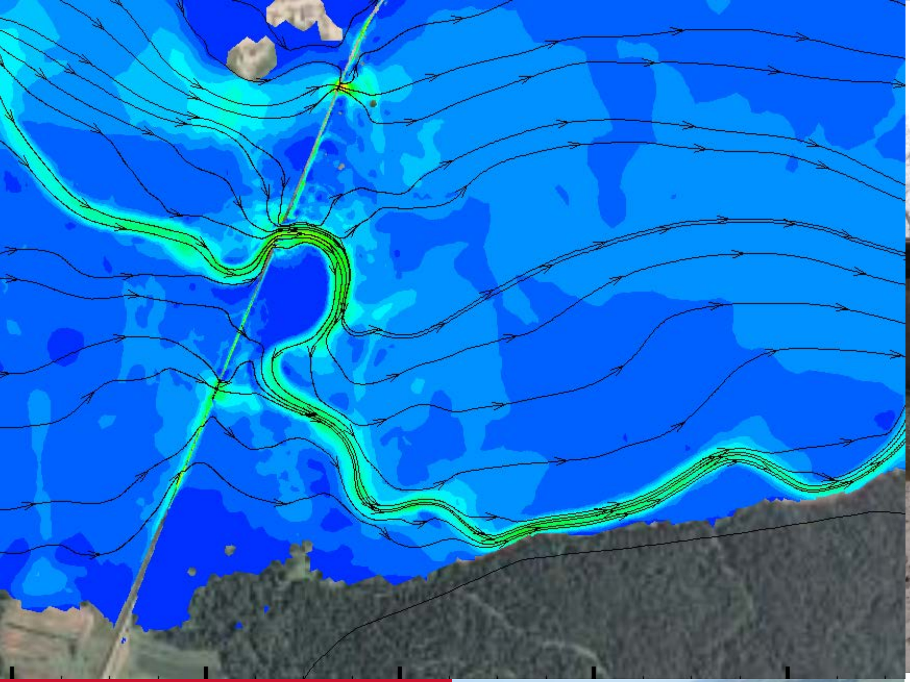


Improvement at the Iowa River Crossing - 2D Hydraulic Analysis

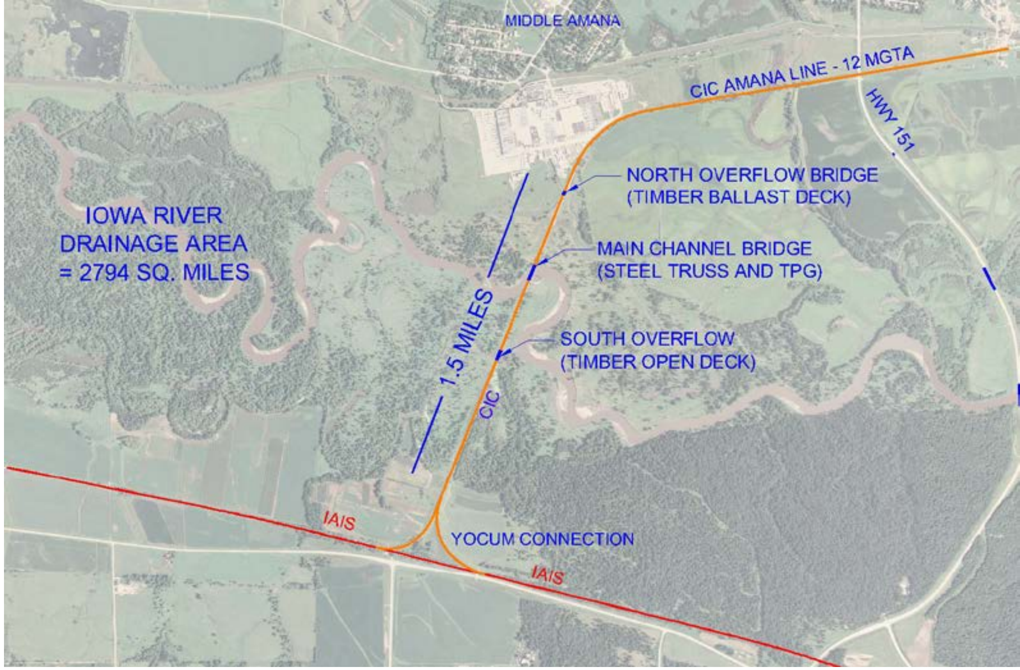
Andrew McCoy, PhD, PE - HDR
Chad Lambi, PE, CRANDIC

Organization

- Background and Purpose
- Model Development
- Calibration and Validation
- Design Features
- Results and Conclusions
- Recent History

Background and Purpose

- CRANDIC connects to four railroads in eastern Iowa (Amana Line)
- 1.5 mile crossing in Iowa River bottom near Amana, Iowa
- Three major structures – main channel bridge, north overflow bridge and south overflow bridge
- Crossing constructed in late 1800s
- CRANDIC purchased Amana line in 1980 from the Milwaukee Road and was flooded out of service in 1993 and 2008

