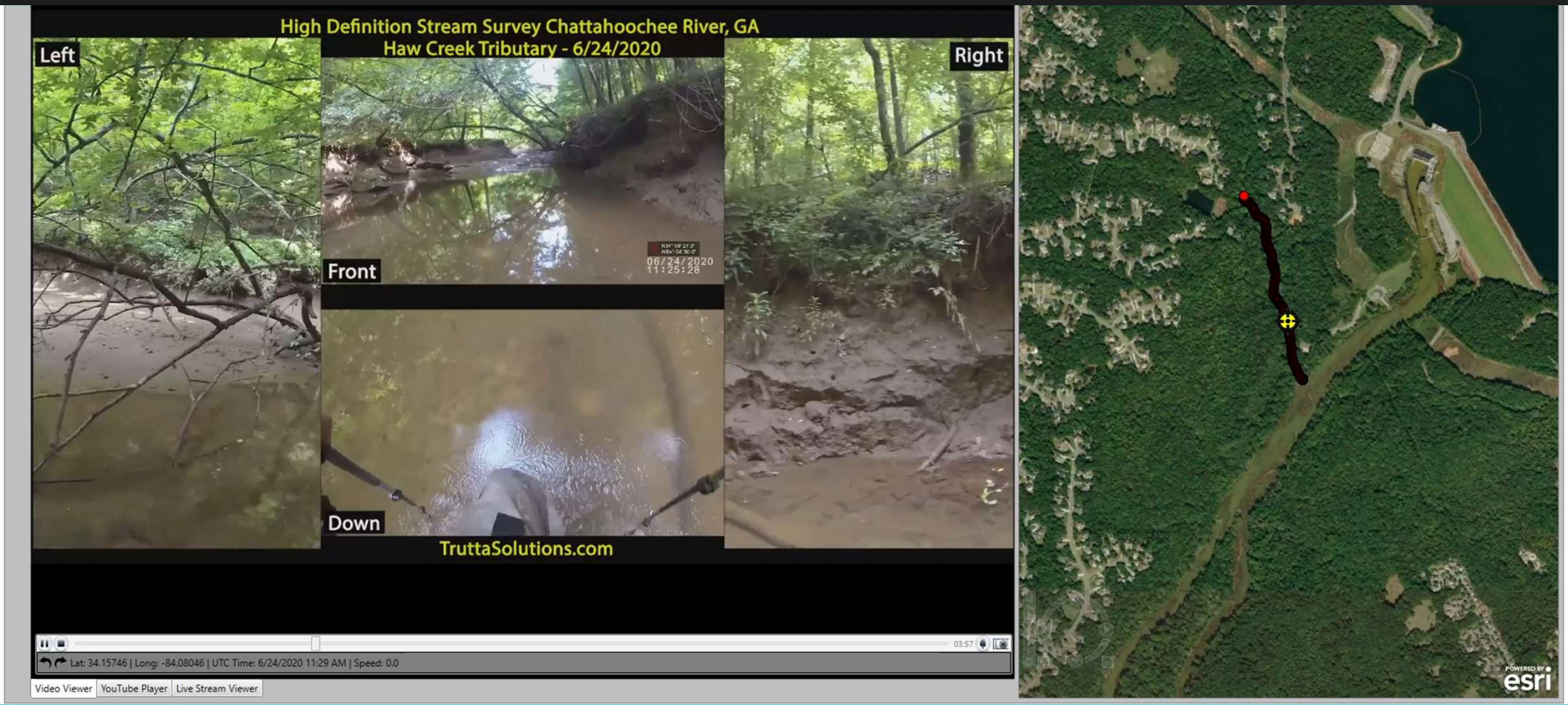
WATER QUALITY



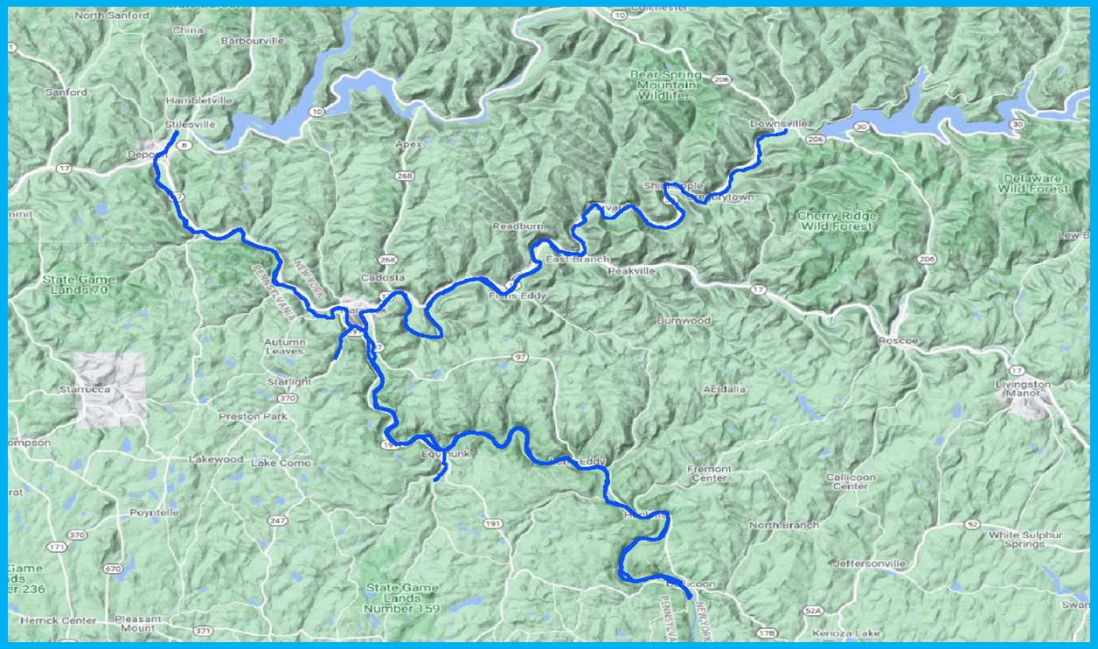

BATHYMETRY
+
LIDAR

SPATIAL METADATA EMBEDDED IN VIDEO:

WORKS IN ARCGIS, QGIS & REMOTE GEOSYSTEMS GEOTAGGER



Goal: HDSS for East, West and Mainstem of Delaware River and HDFS for Shehawken Creek



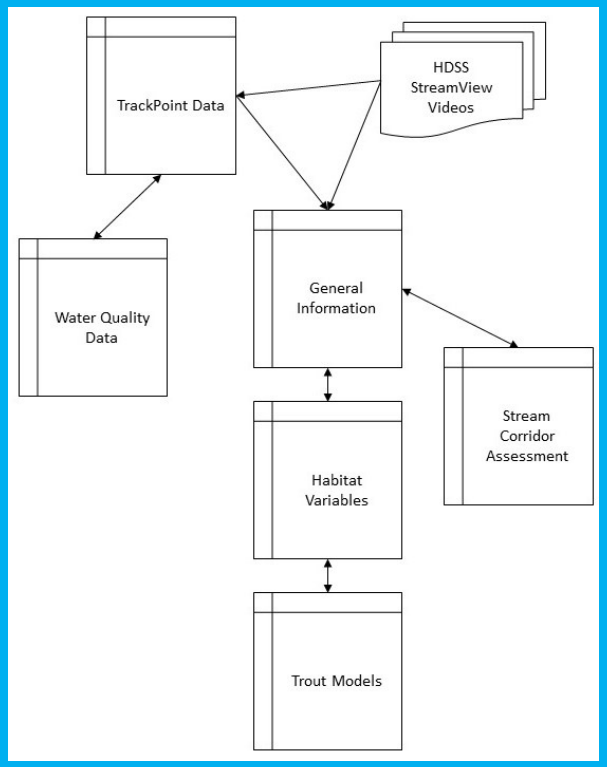
Field work completed - Aug 31 to Sept 9, 2020

Conduct a High Definition Stream Survey on 77 miles of the Upper Delaware River to :

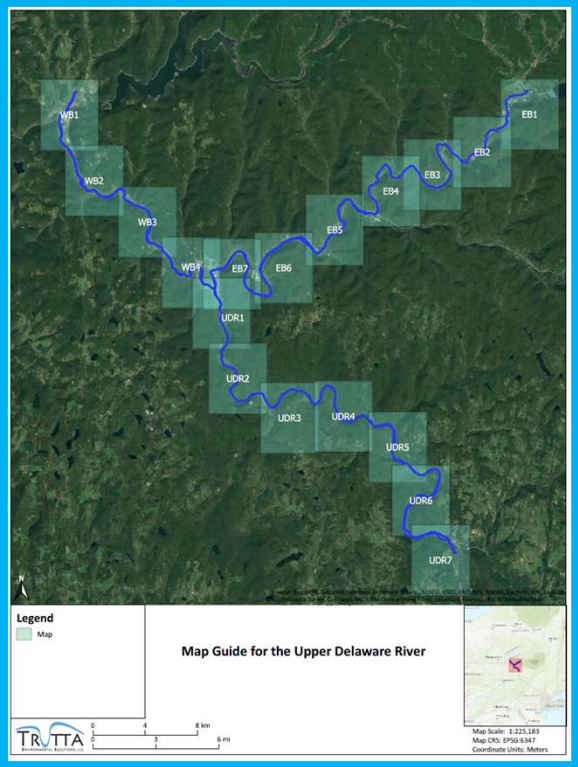
- Complete a Stream Corridor Assessment (SCA).
- Quantify Trout Habitat Suitability

