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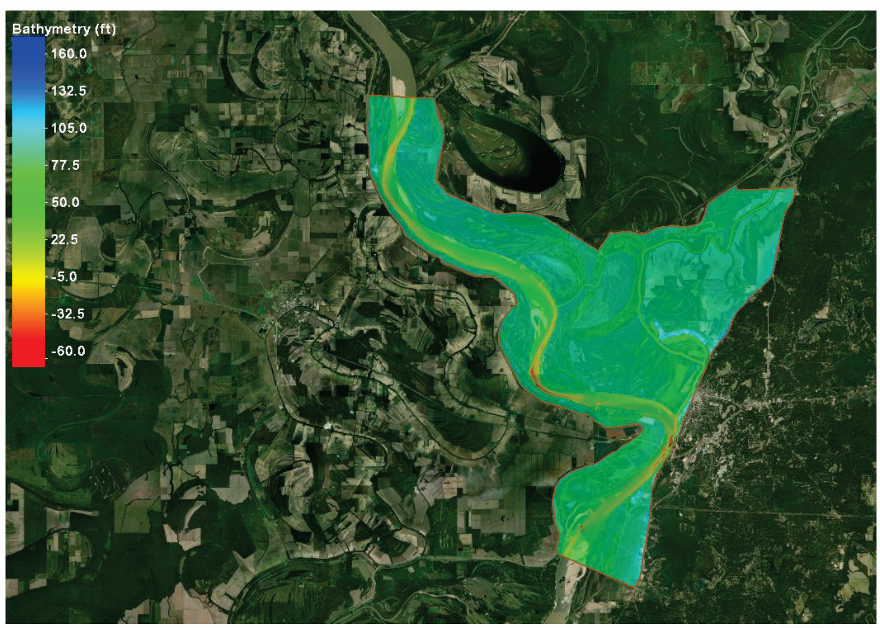
Numerical Analysis of Dike Effects on the Mississippi River Using a Two-Dimensional Adaptive Hydraulics Model (AdH)

MRG&P Report No. 44 • November 2022



MRG&P
Mississippi River Geomorphology & Potamology Program

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Numerical Analysis of Dike Effects on the Mississippi River Using a Two-Dimensional Adaptive Hydraulics Model (AdH)

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Final report

Prepared for Mississippi River Geomorphology and Potamology (MRG&P) Program
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Under Mississippi Valley Division through the MRG&P Program

Abstract

This report describes the hydraulic effects of dikes on water surface elevation (WSE) and velocities in the Mississippi River near Vicksburg, MS, from Interstate 20 to Highway 80 using a previously calibrated 2D Adaptive Hydraulics numerical model. Dike heights and their associated hydraulic roughness values were varied to quantify the overall effects of adjustments to dike fields. Steady flows characterized as low, medium, and high conditions were simulated. The WSE and velocity difference plots were generated to illustrate the hydraulic effects on the river under all scenarios discussed above. Overall, the dike adjustments had negligible impacts on WSEs and showed minimal effects on velocities on a system-wide scale.

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Preface

This study was conducted for the Mississippi River Geomorphology and Potamology (MRG&P) Program under the Mississippi Valley Division through the MRG&P Program. The MRG&P director was Mr. David May.

The work was performed by the River and Estuarine Engineering Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). At the time of publication of this report, Mr. Casey Mayne was branch chief; Dr. Cary A. Talbot was division chief. The deputy director of ERDC-CHL was Mr. Keith Flowers, and the director was Dr. Ty V. Wamsley.

The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

1 Introduction

1.1 Background

The Mississippi River SW2D Adaptive Hydraulics (AdH) model containing the Interstate 20 (I-20) and Highway 80 bridges reach near Vicksburg, MS, was originally developed to investigate the effect of the Marshall Brown Dikes on the velocity distributions and navigation currents through this reach. Alternatives were tested for navigational impacts through the reach. The model was validated to four separate hydrographs from different years (Jones et al. 2020).

Previous studies have been carried out to quantify the hydraulic effects of dike fields in the Mississippi River. The Natchez-to-Baton Rouge SW-2D AdH model was used to investigate the effects of dike fields in that reach (May et al. 2021). This study is another element of the overall effort to quantify the effects of dike fields on the hydrodynamics throughout the Mississippi River.

1.2 Objective

The objective of this study was to quantify the effects of dike fields on water surface elevation (WSE) profiles and velocity distributions through the Mississippi river reach near the I-20 and Highway 80 bridges using a previously calibrated and validated SW-2D AdH model (Jones et al. 2020).

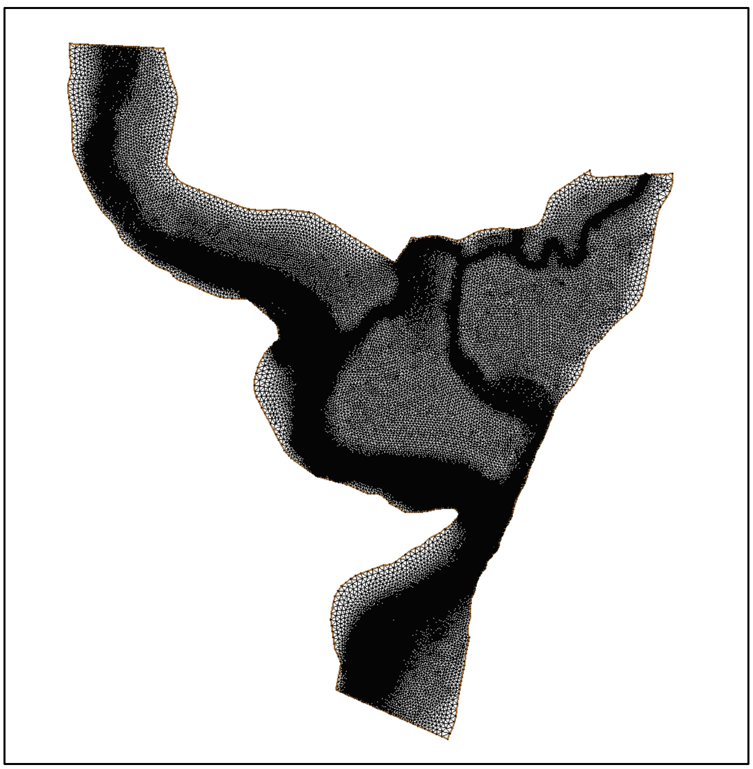
1.3 Approach

- The Mississippi River SW-2D AdH model containing the I-20 bridge reach near Vicksburg, MS, was chosen due to the dike fields present, the level of mesh refinement at the dikes, and the previously carried-out validation.
- Reasonable physical variations in elevation and roughness were chosen based on common sense.
- Appropriate steady state flows were identified and chosen based on previous studies (Jones et al. 2020).
- All scenarios were simulated, and all model output was analyzed to clearly illustrate the effects of the physical variations over the flow ranges.

2 Model Description

The model mesh is composed of 169,994 nodes and 339,105 elements. The projection is Mississippi West State Plane with units of feet. The vertical datum is NAVD88 in feet also. The model encompasses approximately 30 mi[1,2] of the Mississippi River and 17 mi of the Yazoo River. The element sizes vary from 1,000 ft in the overbank and along boundaries down to 10 ft in areas where the geometry is more dynamic. These complex geometry areas include dike locations in the mesh. (For a detailed description of the mesh development, including materials and friction values, see Jones et al. [2020]). Figure 1 below shows the entire model mesh.

Figure 1. Model mesh.



[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[2] For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

The model bathymetry was created from a combination of single-beam cross sections, multi-beam surveys, dike surveys, and a 2008 lidar dataset for the overbank areas within the model. (See Jones et al. [2020] for a detailed description of the bathymetry development for the model.) Figure 2 shows the model bathymetry.

Figure 2. Model bathymetry.

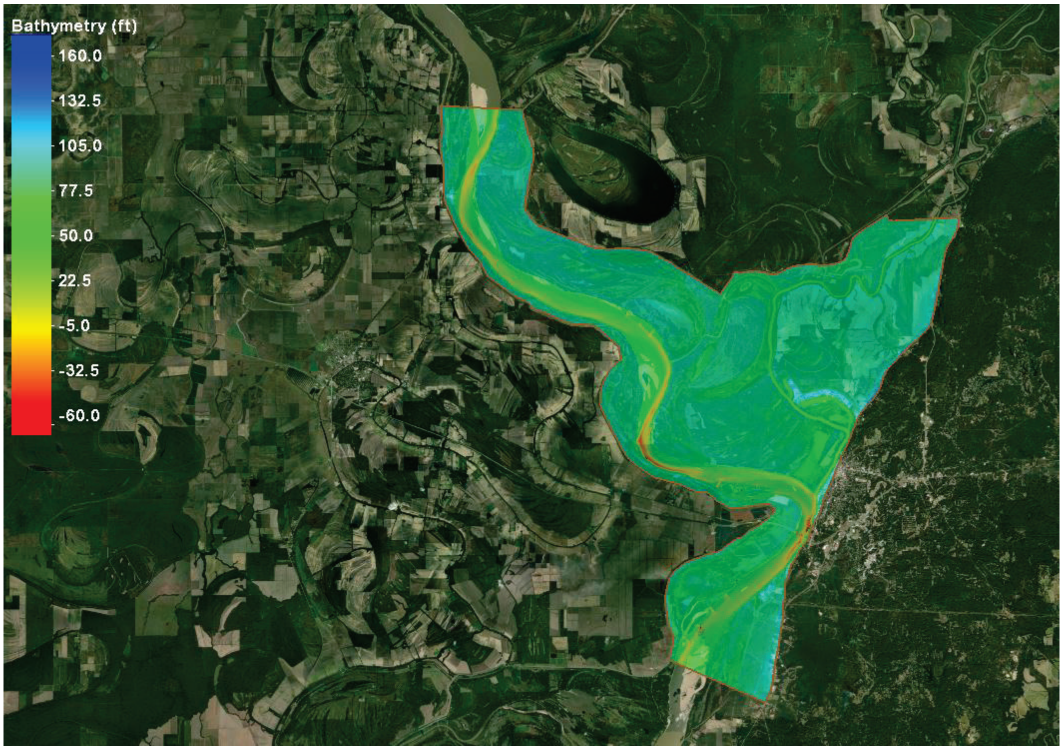


Figure 3 and Figure 4 show the model materials and, specifically, the dike locations in the upper and lower reaches of the domain. Dikes are shown by material 7 (light green). A detailed description of the model development, including the mesh and boundary condition development as well as the model validation to multiple historical floods, can be found in Jones et al. (2020).

Figure 3. Dike location examples/materials in upper model domain.

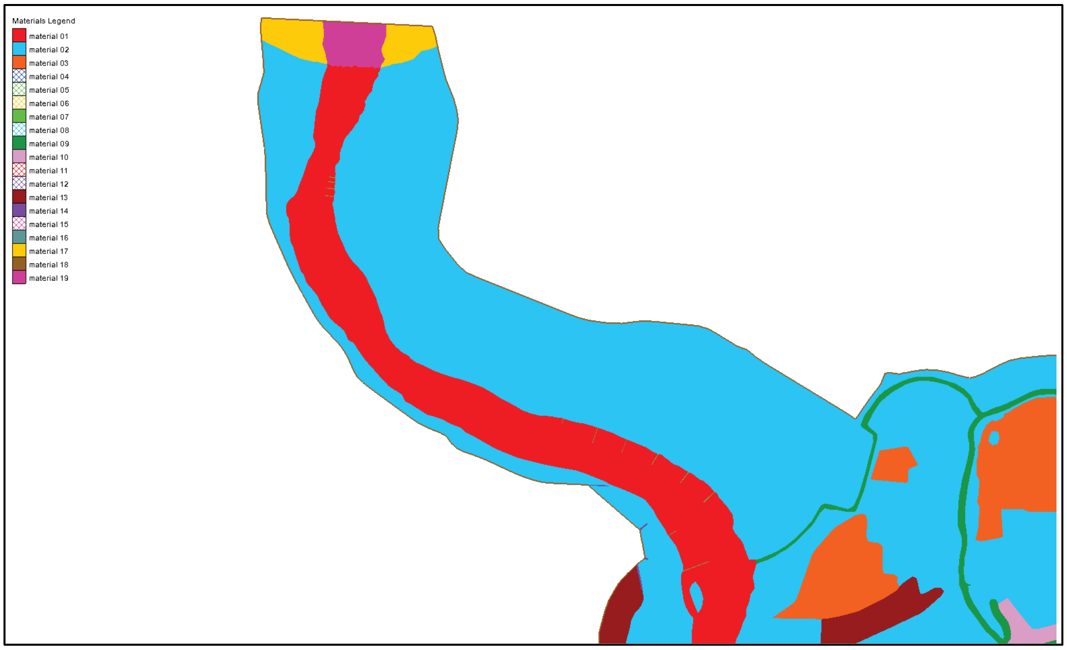
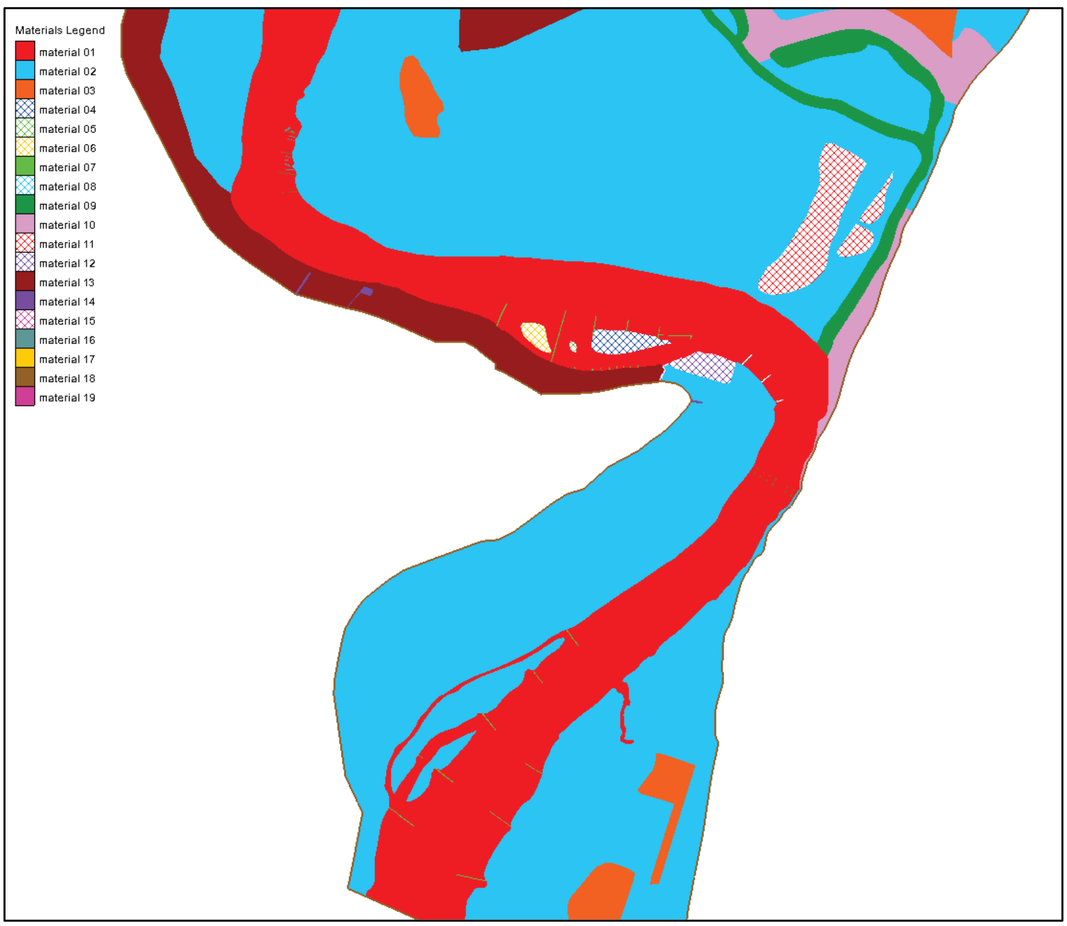


Figure 4. Dike location examples/materials in lower model domain.