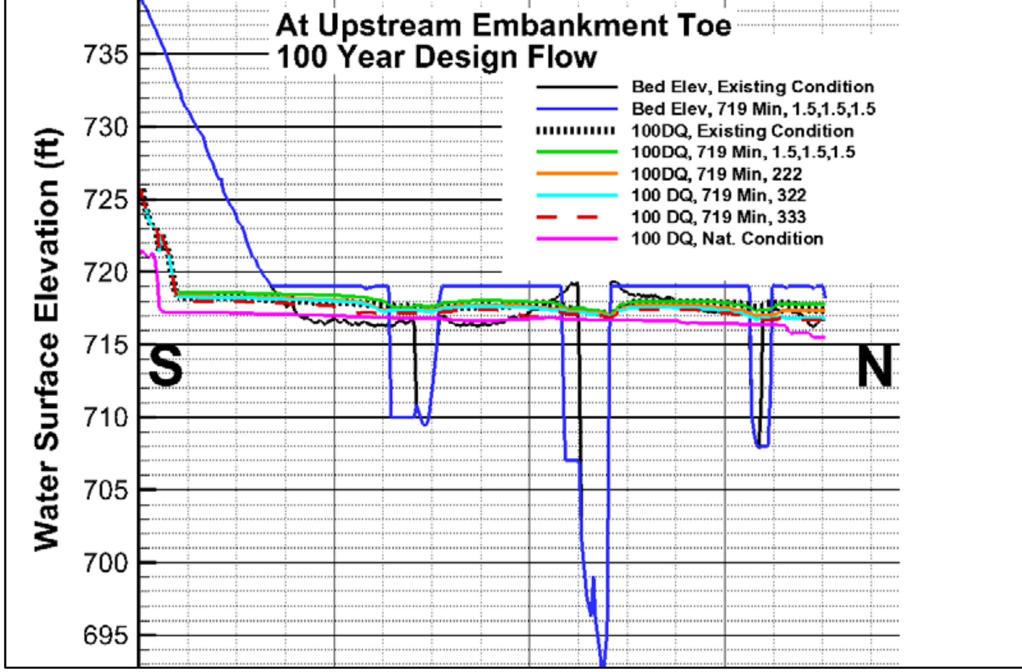


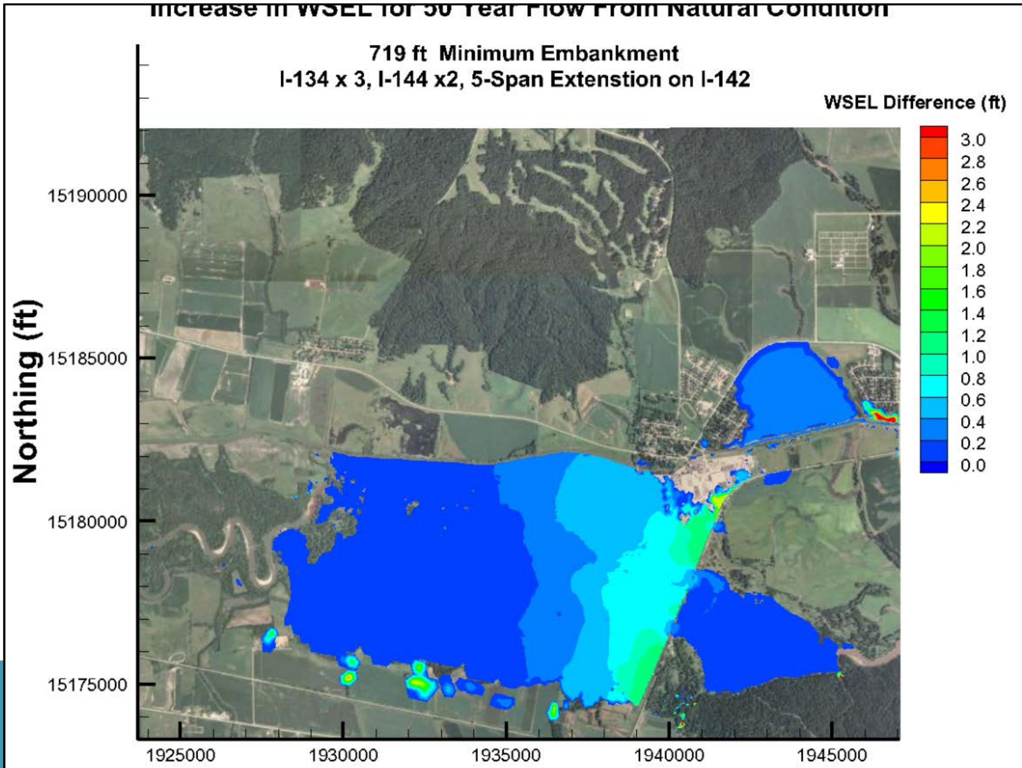
Background and Purpose

- Major floods in 1993 and 2008 took CRANDIC line out of service
- Lateral bank erosion constant battle
- CRANDIC embarked on five year improvement plan to replace track and structures
- CRANDIC wanted to use their limited construction dollars the most effectively as possible
- 2D hydraulic analysis considered 2-4 ft. embankment raise, increased bridge opening to compensate for grade raise, and spur dikes

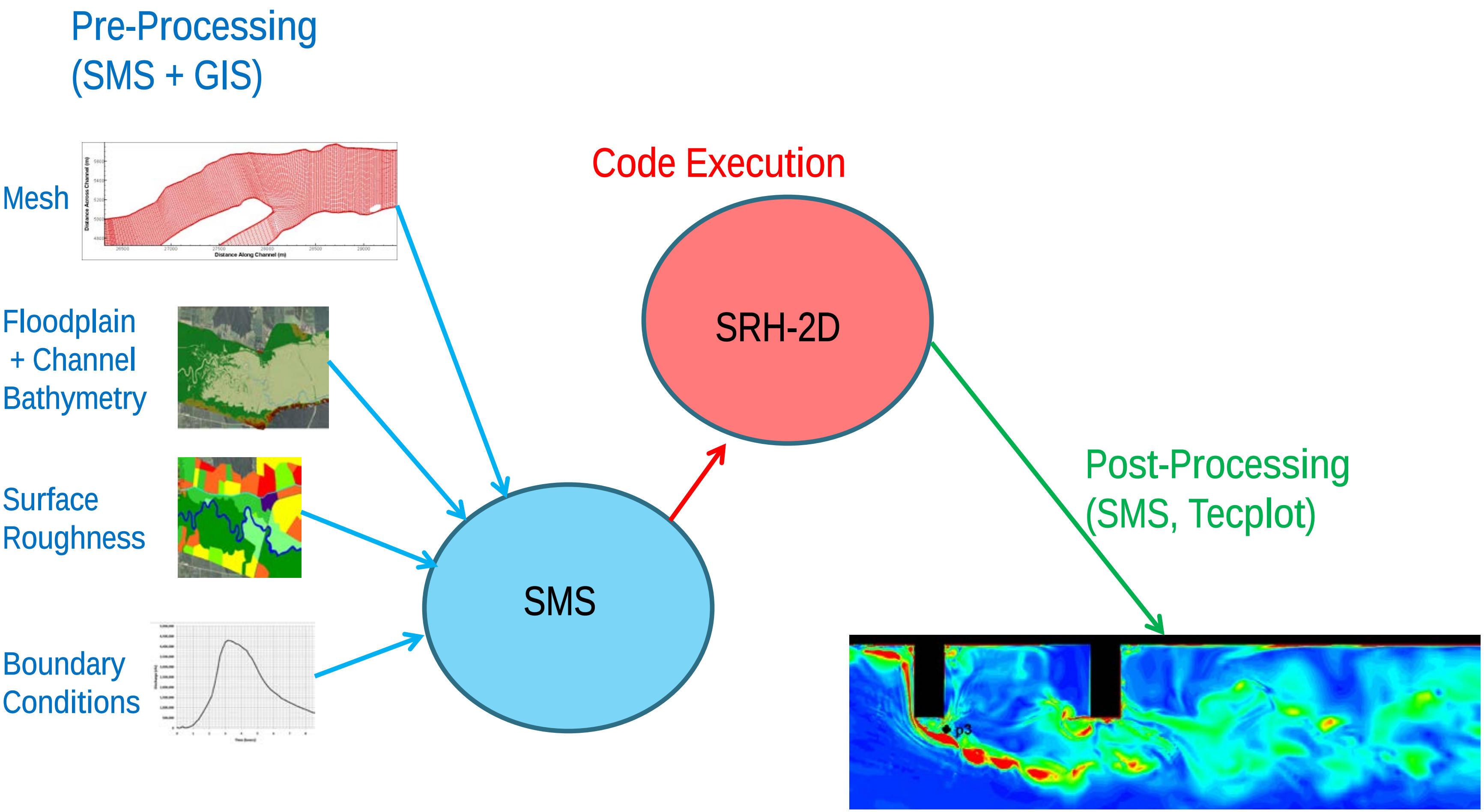
Hydraulic Criteria and Design Issues

- Environmental
  - Increase in footprint of embankment impacts wetlands requires mitigation
- Design
  - Higher embankment blocks overtopping flow
  - Increase size of relief bridges/main bridge to compensate
  - CRANDIC desired at least 100-year level of service but also evaluated performance at 2008 discharge
- Floodplain Permit
  - Meet backwater criteria (State of Iowa)
  - No increase in property damage upstream at the 1-percent annual chance flood (100-year)





2D Model Development



Pre-Processing
(SMS + GIS)

Mesh

Floodplain
+ Channel
Bathymetry

Surface
Roughness

Boundary
Conditions

SMS

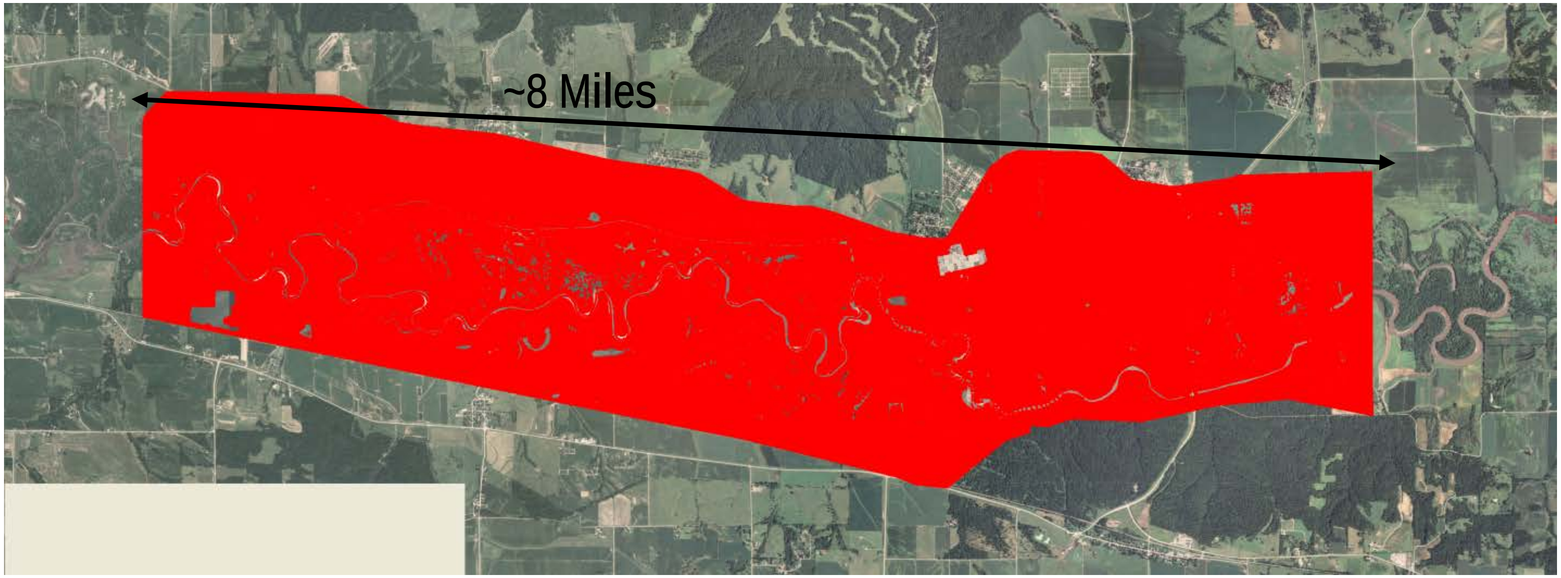
Code Execution

SRH-2D

Post-Processing
(SMS, Tecplot)

