U.S. Department of Transportation
Federal Highway Administration

New Jersey Department of Transportation Tech Talk:
EDC-5 CHANGE and 2-D Modeling Considerations

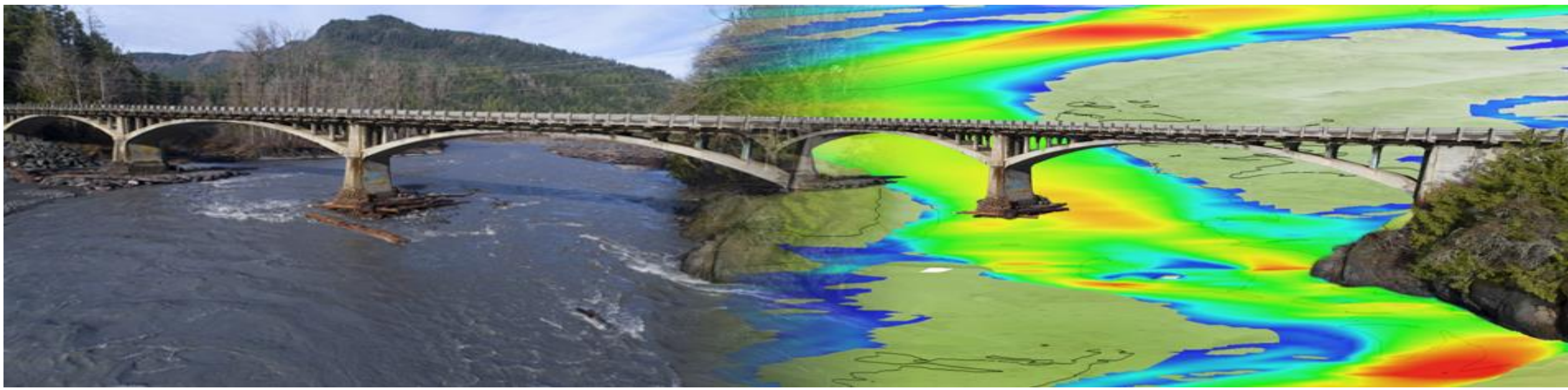

Image by John Gussman / FHWA

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Images: FHWA website

Hydraulic Engineering

Acknowledgments

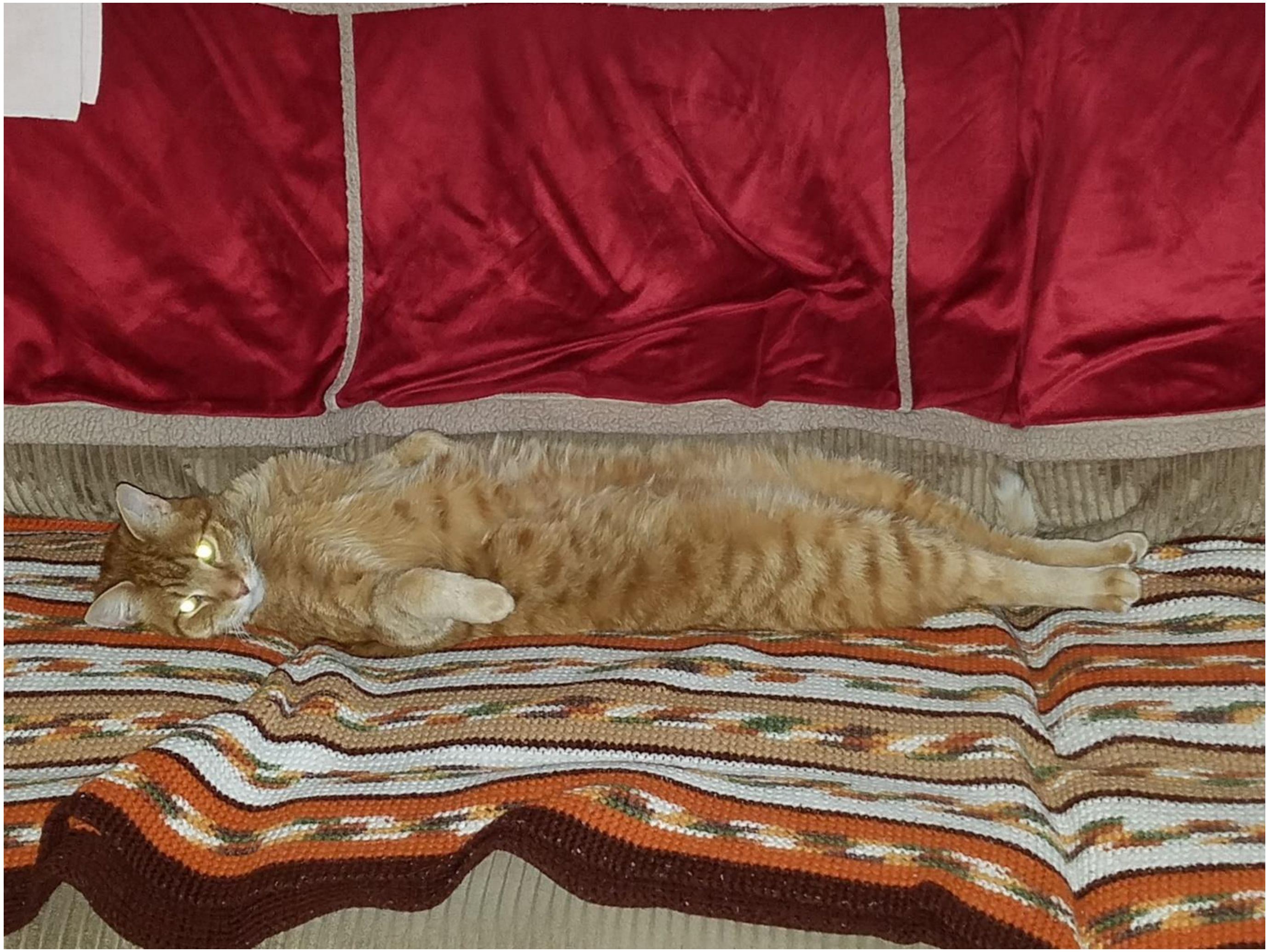
A special thanks to:

- Scott Hogan & Laura Girard (CHANGE Co-Champions)
- Helene Roberts & Paul Cardie (FHWA NJ Division)
- Janet Leli & Omid Sarmad (Rutgers University)
- Sandy Blick & NJDOT Staff

**All photos and figures by FHWA unless otherwise noted.*

Acknowledgments

And a shout-out to McFly Brown (for moral support):



Presentation Outline

1. An introduction to the FHWA Hydraulic Engineering Discipline and resources
2. An overview EDC-5 CHANGE and SMS-SRH2D
3. A holistic approach to employing 2-D modeling
4. Questions and answers (or a reasonable facsimile of answers)

Say Hello to Max....

Max is entering her senior year in college, is looking forward to her classes, and is also considering post-graduation career opportunities.

Image from Cartoonstock.com

All Levels of Government Need Civil Engineers

Agencies such as State Departments of Transportation and the Federal Highway Administration offer challenging and rewarding transportation-focused careers. Max is a Civil Engineering student interested in hydraulic engineering. A brief introduction of the FHWA Hydraulic Engineering Discipline follows.

FHWA Hydraulics Team

Photo credit: FHWA

FHWA Hydraulics Website

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Bridges & Structures

Structures | Geotech | **Hydraulics** | Safety and Management

Hydrology | Highway Drainage | Culvert Hydraulics | Bridge Hydraulics | Scour | Coastal Highways

Home / Programs / Bridges & Structures / Hydraulics

Hydraulic Engineering

The purpose of hydraulic engineering is to design a structure with the proper capacity to divert or remove water from the roadway and pass collected water under the roadway. The design of a hydraulic structure requires knowing how much water is associated with the design storm (hydrology) and calculating the velocity, depth, and type of flow (hydraulics) that must be accounted for in the design.

One of the functions of the National Hydraulic Team (NHT) is to provide FHWA offices with technical expertise in matters of the hydraulic discipline. This involves providing technical assistance in interpretation of FHWA hydraulic policies, technical publications, software, and recommended guidance in solving difficult and unusual drainage problems. We also are instrumental in the deployment of new technologies and research to the Divisions and state DOT partners.

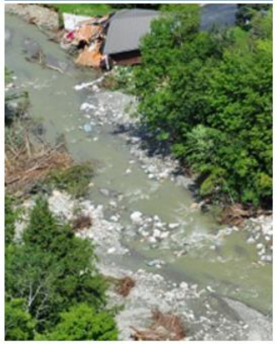
Hydrology

Drainage

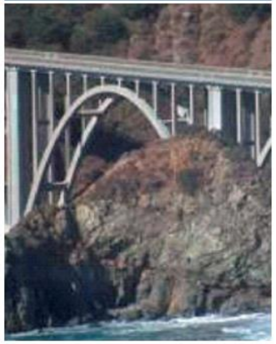
Culverts

Bridge Hydraulics

Scour



Coastal Highways



https://www.fhwa.dot.gov/engineering/hydraulics/index.cfm

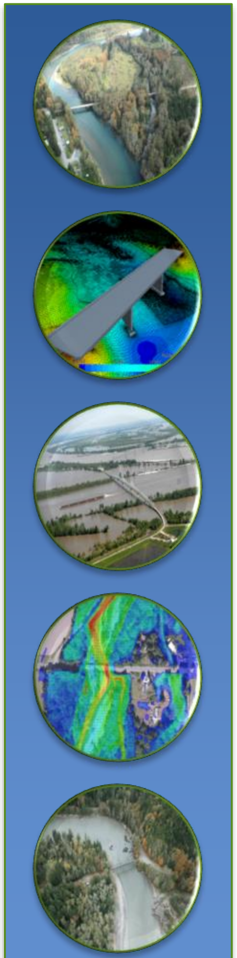
Hydraulic Engineering Website

- Technical guidance documents (as PDFs):
  - Hydraulic Engineering Circulars (HEC)
  - Hydraulic Design Series (HDS)
  - Other
- FHWA sponsored software:
  - HY-8 Culvert Analysis Program
  - Hydraulic Toolbox
  - Surface-water Modeling System (SMS)
  - Watershed Modeling System (WMS)

Hydraulic Engineering Website

- Free web-based training (WBT) through the National Highway Institute (NHI)
  - Hydrology and Hydraulics concepts
  - Software use: HY-8 and the Hydraulic Toolbox
- YouTube videos:
  - Open channel and culvert hydraulics
  - Sediment transport concepts (in development)
  - Project scoping, focusing on hydraulics/drainage (in development)
- Web search: "FHWA Hydraulics Training"… "Videos" … "Publications", etc.

Let's Talk C.H.A.N.G.E.



