2D HYDRAULIC MODELING OF THE STATE ROUTE 76 HATCHIE RIVER BRIDGE REPLACEMENT IN WEST TENNESSEE USING SRH–2D

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TDOT Hydraulic Design Section
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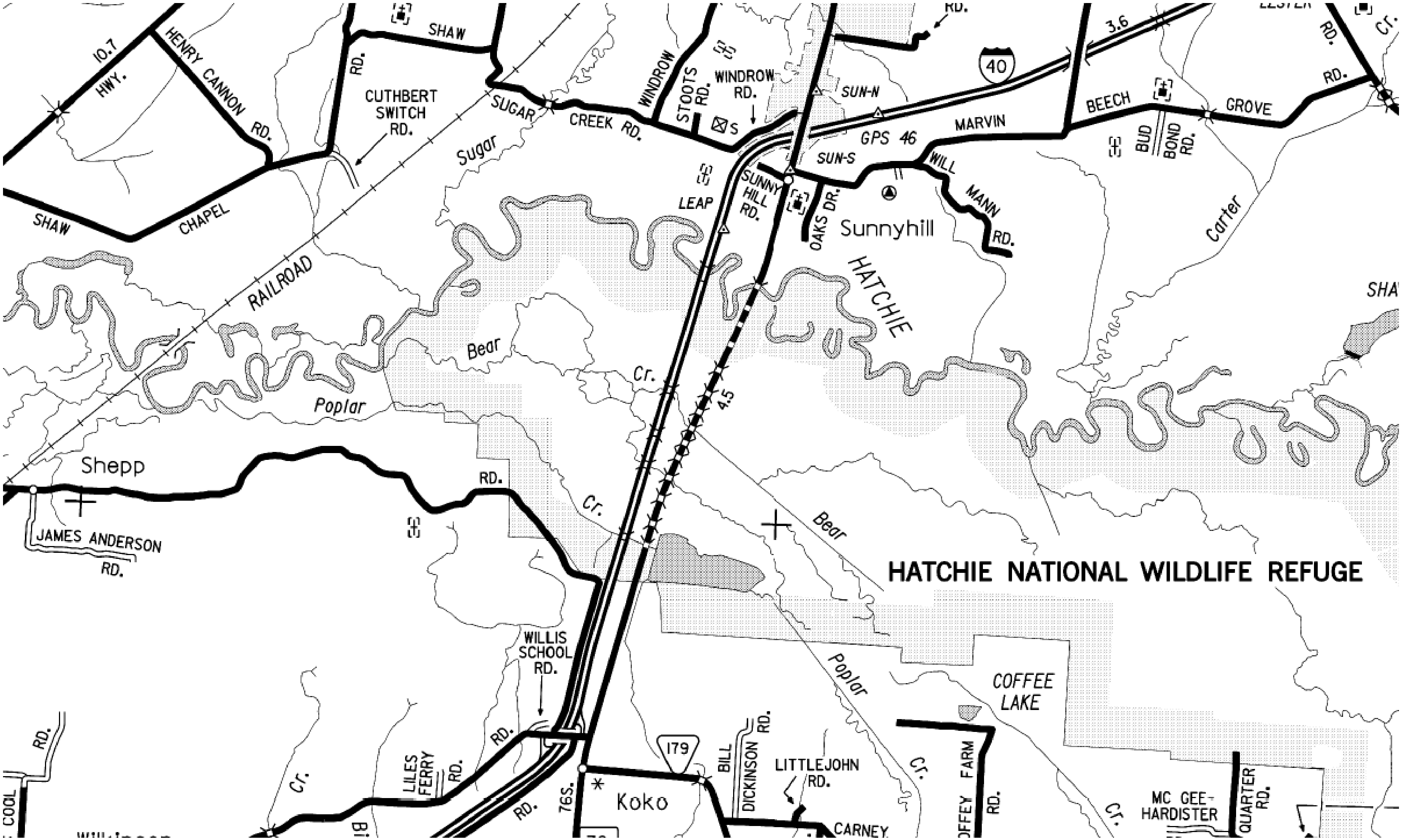
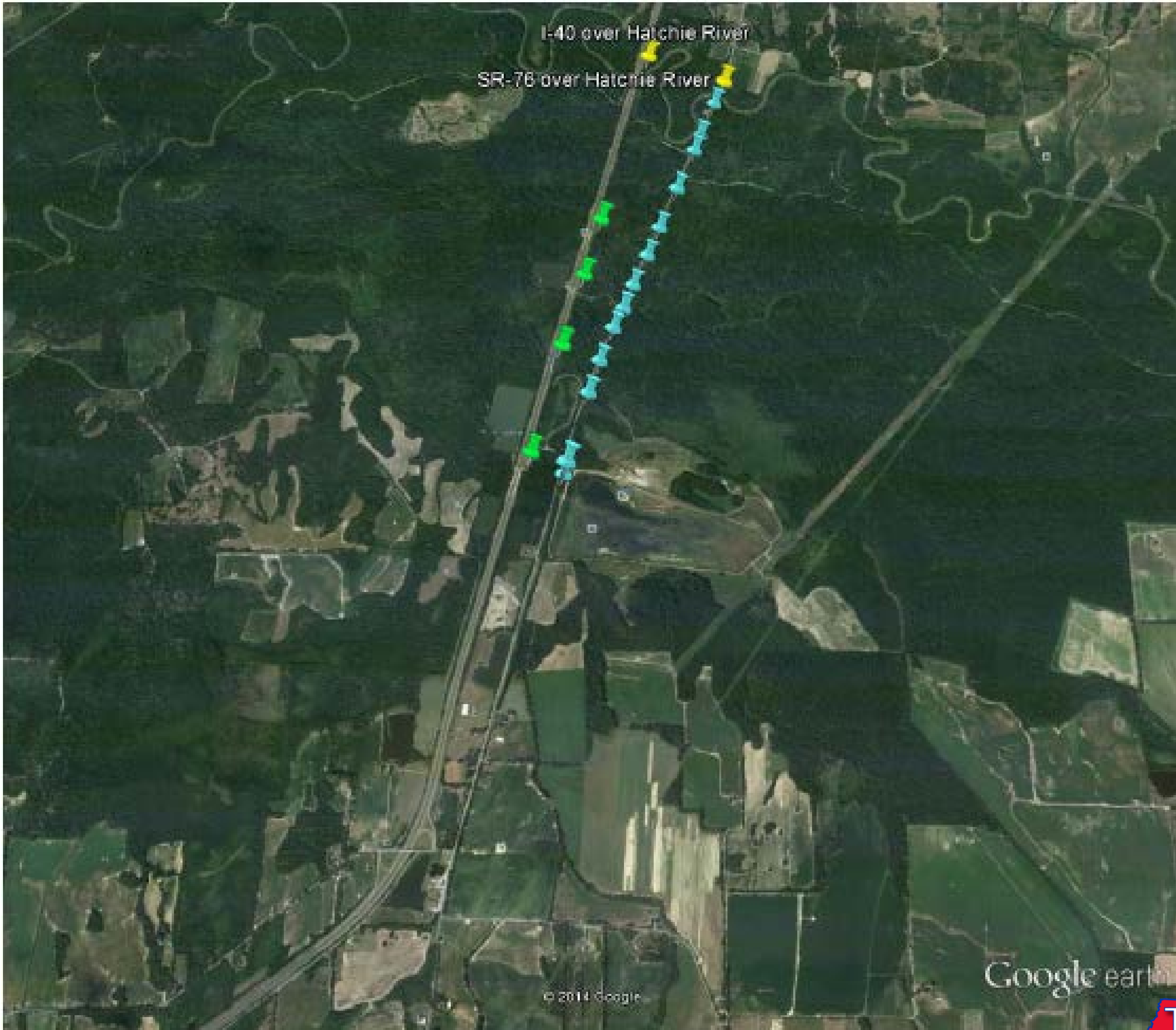
Outline