3 Modeling Approach

Low, medium, and high flow conditions were simulated. These flow conditions (Table 1) were developed previously with the high flow corresponding to 50 ft on the Vicksburg US Geographical Survey gage. The medium flow was determined to be a representative average of approximately 25 ft on the gage, and the low flow was based off of the low water reference plane elevation. During low flow scenarios, the tips of the dikes can be seen above the water level. For high and medium flows, the Marshall Brown dikes are submerged at approximately 35 ft and 10 ft, respectively. (See Jones et al. [2020] for a detailed description of the development of these flow conditions.) This is a hydrodynamic model with a fixed bed, so note that there is no channel bed response modeled with this approach.

Table 1. Flow conditions for steady state simulations.

Flow Conditions	Flux (cfs)
Low	240,000
Medium	650,000
High	1,800,000

Model parameters were varied to quantify the hydraulic effects of dikes within this system. Dikes within the model domain were raised by 5%, 10%, and 15% of the existing elevation. Percentage increases of elevations were used to keep the relative dike shapes intact. A blanket elevation rise could change the relative shape and slopes along the dikes as they do not have constant elevations across the peaks. This method also allowed for easy control. The nodal elevations were easily selected by material number and the elevations modified there using a MATLAB script. Figure 5, Figure 6, and Figure 7 show the elevation modifications based on the 5% increase. The dikes were raised by approximately 3 ft on average with maximum changes of approximately 5 ft.

Figure 5. Dike elevation changes 5% elevation changes (top).

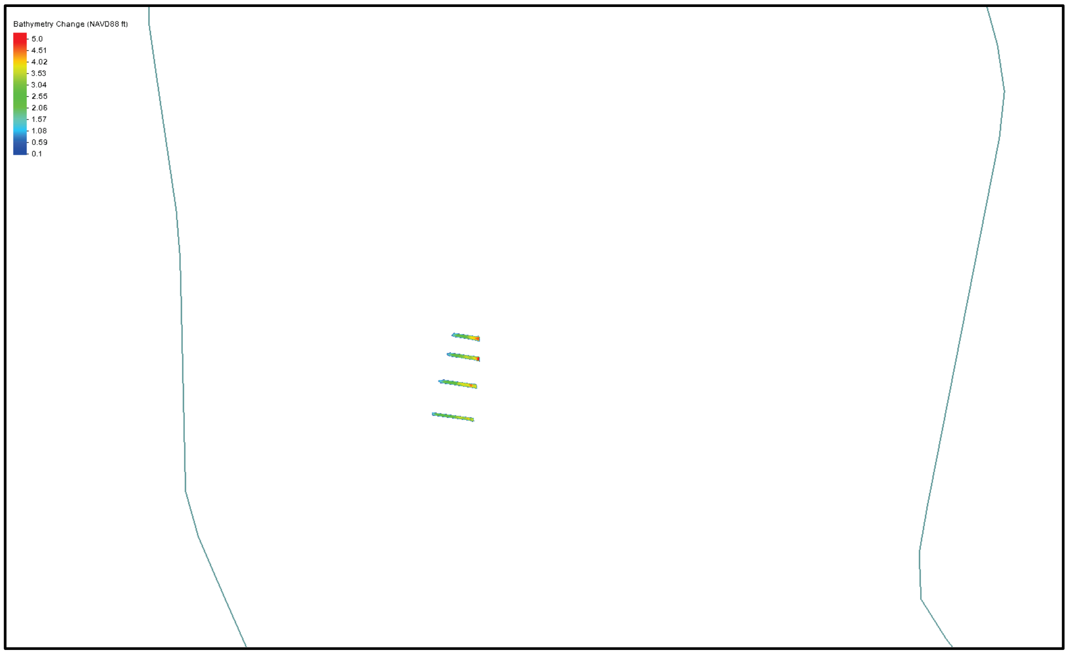


Figure 6. Dike elevation changes 5% elevation changes (middle).

Figure 7. Dike elevation changes 5% elevation changes (bottom).

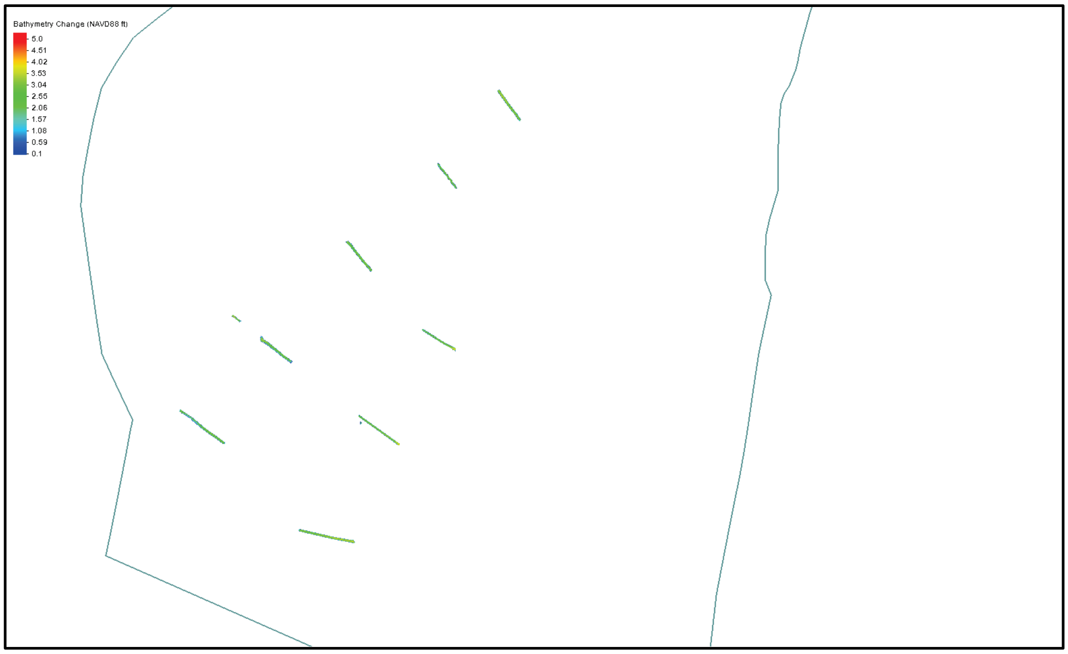


Figure 8, Figure 9, and Figure 10 illustrate the elevation changes based on the 10% increase along the dikes. The dikes were raised by approximately 6 ft on average throughout the domain with maximum changes of approximately 10 ft.

Figure 8. Dike elevation changes 10% elevation changes (top).

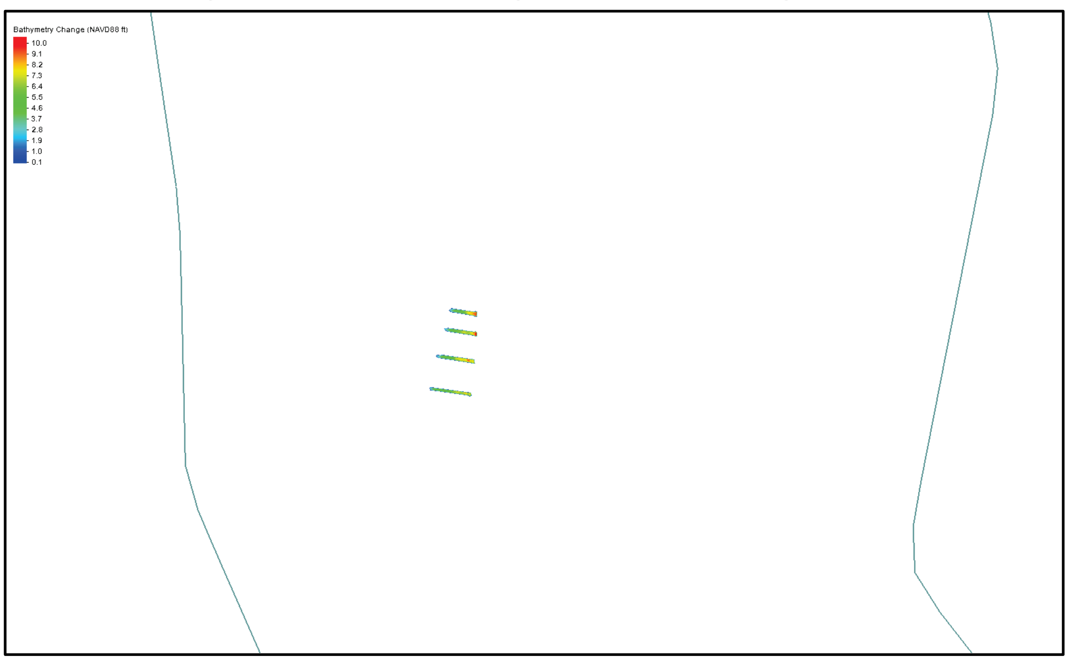


Figure 9. Dike elevation changes 10% elevation changes (middle).

Figure 10. Dike elevation changes 10% elevation changes (bottom).

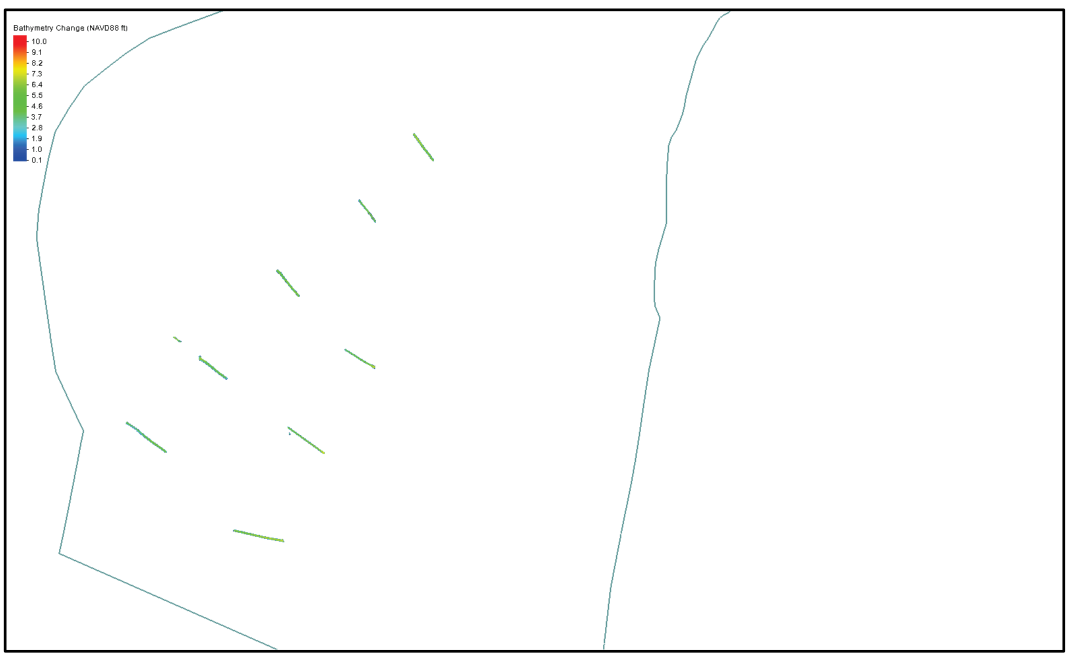


Figure 11, Figure 12, and Figure 13 show the elevation variations due to the 15% increase. The elevations were raised by approximately 10 ft on average with maximum increases of approximately 15 ft.

Figure 11. Dike elevation changes 15% elevation changes (top).

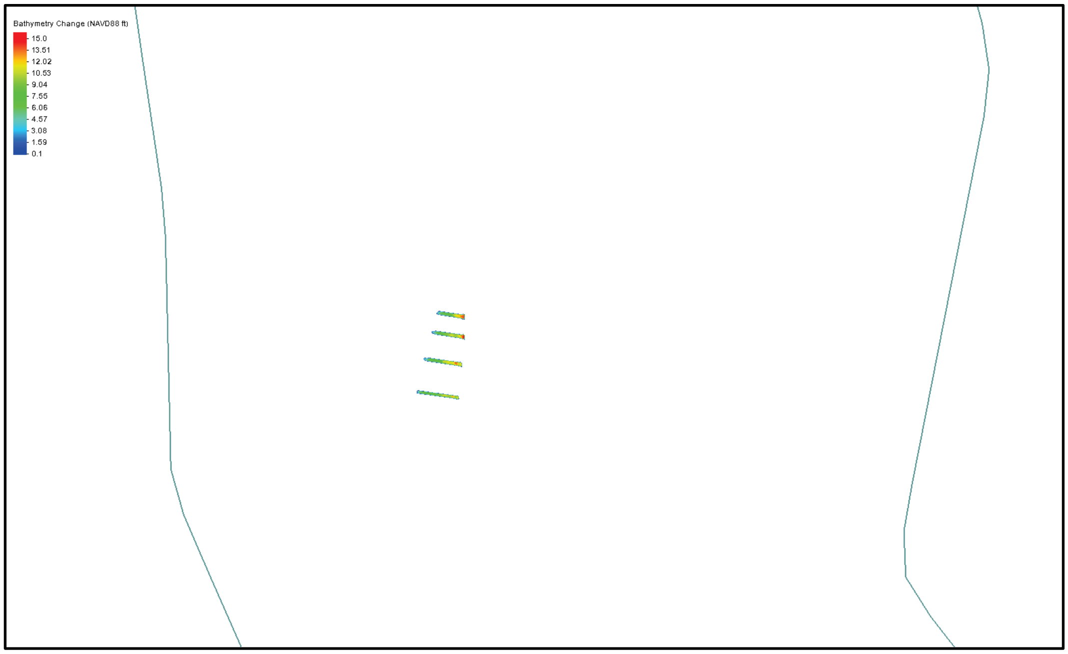


Figure 12. Dike elevation changes 15% elevation changes (middle).