Collaborative

Hydraulics:

Advancing to the

Next

Generation of

Engineering

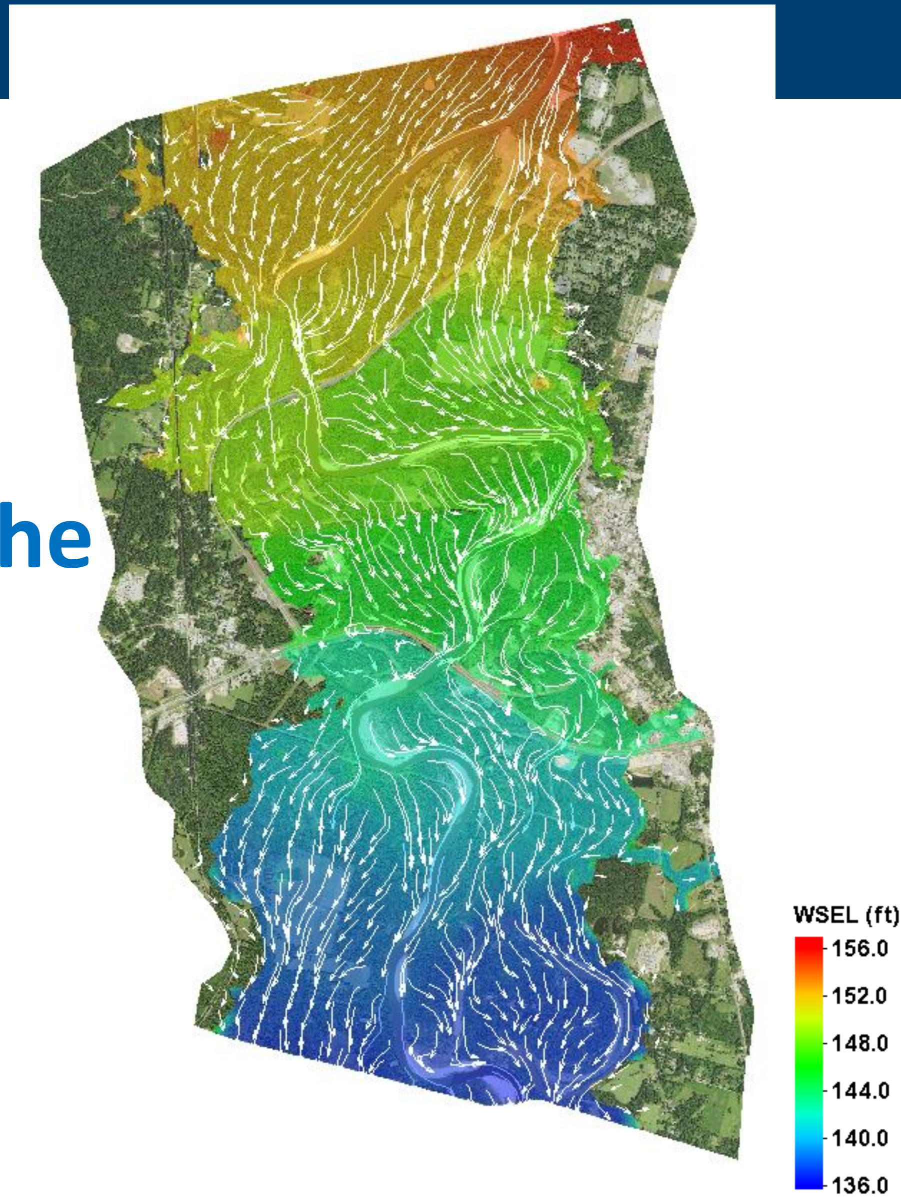


Image Sources: Mississippi State DOT / Earthstar Graphics (Aerial Image)

Tools for C.H.A.N.G.E. Include:

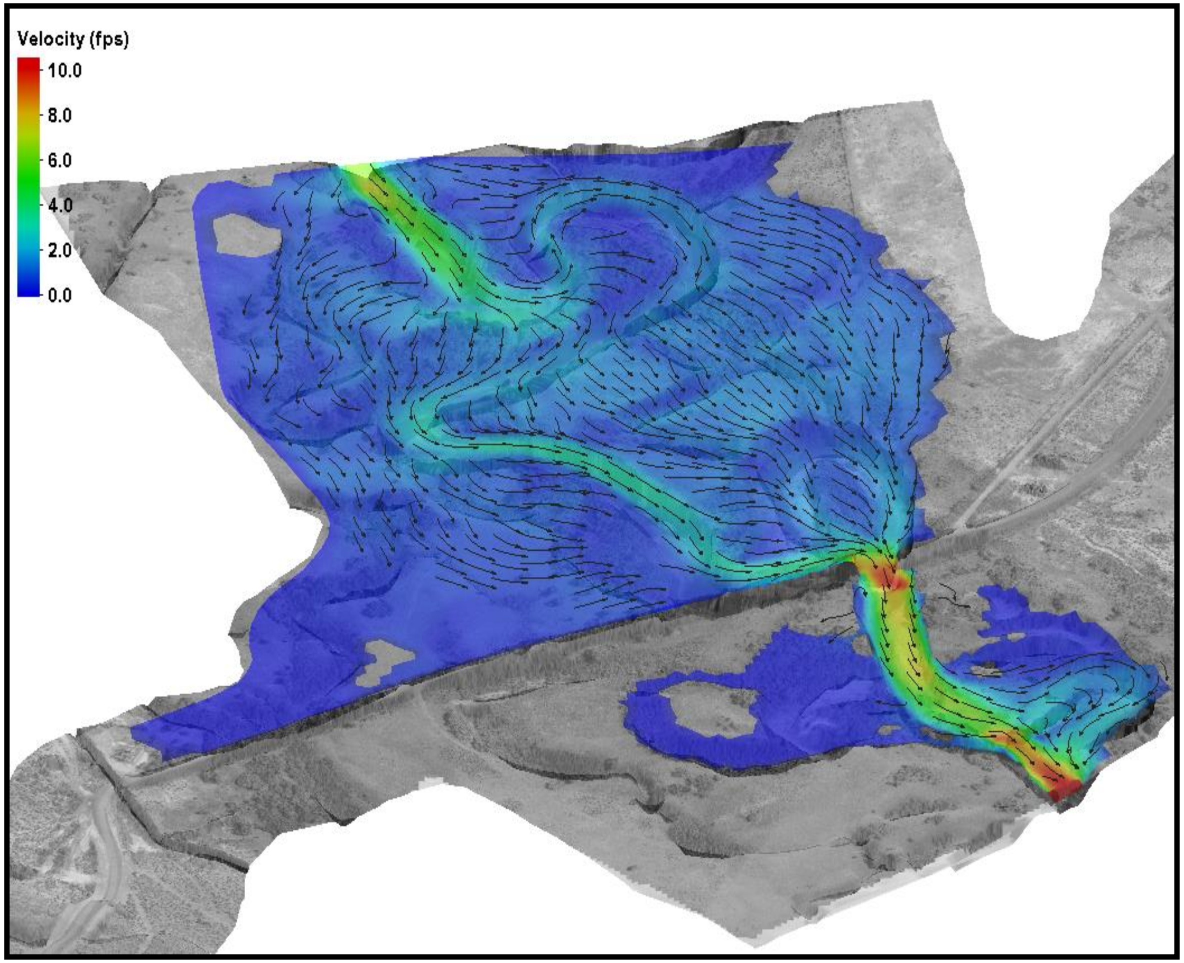


Image Source: Nevada State DOT / Earthstar Graphics (Aerial Image)

- ***Two-dimensional (2D) hydraulic models***
- ***2D & 3D graphical visualization tools to evaluate specific physical, environmental, and habitat characteristics***

A Word on Hydraulic Models

- Hydraulic models (and software) are used to determine flow velocities, elevations, shear stresses and other parameters needed for design.
- Hydraulic model selection is based in large part on the significance of the project, complexity of site conditions, available technology, and knowledge and experience of the project team members (including consultants).
- A wide range of models and tools for hydrologic and hydraulic analysis and design are available to practitioners.

HY-8 and Culvert Nomographs

Photo credit: FHWA

- 2-foot CMP
- Low-volume road
- Rusted invert
- Decision made to replace CMP

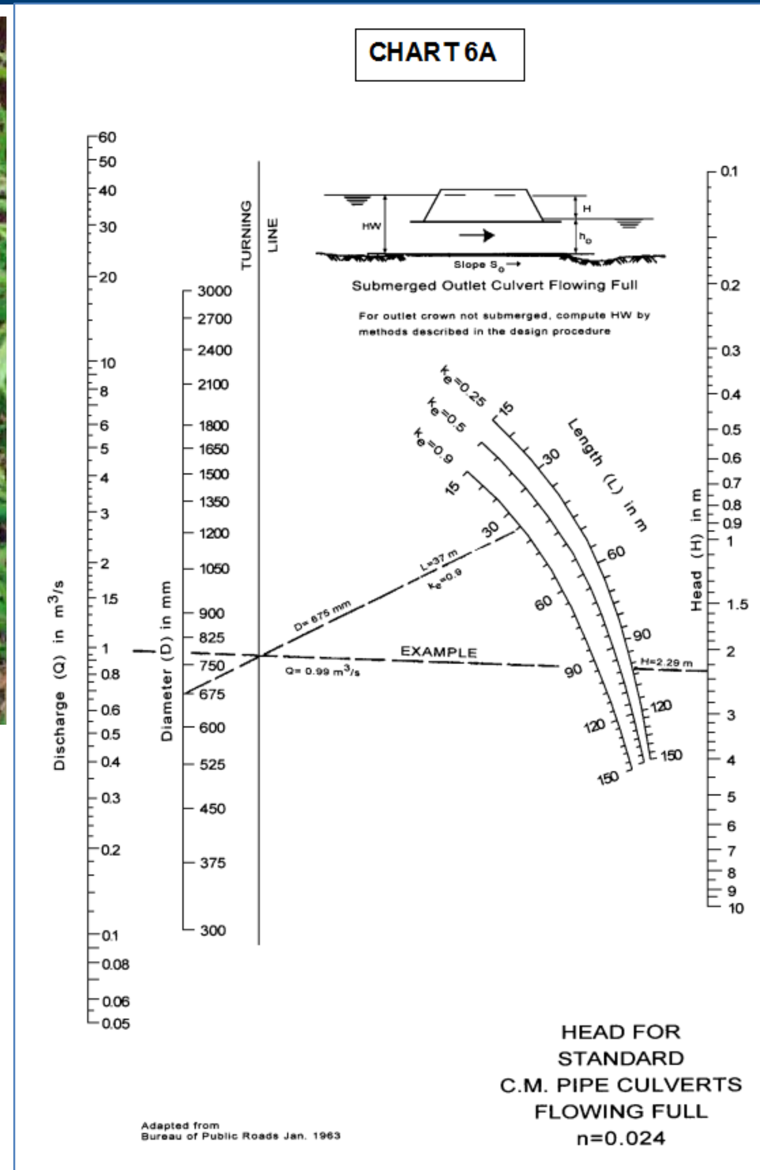
Analyze using:

- HY-8 Culvert Analysis Program
- HDS 5 culvert nomographs

Culvert Nomograph

Example of a culvert nomograph for corrugated metal pipe flowing full

Resource: FHWA HDS 5, Hydraulic Design of Highway Culverts



HY-8 and Culvert Nomographs

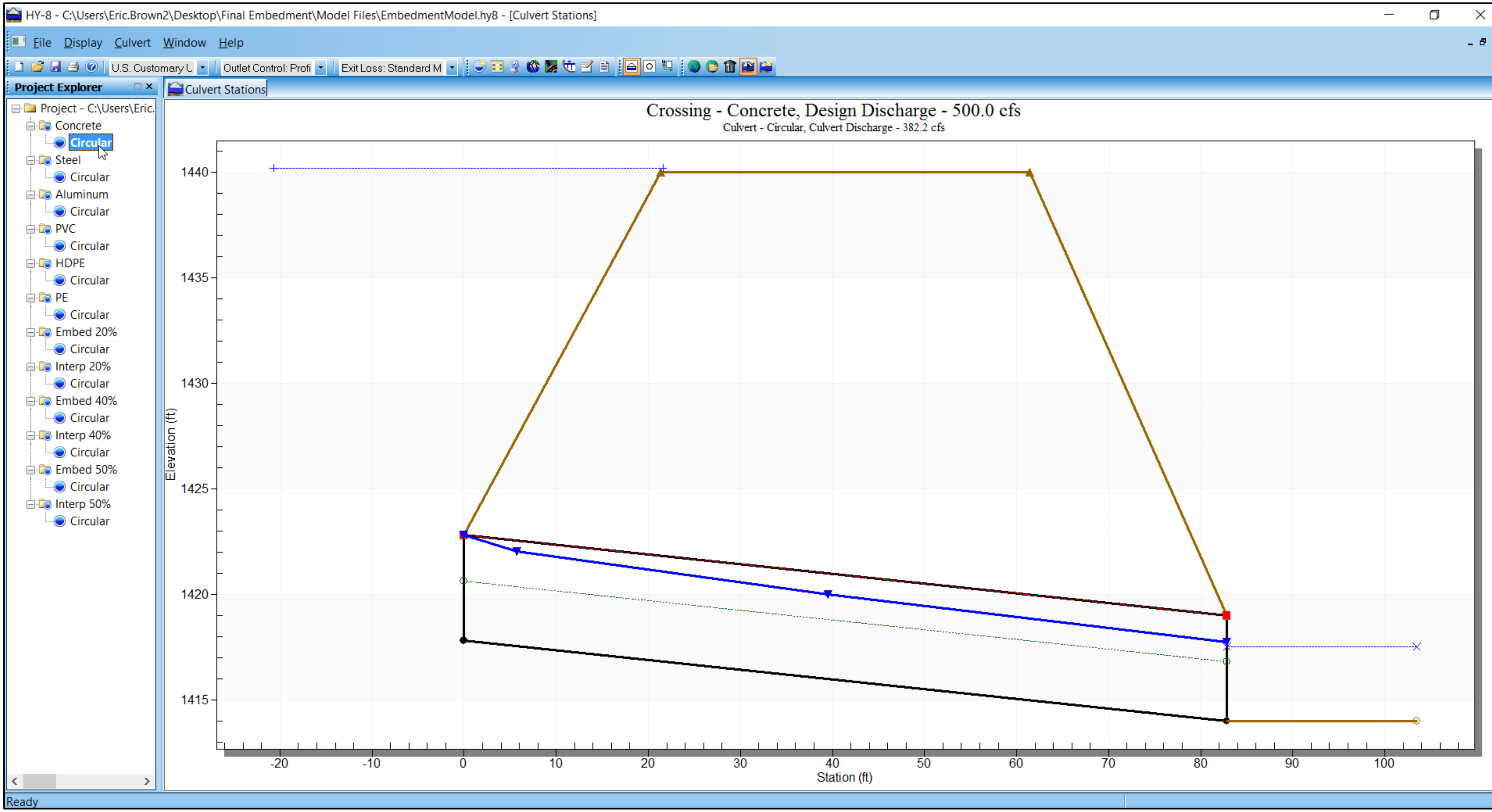
Photo credit: FHWA

- Small reinforced concrete pipe arch culvert
- Same low volume road
- Deteriorated invert
- Decision made to replace culvert

Analyze using:

- HY-8 Culvert Analysis Program
- HDS 5 culvert nomographs

HY-8 Software Screen Capture



HY-8 and Culvert Nomographs

FREE Resources:

- HY-8 Culvert Analysis Program
- HDS 5
- NHI Course 135094, Culvert Hydraulic Analysis and Design Program (HY-8) Web-Based

Hydraulic Toolbox

Photo credit: Colorado DOT

- Ditch sizing for design flood
- Select ditch lining to prevent erosion and improve water quality

Analyze using:

- Hydraulic Toolbox normal depth calculator and channel lining design calculator

Hydraulic Toolbox

Photo credit: Colorado DOT

FREE Resources:

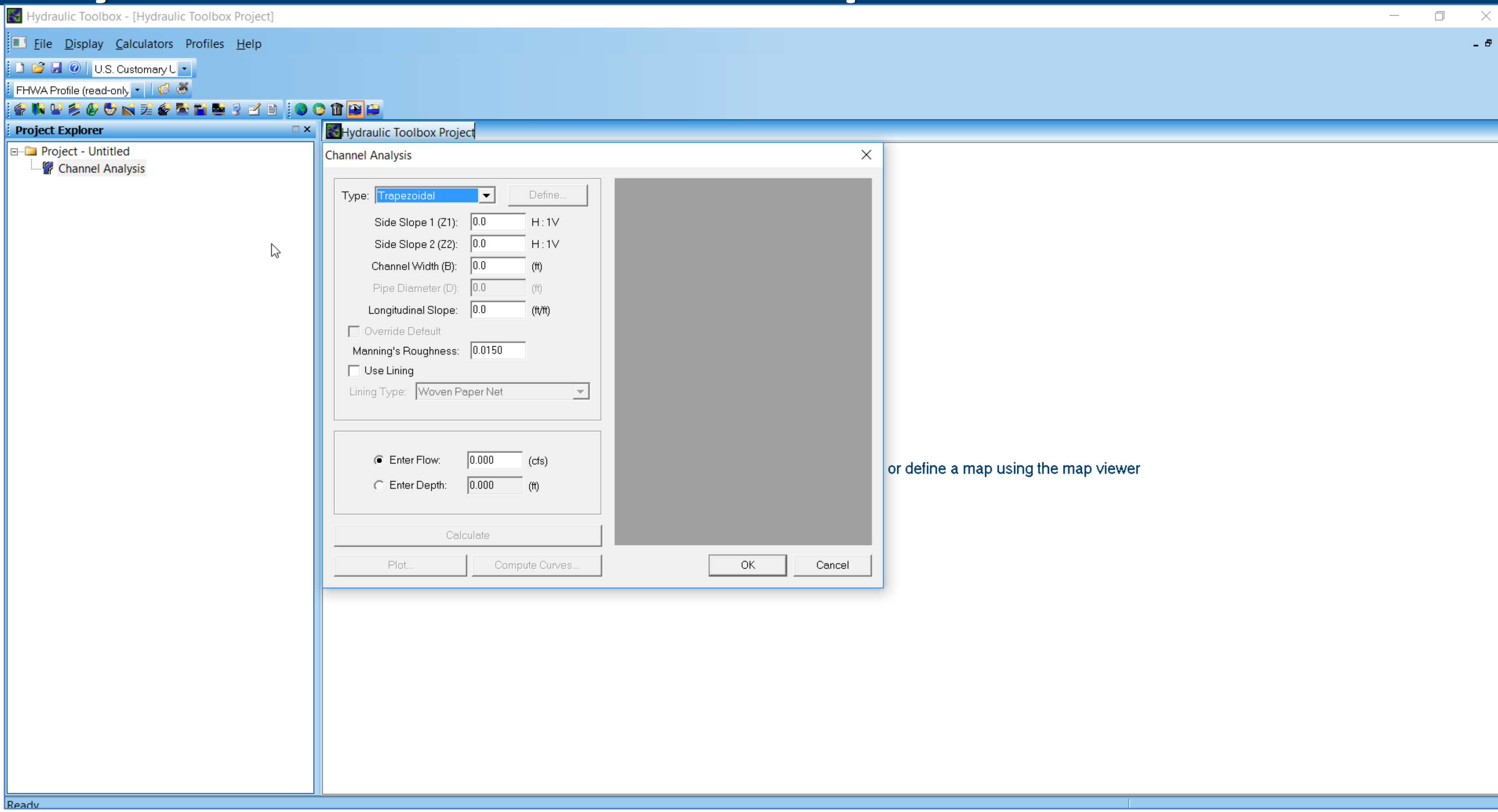
- Hydraulic Toolbox Program
- HDS 4, Introduction to Highway Hydraulics
- NHI Course 135093, Hydraulic Toolbox Web-Based

Hydraulic Toolbox Capabilities

Available Tools:

- Channel analysis
- Channel lining design
- Weir analysis
- Curb and gutter analysis
- Rational method analysis
- Detention basin analysis
- Riprap design
- Gradation analysis
- Median ditch / drop inlet analysis
- Culvert assessment
- Bridge scour analysis
- Horizontal grade inlet analysis

Hydraulic Toolbox Screen Capture



HEC-RAS (US Army Corps of Engineers)

Photo credit: FHWA

Resource: Army Corps website

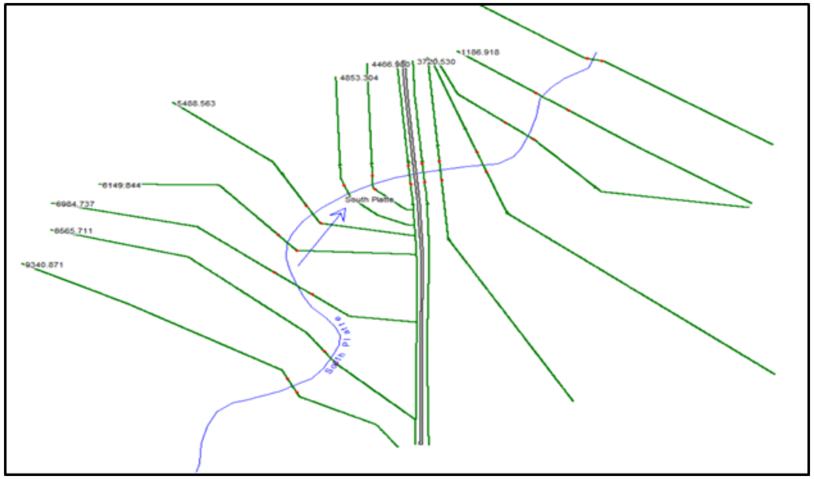
www.hec.usace.army.mil/software/hec-ras/

- Hydraulic design of a large culvert (small-span bridge)
- Flow is directed at culvert opening
- A single channel and simple hydraulics exist

