



Comparing Three 2D Software Packages for Modeling Highway Drainage Structures



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Agenda

- Project Background
- Pilot Study Area – Gunsight Canyon
- When is 2D Modeling Appropriate?
- Modeling Software Overview
- Results and Comparisons
- Recommendations and Guidance

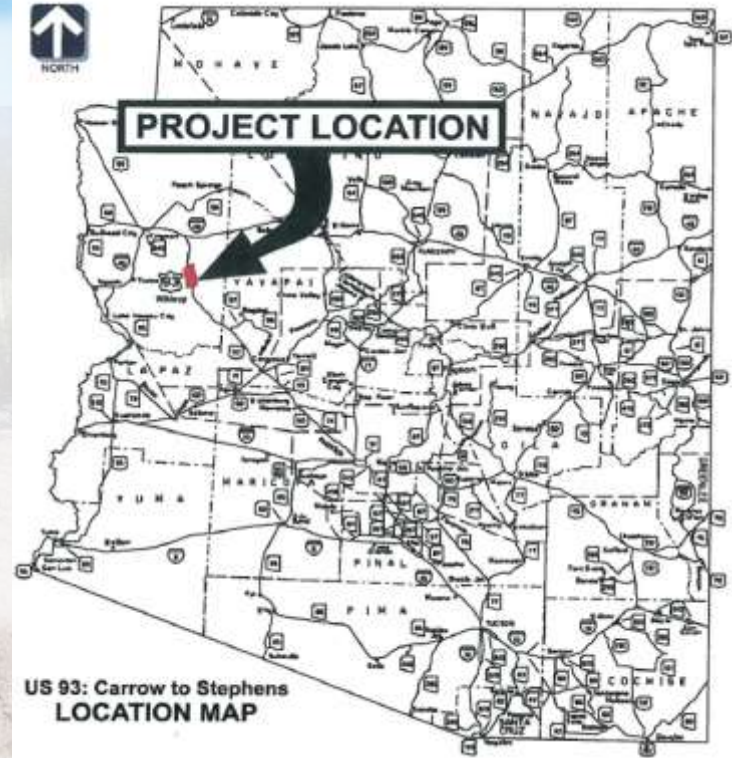
Project Background

EDC-4 CHANGE Program Adoption

- Steven Olmsted, ADOT, Group Manager, Environmental Planning
- ADOT's Rotation Towards Asset Management, Risk Based, \$1B 5-yr Construction Program:
 - Better Adaptation of Technology, Science, & Engineering
 - Aligns with advancements in point cloud and 3D use
 - Adaptation of extreme weather / climate resilience engineering

Pilot Study Area – Gunsight Canyon

- Rural
- Braided Flow Condition
- Design Cross-Culvert

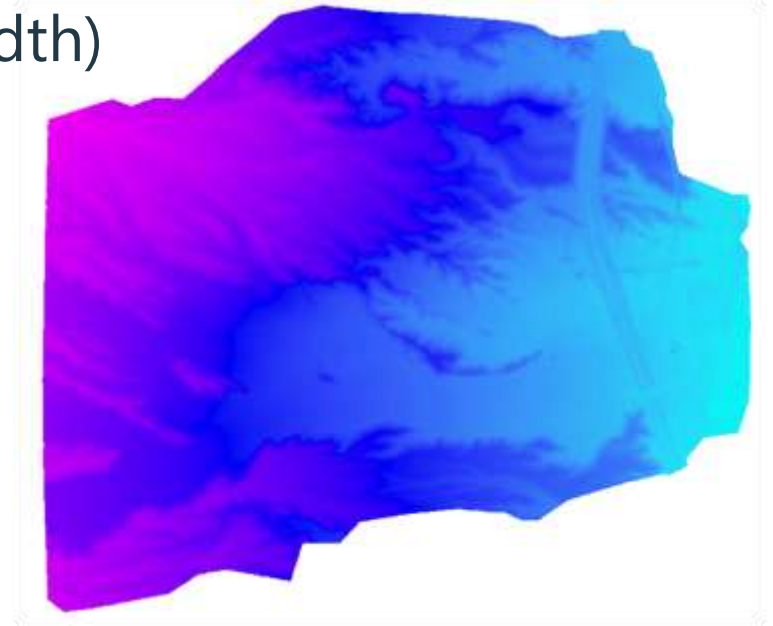


Pilot Study Area – Gunsight Canyon



Pilot Study Area – Gunsight Canyon

- Define Survey Requirements
- ADOT typically provides strip topographic mapping (limited width)
- Mapping
 - USGS Existing Surface Raster
 - Combined Raster with Proposed Roadway



