US Army Corps of Engineers®
St. Paul District

# Hydraulic Modeling and Sediment Analysis

Lake Onalaska

NESP

**January 2024**

# Hydraulic Modeling and Sediment Analysis

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# 1 Introduction

Lake Onalaska is a 7,700-acre backwater lake on the Wisconsin side of the Mississippi River navigation channel in Pool 7. The lake receives flow from both the Mississippi and Black Rivers (WI DNR, 2023). It begins near river mile (RM) 714.2 and extends until RM 698.0.
The project is focused on analyzing the Mississippi River side channels along the western border of Lake Onalaska. The side channels of interest are located between RM 708.5 and 705. These side channels are listed below.

- Bullet Chute
- No Name Chute
- Gibbs Chute
- Goose Chute
- Sommers Chute
- Proudfoot Slough
- Millers Slough

This study includes hydraulic modeling and sediment load calculations to provide a better idea of the dynamics of the side channels listed above to inform future NESP efforts. It's important to determine the hydraulic and sediment characteristics of this area to determine the impact they are having on Lake Onalaska and inform future design alternative decisions. The following sections include a description of the analyses as well as the results. The project area can be seen below in Figure 1.

This report contains analyses and design components that utilize elevation values and data. The project datum is North American Vertical Datum of 1988 (NAVD 88), so all elevations in this report (unless noted otherwise) will utilize that datum. The US Army Corps of Engineers (USACE) discharge and stage gages utilize the Mean Sea Level 1912 (MSL 12) datum. USGS gages typically utilize the National Geodetic Vertical Datum of 1929 (NGVD 29) datum. For reference, conversions from these datums to the project datum are provided below.

Project Datum NAVD 88 (feet) = MSL 12 (feet) – 0.51 feet
Project Datum NAVD 88 (feet) = NGVD 29 (feet) – 0.05 feet

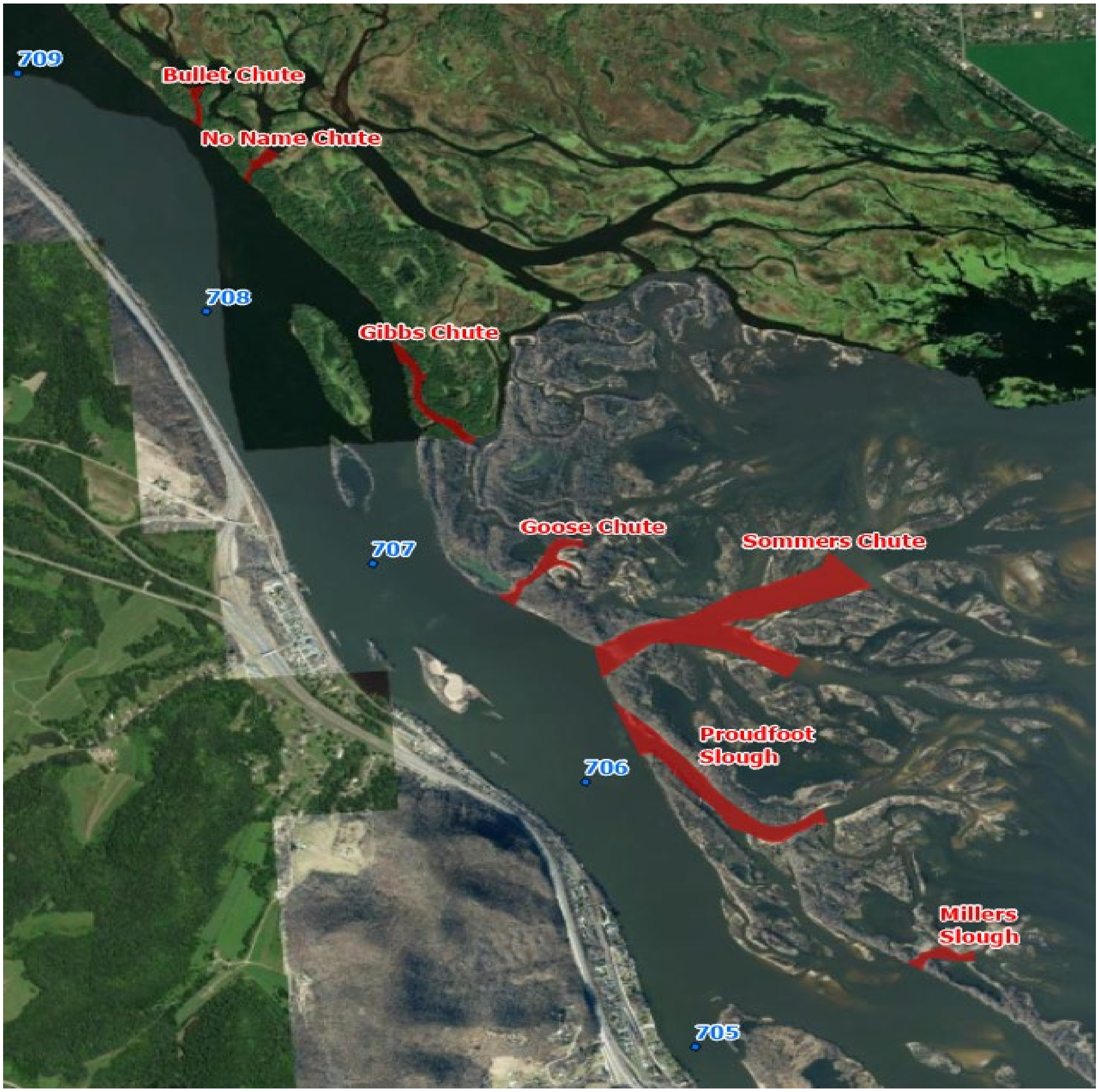



Figure 1: Lake Onalaska Project Area Map

## 2 Hydraulic Modeling

The model utilized during this study is a one- and two-dimensional unsteady state HEC-RAS model derived from the USACE Corps Water Management System (CWMS) model. The base model is described in Section 2.1.1 This model was then adjusted and refined for this specific project area which is described in Section 2.1.2.

## 2.1 Model Development

### 2.1.1 Base Model

The project model used the Upper Mississippi River Phase IV Flood Risk Management Existing Conditions Hydraulic Model as a base (UMR FRM hydraulic model) (USACE, 2020). This model was developed by the Corps to provide a better understanding of how floodwaters are carried by the system in its current/existing condition. This new existing-conditions model is a tool that can lead to better and more consistent characterization of flood risk. The hydraulic model will improve flood preparation and response, real time river forecasting and real time inundation mapping.

This model was developed using USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) software (5.0.7) (HEC, 2019). This model covers 251 river miles of the UMR mainstem from the Coon Rapids Dam tailwater in Coon Rapids, Minnesota (RM 866.29) to the middle of Pool 11, downstream of Guttenberg, Iowa (RM 615).

The UMR FRM hydraulic model leveraged the ongoing Corps Water Management System (CWMS) water control focused modeling effort by using the CWMS model as a base model. The UMR FRM hydraulic model differs from the CWMS model by having more detailed features, additional cross sections, and bluff to bluff coverage of the entire floodplain.

FEMA acknowledges that the UMR FRM hydraulic model cannot be used to produce an update or replacement of the 2004 FFS (USACE, 2004) and FEMA's regulatory products in its current state.

The model geometry was developed using a digital terrain layer comprised of the best available LiDAR (Light Detection and Ranging) terrain data and bathymetry data. The USGS Upper Midwest Environmental Sciences Center (UMESC) topobathy (topography + bathymetry) dataset for the UMR provided much of the necessary terrain and bathymetry data. The topobathy dataset is a combination of USACE-collected LiDAR and bathymetry data, supplemented with other surveyed bathymetry datasets. For the UMR modeling the topobathy datasets were supplemented with state LiDAR data for tributary reaches and more recent USACE-collected bathymetry, where available. The calibrated existing conditions model uses one set of parameters that produce reasonable results for three flood events (2001, 2014, and 2019). The existing levee elevations represent the sum of all activities (flood fighting, repairs, dredge material placement, approved and unapproved alterations) that have occurred over time. The goal of this model is to provide a common tool using the best available data and software that can reasonably recreate a range of events that have occurred or may occur in the future to assess system performance and flood risk management strategies.

### 2.1.2 Truncated and Adjusted Model

The UMR FRM hydraulic model described in the section above was utilized for the Lake Onalaska project design model. The model adjustments were made in HEC-RAS version 6.4.1 (HEC, 2023). The UMR FRM hydraulic model was truncated upstream and downstream of the project area to decrease model run times. The upstream portion of the model was truncated to a cross section at RM 714.23 just upstream of the USACE Lock and Dam 6 (L&D 6)Tailwater Gage (USACE, 2023) because it was the easiest location to break the model and required minimal geometry changes in that area. The downstream portion of the model was truncated to a cross section at RM 689 downstream of L&D 7 at Brownsville, MN. This was the first location downstream of the project area that provided an easy break location and did not require a geometry change. This location is also a sufficient distance downstream of the project area that it ensures the downstream boundary condition does not affect the project area of interest. The truncated model extents is shown in Figure 2.