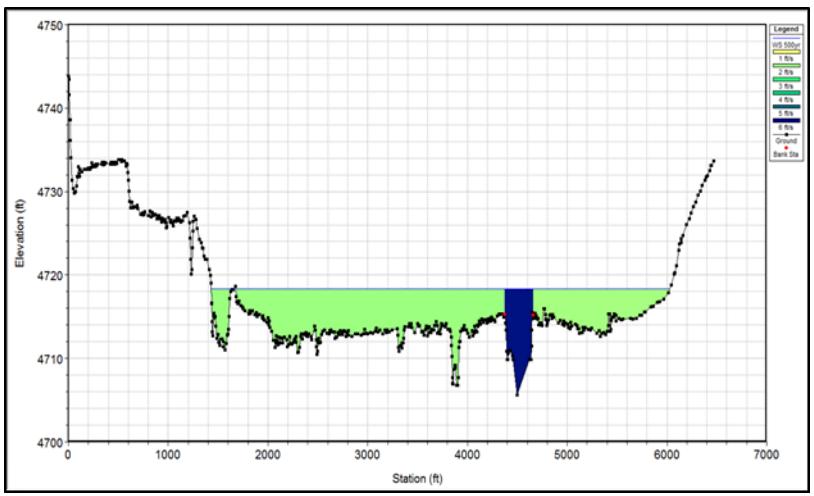
Analyze using:

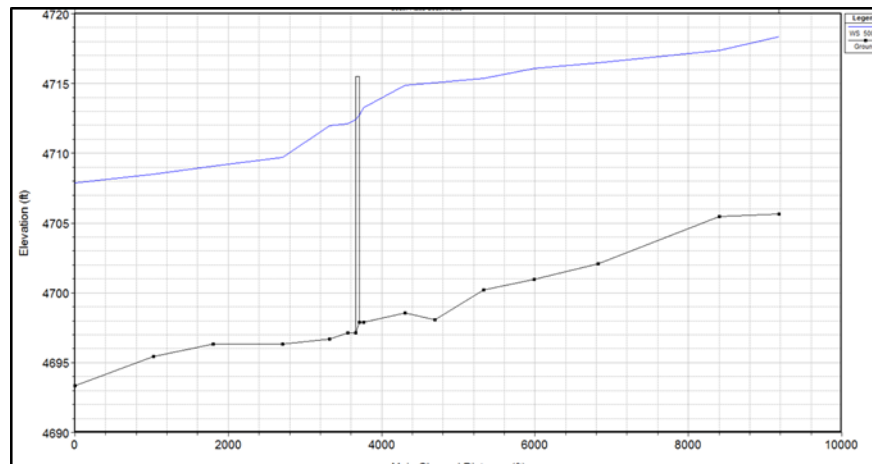
- 1-Dimensional HEC-RAS
- 2-Dimensional SRH-2D

Typical 1D HEC-RAS Modeling Results



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)
9340.871	500yr	53400.00	4705.66	4718.37	4715.94	4718.56	0.001017	5.84
8565.711	500yr	53400.00	4705.46	4717.38	4715.35	4717.66	0.001374	6.62
6984.737	500yr	53400.00	4702.09	4716.47	4711.56	4716.62	0.000349	3.98
6149.844	500yr	53400.00	4700.98	4716.06	4712.32	4716.26	0.000528	5.02
5488.563	500yr	53400.00	4700.22	4715.36	4711.87	4715.78	0.000995	6.70
4853.304	500yr	53400.00	4698.06	4715.04	4711.36	4715.27	0.000526	5.55
4466.980	500yr	53400.00	4698.56	4714.90	4711.11	4715.06	0.000400	4.85
3921.378	500yr	53400.00	4697.90	4713.26	4709.63	4714.51	0.002415	9.88
3816.722		Bridge						
3720.530	500yr	53400.00	4697.15	4712.10	4709.72	4713.79	0.002788	11.28
3477.449	500yr	53400.00	4696.69	4711.99	4709.47	4712.86	0.001728	8.82
2868.990	500yr	53400.00	4696.35	4709.69	4708.57	4711.22	0.003735	11.14
1964.940	500yr	53400.00	4696.34	4709.08	4707.40	4709.25	0.000861	4.70
1186.918	500yr	53400.00	4695.45	4708.49	4705.66	4708.66	0.000719	4.57
159.293	500yr	53400.00	4693.34	4707.88	4704.38	4708.01	0.000536	5.07





FHWA Sponsors 2D Modeling: SMS & SRH2D

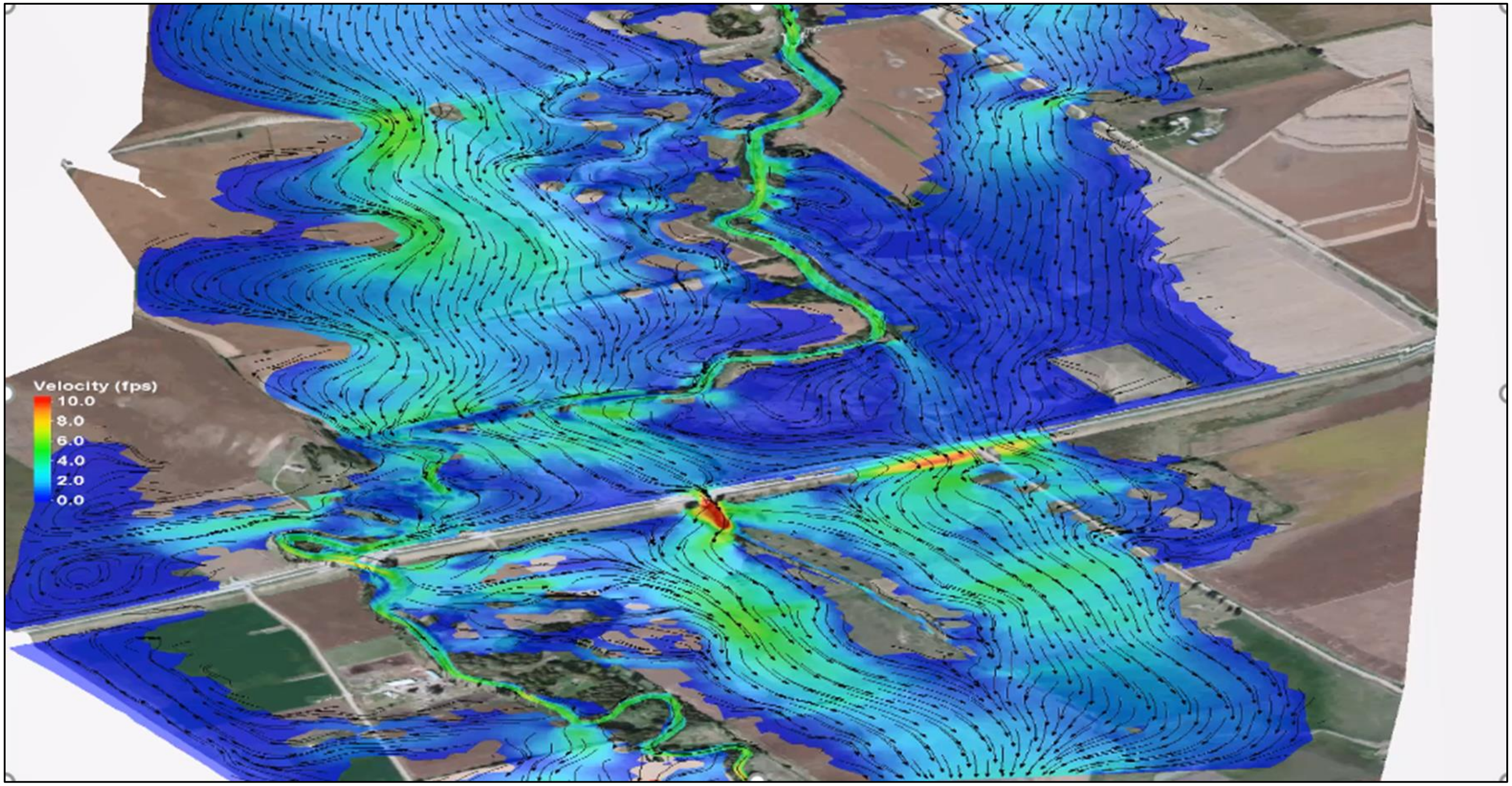


Image credit: Nebraska DOT

- SMS is…the processor that handles the input data and generates the graphics.
- SRH2D is…the code that completes the calculations.

Image Source: FHWA

Max Begins Her Senior Year….

- During her capstone hydraulic engineering course, she learns that student teams will be using 2D modeling to design a project.
- The capstone course relies heavily on:
  - A course curriculum and supporting software and materials provided by the FHWA (available Fall 2019)
  - Project data and support provided by NJDOT staff
- During the course, Max learns a great deal about the theory behind and practical use of 2D modeling.