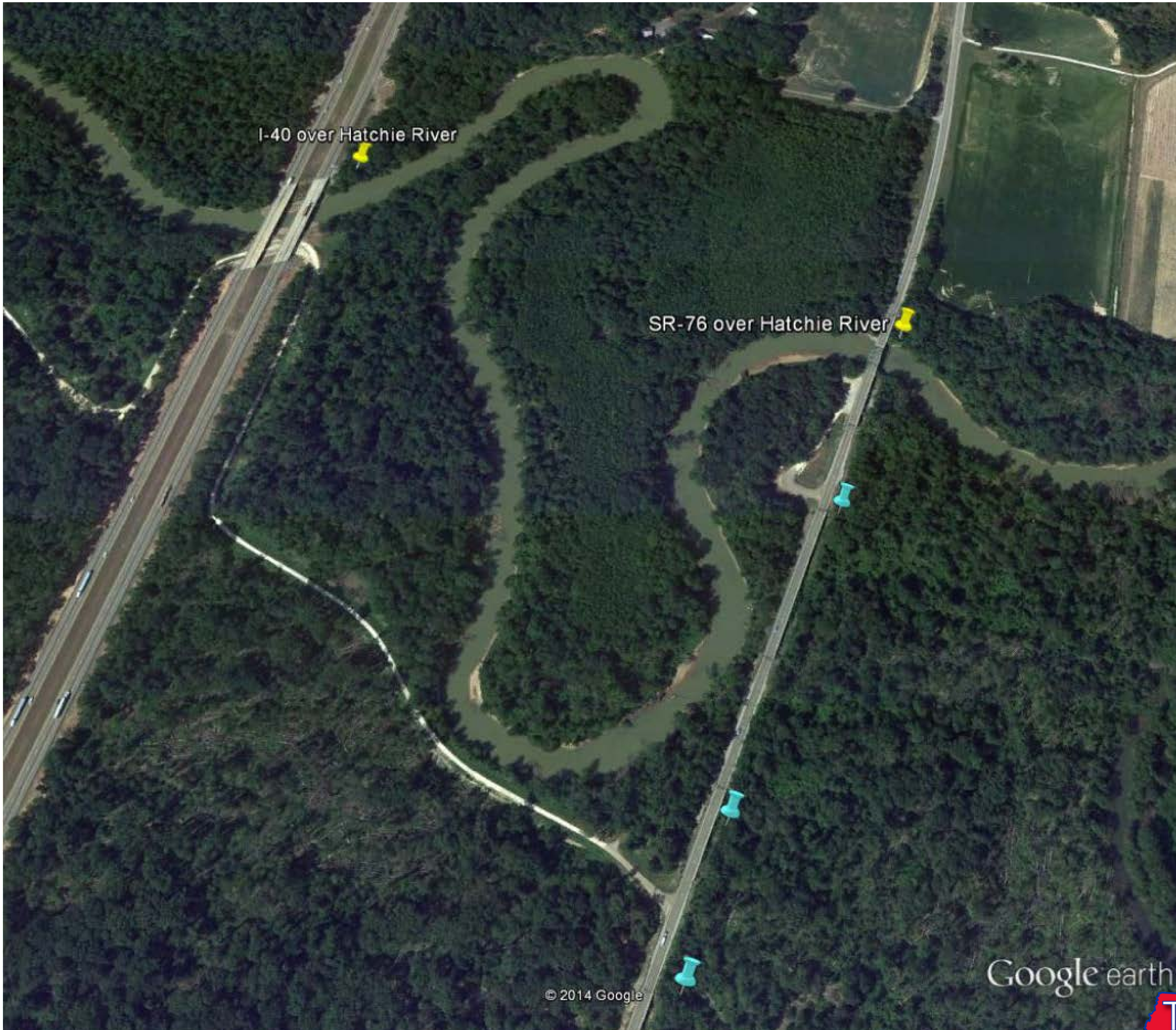
1. Site description
2. Justification for project
3. Why SMS SRH-2D?
4. SMS SRH-2D model details
5. SMS SRH-2D model results

1. Site description



HENRY CANNON RD.
10.7 HWY.
SHAW
CUTHBERT SWITCH RD.
RD.
SHAW
CHAPEL
RAILROAD
SUGAR CREEK RD.
Sugar
WINDROW
STOOTS RD.
WINDROW RD.
S
LEAP
SUNNY HILL RD.
SUN-N
SUN-S
GPS 46
40
3.6
MARVIN
WILL MANN RD.
OAKS DR.
Sunnyhill
BEECH GROVE RD.
BUD BOND RD.
RD.
Carter
HATCHIE
Bear
Cr.
Poplar
4.5
Shepp
RD.
JAMES ANDERSON RD.
Cr.
Bear
HATCHIE NATIONAL WILDLIFE REFUGE
Poplar
COFFEE LAKE
WILLIS SCHOOL RD.
RD.
LILES FERRY RD.
RD.
Cr.
COAL
179
76S.
Koko
BILL DICKINSON RD.
LITTLEJOHN RD.
CARNEY
Cr.
FARM RD.
Cr.
MC GEE-HARDISTER
QUARTER RD.


I-40 over Hatchie River
SR-76 over Hatchie River
Google earth
© 2014 Google


I-40 over Hatchie River
SR-76 over Hatchie River
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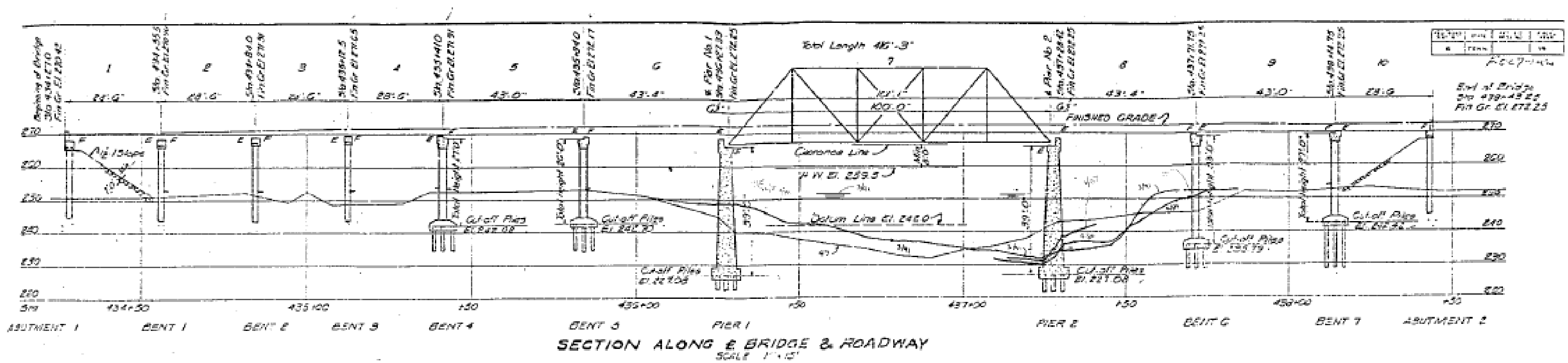
Bridge Data for SR-76 over Hatchie River

