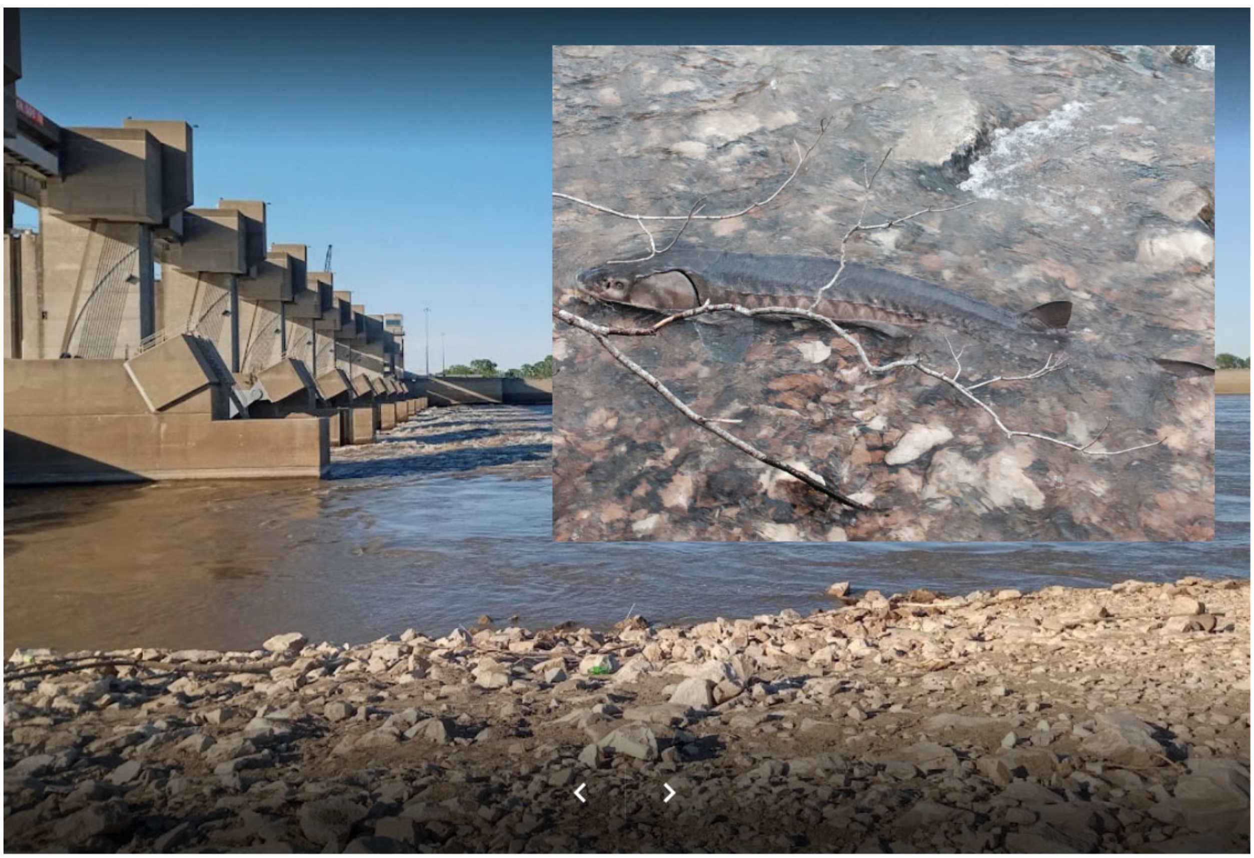
Mel Price Locks and Dam Hydraulic Assessment of Conditions Surrounding the 2015 Lake Sturgeon Spawn



US Army Corps of Engineers

October 2021

Cover photos by Missouri Department of Conservation

Contents

List of Figures

List of Tables

1.0 Introduction

In April of 2015, local fisherman along the right descending bank of the Mississippi River downstream of Mel Price Lock and Dam (L&D) witnessed and recorded video of lake sturgeon spawning. The state-listed species spawning in the Mississippi River has been of great concern to several government agencies but especially USACE and the Missouri Department of Conservation (MDC). This is one of the first recorded spawning events in the area. In addition, historical overharvesting and habitat degradation have made lake sturgeon uncommon is Missouri and Illinois.

With the help of funding from the Sustainable Rivers Program, the hydraulic conditions were analyzed for the April 2015 spawning event to see if it is possible to model the conditions and reproduce similar conditions in the future by altering the gate openings. The goal for the Sustainable Rivers Program is to identify, refine, and implement strategies to increase environmental benefits at USACE water infrastructure. Through the implementation and refinement of any outcomes of this study, USACE aims to improve the spawning habitat at Mel Price L&D for lake sturgeon.

2.0 Environmental Stewardship

In April of 2015, MDC Resource Science staff along with Southeast Missouri State University students collected some of the eggs at the site and had them hatch in an MDC lab in Cape Girardeau. They returned a few days later and collected even more eggs. The total number collected at the Mel Price L&D site was approximately 183 eggs. Though these eggs were hatched in a lab, on subsequent visits it was confirmed that wild Lake Sturgeon reproduction was taking place at the site naturally. **Figure 1** shows the collection efforts that occurred in April 2015. **Figure 2** illustrates the embryo location as well as 30 meter transects of sample locations.

Figure 1. April 2015 Lake Sturgeon Egg Collection (photo by MDC)

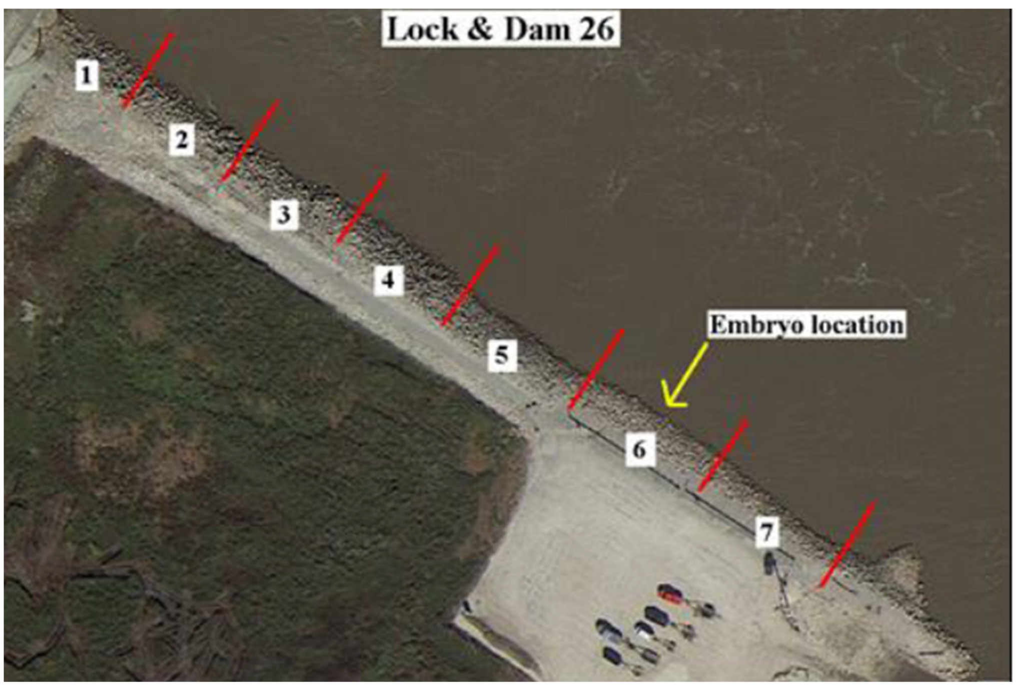


Figure 2. Mel Price L&D Spawn and Sampling Locations (photo by MDC)

Since 2015, the area has been monitored during the lake sturgeon spawning season. Lake sturgeon were observed in the area in 2016 and 2018, however 2015 is the last time lake sturgeon have spawned in the area downstream of Mel Price L&D. The question is if it is possible to recreate this spawning condition every year. Though its primary purpose is to maintain navigation above Mel Price L&D there is the possibility to adjust the gate setting in particular bays and still maintain a navigable channel.

3.0 April 2015 Hydraulic Conditions

Lake sturgeon spawn is a function of water temperature, velocity, substrate, and depth. From 10 April 2015 through 20 April 2015, the observed condition of the functional parameters is listed in **Table 1**.

Table 1. Observation at Time of Lake Sturgeon Spawn

Parameter at Tailwater and Spawn Location	Observation
Water Velocity (Surface)	3.28 ft/sec
Water Velocity (Substrate)	0.66 ft/sec
Substrate	Boulder/Large and Small Cobble
Depth	0.98 – 3.28 ft
Tailwater Range	403.3 – 405.7 ft NAVD 88
Total Gate Opening Range	33 – 57 ft
Water Temperature Range	56.7 – 63.2 ^{o}F

Water velocity, substrate, and depth were recorded during the sampling period of April 2015 by MDC. Temperature and tailwater measurements were from observations at Mel Price L&D the tailwater gage location. Total gate opening is from the L&D operational logs.

The terrain was analyzed to understand the bed form geometry at the spawn location. **Figure 3** shows the terrain along the right overbank.

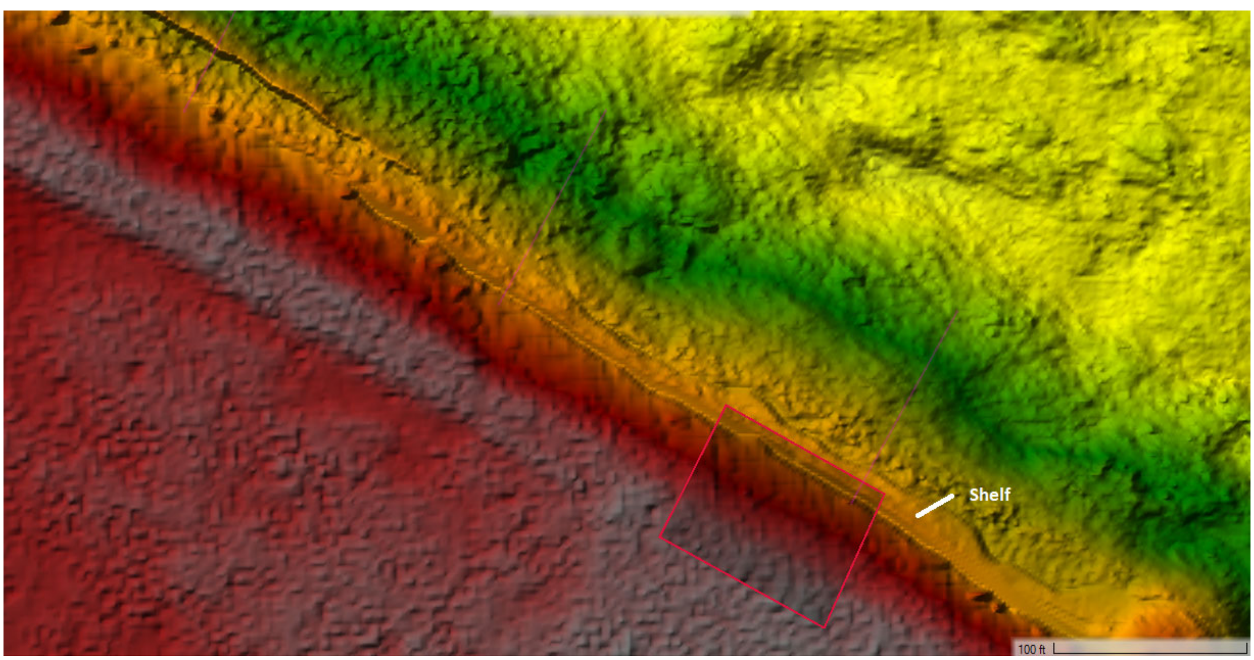


Figure 3. Shelf Along Bankline at Location of 2015 Spawn

Figure 4. Picture of Spawning Area Shelf Downstream of Mel Price (USACE photo)

Along the shoreline in the vicinity of the spawn there exists a shelf or flat area that creates a larger area of shallower depth. In 2015 the depths over the shelf were around 2.0 feet deep. This shelf is also most likely the extent of the cobble and boulder substrate. **Figure 4** shows the spawning area downstream of Mel Price L&D with the shelf exposed during low water.