Gather High Definition Fish Survey on Shehawken and Equinunk Creeks

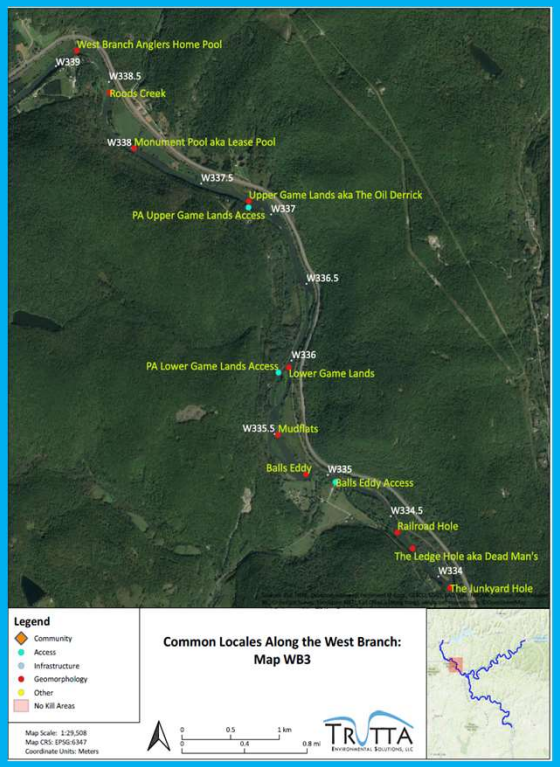
Data Organization and Reporting



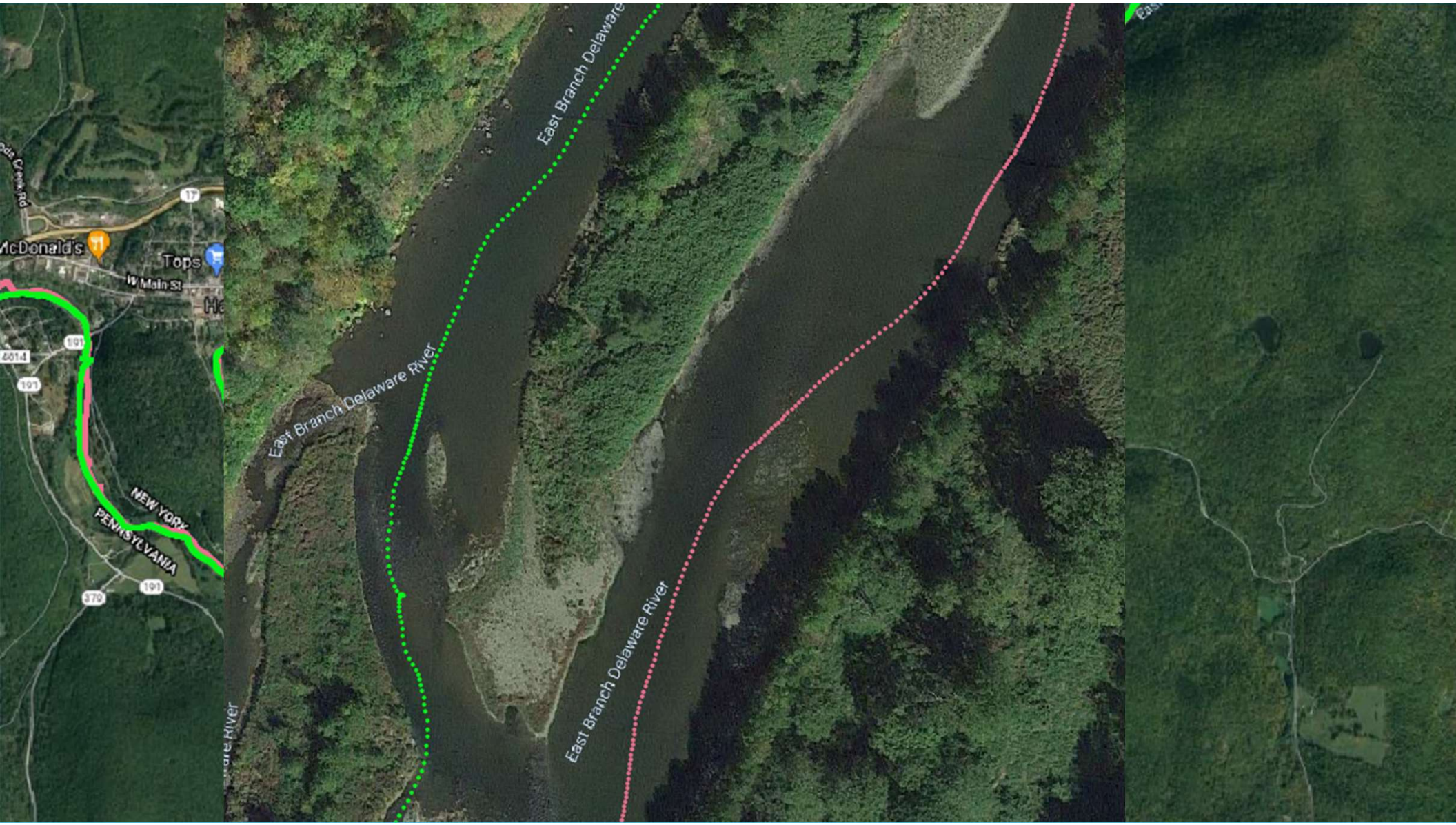
Geopackage Relationships



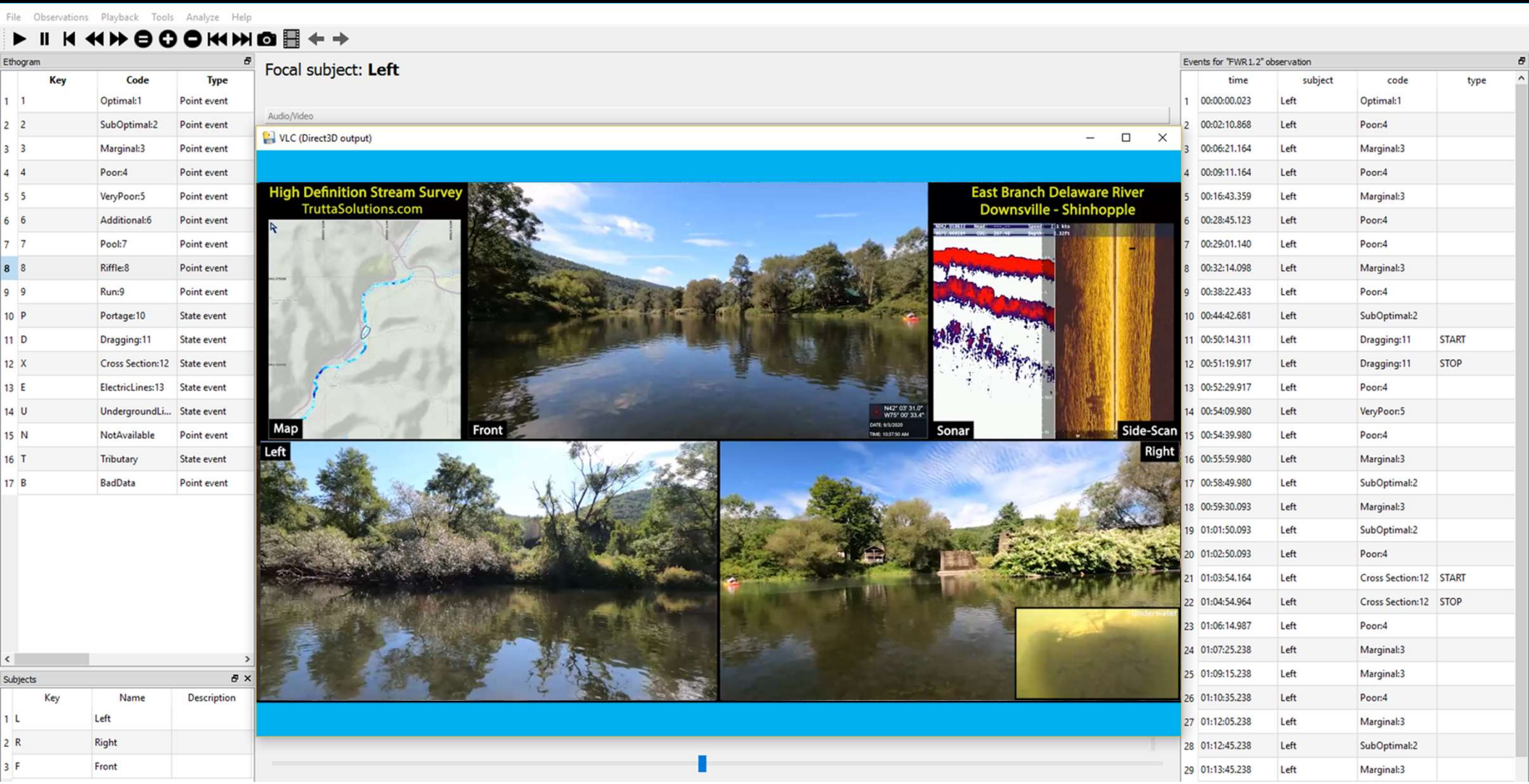
Map Atlases

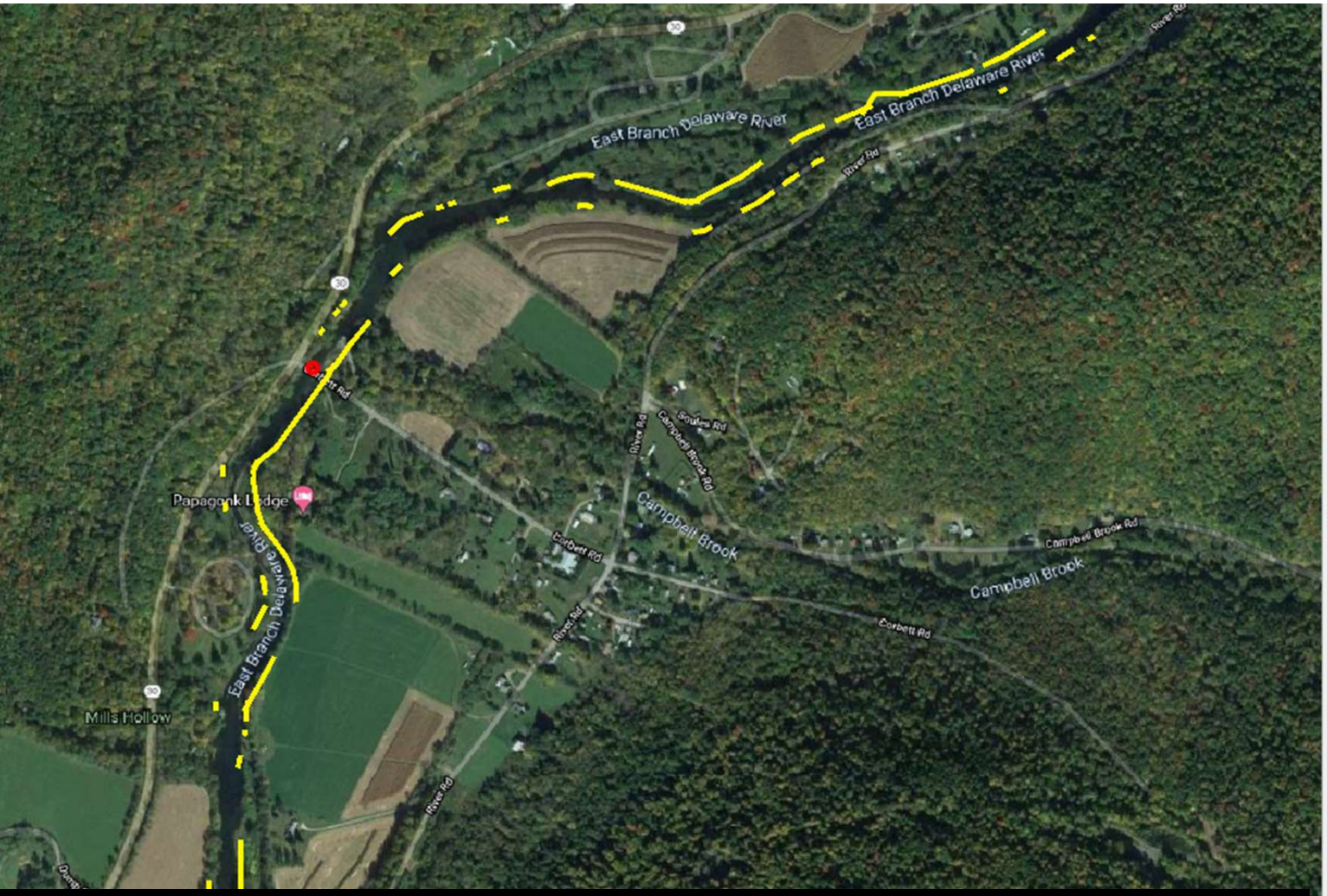


Place Names


McDonald's
Tops
W Main St
17
191
4014
NEW YORK
PENNSYLVANIA
East Branch Delaware River
East Branch Delaware River
East Branch Delaware River

Observed Conditions are Classified from the Video and Sensor Data





Feature	Value
B1_NoTransects	
SonarName	R00005
(Derived)	
(Actions)	
SecID	78299
TimeUTC	2020/09/03 10:14:55.000
UTCx	2020/09/03 15:14:55.000
UTCz	2020/09/03 15:14:55.000
DTE	2020/09/03 10:14:55.000
dateE	2020-09-03
timeE	11:14:55.000
DTEx	2020/09/03 11:14:55.000
DTEz	2020/09/03 11:14:55.000
TRptID	Up_east_004989
Easting	497729.584
Northing	4654931.999
Elevation	295.556
hPrecision	0.091
vPrecision	0.219
AntHeight	0.730
GarminLat	42.04644
GarminLong	-75.02745
D_DQCode	0
D_DQType	Good
DQComment	NULL
Project	Upper Delaware
Track	411
Classifier	Brett
Platform	Single Boat
Version	4
D_LBCCode	3
D_LBCType	Slightly Impaired
D_LBCModCo	8
D_LBCModTy	Modified
LBCComment	NULL
D_RBCCode	3
D_RBCType	Slightly Impaired
D_RBCModCo	8
D_RBCModTy	Modified
RBCComment	NULL
D_LKWCode	KW
D_LKWModCo	left
D_RKWCode	No
D_RKWModCo	right

Mode: Layer Selection

Data linked to GIS and Videos

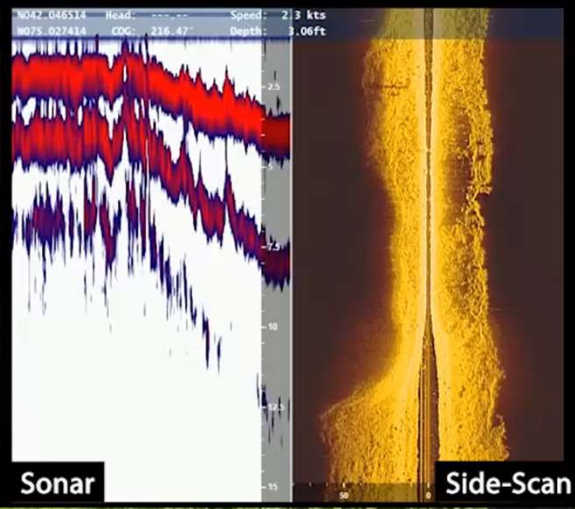
Ex: Japanese Knotweed Distribution

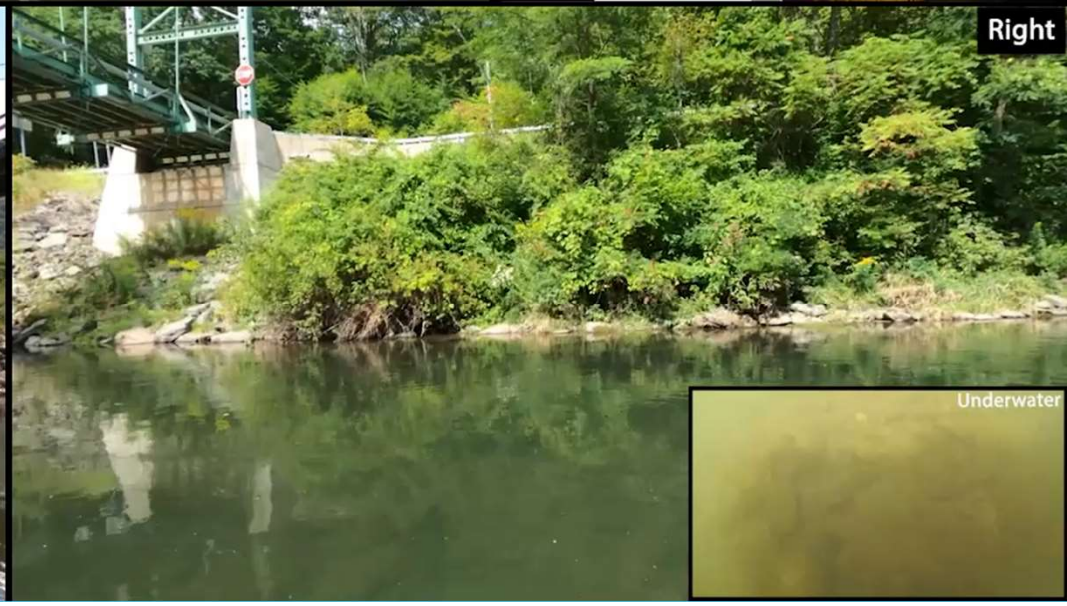
High Definition Stream Survey

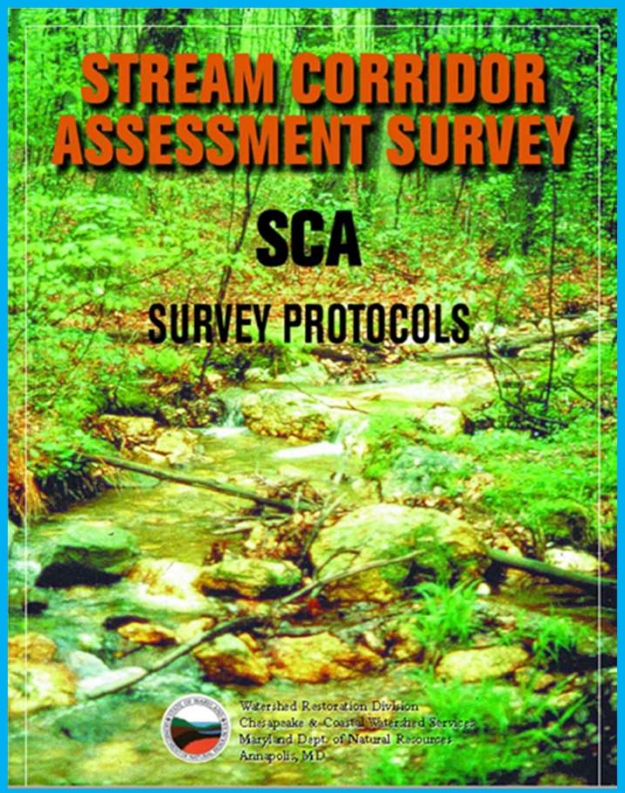
TruttaSolutions.com

East Branch Delaware River

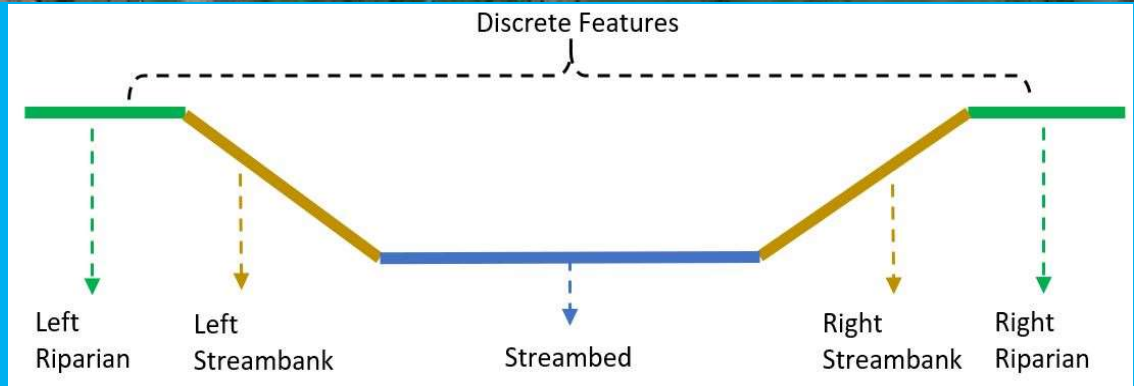
Track 411 RM: E362.5 - E356



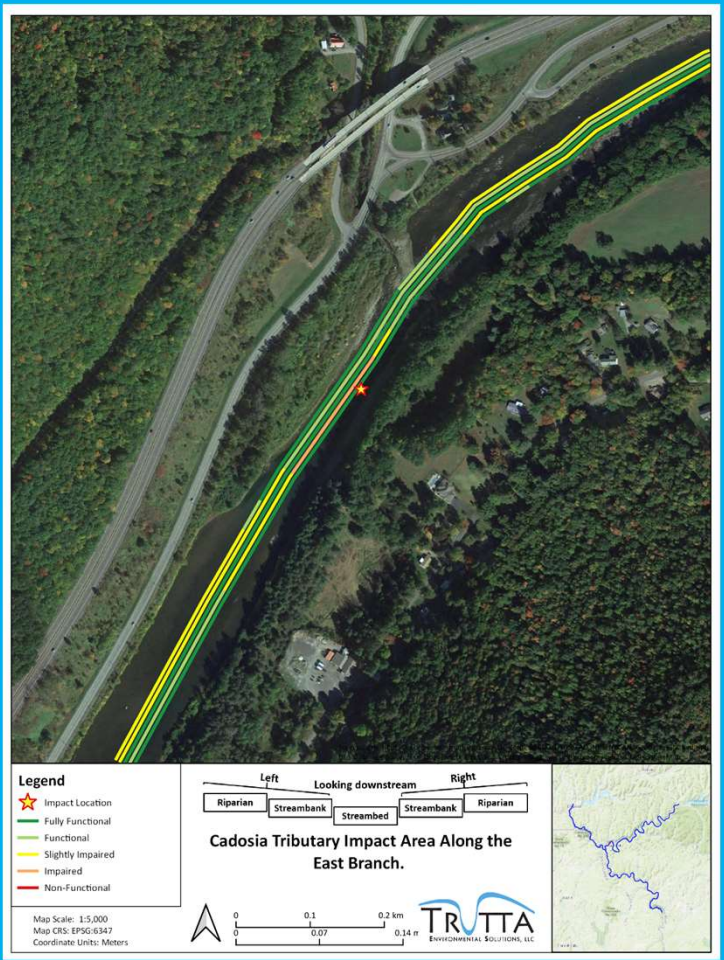




- Riparian
- Streambank
- Streambed
- Discrete Point features
- Japanese Knotweed

