



HABITAT MAPPING WITH HEC-RAS

By Andrew Schied

OVERVIEW

- My research focusses on the Middle Rio Grande river in Albuquerque, NM.
- Utilized modeling to relate hydraulic conditions to suitable available silvery minnow habitat.
- 1) Introduction to HEC-RAS
- 2) How to set up HEC-RAS
- 3) Demonstration of how HEC-RAS works



WHAT IS HEC-RAS

- Stands for Hydrologic Engineering Centers River Analysis System (HEC-RAS)
- Publicly available software create 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



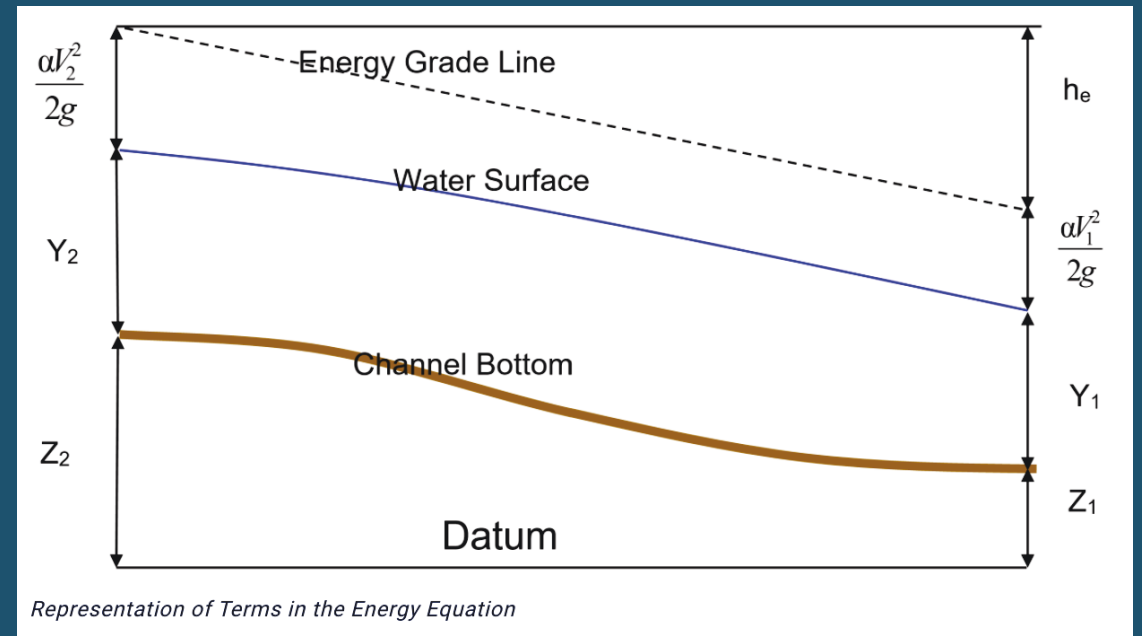
HOW DOES IT WORK?

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



HOW DOES IT WORK?

The energy head loss (h_e) 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?

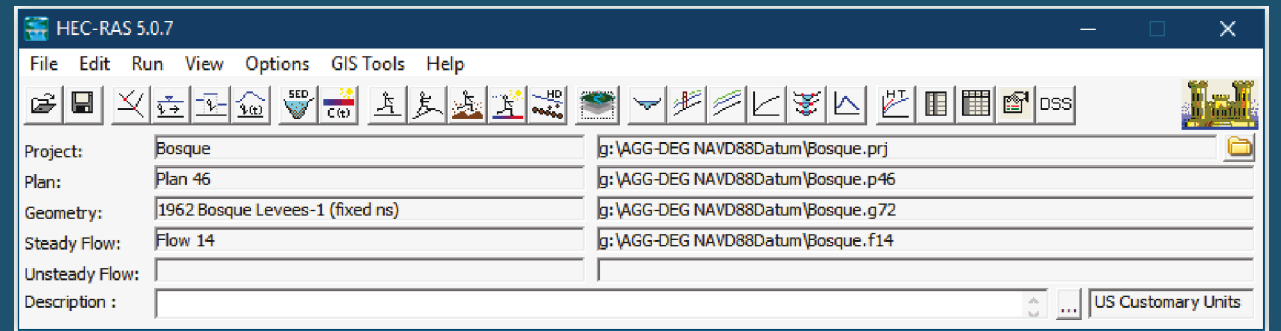
Computational Procedure

- 1) Assume a water surface elevation at the upstream or downstream cross sections.
- 2) Based on the assumed water surface elevation, determine the corresponding total conveyance and velocity head.
- 3) Compute S_f and solve for losses h_e
- 4) Solve the energy equation for the water surface.
- 5) Compare the computed value of depth with the assumed value and iterate until the values agree within 0.01 feet.

SETTING UP HEC-RAS

Required Information

- Surveyed cross sections (STA and ELEV)
- Average reach slope for boundary conditions
- LiDAR topographical data (if using RAS Mapper)



SETTING UP HEC-RAS

Geometry Editor

Run Steady Flow Analysis

- Flow Regime (Sub/super/crit)
- Flow Distribution

RAS Mapper

- View maps and data spatially

The screenshot shows the HEC-RAS 5.0.7 software interface. The menu bar includes File, Edit, Run, View, Options, GIS Tool, and Help. The toolbar contains various icons for file operations, analysis, and visualization. The project name is 'Bosque' and the plan is 'Plan 46'. The file path is 'g:\VGG-DEG NAVD83 Datum\Bosque.prj'. The interface is set to 'US Customary Units'. Several callout boxes point to specific features:

- Geometry Editor**: Points to the 'Geometry Editor' icon in the toolbar.
- Run Steady Flow Analysis**: Points to the 'Run Steady Flow Analysis' icon in the toolbar.
- RAS Mapper**: Points to the 'RAS Mapper' icon in the toolbar.
- Steady Flow Data**: Points to the 'Steady Flow Data' icon in the toolbar.
- View Cross Sections**: Points to the 'View Cross Sections' icon in the toolbar.
- View Profiles**: Points to the 'View Profiles' icon in the toolbar.
- Output Tables**: Points to the 'Output Tables' icon in the toolbar.