Lake sturgeon spawn is directly affected by temperature. As noted in Table 1, the temperatures ranged from 56.7 to 63.2 ^{o}F during spawn activity. **Figure 5** shows the temperature of the Mississippi River at Mel Price tailwater for 2015, 2016, and 2018. These were the years where gate configurations were studied. Temperature collected from the Mel Price gage location are consistently within 50 to 65 ^{o}F temperature range in April, which is ideal for lake sturgeon spawning. Measured water temperatures were similar in 2015 and 2016, especially in early April. 2018 had consistently lower water temperatures. Hydraulic conditions were ideal to analyze higher total gate openings and downstream velocities during 2018. This is discussed in **Section 4.4**.

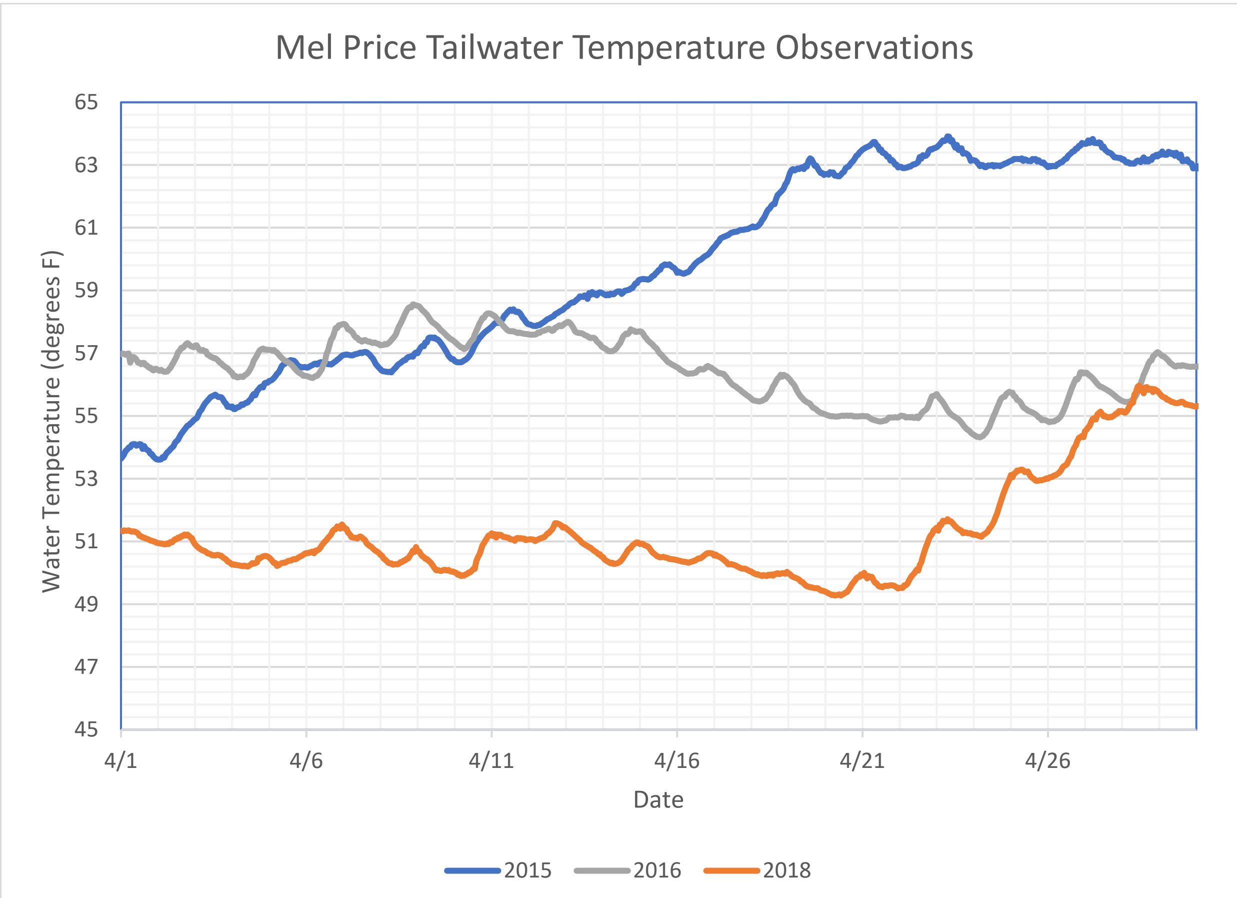


Figure 5. Mel Price TW Temperature Observation - 2015, 2016, and 2018

River flows on the Mississippi River at L&D 22, Illinois River at La Grange L&D, and the Missouri River at Herman, MO during the spring and summer months of 2015 are shown in **Figure 6**.

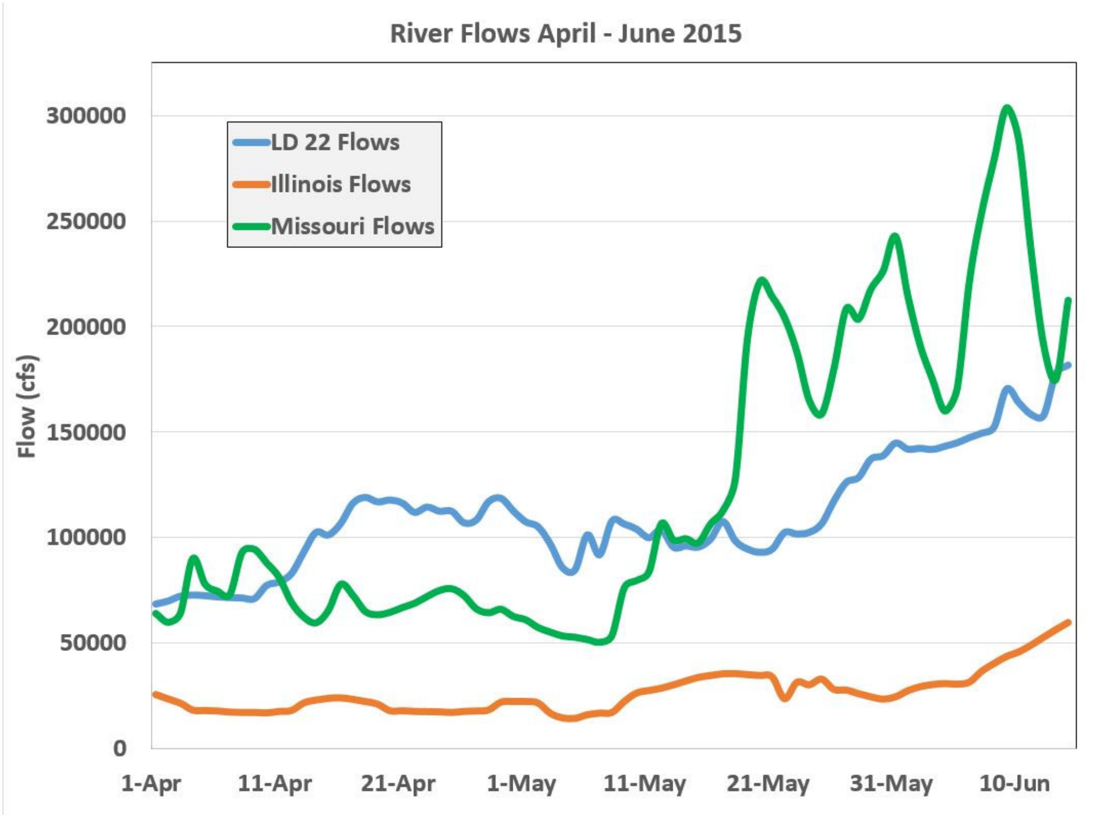


Figure 6. Flow Rates on the Mississippi River at L&D 22, Illinois River at La Grange L&D, and the Missouri River at Herman, MO

During April 2015, USACE was conducting Mel Price pool drawdown as part of its Environmental Pool Management program. These actions are used to stimulate vegetative growth to enhance provision of habitat and forage in L&D pools. From the middle of April through the middle of June 2015, the pool was drawn down at least 1.0 foot from where it would normally be operated (419.0 NGVD 29). A navigable channel was still maintained during this time. **Figure 7** illustrates Mel Price pool levels during the spring and summer of 2015. **Figure 8** illustrates Mel Price L&D tailwater versus total gate opening for the month of April 2015.