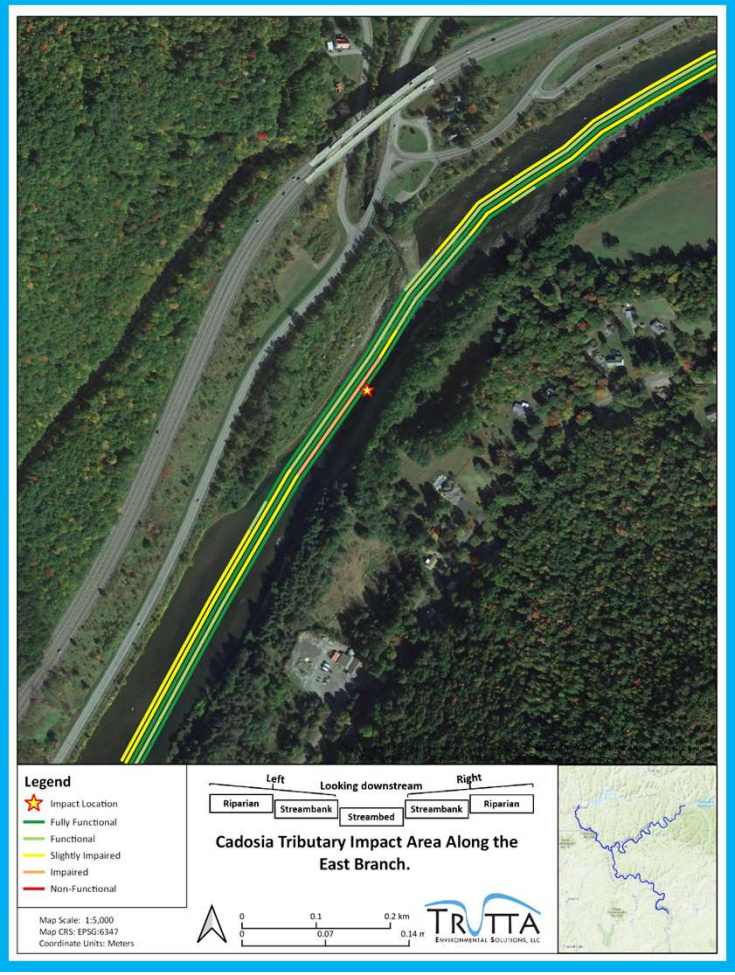


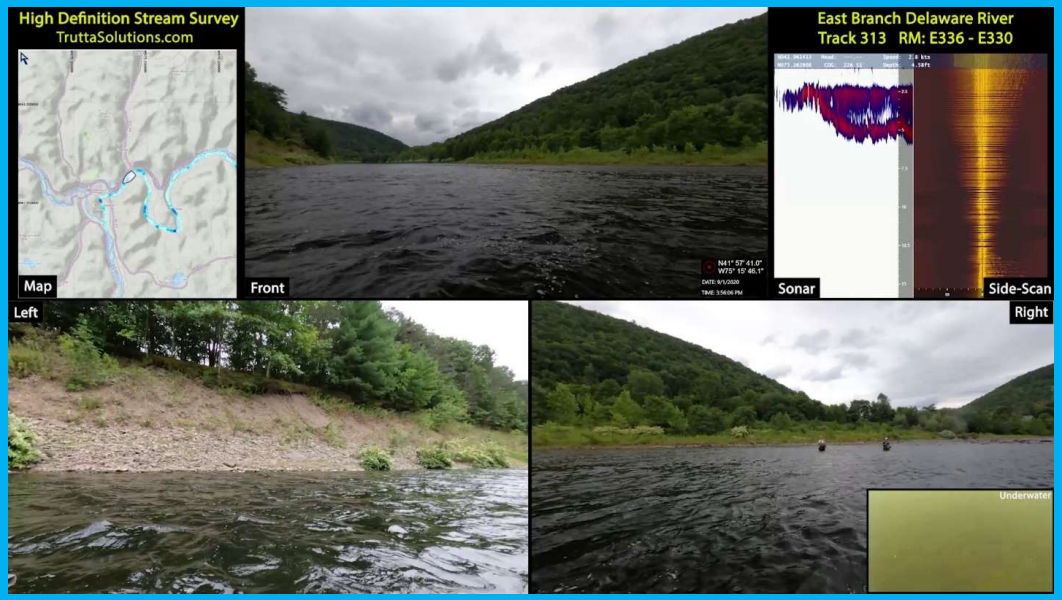
SCA Results



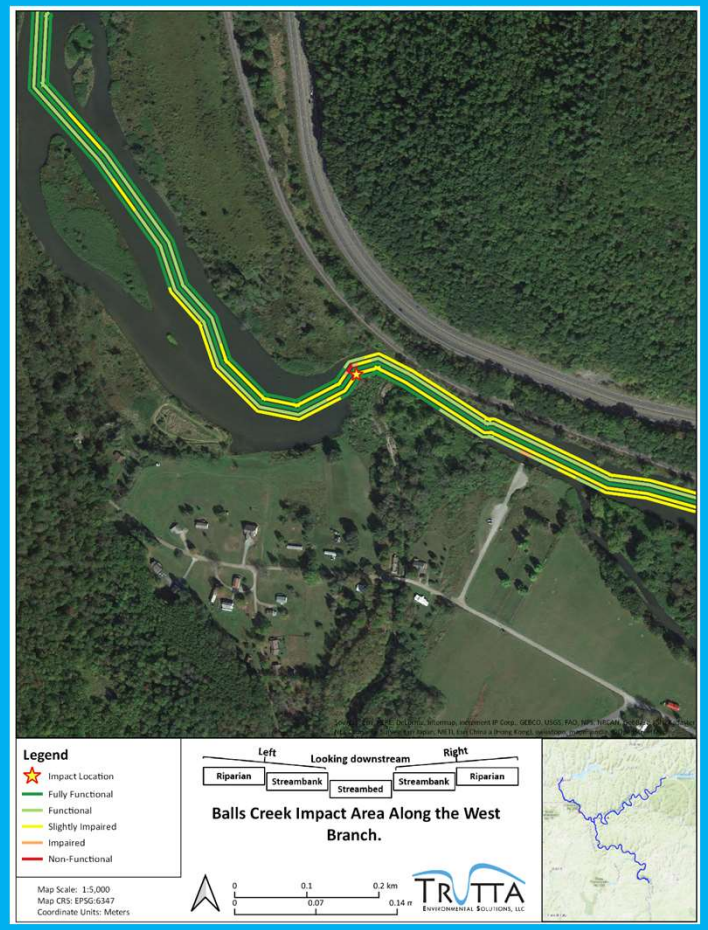
- Overall, UDR was in good condition
  - Impaired or Non-functional segments were less than 3% for riparian, streambank and streambed
- Some Problem Issues were observed
  - Streambank failure near tributary mouths
  - Streambank issue in other areas
  - Areas of sediment runoff
  - Infrastructure problems
  - Invasive plant issue

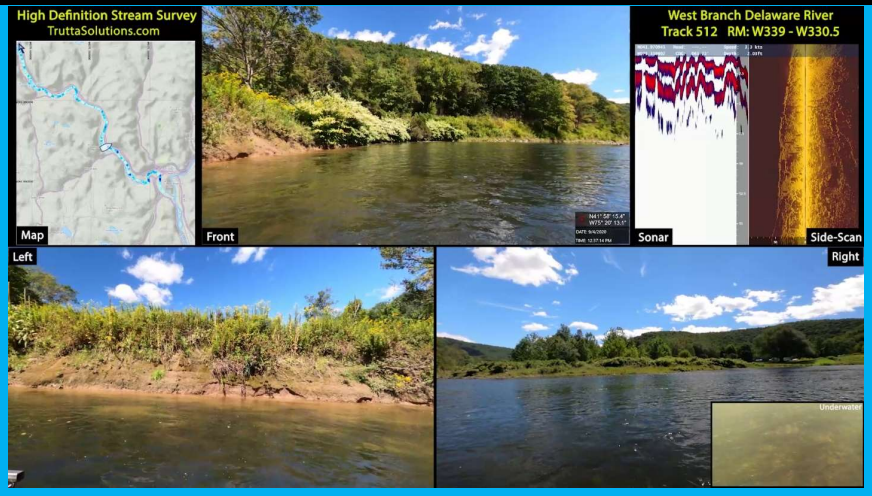
Streambank failure near tributary mouths
Cadosia

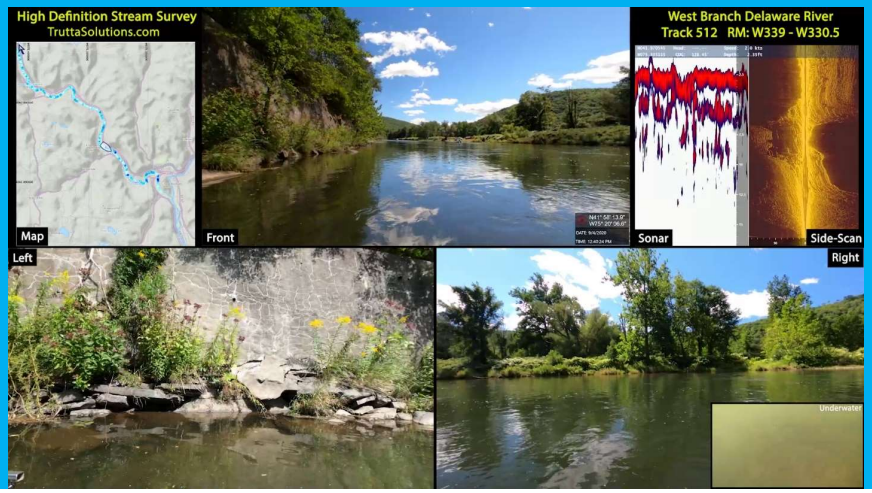




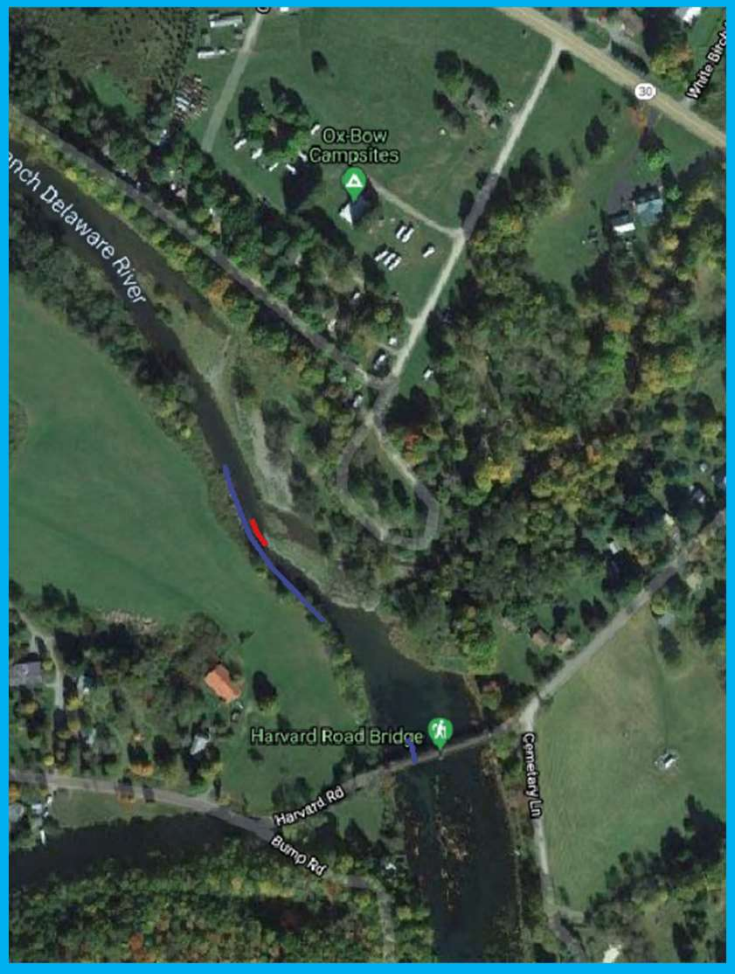
Streambank failure near tributary mouths
Balls Creek

