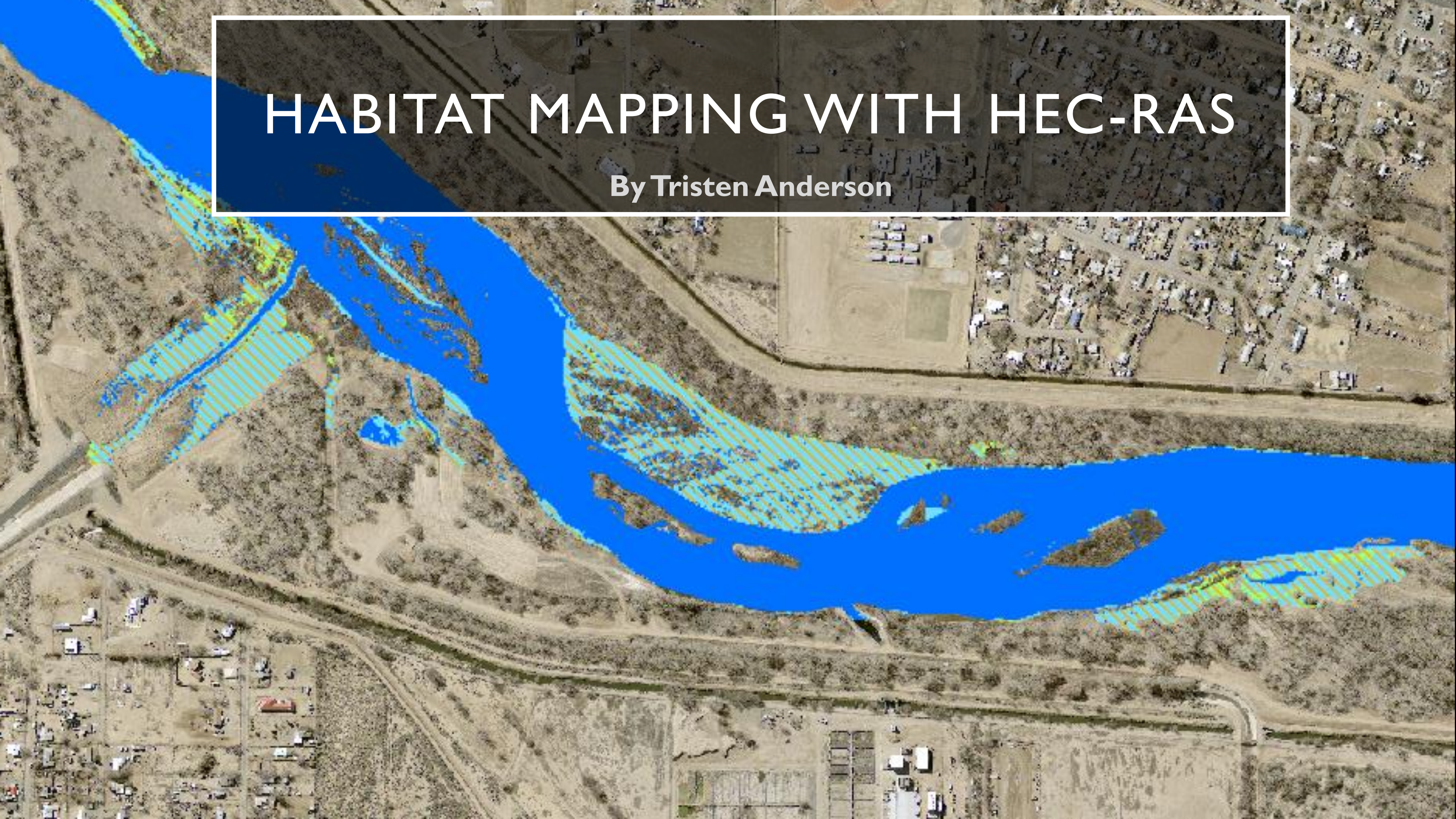
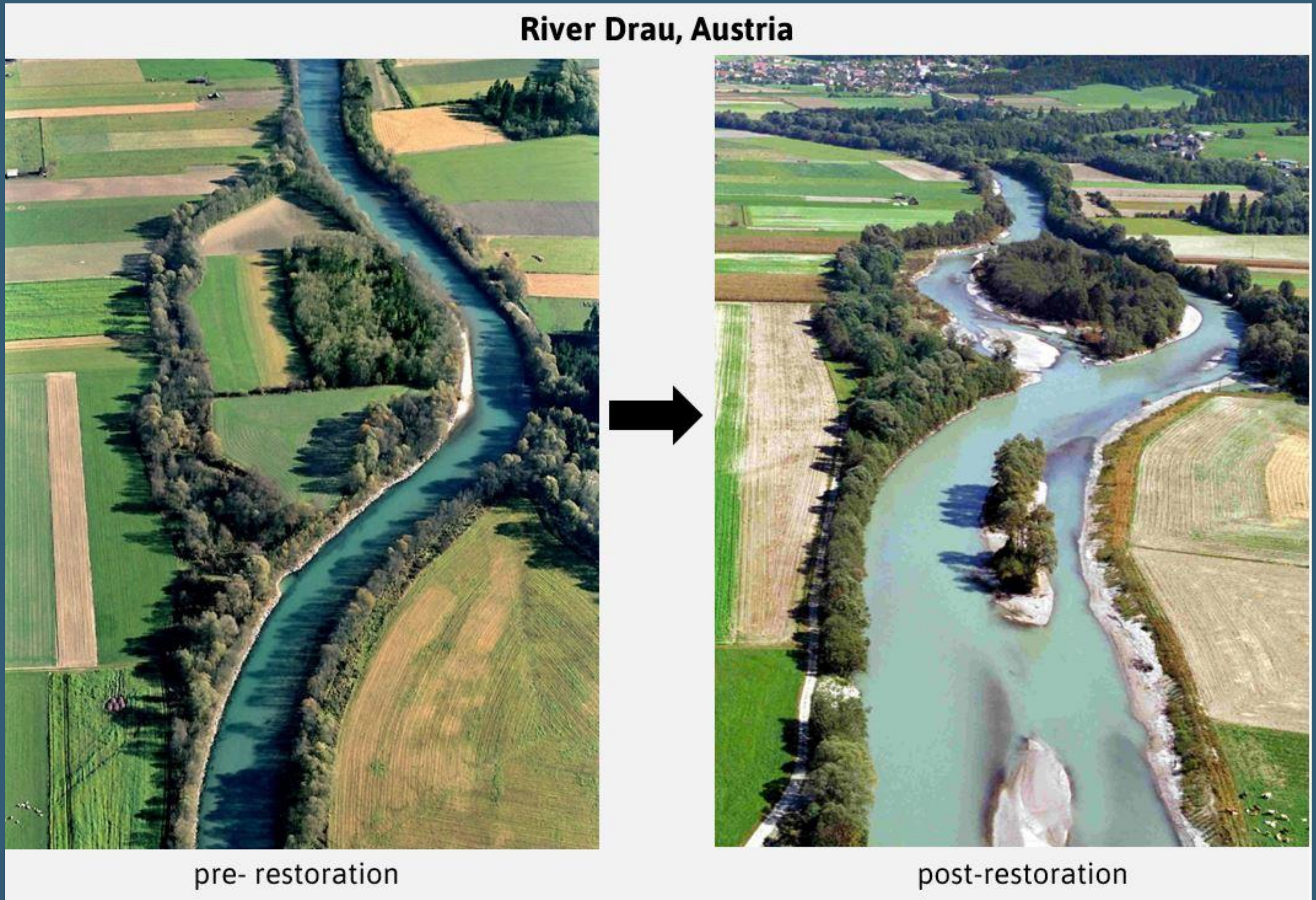
HABITAT MAPPING WITH HEC-RAS

By Tristen Anderson

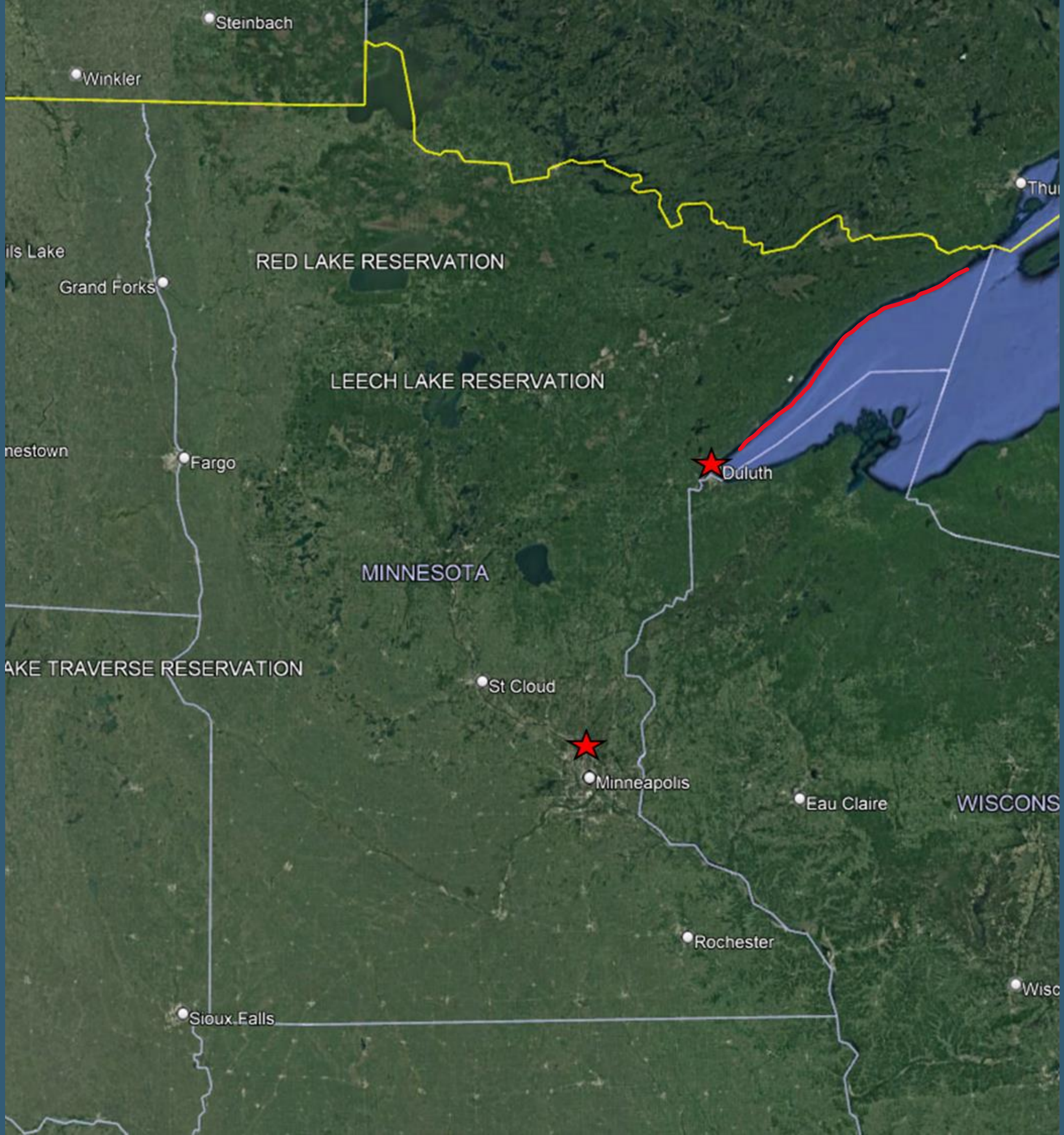


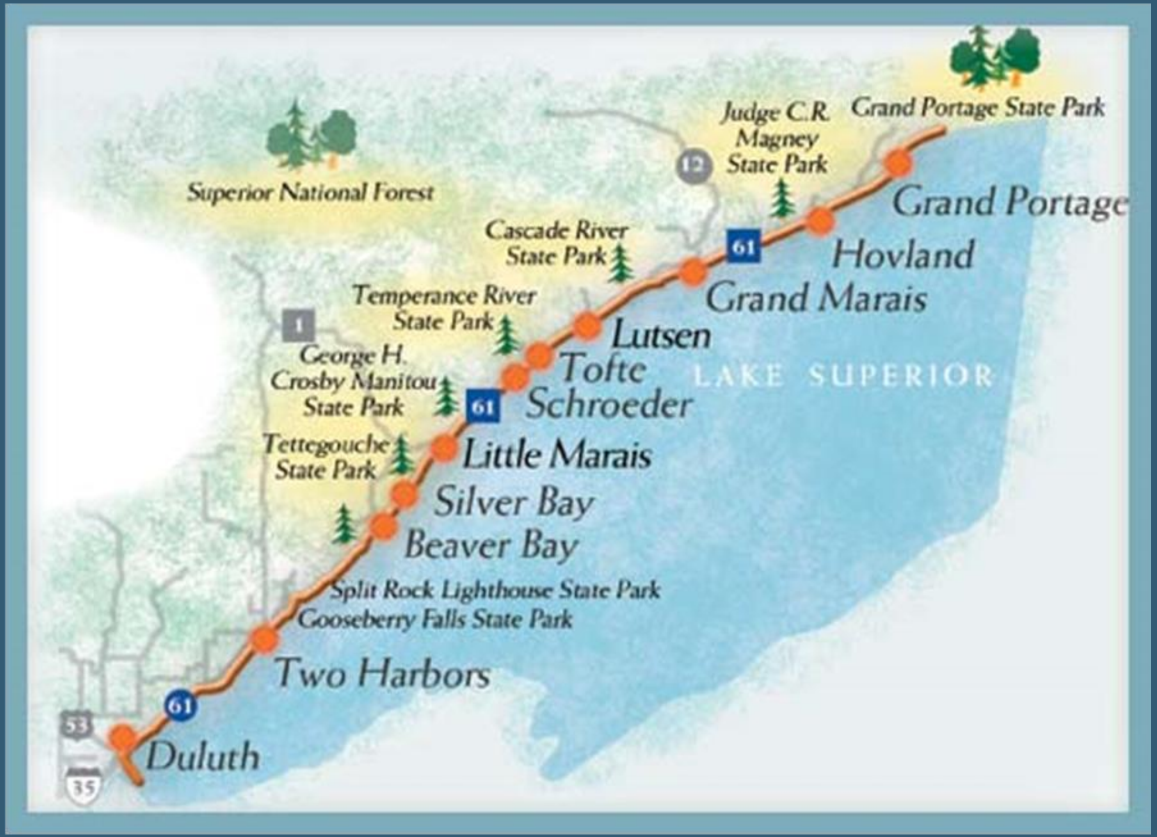
TRISTEN ANDERSON

- Grew up in Blaine, MN (30 minutes North of Minneapolis)
- Graduated from the University of Minnesota Duluth in 2019 – B.S. in Civil Engineering
- Started M.S. degree in Civil Engineering at CSU in Fall 2021
  - Initially funded through Graduate Teaching Assistantship (GTA). Taught CIVE 301 – Fluid Mechanics Laboratory.
  - Transitioned to Graduate Research Assistantship (GRA). Dr. Julien is my advisor, and I am researching the Montano Reach of the Middle Rio Grande River.
- I will graduate this summer and hopefully get a job with an engineering company that specializes in **River Restoration**.