Pilot Study Area – Gunsight Canyon

- Hydrology – HEC-1
 - $Q_{100} = 6,719$ cfs Drainage Area = ~ 11 mi²

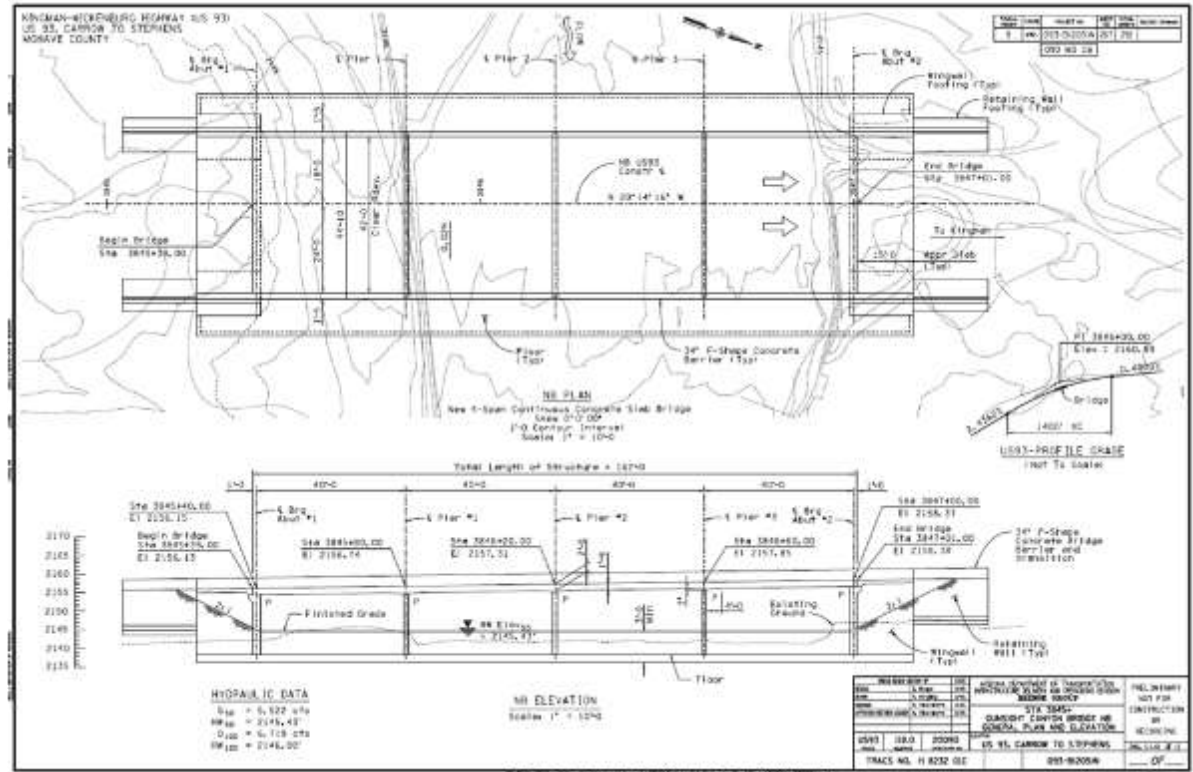


- Bridge Design Plans



Pilot Study Area – Gunsight Canyon

- Bridge Design Plans

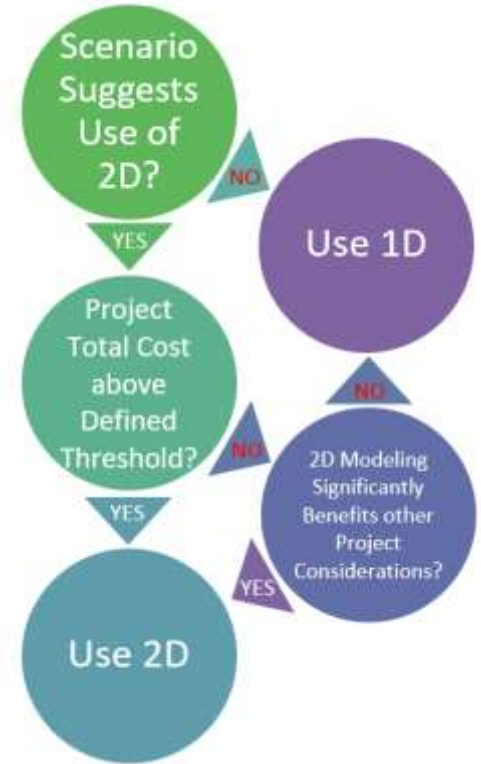


When is 2D Modeling Appropriate?




- 1D Vs. 2D Hydraulic Modeling
 - 1D Cross Sections Vs. 2D Domain
 - 1D modeling generally provides one flow depth and one flow velocity in an assumed direction.
 - 2D modeling allows for prediction of flow depth, direction, and velocity at any given modeling node.

When is 2D Modeling Appropriate?

- Better Data Improves Project Design
- Better Tools for Communicating Results
- Streamlined Delivery – Improved collaboration can reduce environmental and regulatory delays



Modeling Software Overview

Software		Developed/ Supported By	Numerical Method	Cost	Primary GUI
HEC-RAS		USACE	Finite Volume	Free	RASMapper
SRH-2D		Aquaveo FHWA USBR	Finite Volume	\$3,100 (Riverine Pro) Free (Community)	SMS
FLO-2D		FLO-2D Riada	Finite Difference	\$995/year (Pro) Free (Basic)	QGIS GDS

Modeling Software Overview - HEC-RAS

Input

Boundary Conditions

Topographic Mapping

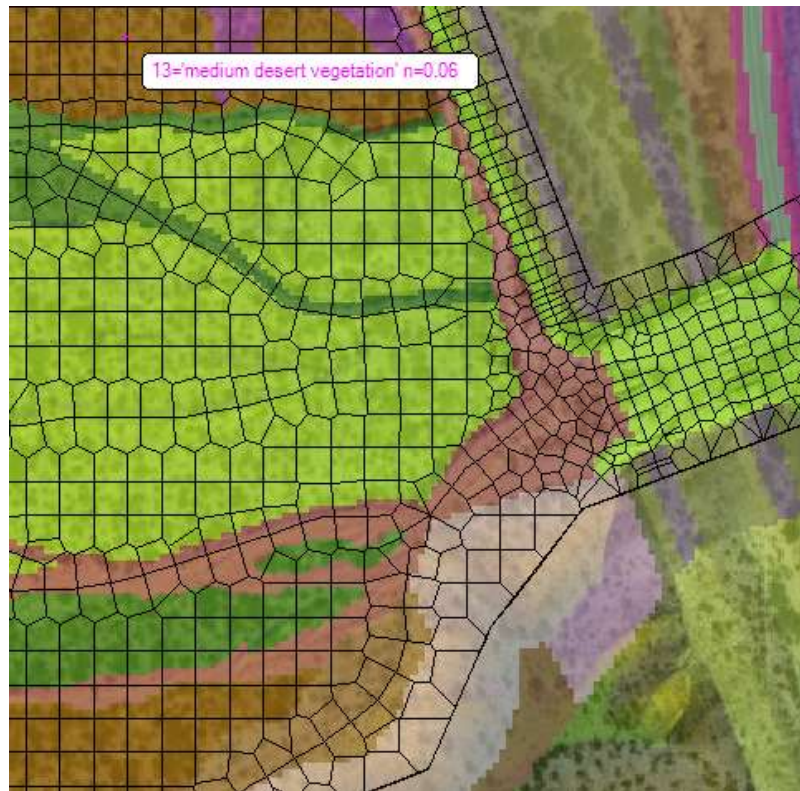
N values

Mesh Network

Bridge Modeling Options

Approximated as Culvert

Modeled in Terrain

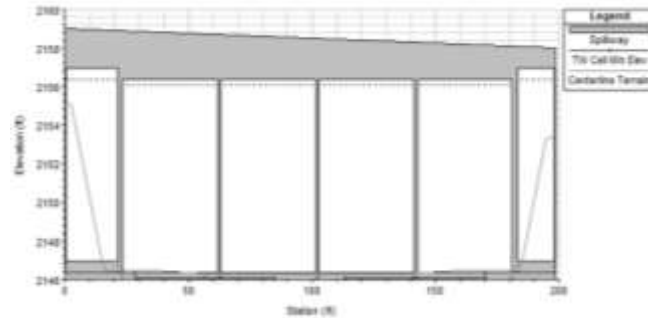


Modeling Software Overview - HEC-RAS

Culvert Method

Considerations

- Simplified Input
- Approximation of Opening
- Pressure Flow ✓
- Flow Direction ✗

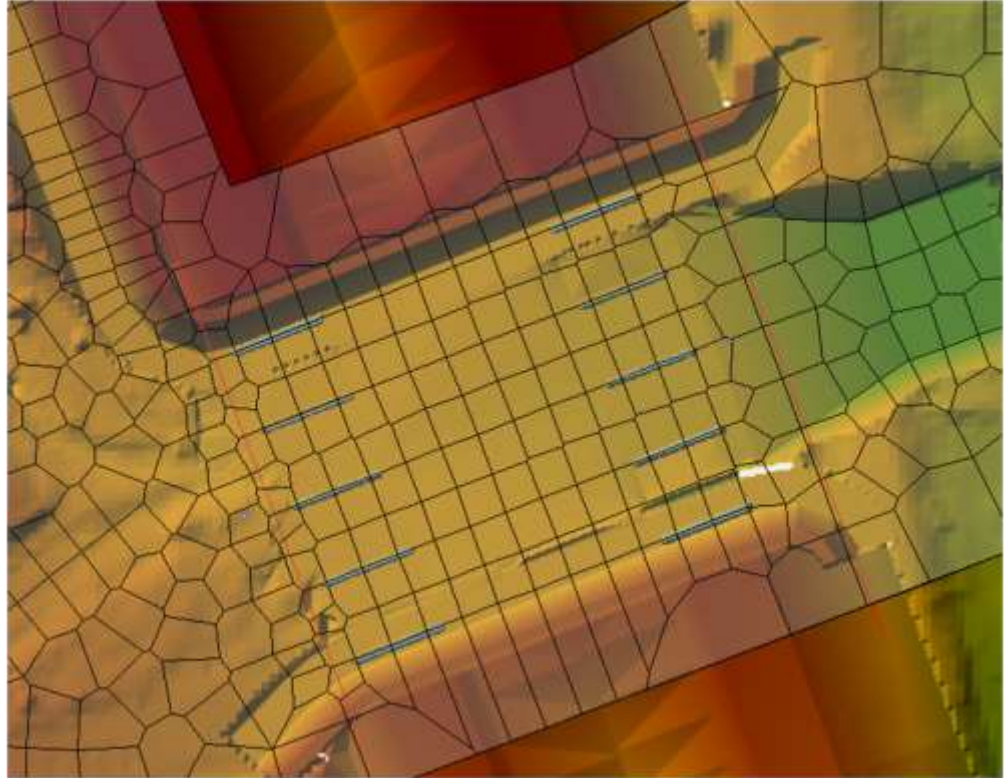


Modeling Software Overview - HEC-RAS

DTM Piers

Considerations:

- DTM Modeling
- Cell Boundary Alignment
- Pressure Flow **X**
- Flow Direction **✓**