Steady Flow Data

- Reach boundary conditions (slope)
- Flow rates

EG N	sque.p46
EG N	sque.g72
EG N	sque.f14

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

Geometric Data - 2012 Bosque No Levees (fixed ns)

File Edit Options View Tables Tools GIS Tools Help

Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Area Conn, SA/2D Area BC Lines, 2D Area Break Lines, 2D Area Mann n Regions, Pump Station, RS (12.99)

Description: Plot WS extents for Profile: (none)

Editors: Junct., Cross Section, Brdg/Culv, Inline Structure, Lateral Structure, Storage Area, 2D Flow Area, SA/2D Area Conn, Pump Station, HTab Param., View Picture

294180.1	1465
291649.8	1470
289157.2	1475
286375.2	1480
283268.9	1486
281264	1490
279218.3	1494
277233.5	1498
274679.5	1503
272154.6	1508
269622.3	1513
266458.2	1519
264509.2	1523
262658.3	1527
259778.1	1532
257086	1537
254343.1	1542
252183.9	1546
250026.4	1550
247032.9	1555
244014	1560
241952.3	1564
238544.8	1572
234083.3	1580
231337.4	1584
228472.1	1588
225568.2	1595
223065.7	1600
220540.3	1605
216960.6	1613
214420.3	1618
211781.8	1624
207590.9	1633
205509.5	1637

1395024.84, 992291.85

SETTING UP HEC-RAS

Geometric Data - 1992 Bosque Levees-1 (fixed ns)

File Edit Options View Tables Tools GIS Tools Help

Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Area Conn, SA/2D Area BC Lines, 2D Area Break Lines, 2D Area Manning Regions, Pump Station, RS 12.99

Description: Plot WS extents for Profile: (none)

485
479
474
469
464
458
452
446
C4411 to EB
435
430
424
419
413
408
402
396
391
386
381
375
369
364
359
354
349
344
339
334
329
324

None of the XS's are Geo-Referenced (— Geo-Ref user entered XS — Geo-Ref interpolated XS — Non Geo-Ref user entered XS — Non Geo-Ref interpolated XS)

-0.2144, 0.0438

SETTING UP HEC-RAS

Cross Section Data - 1962 Bosque Levees-1 (fixed ns)

Exit Edit Options Plot Help

River: Rio Grande Apply Data Plot Options Keep Prev XS Plots Clear Prev Plot Terrain (if available) Cut from Terrain

Reach: Cochiti to EB River Sta.: 485

Description

Del Row	Ins Row	Station	Elevation
		0	4550.28
		77	4550.48
		202	4550.28
		339	4549.78
		467	4549.68
		628	4549.48
		701	4549.58
		822	4549.48
		953	4549.68
		1026	4549.68
		1186	4549.58
		1329	4549.48
		1489	4549.68
		1642	4549.68
		1836	4549.58
		2000	4549.48
		2188	4549.78
		2304	4549.88
		2420	4549.68
		2507	4549.78

Downstream Reach Lengths

LOB	Channel	ROB
500.	485.	485.

Manning's n Values

LOB	Channel	ROB
0.1	0.025	0.1

Main Channel Bank Stations

Left Bank	Right Bank
4357.	4682.

Cont'Exp Coefficient (Steady)

Contraction	Expansion
0.1	0.3

Plan: Plan 46 10/16/2021

River Station, akin to cross section #

Manning's n values

Bank Stationing Used to designate different sections of the channel for calculations