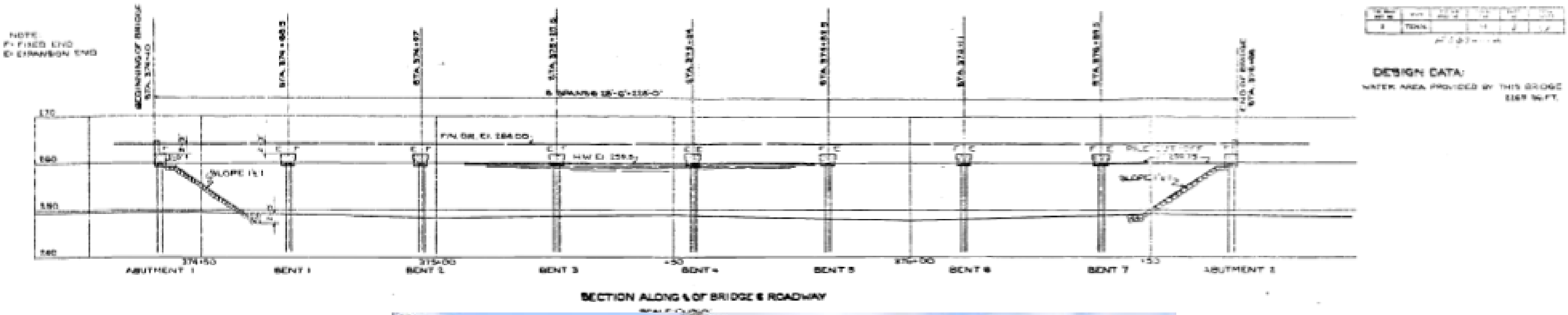
	Proposed	Existing
Type	4 – span Concrete Girder Bridge	Truss main span and 9 concrete approach spans
Length (ft)	425	416
Width (ft)	46	24

Main Span – Truss and approach spans concrete girder bridge




10.10.2013

Typical Concrete Girder Bridge on State Route-76



2. Justification for project

- Originally constructed in 1947
- Insufficient lane width and number
- Minor section loss, cracking, spalling and scour observed in inspection reports
- Scour critical rating
- Inspection reports indicate need of repair
- Classified functionally obsolete, structurally deficient, and fracture critical
- Sufficiency rating of 11.9 out of 100.

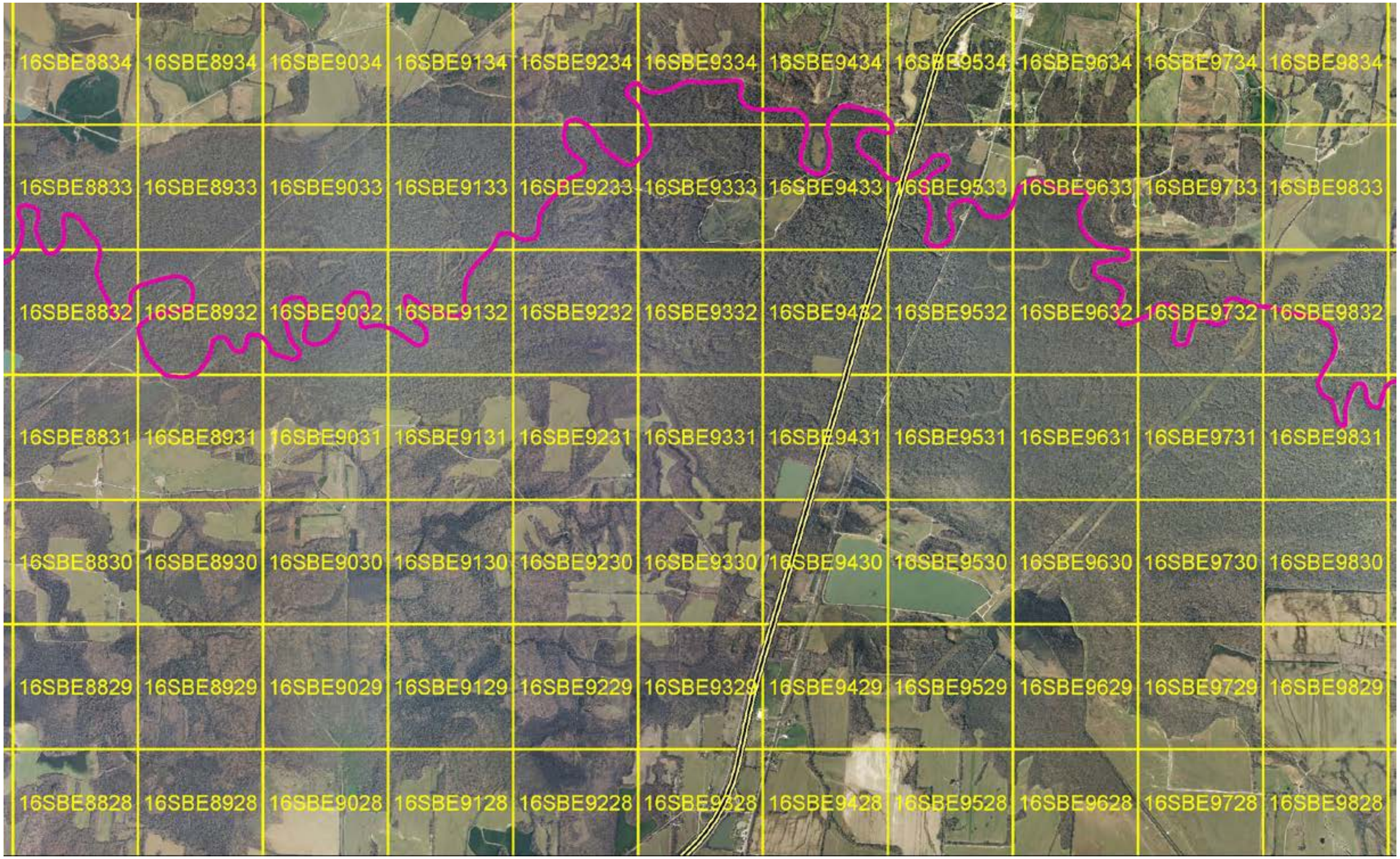
3. Why SMS SRH-2D?