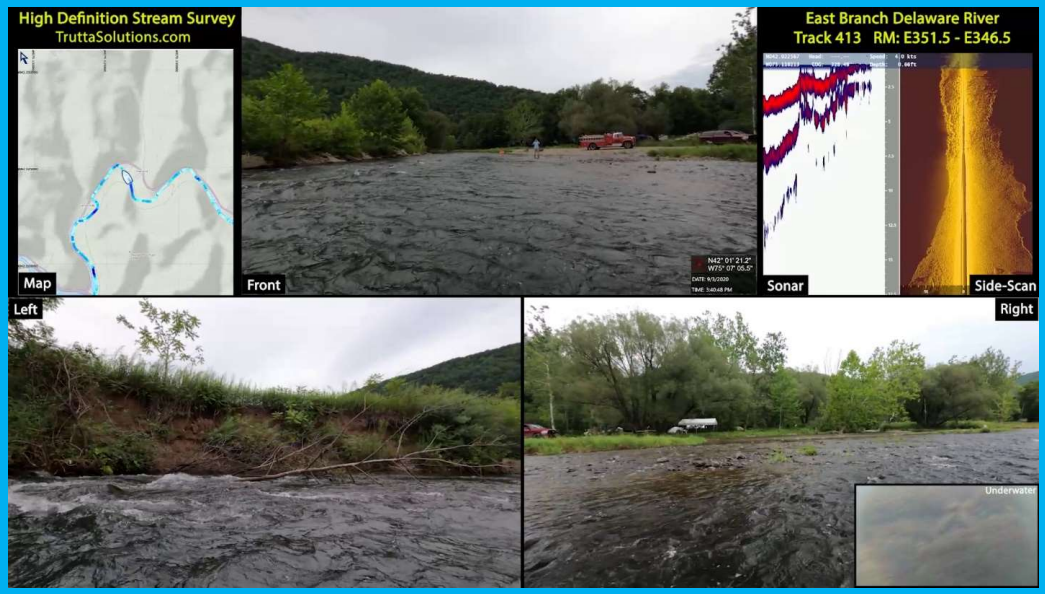




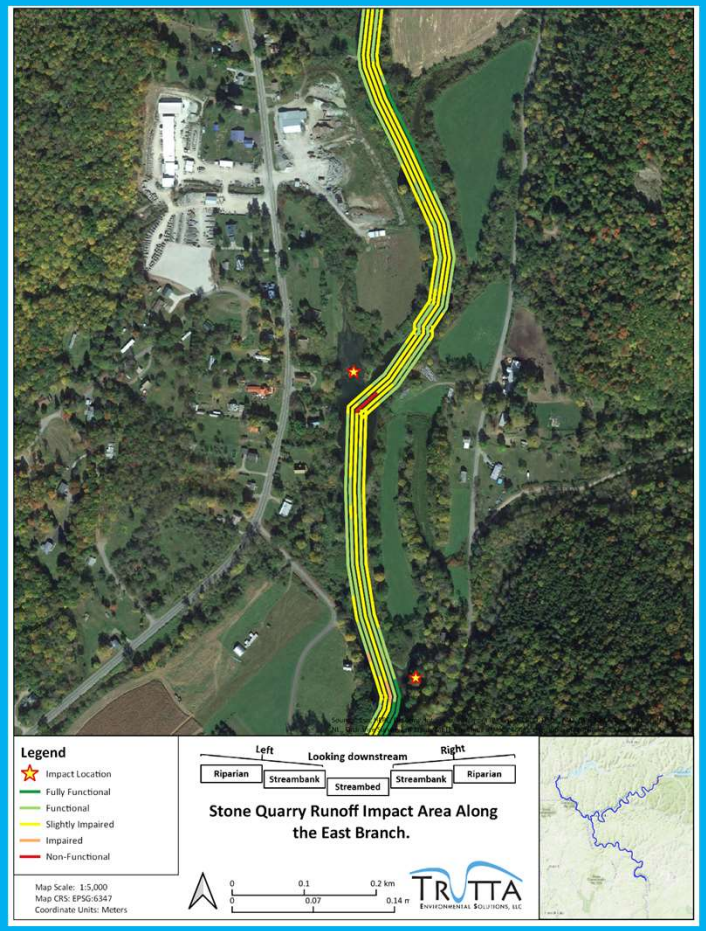


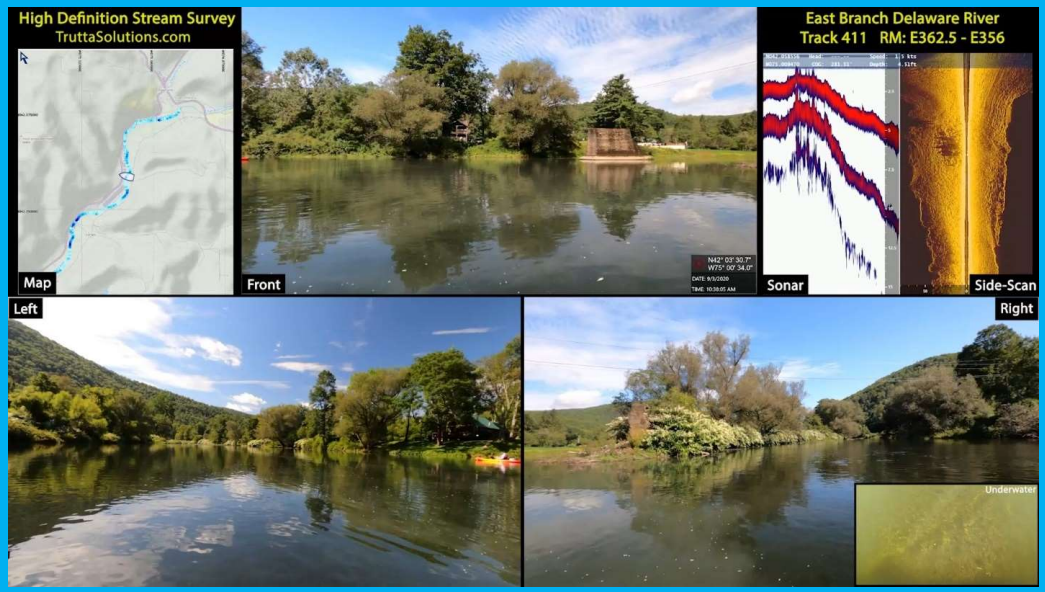
Streambank failure near tributary mouths
Baxter Brook





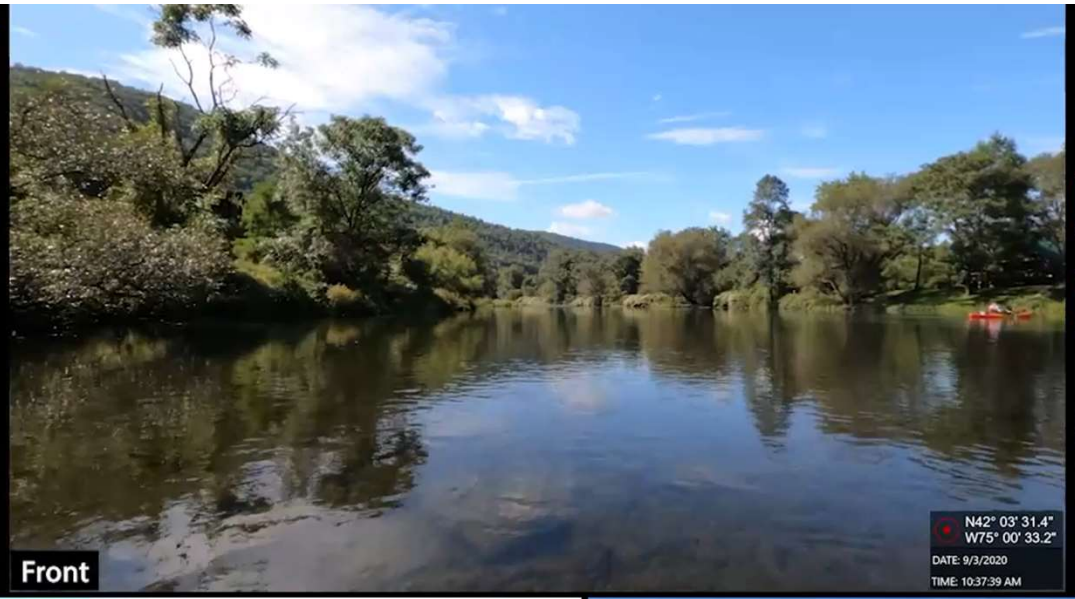
Sediment Runoff
Stone Quarry





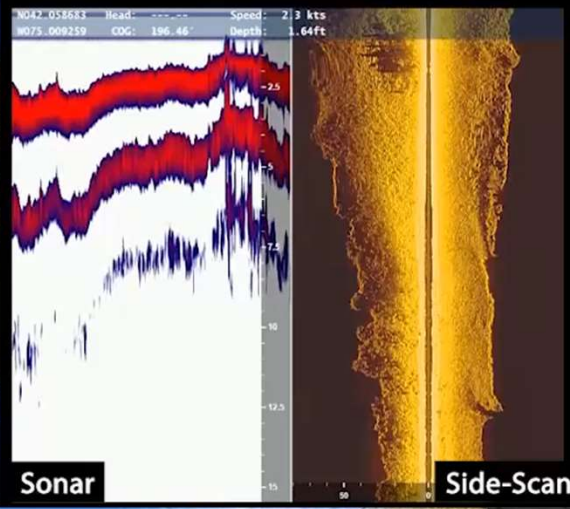
High Definition Stream Survey

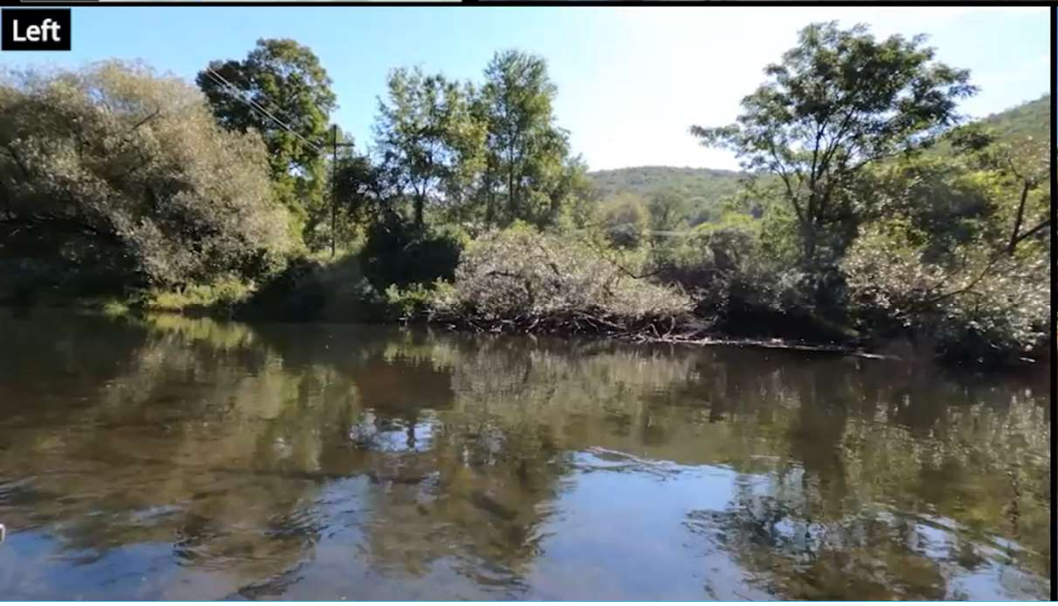
TruttaSolutions.com



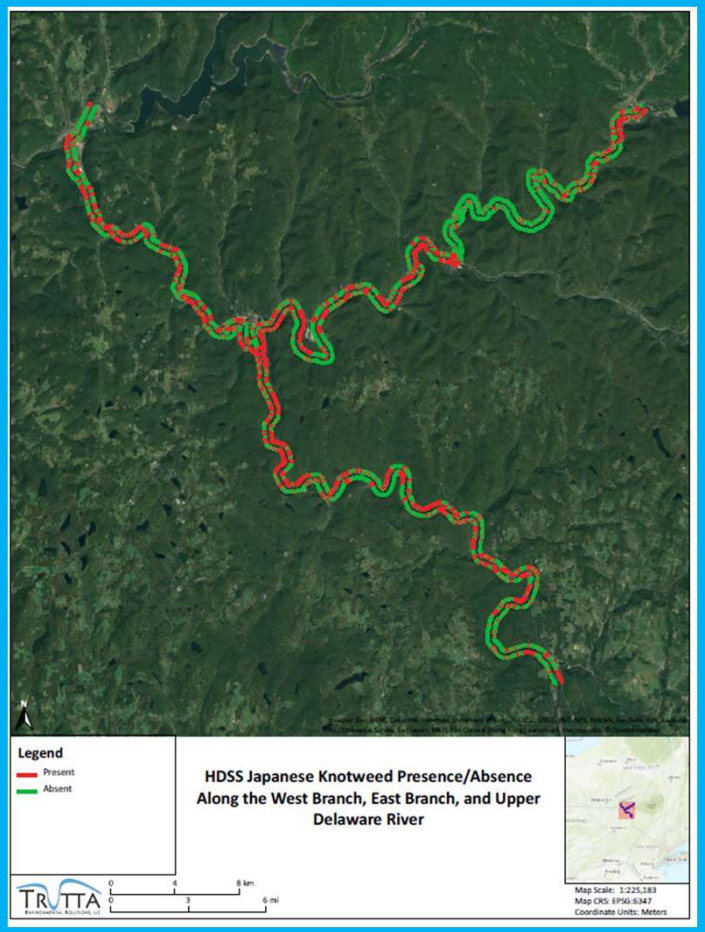
East Branch Delaware River

Track 411 RM: E362.5 - E356





Invasive Plants
Japanese Knotweed

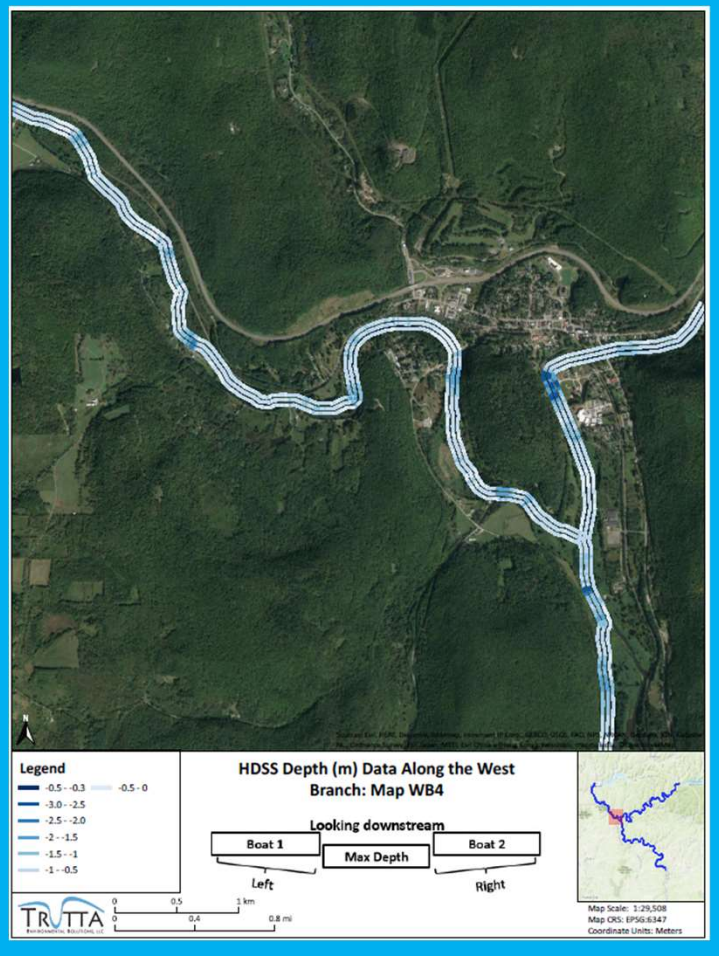


River	Knotweed Present	Knotweed Right bank (m)	Knotweed Left bank (m)	Knotweed Both banks (m)
Delaware River	Yes	47.0%	52.4%	49.7%
Delaware River	No	53.0%	47.6%	50.3%
East Branch	Yes	40.9%	38.8%	39.8%
East Branch	No	59.1%	61.2%	60.2%
West Branch	Yes	50.8%	43.5%	47.2%
West Branch	No	49.2%	56.5%	52.8%
Total	Yes	45.2%	44.8%	45.0%
Total	No	54.8%	55.2%	55.0%

Trout Habitat Assessment

- Based on Habitat Variables
  - Water Depth
  - Habitat Type
  - Roughness and Cover
  - Water Surface Elevation, Bed Elevation, Stream Slope and Water Velocity
- Applied Published Habitat Suitability Criteria
  - Adult Brown Trout
  - Juvenile Brown Trout
  - Brown Trout Spawning Habitat
  - Adult Rainbow Trout
  - Juvenile Rainbow Trout