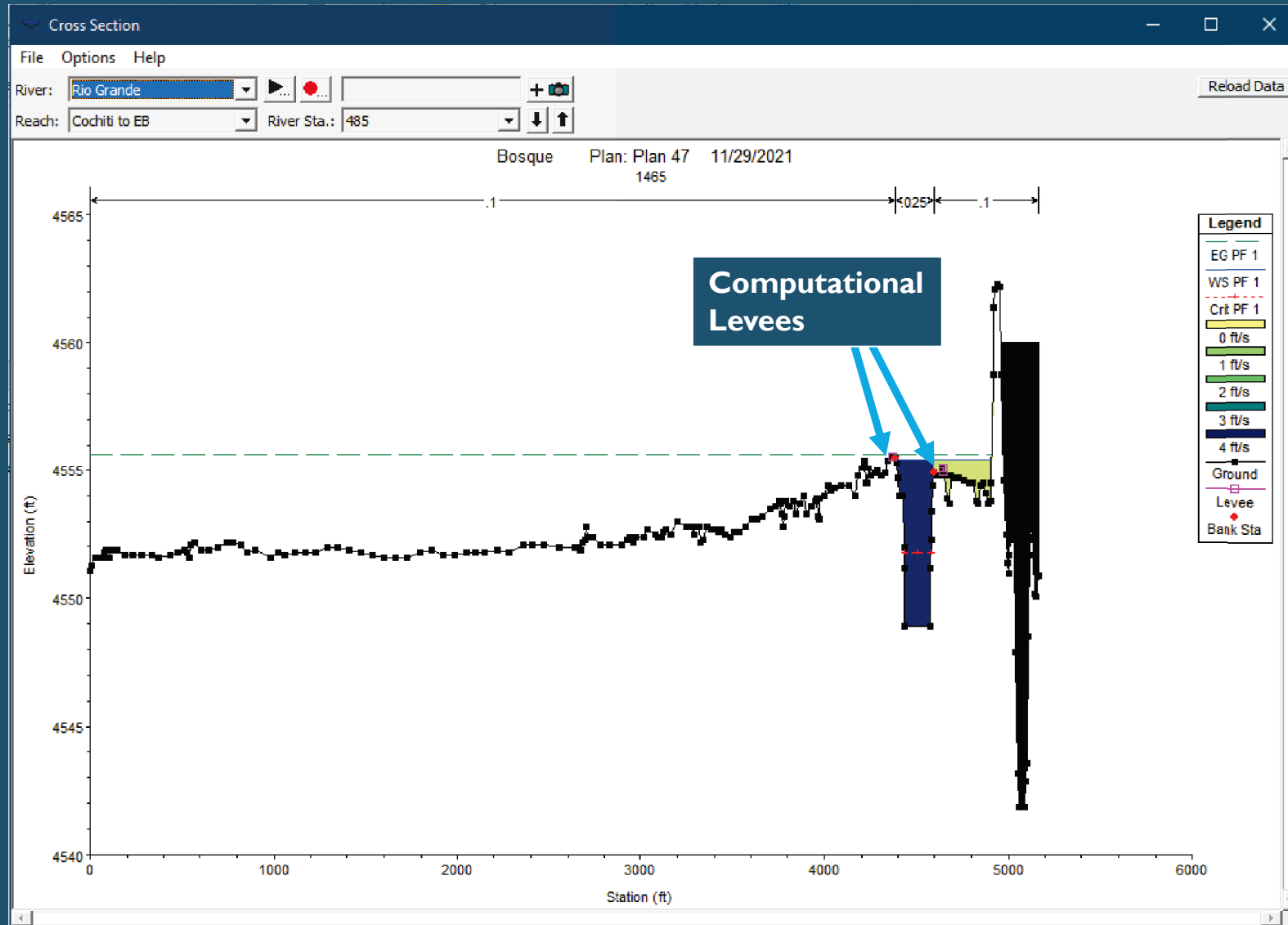
Station/ Elevation Coordinates

Graphical Cross Section Display

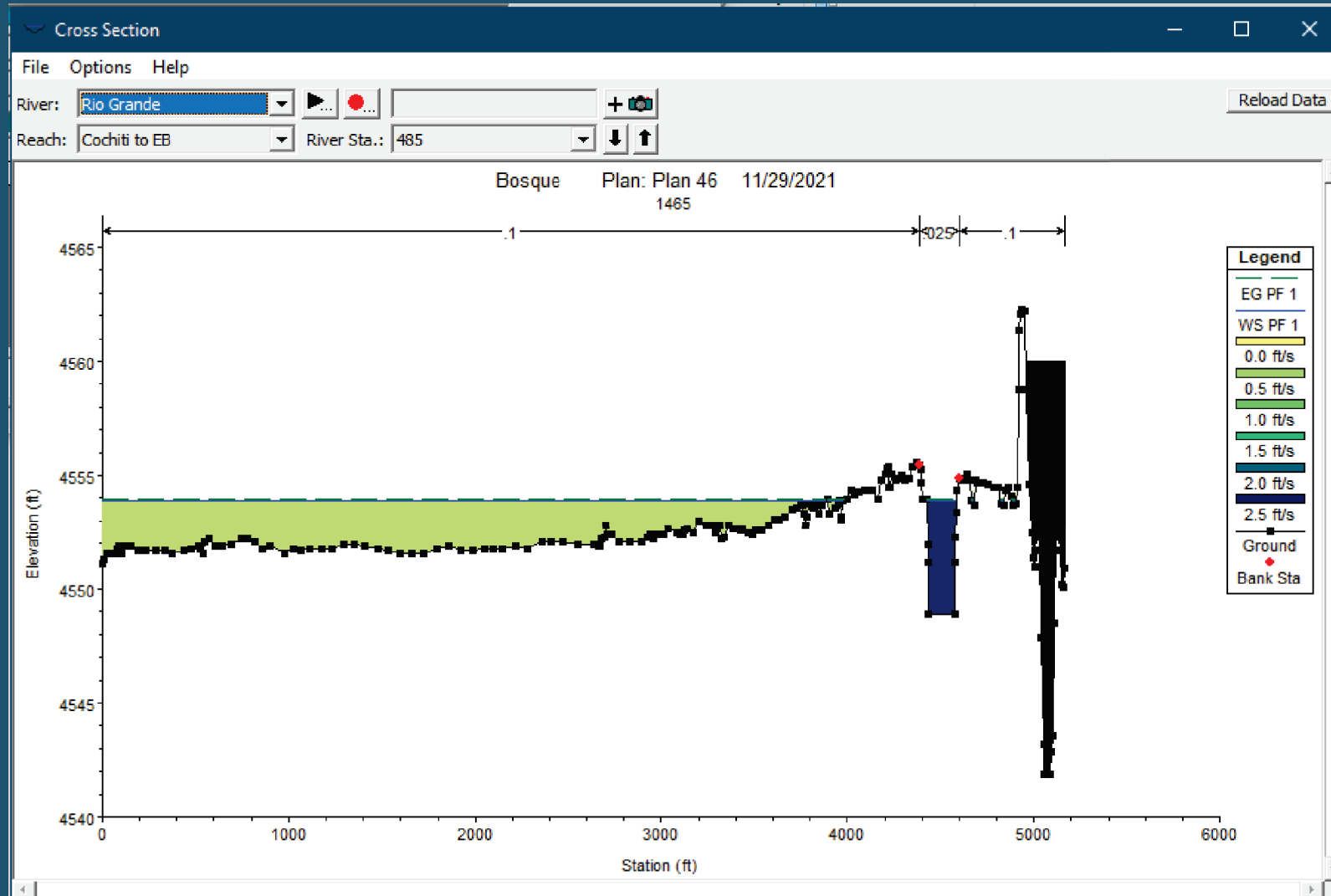
Levee on left and right sides
Normal Blocked obstruction(s)

The graphical display shows a cross-section plot with Elevation (ft) on the y-axis (4540 to 4565) and Station (ft) on the x-axis (0 to 6000). The plot includes a ground profile (black line with squares), a water surface profile (blue line with triangles), and various flow profiles (green and red lines with markers). A legend on the right identifies the series: EG PF 2, WS PF 2, EG PF 1, WS PF 1, Crit PF 2, Crit PF 1, velocity profiles (-4 ft/s to 8 ft/s), Ground, Levee, and Bank Sta. The plot also shows a levee structure on the right side of the channel.

SETTING UP HEC-RAS



SETTING UP HEC-RAS