Calgary
ONTARIO
QUEBEC
Winnipeg
Vancouver
Seattle
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
Gulf of St Lawrence
NB
PE
Ottawa
Montreal
MAINE
NOVA SCOTIA
SOUTH DAKOTA
WISCONSIN
OREGON
IDAHO
WYOMING
MICHIGAN
Toronto
VT
NH
NEW YORK
MA
Boston
CT
RI
IOWA
Chicago
NEBRASKA
ILLINOIS
OHIO
PENN
New York
NEVADA
United States
INDIANA
Washington
UTAH
COLORADO
KANSAS
MISSOURI
WEST VIRGINIA
San Francisco
KENTUCKY
VIRGINIA
CALIFORNIA
Las Vegas
OKLAHOMA
TENNESSEE
NORTH CAROLINA
Los Angeles
ARIZONA
ARKANSAS
NEW MEXICO
MISSISSIPPI
Atlanta
SOUTH CAROLINA
San Diego
Dallas
ALABAMA
GEORGIA
TEXAS
LOUISIANA
San Antonio
Houston
Gulf of California
FLORIDA
Monterrey
Gulf of Mexico
Miami
Mexico
Havana
Cuba
Guadalajara
Mexico City
Dominican Republic
Puerto Rico


Steinbach
Winkler
ils Lake
Grand Forks
RED LAKE RESERVATION
LEECH LAKE RESERVATION
nestown
Fargo
Duluth
MINNESOTA
AKE TRAVERSE RESERVATION
St Cloud
Minneapolis
Eau Claire
WISCONS
Rochester
Wisc
Sioux Falls
Thu


Grand Portage State Park
Judge C.R. Magney State Park
Superior National Forest
Grand Portage
Cascade River State Park
Hovland
Grand Marais
Temperance River State Park
Lutsen
George H. Crosby Manitou State Park
Tofte
Schroeder
LAKE SUPERIOR
Tettegouche State Park
Little Marais
Silver Bay
Beaver Bay
Split Rock Lighthouse State Park
Gooseberry Falls State Park
Two Harbors
Duluth
61
12
1
53
35



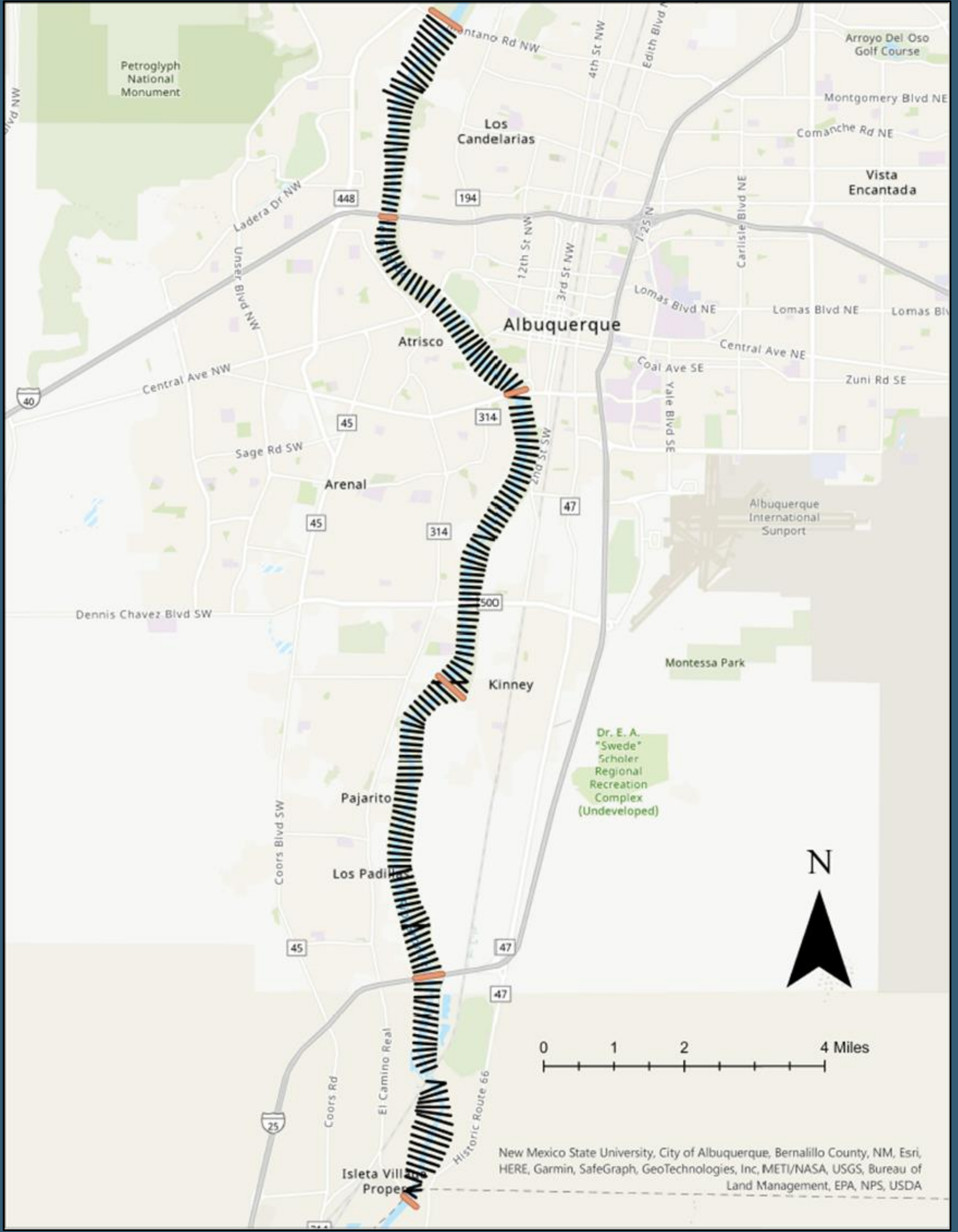
OVERVIEW

- My graduate research focuses on the Middle Rio Grande (MRG) in New Mexico.
- Utilized One-Dimensional hydraulic modeling to relate hydraulic conditions to suitable habitat for Rio Grande Silvery Minnow.
  - 1) Introduction to HEC-RAS
  - 2) How to set up HEC-RAS
  - 3) Demonstration of how HEC-RAS works

BACKGROUND

- Human alterations along the MRG river system have resulted in significant changes to the riverscape.
  - Dams
  - River Straightening
  - Urbanization

- The Rio Grande Silvery Minnow was listed on the endangered species list in 1994
  - Only occupies 7% of its historic range



WHAT IS HEC-RAS

- Stands for Hydrologic Engineering Centers River Analysis System (HEC-RAS)
- Publicly available software created by the US Army Corps of Engineers

WHAT IS HEC-RAS CAPABLE OF?

- One-dimensional steady flow
- One and two-dimensional unsteady flow calculations
- Sediment transport/mobile bed computations
- Water temperature/water quality modeling

WHAT IS A MODEL?

- Simplified description of reality
- Different types
  - Mathematical
  - Conceptual
  - Physical
  - Numerical
- Should use "Occam's Razor"
  - Emphasize the main features at the expense of "smaller" features

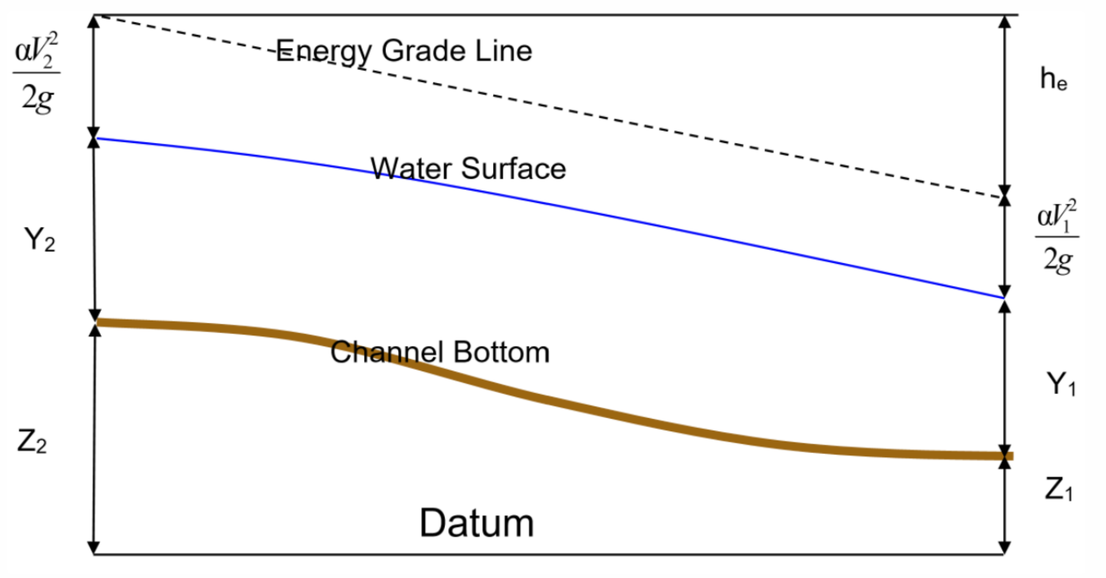
HOW DOES IT WORK?

Water surface profiles are computed from one cross section to the next by solving the Energy equation with an iterative procedure called the standard step method.

- **One Dimensional Energy Equation**

$$z_2 + y_2 + \alpha_2 \frac{{v_2}^2}{2g} = z_1 + y_1 + \alpha_1 \frac{{v_1}^2}{2g} + h_e$$

- Z= elevation of channel inverts
- Y= depth of water
- v= average velocity
- g= gravitational acceleration
- α= velocity weighting coefficients
- h_e= energy head loss



Representation of Terms in the Energy Equation

HOW DOES IT WORK?

The energy head loss (he) between two cross sections is comprised of friction losses and contraction or expansion losses. $h_e = L\bar{S_f} + C\left|\frac{\alpha_1 {v_1}^2}{2g} - \frac{\alpha_2 {v_2}^2}{2g}\right|$

- **Energy Loss Due to Expansion and Contraction**

$$h_{Ce} = C\left|\frac{\alpha_1 {v_1}^2}{2g} - \frac{\alpha_2 {v_2}^2}{2g}\right|$$

L = discharge weighted reach length

S_f = representative friction slope between two sections

C = contraction/expansion coefficient

- **Energy Loss Due to Friction from Manning's Equation**

$$S_f = \left(\frac{Q}{K}\right)^2$$

$$K = \frac{1}{n} {R_h}^{2/3} A$$

n = Manning's coefficient

A = cross sectional area

R_h = hydraulic radius

S_f = friction slope

HOW DOES IT WORK?

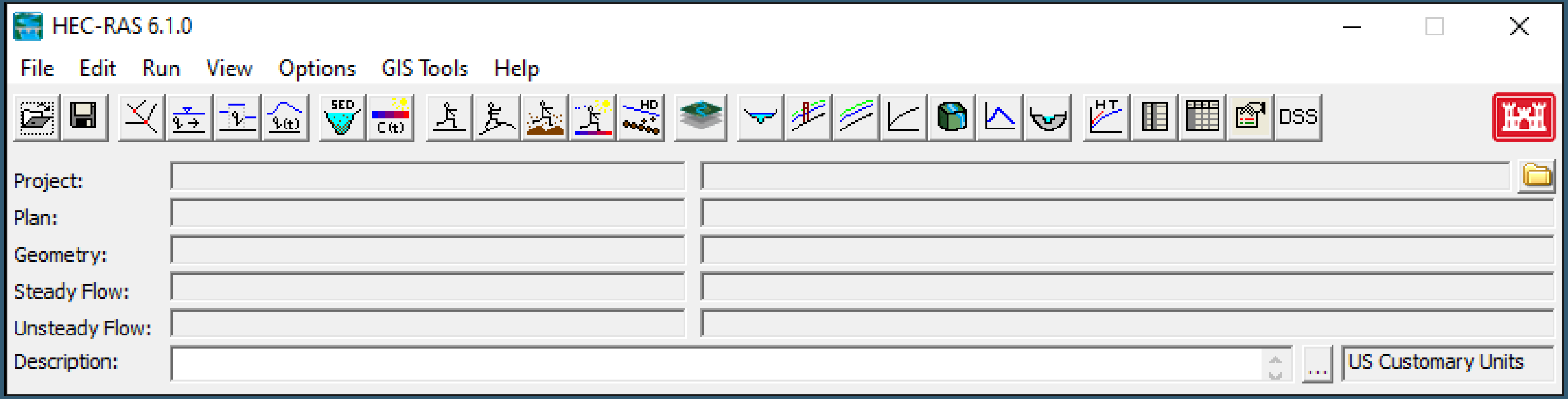
Computational Procedure (Sub-Critical)

1) Starting at the most downstream segment, for a known Q and h, assume a trial flow depth, h^*, at the upstream cross-section.
2) Based on the h^*, determine the corresponding total energy head.
3) Compute S_f and solve for losses h_e
4) Compare the upstream energy head (trial depth) with the known downstream energy head. Iterate (change the trial flow depth) until the energy equation is balanced within a specified error tolerance (typically within 0.01 feet).
5) The unknown (trial) depth now becomes the known depth, and the next upstream cross-section is assigned a trial depth. This procedure is repeated until the upstream end of the channel is reached.