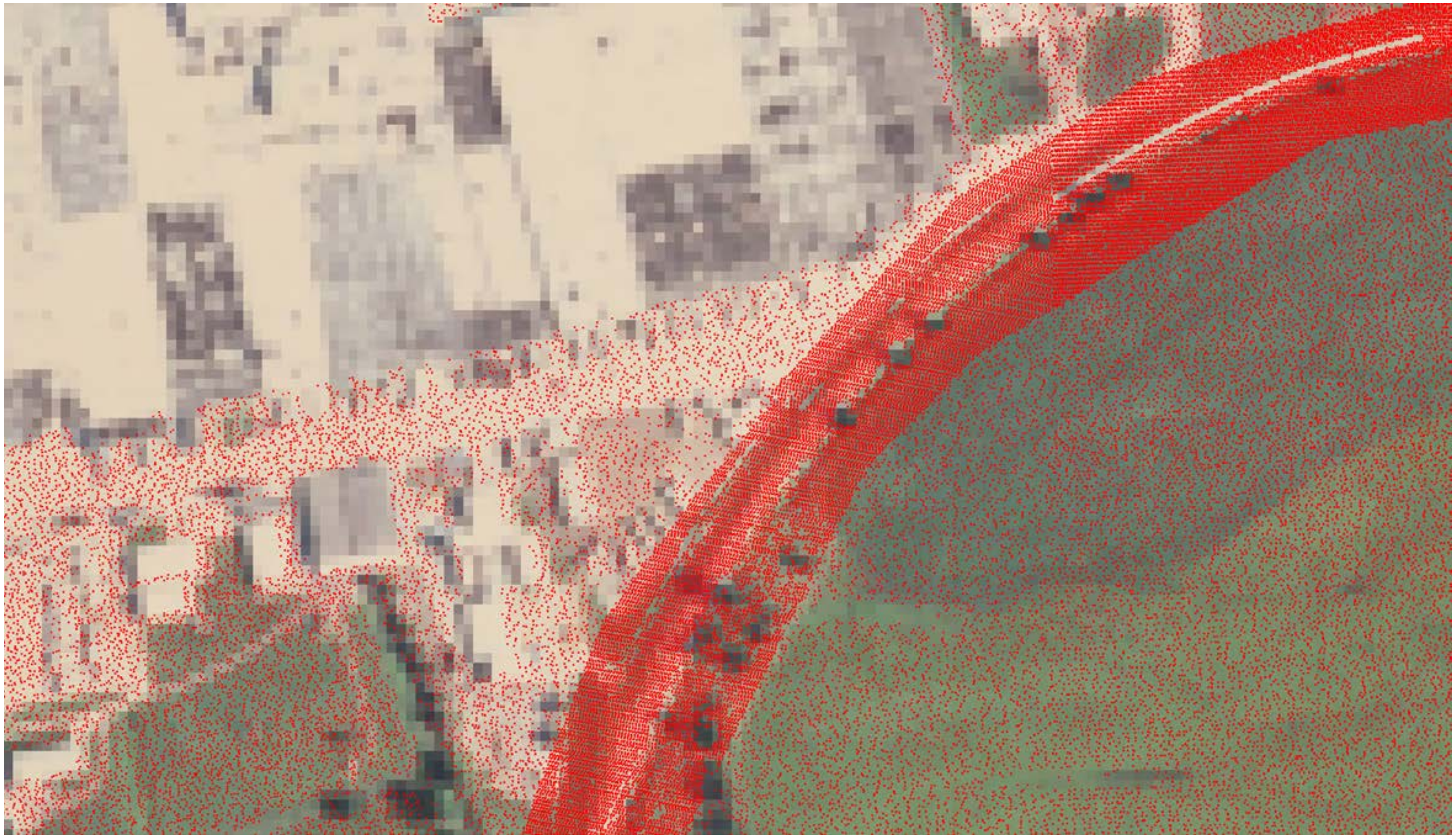
2D Modeling Approach – Land Surface Model - LiDAR

- State of Iowa provides LiDAR data throughout entire state
- Vertically +/- 4 inches



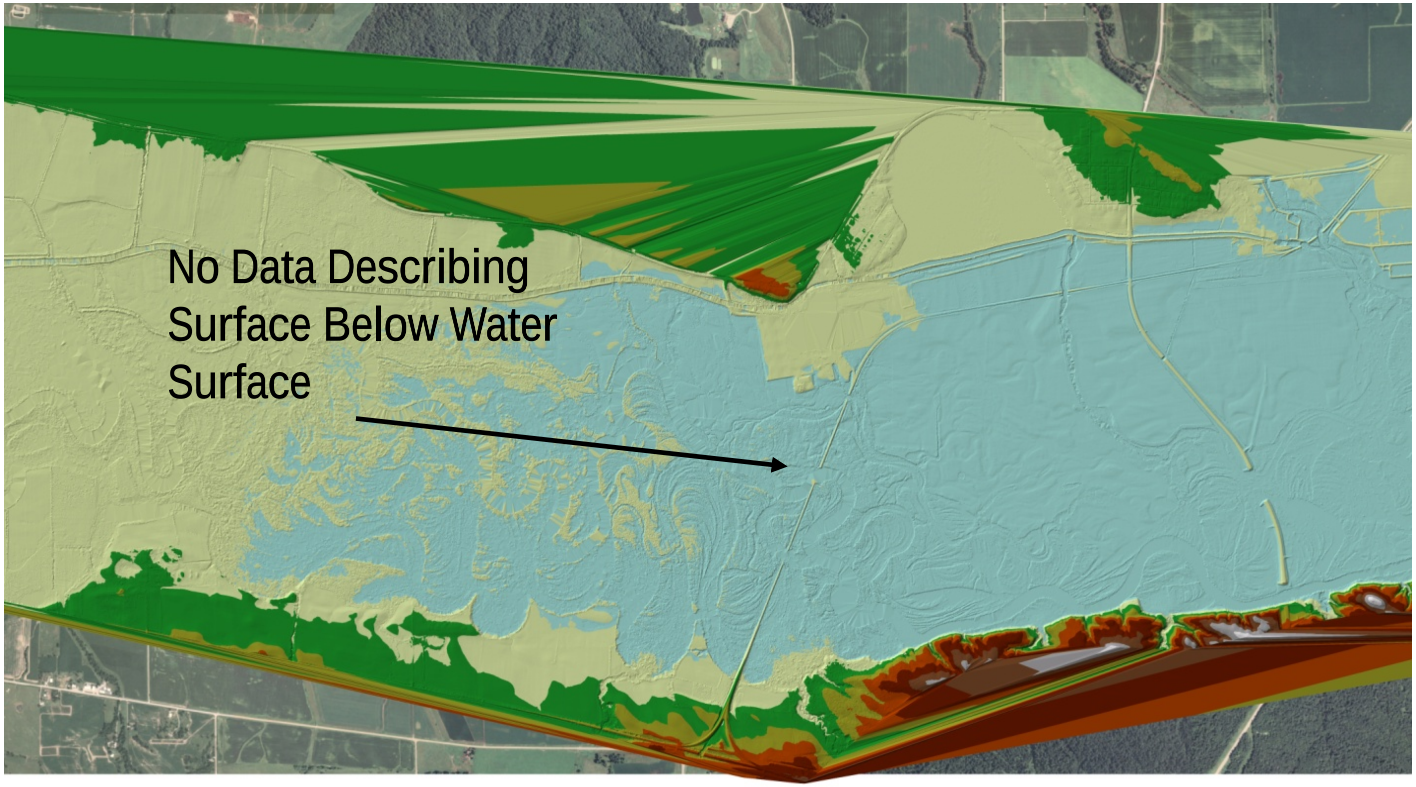
2D Modeling Approach – Land Surface Model – LiDAR Filtering