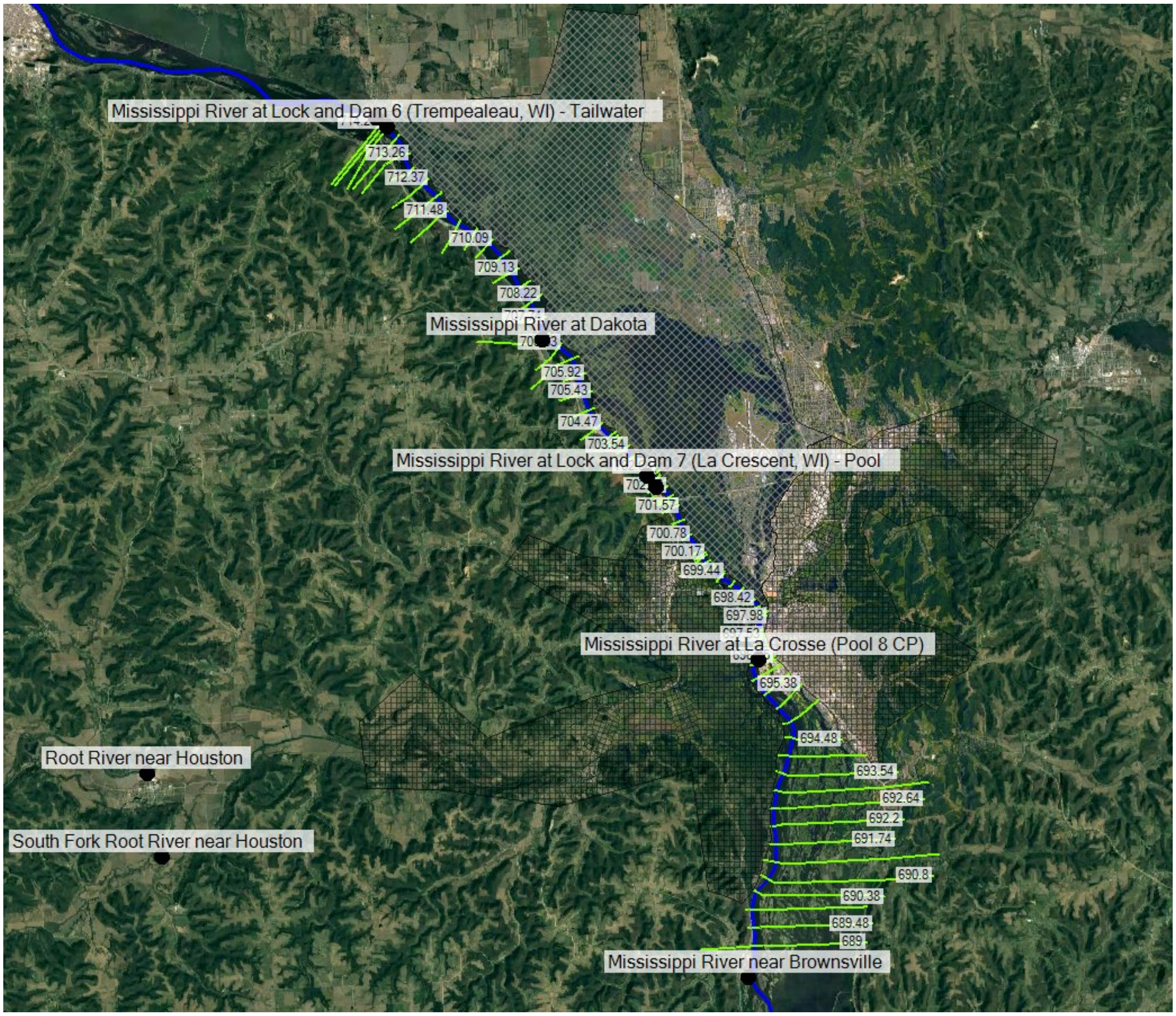



Figure 2: Truncated Model Extents

The UMR FRM hydraulic model did not include enough detail within the 2D flow area covering the project area to model the existing conditions at the level of accuracy needed for this project. Breaklines were added to the 2D flow area to better capture flow entering the existing side channels between the Main Channel of the Mississippi River and Lake Onalaska. The lateral structure equations and coefficients were adjusted in the model to allow for maximum flow to enter the 2D area covering the project area.

Model instabilities were identified near the confluence of the Mississippi and Black Rivers. To address this, the one-dimensional reach of the Black River and its associated elements were removed from the model. This was replaced by extending the 2D area to cover this 1D reach. The terrain was altered in this area to reflect the bathymetry data within the Black River cross sections. These adjustments to the model did not affect the results at the side channels of interest and improved model stability significantly. The adjusted model geometry is shown in Figure 3.

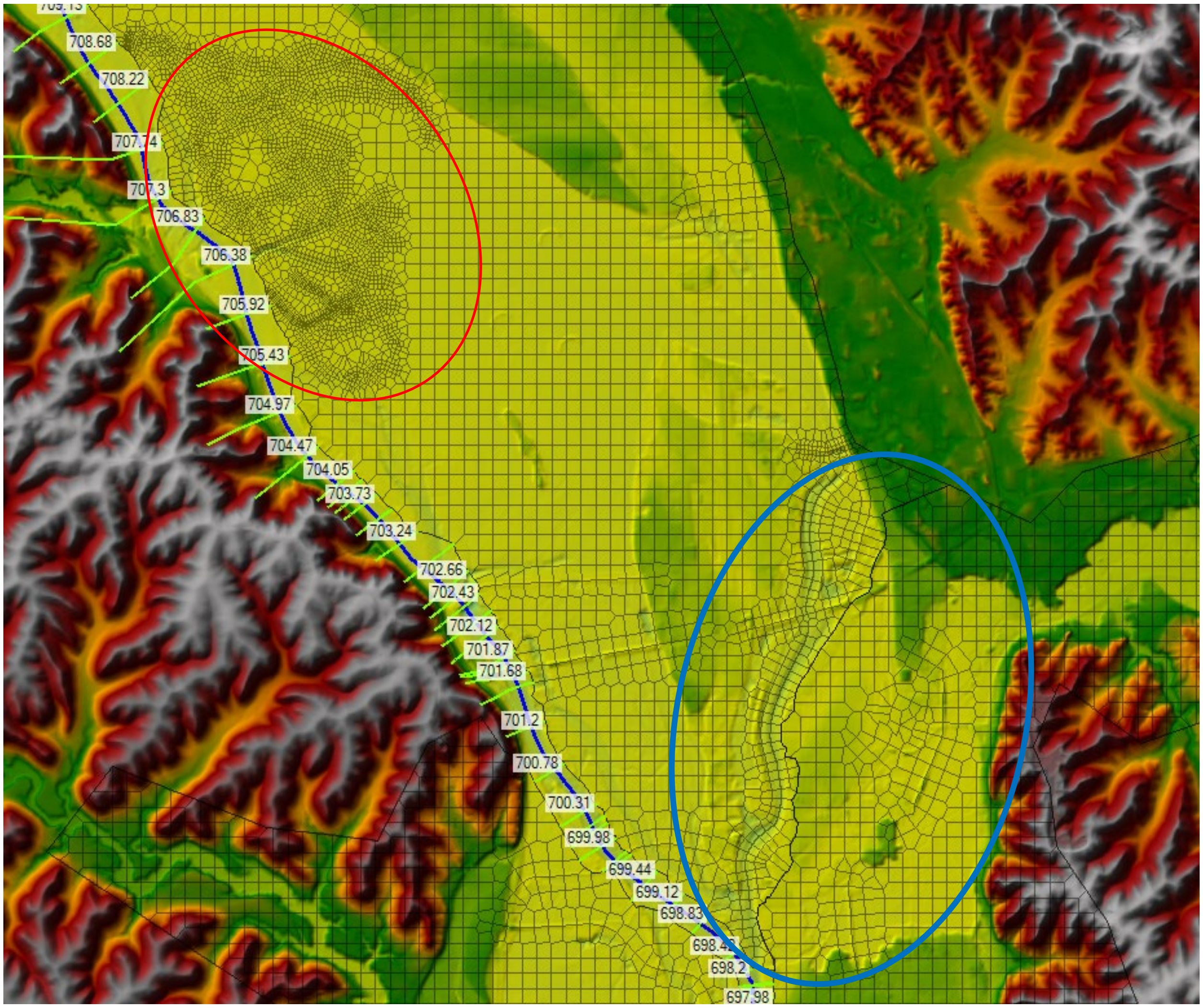



Figure 3: Adjusted Geometry (project area in red and modifications to the Black River in blue)

### 2.1.3 Boundary Conditions

The upstream boundary condition used for the project design model is a flow hydrograph at the most upstream cross section which is the approximate location for the Lock and Dam 6 tailwater gage. Navigation dam rules were added for L&D 7, and the downstream boundary condition included normal depth (0.00001). Upstream boundary conditions for the Black, La Crosse, and Root Rivers are represented with flow hydrographs.