SETTING UP HEC-RAS

Edit Manning's n or k Values

River: Edit Interpolated XS's Channel n Values have a light green background

Reach:

Selected Area Edit Options

	River Station	Frctn (n/K)	n #1	n #2	n #3	n #4	n #5
1	485	n	0.1	0.025	0.1		
2	484	n	0.1	0.025	0.1		
3	483	n	0.1	0.025	0.1		
4	482	n	0.1	0.025	0.1		
5	481	n	0.1	0.025	0.1		
6	480	n	0.1	0.025	0.1		
7	479	n	0.1	0.025	0.1		
8	478	n	0.1	0.025	0.1		
9	477	n	0.1	0.025	0.1		
10	476	n	0.1	0.025	0.1		
11	475	n	0.1	0.025	0.1		
12	474	n	0.1	0.025	0.1		
13	473	n	0.1	0.025	0.1		
14	472	n	0.1	0.025	0.1		
15	471	n	0.1	0.025	0.1		
16	470	n	0.1	0.025	0.1		
17	469	n	0.1	0.025	0.1		
18	468	n	0.1	0.025	0.1		
19	467	n	0.1	0.025	0.1		
20	466	n	0.1	0.025	0.1		
21	465	n	0.1	0.025	0.1		
22	464	n	0.1	0.025	0.1		
23	463	n	0.1	0.025	0.1		
24	462	n	0.1	0.025	0.1		