Modeling Software Overview – SRH-2D

Input

- Boundary Conditions

- Topographic Mapping

- N values

- Mesh Network

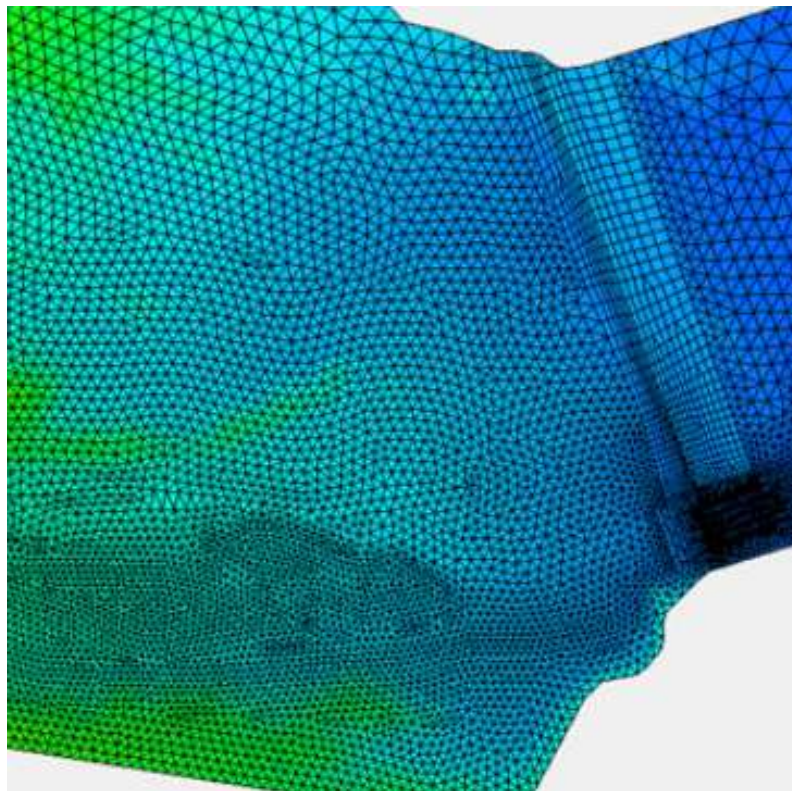
Bridge Modeling Options

- Culvert Equations

- HY-8

- Piers Modeled as Holes in Mesh

- Obstructions



Modeling Software Overview – SRH-2D

Culvert Equations

Considerations

- Simplified Input
- Approximation of Opening
- Pressure Flow ✓
- Flow Direction ✗

The screenshot displays the 'SRH-2D Linear BC' dialog box, which is used for defining boundary conditions for a culvert. The dialog is divided into two main sections: 'Boundary Condition Options' and 'Culvert Options'.

Boundary Condition Options:

- Type: Culvert (selected)
- Culvert Options table:

Object Id	Role
4	culvert upstream
5	culvert downstream

Culvert Options:

- Upstream invert elevation (ZI): 5664.5
- Interior height of barrel (Dc): 6
- Length of barrel (Lc): 85
- Area of barrel (Ac): 48
- Hydraulic radius of barrel (Rh): 1.714
- Slope of barrel (Sp): 0.0176

Units: ft

Number of identical barrels: 5

Entrance type (m_in): non-mitered

Culvert inlet coefficients (Xp, M, cp, Y): Concrete - Rectangular - Headwall; 3/4 in chamfers

Entrance loss coeff K_{et}: 0.5

Manning roughness coefficient in barrel (Nc): 0.012

Use total head (velocity and water surface): ☐ Total head

Crest elevation: 5672

Length of Weir over Culvert: 40

Type: paved

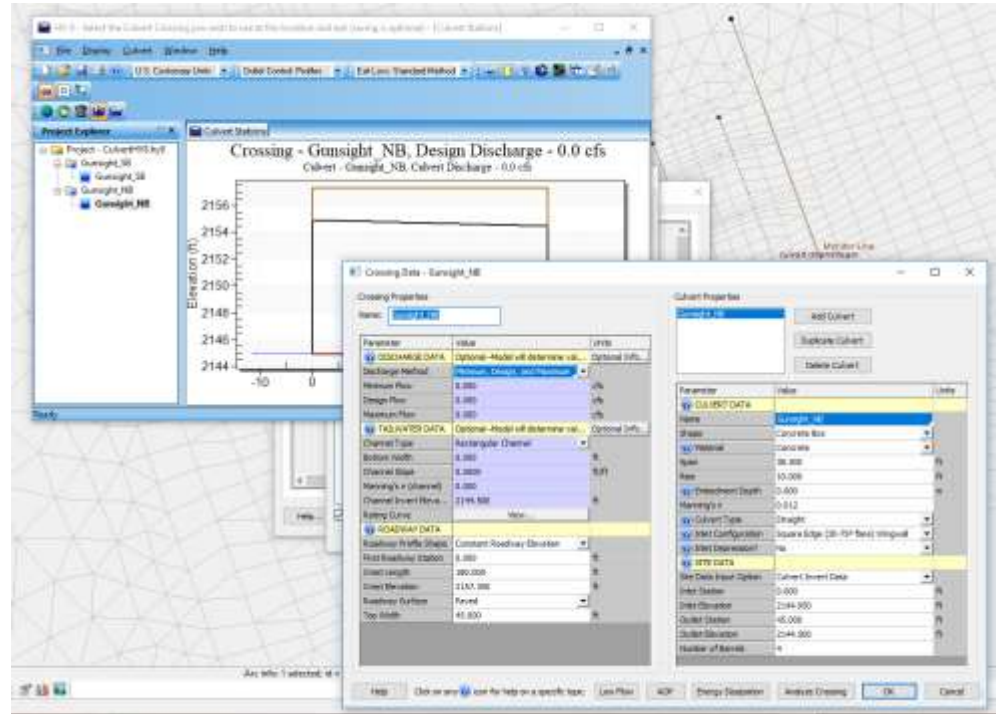
Buttons: Help..., OK

Modeling Software Overview – SRH-2D

Culvert Method using HY-8

Considerations

- Simplified Input
- Approximation of Opening
- Zero Velocity at Inlet
- Pressure Flow ✓
- Flow Direction ✗

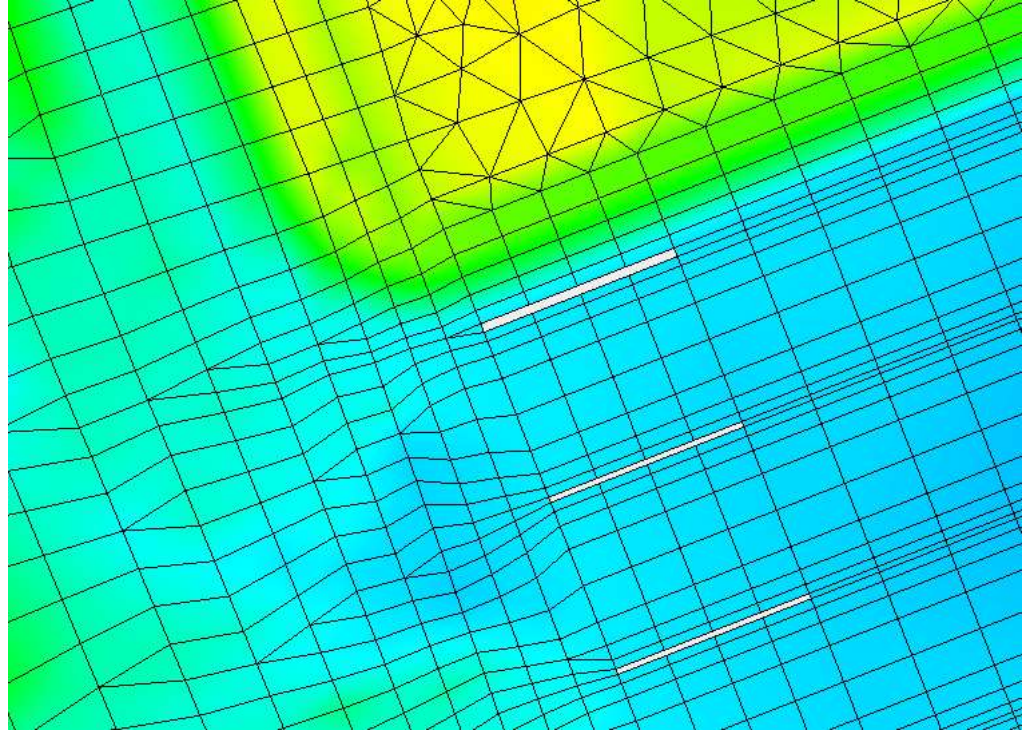


Modeling Software Overview – SRH-2D

Holes in Mesh

Considerations

- Mesh Modification
- Vertical Walls at Boundary
- Most Accurate
- Pressure Flow ✓
- Flow Direction ✓