- Floodplain Filtered
- Embankment Original Density



2D Modeling Approach – Land Surface Model – Channel Bathymetry

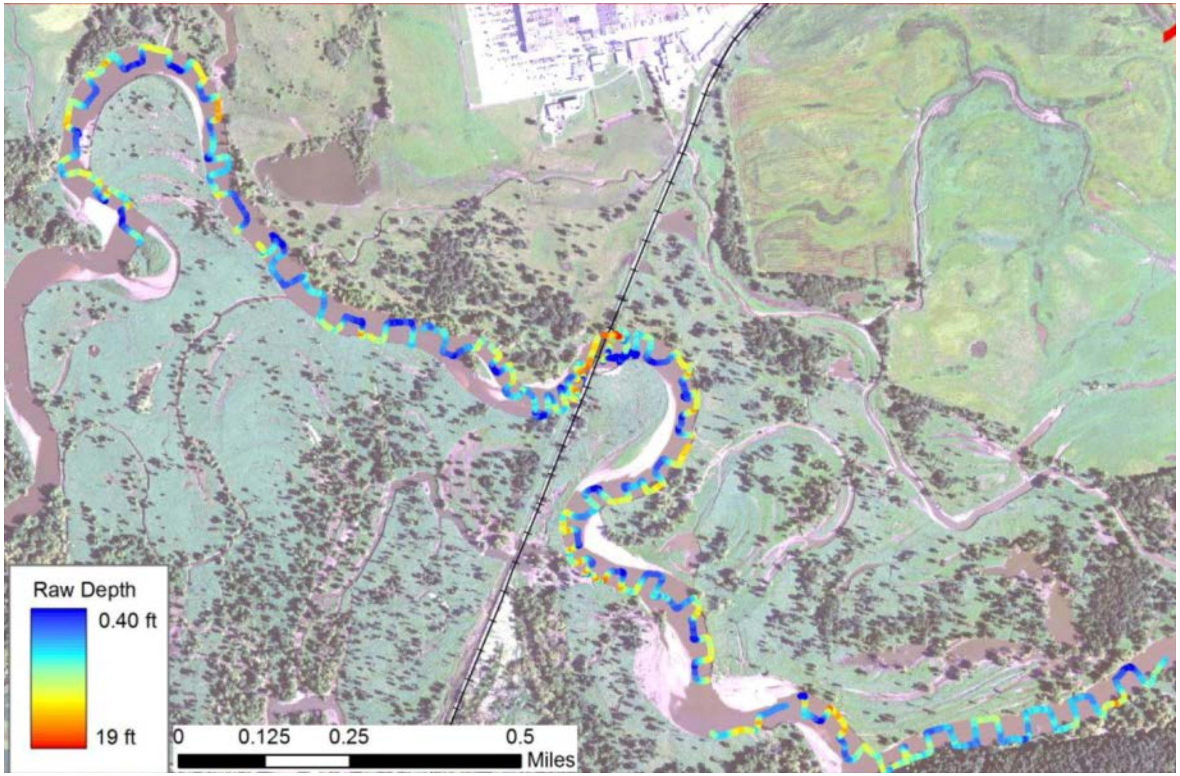
- LiDAR doesn't penetrate water surface



No Data Describing Surface Below Water Surface

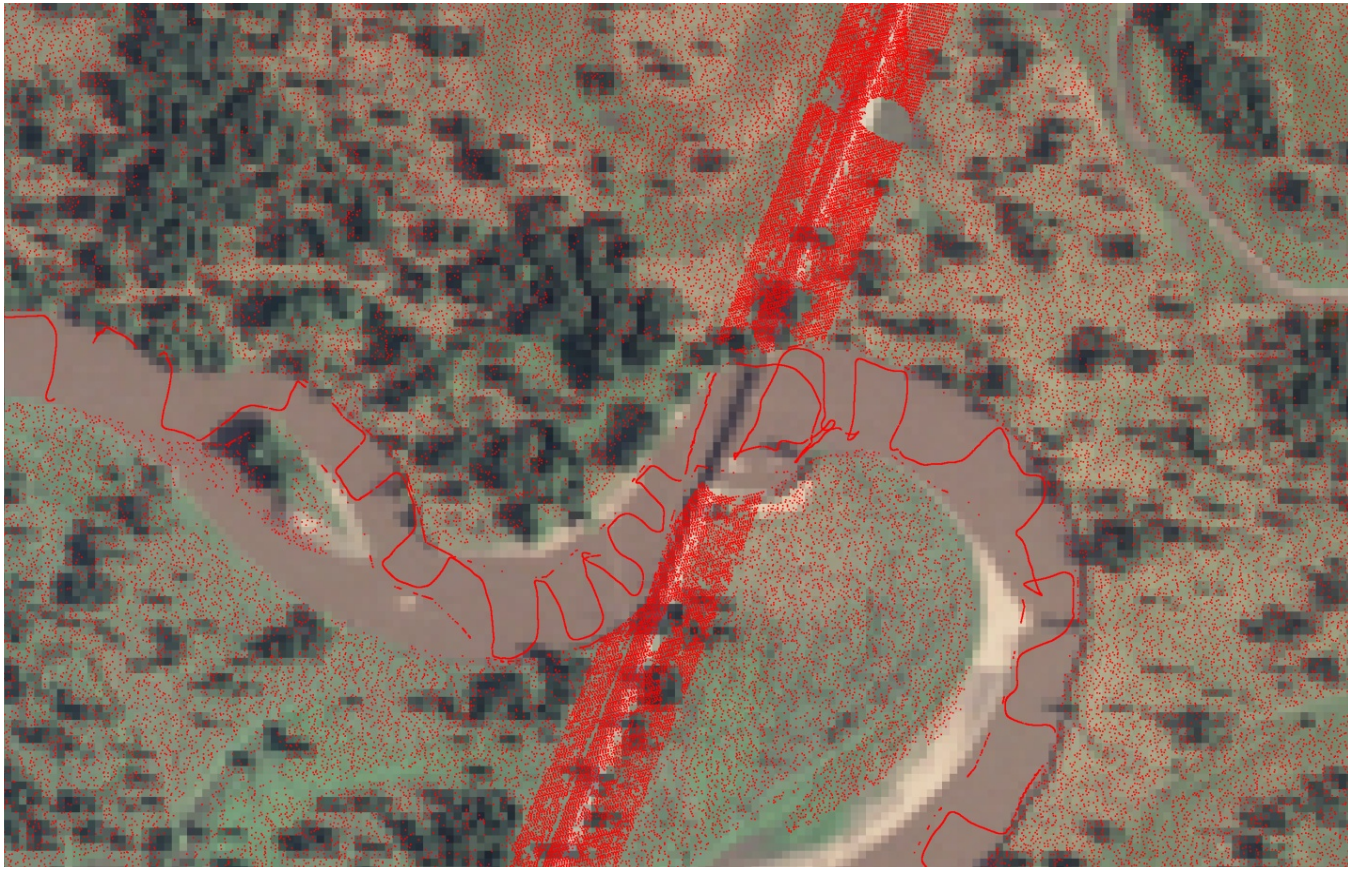
2D Modeling Approach – Adding Channel Bathymetry

- Single-Beam echo-sounder
- Collected by IIHR-Hydroscience and Engineering
- Integrated with LiDAR based DTM