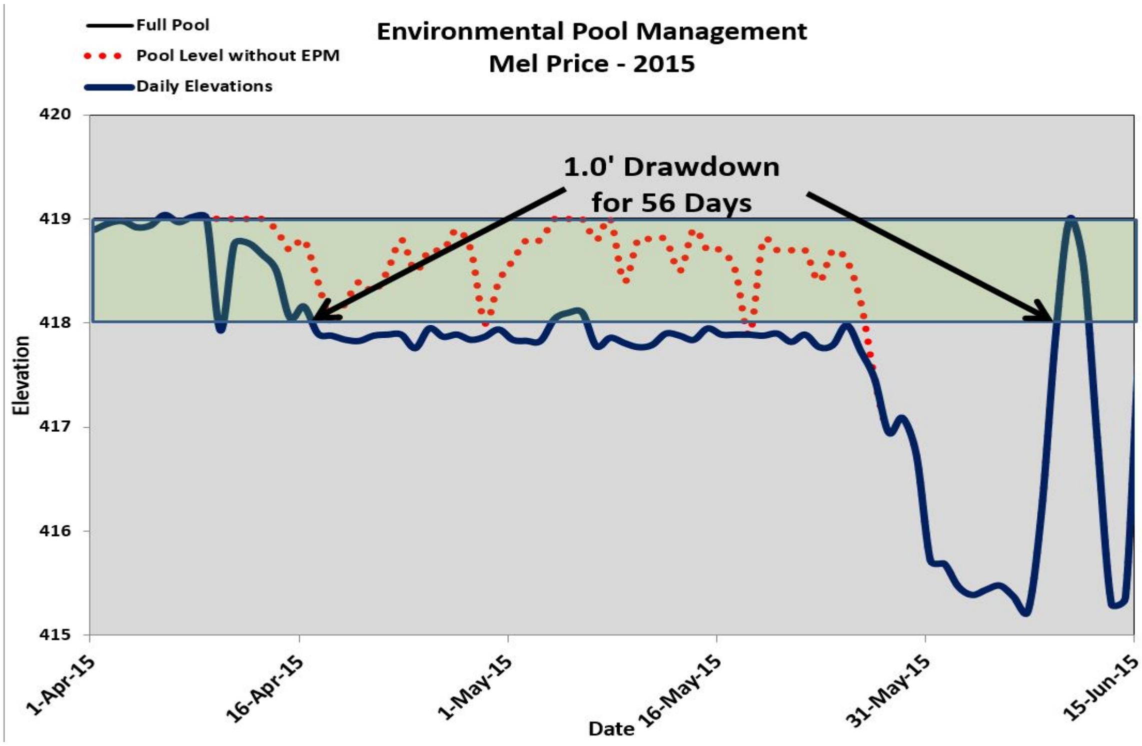


Figure 7. Environmental Pool Management Mel Price Pool Levels for 2015

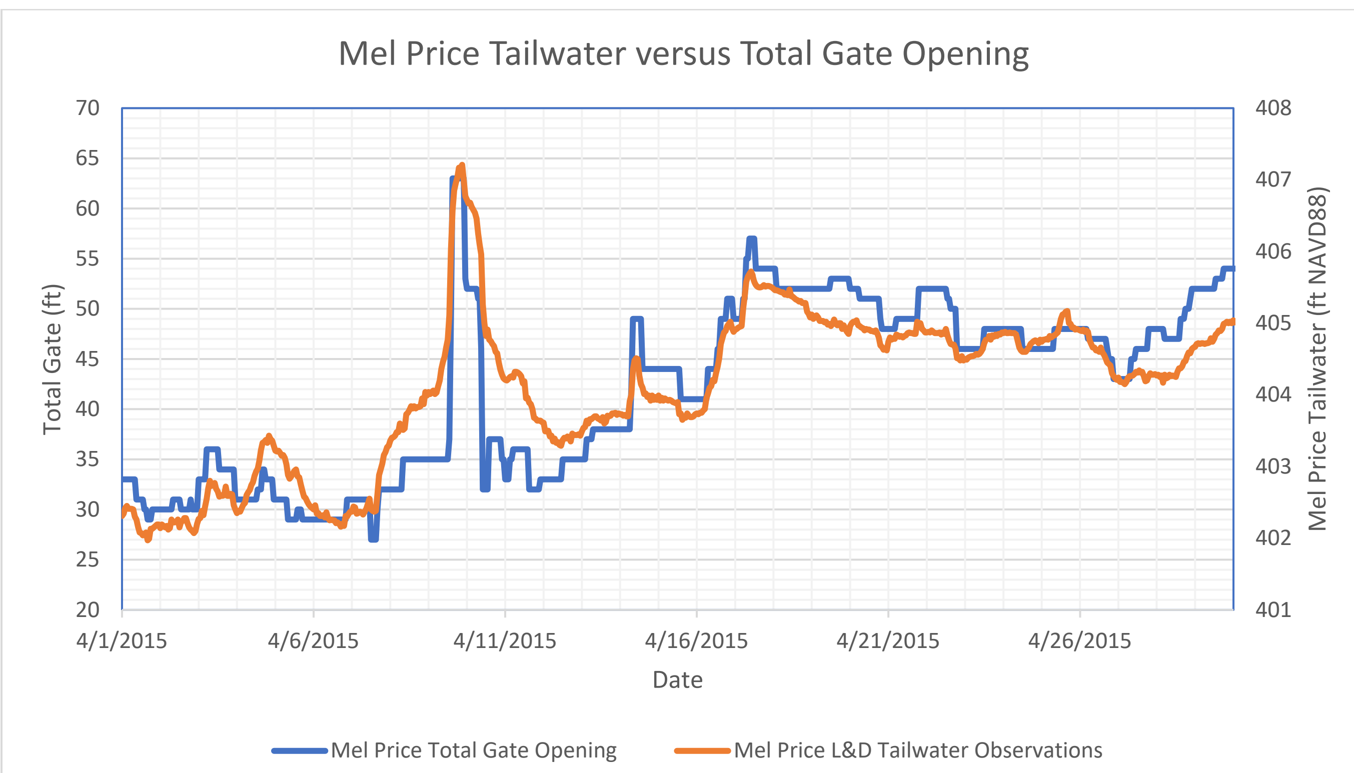


Figure 8. Mel Price Tailwater versus Total Gate Opening

Figures 5, 6, and 7 illustrate time series relationship between Mel Price L&D pool and tailwater, discharge, and total gate opening. Total gate opening is a function of pool, tailwater, and river discharge. A summation of the Mississippi River and Illinois River flows can roughly be used to estimate the total discharge to Mel Price. However, the effects of distance and the channel geometry to Mel Price L&D require adjustments to these discharges to get an accurate discharge at Mel Price pool. Discharge through the L&D is affected by individual gate settings and head difference (head difference is the difference between pool and tailwater water surface level). Missouri River flows also impact stage at Mel Price tailwater from backwater. High Missouri River flows create a backwater effect that increases tailwater levels below Mel Price. Velocities below the dam are directly related to discharge through the individual gates and tailwater conditions. To get an accurate discharge and velocity distribution hydraulic models are used to simulate the effects on the pool, tailwater, discharge, and total gate opening.

4.0 Hydraulic Analysis of River Conditions

The Hydrologic Engineering Center River Analysis System (HEC-RAS) was used to simulate existing channel conditions. A 1D/2D composite model was created with model calibration to the April events was the primary focus. The upstream boundary conditions or the points of model inflow are the Mississippi at L&D 25, Illinois River at Valley City, Cuivre River at Troy, and the Missouri River at Herman. The downstream boundary is the stage observations on the Mississippi River at St. Louis.

Aside from the April 2015 spawn event, two other years were selected for analysis of gate setting changes that would stimulate lake sturgeon reproduction. The time windows simulated are listed in **Table 2**.

Table 2. HEC-RAS Simulation Time Windows

Year	Start Time	End Time
2015	12 April 2015	16 April 2015
2016	19 April 2016	23 April 2016
2018	16 April 2018	20 April 2018

The main study area or the 2D (2-Dimensional) portion extended from Alton, IL through Mel Price L&D downstream to Hartford, IL. **Figure 9** illustrates the 2D segment as it ties into the 1D portion.

The 2D segment is limited in calibratable parameters and calibration could only focus on the 2D mesh pool and tailwater Mannings "n" regions. The 1D (1-Dimensional) portion of the model was calibrated at the L&D 25 tailwater, Alton, and Grafton gages. Parameters such as Mannings "n" values were adjusted through roughness factor adjustments. Calibration of the 1D segment reaches downstream of the 2D segment were used to adjust levels at Mel Price L&D tailwater.

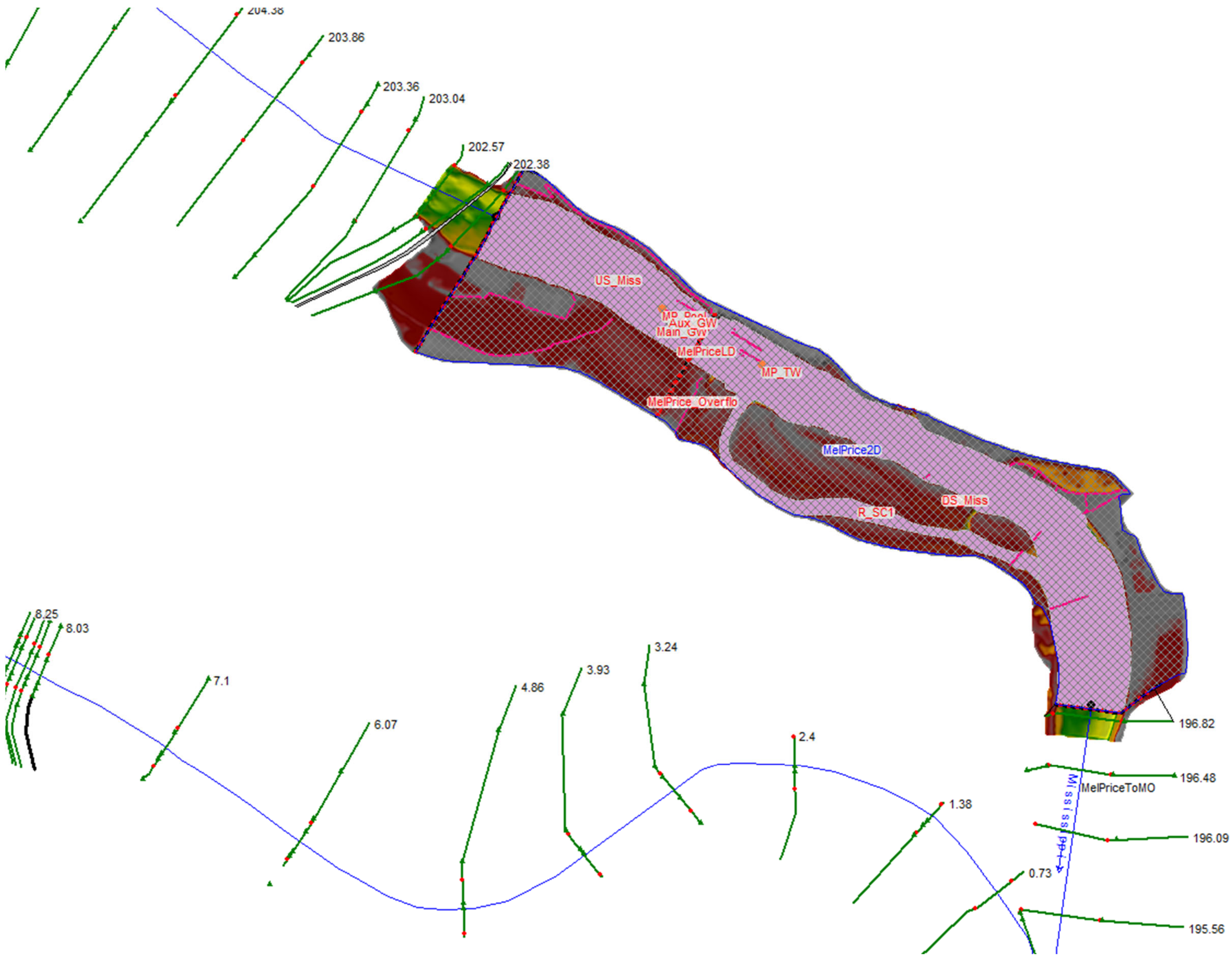


Figure 9. 2D Portion of the Mel Price Lake Sturgeon Model

The hydraulic equations for discharge that Mel Price L&D pool and gate calibration focused on are:

Radial Gate Flow (cfs): $Q = C\sqrt{2g}\,W\,T^{TE}\,B^{BE}\,H^{HE}$

Submerged Orifice Flow (cfs): $Q = C\sqrt{2g}\,W\,T^{TE}\,B^{BE}\,(3H)^{HE}$

C	= Discharge coefficient (typically ranges from 0.6 - 0.8)
W	= Width of the gated spillway in feet
T	= Trunnion height (from spillway crest to trunnion pivot point)
TE	= Trunnion height exponent, typically about 0.16 (default 0.0)
B	= Height of gate opening in feet
BE	= Gate opening exponent, typically about 0.72 (default 1.0)
H	= Upstream Energy Head above the spillway crest $Z_U - Z_{sp}$
HE	= Head exponent, typically about 0.62 (default 0.5)
Z_U	= Elevation of the upstream energy grade line
Z_D	= Elevation of the downstream water surface
Z_{sp}	= Elevation of the spillway crest through the gate

Simulations were iterated until the five calibratable gate coefficient parameters produced the best pool condition. Trunnion height and gate width remain static. Therefore, for computing purpose, discharge is a function of head and gate opening. **Table 3** lists the final radial gate and submerged orifice flow coefficients.

Table 3. April 2015 Radial Gate Flow Coefficients

Radial Gate Flow Parameter	Parameter Estimate
Discharge Coefficient (C)	0.61
Trunnion Height Exponent (TE)	0.06
Opening Height Exponent (BE)	0.69
Head Exponent (HE)	0.56
Trunnion Height (T)	43
Submerged Orifice Coefficient (C)	0.6