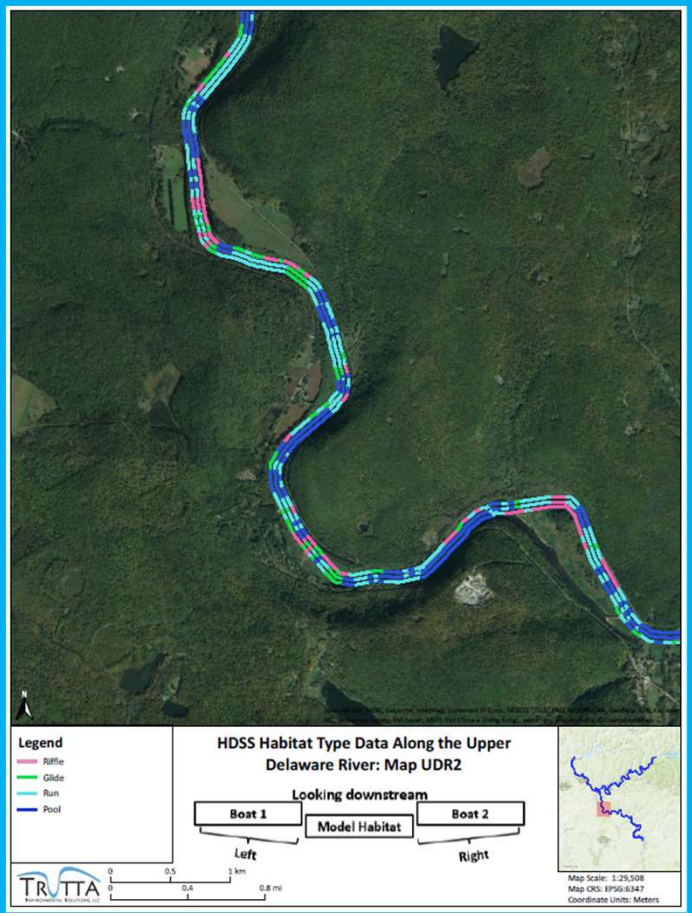
Trout Habitat Assessment – Water Depth



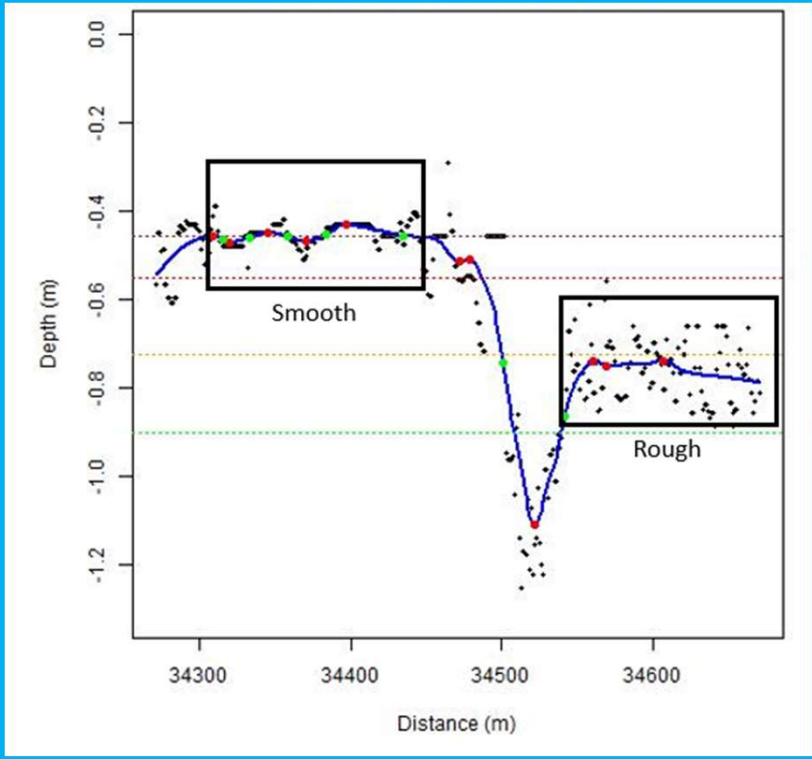
Segment	Readings	Maximum Depth (m)	Average Depth (m)
West Branch	51,872	-2.45	-0.67
Upper East Branch	26,235	-2.97	-0.74
Lower East Branch	52,122	-3.99	-0.81
Delaware River	89,870	-6.97	-1.03
Overall	220,099	-6.97	-0.86

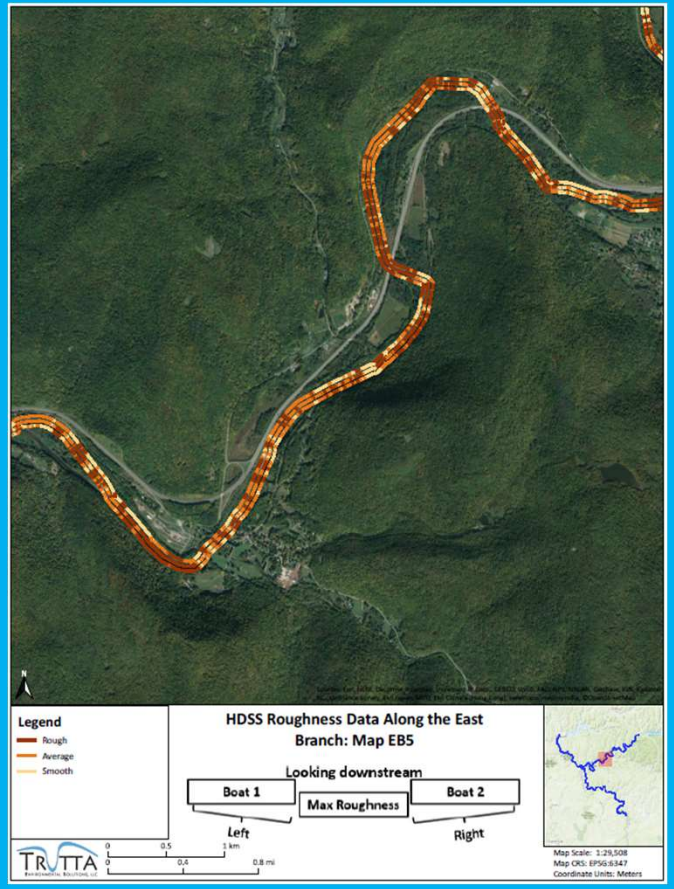
Trout Habitat Assessment – Habitat Type

Habitat Type	Count	Percent	Mean Length (m)	Mean Depth (m)
West Branch				
Riffle	212	23.6%	47.4	-0.42
Glide	178	19.8%	32.1	-0.49
Run	305	33.9%	67.5	-0.63
Pool	205	22.8%	75.7	-0.89
Upper East Branch				
Riffle	110	22.5%	42.5	-0.38
Glide	81	16.6%	41.2	-0.49
Run	183	37.5%	57.2	-0.67
Pool	114	23.4%	67.2	-1.02
Lower East Branch				
Riffle	125	18.7%	55.9	-0.41
Glide	170	25.4%	60.3	-0.52
Run	230	34.4%	79.4	-0.72
Pool	143	21.4%	116.2	-1.09
Delaware River				
Riffle	121	18.1%	129.3	-0.53
Glide	149	22.3%	87.6	-0.65
Run	250	37.4%	134	-0.91
Pool	149	22.3%	185.7	-1.47

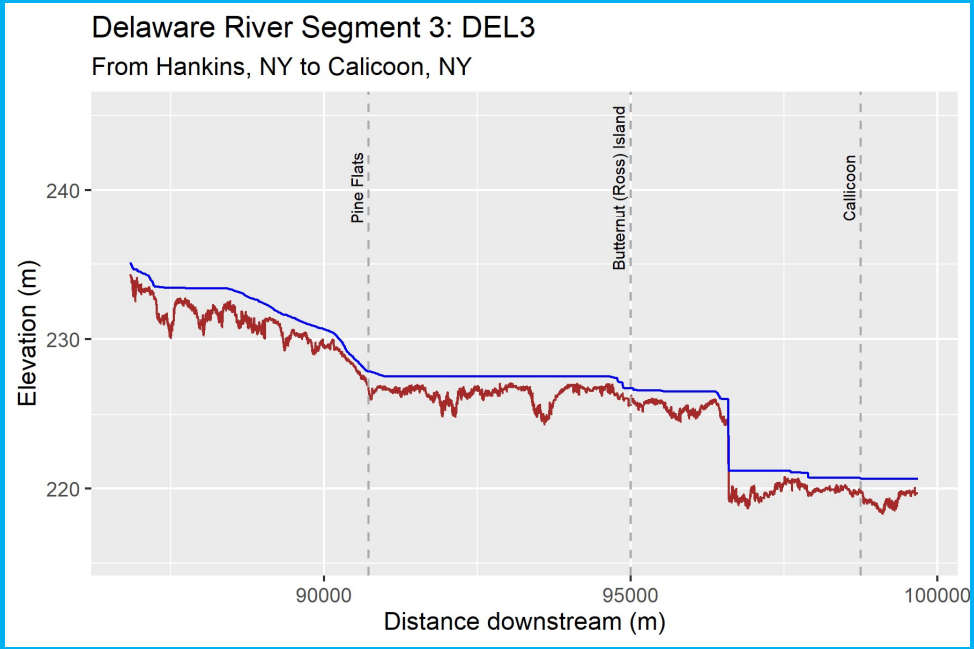


Trout Habitat Assessment – Roughness





Trout Habitat Assessment – Water Surface Elevation, Bed Elevation, Stream Slope and Water Velocity



$$v = \frac{1}{n} R^{0.67} S^{0.5}$$

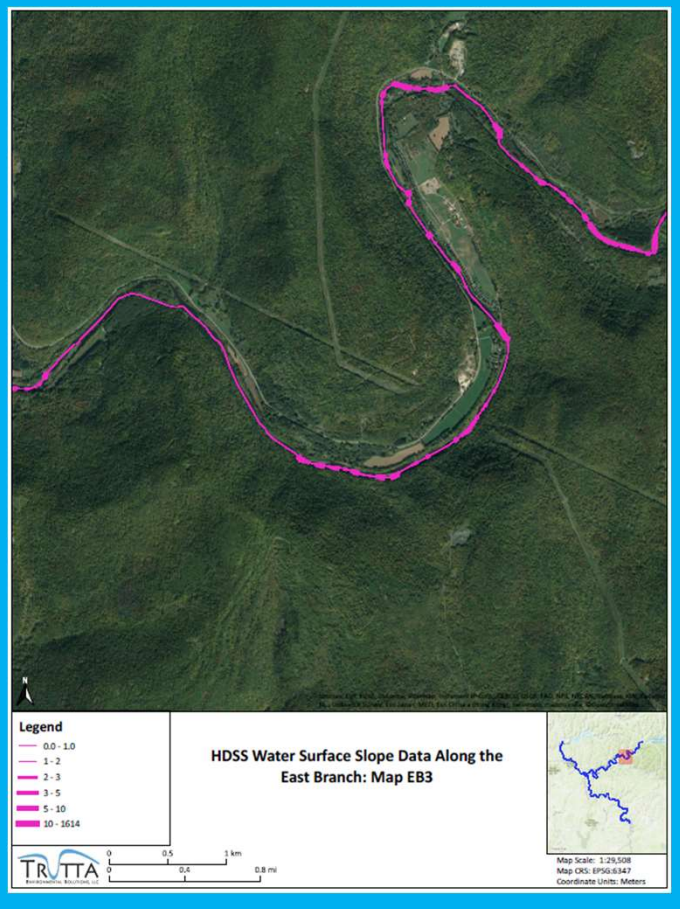
where:

v = velocity (m/sec)

n = roughness coefficient

R = hydraulic radius (or average depth in wide channel (m))

S = slope (m/)



Habitat Suitability: Trout Model

RIVER RESEARCH AND APPLICATIONS
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EVALUATING METHODS TO ESTABLISH HABITAT SUITABILITY CRITERIA: A CASE STUDY IN THE UPPER DELAWARE RIVER BASIN, USA

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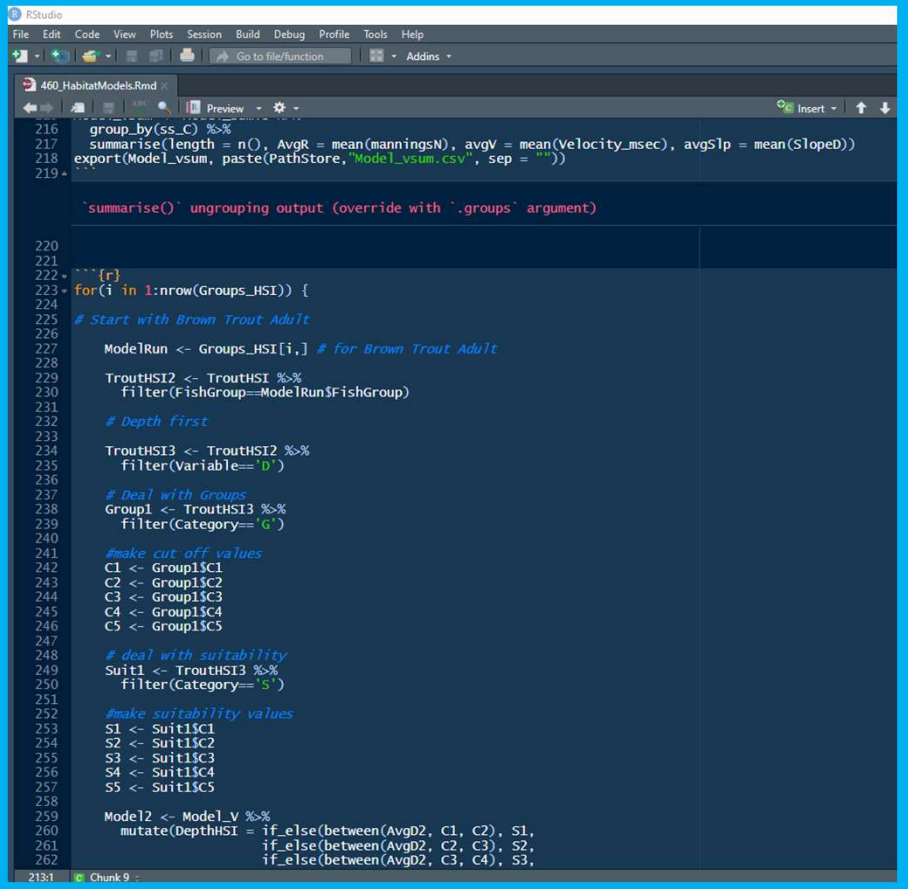
Table I. Habitat suitability criteria (HSC) for depth in metres (a) and velocity in metres per second (b) for nine species/life stage combinations in the upper Delaware River, USA

(a) Species	Life stage	Delphi depth (m)	Lit range depth (m)	Lit IQR depth (m)	Total *N*	% within Delphi range
Brown trout (*Salmo trutta*)	adult	0.3–100	0.05–54.00	0.15–0.59	131	53.44
	juvenile	0.2–0.8	0.05–1.50	0.13–0.38	183	56.28
	spawning	0.2–0.6	0.05–0.52	0.20–0.40	52	84.62
	incubation	0.2–1.0	0.05–0.52	0.18–0.32	33	72.73
Rainbow trout (*Oncorhynchus mykiss*)	adult	0.3–100	0.07–37.90	0.21–1.20	60	70.00
	juvenile	0.2–1.0	0.12–1.70	0.32–0.63	39	82.05
American shad (*Alosa sapidissima*)	spawning	0.3–3.0	0.2–7.30	1.39–4.11	23	47.83
	juvenile	0.25–1.6	0.2–11.00	1.00–4.80	15	40.00
Shallow-slow guild*		0.05–0.3	N/A	N/A	0 100	
Shallow-fast guild †		0.05–0.3	0.1–1.00	0.17–0.48	18	66.67

(b) Species	Life stage	Delphi Vel (m/s)	Lit range Vel (m/s)	Lit IQR–Vel (m/s)	Total *N*	% within Delphi range
Brown trout (*Salmo trutta*)	adult	0.0–1.0	0.02–1.05	0.13–0.43	80	96.25
	juvenile	0.0–0.7	0.00–1.05	0.11–0.36	100	95.00
	spawning	0.3–0.8	0.10–1.08	0.29–0.50	55	70.91
	incubation	0.15–1.2	0.06–1.08	0.31–0.47	33	93.94
Rainbow trout (*Oncorhynchus mykiss*)	adult	0.0–1.2	0.00–0.91	0.06–0.21	25	100.00
	juvenile	0.0–0.8	0.00–1.39	0.04–0.23	43	93.02
American shad (*Alosa sapidissima*)	spawning	0.2–0.7	0.01–1.10	0.41–0.61	19	78.95
	juvenile	0.0–0.6	0.00–1.02	0.10–0.58	12	83.33
Shallow-slow guild*		0.0–0.3	N/A	N/A	1	50.00
Shallow-fast guild†		0.3–1.2	0.09–0.60	0.16–0.46	8	62.50