SETTING UP HEC-RAS

Geometry Editor

Run Steady Flow Analysis

- Flow Regime (Sub/super/crit)
- Flow Distribution

RAS Mapper

- View maps and data spatially

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Project: Bosque

Plan: Plan 46

g:\VGG-DEG NAVD83 Datum\Bosque.prj

EG N

EG N

EG N

sque.p46

sque.g72

sque.f14

US Customary Units

Steady Flow Data

- Reach boundary conditions (slope)
- Flow rates

View Cross Sections

View Profiles

Output Tables

SETTING UP HEC-RAS

Input # Flow Profiles

Steady Flow Data - Flow 14

File Options Help

Description :

Enter/Edit Number of Profiles (32000 max): Reach Boundary Conditions ...

Locations of Flow Data Changes

River: Add Multiple...

Reach: River Sta.: Add A Flow Change Location

Flow Change Location			Profile Names and Flow Rates		
	River	Reach	RS	PF 1	PF 2
1	Rio Grande	Cochiti to EB	485	500	1000

Edit Steady flow data for the profiles (cfs)

Boundary Conditions

- Known W.S.
- Critical depth
- Normal Depth
- Rating Curve

Flow Profiles

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Project: Bosque

Plan: Plan 46

g:\WGG-DEG NAVD88 Datum\Bosque.prj

Steady Flow Data

- Reach boundary conditions (slope)
- Flow rates

View Cross Sections

View Profiles

Output Tables

US Customary Units

SETTING UP HEC-RAS

Options

- Flow Distribution Locations

Flow Regimes

- Subcritical
- Supercritical
- Mixed

Run!

Steady Flow Analysis

File Options Help

Plan : Short ID Plan 46

Geometry File : 1992 Bosque Levees-1 (fixed ns)

Steady Flow File : Flow 14

Plan Description :

Flow Regime

- Subcritical
- Supercritical
- Mixed

Optional Programs

- Floodplain Mapping

Compute

Enter/Edit short identifier for plan (used in plan comparisons)

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.

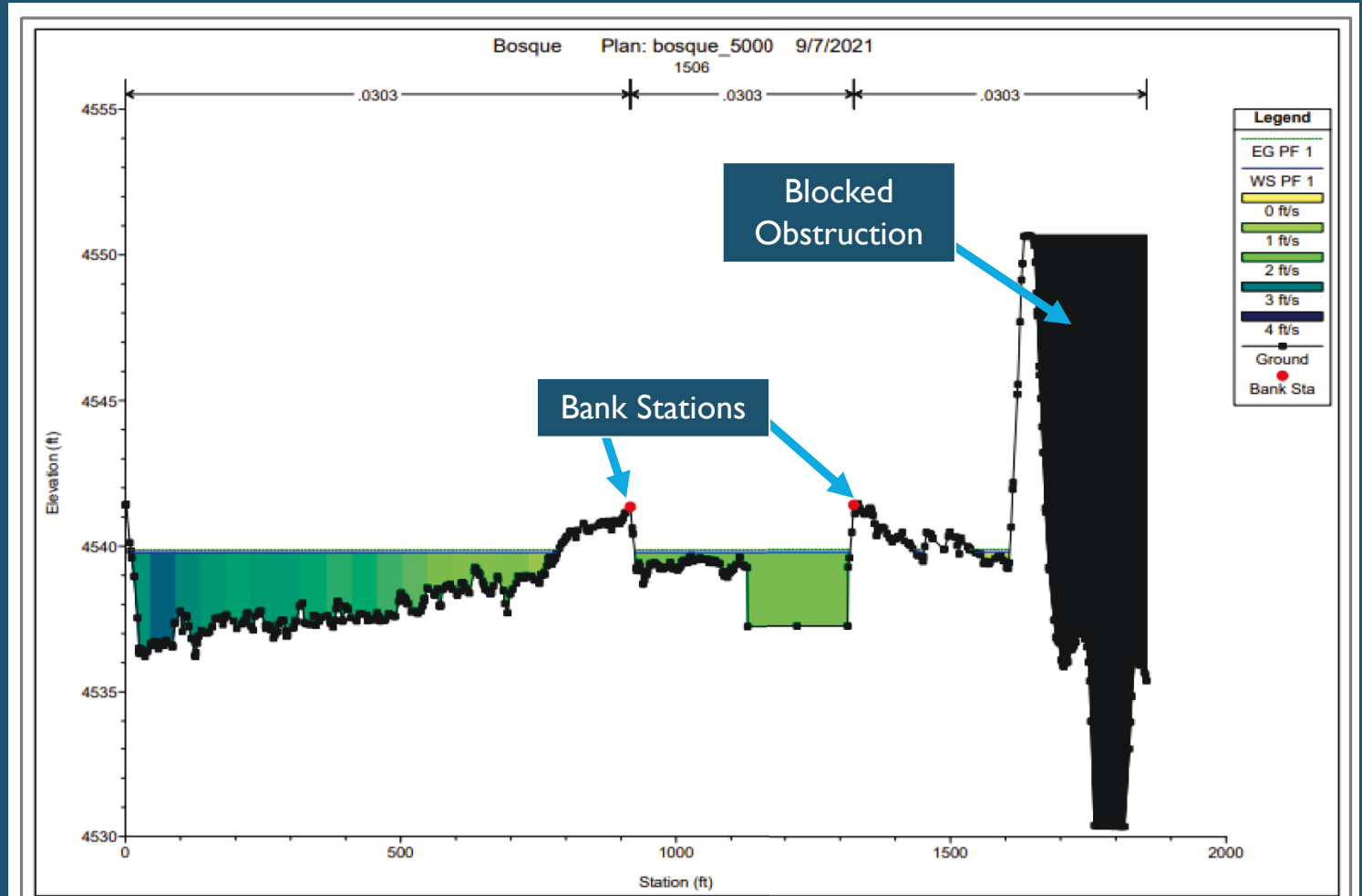
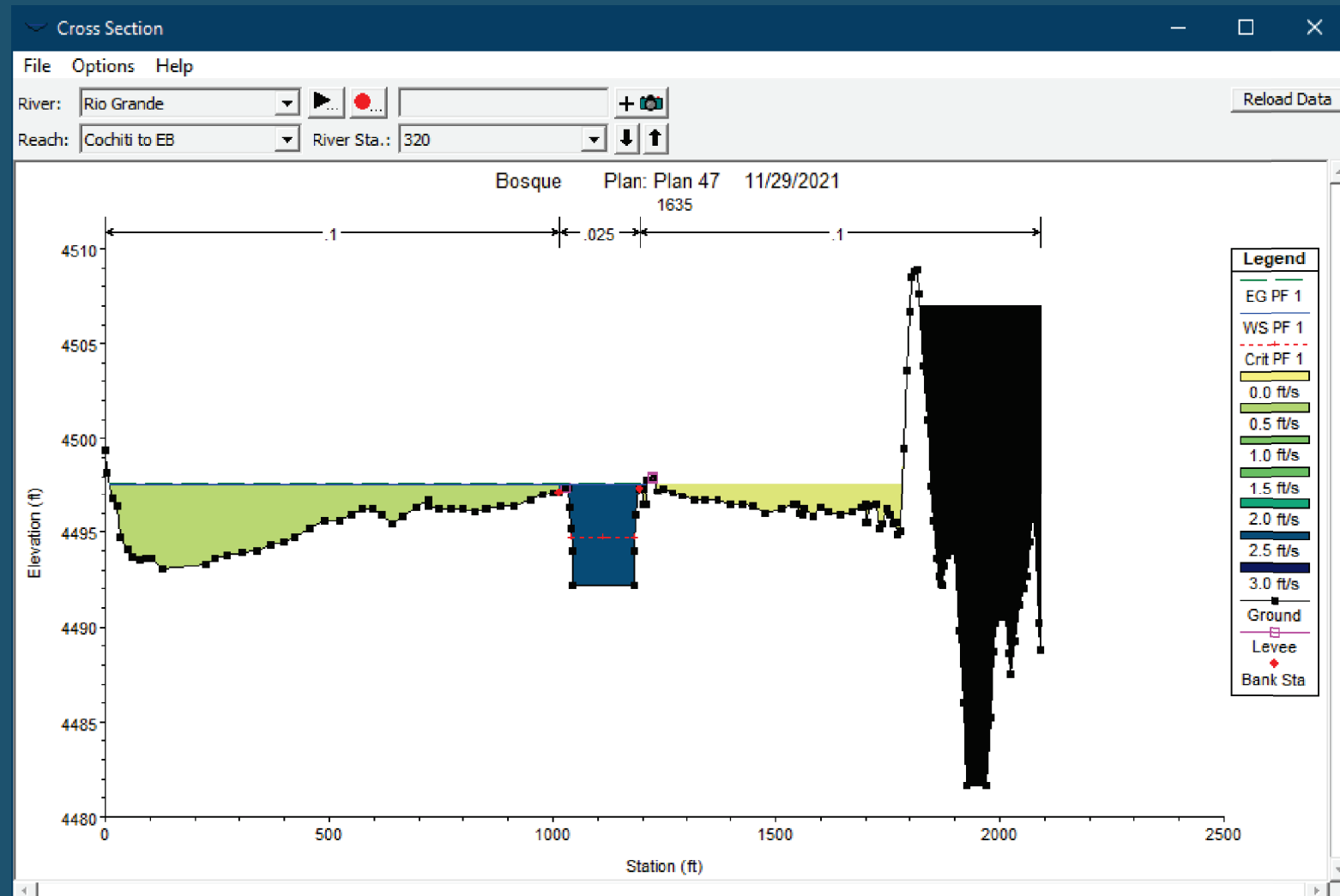