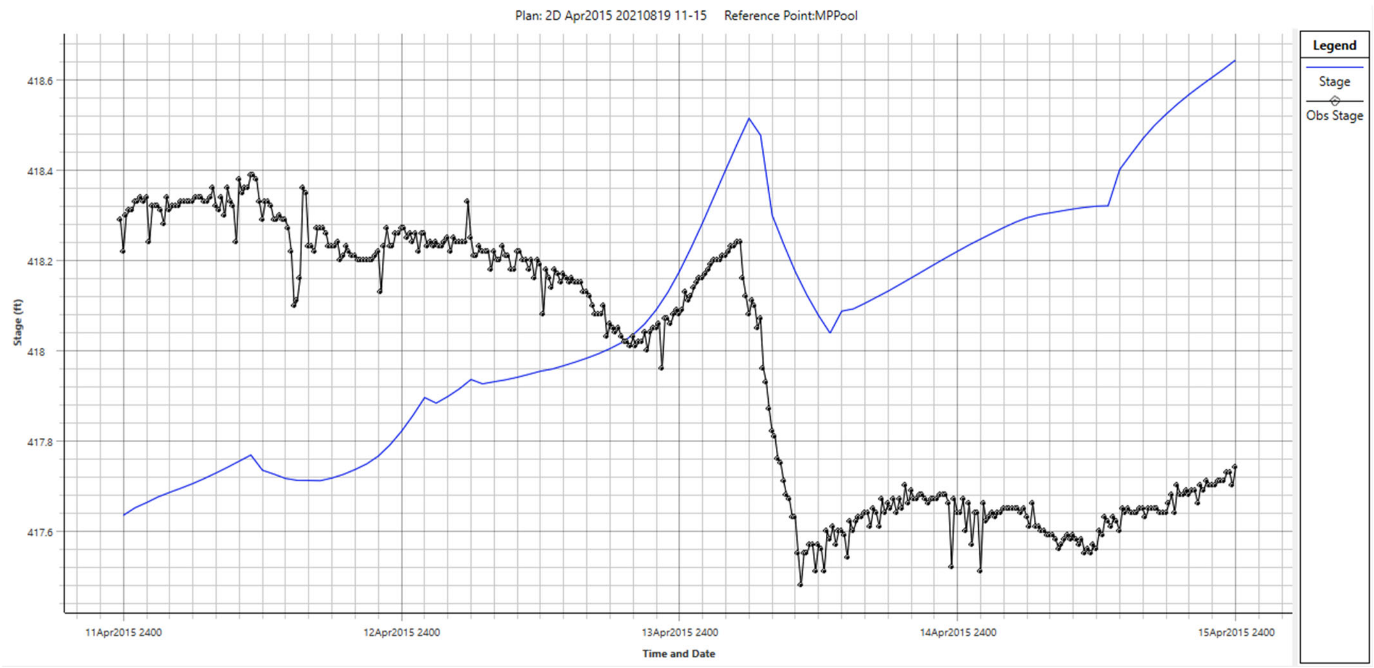


Figure 10. April 2015 Calibration Results at Mel Price L&D Pool

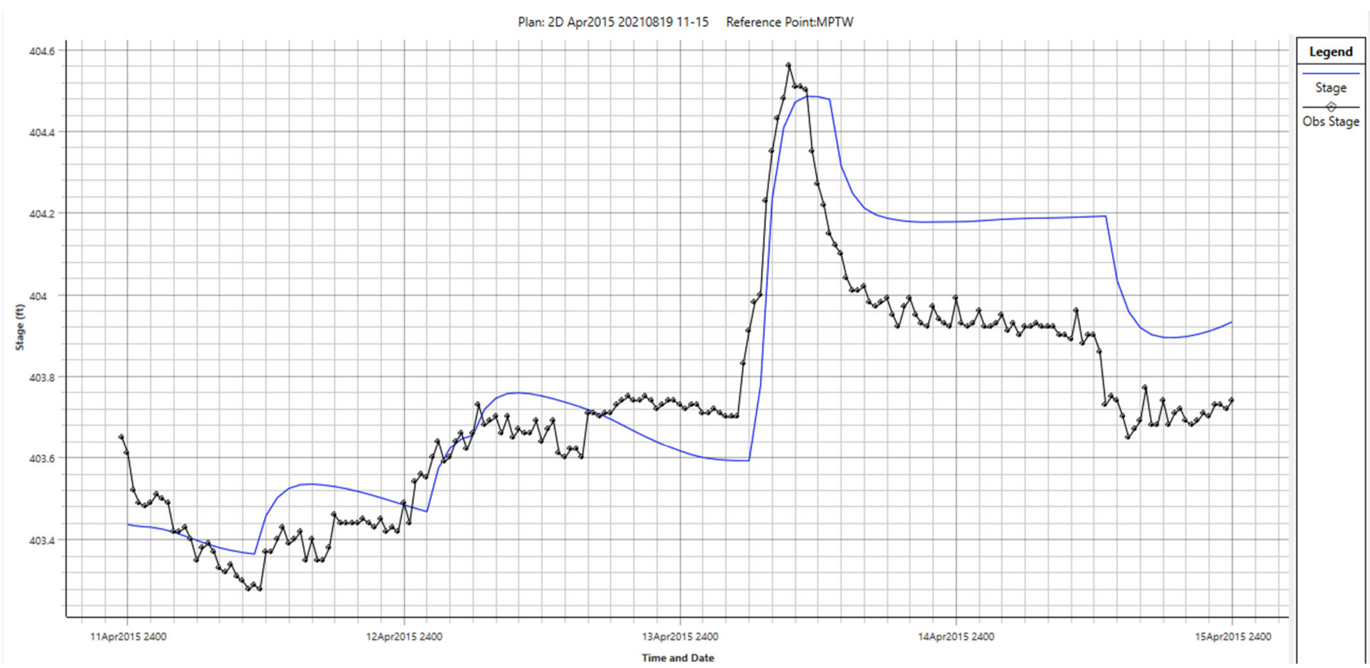


Figure 11. April 2015 Calibration Results of Mel Price L&D Tailwater

Figure 10 and **11** show the results of the calibration to the pool and tailwater gage observations for the April 2015 event.

Calibration results were similar for all events simulated. The best pool calibration was the simulation of an April 2018 event. For April of 2015, the tailwater calibration fell within 0.2 ft of the observed once the computed pool levels were averaged between the observed levels. The results are acceptable since the discharge and tailwater levels are really the factors that affect velocities downstream of the dam.

Model calibration was difficult as the model runtime for a 4-day simulation time window took at least an hour and a half for a full momentum analysis. The simulation events required individual calibration to get Mel Price pool within acceptable ranges. Also, the lack of downstream average depth velocity data during these April events did not allow for tailwater velocity calibration. Though quantitative results are presented, the results should really be considered qualitative between the studied April events.

4.1 April 2015 2D Velocity Conditions

The main part of this analysis is to study velocities affected by gate bay gate settings on the spawning zone of April 2015. Illustrated in **Figure 12** is the aerial representation of the current that occurred in April 2015.

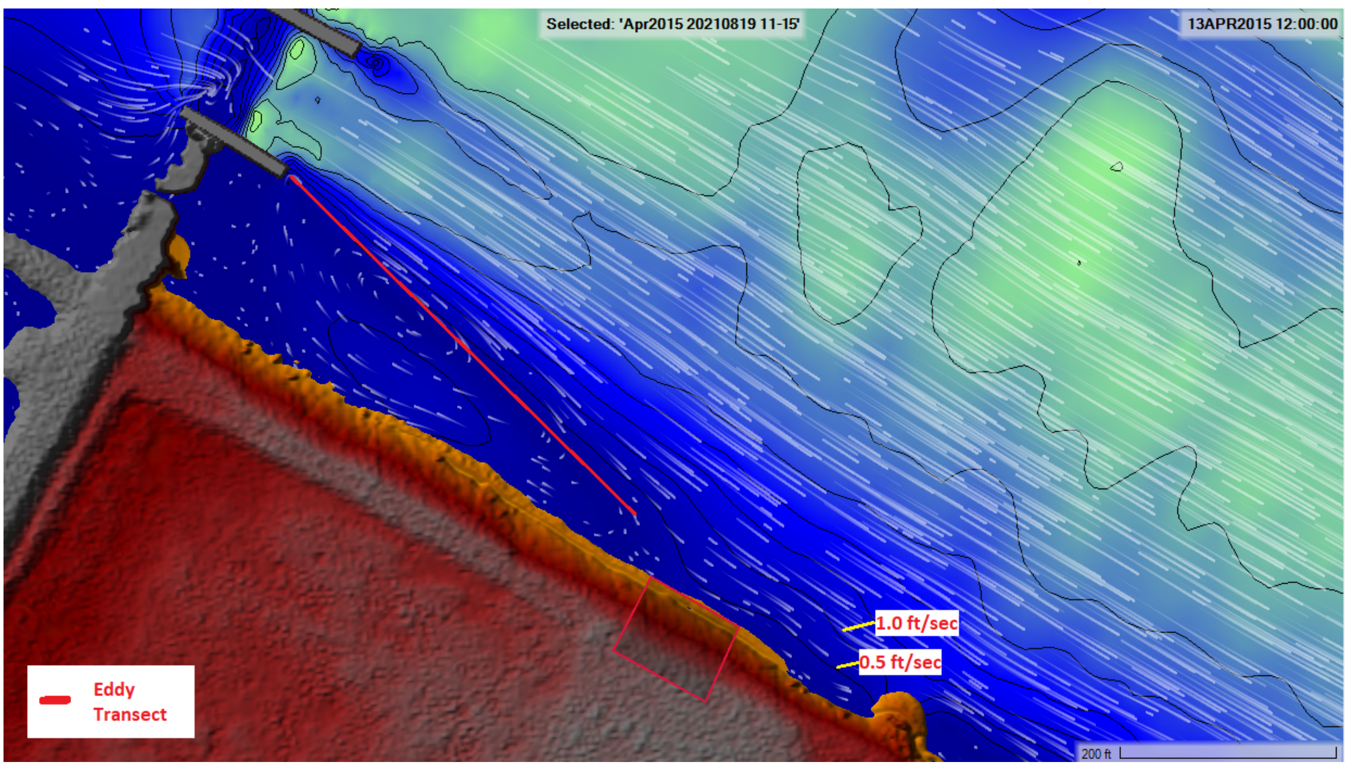


Figure 12. April 2015 Currents

An eddy has formed and extends 400 ft downstream from the Gate 9 bay wall. Just upstream of the spawn location (red box), the eddy switches to a parallel current to the shore. The total gate opening during this time frame averages out to be 38.4 ft. Gates 7, 8, and 9 averaged to openings of 5.0, 4.3, and 3.8 feet.

In terms of velocity, HEC-RAS computes an average velocity over the depth of the computational 2D cell. Illustrated in **Figure 13** is the velocity profile of a column of water in an open channel. The average velocity is approximated by an average of the velocities measured at the 2/10 and 8/10 water depth from the surface. Velocity is assumed to be zero at channel bottom.

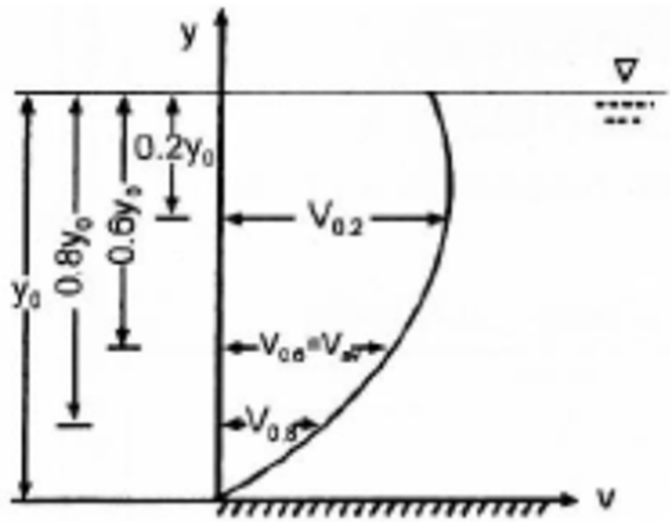


Figure 13. Velocity Profile of an Open Channel

Figure 14 shows the velocity and depth referenced from the shoreline. It shows an average velocity within the first 20 feet from shore of approximately 0.44 ft/sec. Over the same transect from the shoreline, the first 20 ft have an average depth of 2.2 feet. This velocity profile is the target USACE will be trying to reproduce when analyzing the subsequent events in April of 2016 and 2018 (**Section 4.3 and 4.4**).