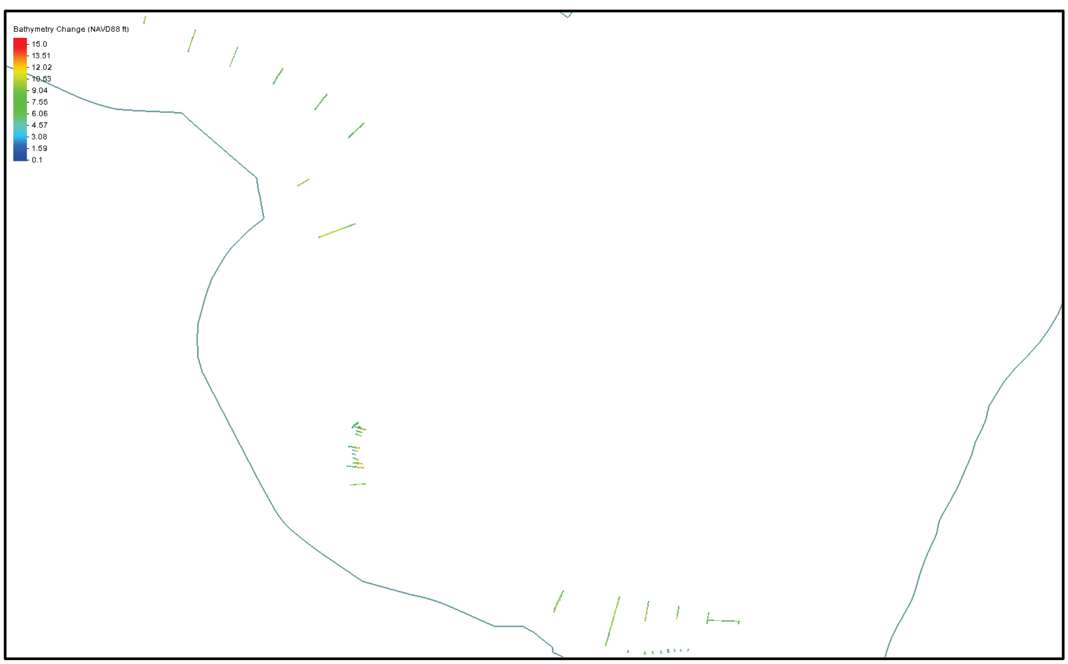
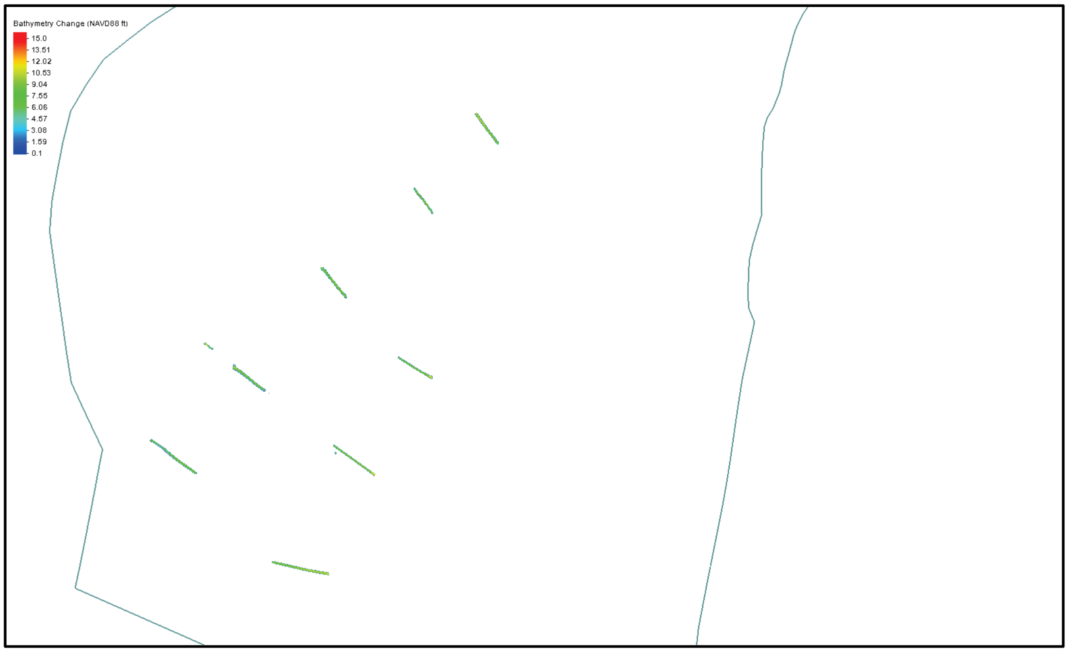


Figure 13. Dike elevation changes 15% elevation changes (bottom).



Roughness parameters were also varied uniformly across the existing dikes. The original model used a Manning's *n* of 0.04, indicated with a MNG card in the AdH boundary condition file, for the existing dikes, which is representative of a partially vegetated or stony channel bottom. The Manning's *n* value was increased to 0.06 to represent a completely vegetated or stony channel bottom. The Manning's *n* was also reduced to 0.0275, which is a representative of a clean reach in good shape (Brater et al. 1996). All variations in physical parameters were simulated with all three flow conditions. Submerged dike cards, SDK cards within the AdH model, were also adjusted to account for the changes in elevations. These cards are used to parameterize the plunge-down effects from dikes that are not accounted for in a 2D model.

4 Model Results

Figure 14 illustrates the thalweg, the dark line, of the river along this reach of the Mississippi River. The thalweg was approximately 170,000 ft long and was used to extract a WSE profile throughout the model domain for all flow conditions and all varied physical representations. Data were extracted every 100 ft along the thalweg for this analysis. This approach was used as WSE is consistent laterally, so this describes the variations throughout the reach better than a contour plot would.

Figure 14. Thalweg of river reach used for analysis.

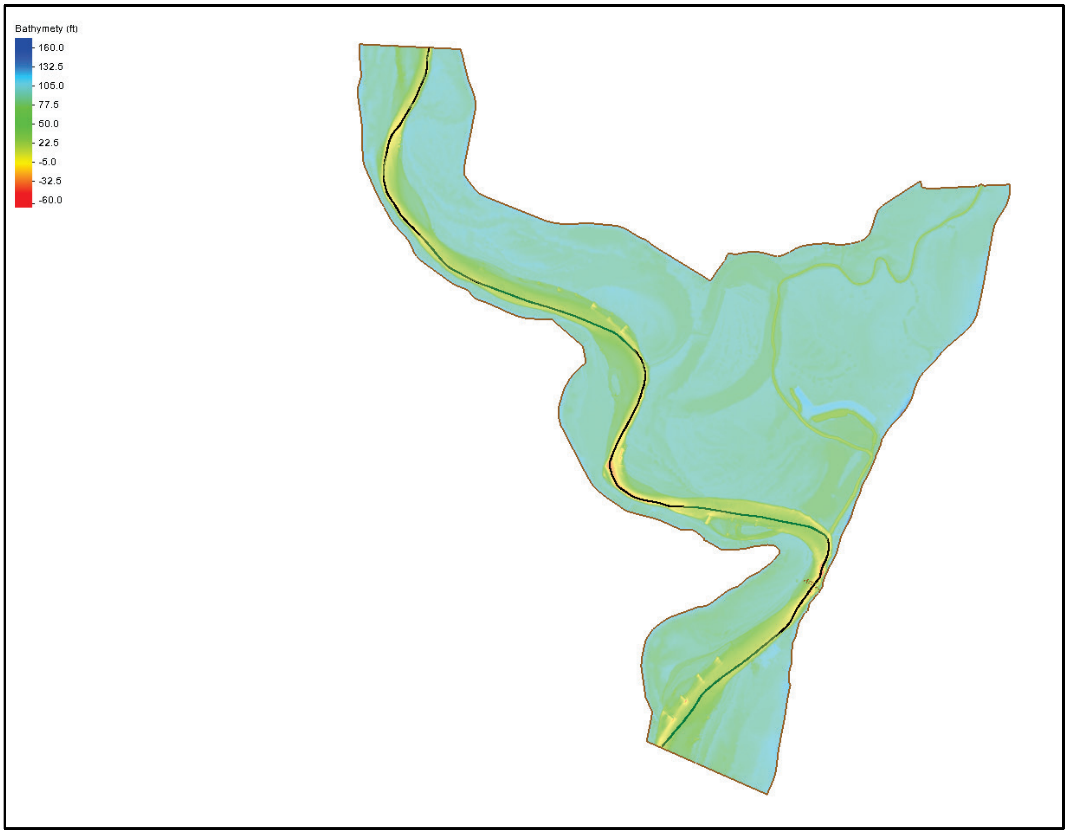


Figure 15 shows the WSE (NAVD88 ft) profile along the thalweg for the low flow condition for all six physical model variations. Overall, the changes along the profile are minimal. This is as expected as the dikes are still exposed for the low flow condition. It would make sense that deviations would be minimal for this condition. Table 2 shows the mean WSE along the thalweg for all six physical variations. This further confirms that the variations are minimal as the maximum difference from the base condition is 0.03 ft in the mean WSE profile. Figure 16 displays the WSE differences for the low flow condition for all six physical model variations.

Figure 15. WSE for low flow conditions.

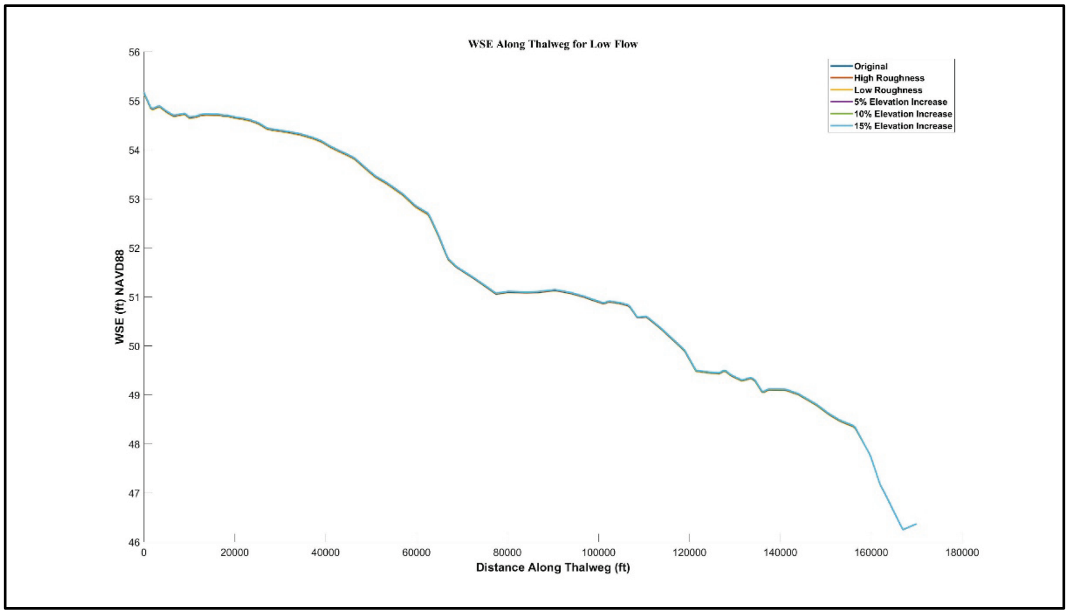


Figure 16. WSE difference for low flow conditions.

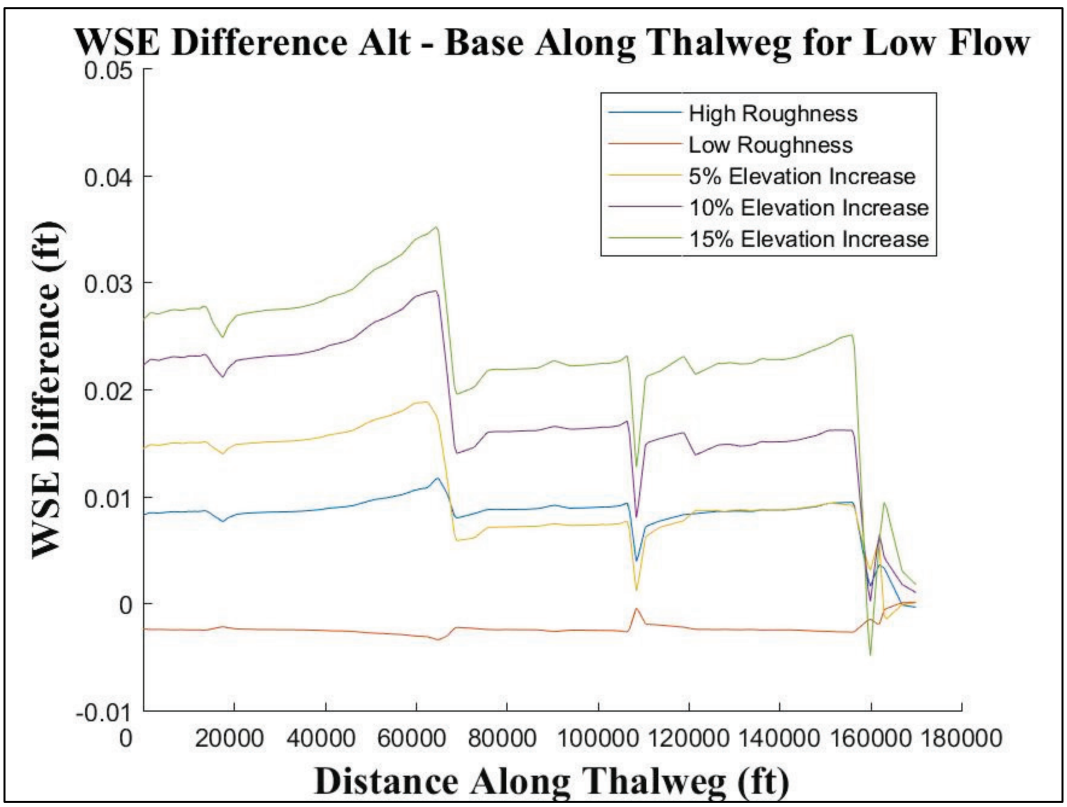


Table 2. Mean WSE (NAVD88 ft) for entire thalweg for low flow conditions.