Figure 63 Cross-section with flow distribution from HEC-RAS with 20 vertical slices in the floodplains and 5 vertical slices in the main channel. The blue and green slices are small enough that the discrete color changes look more like a gradient.

SETTING UP HEC-RAS



VIEWING THE RESULTS

Geometry Editor

Run Steady Flow Analysis

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- View maps and data spatially

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Steady Flow Data

- Reach boundary conditions (slope)
- Flow rates

View Cross Sections

View Profiles

Output Tables

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

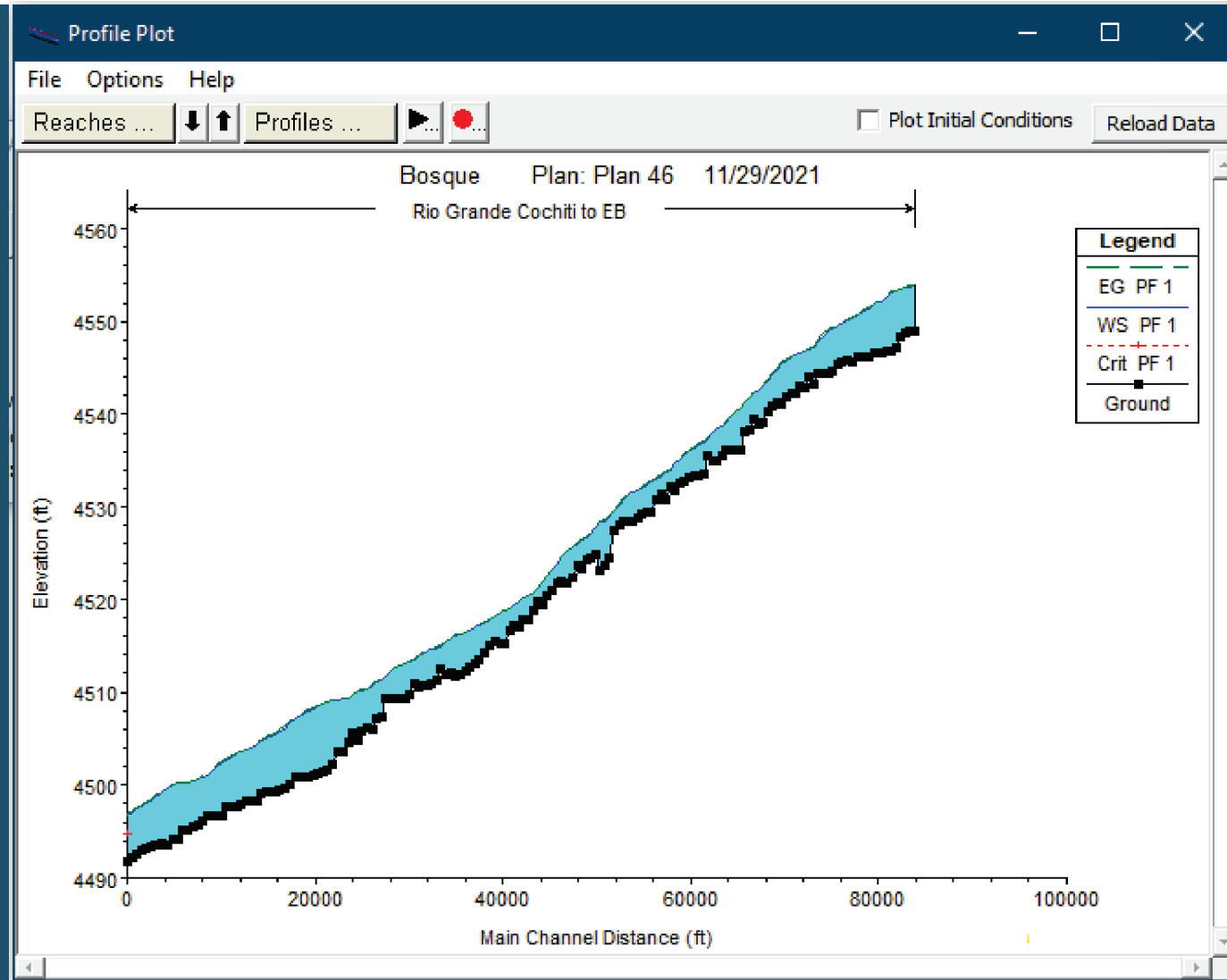
The screenshot shows the HEC-RAS 5.0.7 software interface. The menu bar includes File, Edit, Run, View, Options, GIS Tools, and Help. The toolbar contains various icons for file operations, analysis, and visualization. The project name is 'Bosque' and the plan is 'Plan 46'. The file path is 'g:\WGG-DEG NAVD88 Datum\Bosque.prj'. The interface is divided into several panes, with callouts pointing to specific features:

- Steady Flow Data**: Reach boundary conditions (slope), Flow rates
- View Cross Sections**: View Cross Sections
- View Profiles**: View Profiles
- Output Tables**: Output Tables

The 'Run' menu is highlighted with a red box, and the 'View Cross Sections' icon is also highlighted with a red box. The 'US Customary Units' button is visible in the bottom right corner.

VIEWING THE RESULTS

Flow profile



RAS MAPPER

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Steady Flow Data

- Reach boundary conditions (slope)
- Flow rates

View Cross Sections

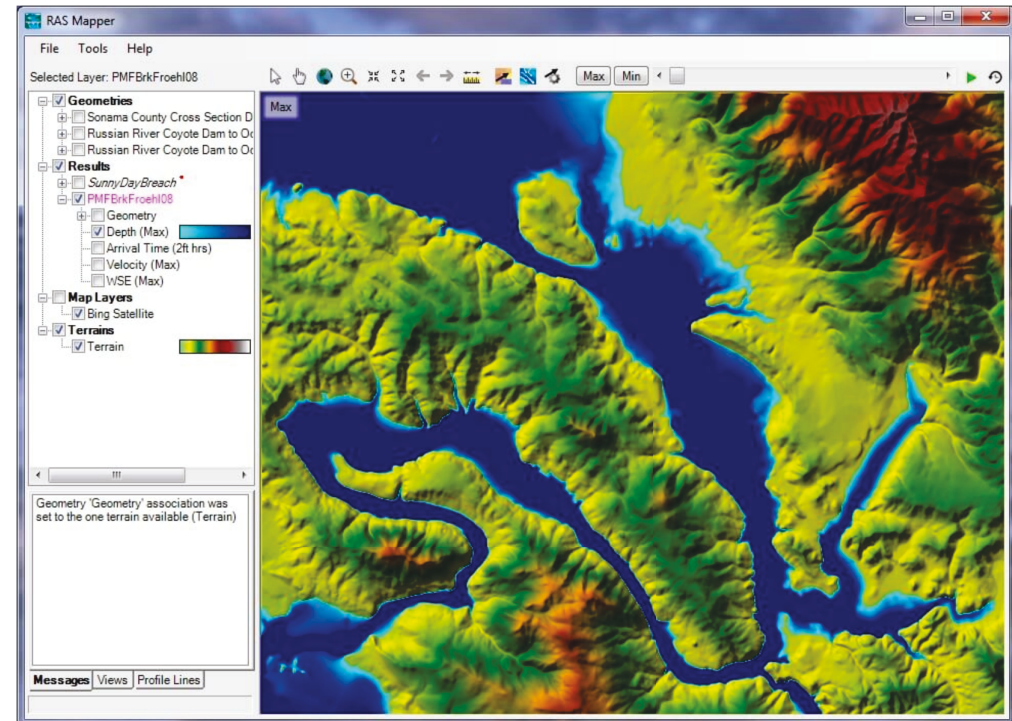
View Profiles

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 ID model results.
- Various types of map layer results can be generated,
 - depth of water
 - water surface elevations;
 - velocity
 - inundation boundary (shapefile)
 - flow (ID only right now)
 - depth times velocity
 - depth times velocity²