Typical 2D Modeling Results

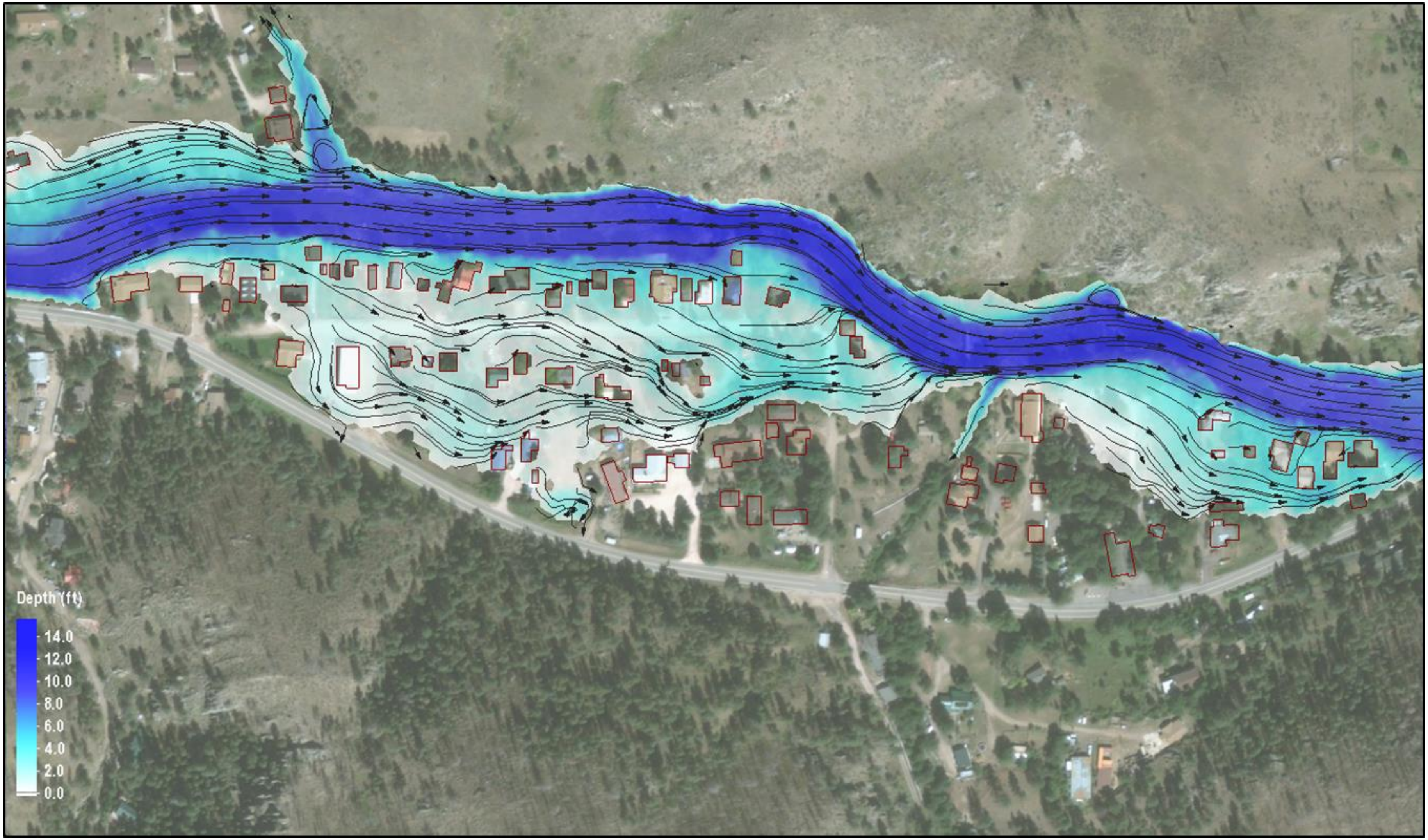


Image credits: FHWA / Earthstar Graphics (Aerial Image)

FHWA Recommends 2D Modeling For:

- Complex situations where water flows in many directions (such as river bends and where tributaries connect)
- Rivers and streams skewed to bridges and culverts
- Stream and river crossings with multiple bridges and/or culverts extending across the channel and floodplain
- Wide floodplains
- Road overtopping
- Tidal conditions

Example 2D Modeling Results

Image credit: Mississippi DOT/Earthstar Graphics

Example 2D Modeling Results

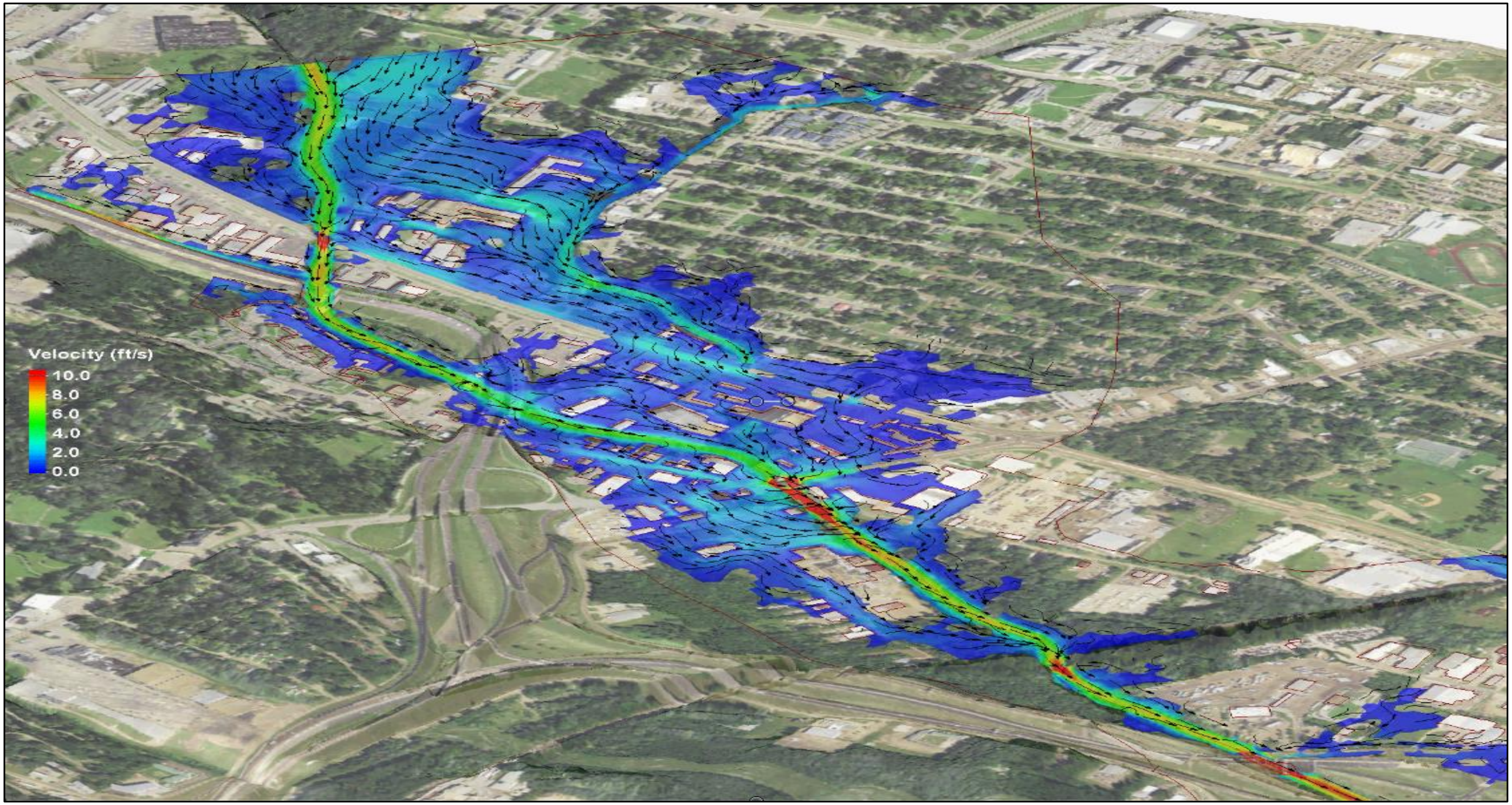


Image credit: Mississippi DOT/Earthstar Graphics

Example 2D Modeling Results

Image credit: Nebraska DOT

Example 2D Modeling Results

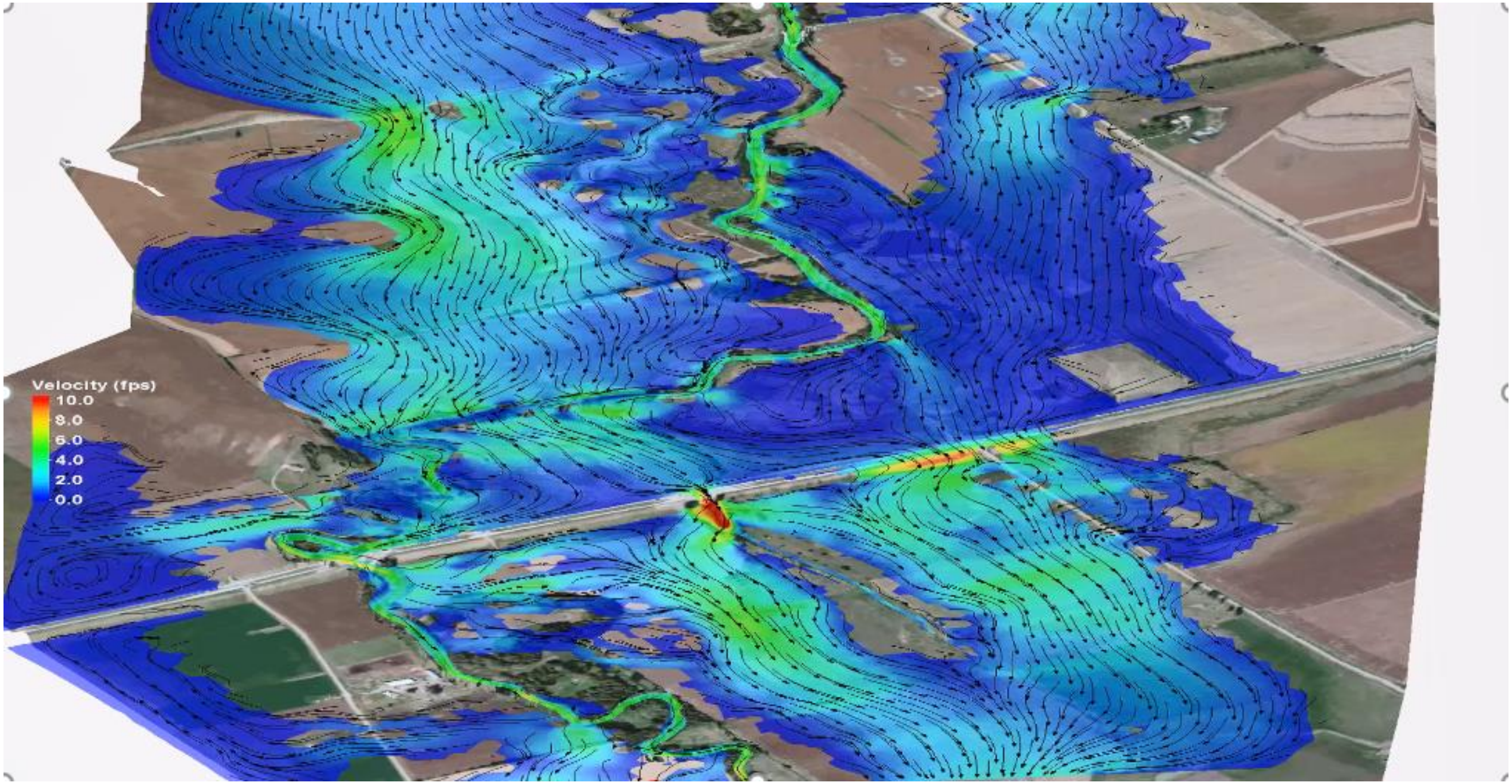


Image credit: Nebraska DOT

Advantages of 2-D Hydraulic Modeling

- Improved design efficiency
- Visual and intuitive display of results
- Enhanced collaboration and communication
- Greater reliability