- Meandering river with good floodplain connection
- Extremely wide floodplain (approximately 19,000 feet)
- 19 bridges within the floodplain on 2 parallel routes
- Quick access to accurate data such as velocities, water depth, and water elevation for multiple structures in the same model
- Ability to assign custom hydraulic data

4. SMS SRH-2D model details

- Six materials (trees, channel, road, grass, …)
- All 19 bridges included in 1 model
- 26 mi^2 area
- Utilized existing Lidar data from NRCS

Material	Manning's coefficient
Channel	0.035
Road	0.013
Grass	0.060
Trees & Grass	0.100
Trees	0.120
Overflow	0.050
Rip-Rap	0.045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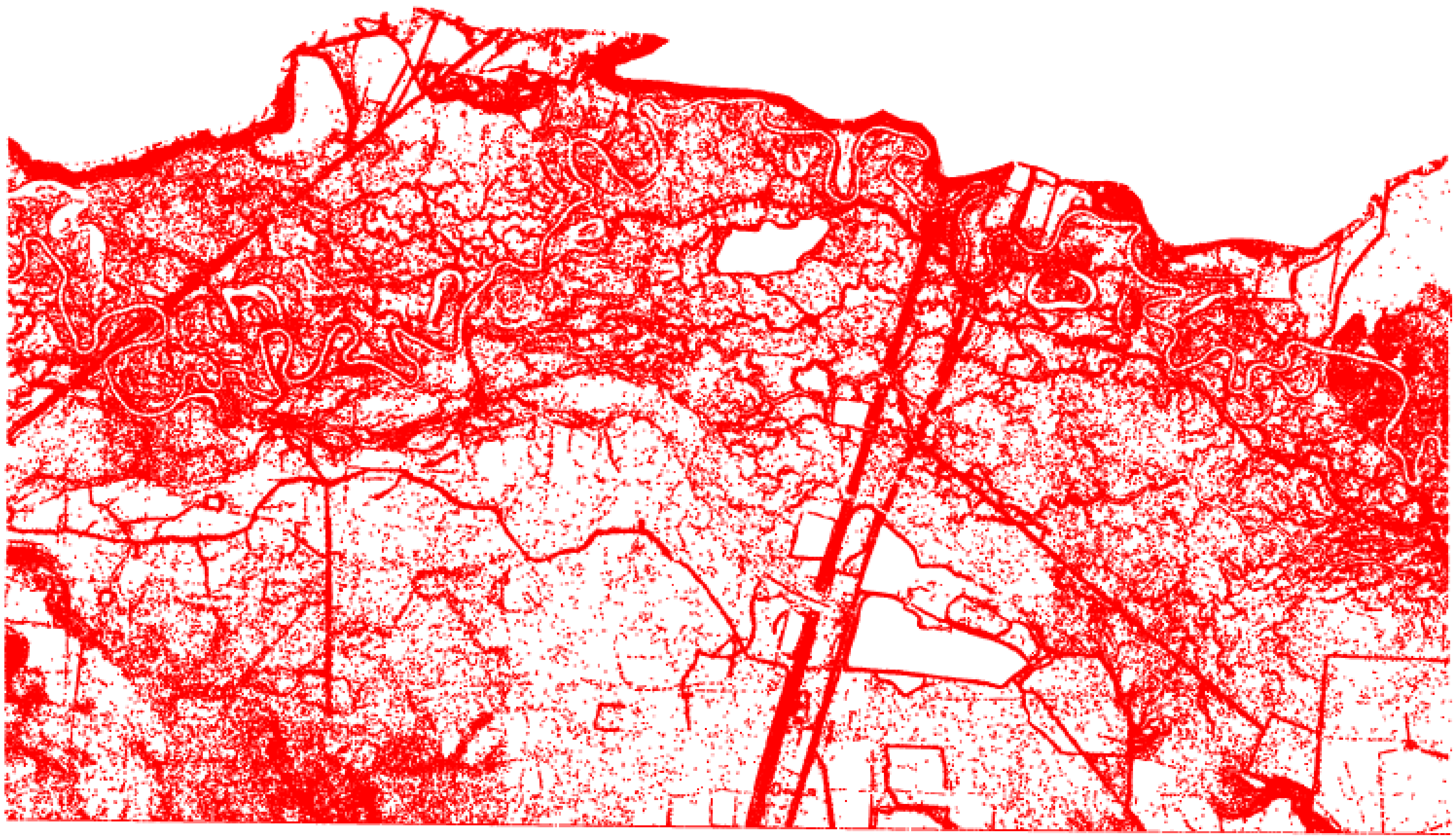

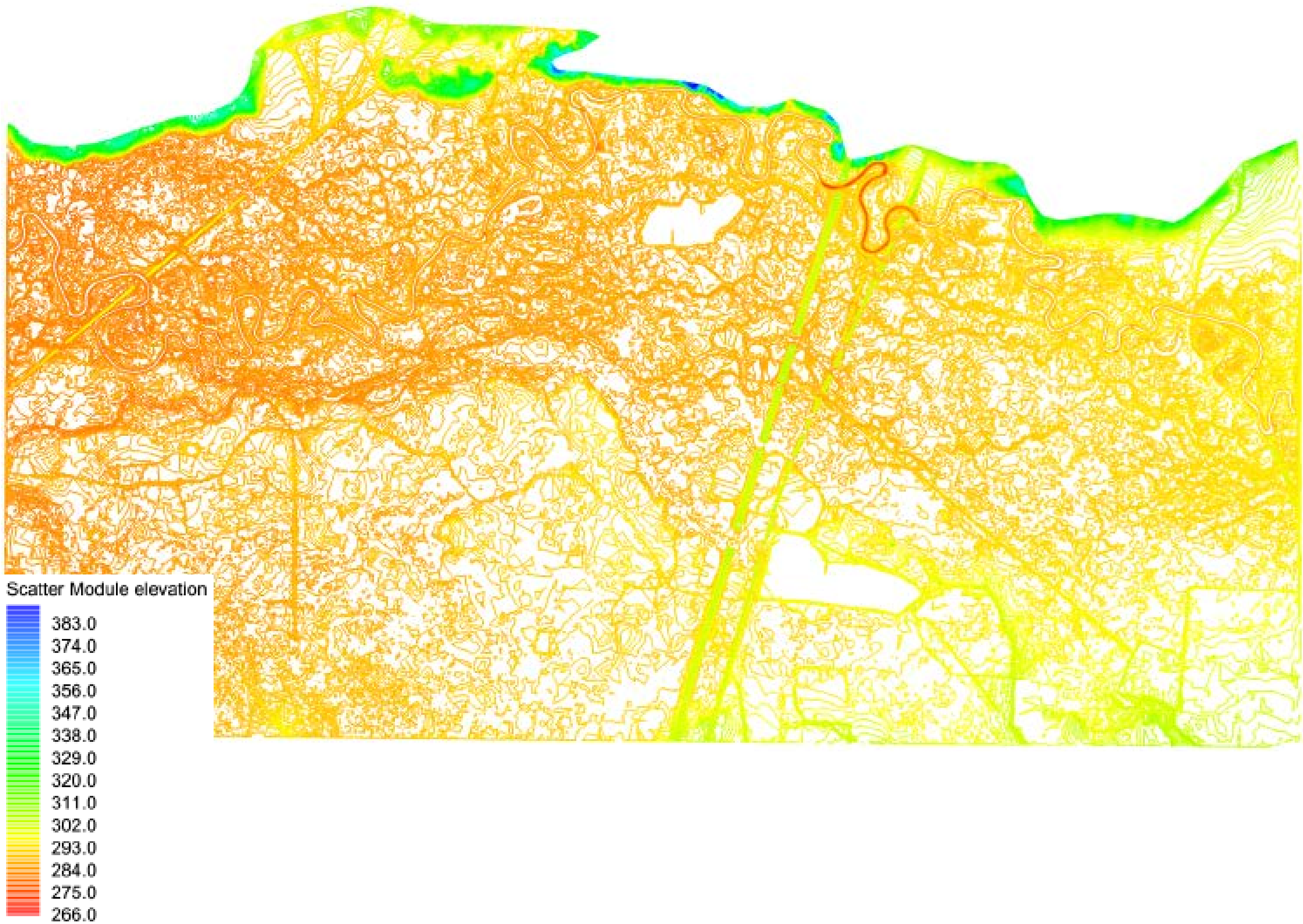
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374.0
365.0
356.0
347.0
338.0
329.0
320.0
311.0
302.0
293.0
284.0
275.0
266.0