Simulation	Mean WSE (NAVD88 ft)
Base	51.43
5% Elevation Increase	51.44
10% Elevation Increase	51.45
15% Elevation Increase	51.46
Decreased Roughness	51.43
Increased Roughness	51.44

Figure 17 shows the WSE profile for the medium flow condition. The effects for these simulations are more pronounced. This flow condition produces the most prominent changes in WSE, which makes sense. The dikes are fully submerged here, but not so submerged where physical changes to the dike field would have less noticeable effects on the hydraulics of the river, as with the high flow condition. The 15% elevation increase simulation has the most pronounced effect, as expected. The increased roughness simulation creates a change approximately equal to the 5% elevation increase simulation. The decreased roughness causes a very small decrease in the WSE profile. Table 3 displays the mean WSE values for the profiles shown below. The biggest change in the mean WSE is from the base condition to the 15% increase in dike elevation. This manifests a 4 in. increase to the mean WSE profile. All other variations are more miniscule. Figure 18 displays the WSE differences for the medium flow condition for all six physical model variations.

Figure 17. WSE for medium flow conditions.

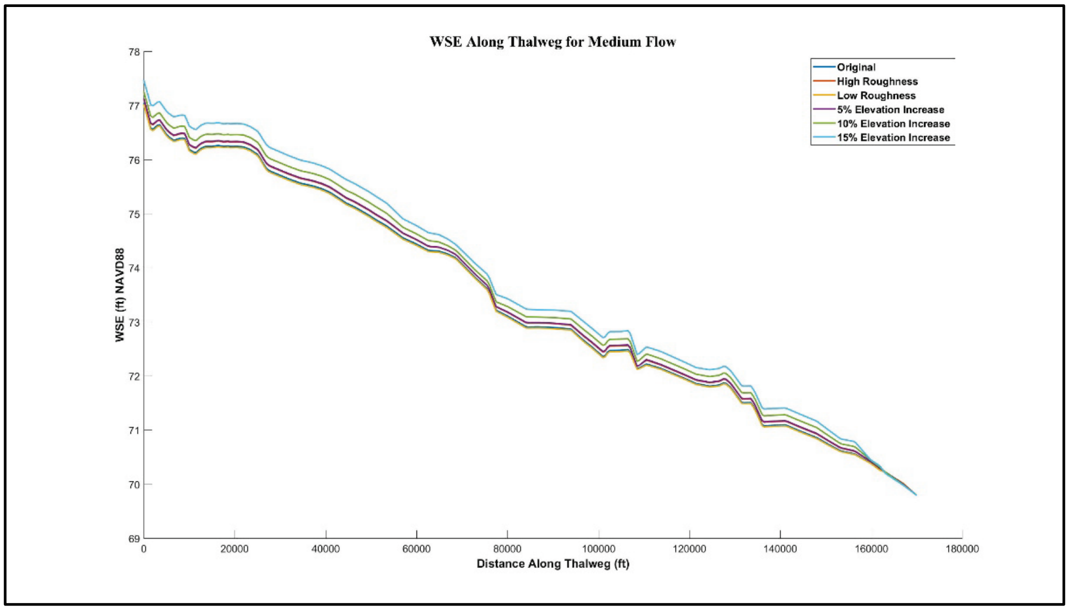


Figure 18. WSE difference for medium flow conditions.

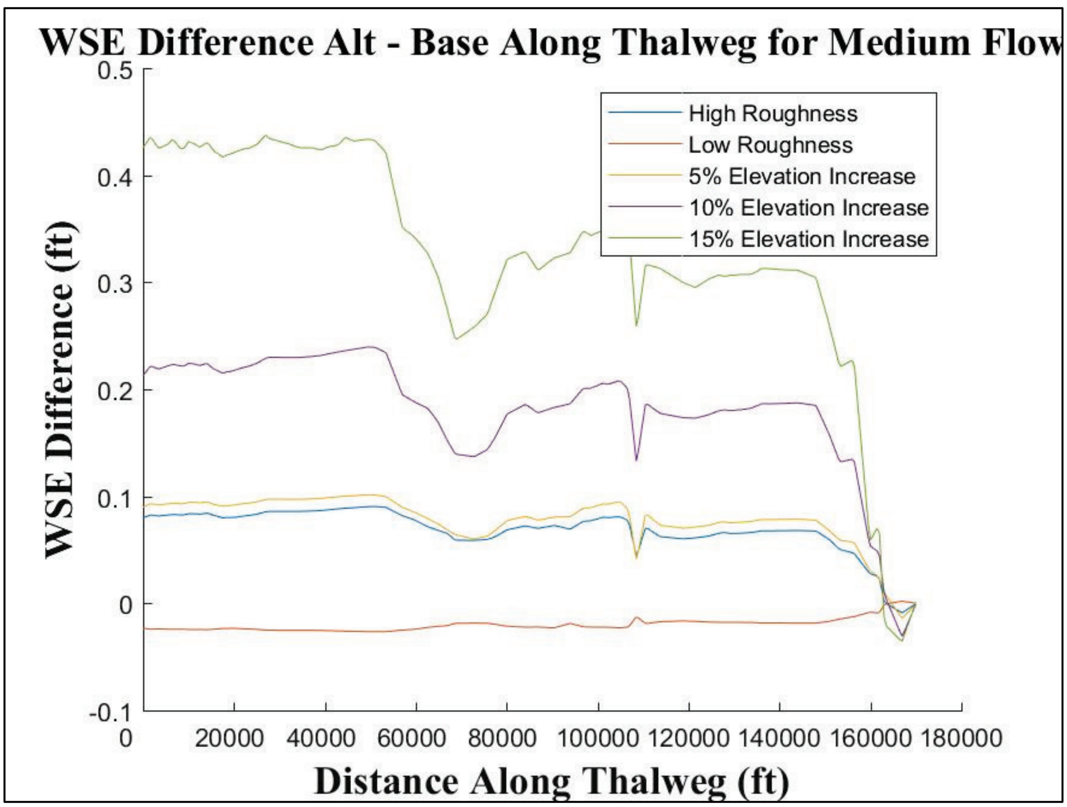


Table 3. Mean WSE (NAVD88 ft) for entire thalweg for medium flow conditions.

Simulation	Mean WSE (NAVD88 ft)
Base	73.35
5% Elevation Increase	73.43
10% Elevation Increase	73.53
15% Elevation Increase	73.68
Decreased Roughness	73.33
Increased Roughness	73.42

Figure 19 shows the WSE profiles for all six physical variations to the dike field for the high flow condition. As expected, the 15% elevation increase shows the biggest deviation from the base condition. The increased roughness WSE profile parallels the 5% elevation increase WSE profile, as with the medium flow condition. The changes are less pronounced than with the medium flow condition as the dikes would have less effects in general under these higher flow conditions. Table 4 displays the mean WSE along the profiles below. There is an increase of approximately 3 in. for the 15% elevation increase from the base condition. The other variations are less pronounced. Figure 20 displays the WSE differences for the high flow condition for all six physical model variations.

Figure 19. WSE for high flow conditions.

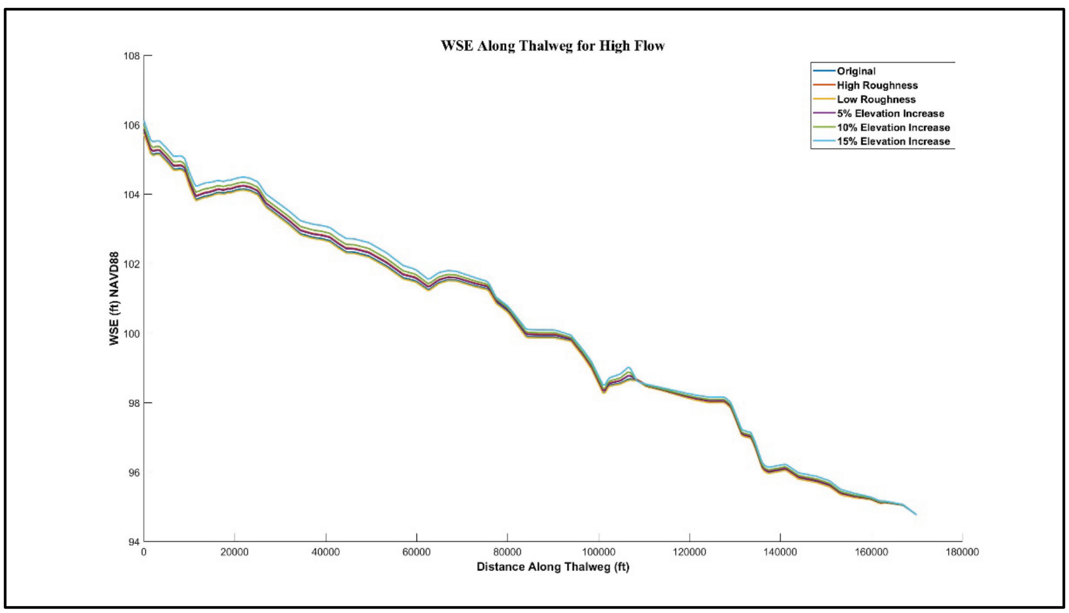


Figure 20. WSE difference for high flow conditions.

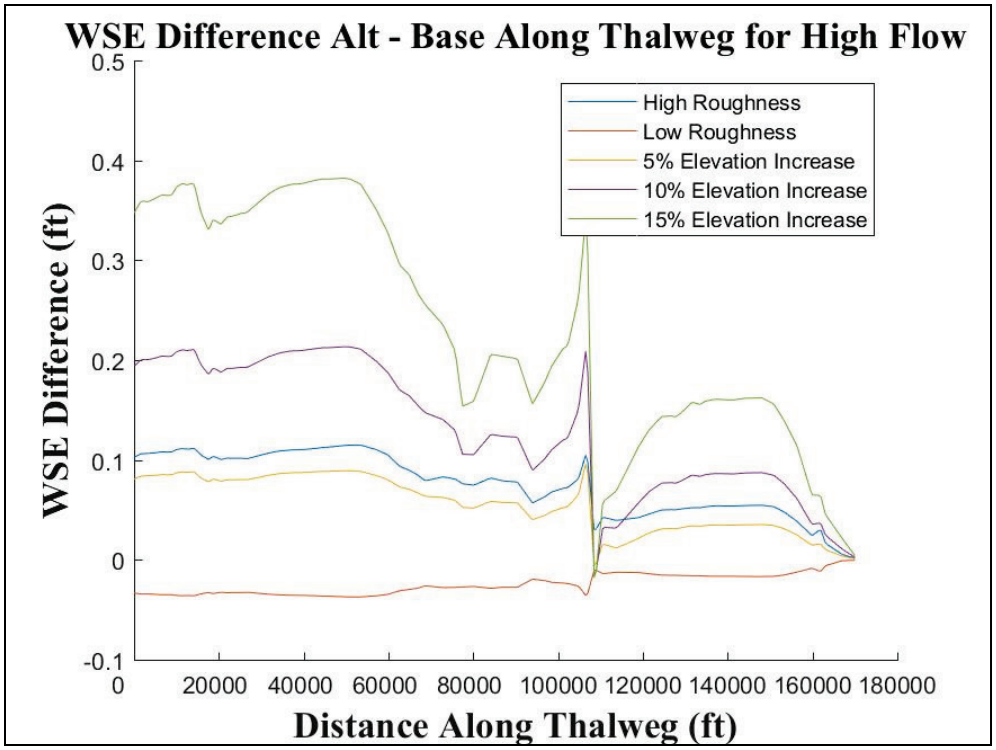


Table 4. Mean WSE (NAVD88 ft) for entire thalweg for high flow conditions.

Simulation	Mean WSE (NAVD88 ft)
Base	99.98
5% Elevation Increase	100.04
10% Elevation Increase	100.11
15% Elevation Increase	100.21
Decreased Roughness	99.96
Increased Roughness	100.06

Figure 21 shows the original velocity distribution for the low flow condition. Typical values are approximately 5 ft/s in the channel with maximums up to 10 ft/s in very specific areas. Figure 22 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 5% elevation increase variation for the low flow condition. The difference is contoured from -0.5 to 0.5 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are minimal here as the dikes have less effect on the low flow conditions. A small decrease in velocities for the 5% increase variation is shown in the lower reach local to the dikes along with a small increase in the channel off the edge of the dike.

Figure 21. Velocity magnitude for the base geometry with low flow.