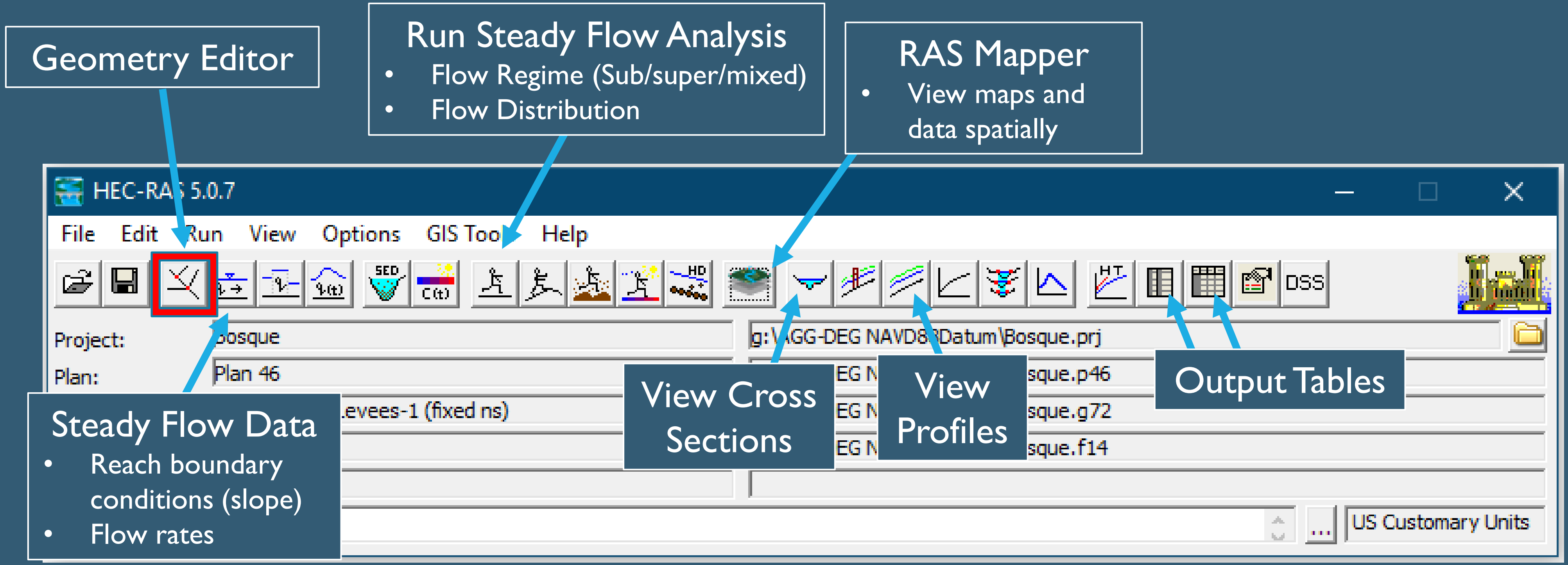
SETTING UP HEC-RAS

Required Information

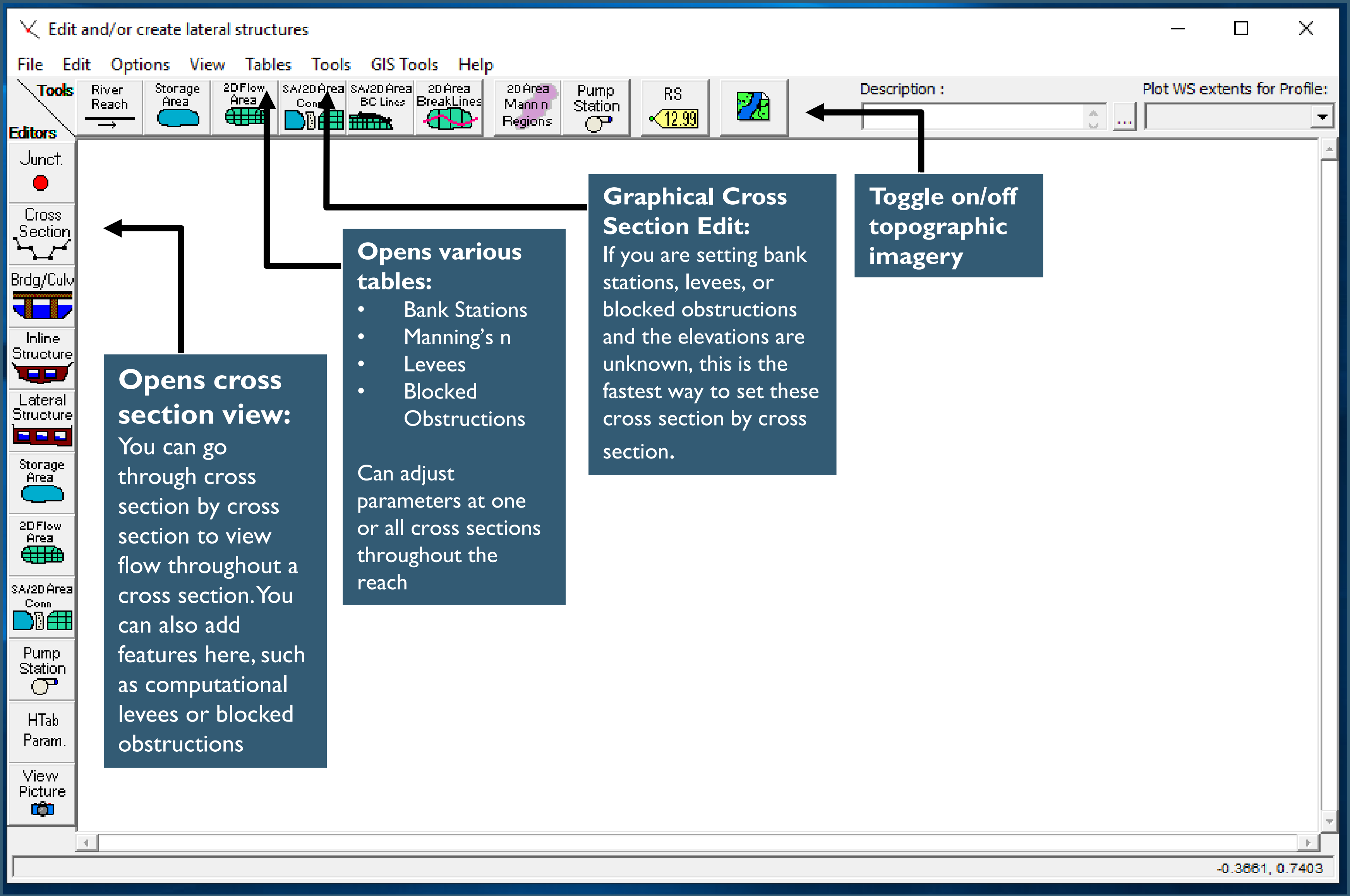
- Surveyed cross-sections (STA and ELEV)
- Boundary conditions (e.g., slope for normal depth calculation)
- LiDAR topographical data (if using RAS Mapper)



SETTING UP HEC-RAS



SETTING UP HEC-RAS



Opens cross section view:
You can go through cross section by cross section to view flow throughout a cross section. You can also add features here, such as computational levees or blocked obstructions

Opens various tables:

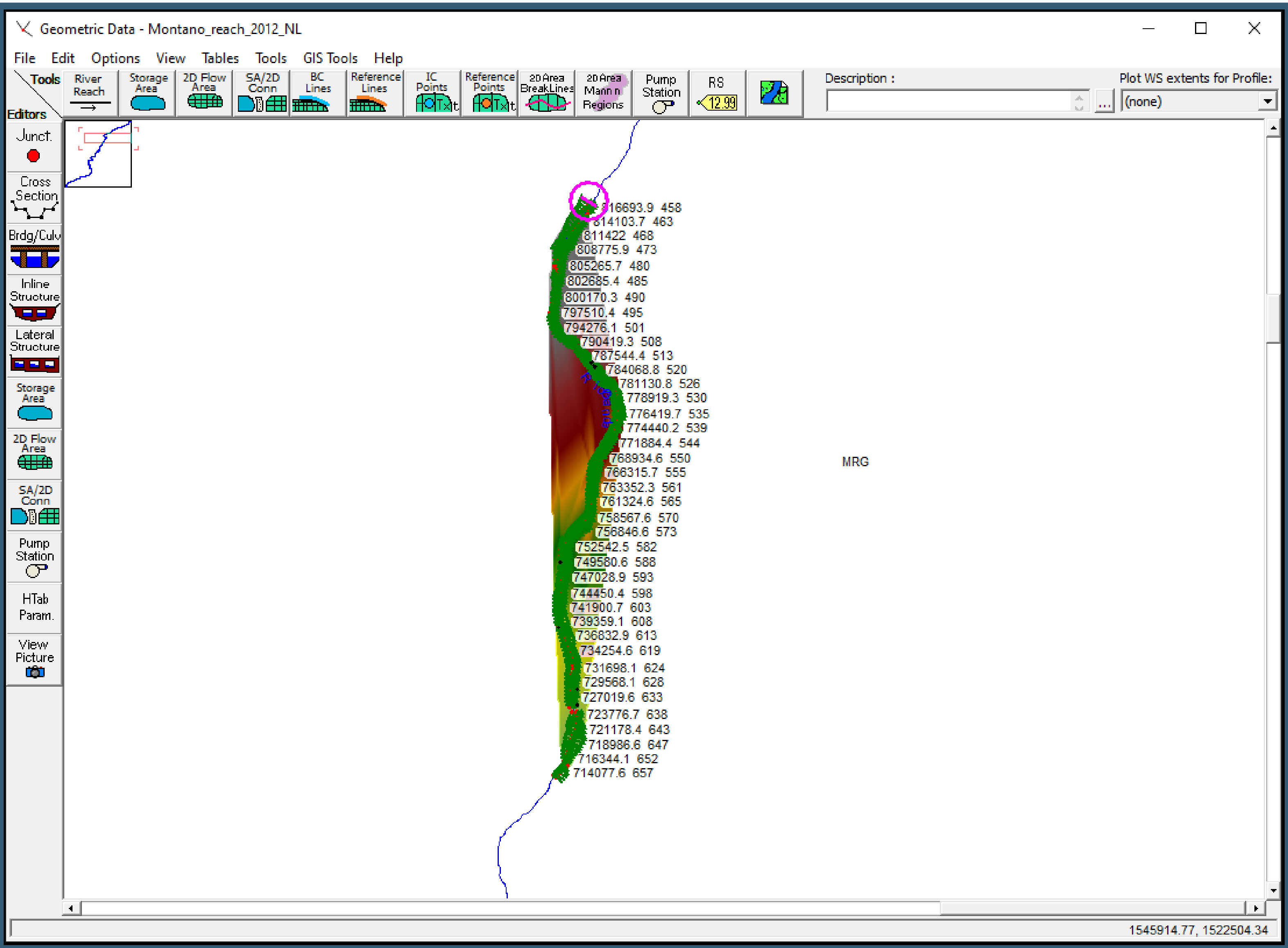
- Bank Stations
- Manning's n
- Levees
- Blocked Obstructions

Can adjust parameters at one or all cross sections throughout the reach

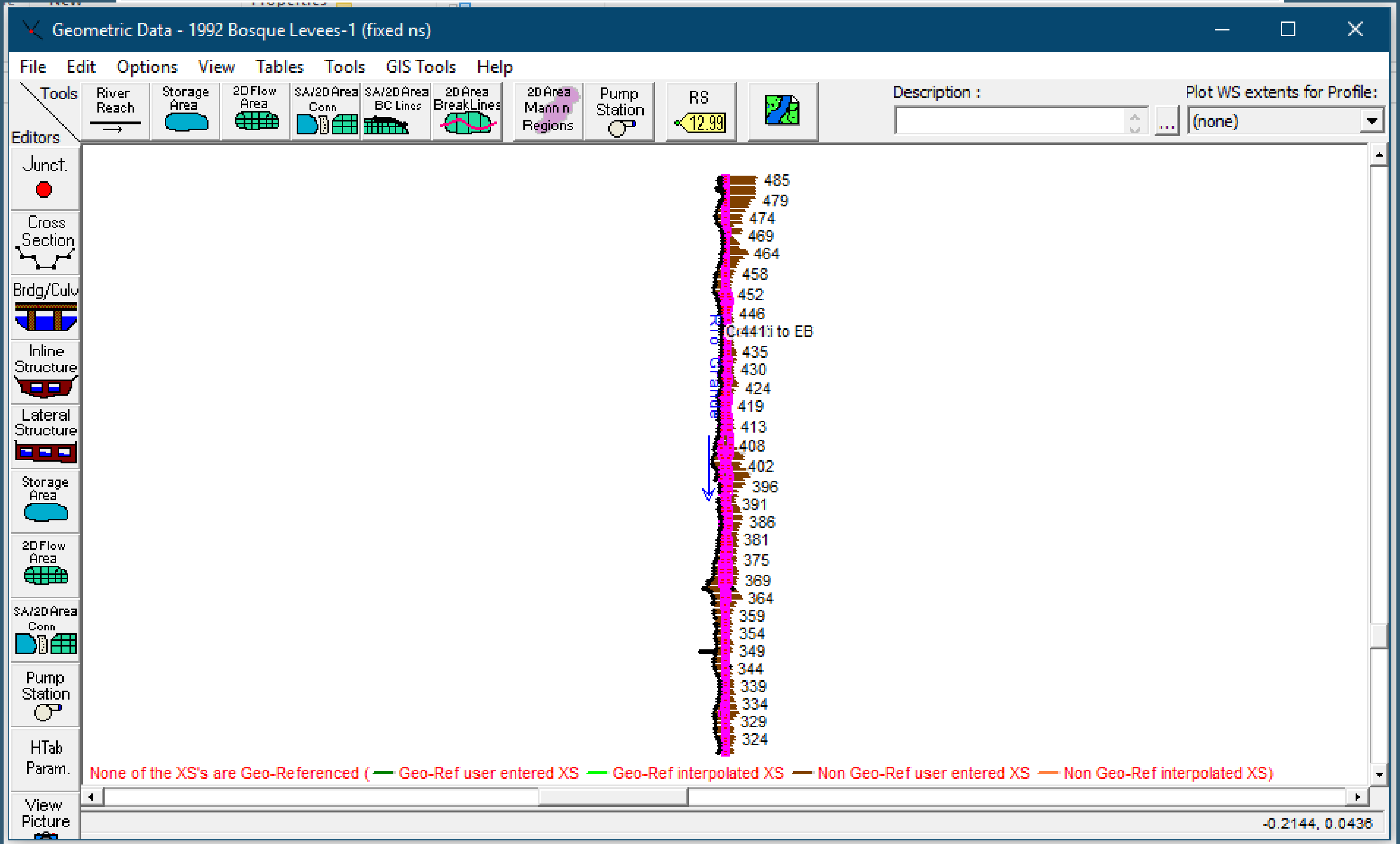
Graphical Cross Section Edit:
If you are setting bank stations, levees, or blocked obstructions and the elevations are unknown, this is the fastest way to set these cross section by cross section.