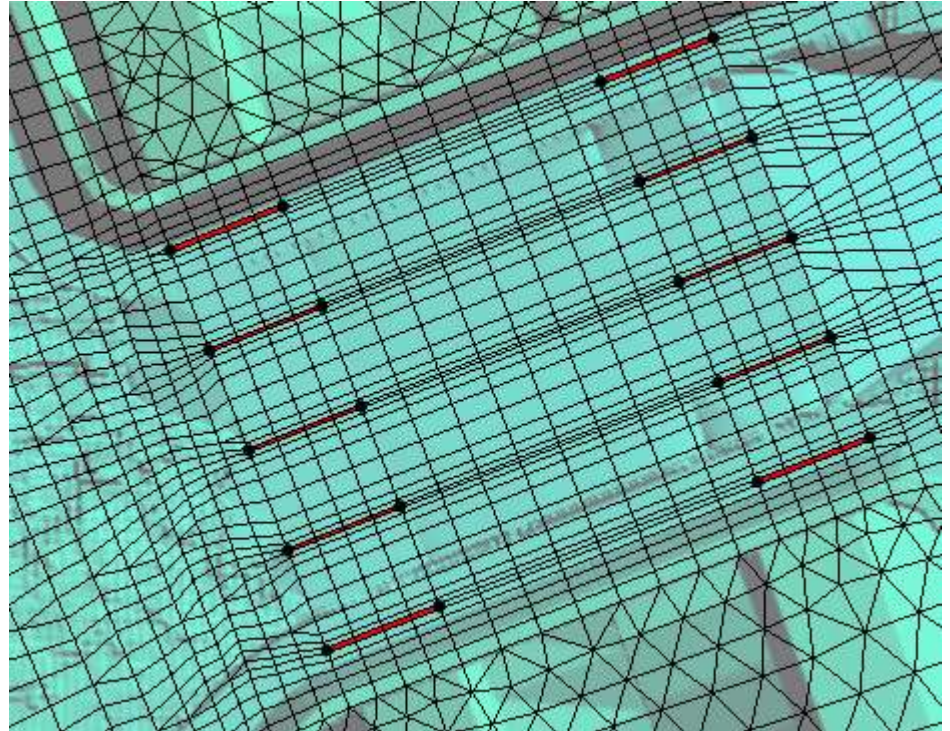


Modeling Software Overview – SRH-2D

Obstructions

Considerations

- No Mesh Modification
- Simplified Head Loss
- Pressure Flow ✓
- Flow Direction ✓



Modeling Software Overview – FLO-2D

Input

Boundary Conditions

Topographic Mapping

N values

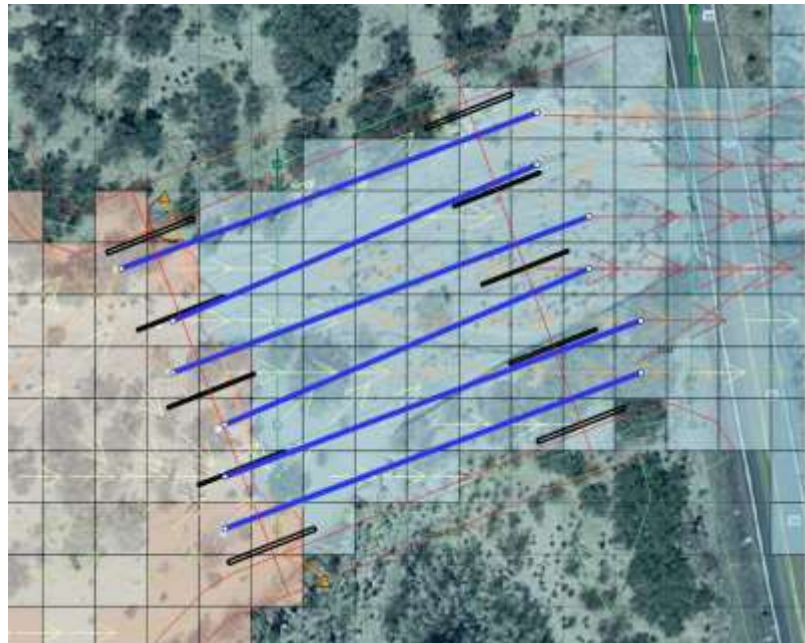
Grid Element Size

Bridge Modeling Options

Culvert Equations

Structure Rating Table

Open Channel / Grid Only

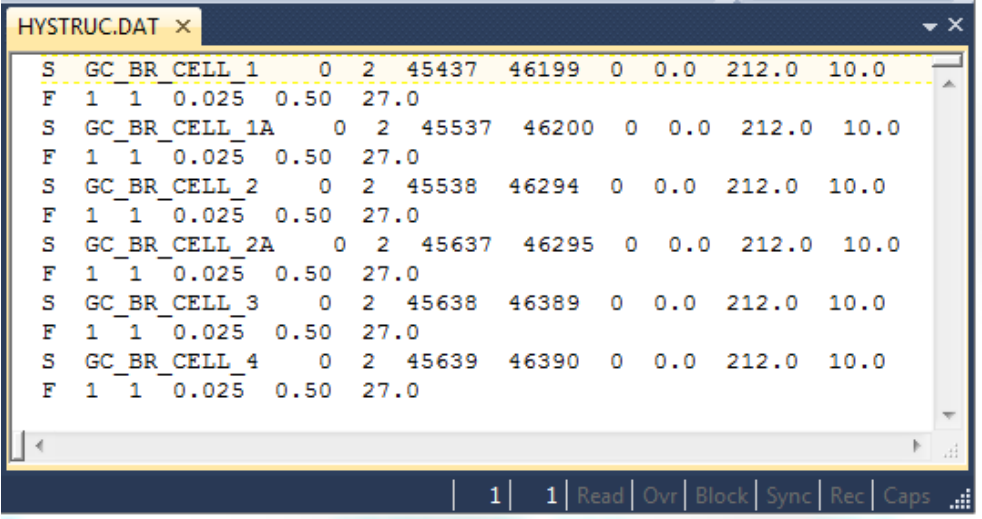


Modeling Software Overview – FLO-2D

Culvert Equations

Considerations

- Simplified Input
- Approximation of Opening
- Pressure Flow ✓
- Flow Direction ✗



The screenshot shows a text-based data file named HYSTRUC.DAT. It contains a series of lines for four culvert cells, each with a start (S) and finish (F) record. The data is as follows:

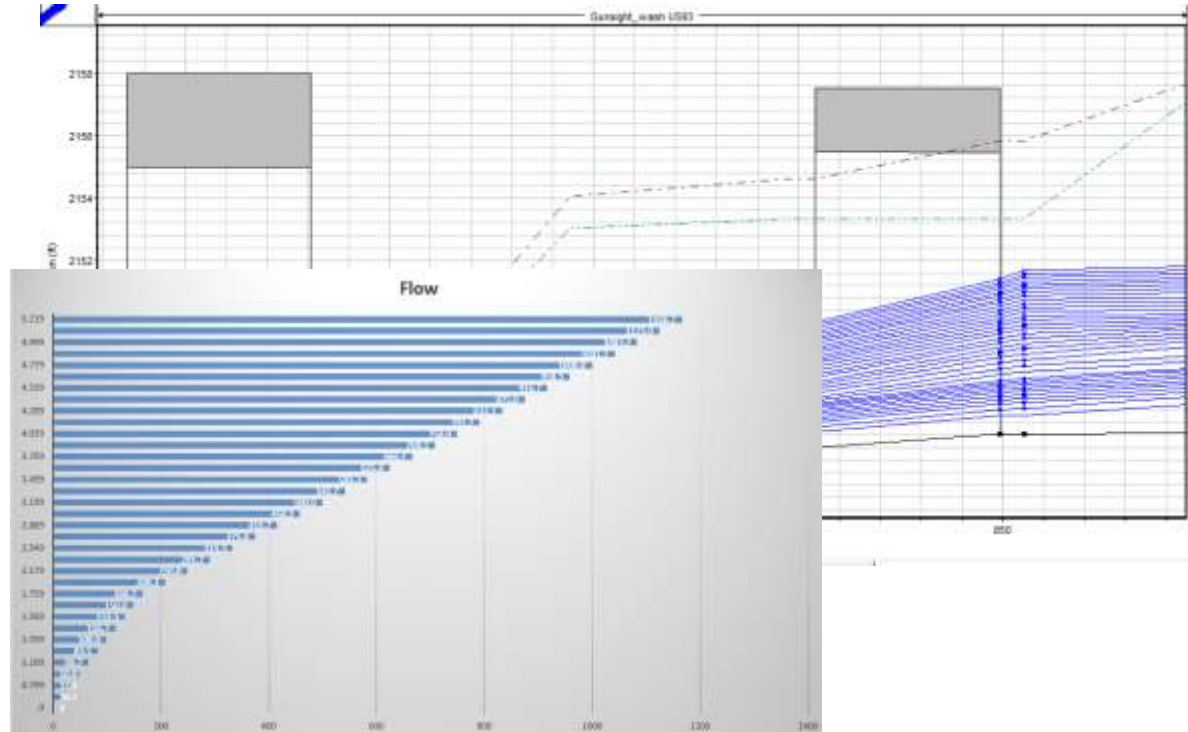
Record Type	Cell ID	Flow Type	Length	Width	Depth	Area	Perim	Wet Area	Wet Perim	Top Width	Bottom Width
S	GC_BR_CELL_1		0	2	45437	46199	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						
S	GC_BR_CELL_1A		0	2	45537	46200	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						
S	GC_BR_CELL_2		0	2	45538	46294	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						
S	GC_BR_CELL_2A		0	2	45637	46295	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						
S	GC_BR_CELL_3		0	2	45638	46389	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						
S	GC_BR_CELL_4		0	2	45639	46390	0	0.0	212.0	10.0	
F	1	1	0.025	0.50	27.0						

Modeling Software Overview – FLO-2D

Structure Rating Table

Considerations

- Simplified Input
- Rating Development
- Pressure Flow ✓
- Flow Direction ✗

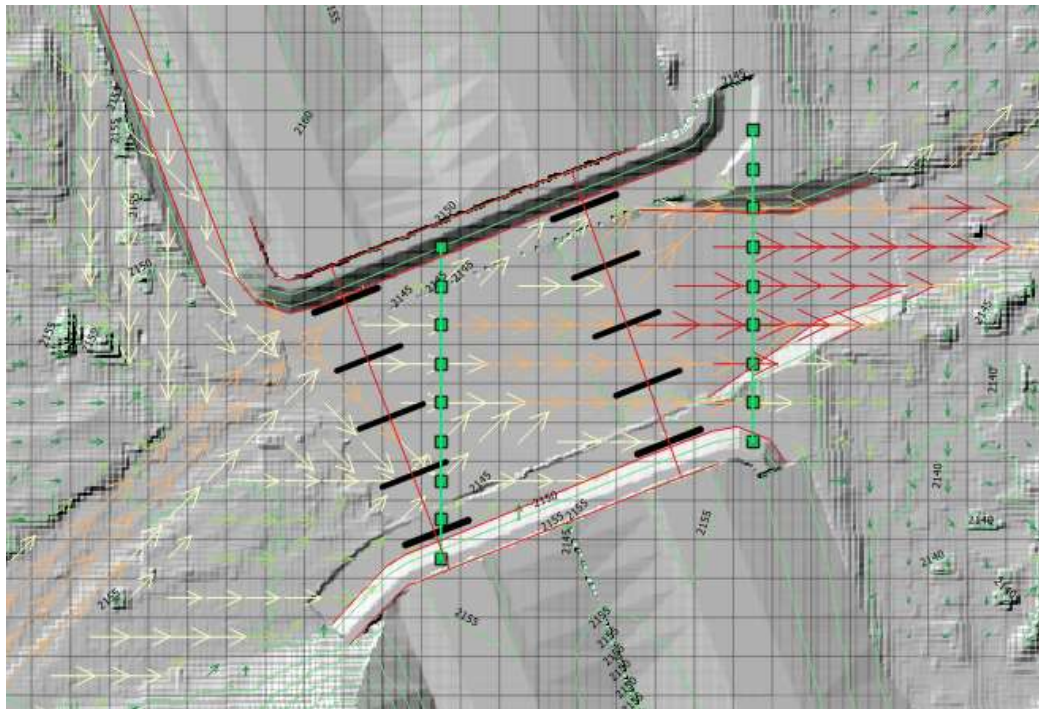


Modeling Software Overview – FLO-2D

Open Channel / Grid Only

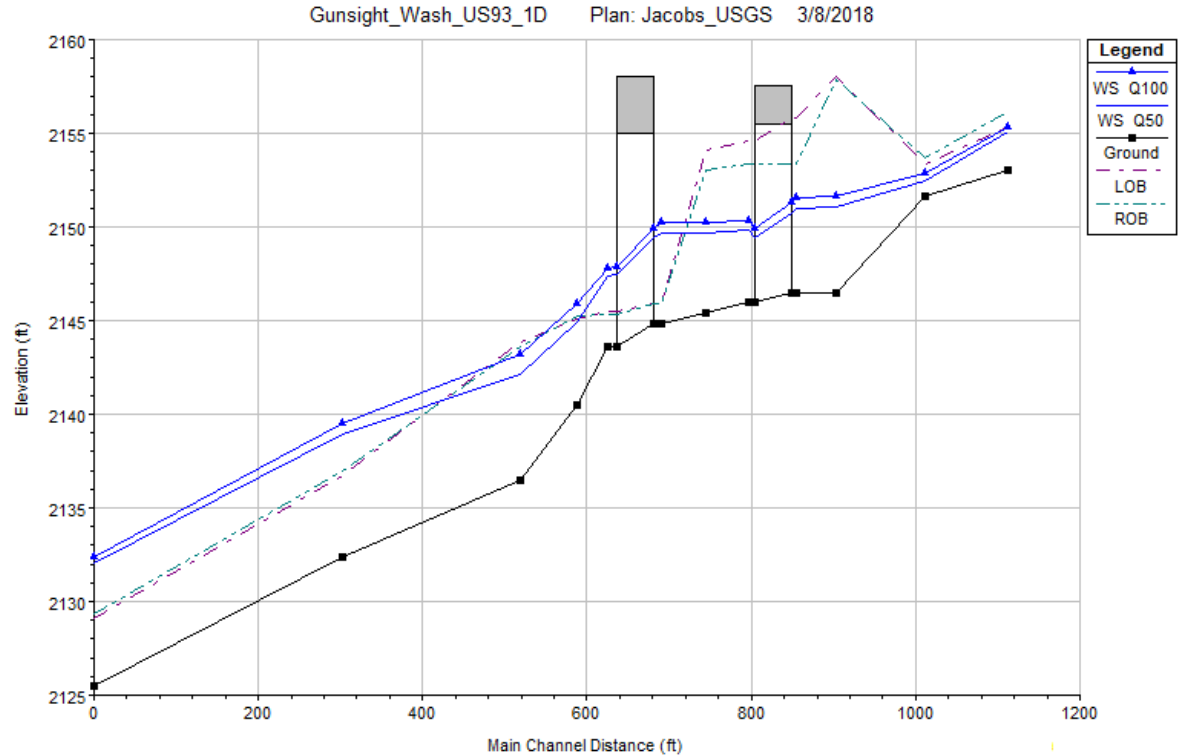
Considerations

- Simplified Input
- Area Reduction Factor
- Pressure Flow **X**
- Flow Direction **✓**