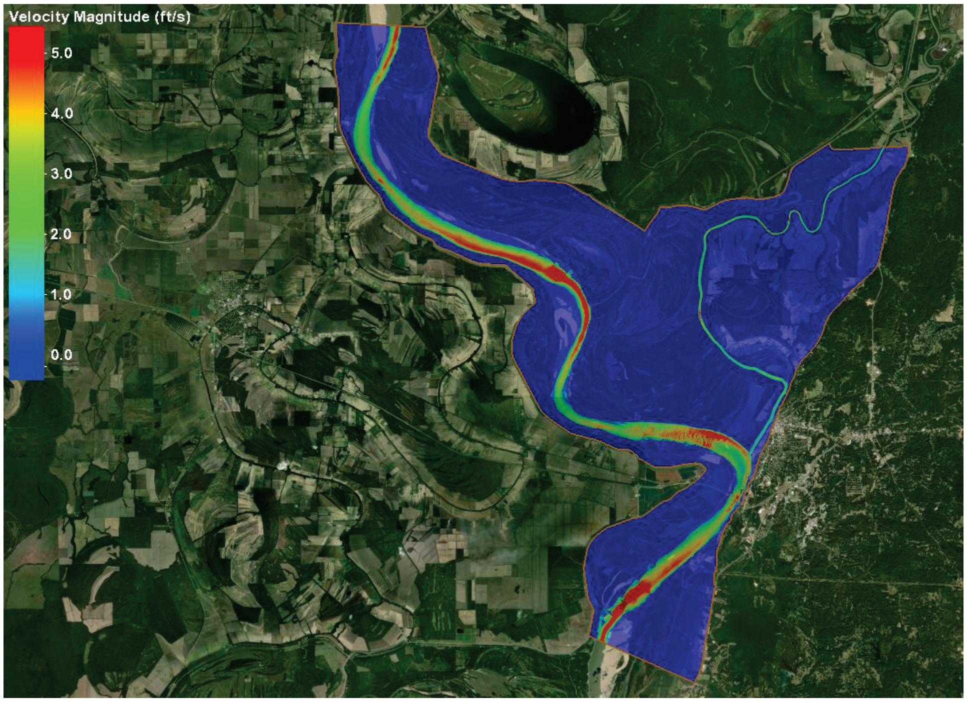


Figure 22. Velocity differences for original conditions minus the 5% elevation increase for low flow conditions.

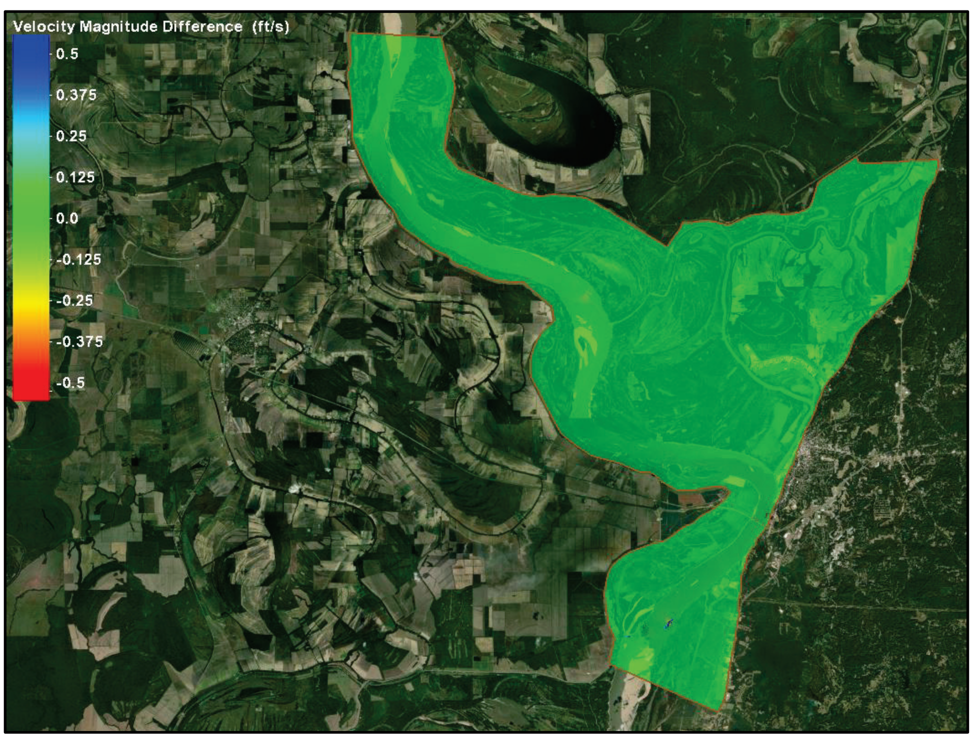


Figure 23 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 10% elevation increase variation for the low flow condition. The difference is contoured from -0.5 to 0.5 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are minimal here as the dikes have less effect on the low flow conditions. A small decrease in velocities for the 10% increase variation is shown in the lower reach local to the dikes there with a small increase in the channel off the edge of the dike. This change is more pronounced than with the 5% change simulation.

Figure 23. Velocity differences for original conditions minus the 10% elevation increase for low flow conditions.

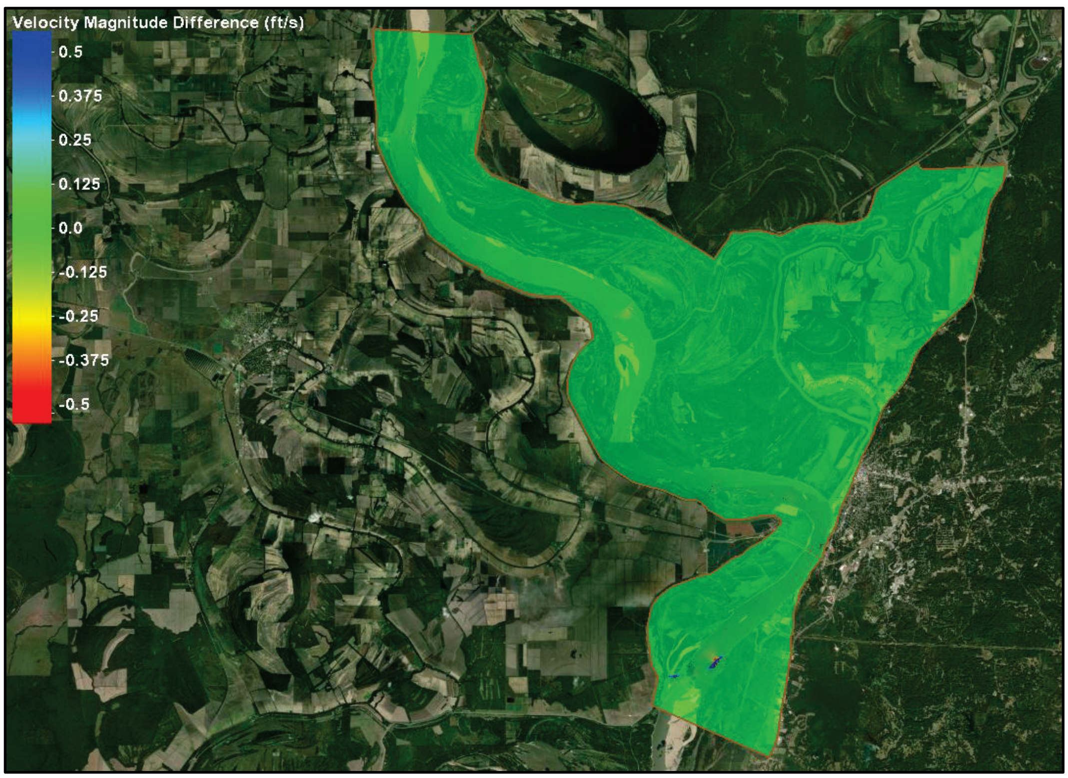


Figure 24 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 15% elevation increase variation for the low flow condition. The difference is contoured from -0.5 to 0.5 ft/s. Blue values indicate a positive difference or that the base condition is larger which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are minimal here as the dikes have less effect on the low flow conditions. A small decrease in velocities for the 15% increase variation is shown in the lower reach local to the dikes there with a small increase in the channel off the edge of the dike. This change is the most pronounced of all variations for the low flow condition.

Figure 24. Velocity differences for original conditions minus the 15% elevation increase for low flow conditions.

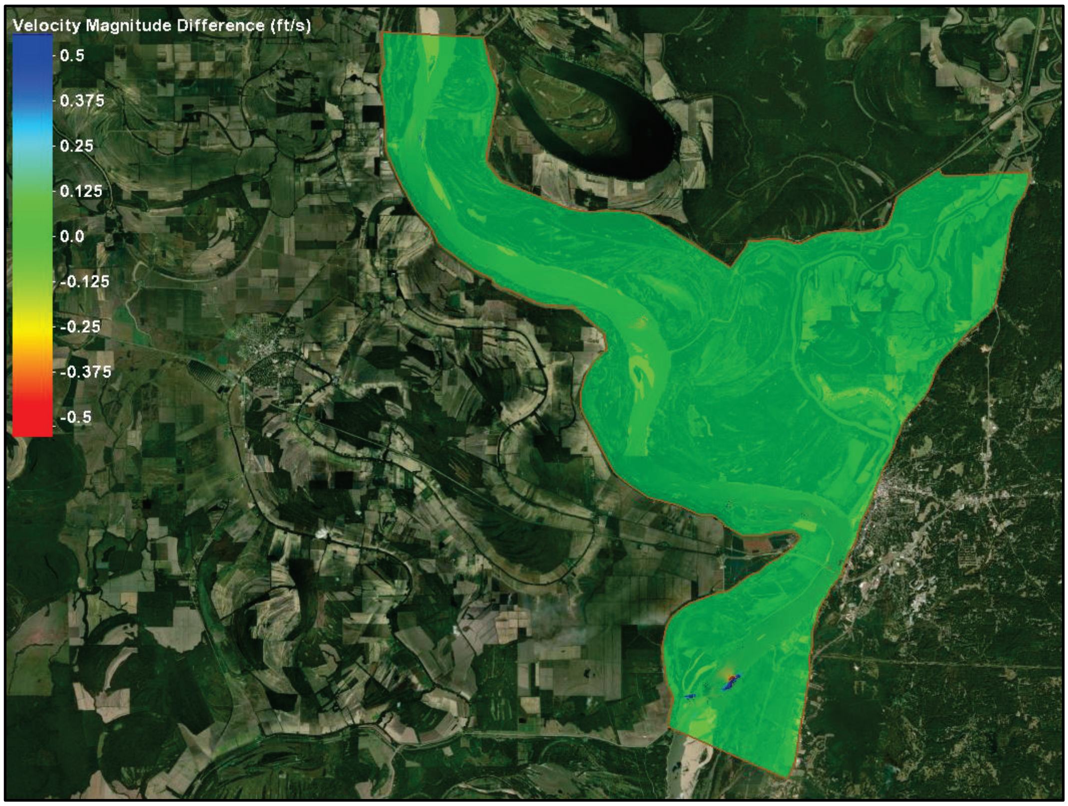


Figure 25 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the increased roughness variation for the low flow condition. The difference is contoured from -0.5 to 0.5 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are minimal here as the dikes have less effect on the low flow conditions. A small decrease in velocities for the increased roughness variation is shown in the lower reach local to the dikes there with a small increase in the channel off the edge of the dike. This change closely follows the same pattern as the 5% elevation increase simulation.

Figure 25. Velocity differences for original conditions minus the increased roughness for low flow conditions.

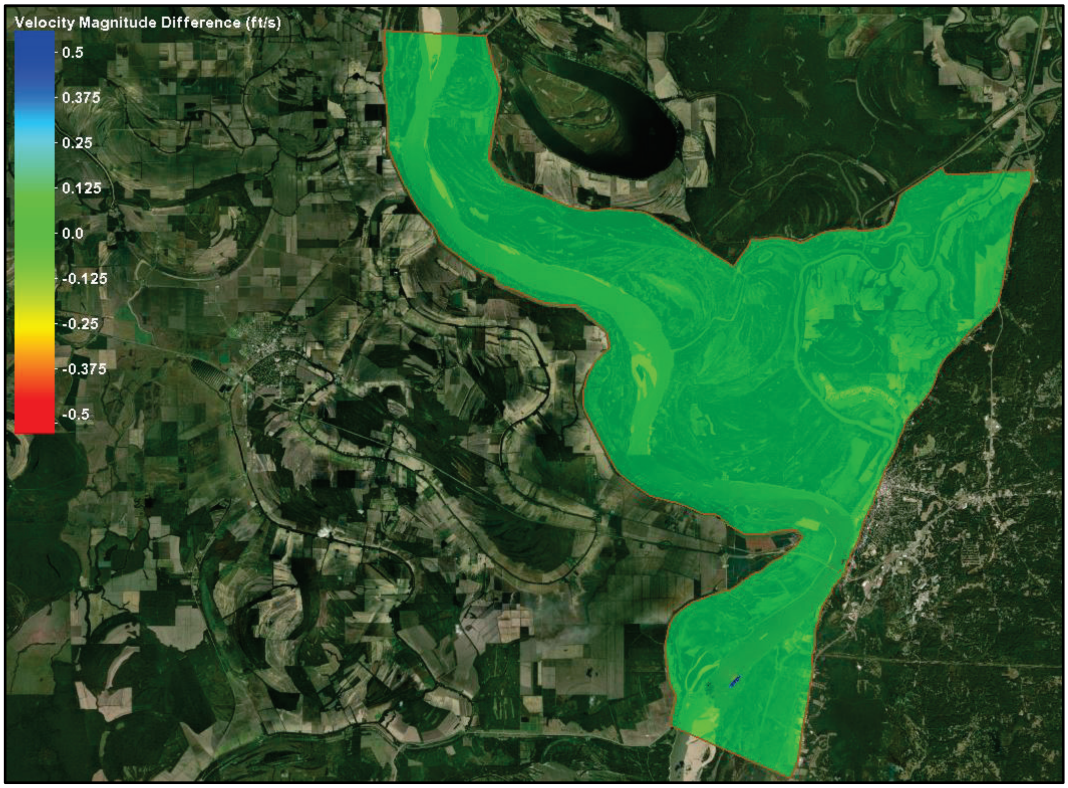


Figure 26 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the decreased roughness variation for the low flow condition. The difference is contoured from -0.5 to 0.5 ft/s. Blue values indicate a positive difference or that the base condition is larger which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are minimal here as the dikes have less effect on the low flow conditions. The differences here are too small to view.

Figure 26. Velocity differences for original conditions minus the decreased roughness for low flow conditions.