In total, there were seven events modeled which include five events based on either a percentage of time exceeded or annual exceedance probability (AEP) and two calibration events (observed data). The five percent time exceeded/AEP event discharges and corresponding WSEs are listed in Table 2 below.

The five events based on a percentage of time exceeded or annual exceedance probability (AEP) utilized a typical shape and duration event taken from the period of record at the tailwater of L&D 6, and then scaled to each of the five hypothetical events. The Black, La Crosse, and Root Rivers also used this typical shape and duration event since the discharges from these rivers are much less than the Mississippi and have minimal effect on the results (especially after calibration).

The L&D 6 gage data (USACE, 2023) was analyzed to find a typical summer event hydrograph that could be scaled to the events in Table 1 below. The flow boundary conditions for both the Mississippi River at the tailwater of L&D 6 (USACE, 2023), the Black River near Galesville, WI (USGS, 2023), the La Crosse River near La Crosse, WI (USGS, 2023), and the Root River near Houston, MN (USGS, 2023) were used for these events are shown in Figure 4, Figure 5, Figure 6, and Figure 7, respectively.

The two calibration specific events shown in Table 1 are described further in Section 2.2 below.

Table 1: Modeled Calibration/Validation Events Descriptions

| Modeled Calibration/Validation Events | | | |
|---|---|---|---|
| **Year** | **Approx. Percent of Time Exceeded** | **Discharge – L&D 6 (cfs)** | **Description of Flow Condition** |
| 2019 | Just above 20% Exceedance Value | 129,848 | Small Flood |
| 2020 | Just above 50% Exceedance Value | 70,141 | Bankfull Event |

**Percent Time Exceeded Events**

The tailwater gage at L&D 6 includes discharge data from 1959-present. The time exceeded values from the L&D 6 gage was used to capture the longest period of record for the analysis (USACE, 2023). The USGS 05382000 Black River near Galesville, WI gage was analyzed from October 1986 to present (USGS, 2023). The USGS 05383075 La Crosse River near La Crosse, WI gage was analyzed from October 1999 to present (USGS, 2023). The USGS 05385000 Root River near Houston, MN gage was analyzed from October 1993 to present (USGS, 2023).

**AEP Events**

The AEP event discharges were taken from the 2004 FFS (USACE, 2004).

Table 2: HEC-RAS Discharge Events

| Discharge (cfs) | | | | Percent of Time Exceeded[1] | Annual Exceedance Probability Event[2] | Description of Flow Condition |
|---|---|---|---|---|---|---|
| **Discharge – L&D 6 (cfs)** | **USGS 05382000 Black River near Galesville, WI** | **USGS 05383075 La Crosse River near La Crosse** | **USGS 05385000 Root River near Houston, MN** | | | |
| 16034 | 666 | 308 | 661 | 50 | | Low Flow |
| 26340 | 1060 | 379 | 1060 | 25 | | Moderate Flow |
| 89500 | 3500 | 1000 | 3000 | - | 50 | Bankfull Event |
| 129000 | 4000 | 1000 | 3000 | - | 20 | Small Flood |
| 240000 | 4000 | 1000 | 3000 | - | 1 | Large Flood |