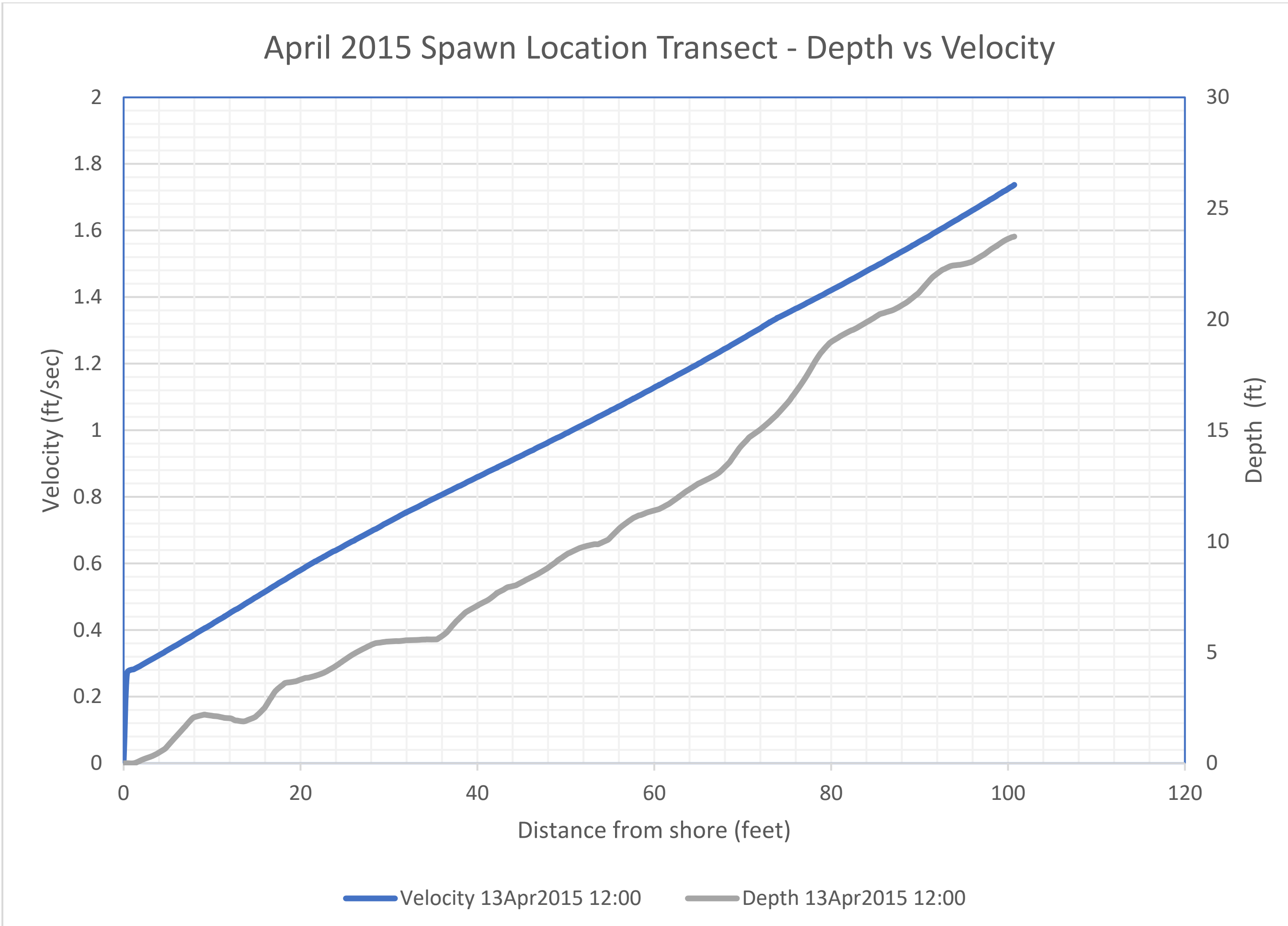


Figure 14. April 2015 Depth and Velocity versus Distance from Shoreline

4.2 April 2015 Gate Modification from Existing Conditions

Modified gate openings were simulated to understand the effects of gates on the downstream current. Specifically, two scenarios were simulated: 1) closing gate 9 and 2) reducing openings for gates 8 and 9 to two feet and 1 foot, respectively.

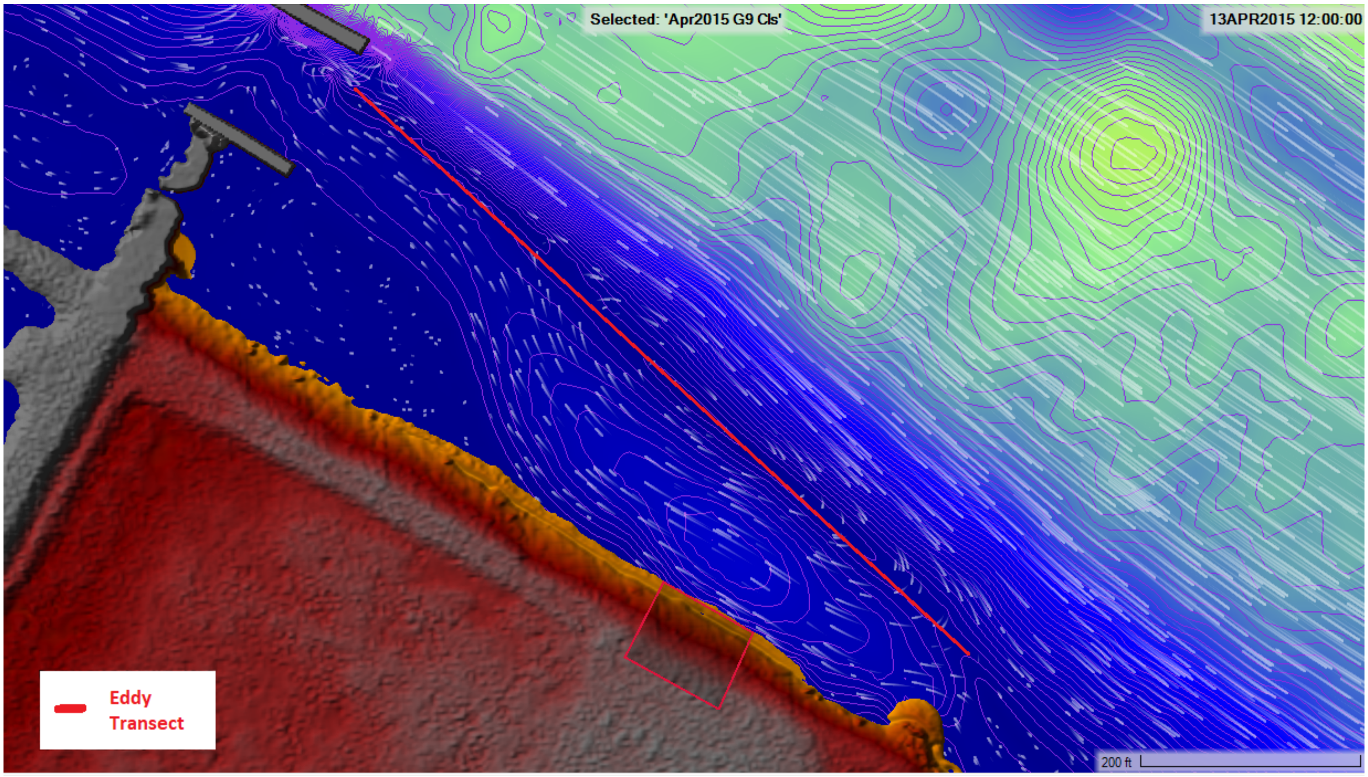


Figure 15. April 2015 Current with Gate 9 Closed

Figure 15 shows the effects of closing gate nine and shifting the openings to the center of the lock. Note the position of the eddy. An increase in 2 ft to the total gate opening was necessary to maintain similar pool conditions. The closing of gate 9 shifts the eddy to roll along the entire right descending bank. This produces the target velocity upstream of the 2015 spawn location with a current moving upstream. This might not be desirable, as it is in the opposite direction of the current observed in April 2015.

Figure 16 shows the effects of cutting back gate 8 to 2 feet and gate 9 to 1 foot and shifting the openings to the center of the lock. An increase in 2 ft to the total gate opening was necessary to maintain similar pool conditions. Note the position of the eddy. The closing of gate 8 to 2 feet and gate 9 to 1 foot shifts the eddy to roll closer to the lock. Velocity conditions from those gate cutbacks on the Missouri side will increase that parallel downstream current over a longer area along the shore. Though velocities might be low, maintaining a parallel current along the shore has been documented in research studies to be more desirable for spawn.

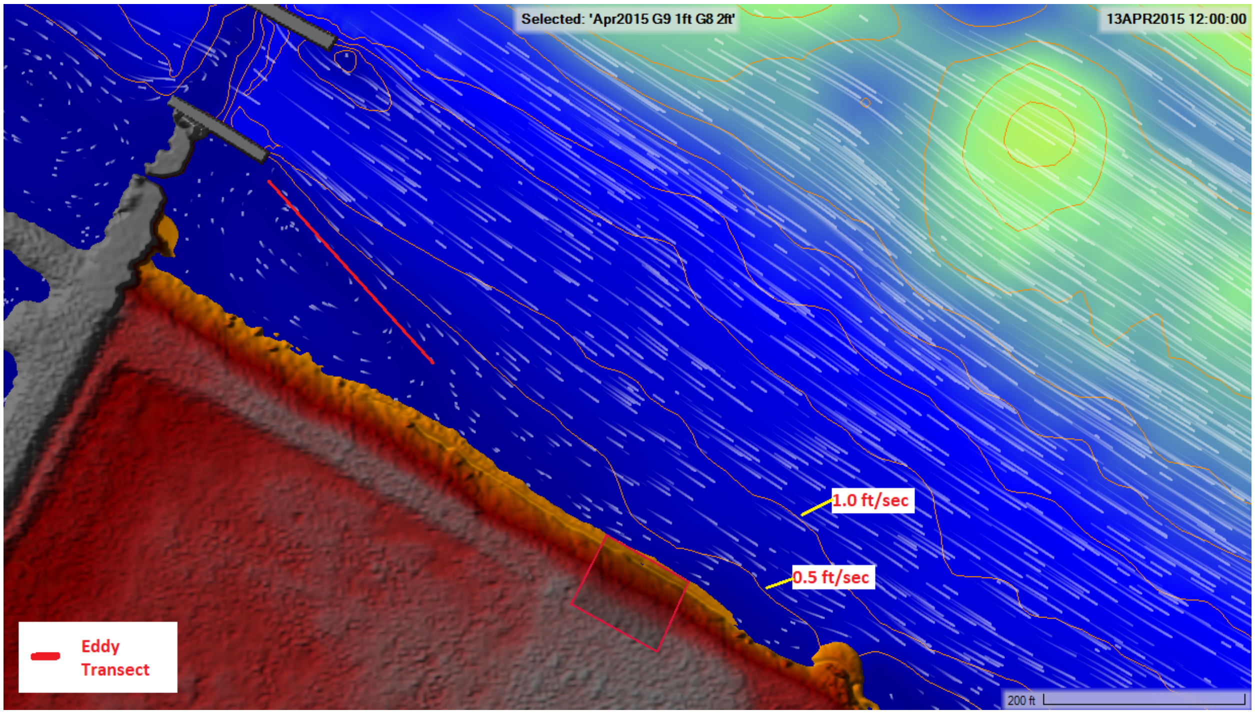


Figure 16. April 2015 Current with Gate 8 at 2 ft and Gate 9 at 1 ft

4.3 April 2016 Modification to Existing Conditions

Focusing on Gate 7, 8, and Gate 9 setting adjustments, changes were made to the April 2016 gate openings to get the shoreline velocities to match those of April 2015. Based on the findings discussed in Section 4.2, gates 8 and 9 were not set below 2 feet and 1 foot. **Table 4** lists the gate 7, 8, and 9 settings that were the closest to matching the April 2015 conditions.

Total gate opening was iterated to ensure the existing April 2016 pool conditions were reproduced within 0.5 feet. To compensate for the lower gate setting on the Missouri side of the river, total gate openings increased. The average total gate setting was set about 2 to 3 feet above the existing 2016 settings. The total gate opening in 2015 averaged to be 39.4 feet as opposed to a total gate opening of 74.3 ft for the second modified 2016 case.

Table 4. April 2016 Gate Setting Modifications Examined (Existing Conditions is Highlighted in Blue)

Scenario Gates 7, 8, & 9 in % of Total Gate Opening	**Setting** Average Gate Settings Over the Simulation Period (feet)				**Tailwater Simulated Average Discharge (cfs)**
	Gate 7	**Gate 8**	**Gate 9**	**Total Gate**	
Existing 2015 Conditions 12.8%, 11.9%, 9.3%	5.1	4.7	3.7	39.4	120,000
Existing 2016 Conditions 11.4%, 11.2%, 10.6%	8.2	8.1	7.6	70.3	153,000
11.2%, 5.5%, 2.8%	8.2	4.0	2.0	73.3	
11.0%, 6.8%, 2.7%	8.2	5.0	2.0	74.3	

The resulting velocity and depth profiles at the transect located near the Lake Sturgeon spawning location during April 2015 is shown in **Figure 18**. Seen in **Figure 17**, the transect is the thin magenta line bisecting the shoreline.