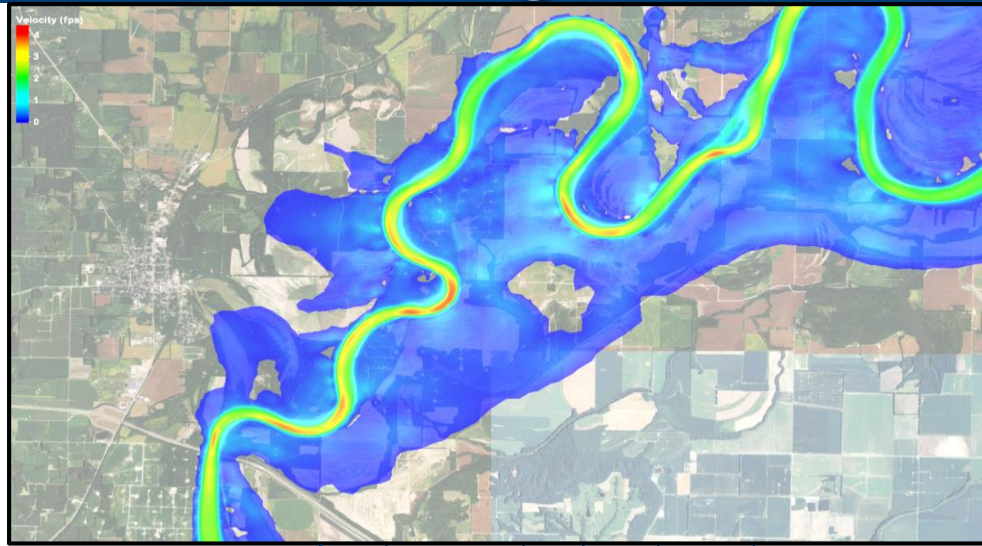


Image Sources: USGS / Earthstar Graphics (Aerial Image)

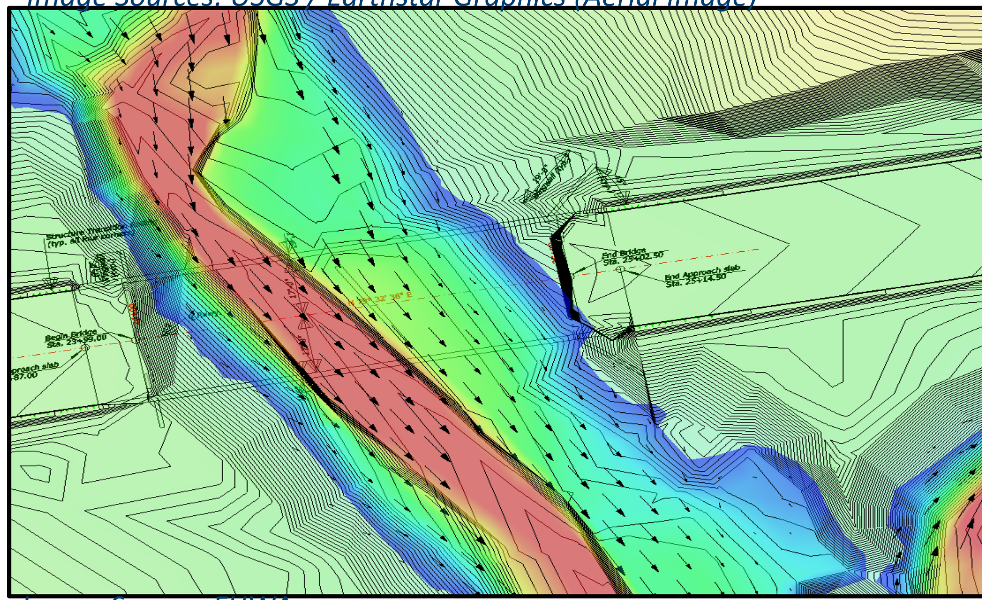


Image Source: FHWA

Example: Death Valley National Park, CA

- Northern Mojave Desert
- Hottest and driest place on earth
- Averages 2.4 inches of annual rainfall
- Unique ecological, archaeological, cultural and geologic attractions

Image credit: National Park Service

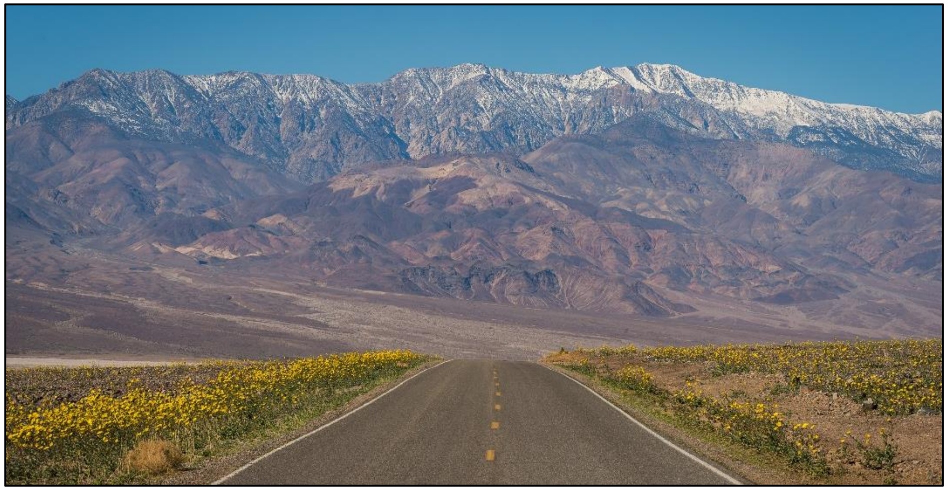


Image credit: National Park Service

October 2015 Flooding

- Flood damage:
  - Historic Buildings
  - Utility lines
  - 8 Miles of Roadway

Image credit: National Park Service

Image credit: National Park Service

Image credit: FHWA

Roadway Damage

Image credit: FHWA

Image credit: FHWA

Image credit: FHWA

Images: FHWA

Cross Discipline Collaboration

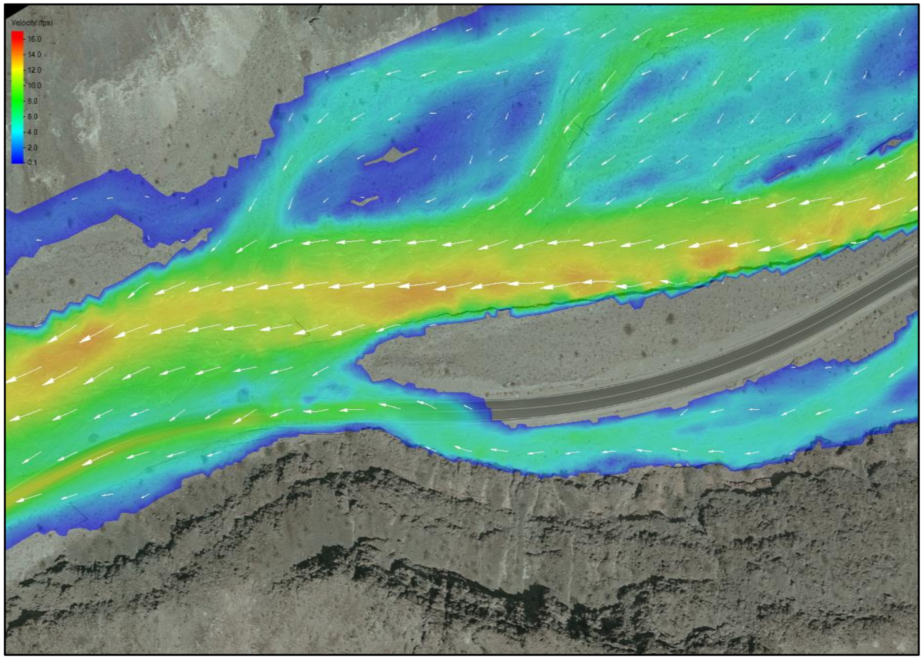
Move Road Out of Floodplain – Proposed Design

Image Credit: Google Earth, 5/2012

Project Partner – Death Valley National Park

2-D graphics helped alleviate the concerns of NPS of subsequent floods threatening staff housing.

Proposed Condition – No spurs



Proposed Condition – With spurs

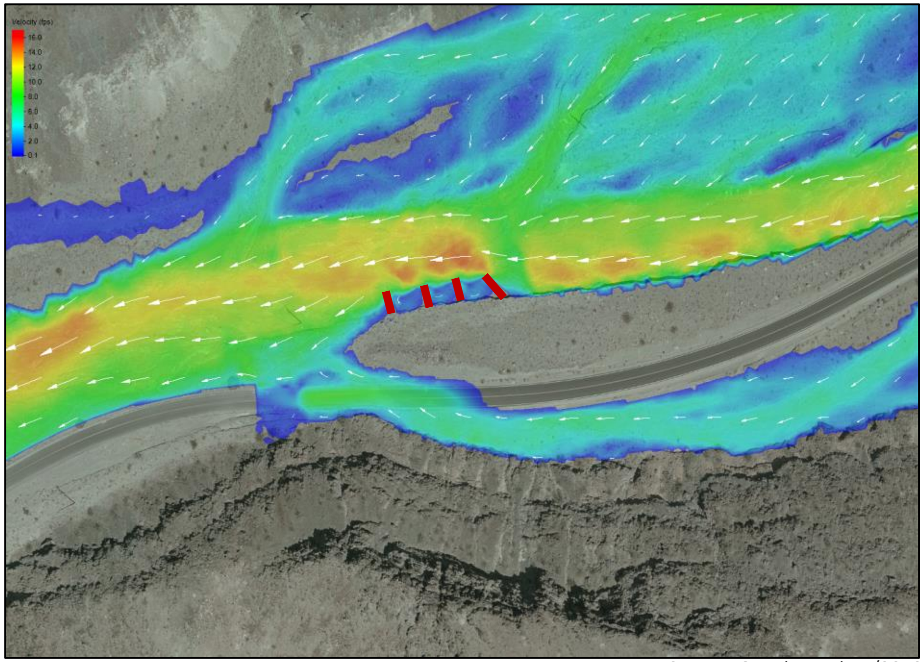


Image Credit: Google Earth, 5/2012

Image Source: Google Earth, 5/2012

Example: Wellington Creek Bridge, ID

- A 2016 flood event undermined the west abutment
- 2-D modeling was used to determine the scour elevations and scour countermeasure designs for the replacement bridge