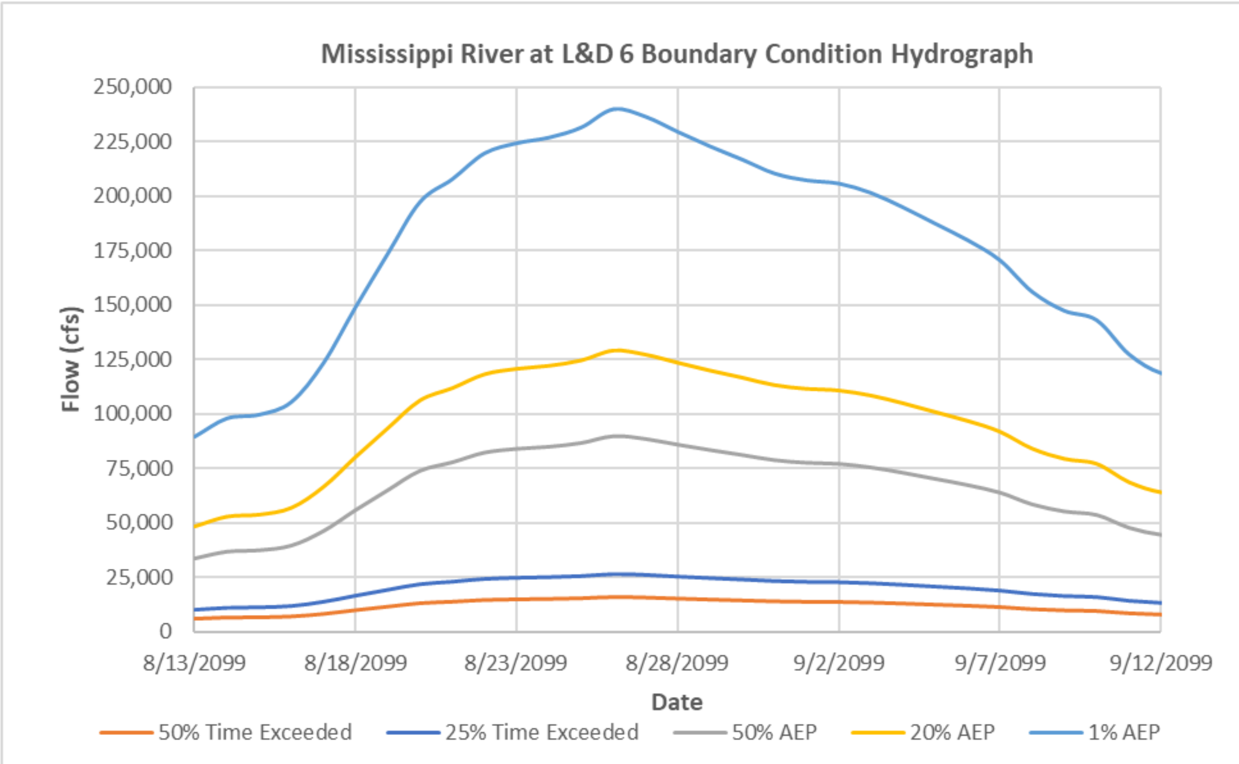



Figure 4: HEC-RAS Boundary Condition Hydrographs for the L&D 6 Tailwater

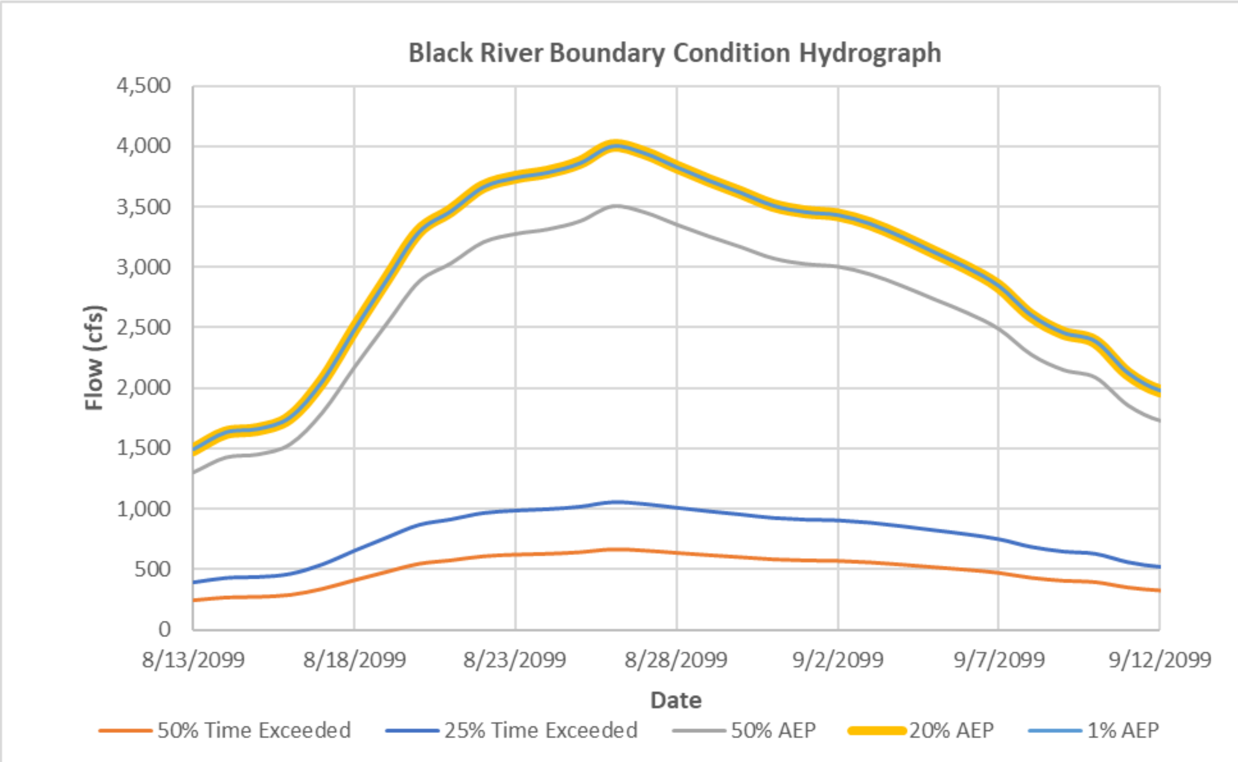



Figure 5: HEC-RAS Boundary Condition Hydrographs for the Black River

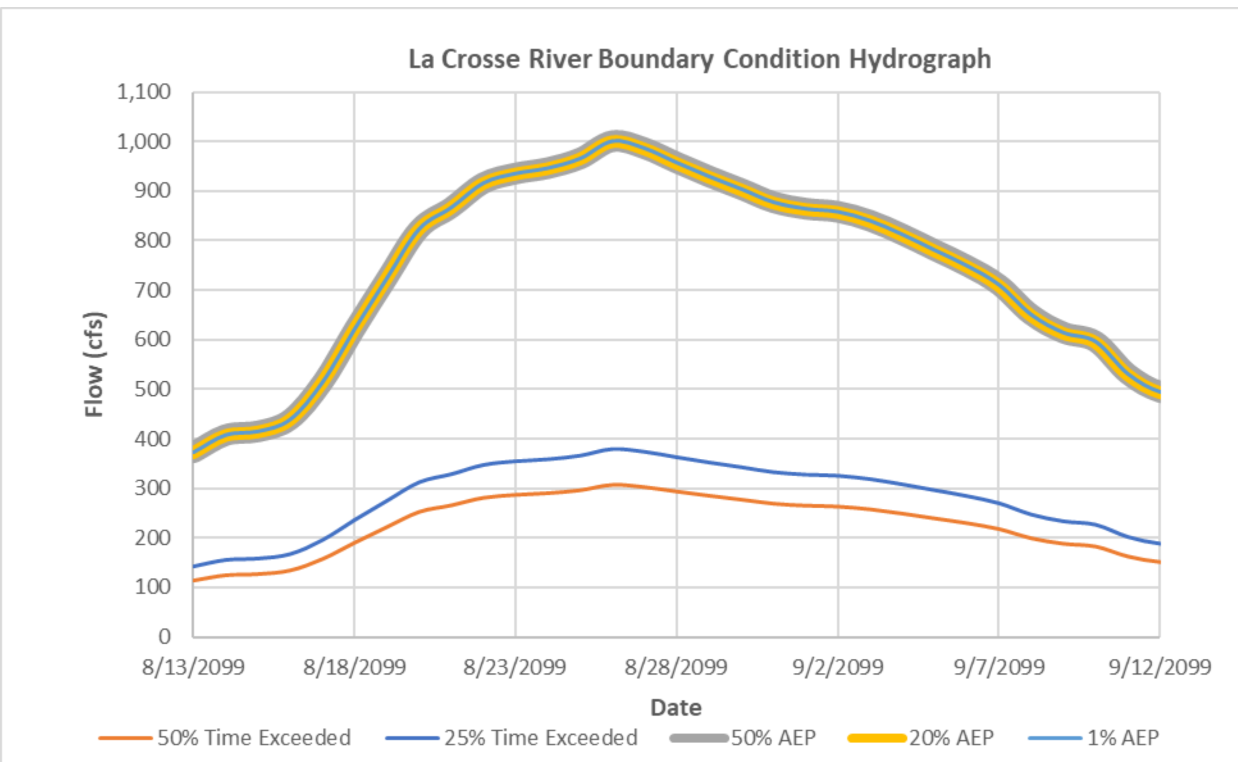



Figure 6: HEC-RAS Boundary Condition for the La Crosse River

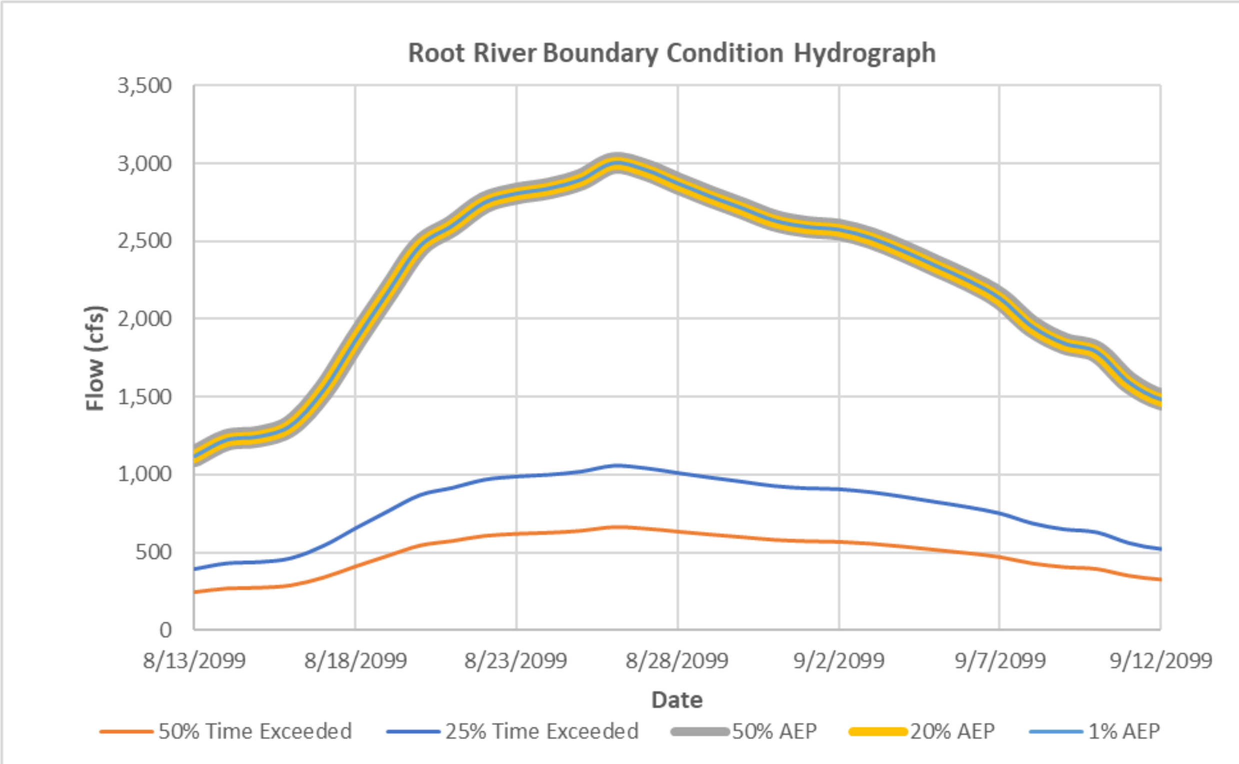



Figure 7: HEC-RAS Boundary Condition for the Root River

## 2.2 Model Calibration/Verification

### 2.2.1 Mainstem Calibration

The UMR FRM hydraulic model was used as the basis of the project design model. That model was calibrated to the three events listed in Table 3 below. The UMR FRM hydraulic model was not calibrated to a flow associated with a specific return interval (e.g., 1% AEP event). A comparison of this model with the 2004 FFS was outside the scope of this model.

Table 3: UMR FRM Hydraulic Model Calibration Events

| Calibration Events | Lock and Dam No. 2 | | Lock and Dam No. 10 | |
|---|---|---|---|---|
| | Peak Flow (cfs) (approx. AEP) | Date | Peak Flow (cfs) (approx. AEP) | Date |
| 2001 | 141,000 (~0.01) | 28APR01 | 271,000 (~0.01) | 21APR01 |
| 2014 | 101,000 (~0.04) | 27JUN14 | 190,000 (~0.1) | 04JUL14 |
| 2019 | 105,000 (~0.04) | 01APR19 | 240,000 (~0.03) | 27APR19 |

Because there were changes to the project area geometry, the project design model (existing conditions) was briefly calibrated/verified for this effort using an observed event in 2020, an observed event in 2019, and the one percent AEP event to capture a large-scale flooding event.

Observed discharge at the Lock and Dam 6 Tailwater (USACE, 2023) gage was used as the upstream boundary condition for the 2020 and 2019 events. The Dakota gage near the project area and the L&D 7 pool gage were analyzed for calibration (USACE, 2023). The L&D 6 peak flow values from the observed calibration events are listed in Table 4 below.

Table 4: Project Design Hydraulic Model Observed Calibration Events

| Calibration Event | L&D 6 Peak Flow (cfs) | Date |
|---|---|---|
| 2019 | 111,700 | 10-Oct-19 |
| 2020 | 61,100 | 2-Aug-20 |

The 2020 and 2019 events are plotted with the observed data in Figure 8 and Figure 9 below, respectively.