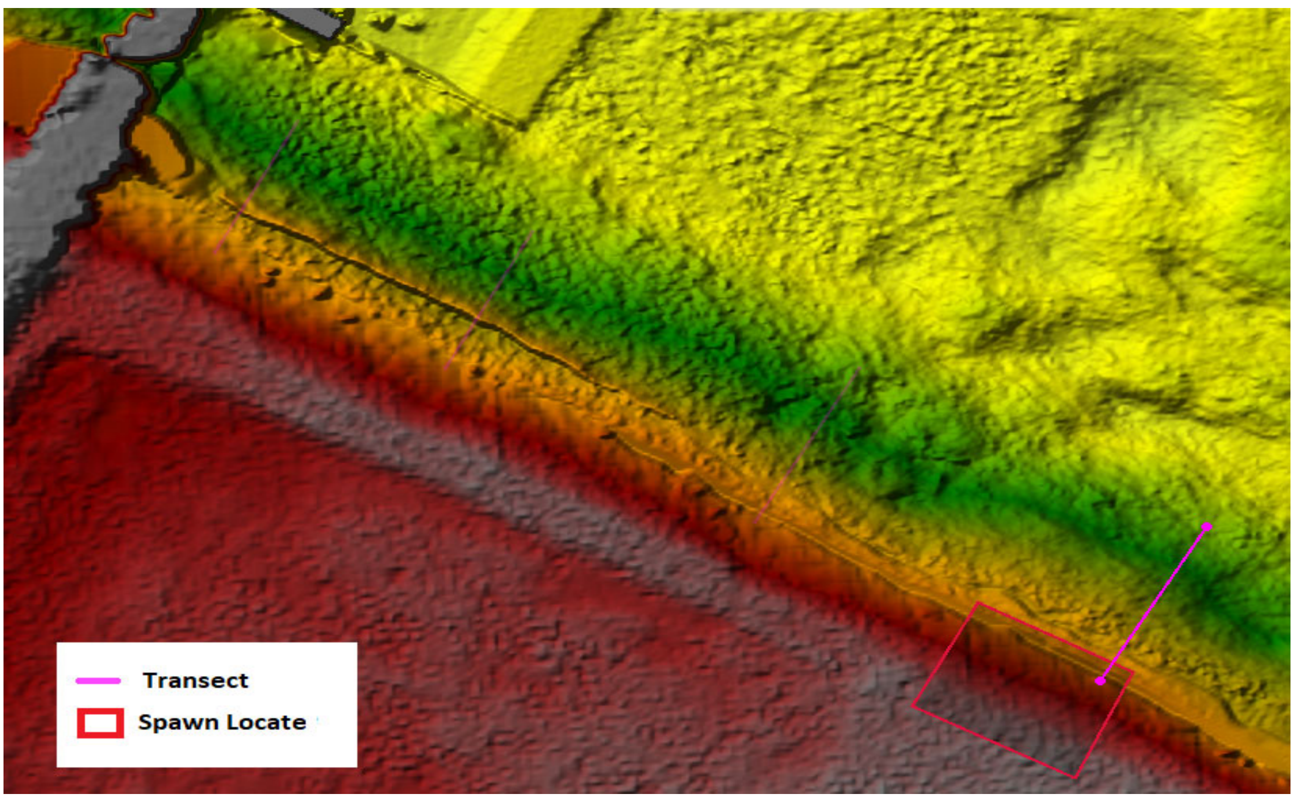


Figure 17. Velocity Profile Transect Location

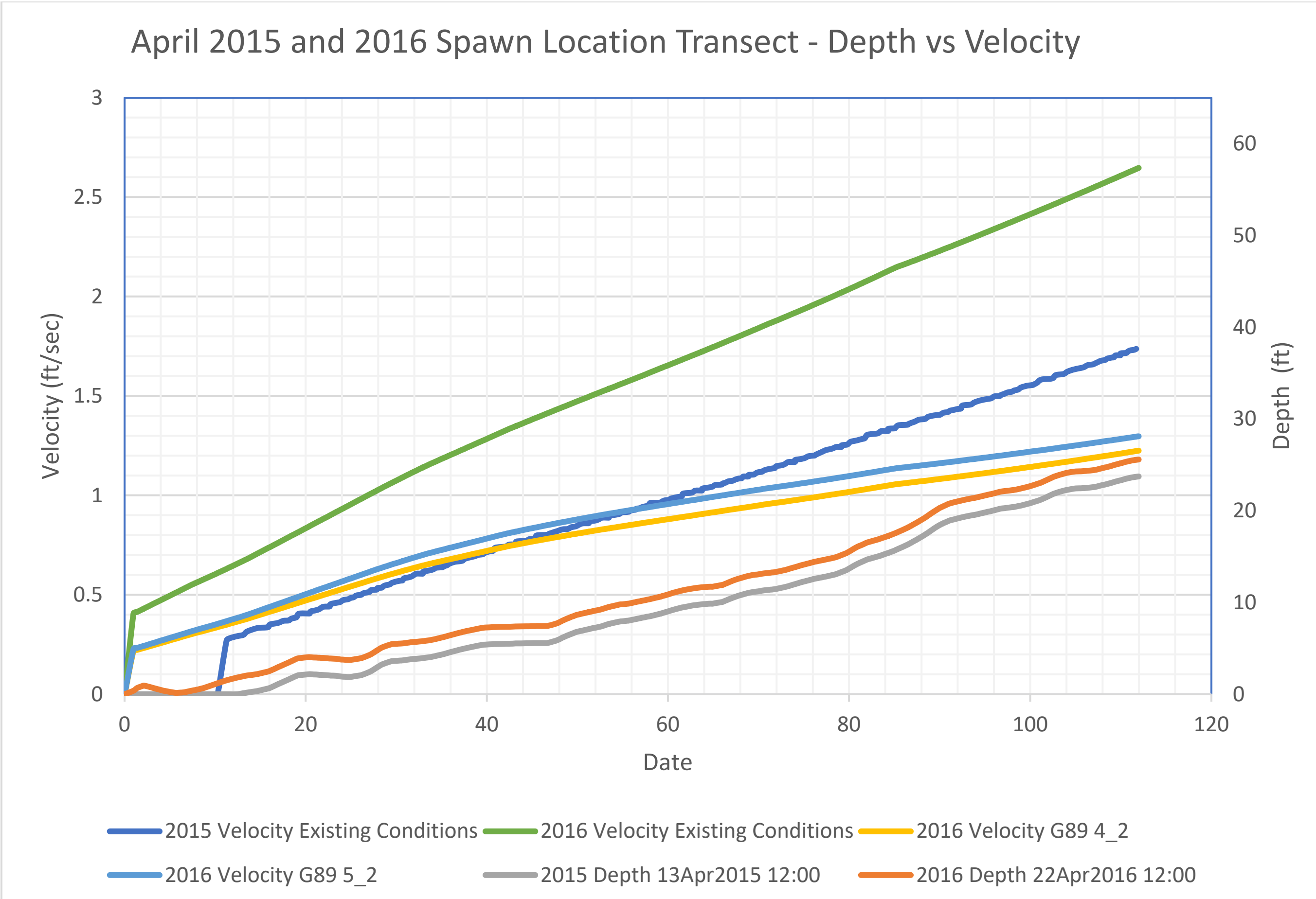


Figure 18. April 2015 and 2016 Velocity and Depth Profiles

Results of simulated gate scenarios show that it would have been possible to re-create 2015 conditions at the spawn location in 2016, even with the different tailwater discharges. For April 2016, gate 7 can be held to an average opening of 8 feet as in the existing conditions. Gate 8 should be in a range from 4 to 5 feet and gate 9 set at 2 feet.

Shore line inundation differences between April 2016 and 2015 are shown in **Figure 19**. As is shown, 1.48 ft is the depth in April 2016 at the April 2015 shoreline. The tailwater average depths were 405.3 feet for 2018 versus the 2015 elevation of 404.4 feet (NAVD 88.

The velocities from the shoreline average to be 0.4 ft/sec within the first 20 ft of water from the two different shorelines. The modified 2016 case is a similar velocity condition to April 2015, but during April 2016 the same depth profile exists but higher on the shore. For the modified April 2016 operation, there should be enough cobble substrate at this higher 2016 tailwater to simulate the same spawn condition as in 2015.

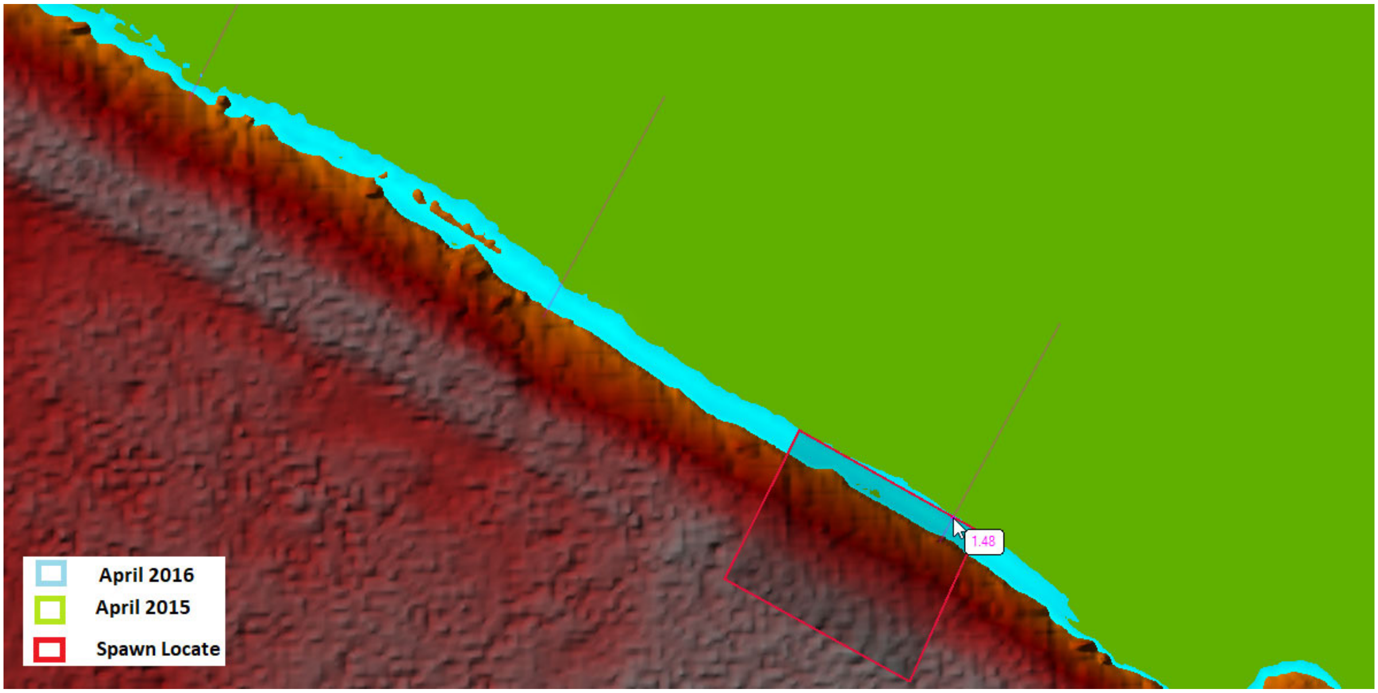


Figure 19. April 2015 and 2016 Shoreline Inundation.

April 2016 water temperatures were more like those of April 2015 than April 2018 (shown in Figure 3). This would make 2016 an ideal case for reproducing spawn conditions.

4.4 April 2018 Modification to Existing Conditions

Focusing on Gate 7, 8, and Gate 9 setting adjustments, changes were made to the April 2018 gate openings to get the shoreline velocities to match those of April 2015. Based on the findings discussed in Section 4.2, gates 8 and 9 were not set below 2 feet and 1 foot. **Table 5** lists the gate 7, 8, and 9 settings that were the closest to matching the April 2015 conditions.