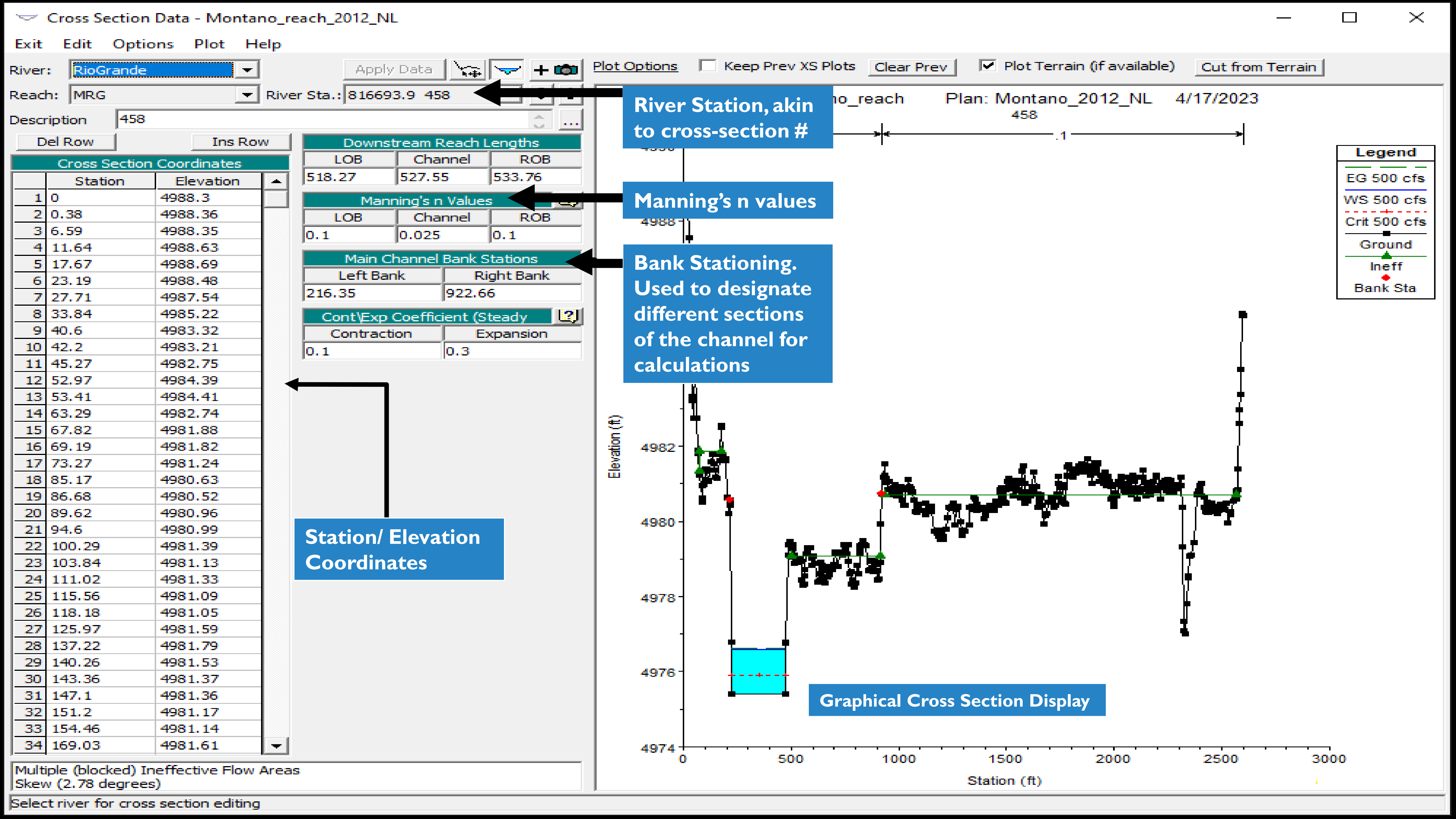
Toggle on/off topographic imagery

SETTING UP HEC-RAS

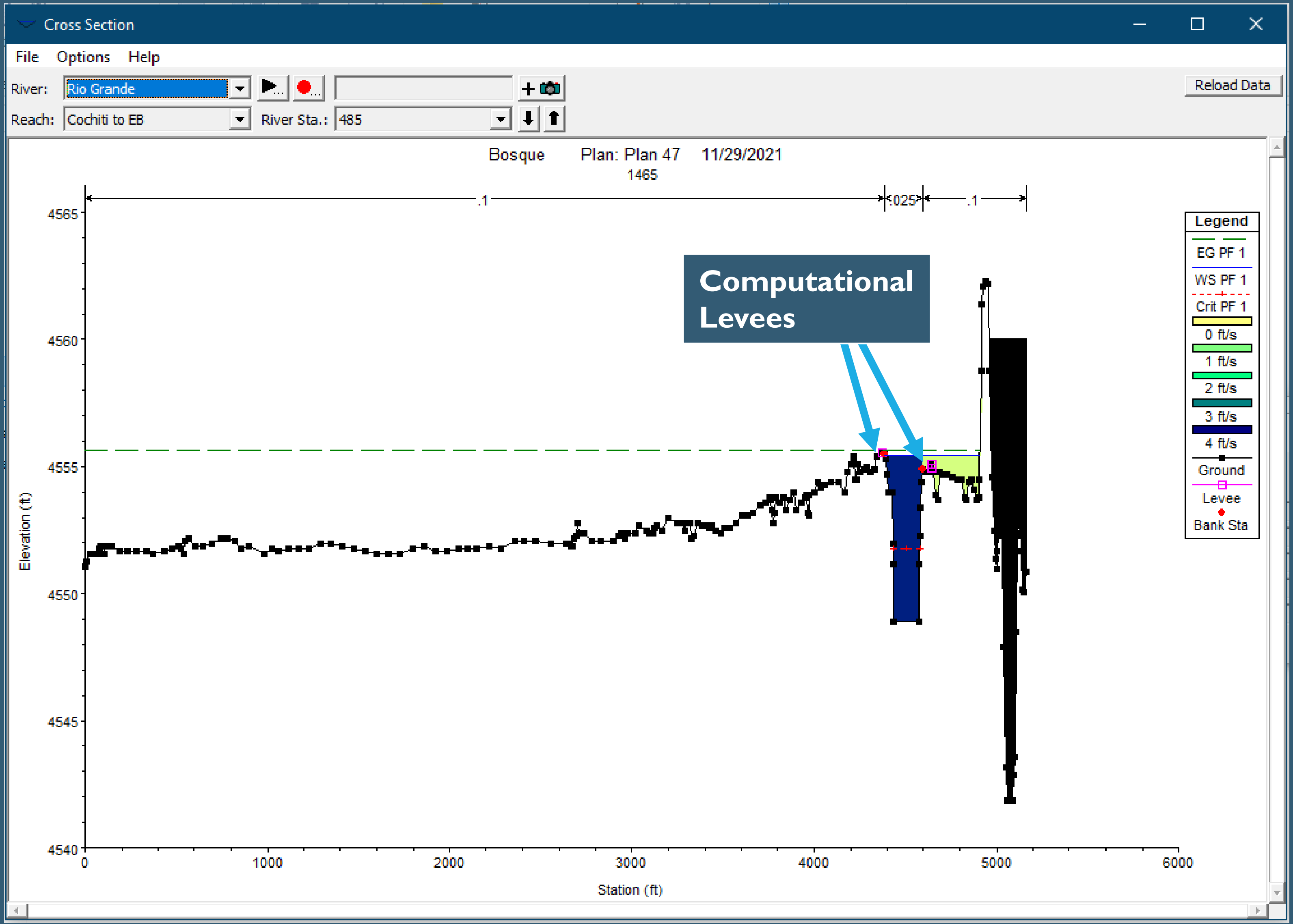


SETTING UP HEC-RAS

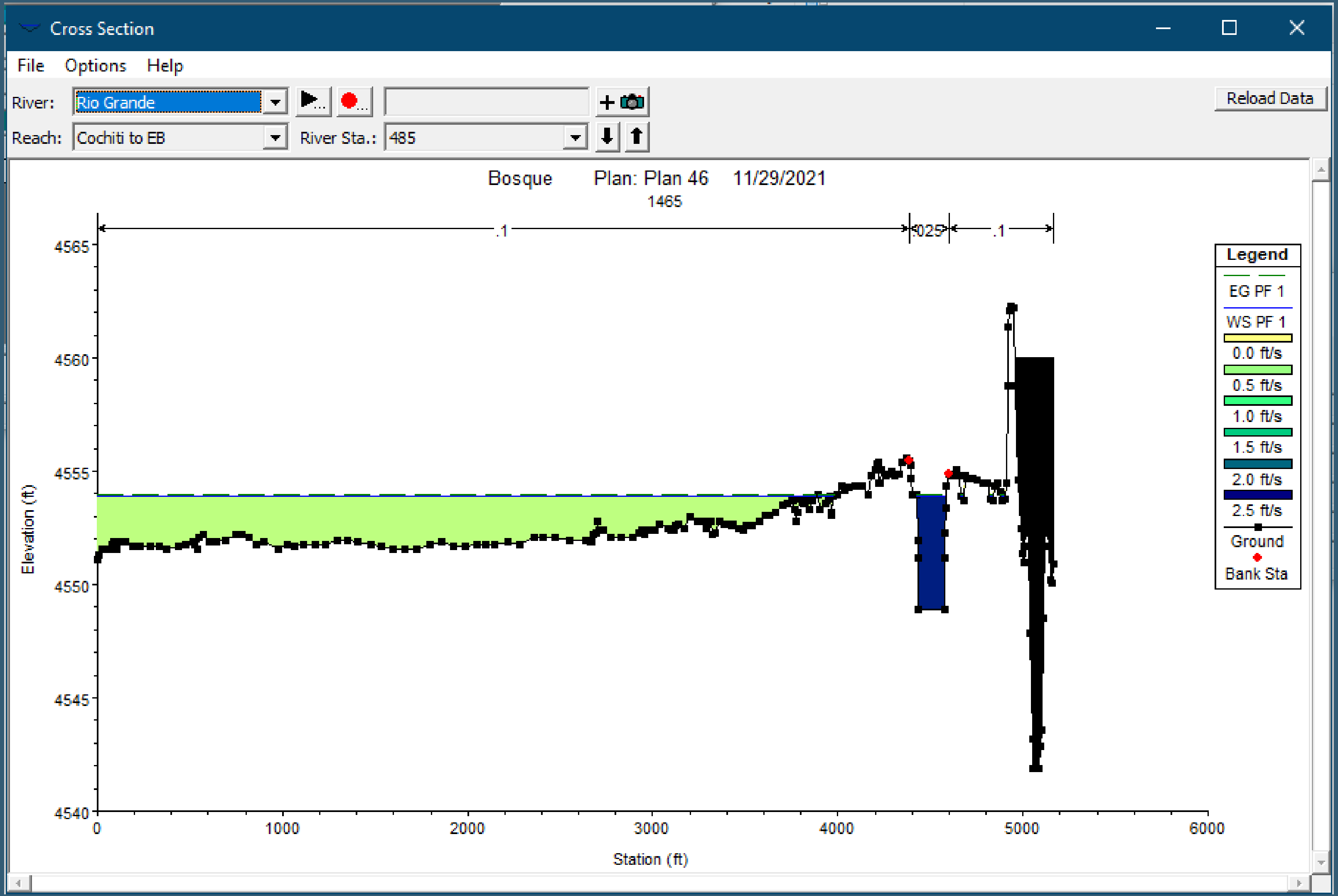



Cross Section Data - Montano_reach_2012_NL
Exit Edit Options Plot Help
River: RioGrande
Apply Data
Plot Options
Keep Prev XS Plots
Clear Prev
Plot Terrain (if available)
Cut from Terrain
Reach: MRG
River Sta.: 816693.9 458
Description 458
Del Row
Ins Row
Cross Section Coordinates
Station Elevation
1 0 4988.3
2 0.38 4988.36
3 6.59 4988.35
4 11.64 4988.63
5 17.67 4988.69
6 23.19 4988.48
7 27.71 4987.54
8 33.84 4985.22
9 40.6 4983.32
10 42.2 4983.21
11 45.27 4982.75
12 52.97 4984.39
13 53.41 4984.41
14 63.29 4982.74
15 67.82 4981.88
16 69.19 4981.82
17 73.27 4981.24
18 85.17 4980.63
19 86.68 4980.52
20 89.62 4980.96
21 94.6 4980.99
22 100.29 4981.39
23 103.84 4981.13
24 111.02 4981.33
25 115.56 4981.09
26 118.18 4981.05
27 125.97 4981.59
28 137.22 4981.79
29 140.26 4981.53
30 143.36 4981.37
31 147.1 4981.36
32 151.2 4981.17
33 154.46 4981.14
34 169.03 4981.61
Downstream Reach Lengths
LOB Channel ROB
518.27 527.55 533.76
Manning's n Values
LOB Channel ROB
0.1 0.025 0.1
Main Channel Bank Stations
Left Bank Right Bank
216.35 922.66
Cont\Exp Coefficient (Steady
Contraction Expansion
0.1 0.3
Multiple (blocked) Ineffective Flow Areas
Skew (2.78 degrees)
Select river for cross section editing
River Station, akin to cross-section #
Manning's n values
Bank Stationing. Used to designate different sections of the channel for calculations
Station/ Elevation Coordinates
Graphical Cross Section Display
o_reach
Plan: Montano_2012_NL 4/17/2023
458
.1
Legend
EG 500 cfs
WS 500 cfs
Crit 500 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
4974
4976
4978
4980
4982
4988
0
500
1000
1500
2000
2500
3000
Station (ft)