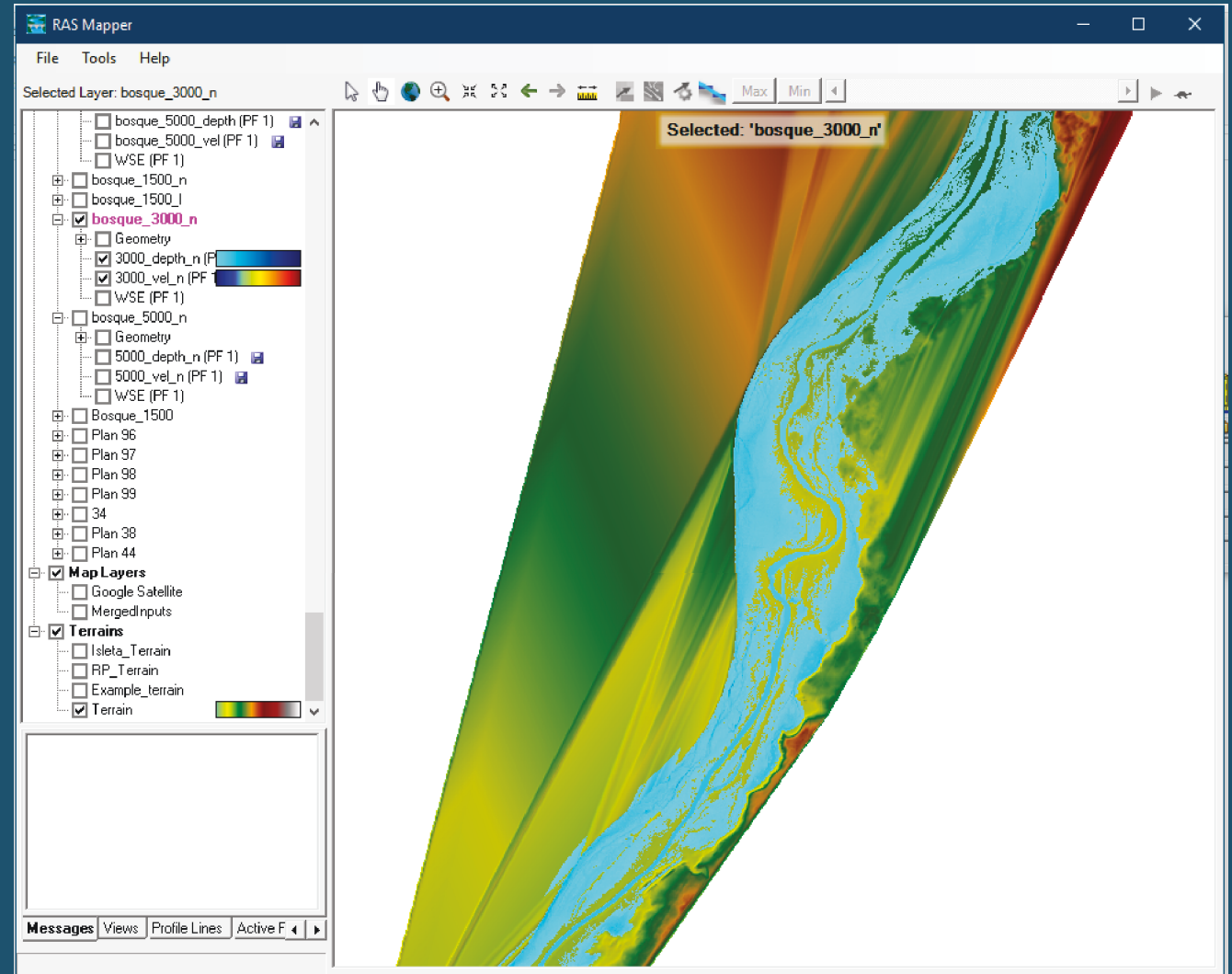
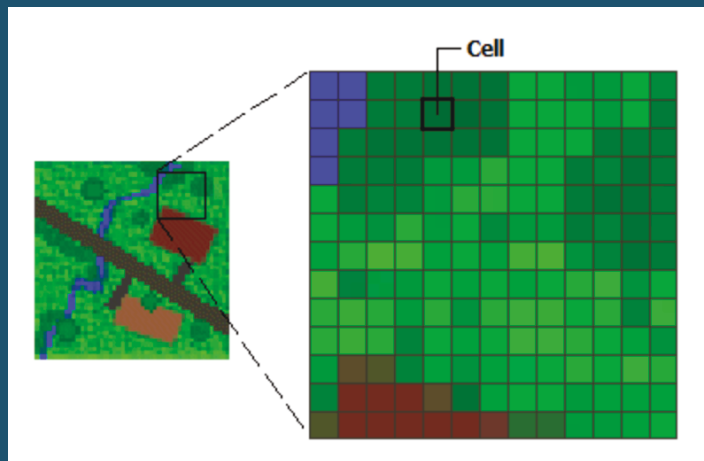


RAS MAPPER

- 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.