Total gate opening was iterated to ensure the existing April 2018 pool conditions were reproduced within 0.5 feet. To compensate for the lower gate setting on the Missouri side of the river, total gate openings increased. The average total gate setting was set about 2 to 3 feet above the existing 2018 settings. The total gate opening in 2015 averaged to be 45.2 feet as opposed to a total gate opening of 91.2 ft for the modified 2018 case.

Table 5. April 2018 Gate Setting Modifications Examined (Existing Conditions is Highlighted in Blue)

Scenario Gates 7, 8, & 9 in % of Total Gate Opening	**Setting** Average Gate Settings Over the Simulation Period (feet)				**Tailwater Simulated Average Discharge (cfs)**
	Gate 7	**Gate 8**	**Gate 9**	**Total Gate**	
Existing 2015 Conditions 12.8%, 11.9%, 9.3%	5.1	4.7	3.7	39.4	120,000
Existing 2018 Condition 9.3%, 9.1%, 9.1%	8.3	8.1	8.1	89.2	143,000
9.1%, 5.5%, 3.3%	8.3	5.0	3.0	91.2	
9.1%, 4.4%, 2.2%	8.3	4.0	2.0	91.2	

The resulting velocity and depth profiles at the transect located near the lake sturgeon spawning location during April 2015 is shown in **Figure 20**. The transect is the magenta line seen in **Figure 17**.

Results of simulated gate scenarios show that it would have been possible to re-create 2015 conditions at the spawn location in 2018, even with the different tailwater discharges. For April 2018, gate 7 can be held to an average opening of 8 feet as in the existing conditions. Gate 8 should be in a range from 4 to 5 feet, and gate 9 from 2 to 3 feet.

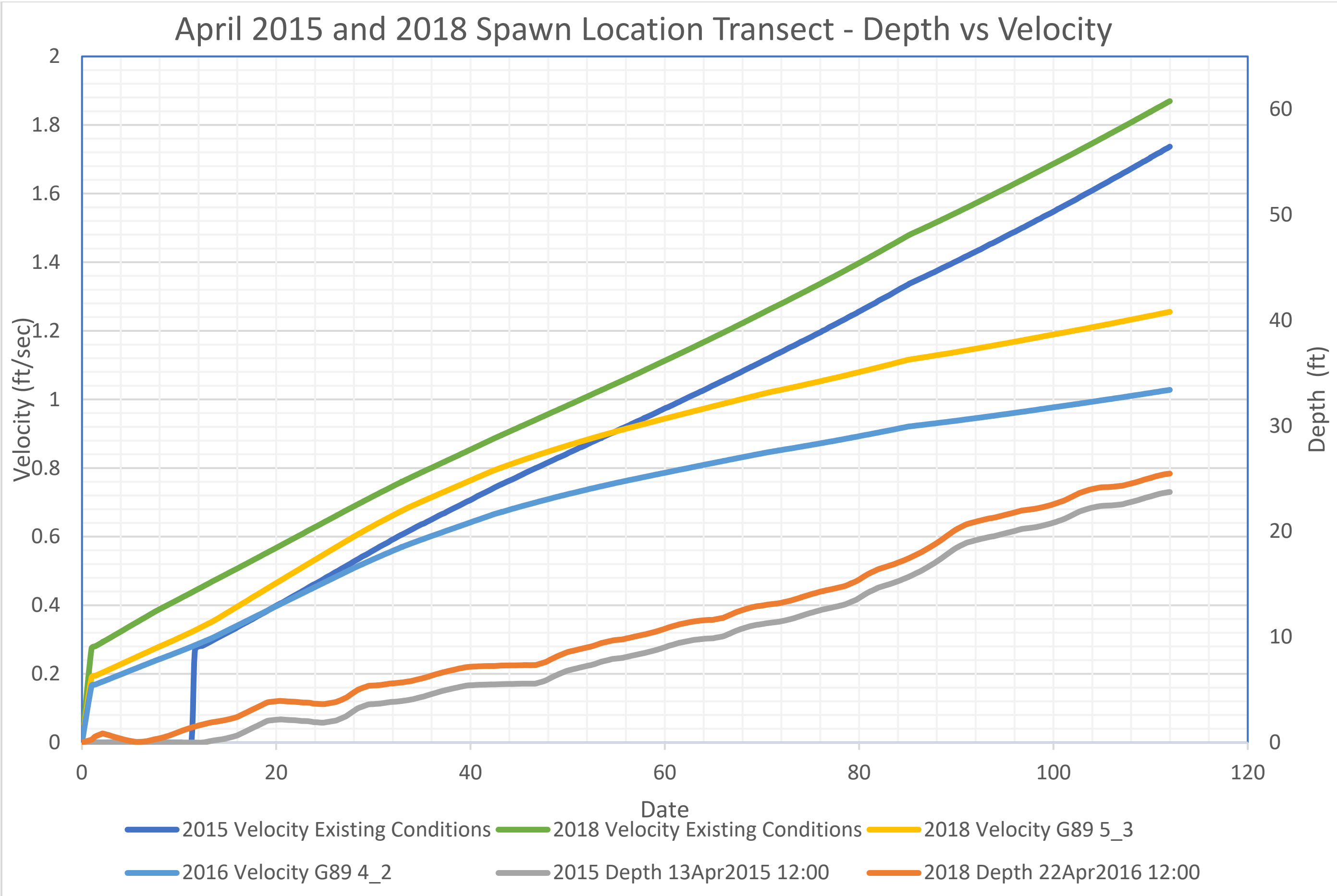


Figure 20. April 2015 and 2018 Velocity and Depth Profiles

Shore line inundation differences between April 2018 and 2015 are shown in **Figure 21**. As is shown, 1.62 ft is the depth in April 2018 at the April 2015 shoreline. The tailwater average depths were 405.3 feet for 2018 versus the 2015 elevation of 404.4 feet (NAVD 88).

The velocities from the shoreline average to be 0.3 ft/sec within the first 20 ft of water from the two different shorelines. The modified 2018 case is a similar velocity condition to April 2015, but during April 2018 the same depth profile exists but higher on the shore. For the modified April 2018 operation, there should be enough cobble substrate at this higher 2016 tailwater to simulate the same spawn condition as in 2015.

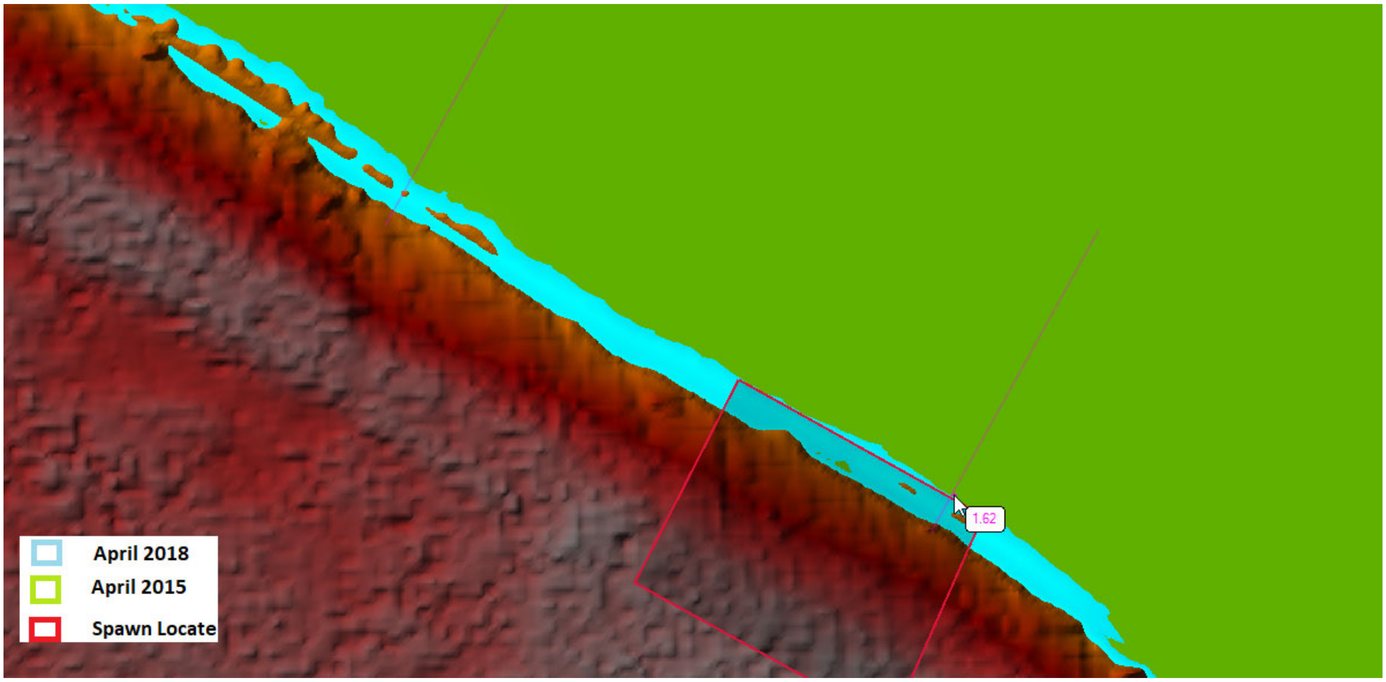


Figure 21. April 2015 and 2018 Shoreline Inundation.

April 2016 water temperatures were more like those of April 2015 than April 2018 (shown in Figure 3). This would make 2016 an ideal case for reproducing spawn conditions.

5.0 Boat Ramp Alignment

Also being considered is the realignment of the boat ramp into the Mississippi River that currently enters at the side channel just downstream of the Mel Price L&D on the right overbank. The proposed alignment is shown in **Figure 22**. The existing alignment of the boat ramp is not ideal since it dumps out into a side channel that regularly gets silted in. Shown in **Figure 23**, an eddy forms at the entrance to the tributary. This will lead to sediment being pulled into the side channel entrance and deposited along both sides of the channel. Turning the boat ramp perpendicular to river flow just before the jutting point downstream of the spawning location would be ideal to alleviate the need for mechanical dredging. However, potential Lake Sturgeon spawning habitat would be reduced. Also, a direct perpendicular to flow ramp may not be ideal for boating in at. It is recommended to maybe angle the proposed ramp more toward a perpendicular alignment river to minimize sediment build up. This would terminate the ramp just downstream of the bank point. This would be angled up just upstream of the potential realignment shown in **Figure 22**.