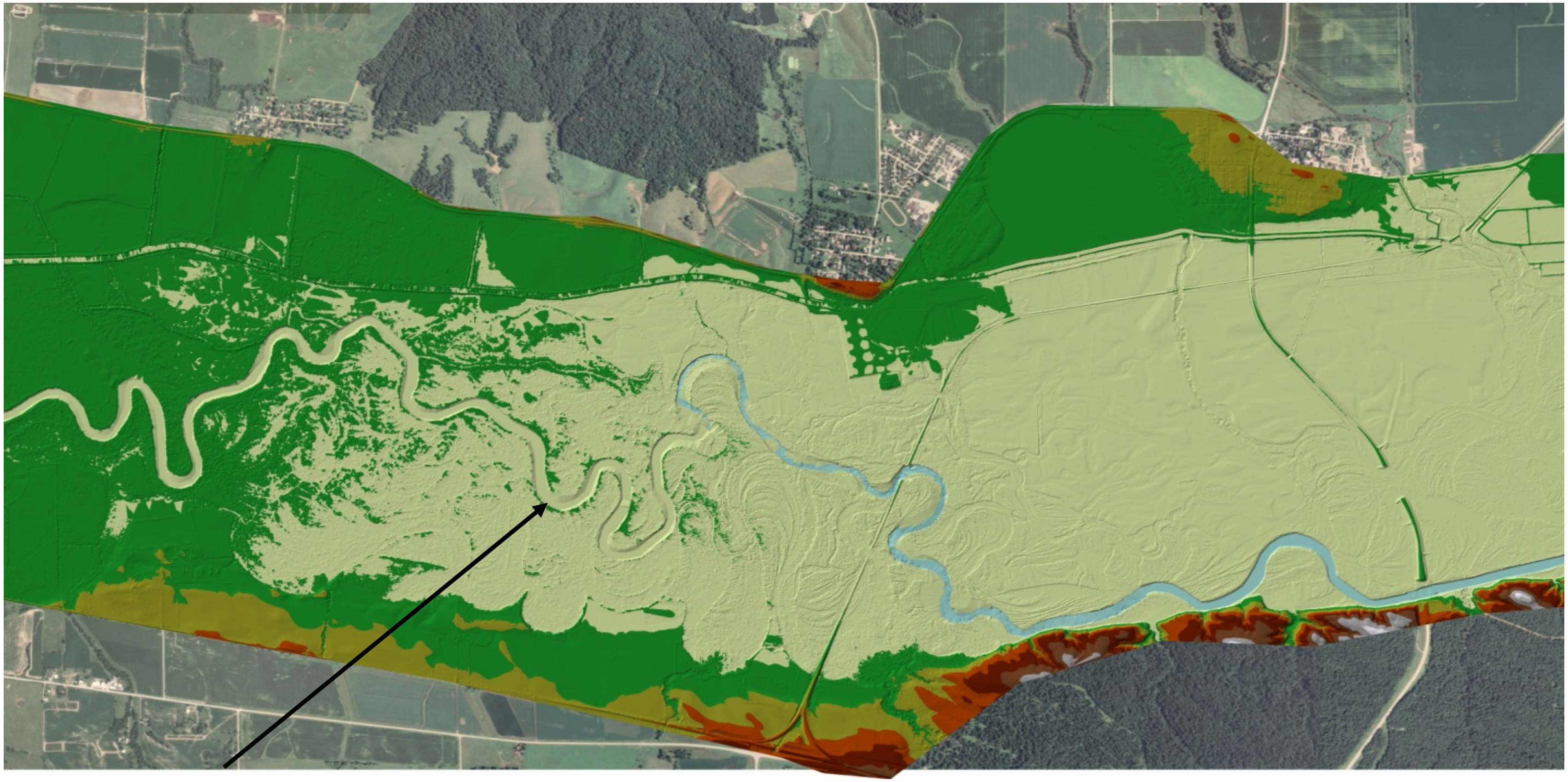
2D Modeling Approach – Combine LiDAR + Bathymetry