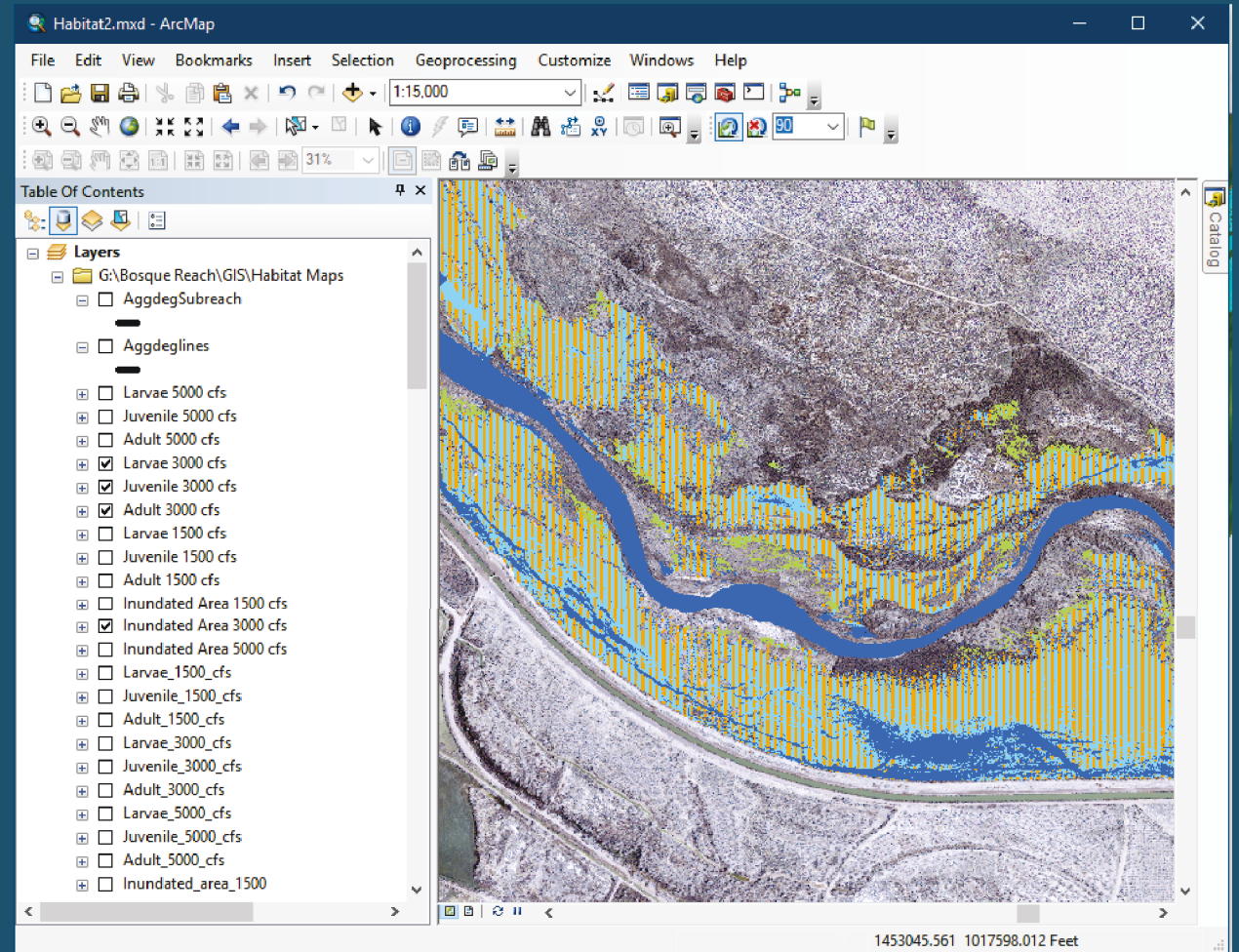


RAS MAPPER+ARCMAP

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

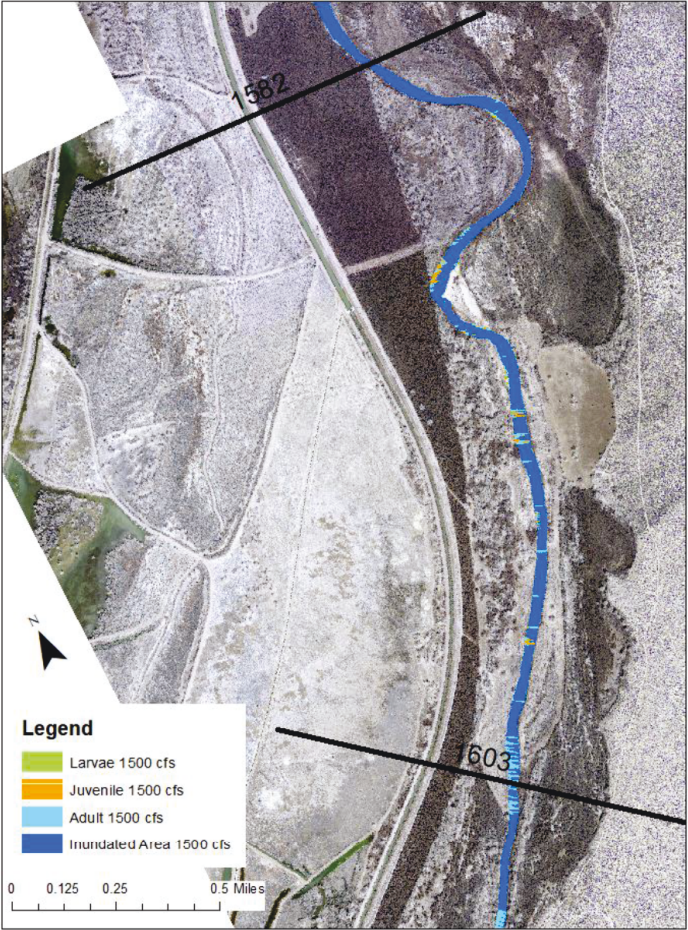
	Velocity (cm/s)	Depth (cm)
Adult Habitat	<40	>5 and <60
Juvenile Habitat	<30	>1 and <50
Larvae Habitat	<5	<15

- ArcMap is a mapping software developed by ESRI.
- Using a tool called “ModelBuilder” the raster can be split up based on the depth and velocity requirements for each life stage of the Silvery Minnow.

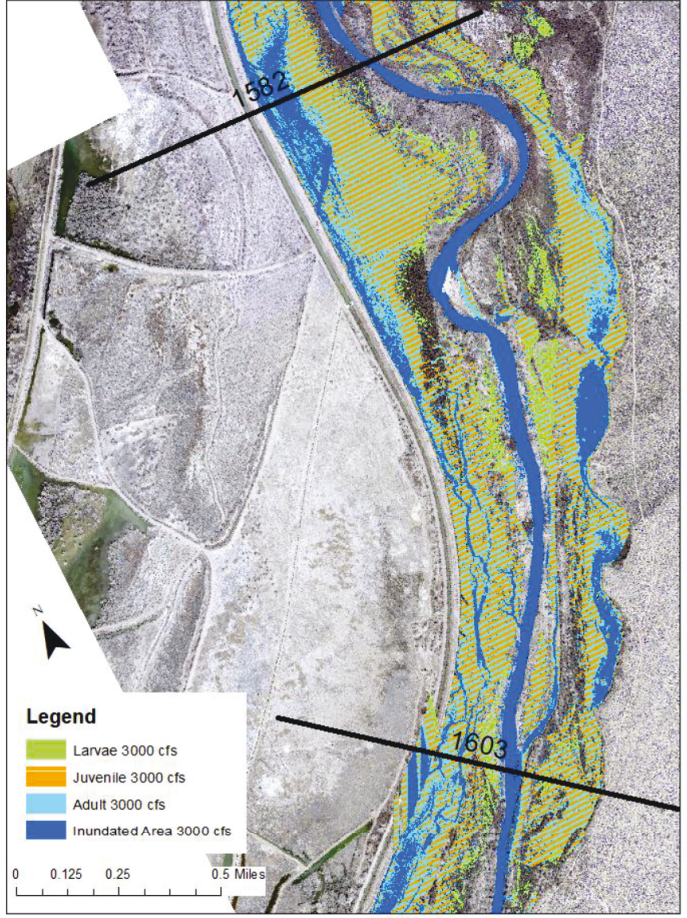


RAS MAPPER+ARCMAP

B4 Habitat (1500 cfs)



B4 Habitat (3000 cfs)



B4 Habitat (5000 cfs)