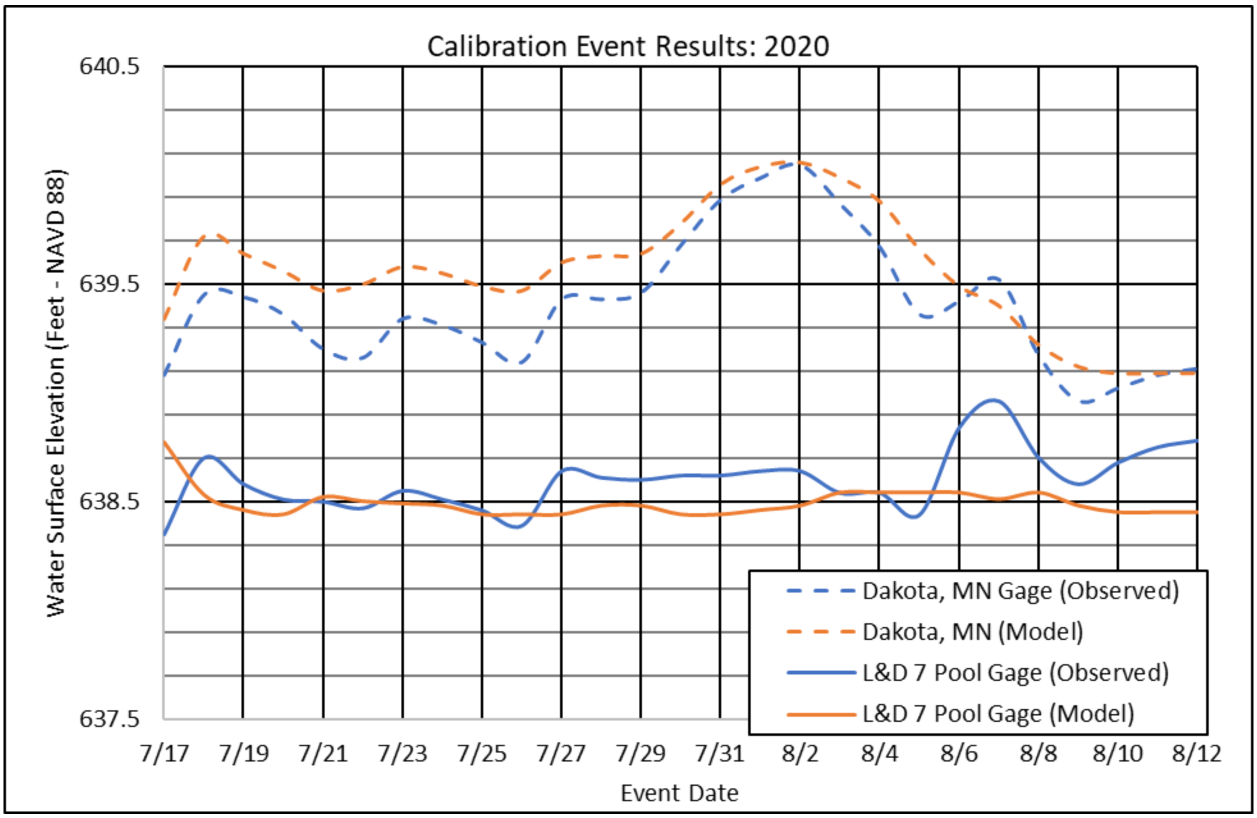



Figure 8: Calibration Event 2020 Results

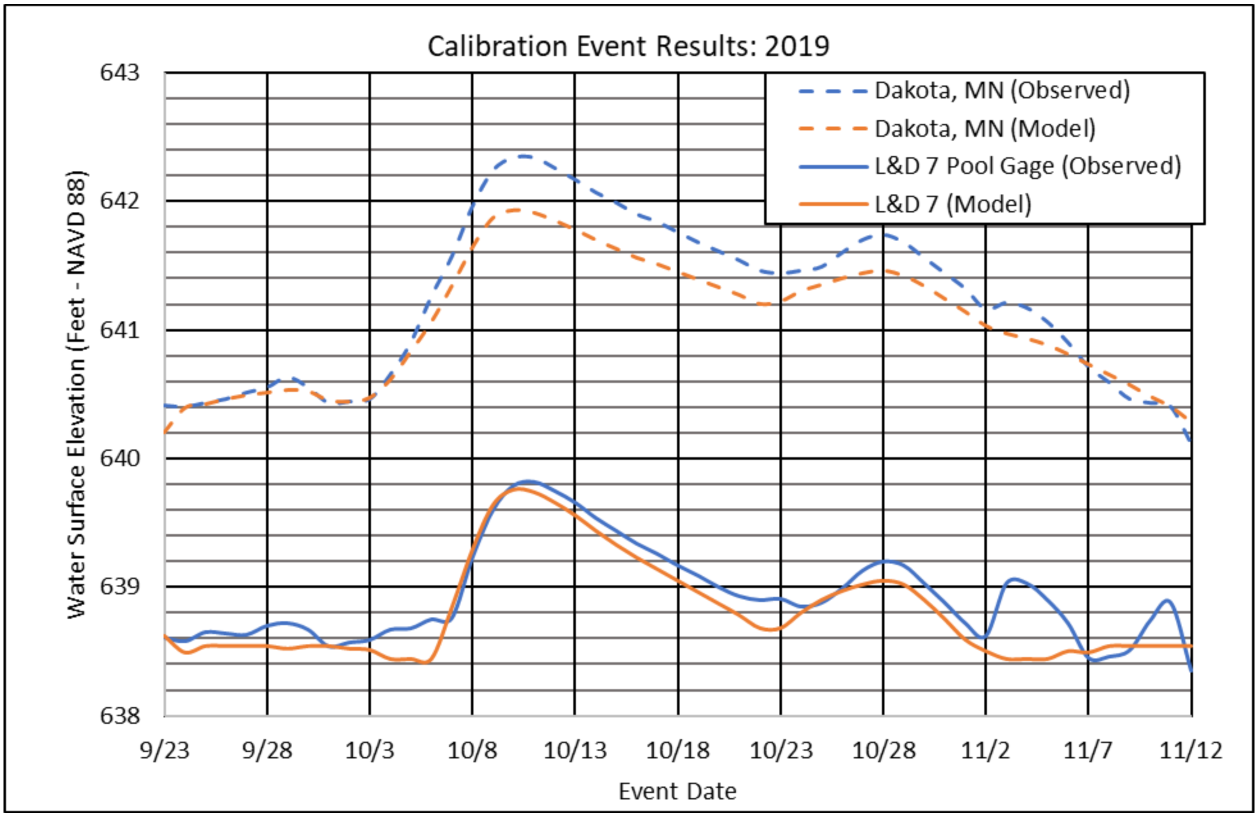


Figure 9: Calibration Event 2019 Results

To verify the truncated geometry is more accurate than the original UMR Phase IV geometry, the original model 2019 results were plotted at the same locations (Dakota gage and L&D 7 gage) as the truncated model 2019 event results. Note, the 2019 event dates do not match between the two models. However, this comparison still provides a general idea on the accuracy of each model's calibration. The results for the original UMR Phase IV model 2019 event can be seen in Figure 10. As seen in this plot, the original UMR Phase IV model differs from the observed data by up to 1.5 feet at the Dakota gage. As seen in Figure 9, the truncated model differs from the observed data by only 0.2 feet at most. The significant improvement for the truncated model geometry over the original model proves the truncated model results are more ideal for this project.