Processing LIDAR Data for SMS SRH-2D

- Used to describe the topography in SMS
- Conversion to readable format required
- Requires high power computing (experienced frequent crashes using unfiltered data)
- Geopak was used to do the initial filtering
- Data was further reduced once loaded in SMS

Processing LIDAR Data for SMS SRH-2D

Method 1

- Start with a Microstation dgn file which used the ImageStation DTMQue software to import a LAS file
- All global coordinates are correctly translated into SMS

Processing LIDAR Data for SMS SRH-2D

Method 2

- Start with a LAS file using Geopak without using ImageStation DTMQue software
- The resulting XML file exported by Geopak lacks all of the required global coordinate data

Method 1: used by TDOT

In Microstation Geopak

- Open Civil Workflow
- DTM Tools
- Extract Graphics
- Create Spots and Append Breaklines

Filter the DAT file created in the previous step

- Open Civil Workflow
- DTM Tools
- Filter vertices
- Input the z - tolerance and xy – tolerance

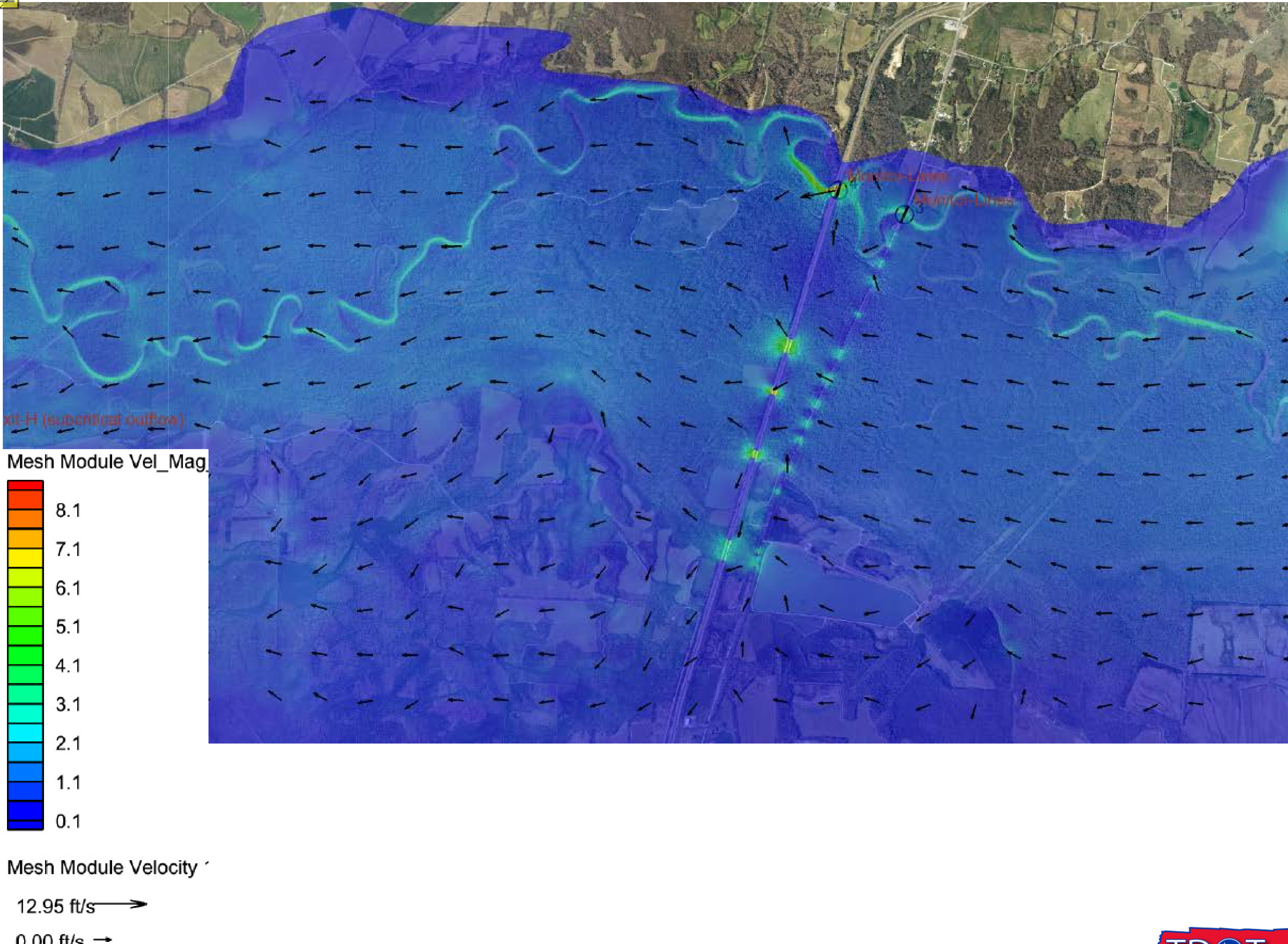
Convert filtered DAT file to TIN file

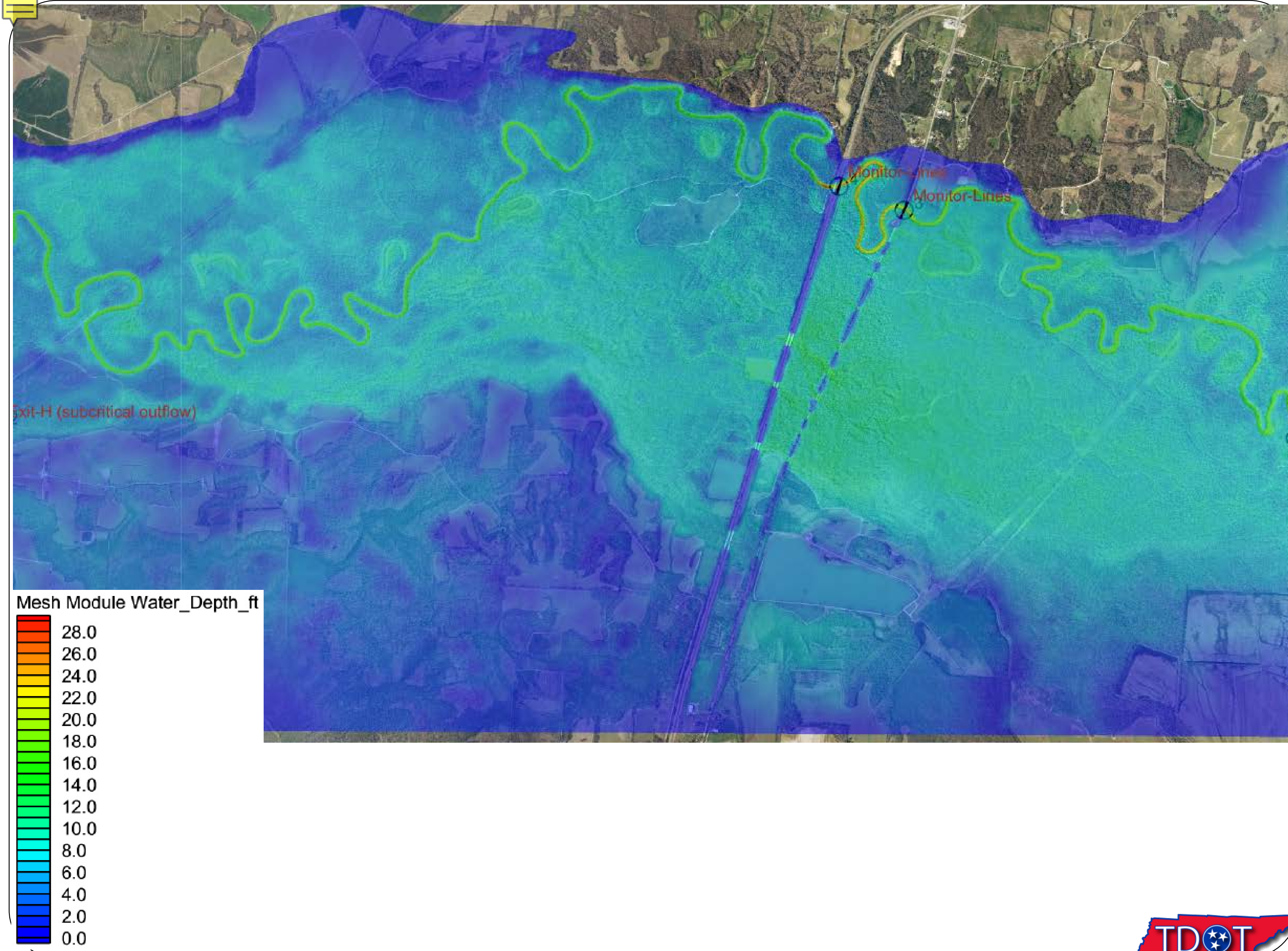
- Open Civil Workflow
- DTM Tools
- Build Triangles