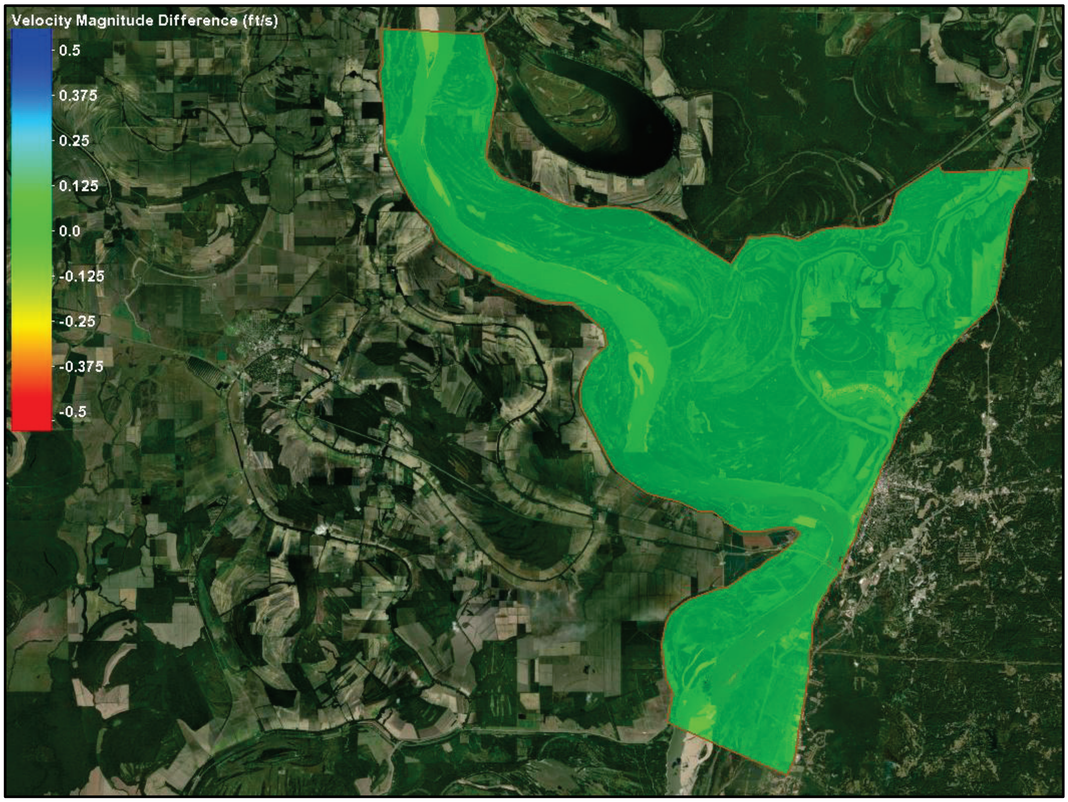


Figure 27 is the velocity magnitudes for the original geometry with medium flow conditions. Values can reach up to 6 ft/s within the channel and approach 10 ft/s as a maximum. Figure 28 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 5% elevation increase variation for the medium flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are the most pronounced as the dikes have the most effect on the medium flow conditions. Velocity decreases for the varied simulation can be seen throughout the reach local to the dike fields. There are also areas of increased velocities near the dikes in the central and lower domains. This is due to the flows moving to either side of the dikes due to the elevation variations.

Figure 27. Velocity magnitude for the base geometry with medium flow.

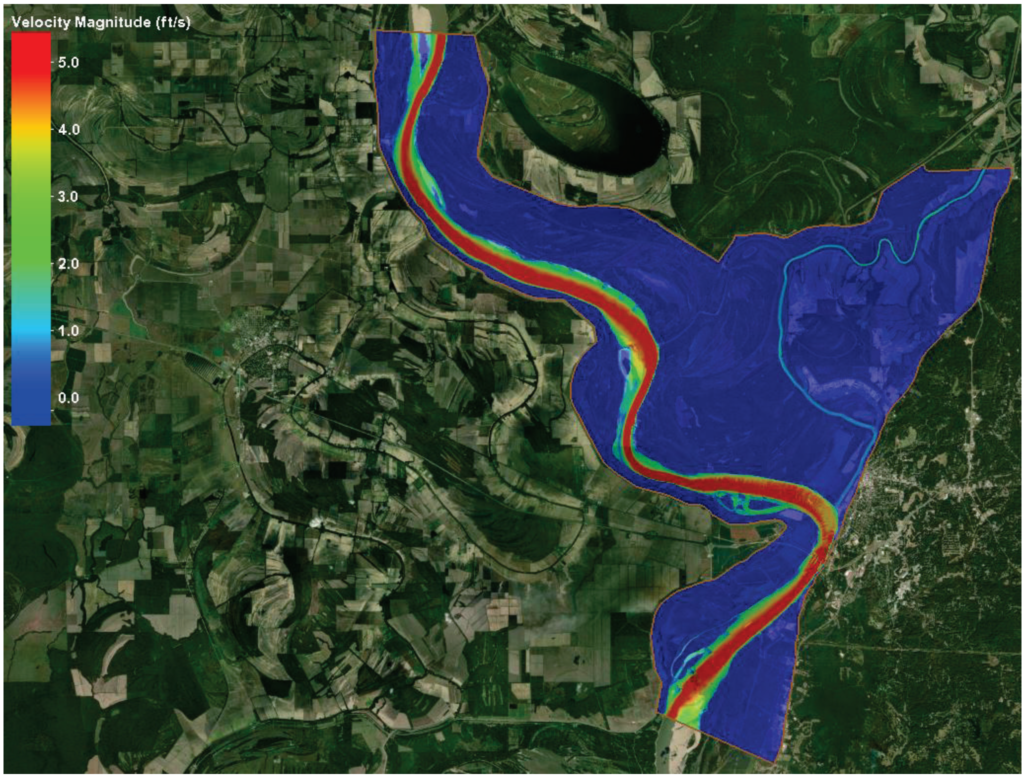


Figure 28. Velocity differences for original conditions minus the 5% elevation increase for medium flow conditions.

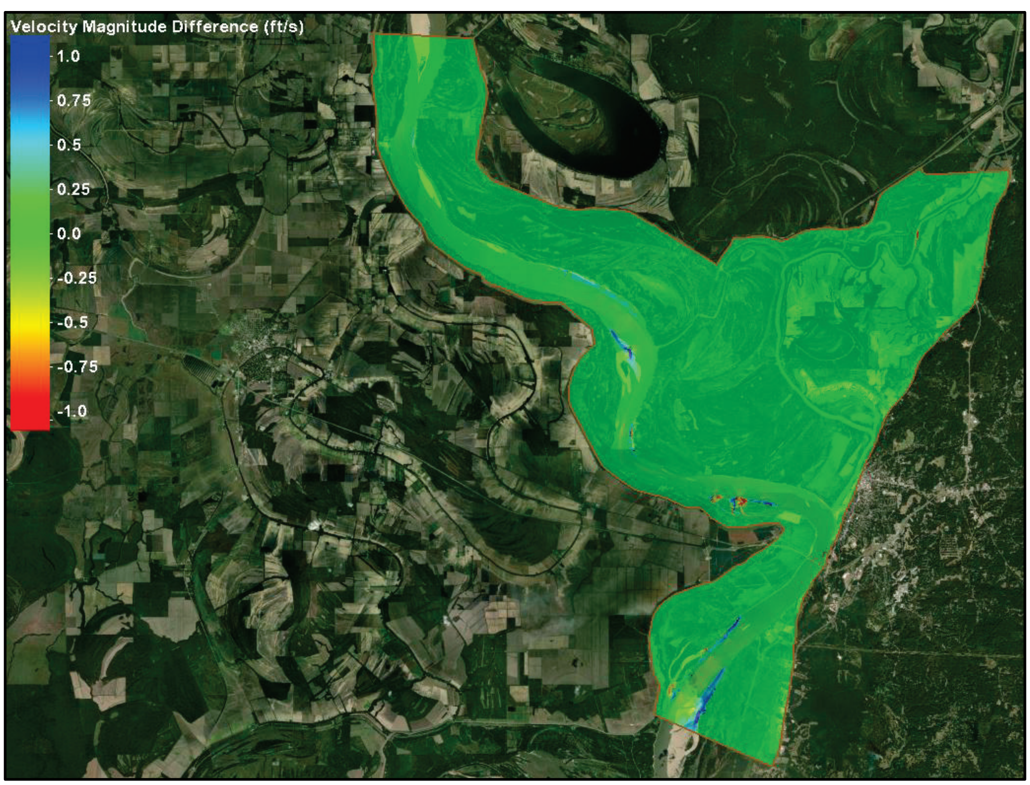


Figure 29 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 10% elevation increase variation for the medium flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are the most pronounced as the dikes have the most effect on the medium flow conditions. Velocity decreases for the varied simulation can be seen throughout the reach local to the dike fields. There are also areas of increased velocities near the dikes in the central and lower domains. This is due to the flows moving to either side of the dikes due to the elevation variations. The patterns are similar to the 5% conditions with more noticeable increases in velocities in the center channel, especially in the center and lower domain local to the dike fields.

Figure 29. Velocity differences for original conditions minus the 10% elevation increase for medium flow conditions.

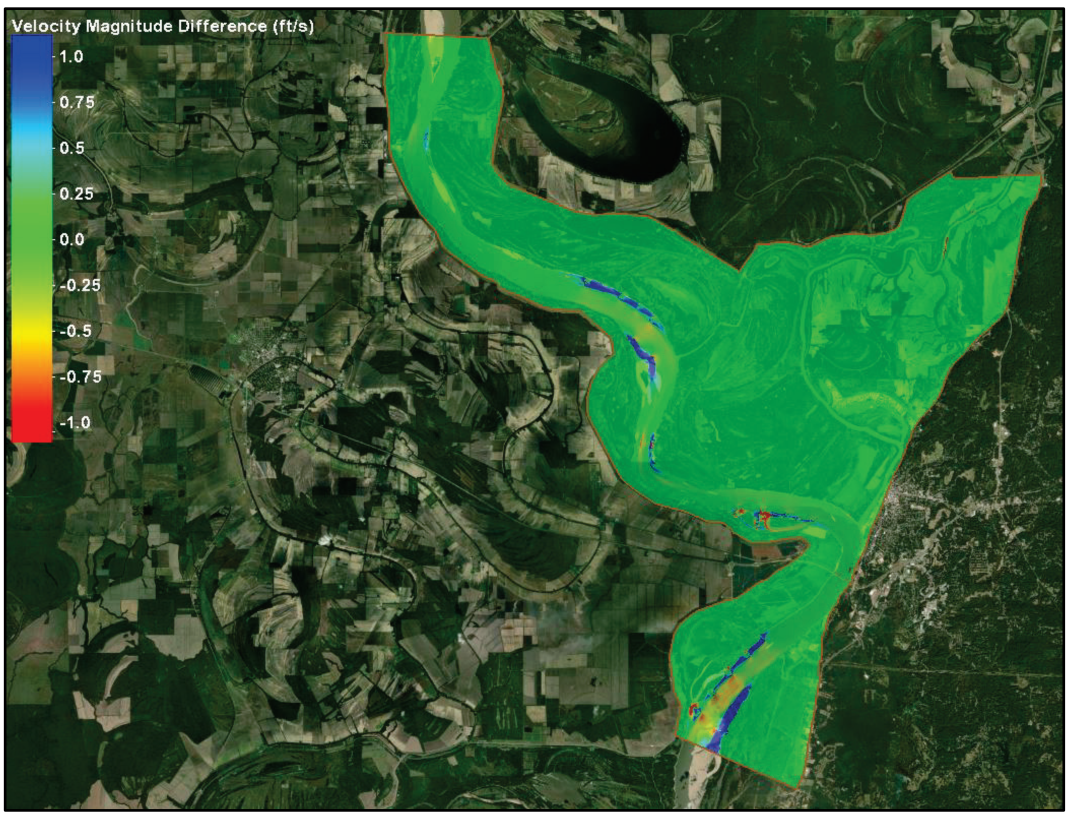


Figure 30 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 15% elevation increase variation for the medium flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Overall, the changes are the most pronounced as the dikes have the most effect on the medium flow conditions. Velocity decreases for the varied simulation can be seen throughout the reach local to the dike fields. There are also areas of increased velocities near the dikes throughout the domain. This is due to the flows moving to either side of the dikes due to the elevation variations. The patterns are similar to the 5% and 10% conditions with the most noticeable increases in velocities in the center channel, especially in the center and lower domain local to the dike fields.

Figure 30. Velocity differences for original conditions minus the 15% elevation increase for medium flow conditions.

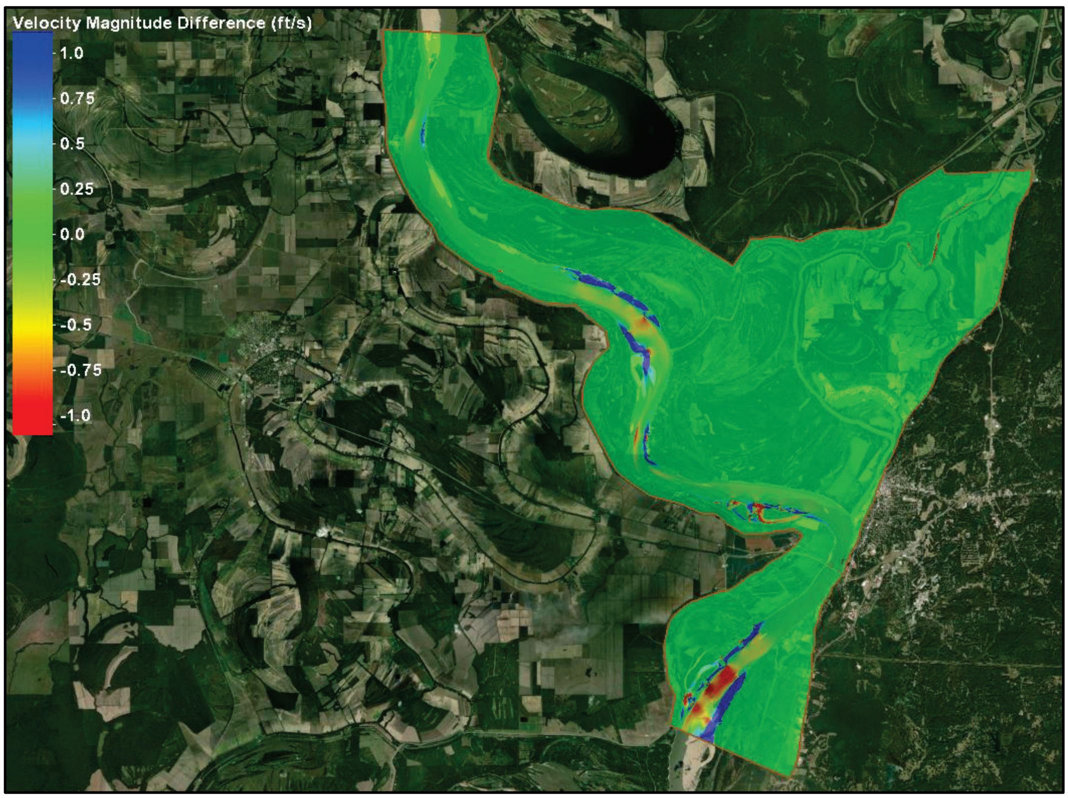


Figure 31 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the increased roughness variation for the medium flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. A small decrease in velocities for the increased roughness variation is shown throughout the reach local to the dikes there with a small increases in the center channel local to the dikes. This change closely follows the same pattern as the 5% elevation increase simulation.