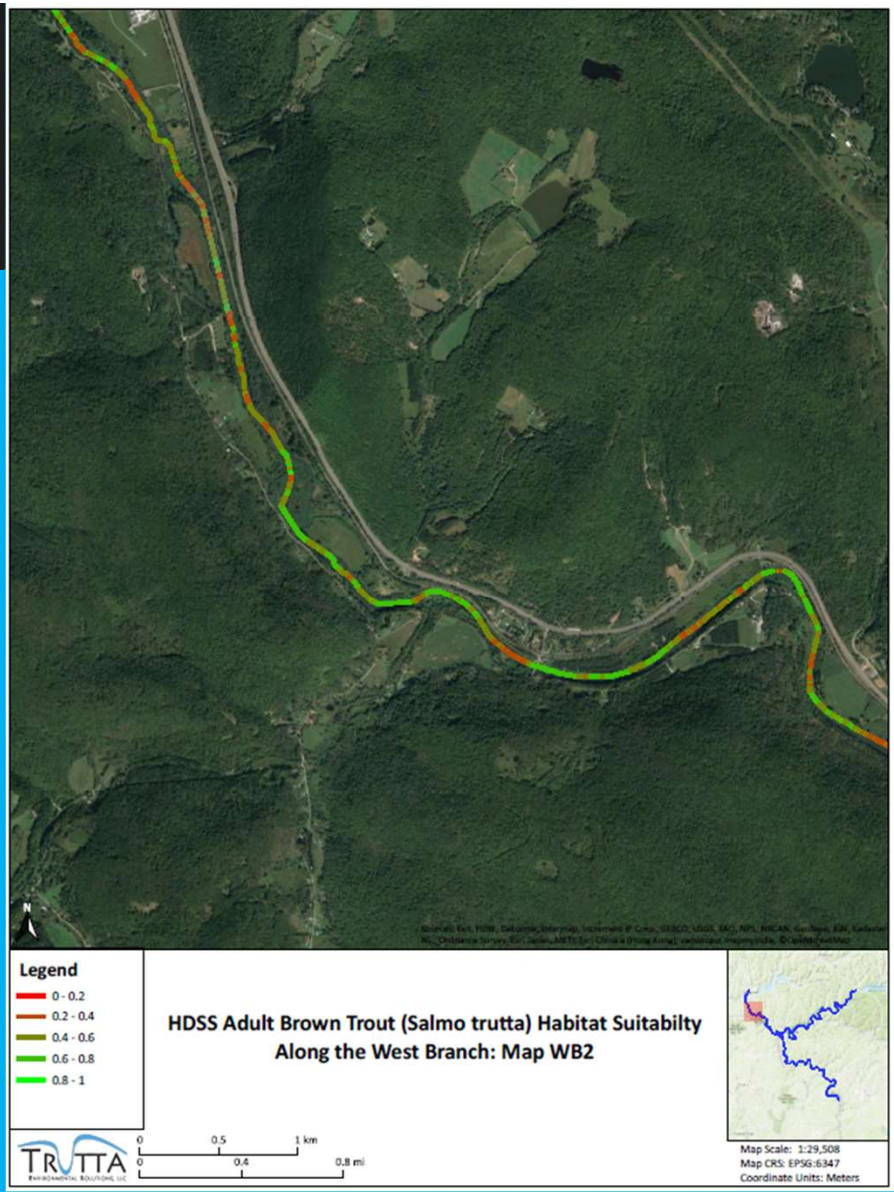
Delphi, HSC developed by the expert opinion Delphi method and reported in Bovee *et al.* (2007); *Lit range*, literature-derived HSC for either depth or velocity including all literature observations; *Lit IQR*, interquartile range of literature observations for either depth or velocity (refer to text for details); *Total N*, total number of observations in the literature for a given species/life stage combination; *% within Delphi range*, percentage of literature values that fell within Delphi HSC.
*Bridle shiner (*Notropis bifrenatus*), blue spotted sunfish (*Enneacanthus gloriosus*), eastern mudminnow (*Umbra pygmaea*), and cutlips minnow (*Exoglossum maxillingua*); refer to Bovee *et al.* (2007)
†Margined madtom (*Notorus insignis*), juvenile fallfish (*Semotilus corporalis*), and American eel (*Anguilla rostrata*); refer to Bovee *et al.* (2007)



Habitat Suitability: Trout Model Results

HSI Based on Depth, Velocity, Substrate and Cover

Segment	Brown Trout Adult	Brown Trout Juvenile	Brown Trout Spawning	Rainbow Trout Adult	Rainbow Trout Juvenile
West Branch	0.52	0.53	0.41	0.63	0.64
Upper East Branch	0.45	0.52	0.44	0.56	0.54
Lower East Branch	0.56	0.49	0.38	0.63	0.62
Delaware River	0.63	0.45	0.32	0.67	0.65



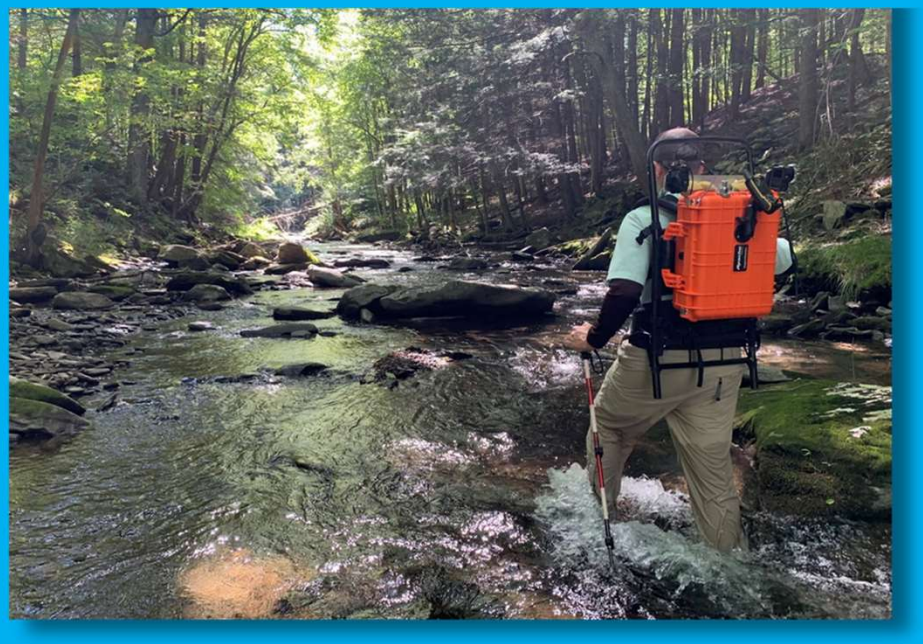
Habitat Suitability: Trout Model Application

Brown Trout:
Compare Sites near good adult habitat with good spawning habitat

Anglers:
Find new fishing locations

Tributary Stream Habitat and Fish Surveys

- Goal was to train TU members to do High Definition Fish Surveys (HDFS) on Shehawken Creek
- COVID changed everything
- We did HDSS and HDFS for Shehawken and Equinunk Creeks




Right
Left
Right
Left
Fully Functional
Functional
Slightly Impaired
Impaired


Right
Left
Right
Unmodified
Modified
Highly Modified

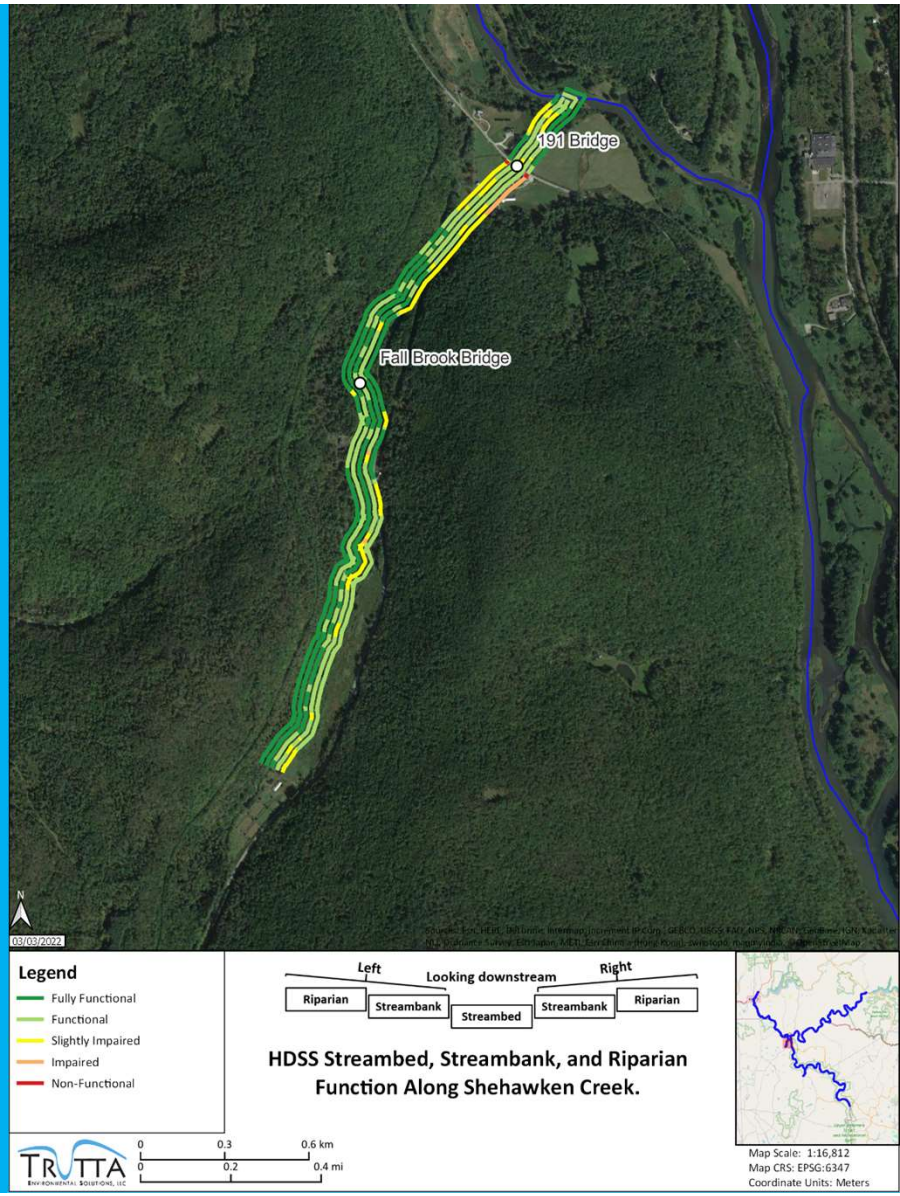

191 Bridge
Fall Brook Bridge
N
03/03/2022
Legend
Fully Functional
Functional
Slightly Impaired
Impaired
Non-Functional
Left
Looking downstream
Right
Riparian
Streambank
Streambed
Streambank
Riparian
HDSS Streambed, Streambank, and Riparian Function Along Shehawken Creek.
TRTTA
ENVIRONMENTAL SOLUTIONS, LLC
0
0.3
0.6 km
0
0.2
0.4 mi
Map Scale: 1:16,812
Map CRS: EPSG:6347
Coordinate Units: Meters

Table 10: Length and percent of Right Riparian, Right Streambank, Streambed, Left Riparian and Left Streambank Function Scores for Shehawken and Equinunk creeks.

River Segment	Function	Right Riparian Count (m)	Right Riparian Percent	Right Streambank Count (m)	Right Streambank Percent	Streambed Count (m)	Streambed Percent	Left Streambank Count (m)	Left Streambank Percent	Left Riparian Count (m)	Left Riparian Percent
Shehawken Creek	Fully Functional	933	33.2	487	17.3	1414	50.2	1173	41.7	2032	72.2
Shehawken Creek	Functional	967	34.4	1754	62.3	1242	44.1	1509	53.6	393	14
Shehawken Creek	Slightly Impaired	711	25.3	538	19.1	141	5	132	4.7	371	13.2
Shehawken Creek	Impaired	187	6.6	35	1.2	0	0	0	0	7	0.2
Shehawken Creek	Non-functional	16	0.6	0	0	0	0	0	0	11	0.4
Equinunk Creek	Fully Functional	1560	61.4	0	0	1171	46.1	0	0	766	30.1
Equinunk Creek	Functional	599	23.6	1913	75.3	1161	45.7	1987	78.2	1143	45
Equinunk Creek	Slightly Impaired	220	8.7	595	23.4	209	8.2	554	21.8	581	22.9
Equinunk Creek	Impaired	117	4.6	33	1.3	0	0	0	0	16	0.6
Equinunk Creek	Non-functional	45	1.8	0	0	0	0	0	0	35	1.4

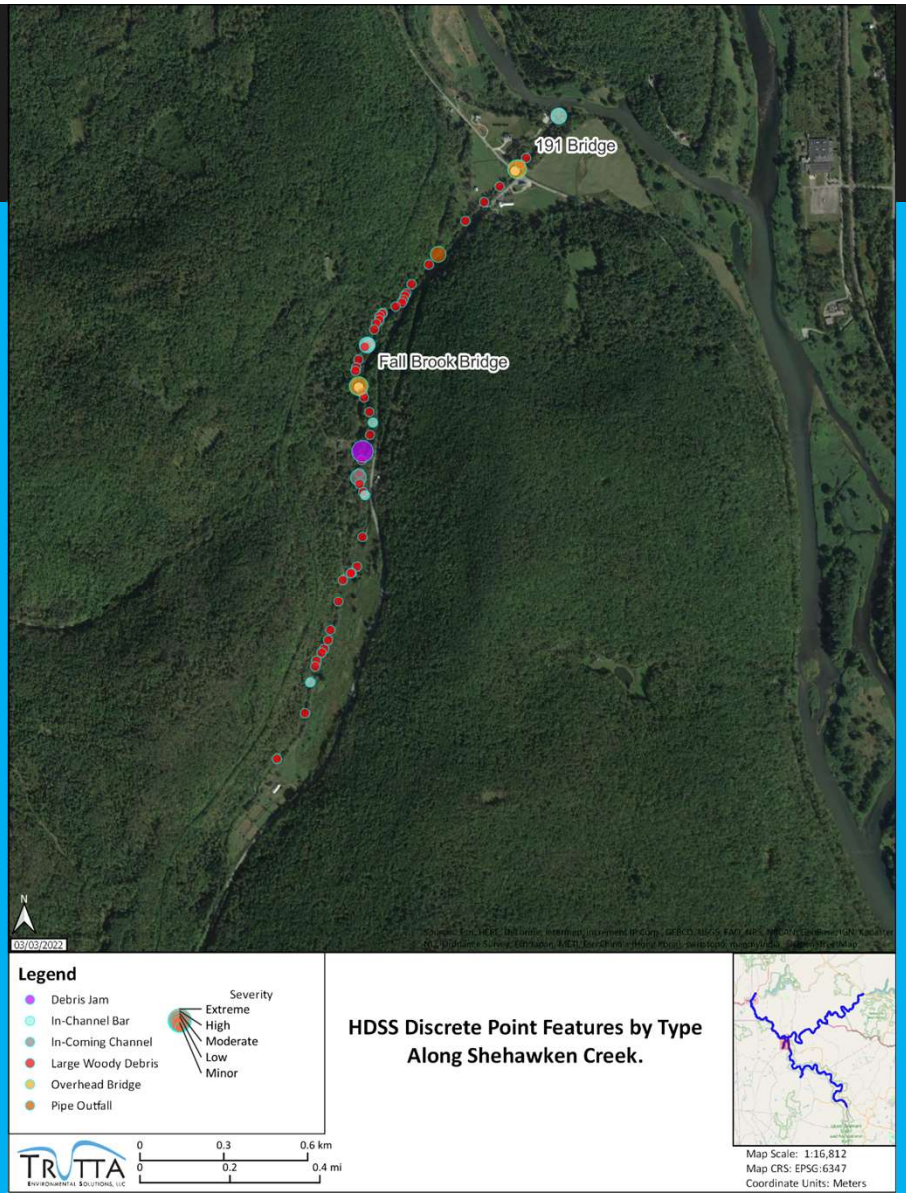
Table 11: Length and percent of Right Streambank, Streambed and Left Riparian Modification Scores for Shehawken and Equinunk creeks. Note: There are no modification scores for the riparian areas as the riparian condition score considers the amount of modification as part of its categorical scoring.