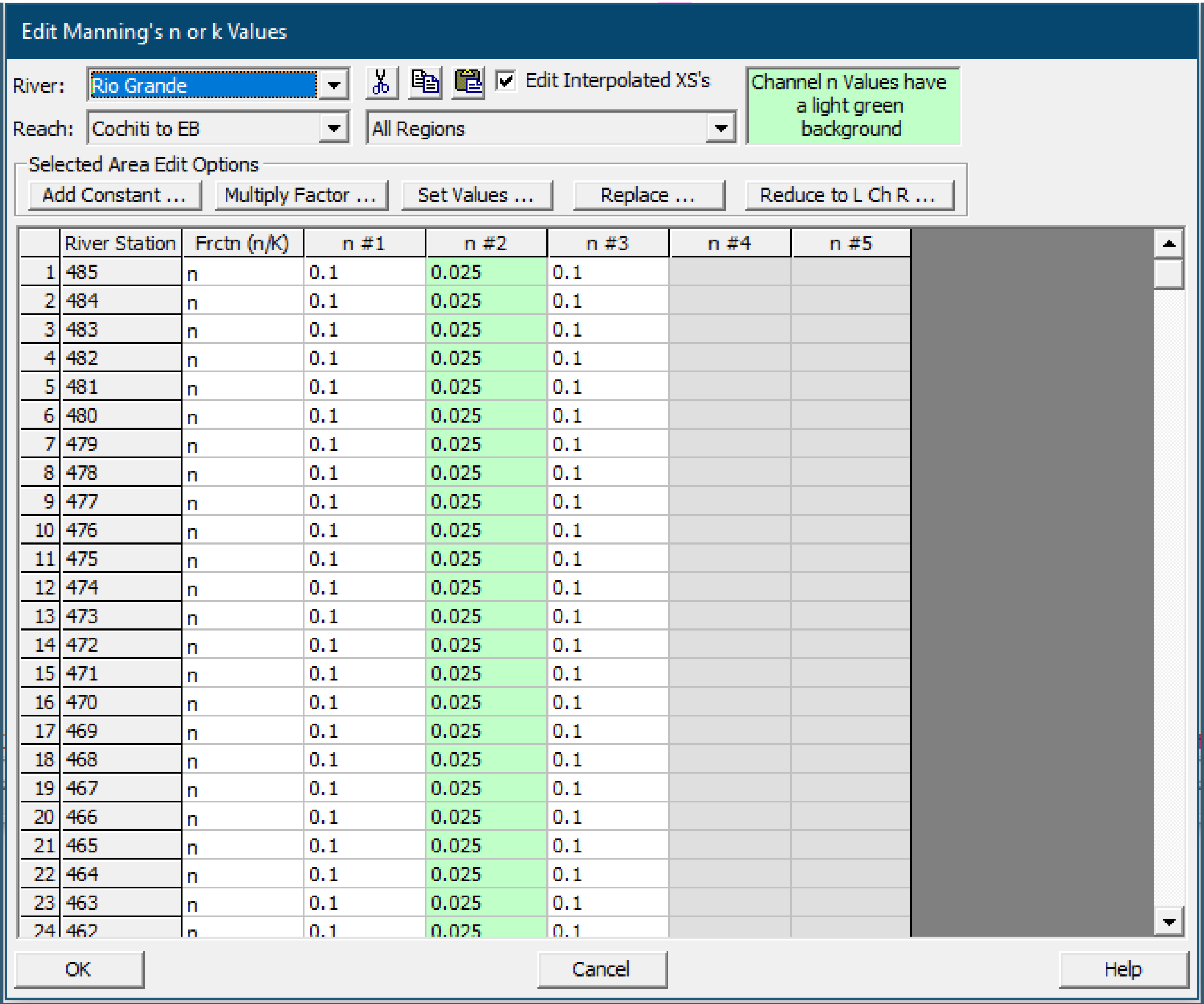
SETTING UP HEC-RAS



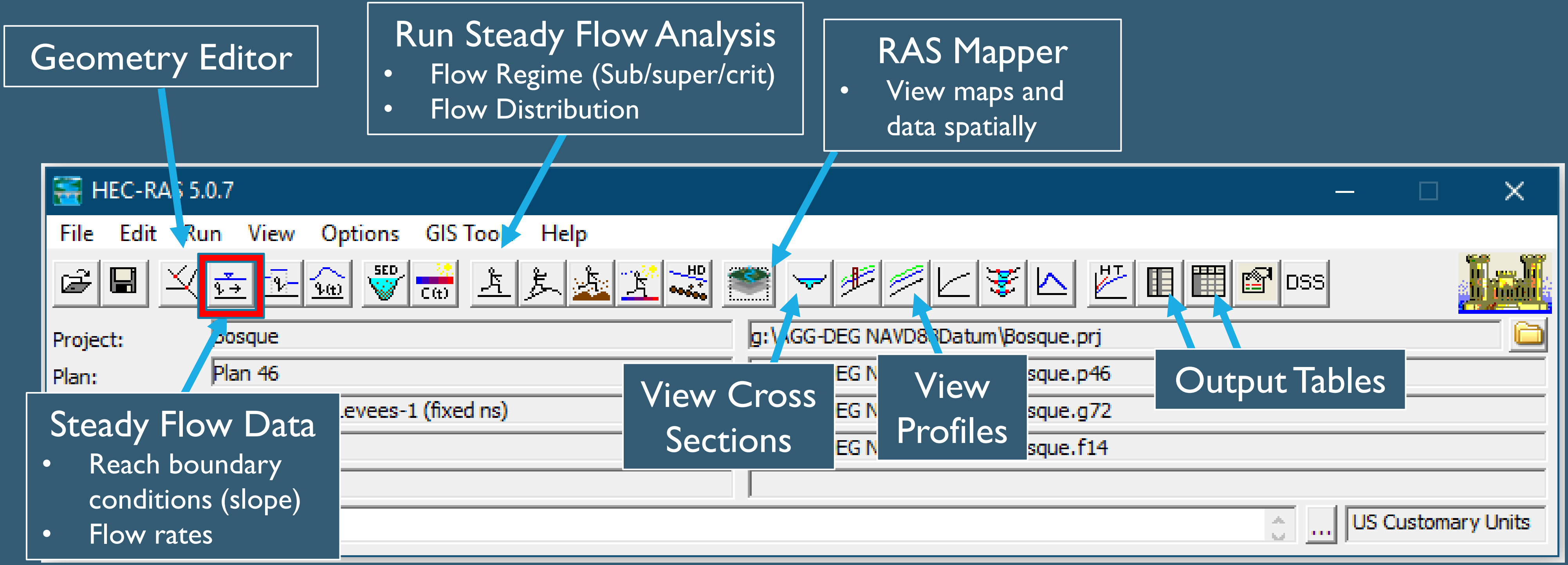
SETTING UP HEC-RAS



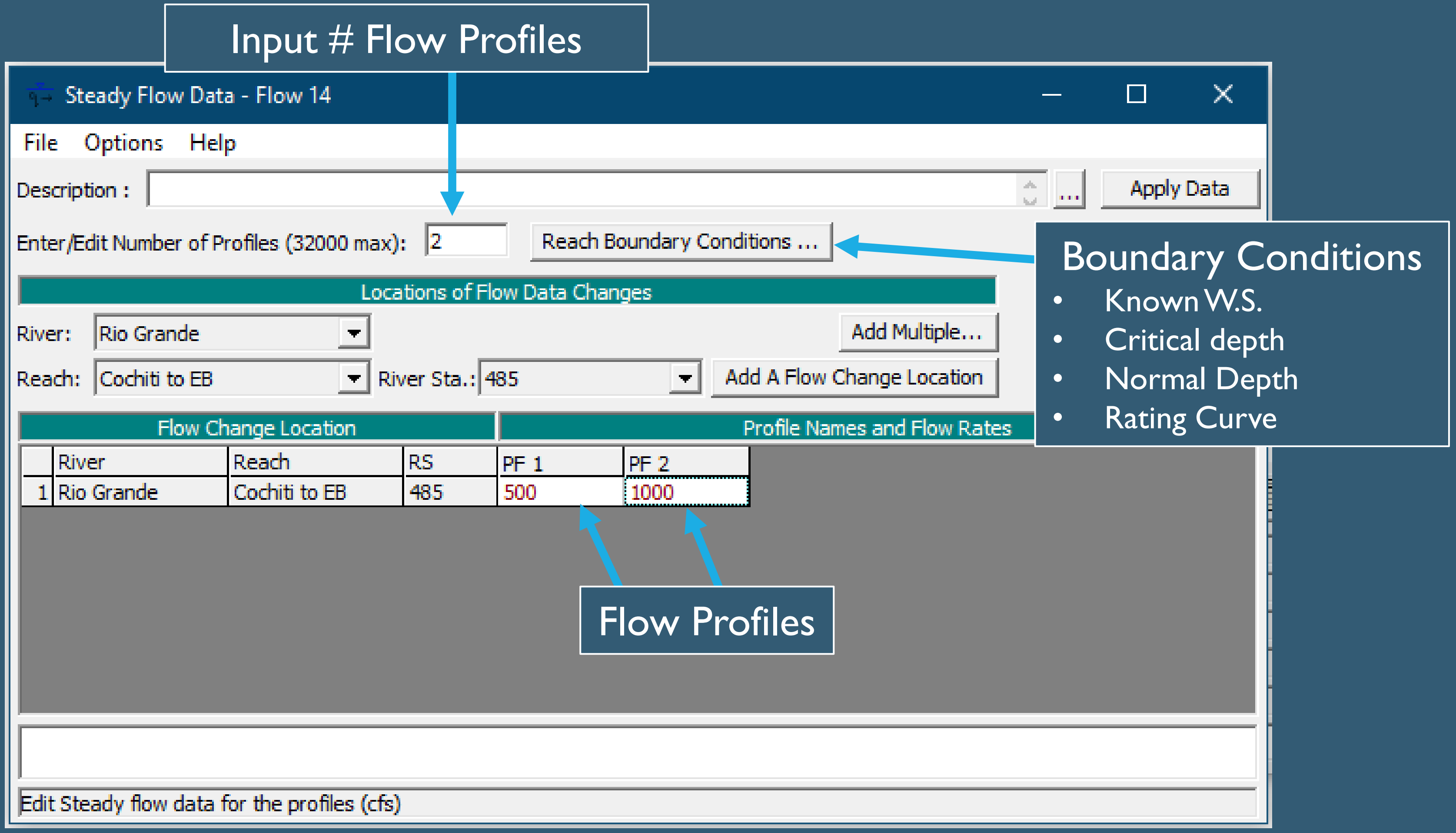
SETTING UP HEC-RAS



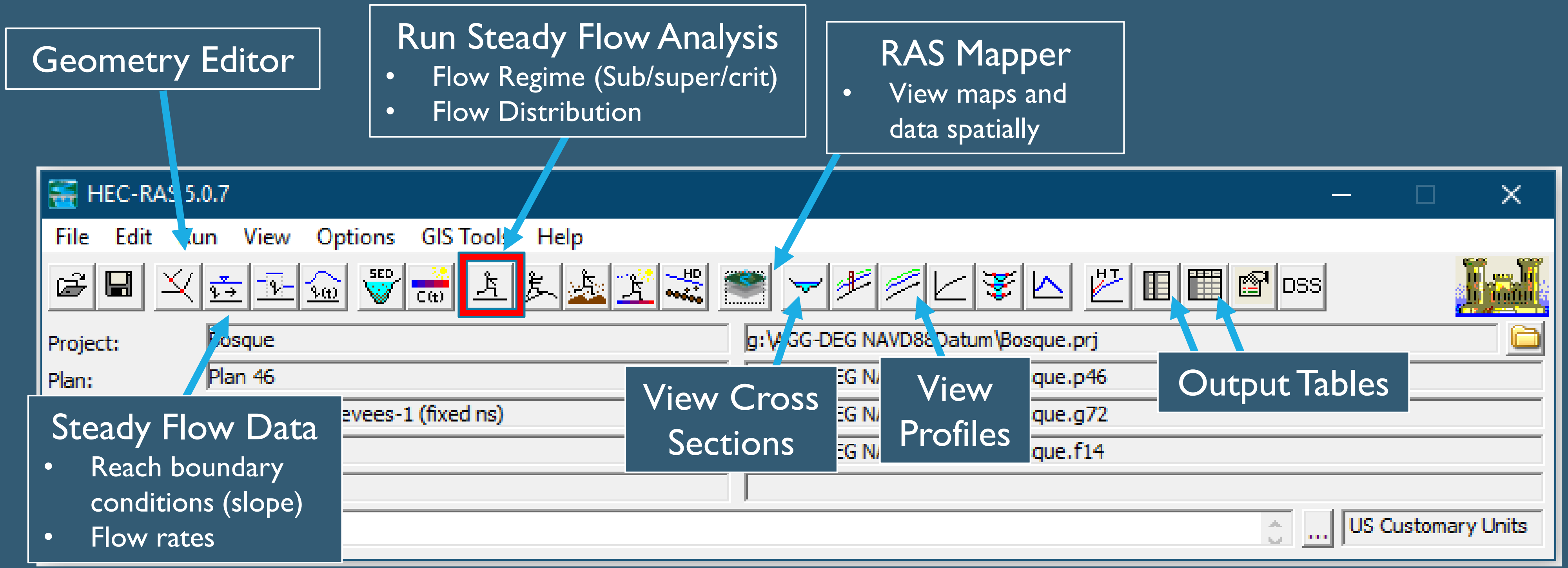
SETTING UP HEC-RAS



SETTING UP HEC-RAS



SETTING UP HEC-RAS

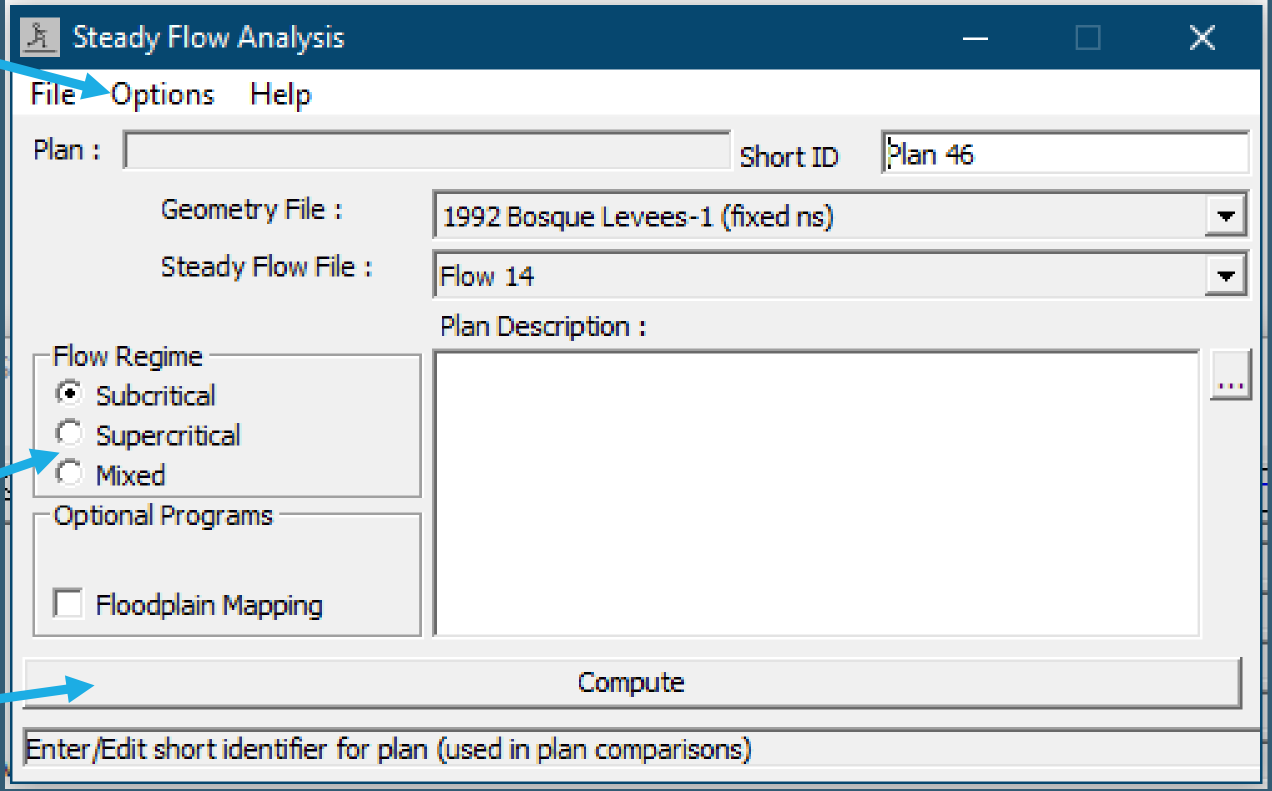


SETTING UP HEC-RAS

Options
- Flow Distribution Locations

Flow Regimes
- Subcritical
- Supercritical
- Mixed

Run!



SETTING UP HEC-RAS

Flow Distributions

- By default HEC-RAS will use 3 flow distributions (left floodplain, main channel, right floodplain)
- Can define a greater resolution, up to 45 slices.
- In this case, I wanted to most resolution possible for the floodplains.

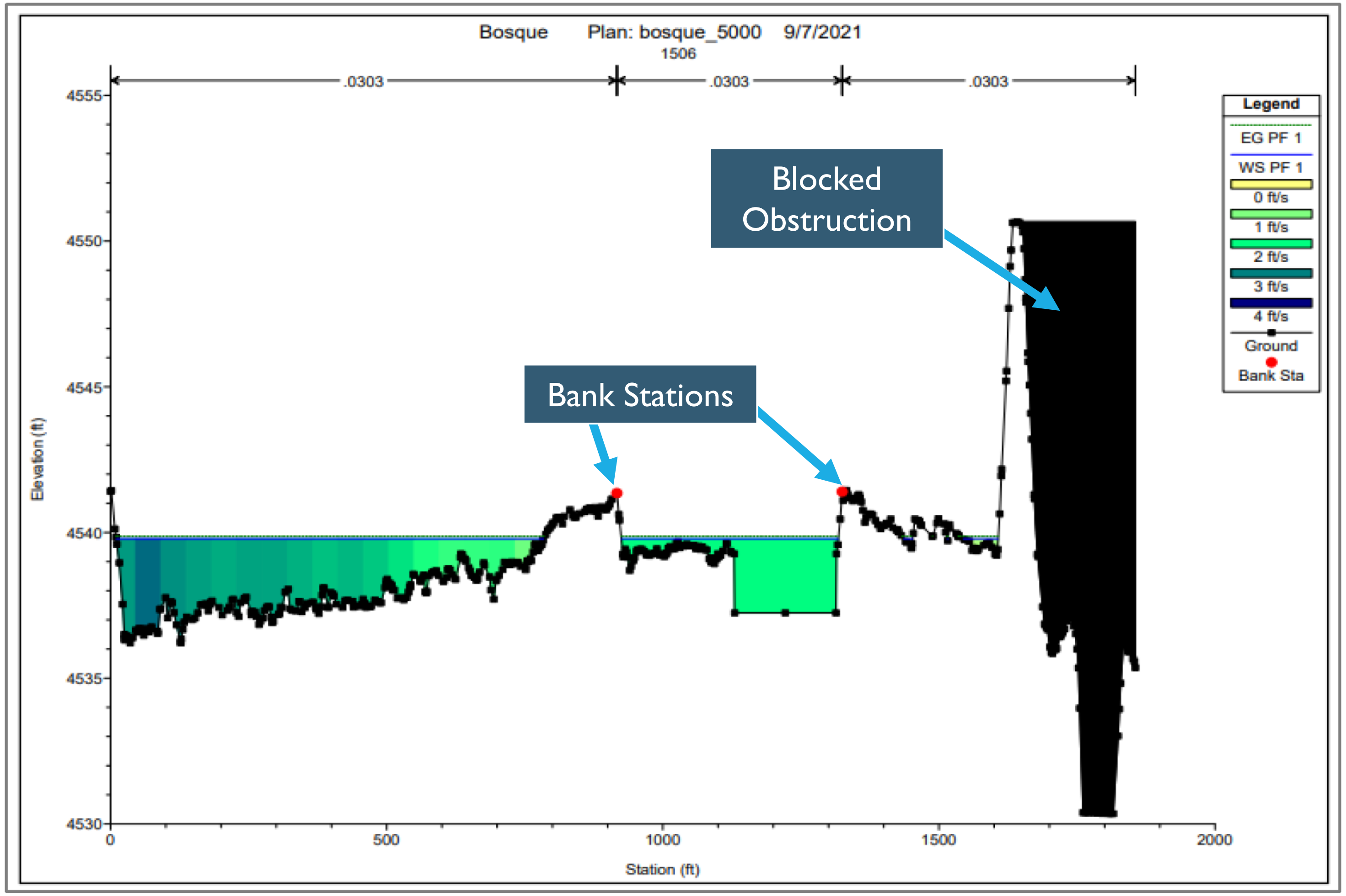
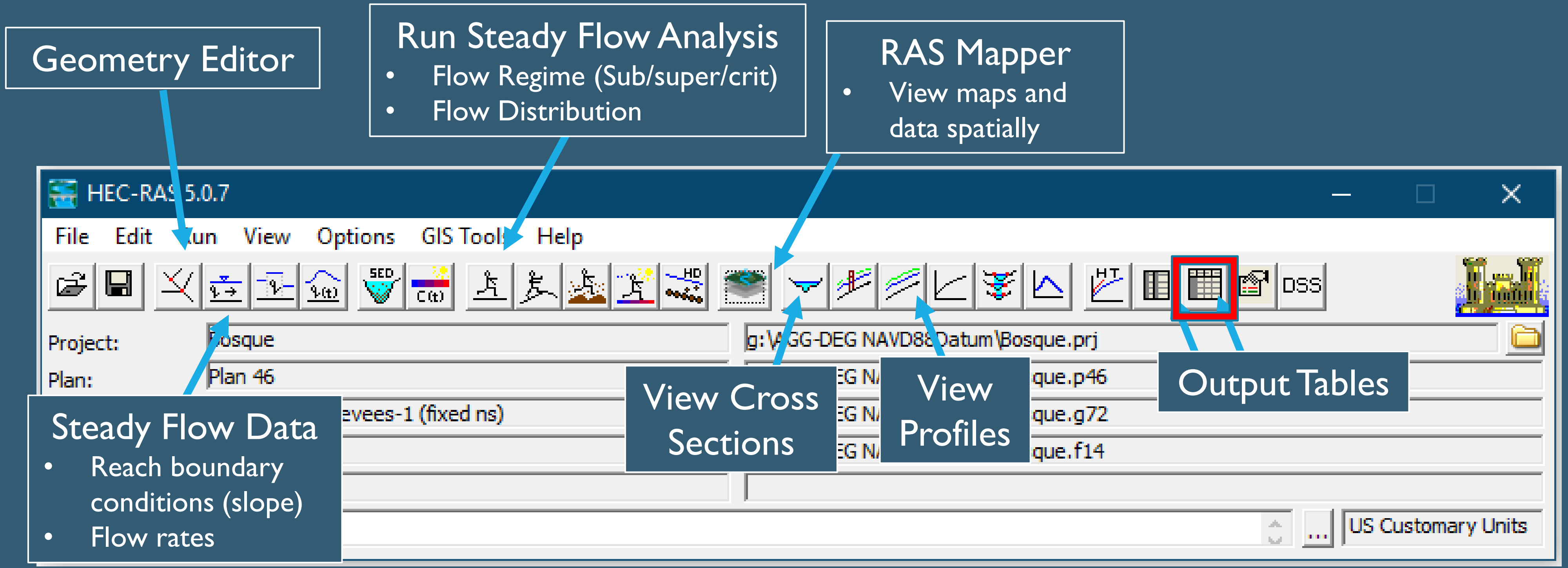


Figure 63 Cross-section with flow distribution from HEC-RAS with 20 vertical slices in the floodplains and 5 vertical slices in the main channel. The blue and green slices are small enough that the discrete color changes look more like a gradient.

VIEWING THE RESULTS



VIEWING THE RESULTS

Options allows you to further define output values

Profile Output Table - Standard Table 1

File Options Std. Tables User Tables Locations Help

HEC-RAS Plan: Plan 46 River: Rio Grande Reach: Cochiti to EB Profile: PF 1

Reload Data

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Cochiti to EB	485	PF 1	4000.00	4548.88	4553.91		4553.95	0.000208	2.35	7849.31	4186.62	0.19
Cochiti to EB	484	PF 1	4000.00	4548.97	4553.77		4553.83	0.000303	2.75	6962.96	4271.02	0.23
Cochiti to EB	483	PF 1	4000.00	4548.77	4553.63		4553.68	0.000281	2.63	7119.76	4243.68	0.22
Cochiti to EB	482	PF 1	4000.00	4548.37	4553.47		4553.53	0.000326	2.92	6586.51	4239.68	0.24
Cochiti to EB	481	PF 1	4000.00	4547.27	4553.29		4553.38	0.000275	2.92	5589.86	3707.17	0.22
Cochiti to EB	480	PF 1	4000.00	4546.87	4553.12		4553.23	0.000314	3.29	5119.97	3535.26	0.24