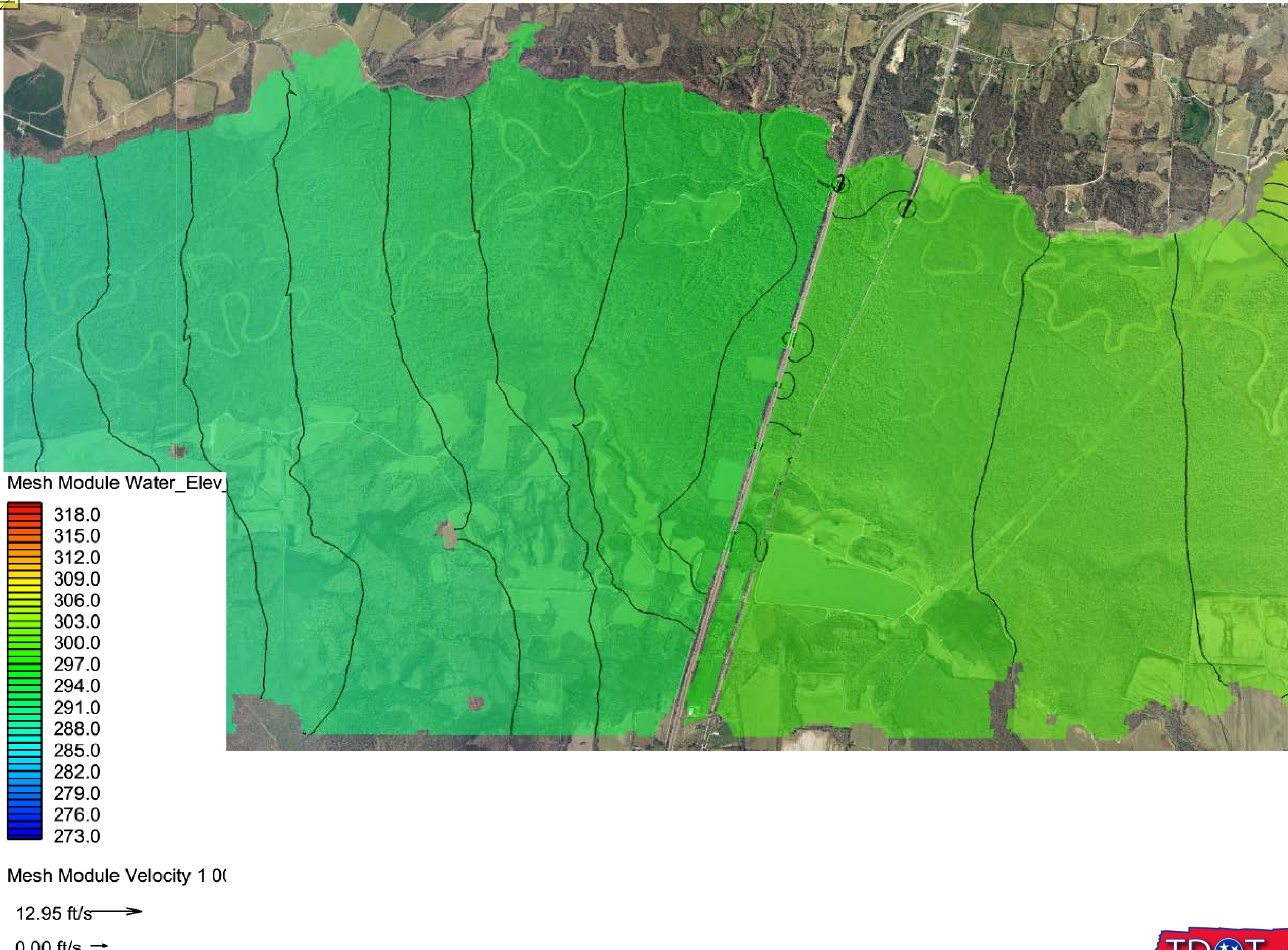
Convert TIN file to LandXML file

- Open Civil Workflow
- DTM Tools
- Export LandXML

5. SMS SRH-2D model results


xit-H (subcritical outflow)
Mesh Module Vel_Mag
8.1
7.1
6.1
5.1
4.1
3.1
2.1
1.1
0.1
Mesh Module Velocity
12.95 ft/s
0.00 ft/s


Monitor-Lines
Monitor-Lines
Exit-H (subcritical outflow)
Mesh Module Water_Depth_ft
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0