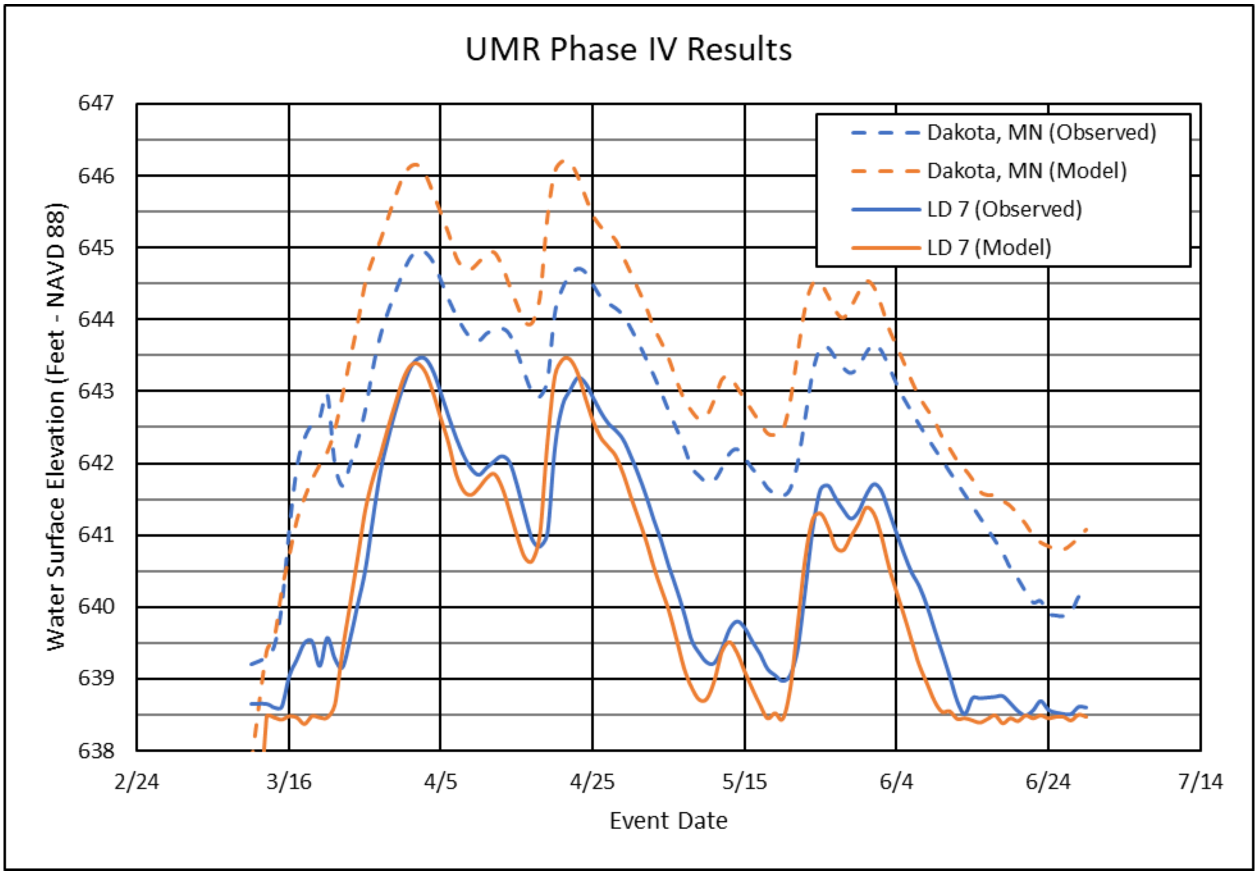



Figure 10: Original UMR Phase IV Stage Hydrograph

The three existing conditions calibration events (2020, 2019 and 1% AEP) were also plotted against the primary USACE WCM operating Curves for L&D 7 which are the Dakota Gage and the L&D 7 Pool Gage (USACE, 2004). The results of this portion of the calibration effort are shown in Figure 11 and Figure 12 below.

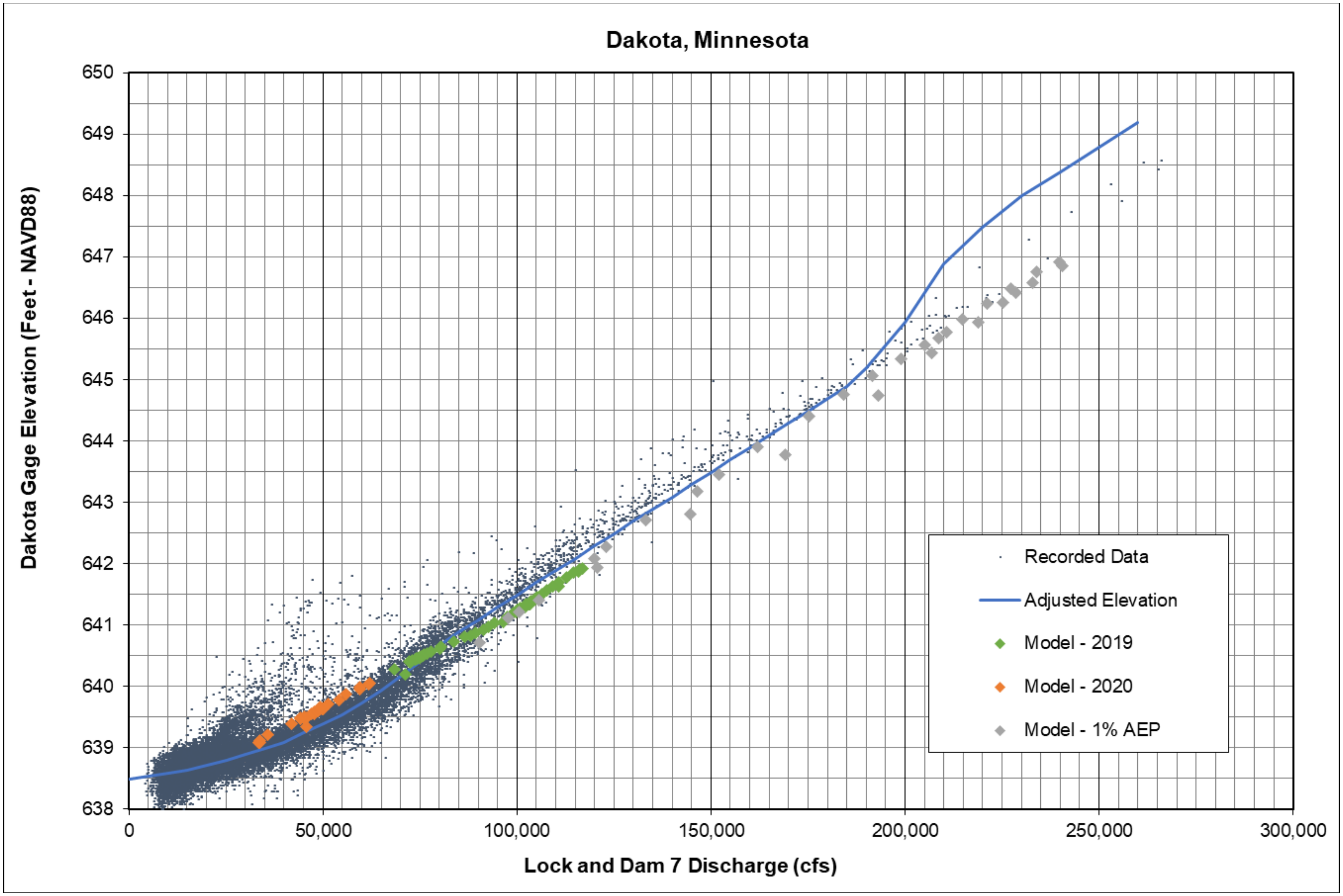



Figure 11: Dakota, MN Gage WCM Operating Curve with Hydraulic Model Results

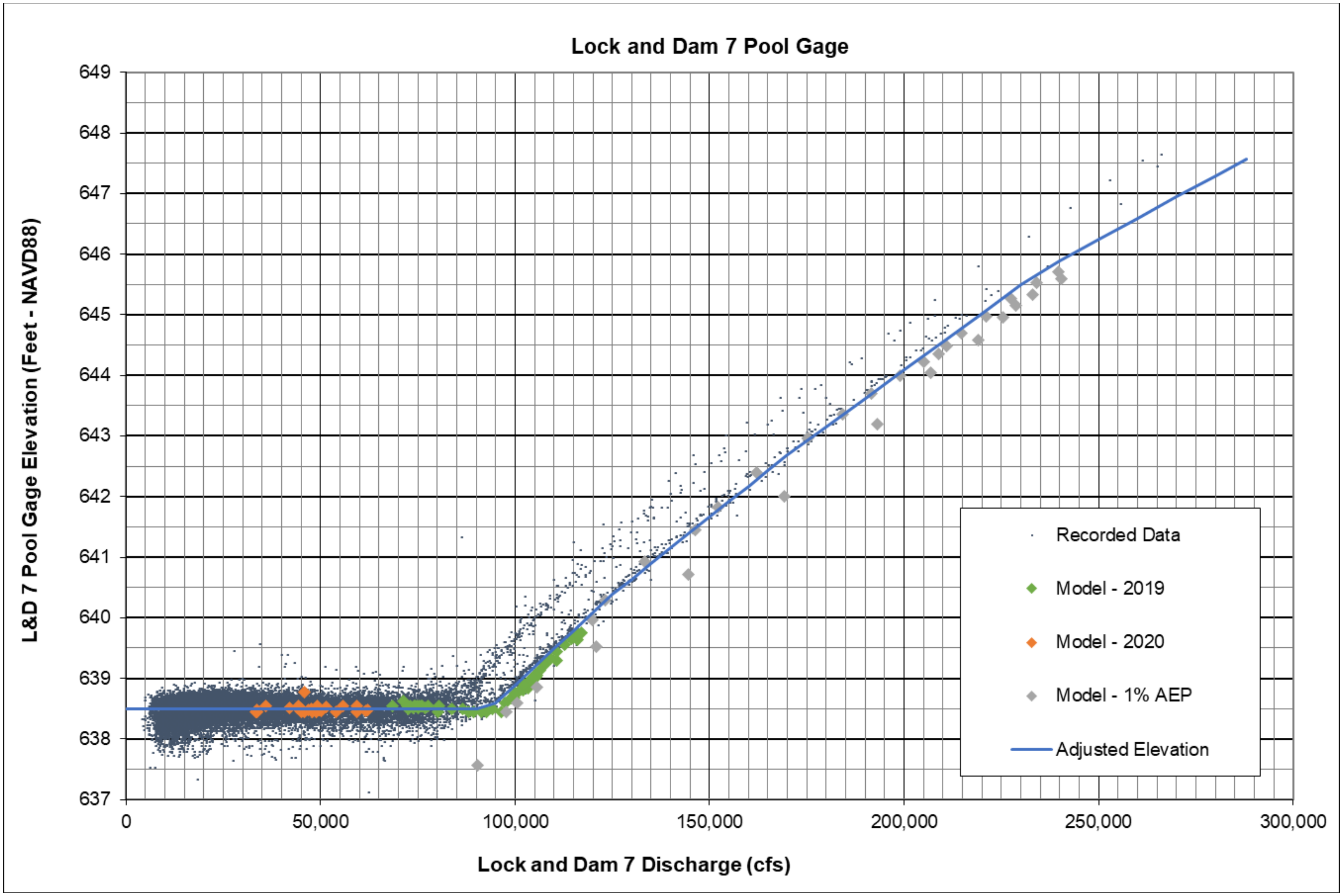



Figure 12: L&D 7 Pool Gage WCM Operating Curve with Hydraulic Model Results

### 2.2.2 Side Channel Calibration

Discharge measurements have been taken at several transects near the project area. Figure 13 shows the major transect locations near the project area. This figure can be referenced to identify the discharge measurement transects whose rating curves are given in subsequent figures. In general, the measurement site names are based on river mile, along with a distance and direction from the navigation channel centerline.