Figure 31. Velocity differences for original conditions minus the increased roughness for medium flow conditions.

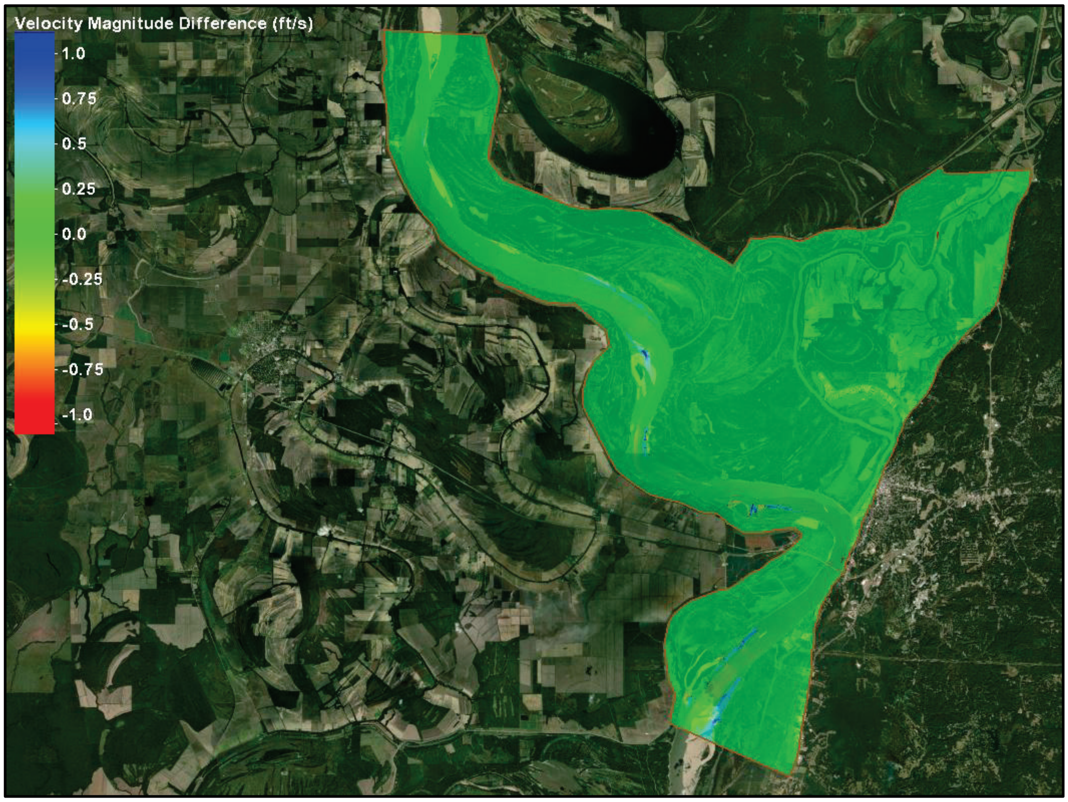


Figure 32 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the decreased roughness variation for the medium flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. There are small increased velocities along the banks local to the dike fields.

Figure 32. Velocity differences for original conditions minus the decreased roughness for medium flow conditions.

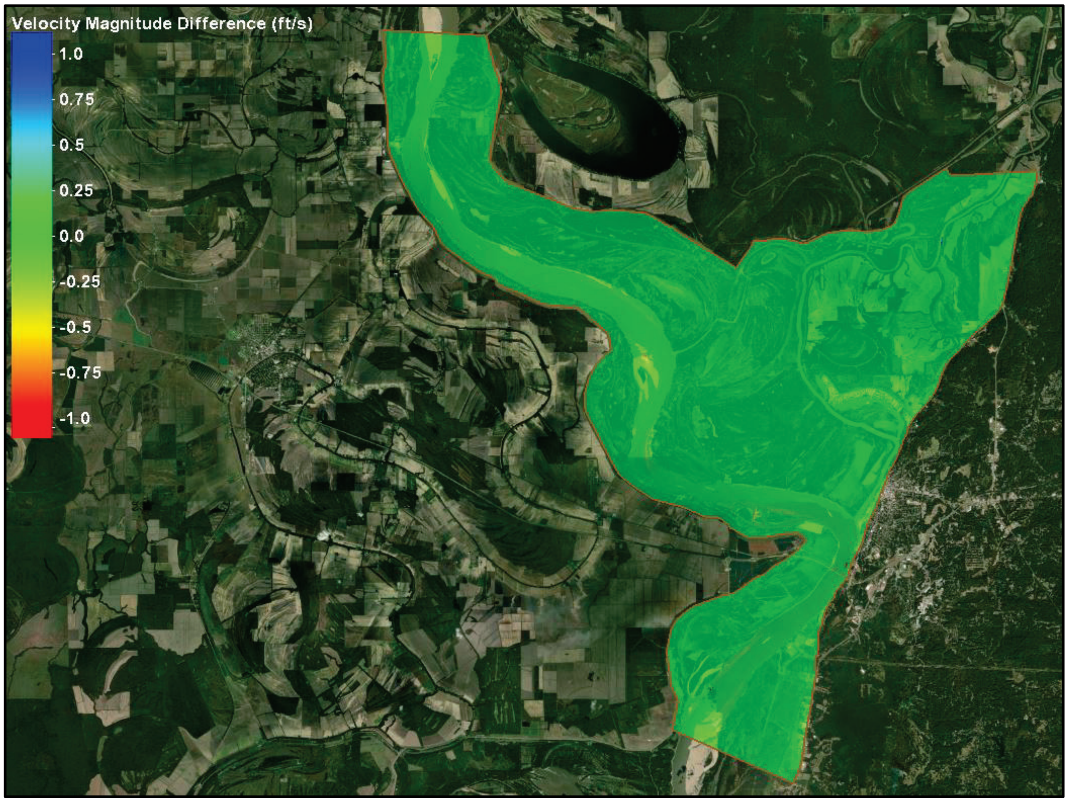


Figure 33 displays the velocity magnitude distribution for the high flow condition. Velocities are typically 8 to 9 ft/s within the channel and are at maximums of approximately 13 ft/s. Figure 34 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 5% elevation increase variation for the high flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. Reductions in the velocity magnitudes can be seen throughout the domain along the banks local to the dike fields. Slight increases in velocity can be seen opposite to the dike fields and in the channel.

Figure 33. Velocity magnitude for the base geometry with high flow.

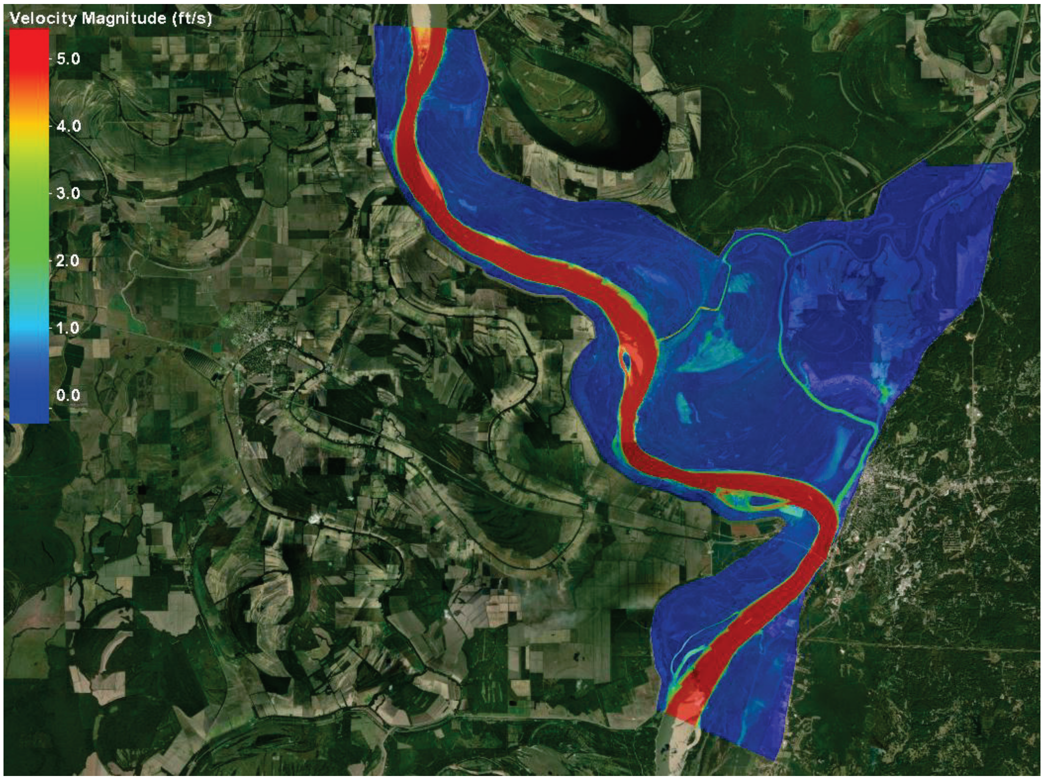


Figure 34. Velocity differences for original conditions minus the 5% elevation increase for high flow conditions.

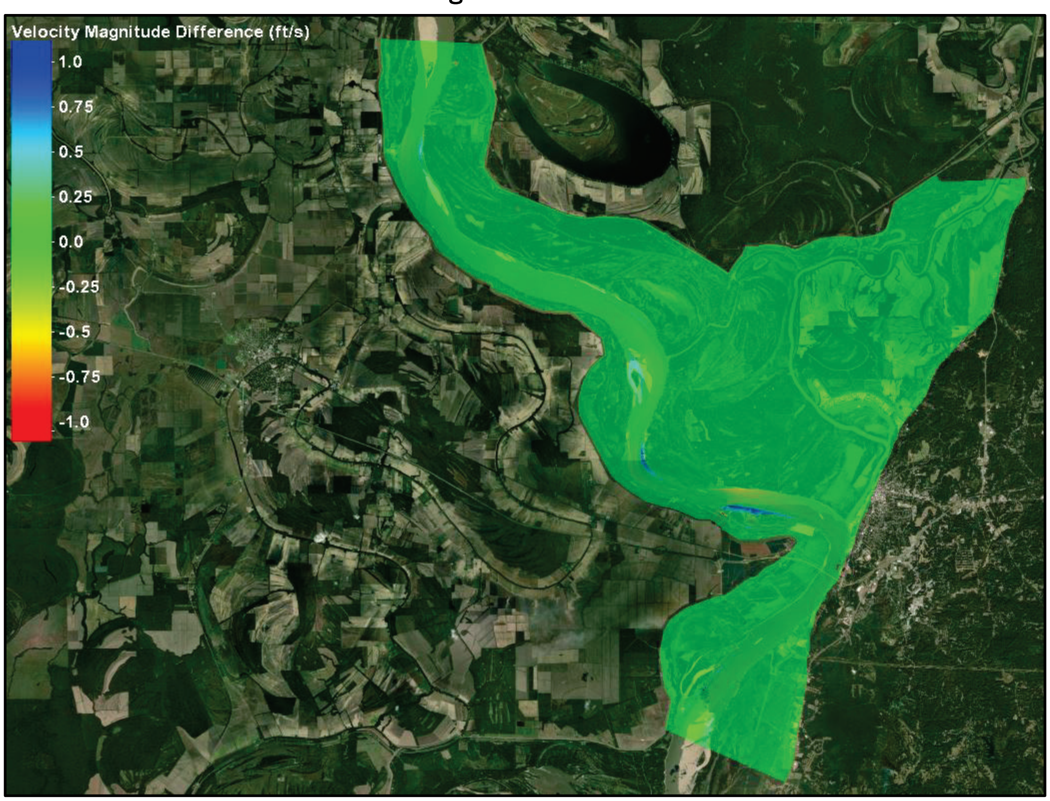


Figure 35 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 10% elevation increase variation for the high flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. The results have the same pattern as the 5% increase condition but are larger in magnitude.

Figure 35. Velocity differences for original conditions minus the 10% elevation increase for high flow conditions.

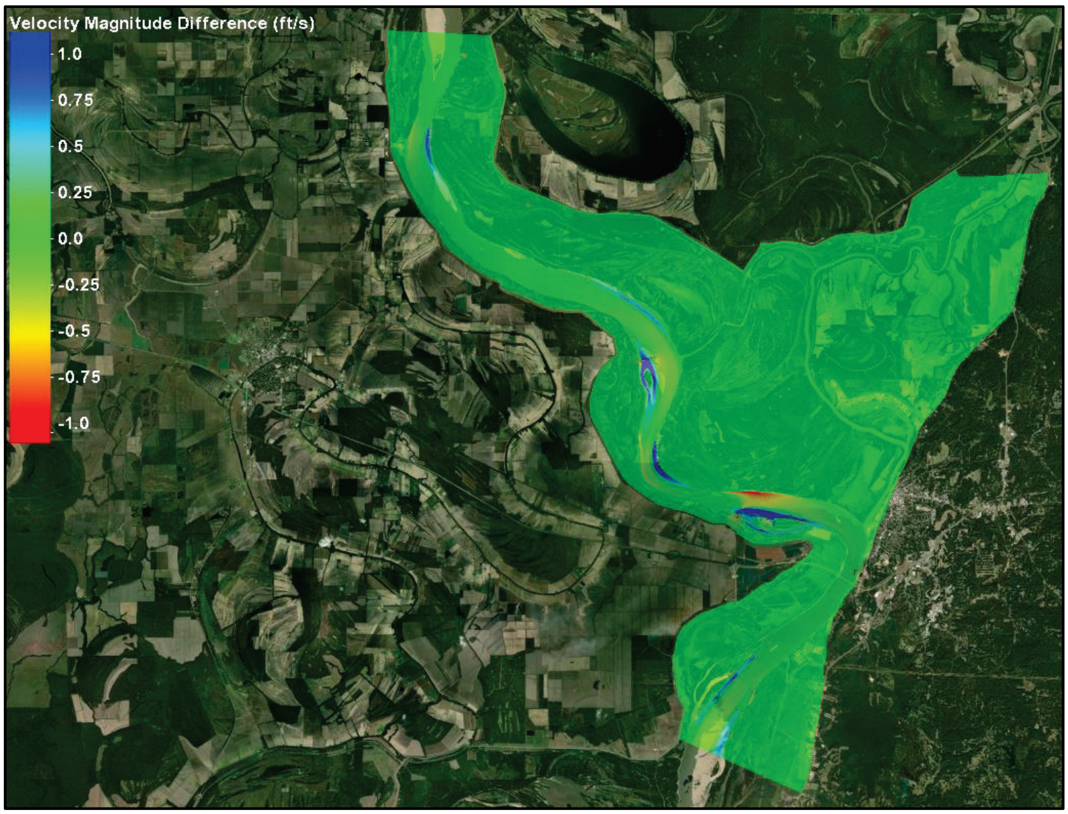


Figure 36 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the 15% elevation increase variation for the high flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. These results have the same form as the 5% and 10% but show the largest effect with the high flow condition with differences between 1 to 2 ft/s being typical.