Mesh Module Water_Elev_
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315.0
312.0
309.0
306.0
303.0
300.0
297.0
294.0
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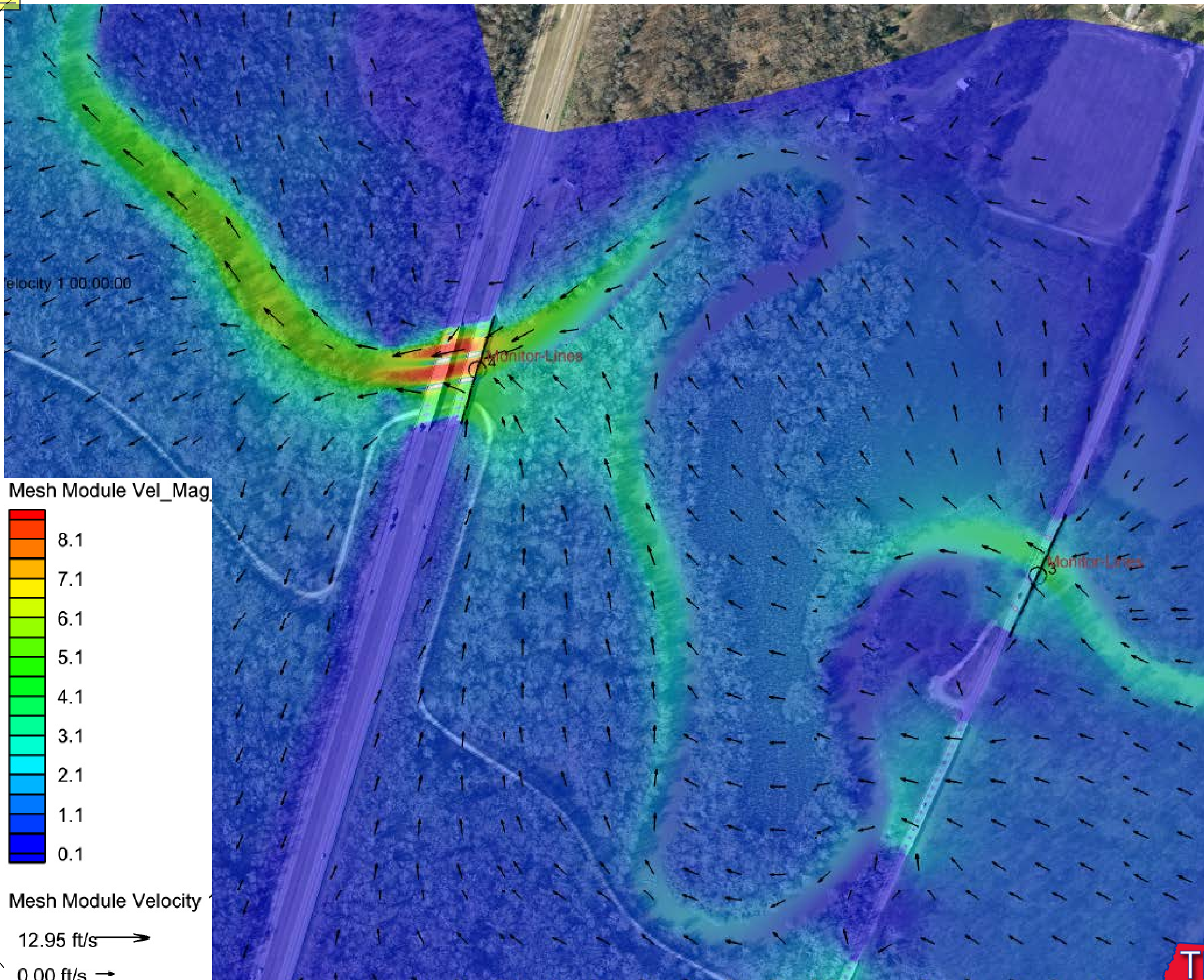
288.0
285.0
282.0
279.0
276.0
273.0
Mesh Module Velocity 1 0(
12.95 ft/s
0.00 ft/s


elocity 1 00:00:00
Monitor-Lines
Monitor-Lines
Mesh Module Vel_Mag
8.1
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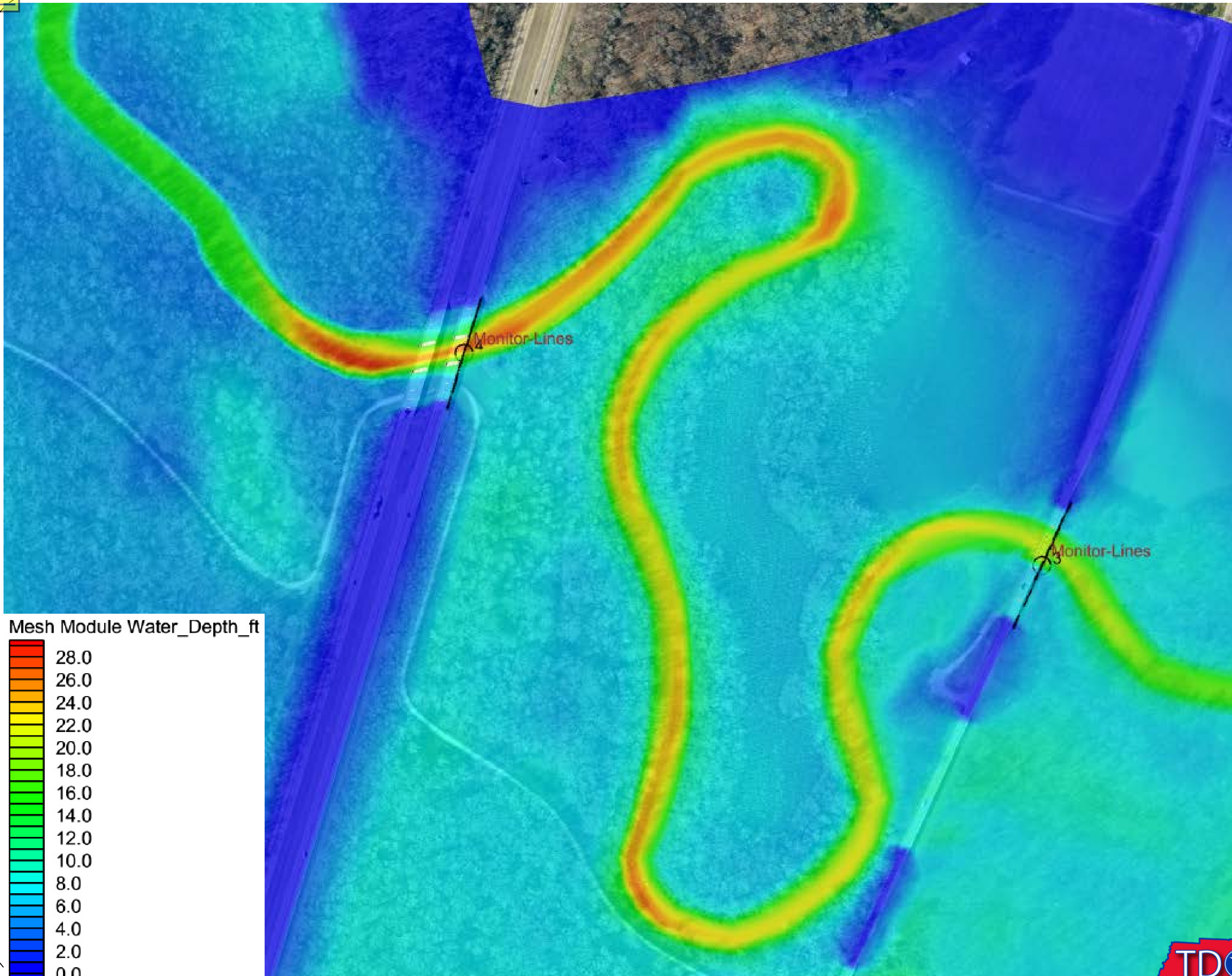
3.1
2.1
1.1
0.1
Mesh Module Velocity
12.95 ft/s
0.00 ft/s
TDOT


Monitor-Lines
4
Monitor-Lines
3
Mesh Module Water_Depth_ft
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

TDOT


Mesh Module Water_Elev_
318.0
315.0
312.0
309.0
306.0
303.0
300.0
297.0
294.0
291.0
288.0
285.0
282.0
279.0
276.0
273.0
Mesh Module Velocity 1 00
12.95 ft/s
0.00 ft/s

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Hydraulic Data for SR-76 over Hatchie River

	Proposed	Existing
Drainage Area (mi^2)	1,849	1,849
Design Frequency (year)	100	100
Design Discharge (cfs)	8,267.2	8,245.03
Design Velocity (fts)	3.10	3.08
Design Water Area (sft)	2,667.00	2,677.00
Design Backwater (ft)	0.17	0.14
Design Backwater Elevation (ft)	298.25	298.22
Roadway Overtopping Elevation (ft)	302.50	302.50
500 yr. Design Backwater (ft)	0.21	0.19
500 yr. Design Backwater Elevation (ft)	299.55	299.53