Image credit: FHWA

Image credit: FHWA

Example: Wellington Creek Bridge, ID

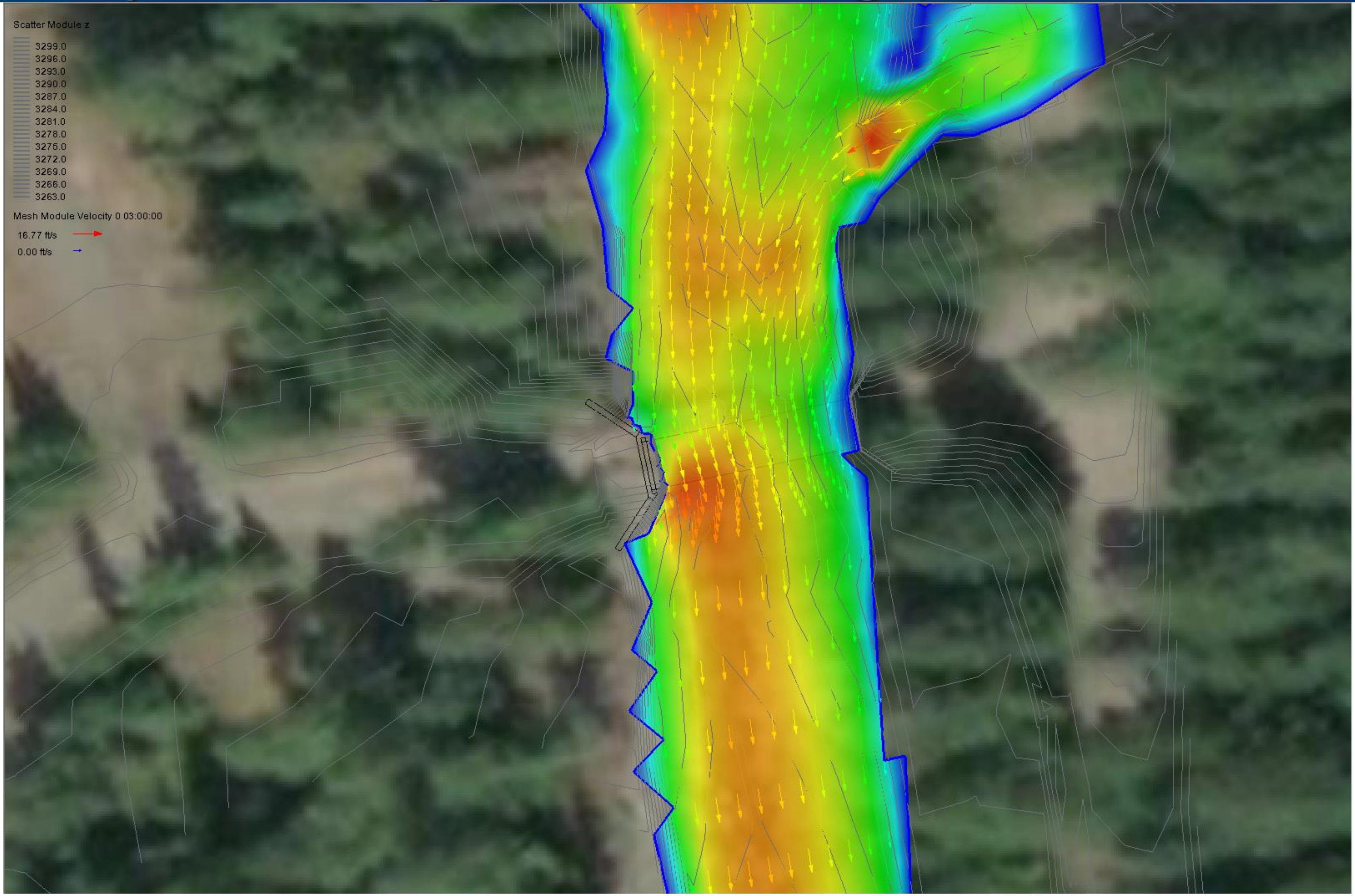


Image credit: FHWA

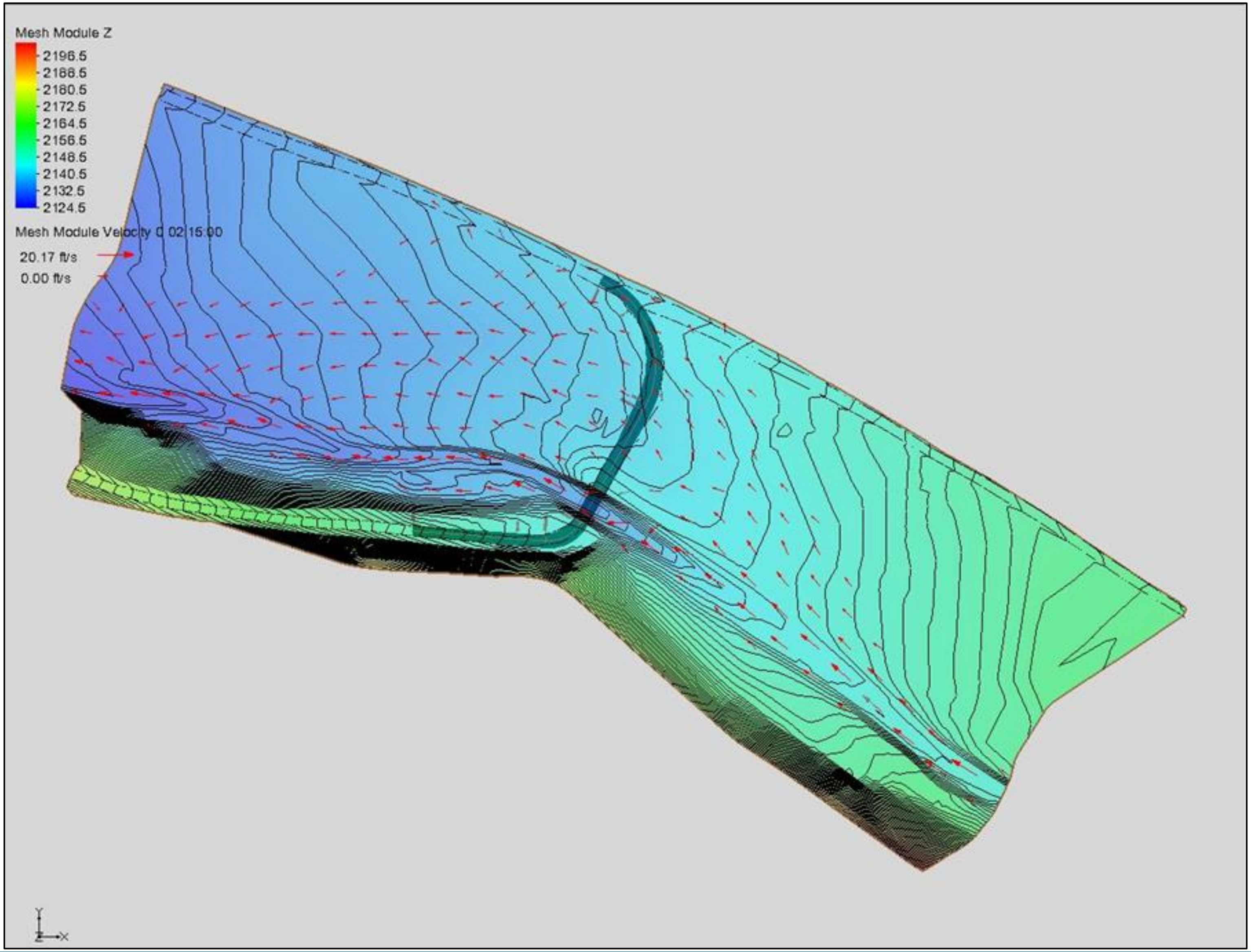
Example: Monongahela National Forest, WV

- A flood event damaged the bridge deck and abutments
- 2-D modeling was used to determine the amount of roadway and bridge overtopping flow to assist designers with the new roadway profile and scour protection