- Combine LiDAR + Bathymetry in GIS



2D Model Approach – Combine LiDAR + Bathymetry

- Finished surface includes channel

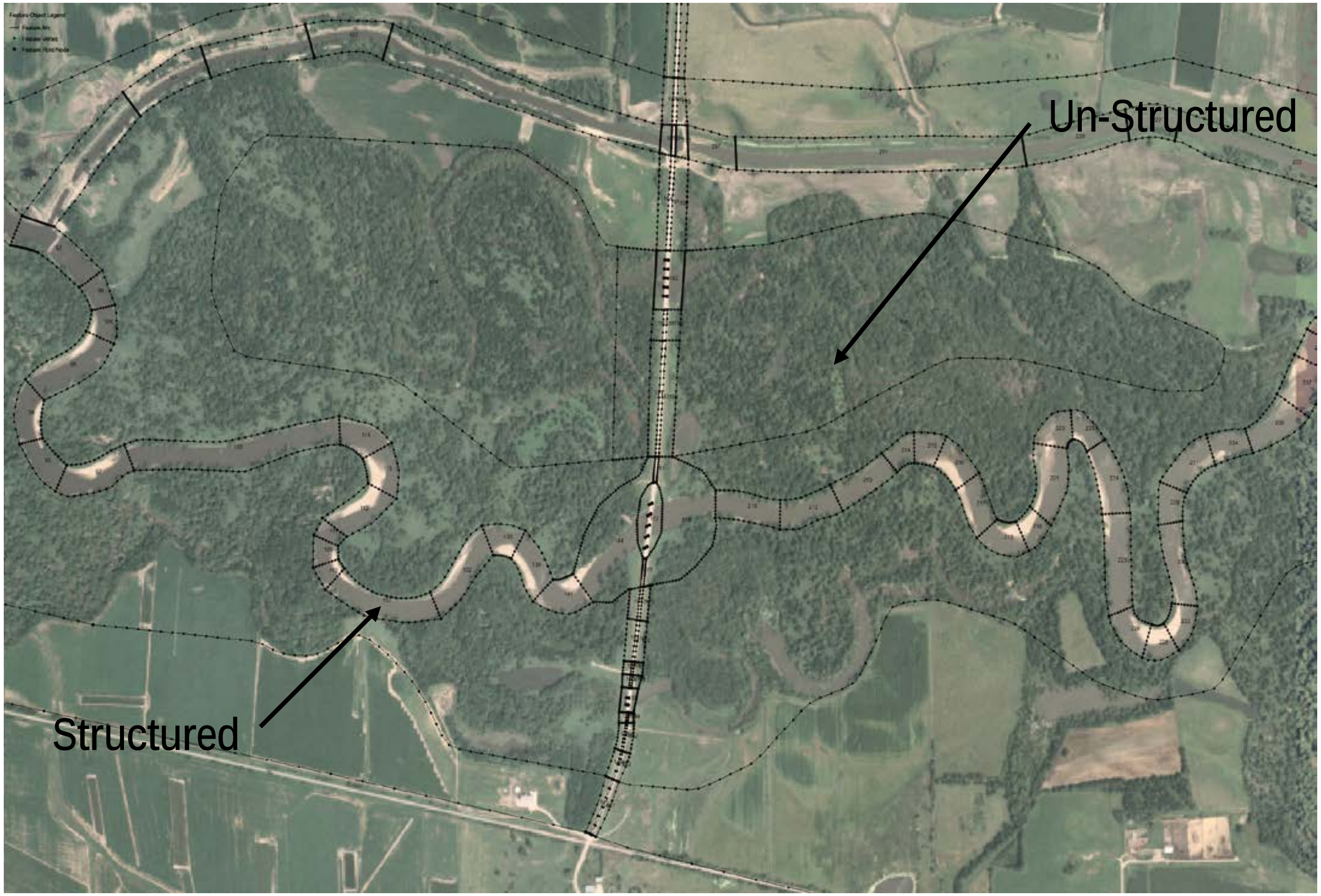


2D Modeling Approach – Computational Mesh in SMS

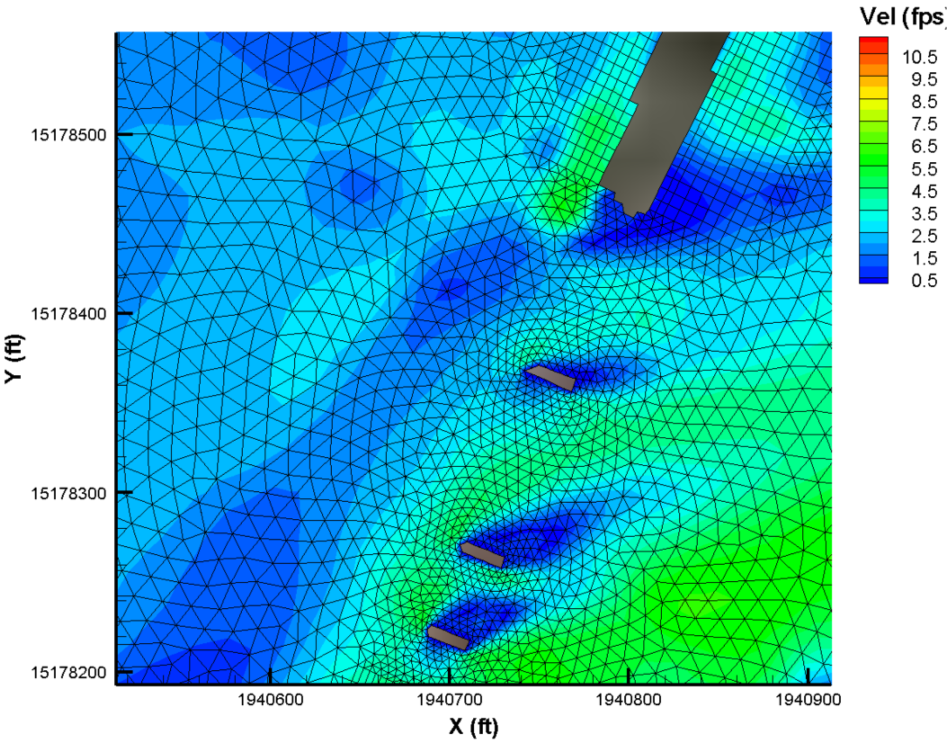
Elements sized according to required solution, velocity gradients, changes in bathymetry, and computational power

2D Modeling Approach – Building Mesh in SMS

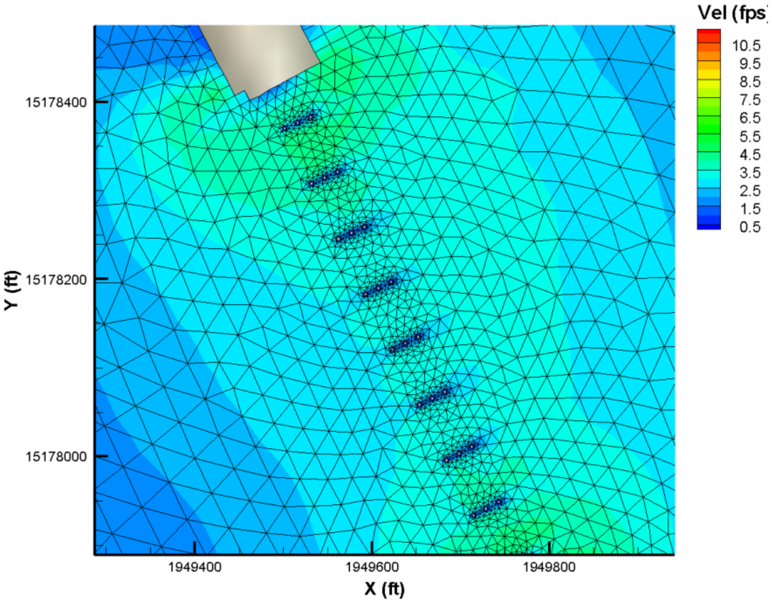
SMS map module allows for excellent control of structured/unstructured mesh



2D Modeling Approach – Computational Mesh + Bridge Piers



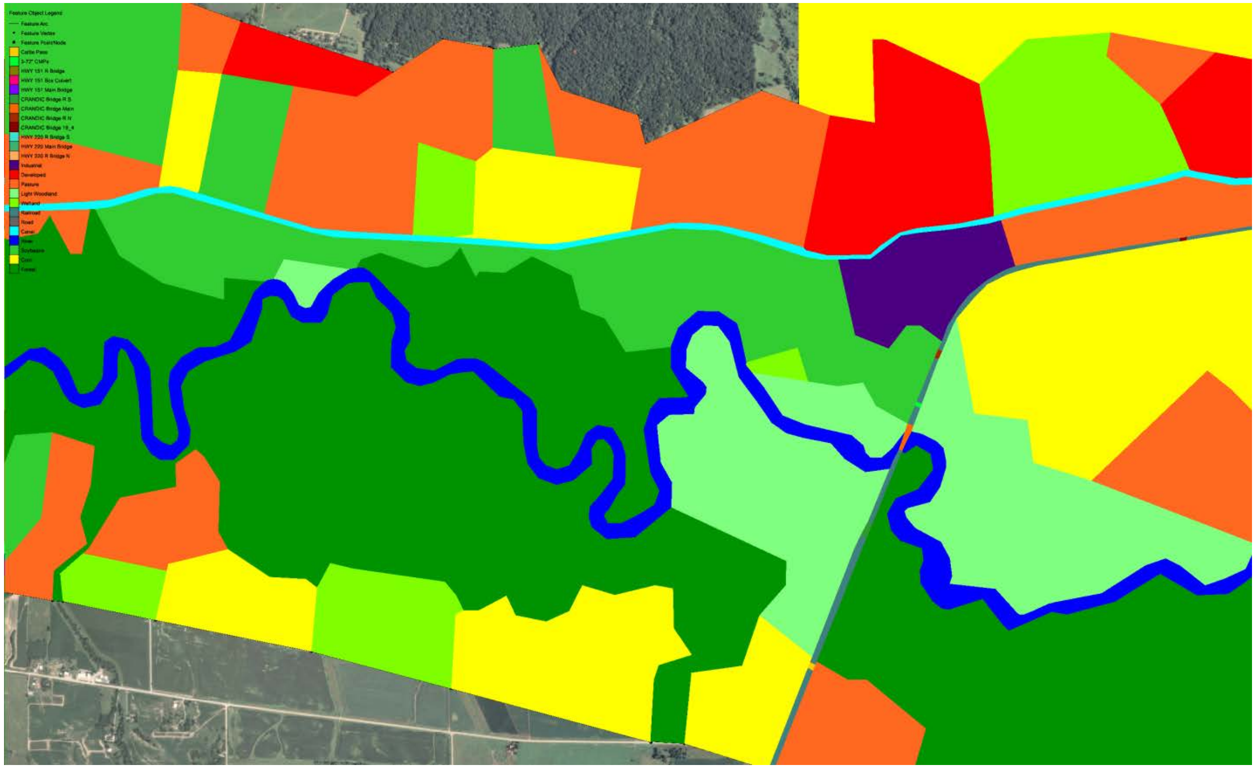
Bridge piers are modeled explicitly in mesh



2D Modeling Approach – Surface Roughness

Feature Object Legend

- — Feature Arc
- ▪ Feature Vertex
- ● Feature Point/Node
- 🟨 Cattle Pass
- 🟩 3-72" CMPs
- 🟫 HWY 151 R Bridge
- 🟥 HWY 151 Box Culvert
- 🟪 HWY 151 Main Bridge
- 🟩 CRANDIC Bridge R S
- 🟧 CRANDIC Bridge Main
- 🟫 CRANDIC Bridge R N
- 🟥 CRANDIC Bridge 19_4
- 🟦 HWY 220 R Bridge S
- 🟩 HWY 220 Main Bridge
- 🟧 HWY 220 R Bridge N
- 🟪 Industrial
- 🟥 Developed
- 🟧 Pasture
- 🟩 Light Woodland
- 🟩 Wetland
- 🟦 Railroad
- ⬛ Road
- 🟦 Canal
- 🟦 River
- 🟩 Soybeans
- 🟨 Corn
- 🟩 Forest