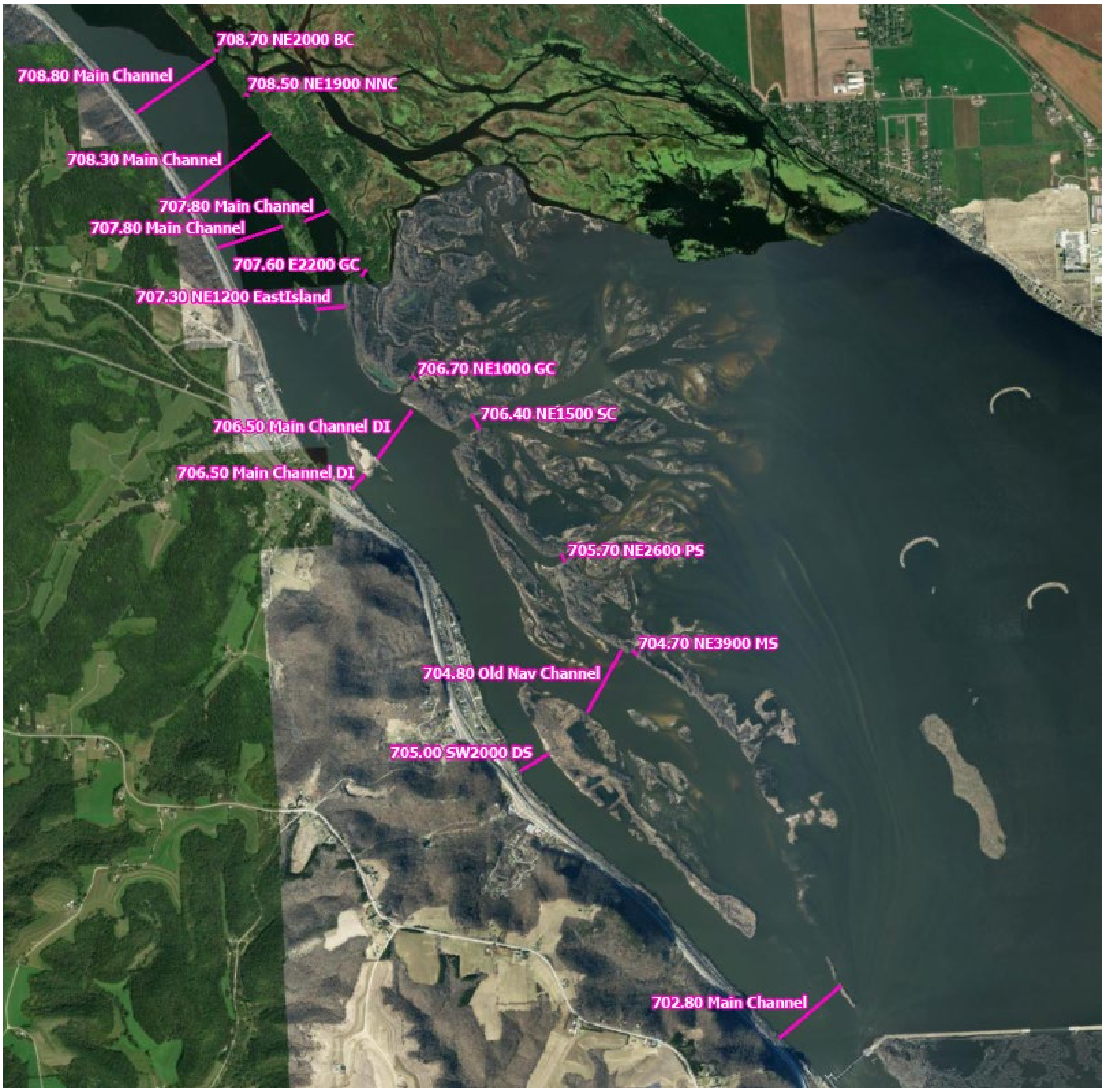



Figure 13: Discharge Transects Near the Project Area

Rating curves for these discharge transects are shown in Figure 14 through Figure 27 below. The figures outlined in red are the side channels of interest identified previously in the report. These figures include model results and data collected in the field. The model results include the modeled 20% AEP event, 50% AEP event, 25% of time exceeded (TE), and 50% TE. The observed data includes data collected by the Corps, US Fish and Wildlife Service, and Wisconsin Department of Natural Resources. In general, the observed data and the modeled results match well for the Main Channel discharge transects. Most of the side channel model results do not match the observed data as well; this is likely due to the bathymetry data used throughout these areas. This data is from 1992-1995 which is why some of the side channel model results match well with the observed data from those dates. It is recommended to collected updated bathymetry in future project efforts. The discharge transects are shown in Figure 14 to Figure 27.