Cochiti to EB	479	PF 1	4000.00	4546.76	4552.79		4552.97	0.000766	3.78	2972.16	2822.65	0.35
Cochiti to EB	478	PF 1	4000.00	4546.66	4552.13		4552.51	0.001169	5.34	1942.22	1695.46	0.45
Cochiti to EB	477	PF 1	4000.00	4546.56	4552.04		4552.15	0.000364	2.90	2952.82	1832.05	0.25
Cochiti to EB	476	PF 1	4000.00	4546.56	4551.84		4551.96	0.000459	3.09	2595.49	1955.26	0.28
Cochiti to EB	475	PF 1	4000.00	4546.26	4551.33		4551.54	0.001103	4.29	1986.26	915.83	0.42
Cochiti to EB	474	PF 1	4000.00	4546.25	4550.87		4551.05	0.000617	3.86	2900.62	1971.64	0.33
Cochiti to EB	473	PF 1	4000.00	4546.15	4550.64		4550.75	0.000518	3.33	4266.36	2815.24	0.30
Cochiti to EB	472	PF 1	4000.00	4545.65	4550.36		4550.46	0.000614	3.11	3910.37	2527.76	0.31
Cochiti to EB	471	PF 1	4000.00	4545.75	4550.08		4550.18	0.000468	2.95	3501.97	1852.25	0.28
Cochiti to EB	470	PF 1	4000.00	4545.55	4549.82		4549.91	0.000495	2.62	3207.31	1931.79	0.28
Cochiti to EB	469	PF 1	4000.00	4545.34	4549.59		4549.69	0.000399	2.72	2721.42	1566.22	0.26
Cochiti to EB	468	PF 1	4000.00	4544.64	4549.25		4549.43	0.000696	3.68	2041.52	1198.11	0.34
Cochiti to EB	467	PF 1	4000.00	4544.44	4548.98		4549.08	0.000569	3.33	3444.72	1641.47	0.31
Cochiti to EB	466	PF 1	4000.00	4544.34	4548.46		4548.67	0.001307	4.62	2732.31	1903.74	0.46
Cochiti to EB	465	PF 1	4000.00	4544.44	4547.85		4548.03	0.001429	4.60	2717.54	1635.96	0.47
Cochiti to EB	464	PF 1	4000.00	4543.33	4547.23		4547.39	0.001114	4.00	2673.44	1601.64	0.41
Cochiti to EB	463	PF 1	4000.00	4543.93	4546.92		4546.96	0.000564	2.72	5117.70	2838.38	0.29
Cochiti to EB	462	PF 1	4000.00	4542.83	4546.70		4546.74	0.000315	2.43	5565.64	2761.69	0.23
Cochiti to EB	461	PF 1	4000.00	4543.03	4546.55		4546.58	0.000314	1.96	5675.34	2566.40	0.22
Cochiti to EB	460	PF 1	4000.00	4542.23	4546.37		4546.42	0.000409	2.30	4821.52	2400.48	0.25
Cochiti to EB	459	PF 1	4000.00	4542.33	4546.16		4546.22	0.000426	2.58	4278.39	2300.57	0.26
Cochiti to EB	458	PF 1	4000.00	4541.83	4545.77		4545.94	0.000698	3.69	2872.97	2344.23	0.34