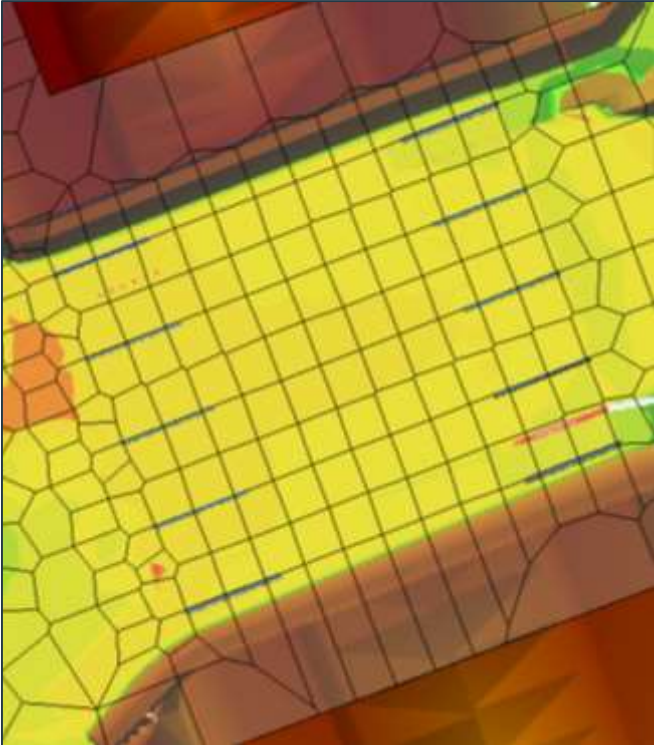
Results - HEC-RAS 1D

- Upstream WSEL
- Max Velocity

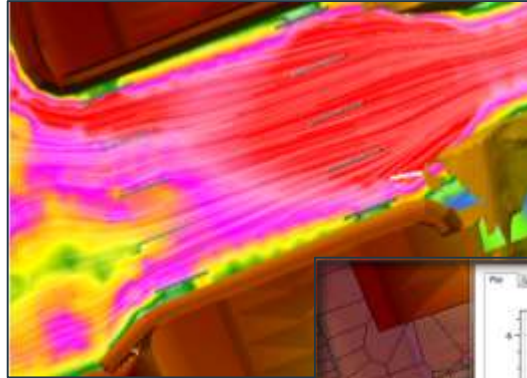


Results - HEC-RAS 2D

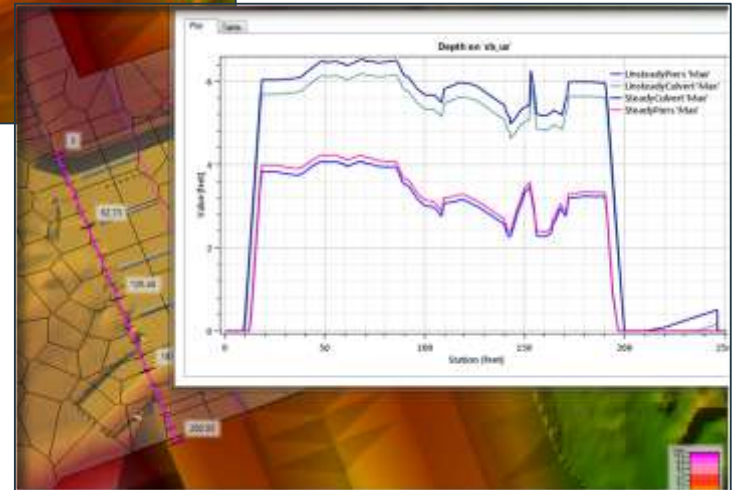
Max Flow Depth



Velocity with Flow-Tracing

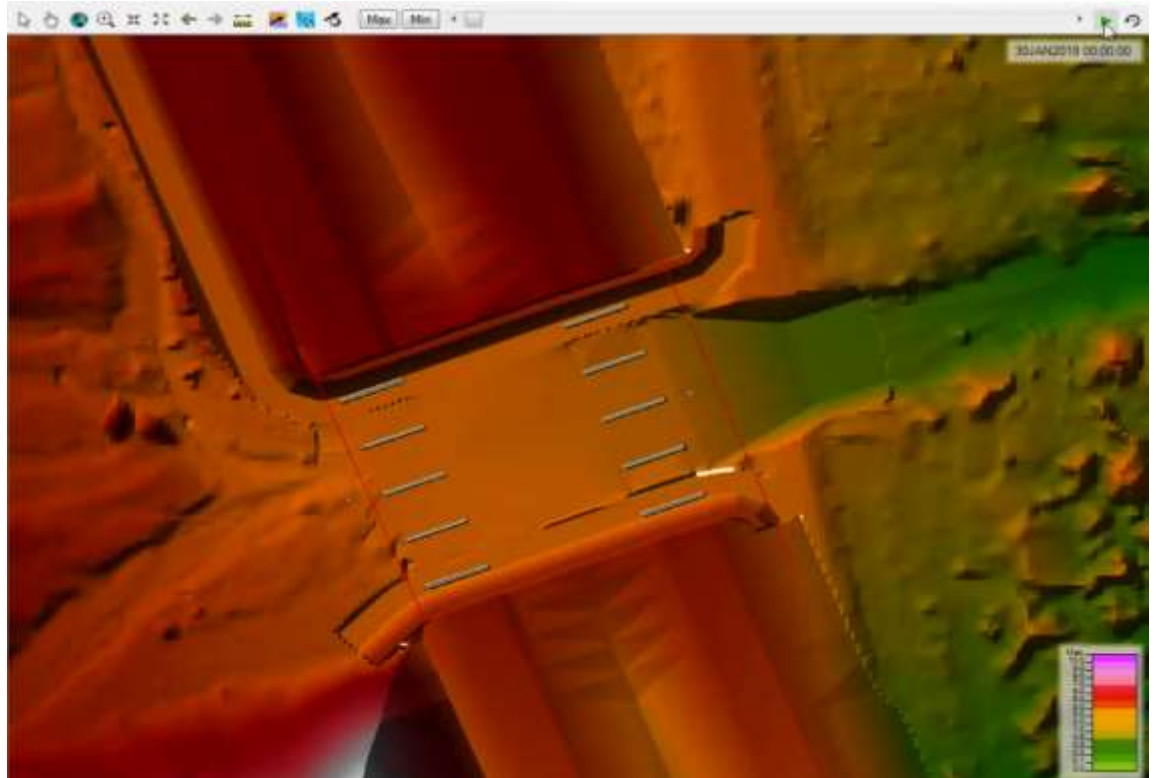


Profile Lines



Results - HEC-RAS 2D

- Animation

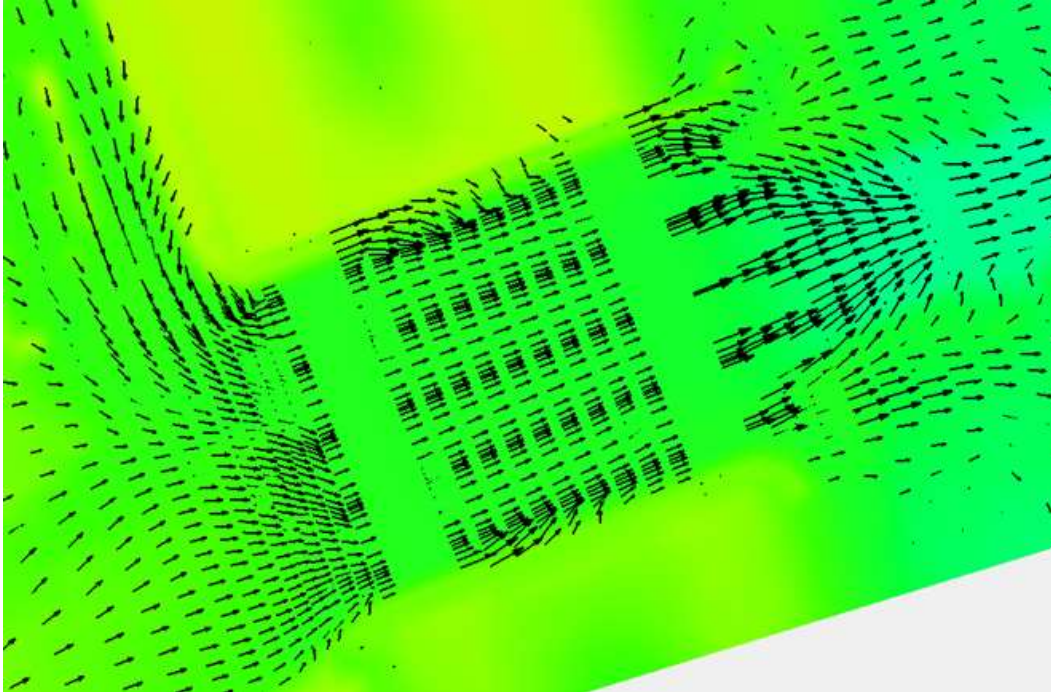


Results - HEC-RAS

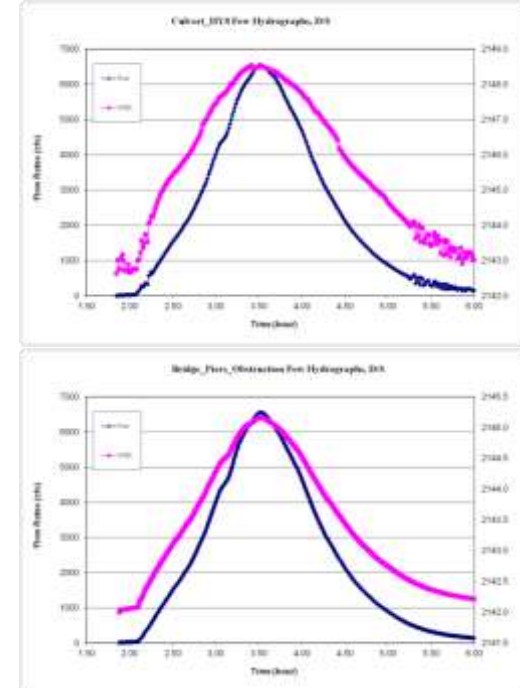
HEC-RAS Results - (100 Year)				
Bridge Modeling Method			Culvert	DTM Piers
1D	Steady	WSEL (ft)	2151.7	N/A
		Vel (ft/s)	9.1	N/A
2D	Steady	WSEL (ft)	2152.8	2150.4
		Vel (ft/s)	9.7	12.7
	Unsteady	WSEL (ft)	2152.4	2150.2
		Vel (ft/s)	8.1	11.3