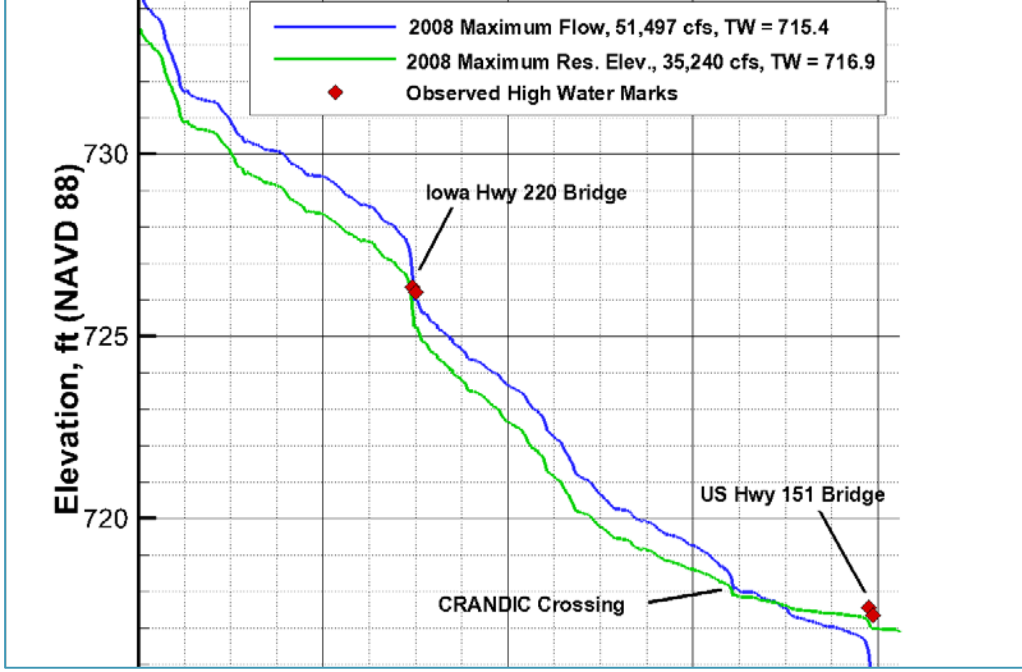
2D Modeling Approach – Boundary Conditions

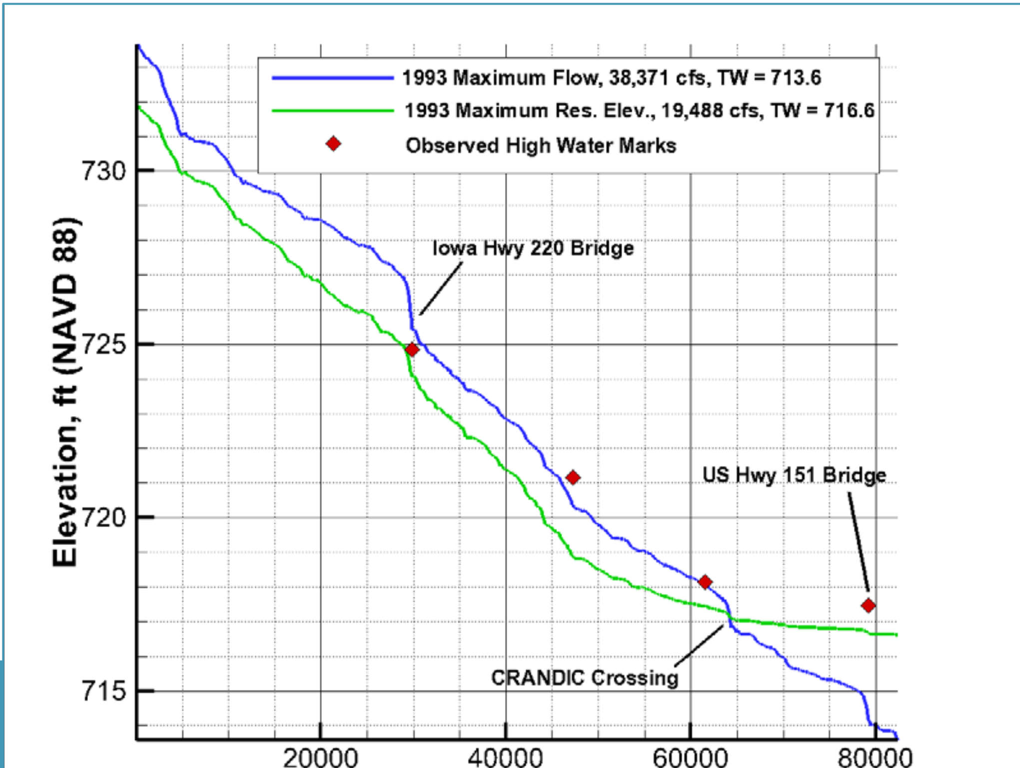
- Implemented along node strings at boundaries
- Simulated until steady-state discharge
- Stage boundary at d/s

Event Description	*Flow at Marengo (cfs)*	*Flow at CRANDIC Crossing (cfs)*	*Downstream Water Surface Elevation (ft)*
2-year	12,350	12,470	707.6
5-year	19,770	19,963	709.1
10-year	25,030	25,274	709.9
25-year	31,970	32,282	710.8
50-year	37,290	37,654	711.4
100-year	42,720	43,137	712.0
200 year	48,280	48,751	712.5
500 year	55,830	56,375	713.3
2008 Event- Max Discharge	51,000	51,497	712.8
2008 Event- Max Reservoir Height	38,000	38,370	715.4
1993 Event- Max Discharge	34,900	35,240	711.4
1993 Event- Max Reservoir Height	19,300	19,488	716.9

Calibration and Validation

- 1993 Event and 2008 Event
- Considered both peak flow and peak tail water events





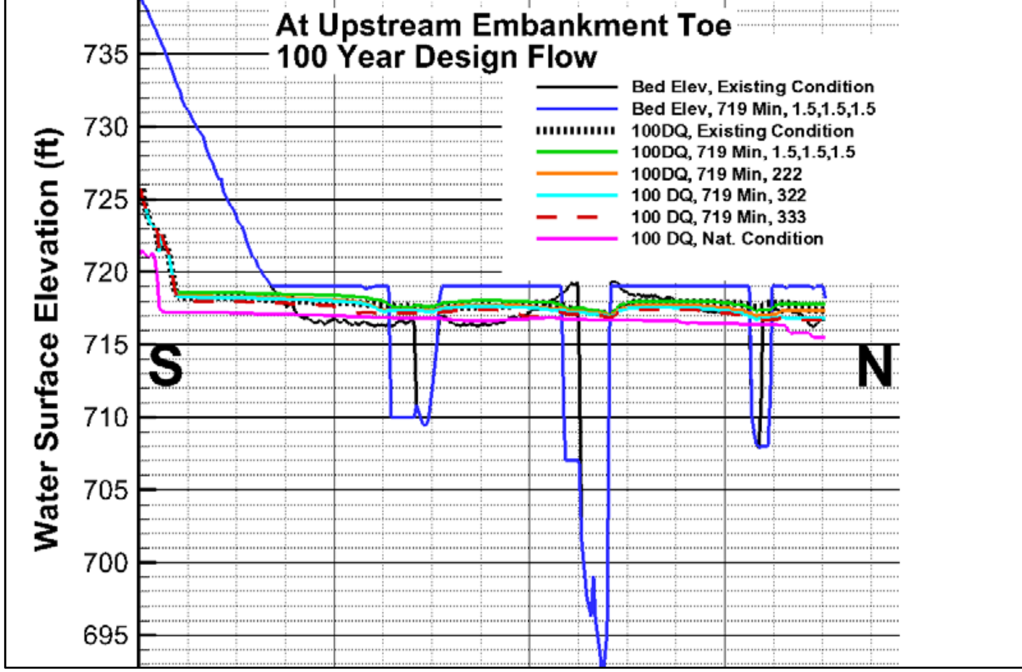
2D Modeling Approach – Calibration and Validation