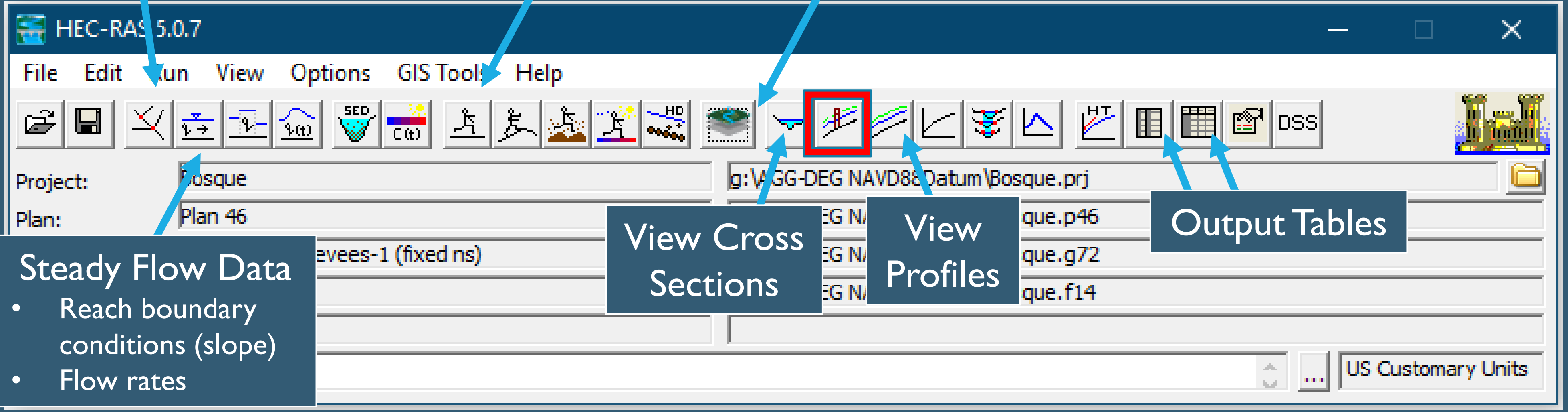
Total flow in cross section.

VIEWING THE RESULTS

Geometry Editor

Run Steady Flow Analysis
- Flow Regime (Sub/super/crit)
- Flow Distribution

RAS Mapper
- View maps and data spatially



View Cross Sections

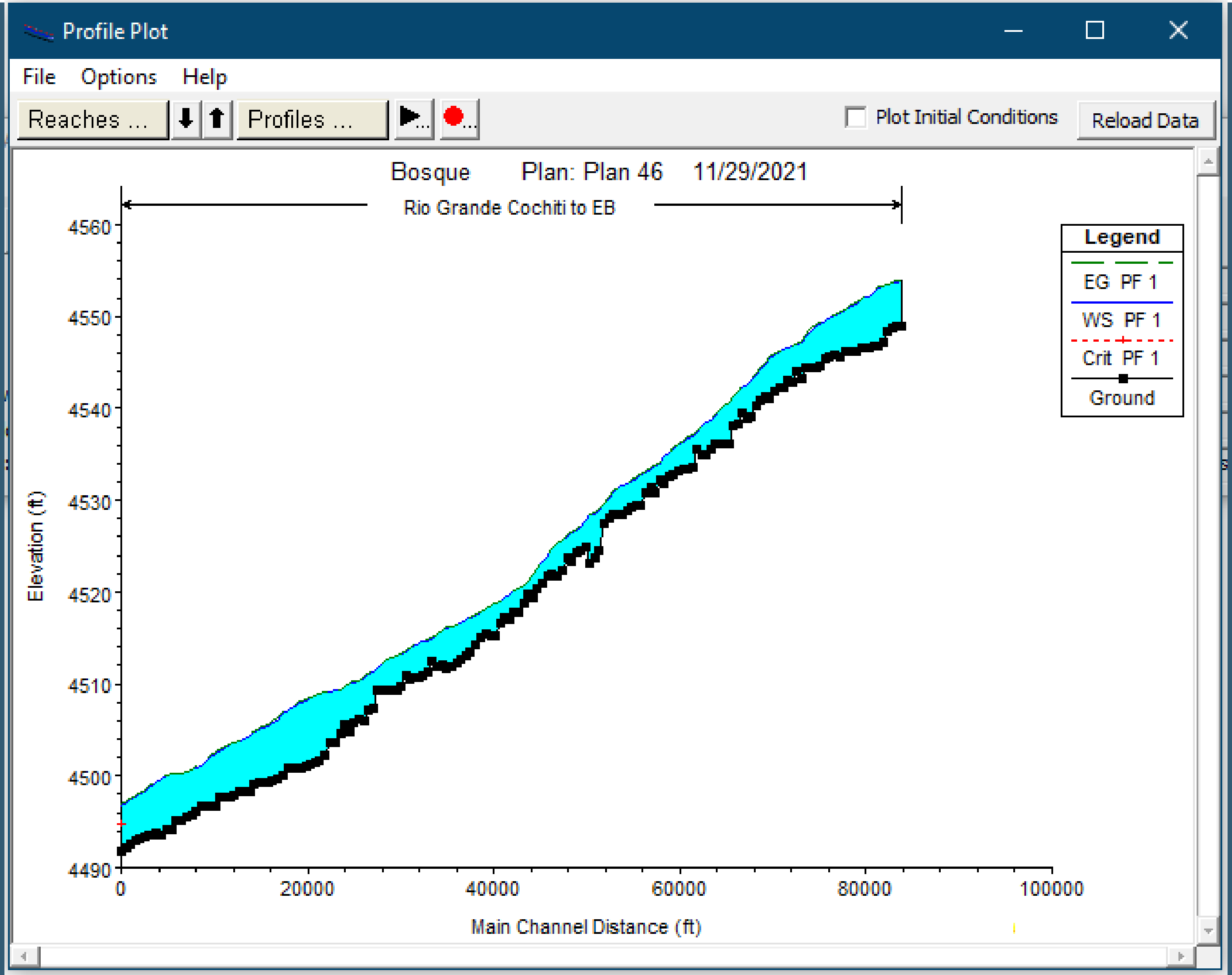
View Profiles

Output Tables

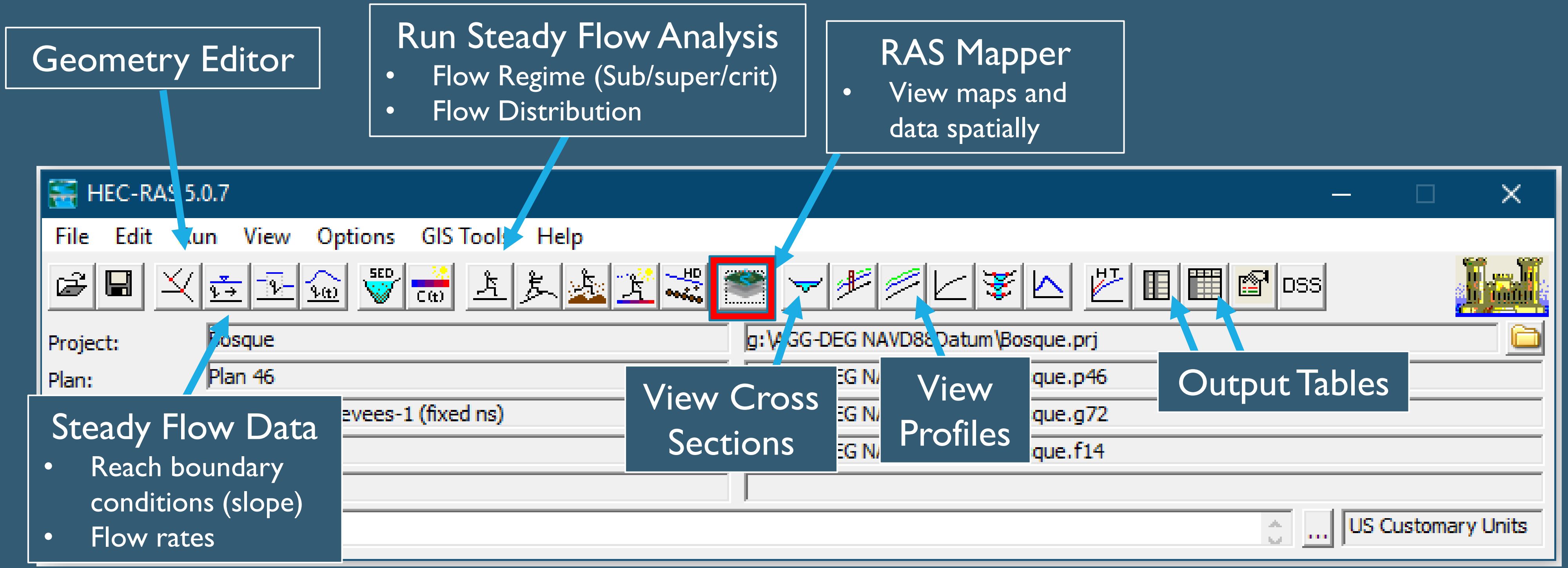
Steady Flow Data
- Reach boundary conditions (slope)
- Flow rates

VIEWING THE RESULTS

Flow profile



RAS MAPPER

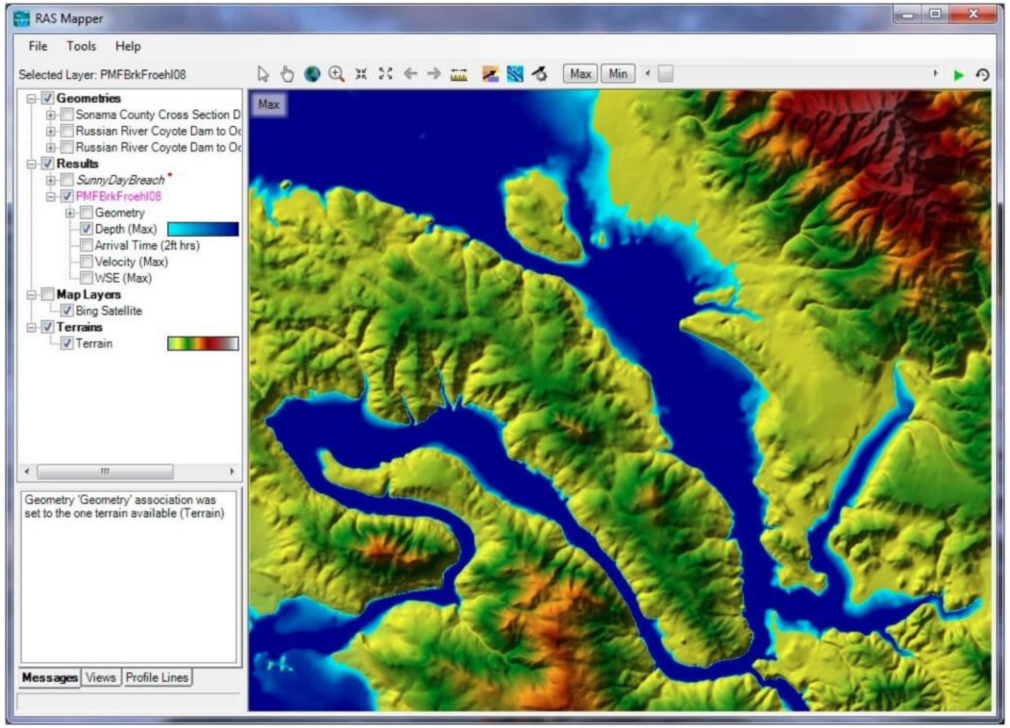


Geometry Editor
Run Steady Flow Analysis
• Flow Regime (Sub/super/crit)
• Flow Distribution
RAS Mapper
• View maps and data spatially
HEC-RAS 5.0.7
File Edit Run View Options GIS Tools Help
SED
C(t)
HD
HT
DSS
Project:
Plan:
Plan 46
evees-1 (fixed ns)
que.p46
que.g72
que.f14
US Customary Units
Steady Flow Data
• Reach boundary conditions (slope)
• Flow rates
View Cross Sections
View Profiles
Output Tables

RAS MAPPER

What is RAS Mapper?

- HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS.
- Visualizes 1D model results.
- Various types of map layer results can be generated,
  - depth of water
  - water surface elevations;
  - velocity
  - inundation boundary (shapefile)
  - flow (1D only right now)
  - depth times velocity
  - depth times velocity^2

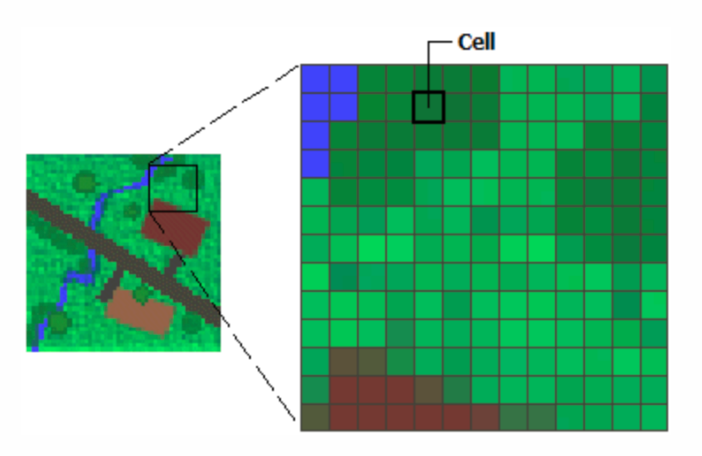


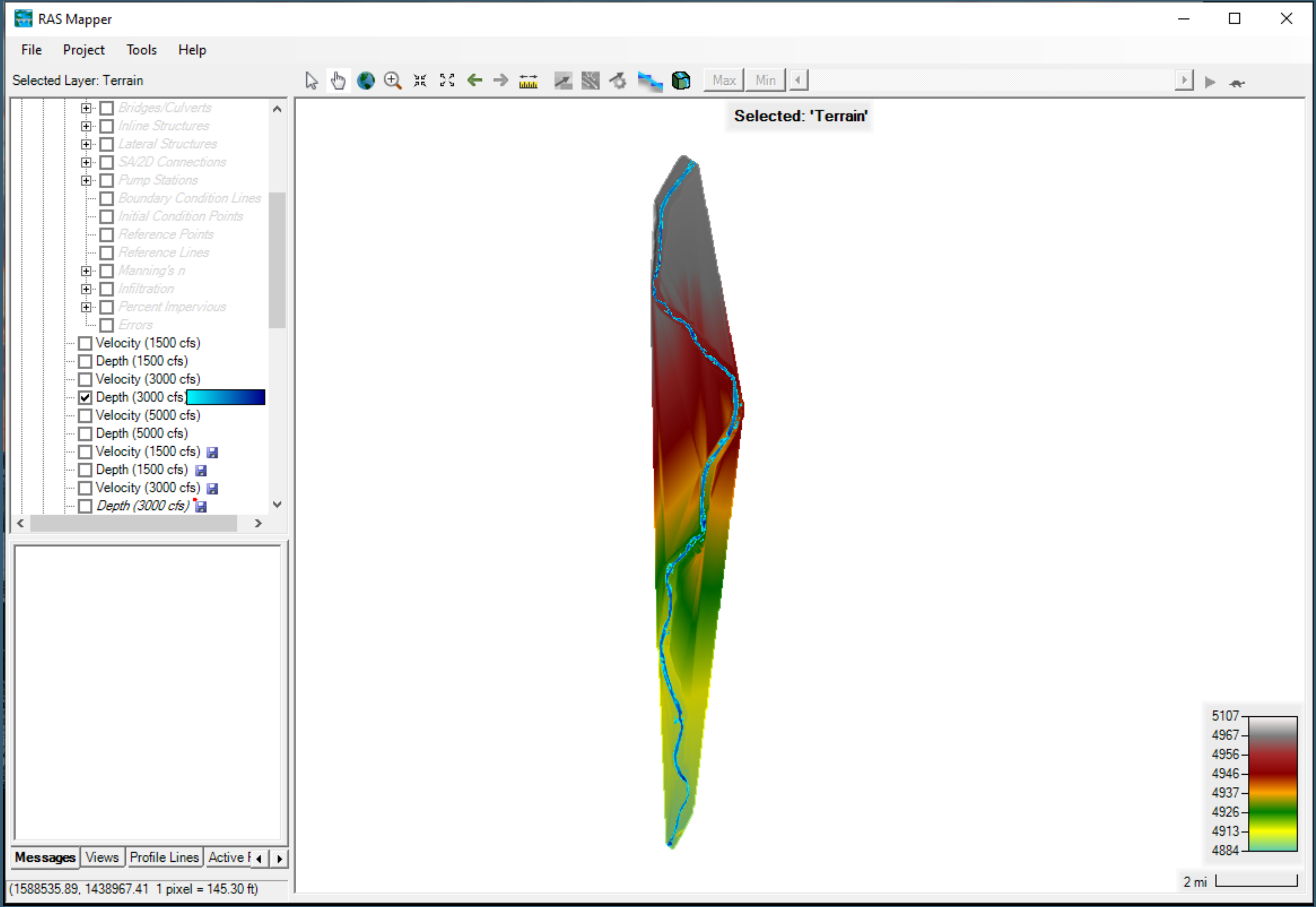
RAS MAPPER

- Allows for the exportation of raster files. (.tif and .vrt)

What is a Raster File?

- A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as depth.



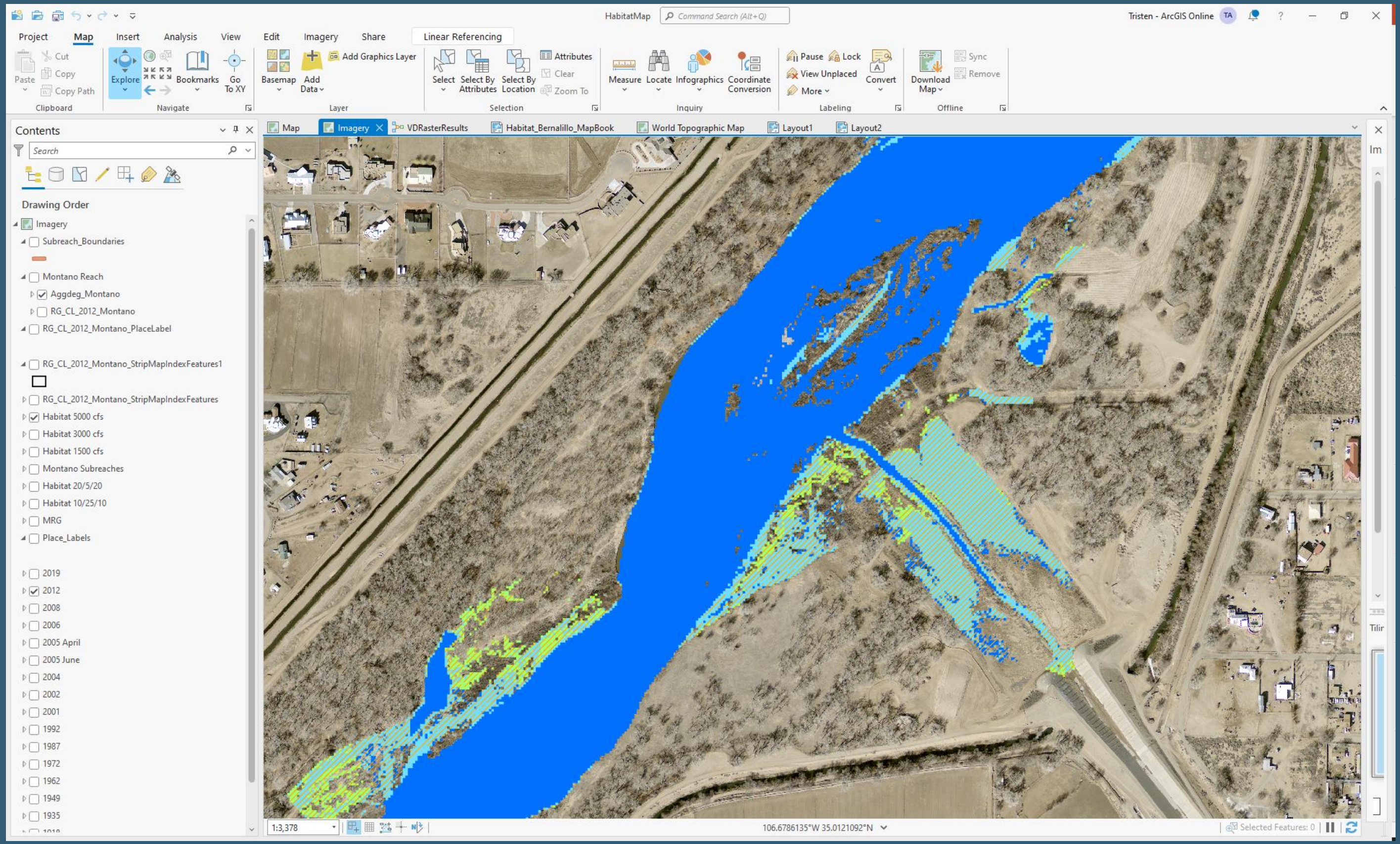


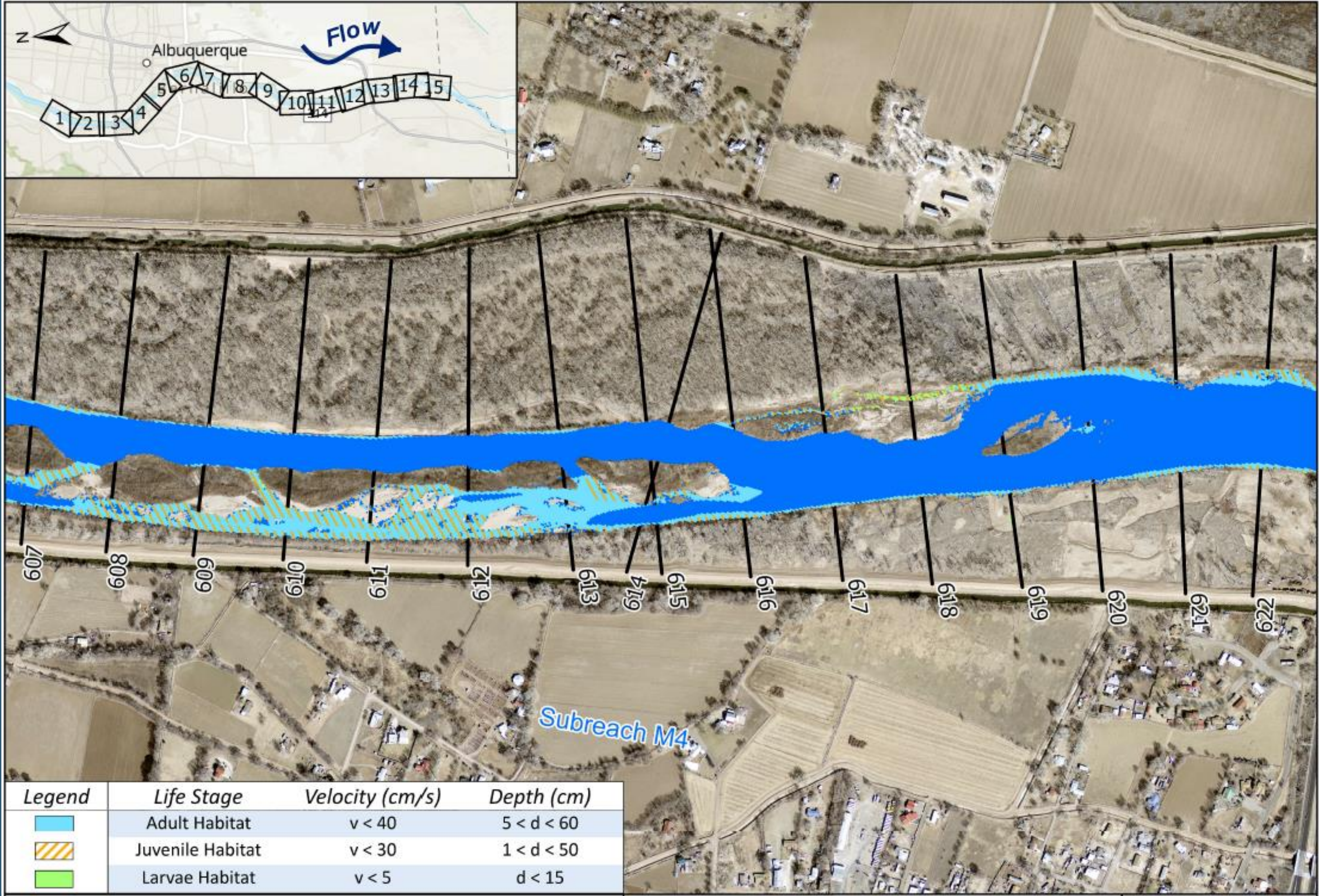
RAS MAPPER + ARCGIS PRO

Table 5 Rio Grande Silvery Minnow habitat velocity and depth range requirements (from Mortensen et al., 2019)

	Velocity (cm/s)	Depth (cm)
Adult Habitat	<40	>5 and <60
Juvenile Habitat	<30	>1 and <50
Larvae Habitat	<5	<15

- ArcGIS Pro is a mapping software developed by ESRI.
- Using a tool called "ModelBuilder" the depth and velocity rasters can be combined. Then the hydraulic requirements for each life stage of the Silvery Minnow are applied.





Legend	Life Stage	Velocity (cm/s)	Depth (cm)
	Adult Habitat	v < 40	5 < d < 60
	Juvenile Habitat	v < 30	1 < d < 50
	Larvae Habitat	v < 5	d < 15

N 1,000 500 0 1,000 Feet

MRG Habitat Map at 1,500 cfs
Montaño Rd to Isleta Diversion Dam

TAKE-AWAYS

- HEC-RAS is a useful tool to produce modeling results with a relatively small amount of data.
  - Cross-sectional geometry
  - Channel slope
  - Manning's roughness values
  - LiDAR data (if using RAS Mapper)