Figure 22. Proposed Boat Ramp Alignment

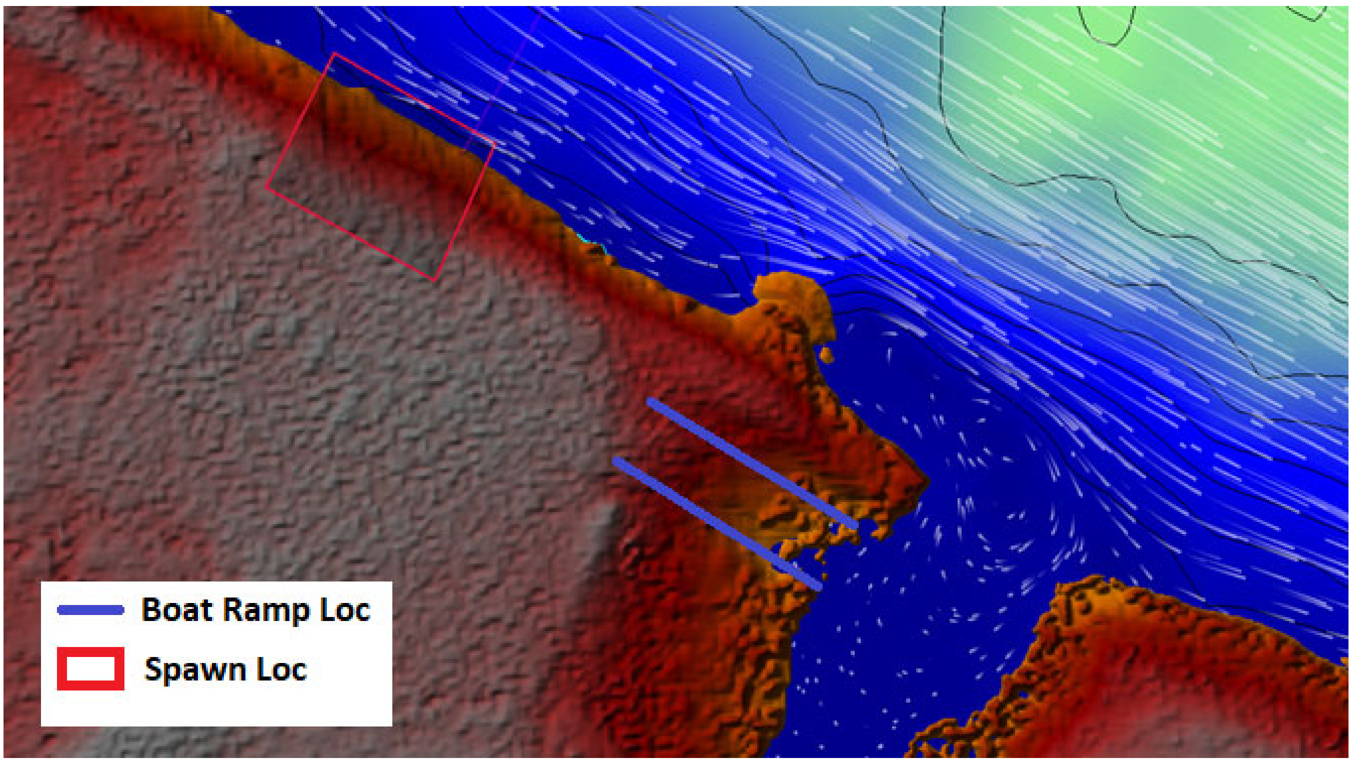


Figure 23. Eddy Formation at Tributary Confluence

6.0 Conclusion

For the two events studied that were not the April 2015 event, the tailwater averages for the 2018 and 2016 events were 405.3 and 405.1. It was also shown that during those April 2016 and 2018 timeframes that gate 8 would best be operated between 4 and 5 feet, and gate 9 would best be operated between 2 and 3 feet. The approximate tailwater elevation relationships between events simulated seem to indicate that tailwater might be the most functional parameter in establishing a relationship between the hydraulics and lake sturgeon spawn. Because only two events were analyzed and there were not other ideal flow conditions to analyze since 2015, a relationship could not be established. Because of the tailwater similarities between 2016 and 2018, more events are needed to analyze a wider range of tailwater levels yielding more points to graph. Organized by gate 9 opening **Figure 24,** illustrates the relationship from simulation of Mel Price L&D tailwater and total gate opening. **Figure 25** shows a similar trend but for Mel Price L&D head versus total gate opening organized by gate 9 opening. Head is a more correct functional parameter as it is related directly to flow through the gate. The relationship between head and total gate opening is not as clear.

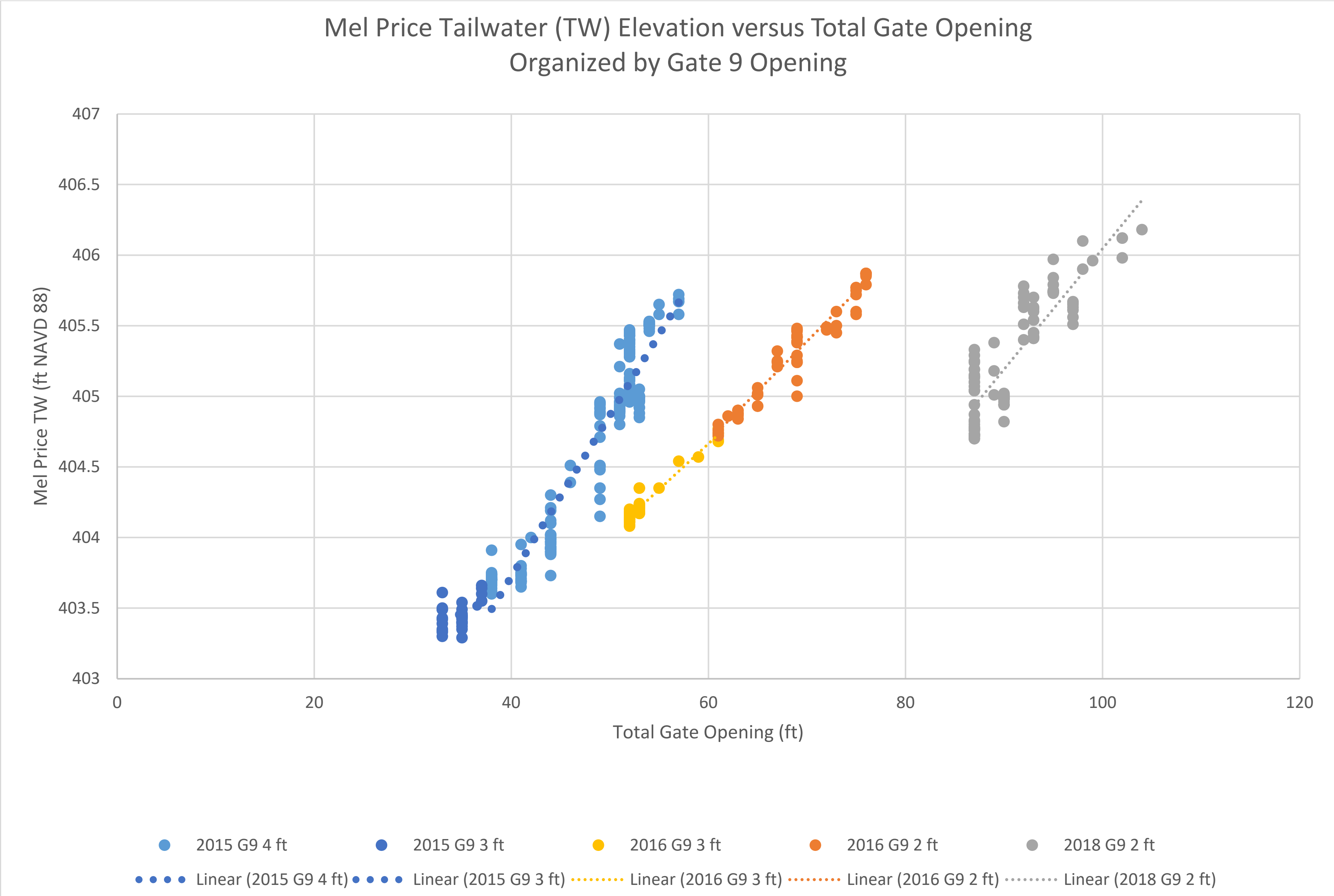


Figure 24. Mel Price TW versus Total Gate Opening for Various Gate 9 Opening

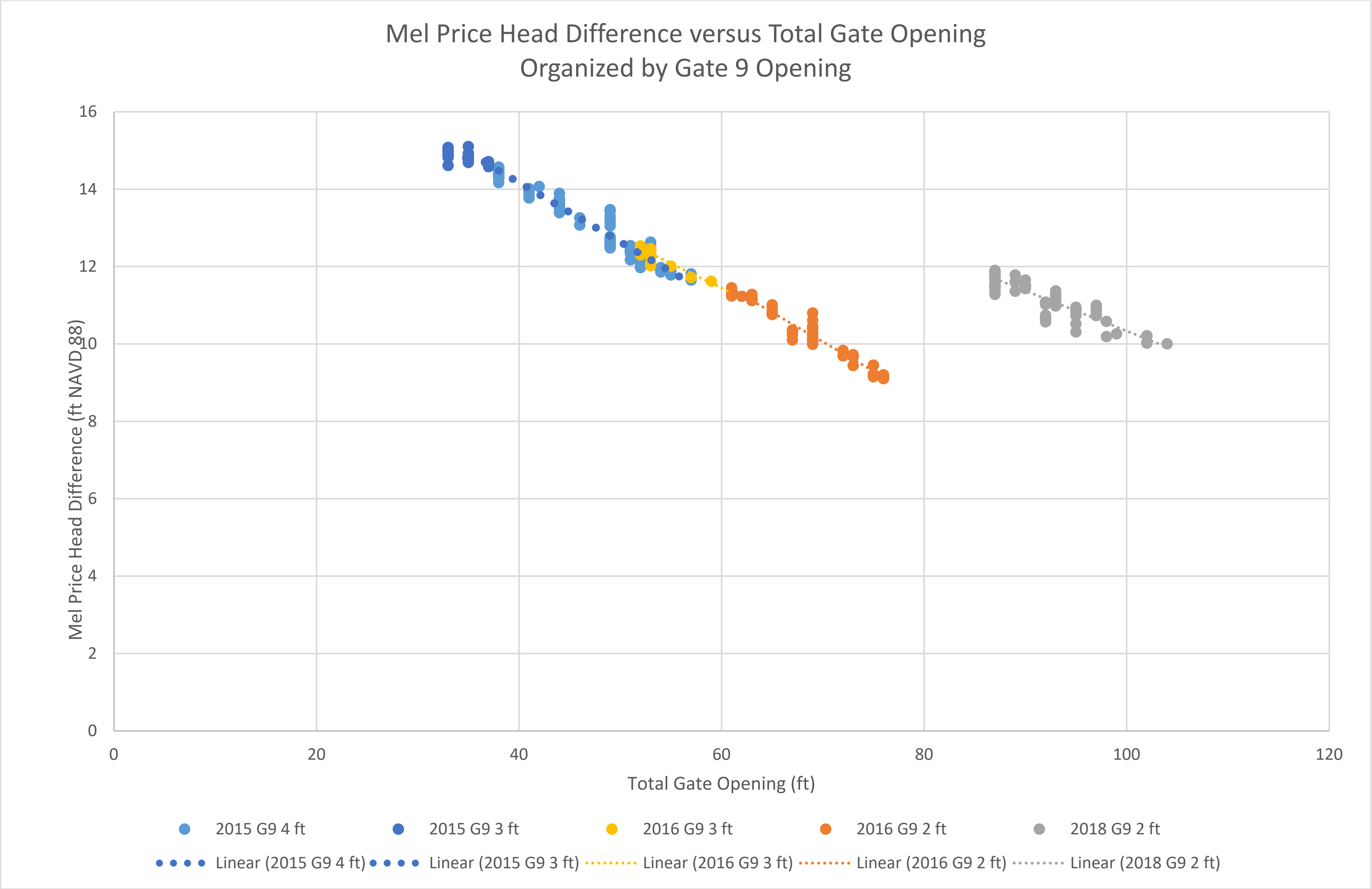


Figure 25. Head versus Total Gate Opening for Various Gate 9 Opening

It was also shown that lake sturgeon prefer to spawn at the location downstream of Mel Price L&D on the right overbank. It may be worth considering extending the cobble and bolder substrate further up on the bank to increase potential spawning habitat at higher tailwater depths. This report shows that for a wide range of total gate opening, that conditions can be adjusted to reach target velocities along the Missouri shore. This would ensure that the proper spawning substrate is available at a wider range of tailwater levels.

There are adjustments to the gates that can be made that may provide suitable habitat for Lake Sturgeon reproduction. These functional relationships can be used as a determining factor for decisions on ideal gate 9 and/or gate 8 settings. **For a tailwater ranging from 403.0 feet to 406.5 ft, the current recommended settings for gate 8 is 4 to 5 feet, and gate 9 of 2 to 4 feet.** A gate 8 and gate 9 opening of 5 feet and 4 feet would coincide with the lowest total gate openings within this tailwater range. To improve study results, it is recommended to analyze more subsequent events to 2015 to produce data points for establishing a relationship between tailwater or head and total gate opening. Gate adjustments should be considered based on Lake Sturgeon activity and measured velocity.

Because of the lack of velocity observation at the fish spawn location, the model should be considered qualitative. Having velocity information for calibration in this area would give more credence to the quantitative results. It is recommended to set up an Acoustic Doppler Current Profiler (ADCP), or at a minimum, take velocity measurements during future spawn sampling to improve model results. For calibration purposes the ideal sampling depth for average velocity measurements is 2/10 to 3/10 of the depth of water from the surface. The installation of ADCP equipment can also be used to better tune gate settings to the actual resulting velocities at the spawn location.