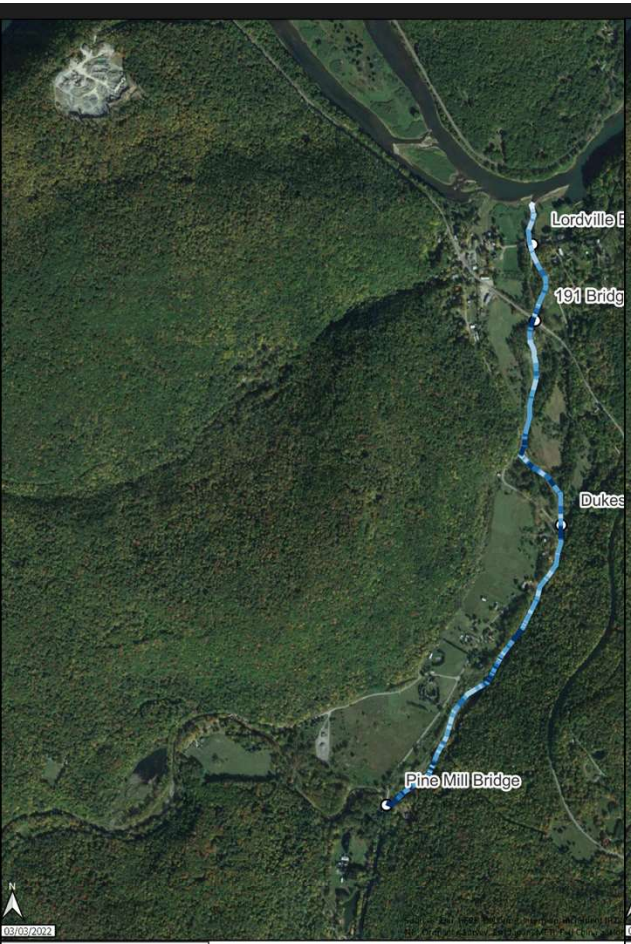
River Segment	Modification	Right Streambank Count (m)	Right Streambank Percent	Streambed Count (m)	Streambed Percent	Left Streambank Count (m)	Left Streambank Percent
Shehawken Creek	Unmodified	2680	95.2	2814	100	2779	98.8
Shehawken Creek	Modified	118	4.2	0	0	15	0.5
Shehawken Creek	Highly Modified	16	0.6	0	0	20	0.7
Equinunk Creek	Unmodified	2335	91.9	2541	100	2314	91.1
Equinunk Creek	Modified	132	5.2	0	0	150	5.9
Equinunk Creek	Highly Modified	74	2.9	0	0	77	3

Point Issues

Table 12: Discrete Point Feature observations within the survey area.

Stream Segment	Point Class	Point Type	Count
Shehawken Creek	Other	Debris Jam	1
Shehawken Creek	Other	In-Channel Bar	5
Shehawken Creek	Other	In-Coming Channel	1
Shehawken Creek	Other	Large Woody Debris	46
Shehawken Creek	Pipe	Pipe Outfall	1
Shehawken Creek	Road	Overhead Bridge	2
Equinunk Creek	Other	Large Woody Debris	9
Equinunk Creek	Road	Overhead Bridge	3

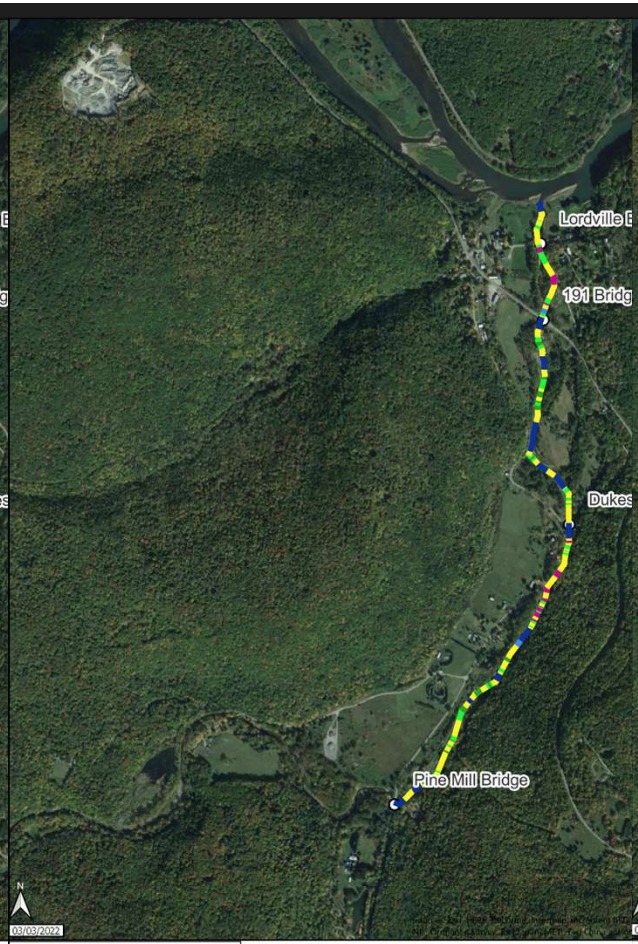




Legend
- 10 cm
- 20
- 30
- 40
- 50+

HDSS Water Depth (cm) Along Equinunk C

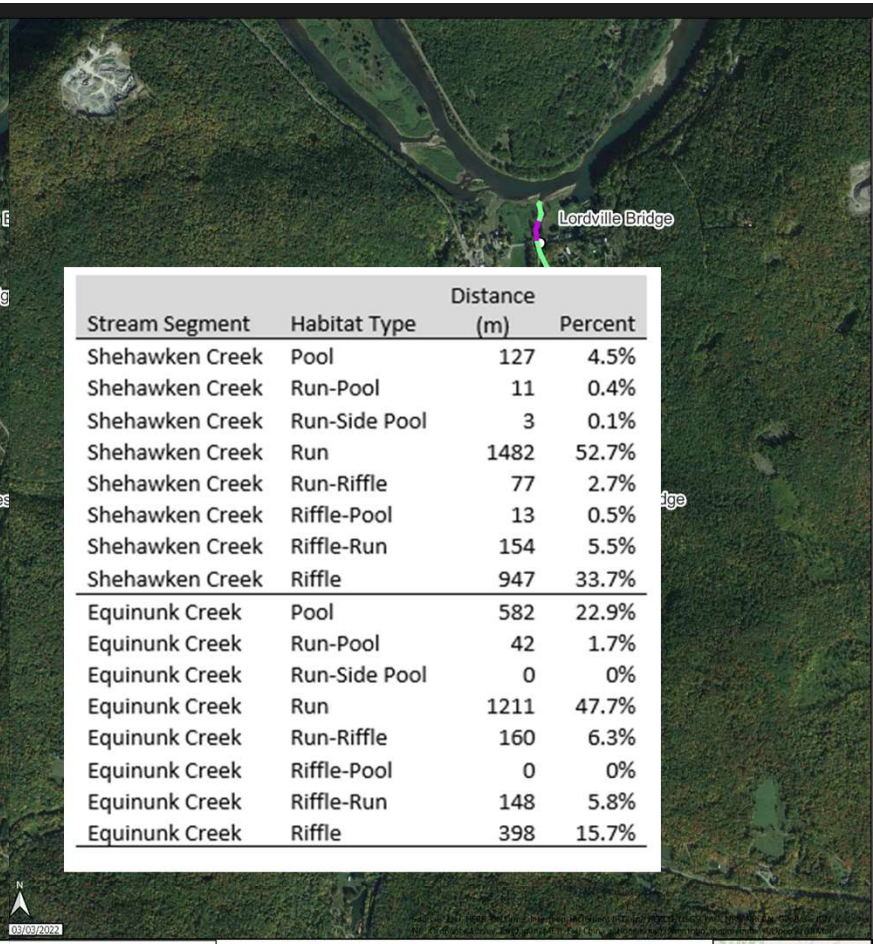
TRUTTA ENVIRONMENTAL SOLUTIONS, LLC
0 0.3 0.6 km
0 0.2 0.4 mi



Legend
- riffle
- riffle-pool
- riffle-run
- run-pool
- run
- pool
- run-riffle
- run-side pool

HDSS Habitat Type Along Equinunk Cr

TRUTTA ENVIRONMENTAL SOLUTIONS, LLC
0 0.3 0.6 km
0 0.2 0.4 mi



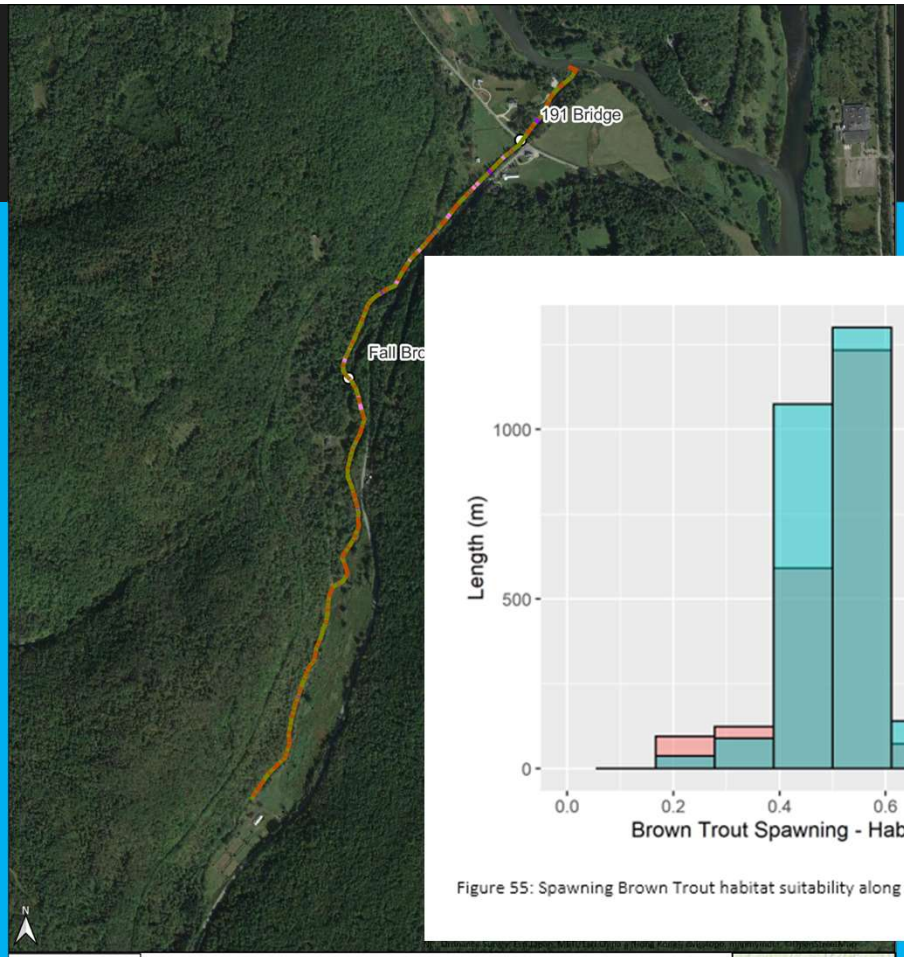
Stream Segment	Habitat Type	Distance (m)	Percent
Shehawken Creek	Pool	127	4.5%
Shehawken Creek	Run-Pool	11	0.4%
Shehawken Creek	Run-Side Pool	3	0.1%
Shehawken Creek	Run	1482	52.7%
Shehawken Creek	Run-Riffle	77	2.7%
Shehawken Creek	Riffle-Pool	13	0.5%
Shehawken Creek	Riffle-Run	154	5.5%
Shehawken Creek	Riffle	947	33.7%
Equinunk Creek	Pool	582	22.9%
Equinunk Creek	Run-Pool	42	1.7%
Equinunk Creek	Run-Side Pool	0	0%
Equinunk Creek	Run	1211	47.7%
Equinunk Creek	Run-Riffle	160	6.3%
Equinunk Creek	Riffle-Pool	0	0%
Equinunk Creek	Riffle-Run	148	5.8%
Equinunk Creek	Riffle	398	15.7%

Legend
- Bedrock
- Small Mix
- Large Mix
- Gravel
- Boulder
- Medium Mix
- Cobble

HDSS Streambed Composition Along Equinunk Creek.