Figure 36. Velocity differences for original conditions minus the 15% elevation increase for high flow conditions.

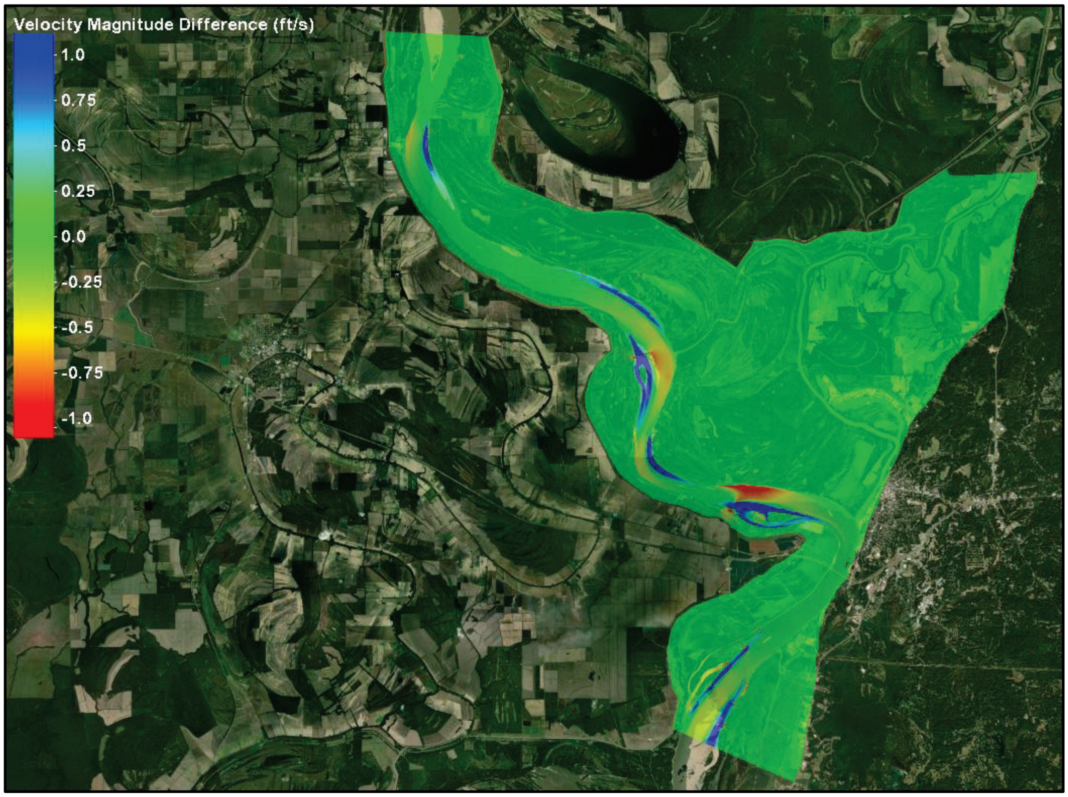


Figure 37 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the increased roughness variation for the high flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. This result closely follows the 5% as was shown for the low and medium flow conditions.

Figure 37. Velocity differences for original conditions minus the increased roughness for high low conditions.

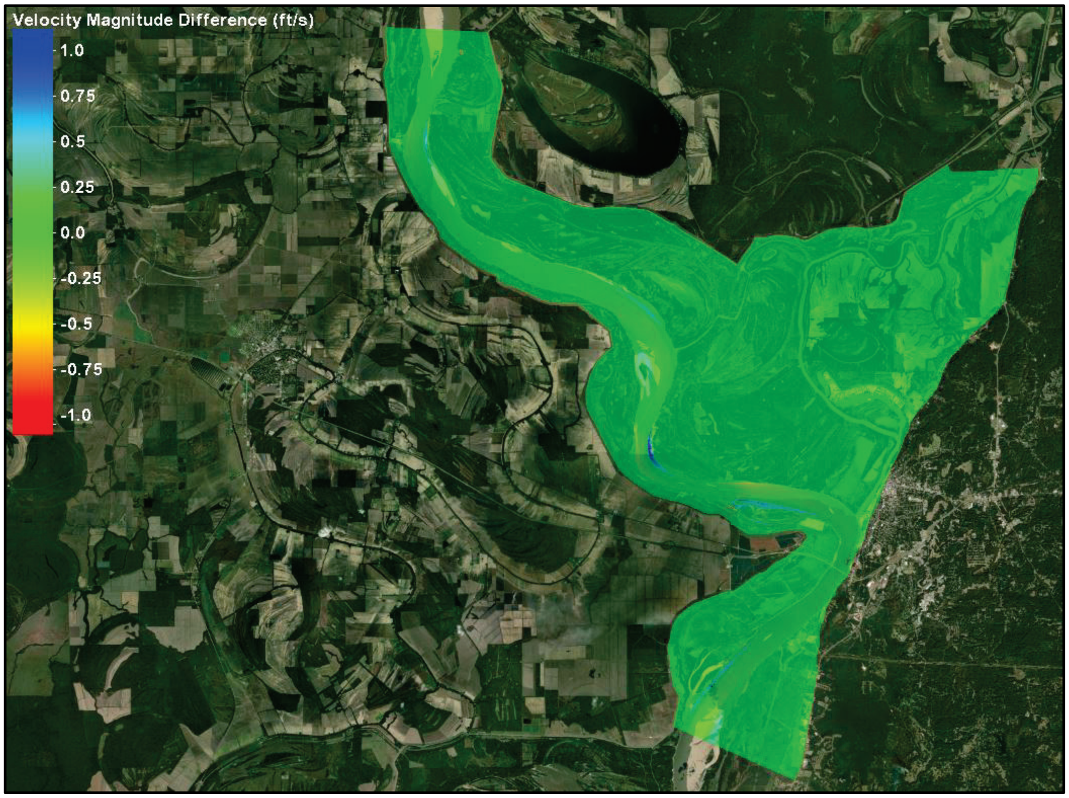
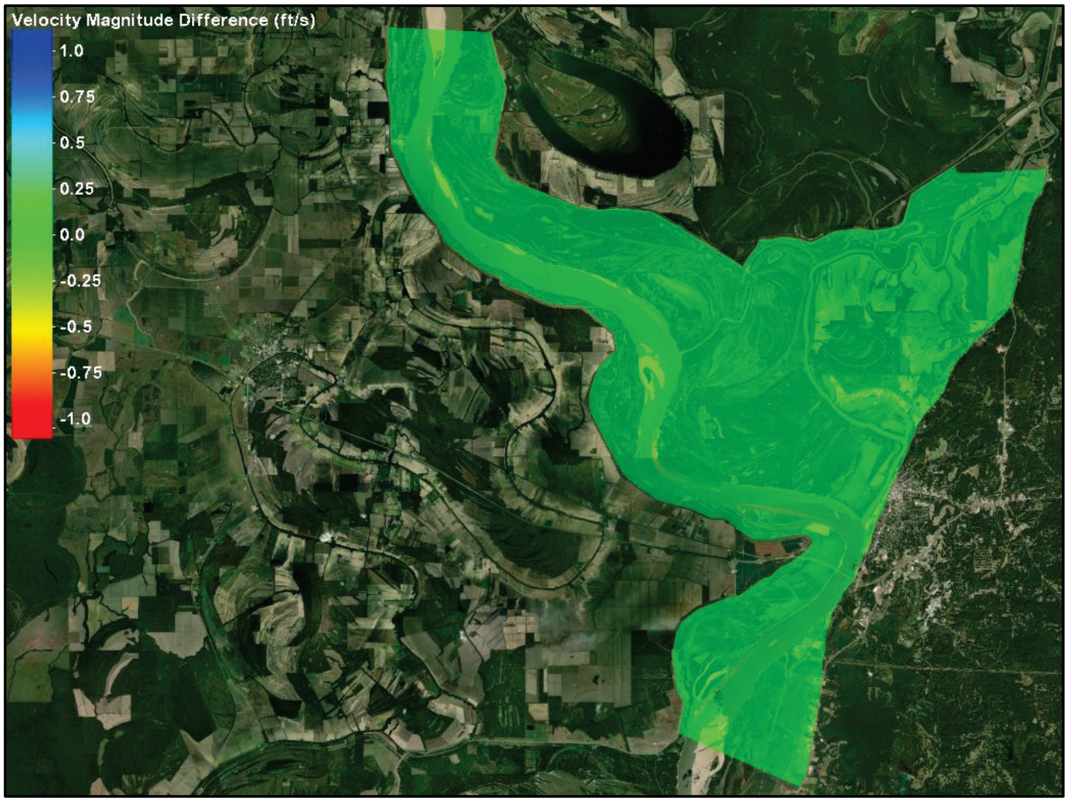


Figure 38 shows a difference plot of velocity magnitude (ft/s) of the base condition minus the decreased roughness variation for the high flow condition. The difference is contoured from -1 to 1 ft/s. Blue values indicate a positive difference or that the base condition is larger, which corresponds to a decrease in velocity values for the varied simulation. Red values indicate an increase in velocity values for the varied condition. This result is the opposite of what was seen with the increased roughness and elevation increases, as expected. There are small increases in velocity magnitudes shown along the banks local to the dike fields.

Figure 38. Velocity differences for original conditions minus the increased roughness for high flow conditions.



5 Conclusions

- Increases in dike elevation or roughness values increased WSE along the thalweg slightly. The largest increase in the mean WSE profile was with the 15% elevation increase for the medium flow condition (approximately a 10 ft increase to the dike elevations on average for the domain), which resulted in a 4 in. increase to the mean WSE profile. (Figure 16 and Table 3). The effects of varying the elevations and roughness of the dikes on WSE are negligible overall.
- Velocities were generally reduced local to the dike fields where elevation or roughness was increased. Velocities in the channels generally increased (Figure 18–Figure 32). The greatest variation can be seen in Figure 25, which shows the difference plot for the 15% elevation increase for the medium flow condition. Velocity magnitudes were decreased local to the dike field by approximately 1 ft/s and increased in the channel by approximately 1 ft/s. Once again, note that this elevation increase equates to approximately 10 ft on average for the domain.
- Dike variations had minimal to no noticeable effect for the low flow condition (Figure 15 and Figure 18–Figure 22). This is as expected due to the low flow condition being designed where most dikes in the system are emergent (Jones et al. 2020).
- Dike variations showed the most pronounced effect for the medium flow condition (Figure 16 and Figure 23–Figure 27). This is reasonable as the medium flow condition was designed to keep the Marshall Brown dikes submerged at approximately 10 ft (Jones et al. 2020). The effects of these variations will be more obvious due to the smaller amount of water in the column above when compared to the high flow condition which was designed to submerge the Marshall Brown dikes at approximately 35 ft (Jones et al. 2020).
- This study shows similar results to what was seen in *Hydraulic Dike Effects Investigation…Natchez to Baton Rouge,* a study carried out using the Natchez to Baton Rouge model (May et al. 2021), which found that the dike variations showed little to no impact on WSE profiles and resulted in changes on the scale of inches. This study agreed that the scale of change on the WSE profiles was inches with a maximum change of 4 in. in the mean WSE profile for one condition. This study provides evidence that perturbations to the dikes in this system have negligible effects on WSE throughout this reach of the Mississippi River.

References

Brater, Ernest, Horace King, James Lindell, and CY Wei. 1996. *Handbook of Hydraulics*. New York: McGraw-Hill Education.

Jones, Keaton, Tate McAlpin, and Terry Waller. 2020. *Hydraulic Analysis and Modeling of Navigation Conditions Near the Mississippi River Bridges in Vicksburg, Mississippi*. 2020. MRG&P Report No. 33. Vicksburg, MS: US Army Engineer Research and Development Center.

May, David, David Biedenharn, Tate McAlpin, and Ty V. Wamsley. 2021. *Hydraulic Dike Effects Investigation on the Mississippi River: Natchez to Baton Rouge*. MRG&P Report No. 37. Vicksburg, MS: US Army Engineer Research and Development Center.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
November 2022	Final Report	FY21—FY22

4. TITLE AND SUBTITLE
Numerical Analysis of Dike Effects on the Mississippi River Using a Two-Dimensional Adaptive Hydraulics Model (AdH)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
C. Jared McKnight, David P. May, and Keaton Jones

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
MRG&P Report No. 44

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Mississippi River Geomorphology and Potamology (MRG&P) Program
US Army Corps of Engineers, Mississippi Valley Division
1400 Walnut Street
Vicksburg, MS 39180-3262

10. SPONSOR/MONITOR'S ACRONYM(S)
MRG&P

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Mississippi Valley Division through the MRG&P Program

14. ABSTRACT
This report describes the hydraulic effects of dikes on water surface elevation (WSE) and velocities in the Mississippi River near Vicksburg, MS, from Interstate 20 to Highway 80 using a previously calibrated 2D Adaptive Hydraulics numerical model. Dike heights and their associated hydraulic roughness values were varied to quantify the overall effects of adjustments to dike fields. Steady flows characterized as low, medium, and high conditions were simulated. The WSE and velocity difference plots were generated to illustrate the hydraulic effects on the river under all scenarios discussed above. Overall, the dike adjustments had negligible impacts on WSEs and showed minimal effects on velocities on a system wide scale.

15. SUBJECT TERMS
Dikes (Engineering), Hydraulic models, Hydraulic structures, Streamflow—Mississippi, Vicksburg (Miss.), Water levels—Mississippi River

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			C. Jared McKnight
					19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	SAR	42	601-634-2844