Results – SRH-2D

Velocity

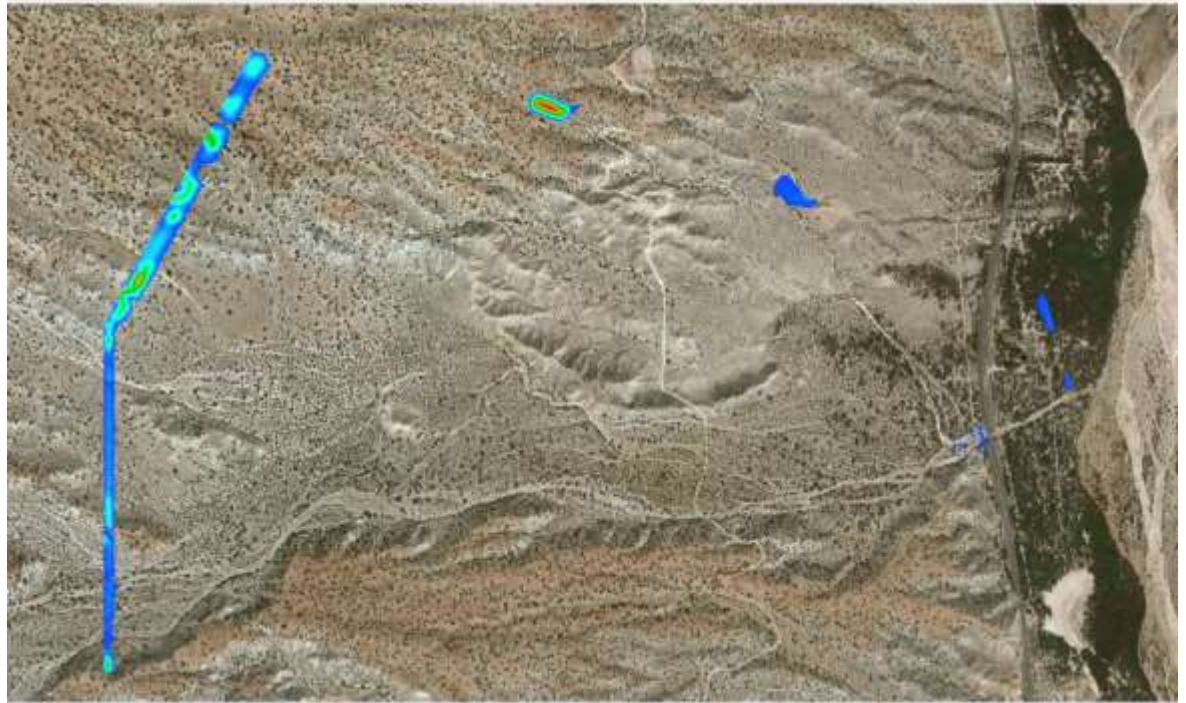


Observation Lines



Results – SRH-2D

Animation

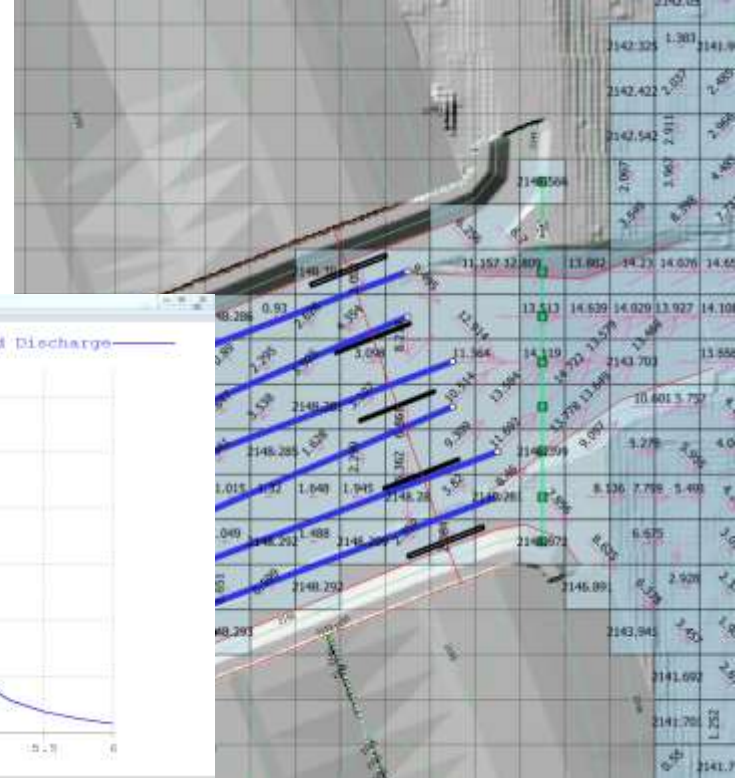
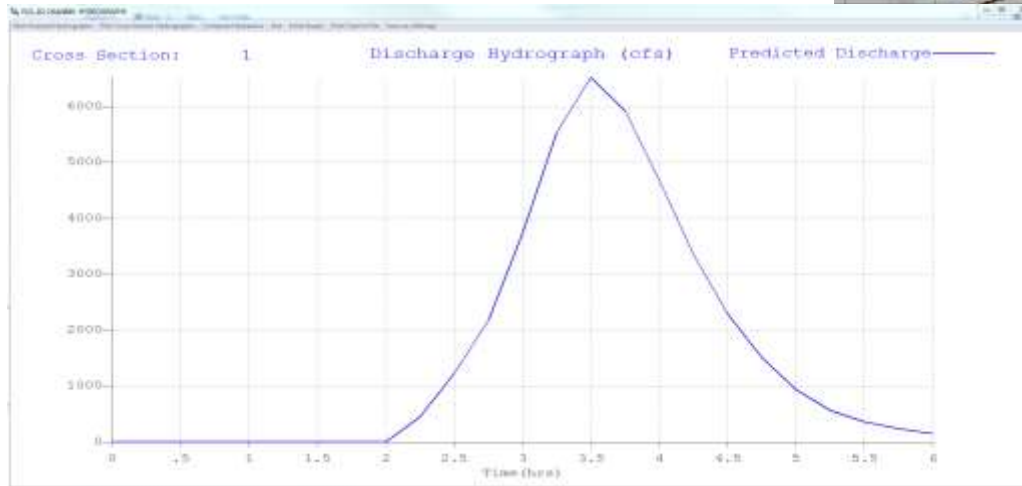


Results - SRH 2D

SRH-2D Results - (100 Year)				
Bridge Modeling Method		HY-8	Holes	Obstruction
Steady	WSEL (ft)	2153.3	2151.1	2151.0
	Vel (ft/s)	8.0	13.1	13.3
Unsteady	WSEL (ft)	2152.9	2150.8	2150.7
	Vel (ft/s)	7.9	12.9	13.1

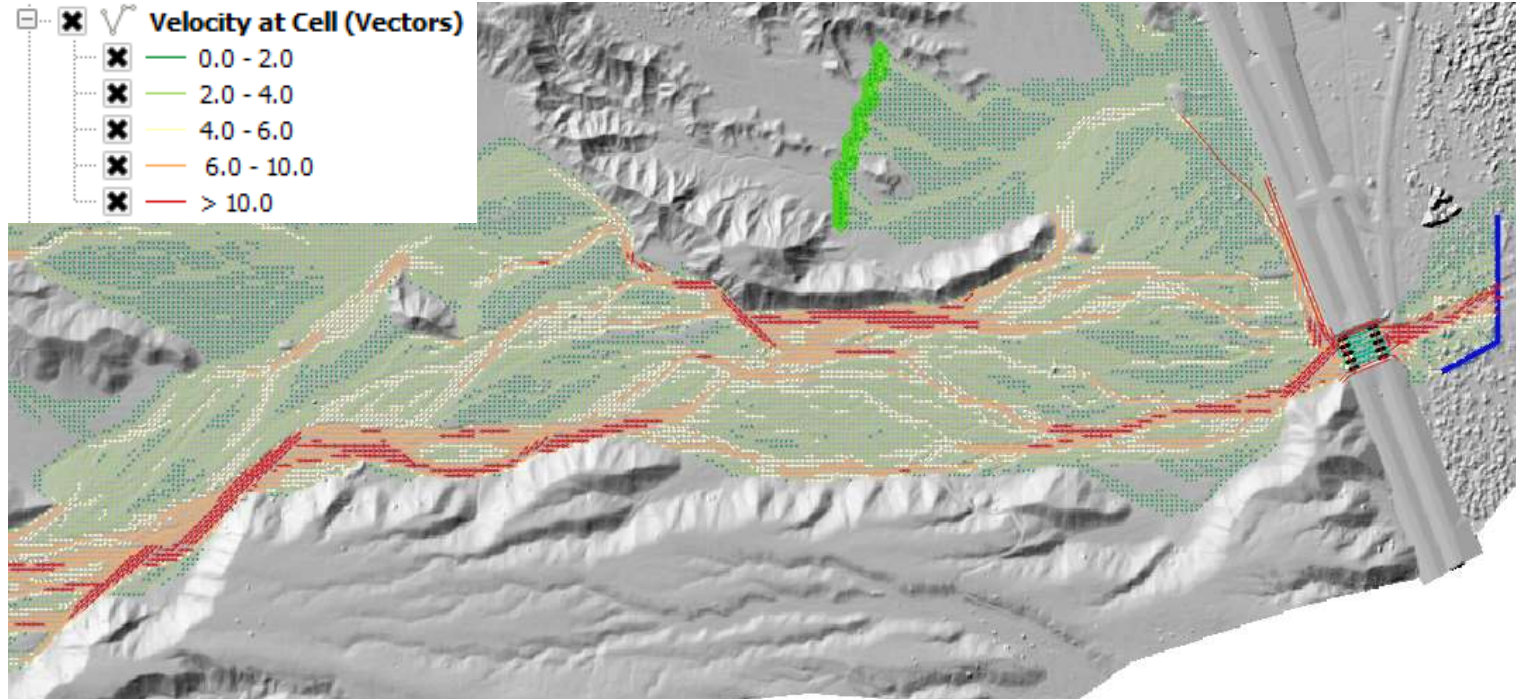
Results – FLO-2D

- Summary of Modeling Results



Results – FLO-2D

- Summary of Modeling Results



Results – FLO-2D

FLO-2D Modeling Summary Table for Gunsight Wash Bridge					
FLO-2D	Bridge Modeling Method		Culvert Equations	Rating Table	Open Channel / Grid Only
2D	Steady	WSEL (ft)	2153.4	2151.8	2151.0
		Vel (ft/s)	9.4	12.5	13.5
	Unsteady	WSEL (ft)	2153.3	2151.5	2150.8
		Vel (ft/s)	8.9	12.1	13.0



Comparison

Overall Comparison (100 Year)				
	HEC-RAS 1D	HEC-RAS 2D	SRH-2D	FLO-2D
Recommended Option	Culvert	DTM Piers	Holes	Rating Table
WSEL (ft)	2151.6	2151.3	2150.8	2151.5
Vel (ft/s)	9.1	11.1	12.9	12.1
Input Data	Simple	Complex	Medium	Medium



Recommendations & Guidance

Modeling Recommendations					
Applications		HEC-RAS 1D	HEC-RAS 2D	SRH-2D	FLO-2D
Existing Bridge/Culvert Hydraulics	1	Applicable	Applicable	Recommended	Applicable
New Bridge/Culvert Design	2	Applicable	Applicable	Recommended	Not Recommended
Simple Wash/Channel Hydraulics	3	Recommended	Not Recommended	Not Recommended	Not Recommended
Multiple Openings	4	Not Recommended	Applicable	Recommended	Applicable
Complex Flow Patterns/Braided Flow	5	Not Recommended	Recommended	Applicable	Applicable
Basin System Hydraulics	6	Applicable	Recommended	Not Recommended	Applicable
FEMA FIS/CLOMR/LOMR	7	Recommended	Applicable	Applicable	Applicable
Bridge Scour Evaluation	8	Applicable	Applicable	Recommended	Applicable
Urbanized/Stormdrain	9	Not Recommended	Applicable	Applicable	Recommended



The background of the slide features a series of concentric circles in two shades of purple and pink, creating a modern, abstract design.

Q&A

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