Scour Data for SR-76 over Hatchie River

Proposed	
100 yr Total Scour Depth (ft)	10.05
500 yr Total Scour Depth (ft)	18.88

Table 4. Summary of 100-Year Event Scour Computations

Substructure	Type of Scour			
	Aggradation/ Degradation	Contraction	Local Scour	Total
Left Abutment	0	5.9	17.9	23.8
Bents 1, 2, & 3	0	5.9	2.6	8.5
Bents 4 & 5	0	5.9	4.2	10.1
Pier 1	0	13.2	8.0	21.2
Pier 2	0	13.2	9.6	22.8
Bents 6 & 7	0	13.2	4.2	17.4
Right Abutment	0	13.2	19.9	33.1

Notes:
1. Aggradation/degradation assumed to be zero. No significant changes in streambed due to aggradation/degradation.
2. No skew adjustments required.
3. Froehlich's equation was used for abutment scour.

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Scour Data for SR-76 over Hatchie River

Pier Scour in Cohesive Materials
100 YRS CHANNEL

Pier Scour for Cohesive Materials:

$$y_s = 2.2K_1K_2a^{0.65}\left(\frac{2.6V_1 - V_c}{\sqrt{g}}\right)^{0.7}$$ Eq. 7.35

1.0	K_1	Correction factor for pier nose shape from Table 7.1
1.0	K_2	Correction factor for angle of attack of flow from Table 7.2 or Eq. 7.4
5	a	Pier width (ft)
3.2	V_1	Mean velocity of flow of directly upstream of the pier (ft/s)
1.1795	V_c	Critical velocity for initiation of erosion of the cohesive material (ft/s)
32.2	g	Acceleration due to gravity (ft/s²)
7.36	y_s	Total Scour

$$V_c = K_u y^{1/6} D^{1/3} = 1.1795\ fts$$

Pier Shear Stress for Cohesive Materials:

$$\tau_{pier} = \frac{\gamma}{y_1^{1/3}}\left(\frac{nKV_1}{K_1}\right)^2$$ Eq. 7.36

62.4	γ	unit weight of water (lb/ft³)
20.1	y_1	Depth of flow at pier (ft)
0.035	n	Manning n of the channel bed
2	K	Velocity coefficient = 2.0 for circular piers, 2.5 for square piers
1.486	K_u	Constant
0.52	τ_{pier}	Shear stress at pier

Contraction Scour in Cohesive Materials
100 yrs CHANNEL

Ultimate Scour for Cohesive Materials:

$$y_{s-ult} = 0.94y_1\left(\frac{1.83V_2}{\sqrt{gy_1}} - \frac{K_u\sqrt{\frac{\tau_c}{\rho_w}}}{gny_1^{1/3}}\right)$$ Eq. 6.6

15.4	y_1	Upstream average flow depth (ft.)
2.5	V_2	Average velocity in the contracted section (ft/s)
0.0027	τ_c	Critical shear stress (lb/ft²)
0.035	n	Manning n
1.486	K_u	1.486 (English units)
32.2	g	Acceleration of gravity (ft/s²)
1.939	ρ	Density of water (slugs/ft³)
2.69	y_{s-ult}	Ultimate Scour

$$\tau_c = 0.05(D_{50})^{-0.4}$$

$$\tau_c = 0.1302\frac{N}{m^2} = 0.0027\frac{lbf}{ft^2}$$

Initial shear stress for a specific flow:

$$\tau = \gamma\left(\frac{V_2 n}{K_u}\right)^2 y_0^{-1/3}$$ Eq. 6.7

62.366	γ	Specific weight of water (lbs/ft³)
2.5	V_2	Average velocity in the contracted section (ft/s)
0.035	n	Manning n
1.486	K_u	1.486 (English units)
20.1	y_o	Depth of flow in the contracted bridge section before scour
0.08	τ	Initial shear stress

$\tau > \tau_c$ *contraction scour will occur for the flow period*

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

In cooperation with
Tennessee Agricultural
Experiment Station

Soil Survey of Haywood County, Tennessee

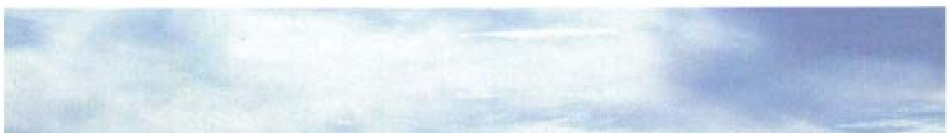


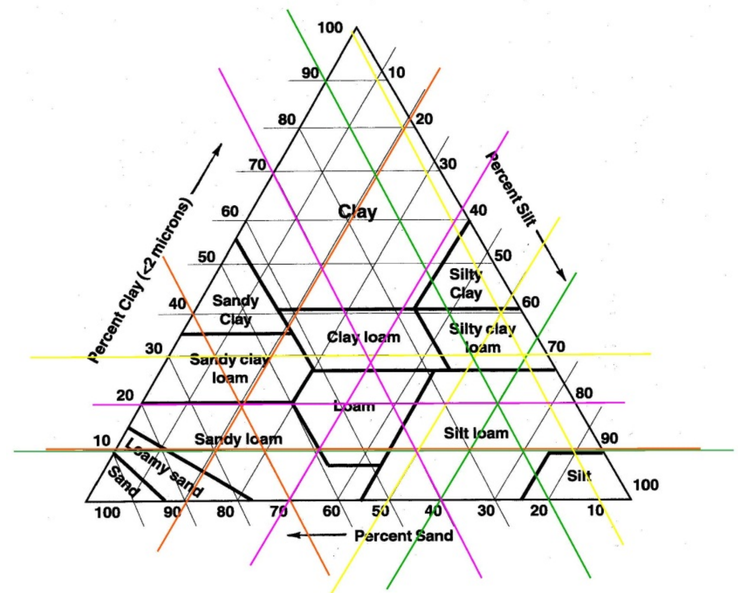
TABLE 14.--ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	4	10	40	200		
	In								Pct	
OA: Oaklimeter	0-7	Silt loam	ML, CL, CL-ML	A-4	100	100	90-100	70-90	<30	NP-8
	7-46	Very fine sandy loam, silt loam, loam.	ML, CL, CL-ML	A-4	100	100	85-95	60-85	<30	NP-8
	46-60	Silt loam, silty clay loam.	ML, CL, CL-ML	A-4	100	100	90-100	90-100	<30	NP-10

	0 - 7 inches	
	Silt Loam	average
Sand	0.2	0.00041
Silt	0.7	0.00008
Clay	0.1	0.00000
xw	0.00014	

7 - 46 inches					
Very Fine Sandy Loam		Silt Loam		Loam	
0.7	0.00041	0.2	0.00041	0.3	0.00041
0.2	0.00008	0.7	0.00008	0.4	0.00008
0.1	0.00000	0.1	0.00000	0.2	0.00000
0.00030		0.00014		0.00017	

46 - 60 inches			
Silt Loam		Silty Clay Loam	
0.2	0.00041	0.1	0.00041
0.7	0.00008	0.6	0.00008
0.1	0.00000	0.3	0.00000
0.00014		0.00009	



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Acknowledgements

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QUESTIONS?