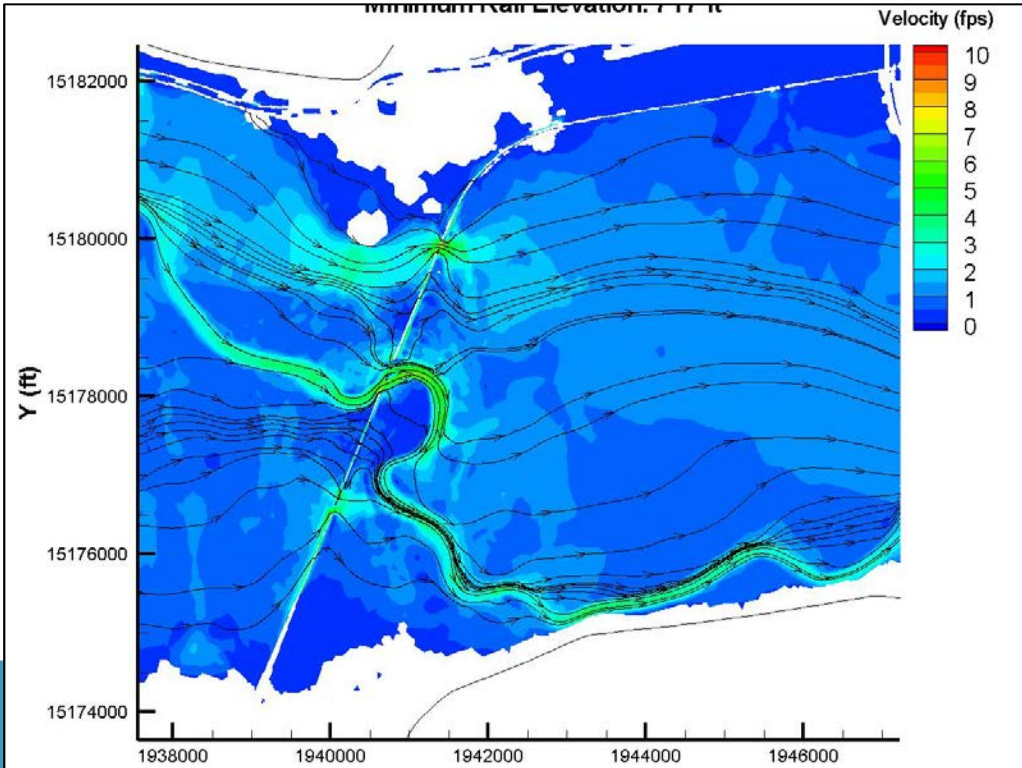
Location	***Observed***	***Modeled- Max. Flow***	***Difference***	***Modeled- Max. Res. Elev.***	***Difference***
RM 128.2- Hwy 220	*724.85*	*725.51*	***0.66***	*724.09*	*-0.76*
RM 124.8	*721.15*	*720.34*	***-0.81***	*718.87*	*-2.28*
RM 122.0	*718.15*	*718.07*	*-0.08*	*717.43*	***-0.72***
RM 118.7- Hwy 151	*717.45*	*714.14*	*-3.31*	*716.14*	***-1.31***

Location	***Observed***	***Modeled- Max. Flow***	***Difference***	***Modeled- Max. Res. Elev.***	***Difference***
Upstream Hwy 220	*726.35*	*726.66*	***0.31***	*725.70*	*-0.65*
Downstream Hwy 220	*726.21*	*725.99*	***-0.22***	*725.26*	*-0.95*
Upstream Hwy 151	*717.56*	*716.32*	*-1.24*	*717.17*	***-0.39***
Downstream Hwy 151	*717.36*	*715.71*	*-1.65*	*716.97*	***-0.39***

Design Features

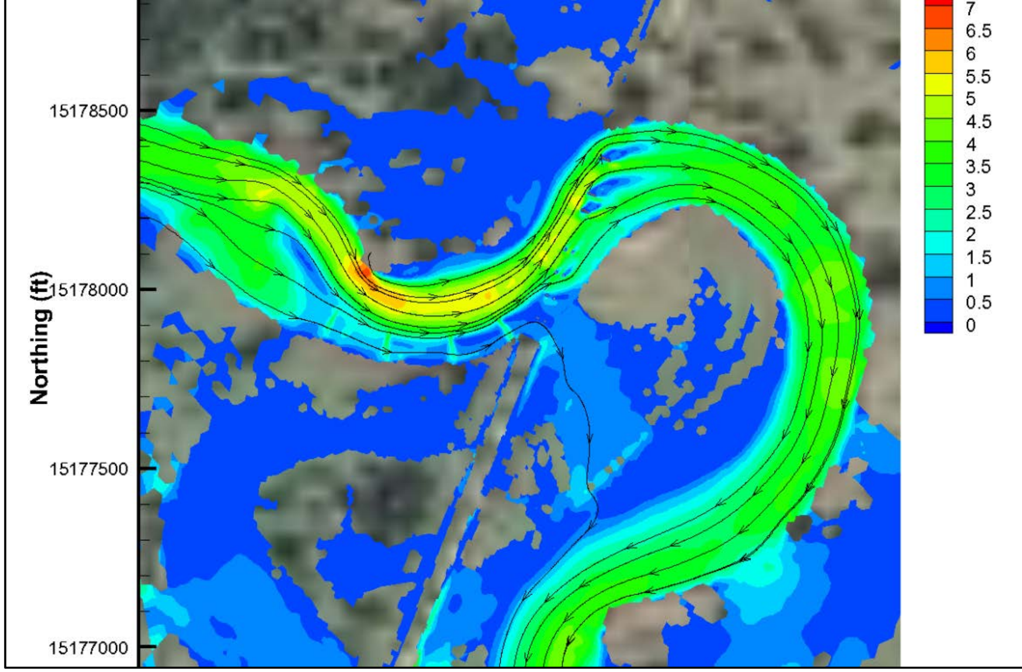
- Balance between raising embankment and increasing overflow bridge capacity
- Lower velocities through overflow structures
- Minimize cost and environmental impact
- Looked at individual openings and combinations of openings
- Final design included embankment increased 4 ft., South overflow bridge increased two times and North overflow bridge increased 3 times
- Did not increase water surface elevations upstream from project at 100-year and kept Amana Line in service during 100-year event





Spur Dikes

- Lateral bank erosion a maintenance problem
- Designed submerged spur dikes arrest lateral bank erosion and promote infill
- Design confirmed with hydraulic model
- Permitting documents prepared with information from modeling

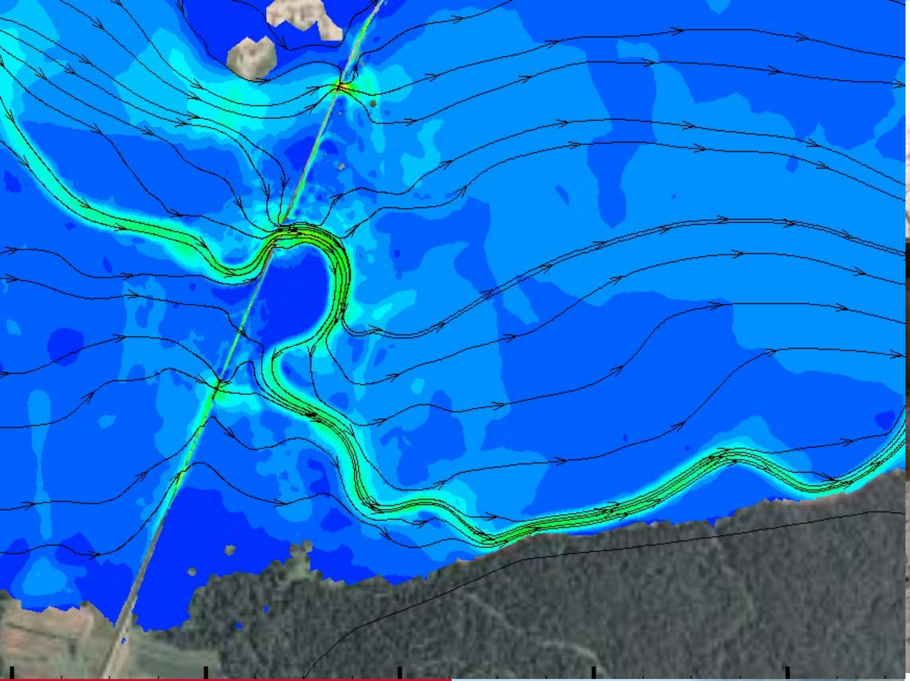


Post Construction

- Spurs Constructed in 2013
- North and South Overflow constructed in 2013

Recent History and Conclusions

- Pre-Iowa River Crossing Improvements – overtopping occurred at 32,000 cfs (25 year event)
- 2008 – Peak was 51,500 cfs
- 35,000 cfs (Top)
- 2013 ~ 35,000 cfs (Bottom) – stayed in service
- 2014 ~ 35,000 cfs - stayed in service
- Crossing updated to over 100-year design
- TIMELY IMPOVEMENTS. Since construction CRANDIC and the Iowa River have experienced 2 approximately 50-year events at the site and have stayed in service through both
- The 2D hydraulic analysis provided the level of detail necessary to plan, design, permit and build the project



CEDAR RAPIDS AND IOWA CITY RAILWAY
The CRANDIC Route
SINCE 1904

Thank you.
Questions?

HDR