TRUTTA ENVIRONMENTAL SOLUTIONS, LLC
0 0.3 0.6 km
0 0.2 0.4 mi

Map Scale: 1:16,812
Map CRS: EPSG:6347
Coordinate Units: Meters



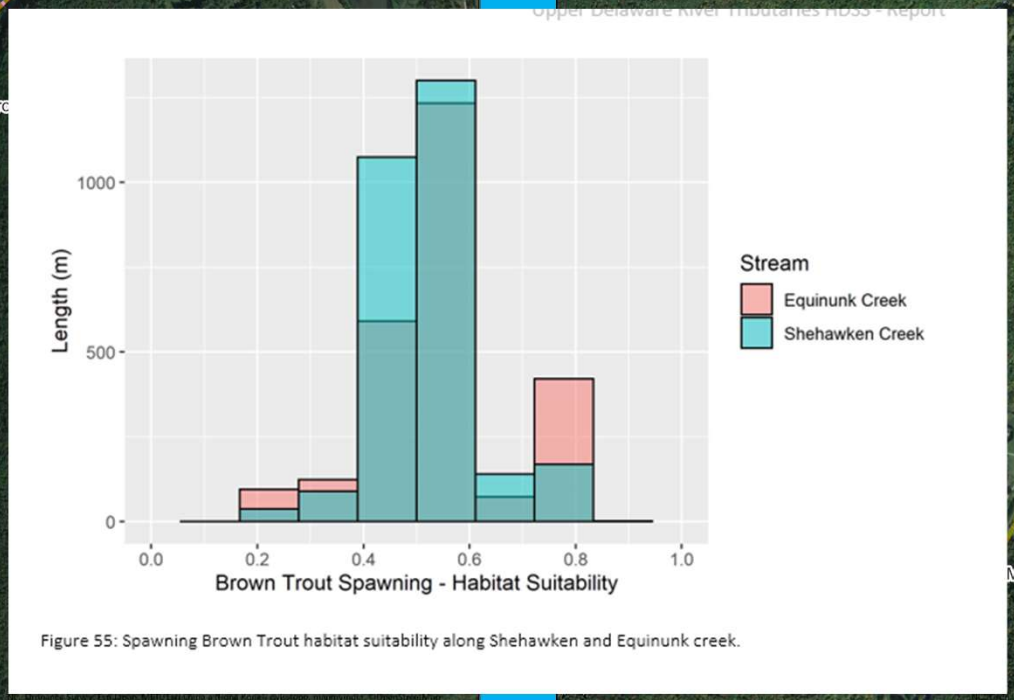
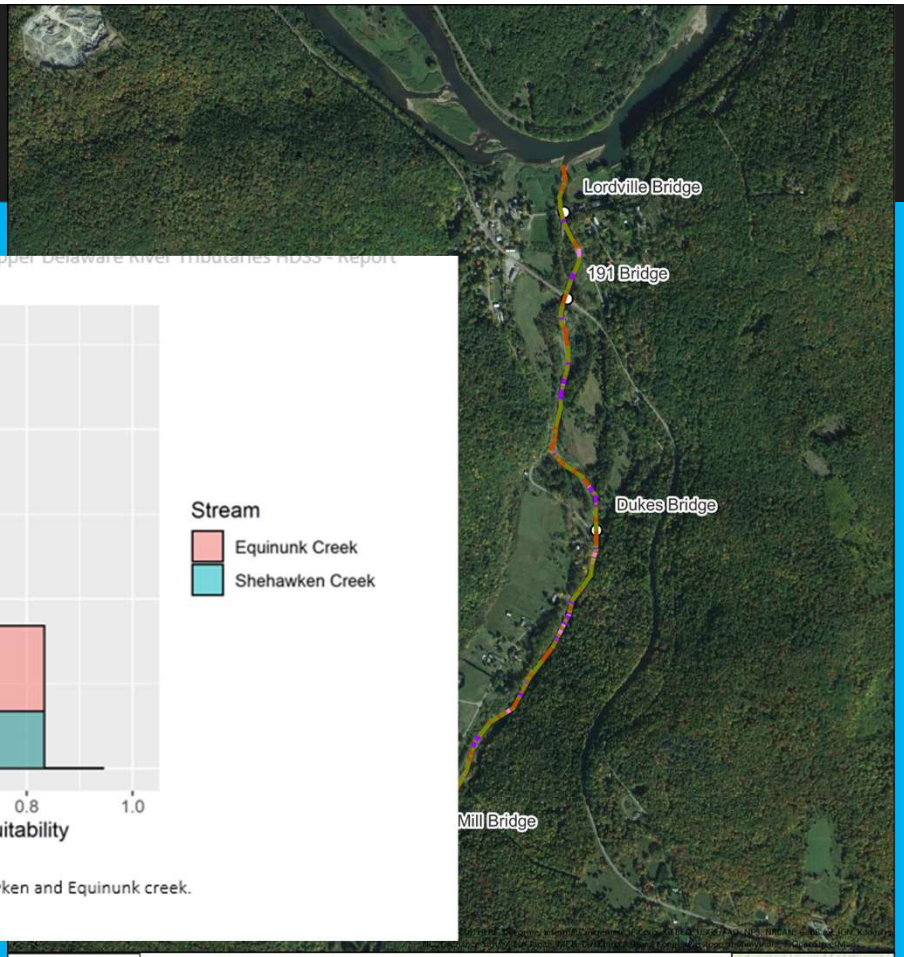
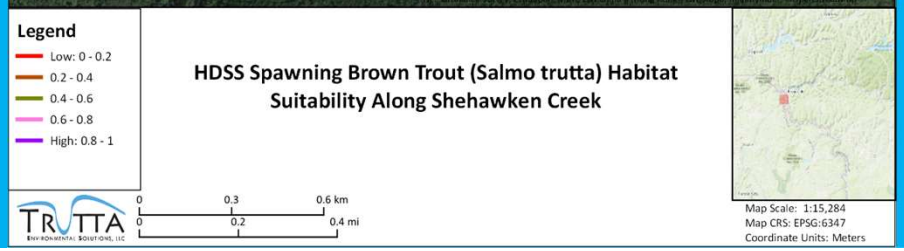
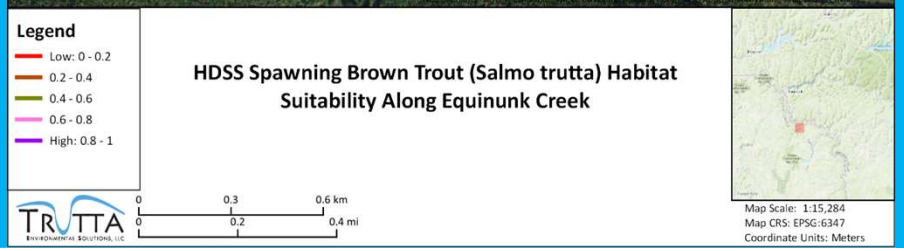


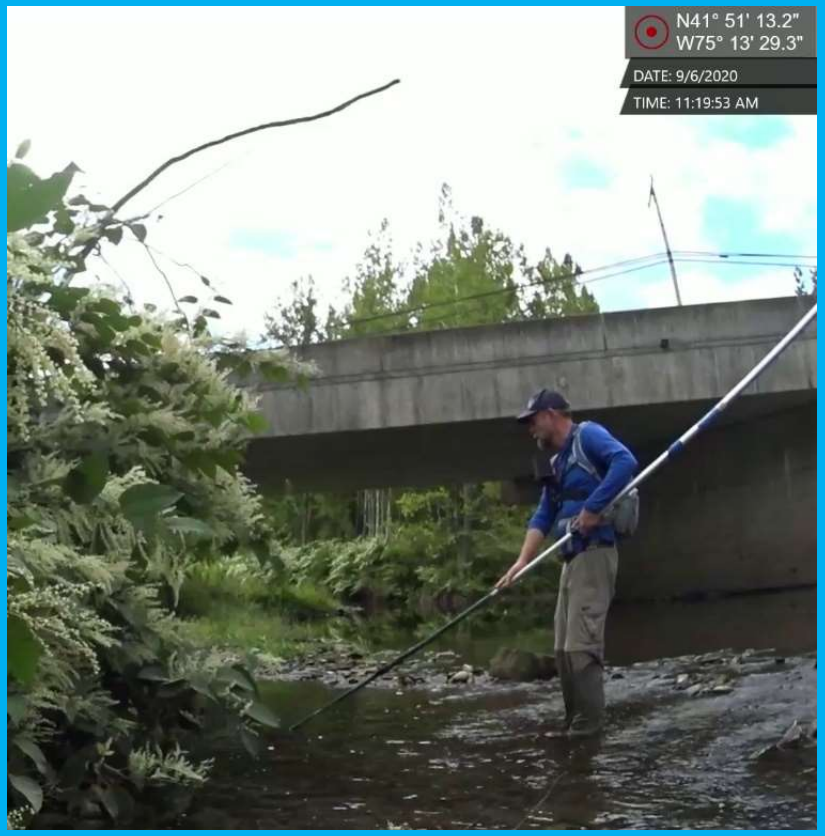
Figure 55: Spawning Brown Trout habitat suitability along Shehawken and Equinunk creek.







High Definition Fish Survey (HDFS)



Pole Camera Set Up

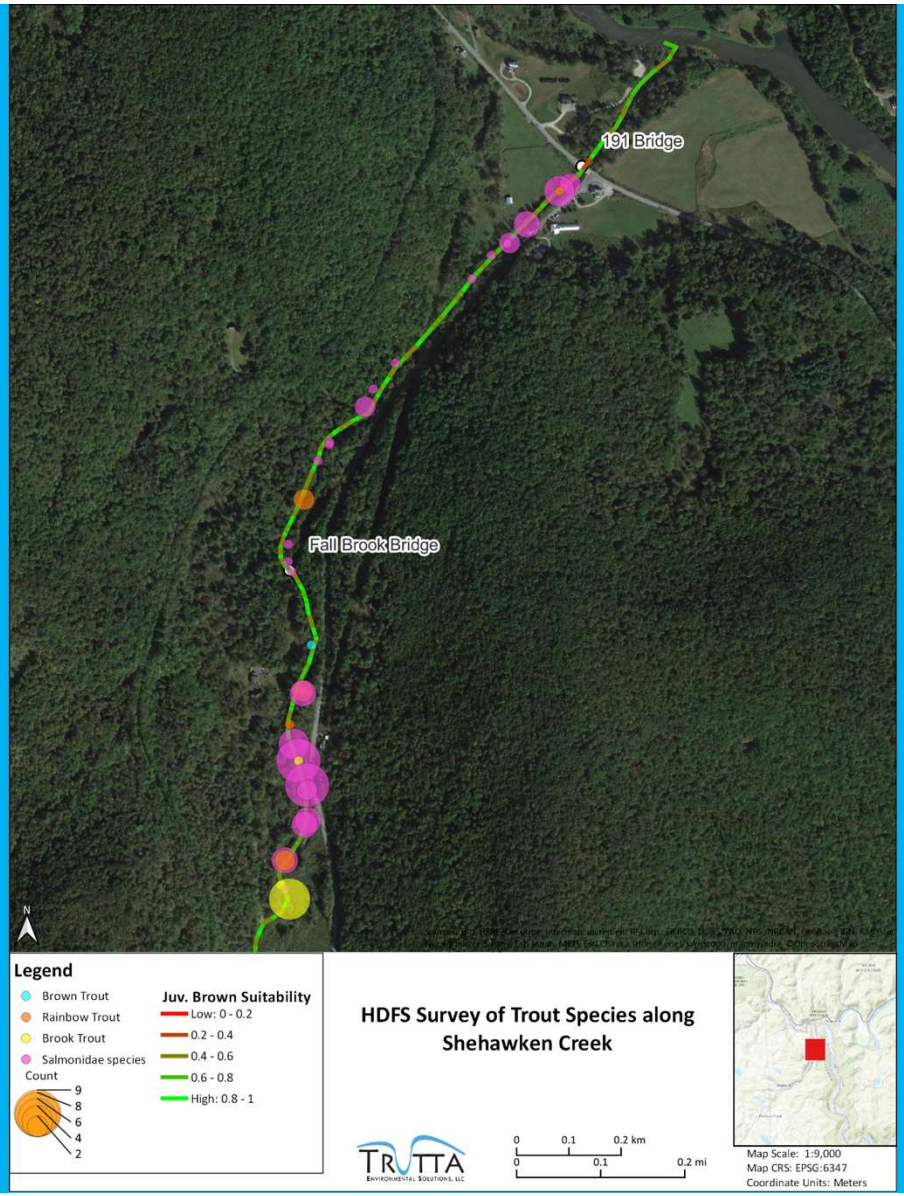
Underwater Camera

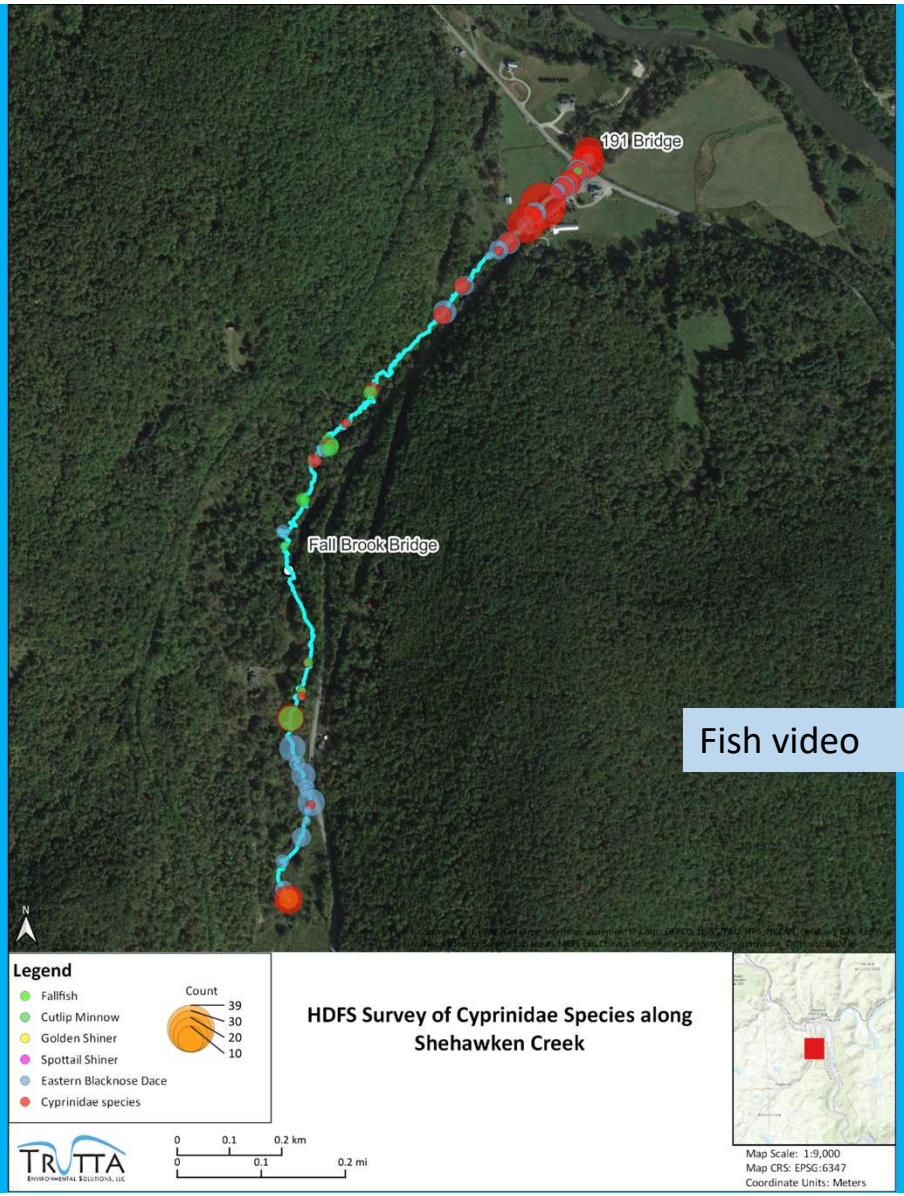
HDFS Training

Survey by Lee Hartman

HDFS Observations


High Definition Fish Survey
TruttaSolutions.com
Shehawken Creek - Track 2
N41° 55' 47.4"
W75° 17' 45.1"
DATE: 9/7/2020
TIME: 12:47:43 PM


191 Bridge
Fall Brook Bridge
N
Legend
Brown Trout
Rainbow Trout
Brook Trout
Salmonidae species
Count
9
8
6
4
2
Juv. Brown Suitability
Low: 0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
High: 0.8 - 1
HDFS Survey of Trout Species along Shehawken Creek
TRUTTA
ENVIRONMENTAL SOLUTIONS, LLC
0 0.1 0.2 km
0 0.1 0.2 mi
Map Scale: 1:9,000
Map CRS: EPSG:6347
Coordinate Units: Meters


191 Bridge
Fall Brook Bridge
N
Legend
Fallfish
Cutlip Minnow
Golden Shiner
Spottail Shiner
Eastern Blacknose Dace
Cyprinidae species
Count
39
30
20
10
HDFS Survey of Cyprinidae Species along Shehawken Creek
TRUTTA
ENVIRONMENTAL SOLUTIONS, LLC
0 0.1 0.2 km
0 0.1 0.2 mi
Map Scale: 1:9,000
Map CRS: EPSG:6347
Coordinate Units: Meters

Fish video

Conclusions

- StreamView Video on over 80 miles of Upper Delaware River and lower Shehawken and Equinunk Creeks
- SCA showed the river in overall good condition with some areas of concern
  - Streambank Erosion
  - Invasive Plants
- Trout Habitat Assessment
  - Provided continuous habitat and habitat suitability for Adult Brown and Rainbow Trout, Juvenile Brown and Rainbow Trout, and Brown Trout Spawning Habitats
  - Highly depended on suitability criteria
  - Find new, good fishing areas
- Excellent baseline documentation for public outreach, management actions, and future comparisons

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BETTER DATA. BETTER DECISIONS.

Jim.Parham@TruttaSolutions.com
TruttaSolutions.com