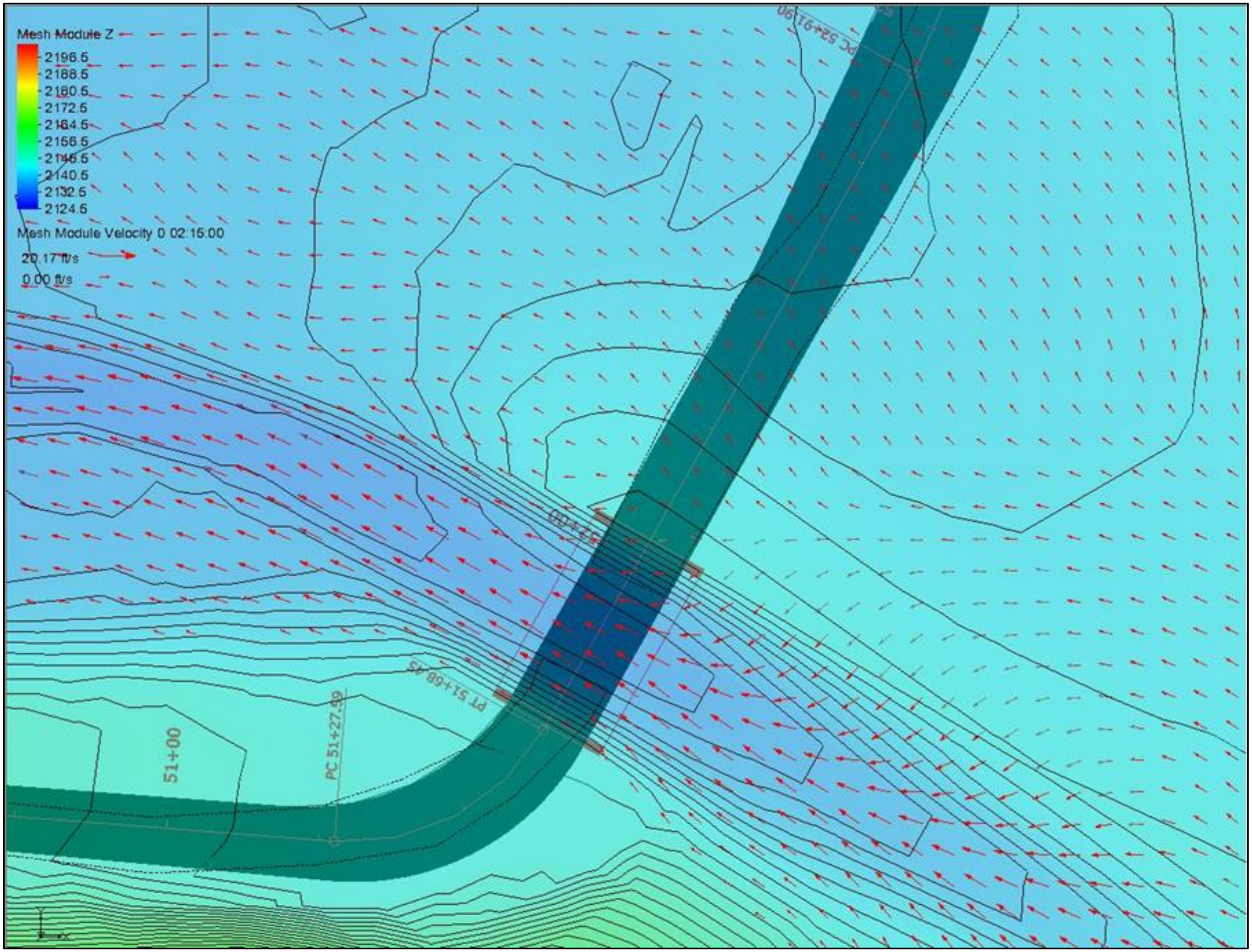
Image credit: FHWA

Image credit: FHWA

Example: Mononganela National Forest, WV



Example: Monongahela National Forest, WV



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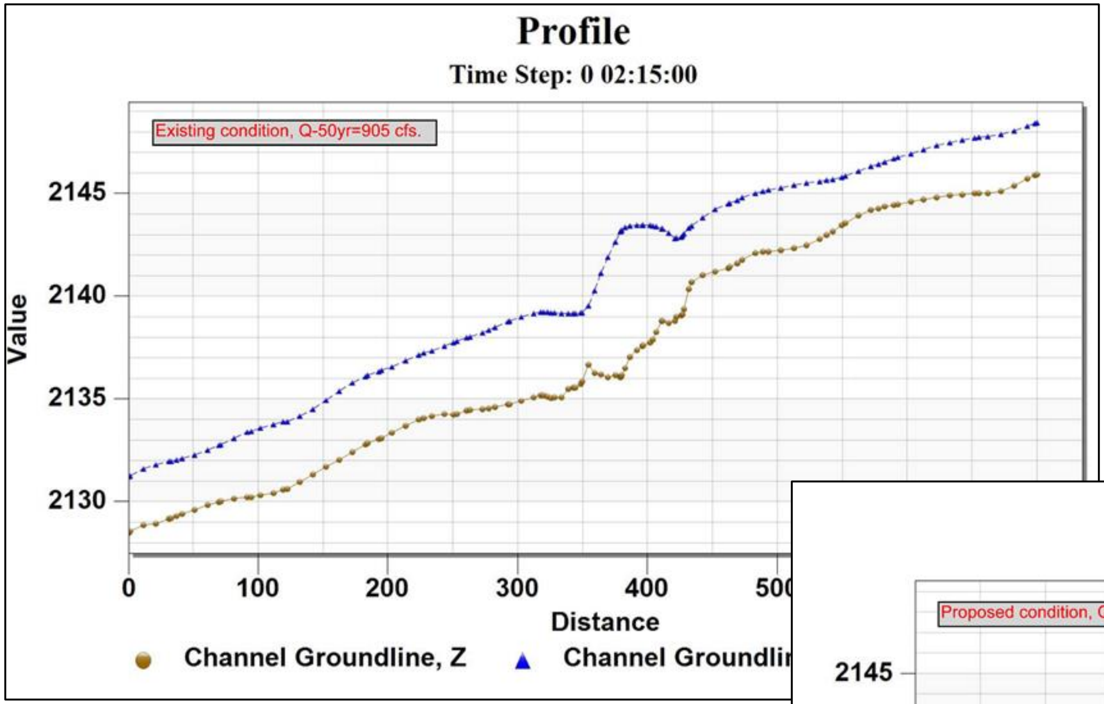

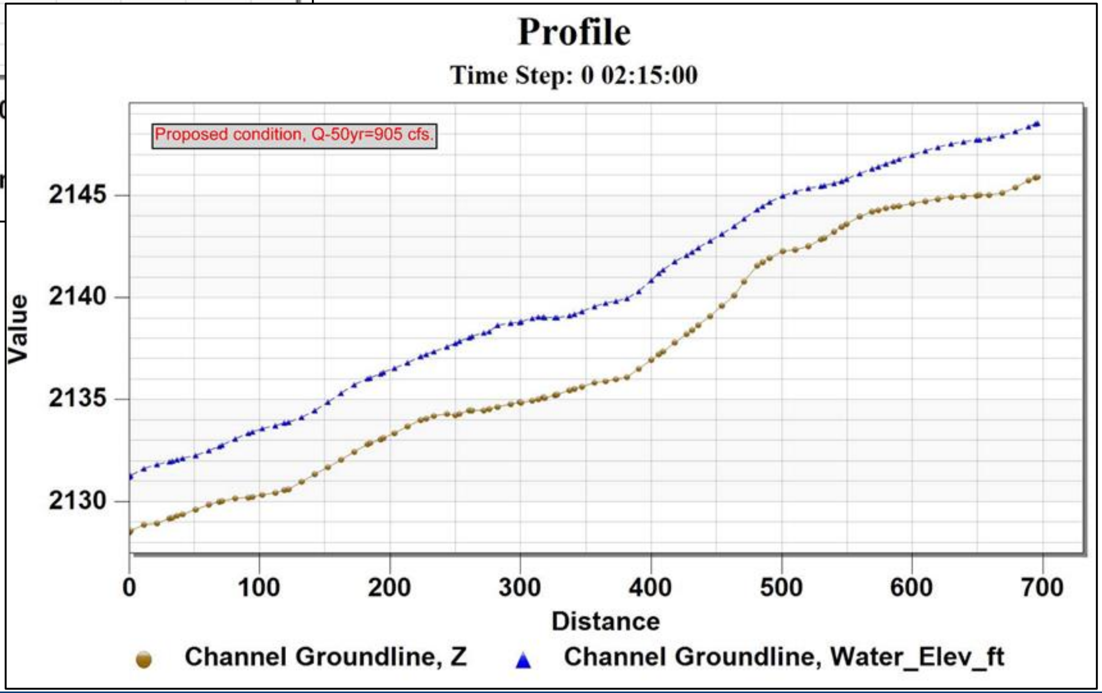

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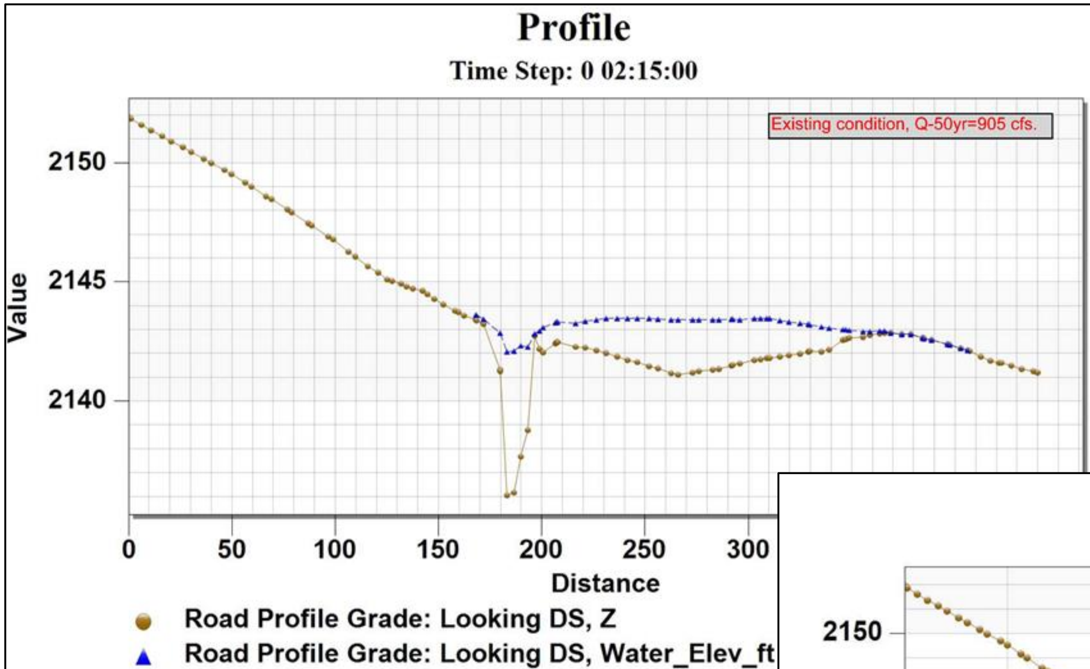

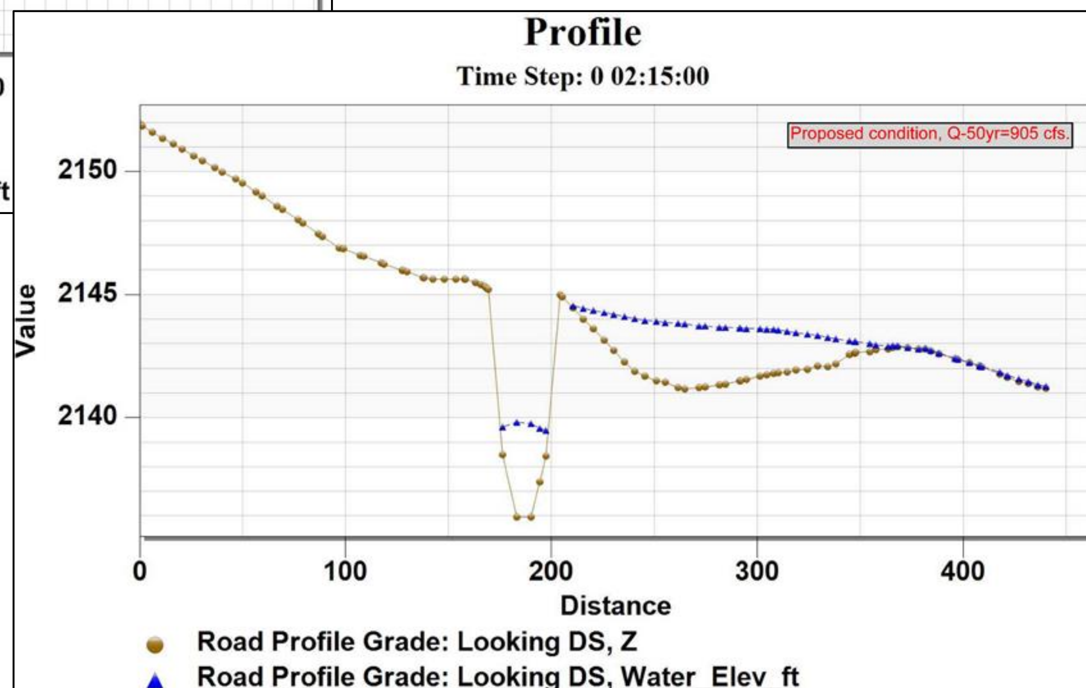

Max Nears Graduation and Interviews with NJDOT….

- She is excited about 2D modeling and is glad to know NJDOT is implementing EDC-5 CHANGE tools and technology.
- Sandy fills her in on all of the FHWA free resources.

Image from Pinterest.com

Free 2D Modeling Resources

- Licenses for SMS software (community version is free for non-DOT users)
- Bimonthly 2D Hydraulic Modeling User's Forum webinars (email: scott.hogan@dot.gov)
- 2D modeling documents:
    - 2D modeling reference guide
    - Sample scope-of-work language for contracts
    - College curriculum
- On-line 2D modeling tutorials
- 2D Modeling YouTube videos (web search "FHWA SRH-2D Videos")

Max Also Learns that Through 2D Modeling….

- NJDOT hopes to attract more talented college graduates to its Hydraulics Program.
- NJDOT hopes to retain staff longer since they are using an innovative technology that is interesting and enjoyable.
- NJDOT staff realize increased project collaboration because 2D modeling results are visual and intuitive.
- NJDOT hydraulics staff feel less isolated and more valued. Staff also realize more collaboration with peer institutions (e.g. neighboring State DOTs).

Websites for More Information

- EDC-5 CHANGE (the 2-D modeling initiative): https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/index.cfm
- FHWA Hydraulic Engineering Resources: https://www.fhwa.dot.gov/engineering/hydraulics/index.cfm
- National Highway Institute Training Courses: https://www.nhi.fhwa.dot.gov/home.aspx

THANK YOU!

QUESTIONS?

FHWA Resource Center

Geotechnical & Hydraulic Engineering Team

https://www.fhwa.dot.gov/resourcecenter/teams/geohydraulics/

Image credit: FHWA

Image credit: FHWA