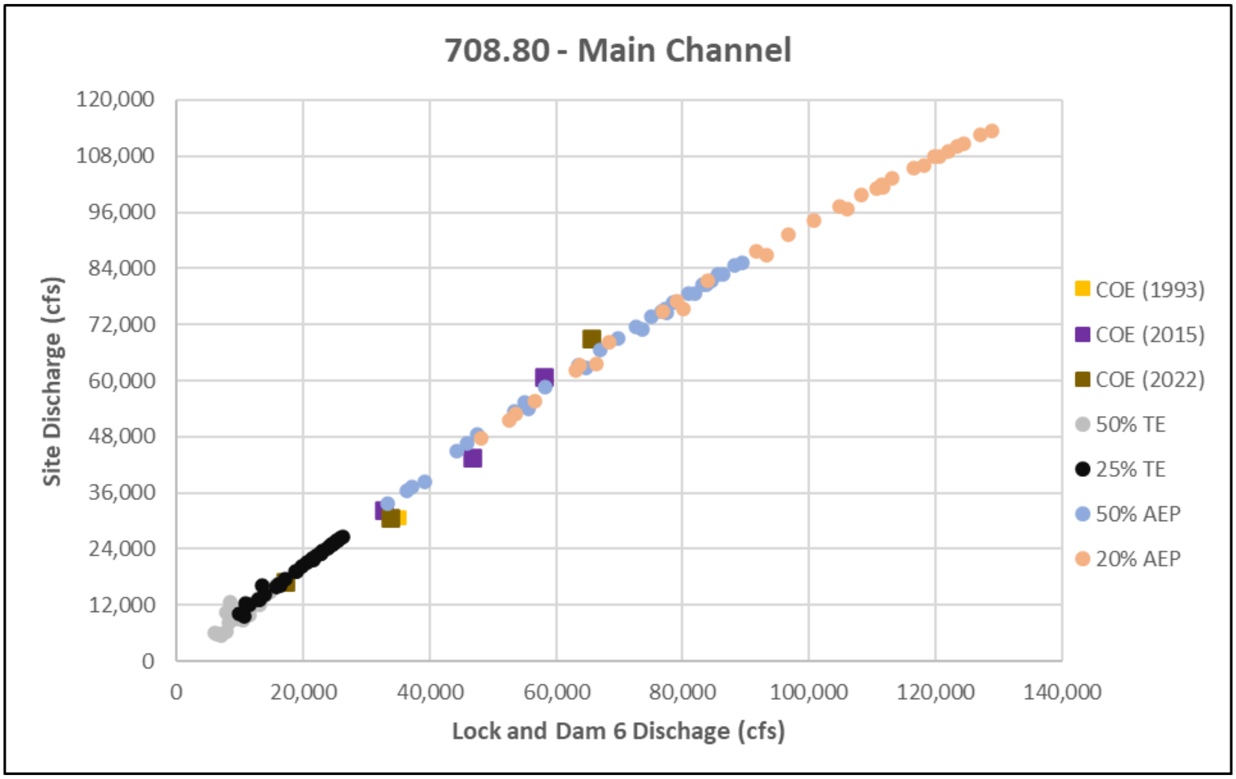



Figure 14: Rating Curve RM 708.80 - Main Channel

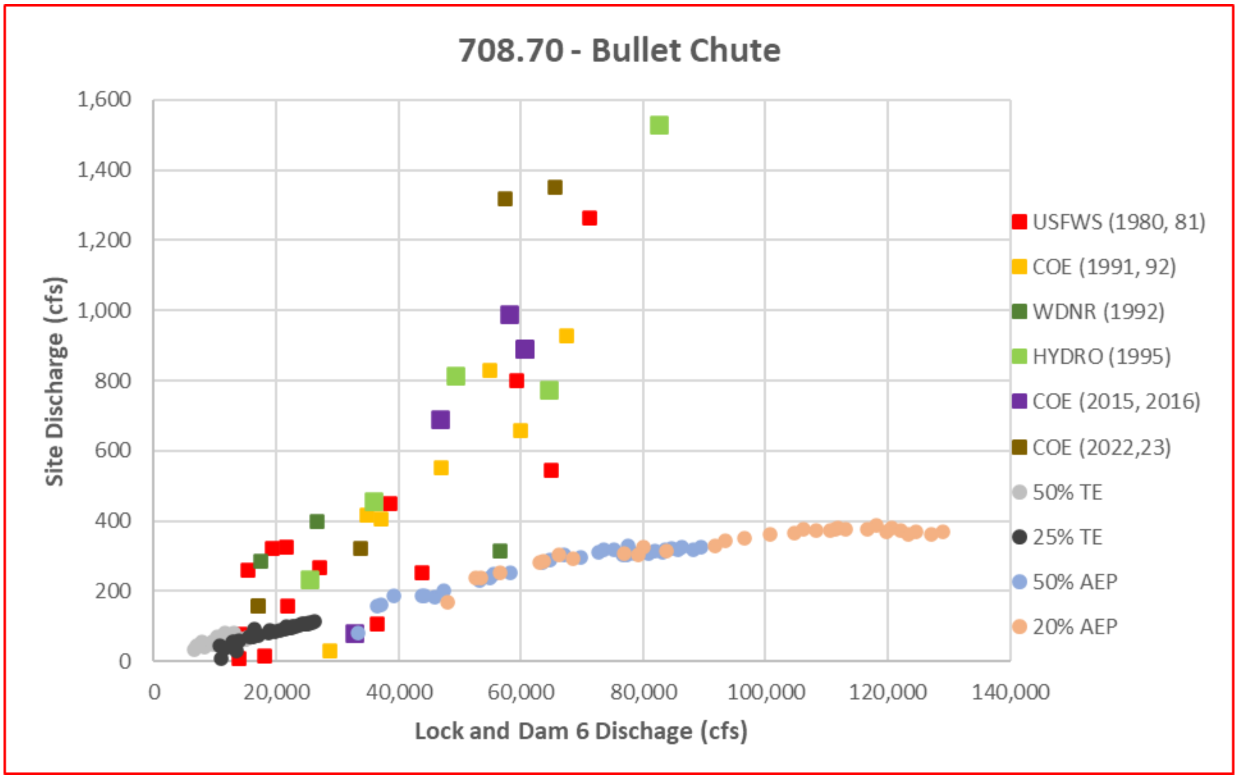



Figure 15: Rating Curve RM 708.70 – Bullet Chute

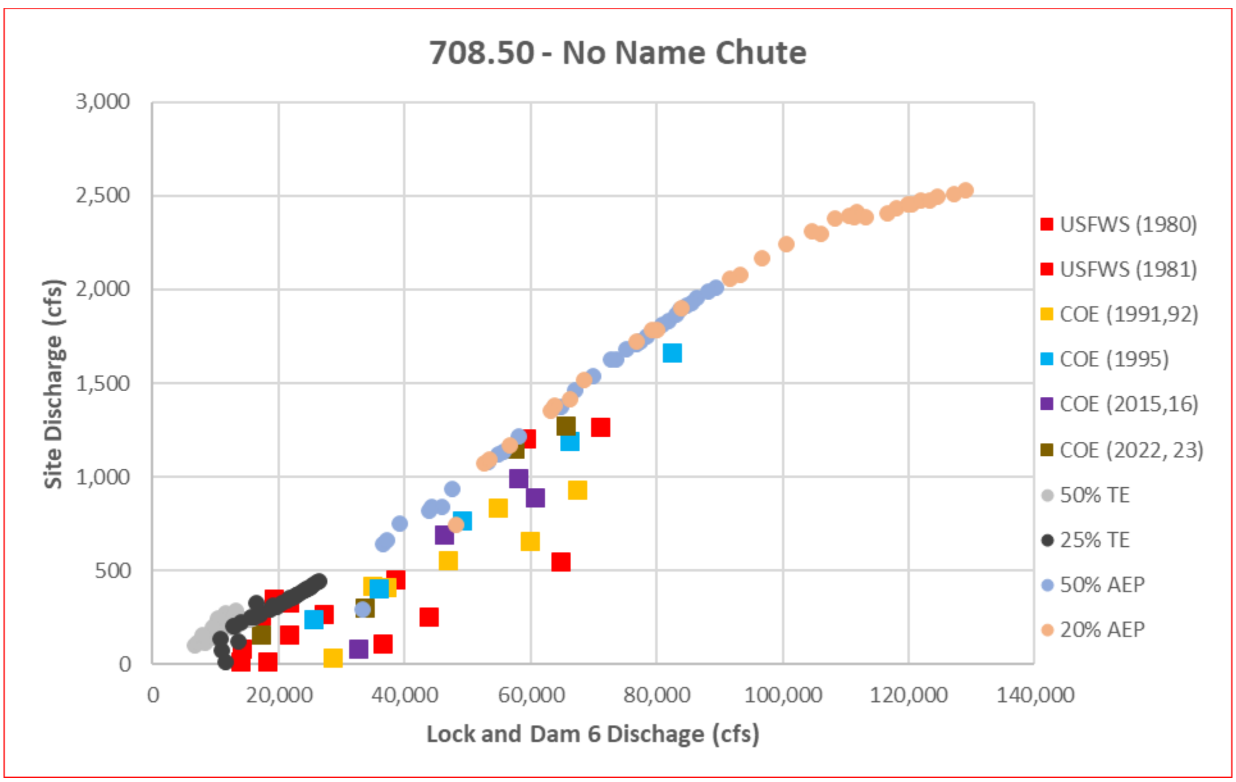



Figure 16: Rating Curve RM 708.50 – No Name Chute

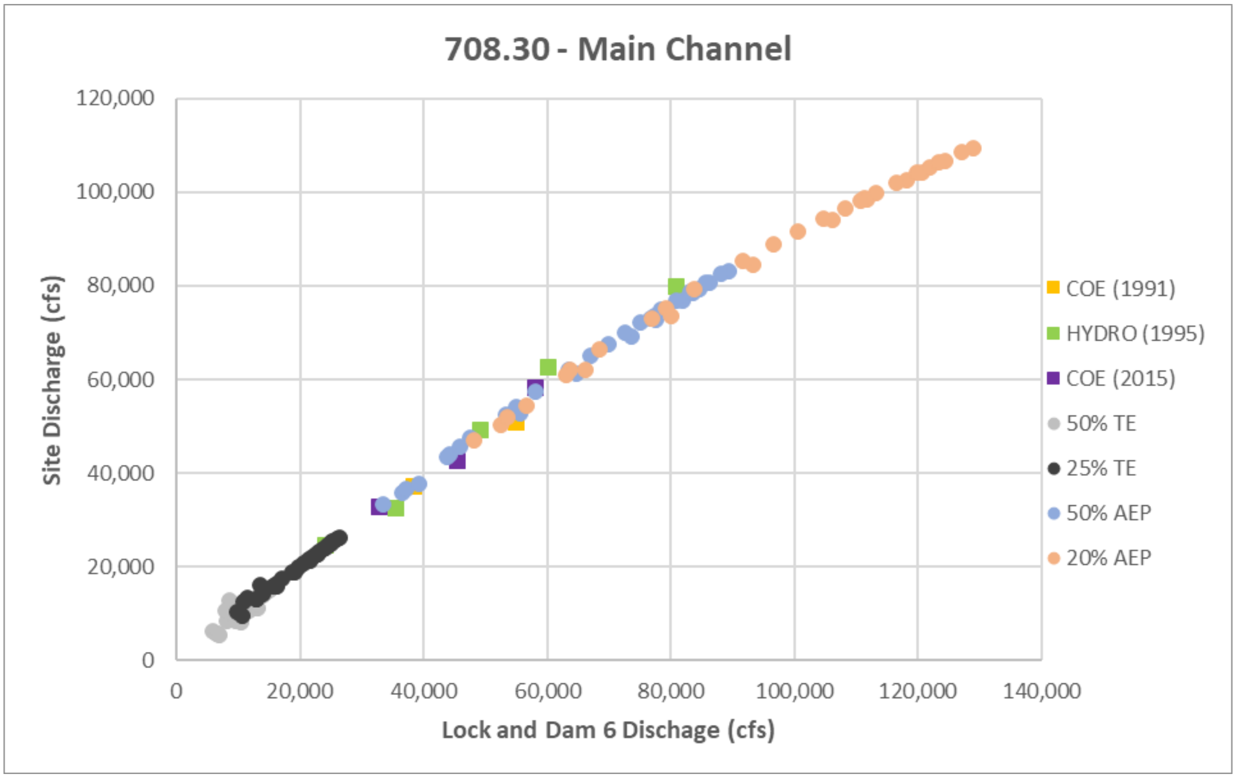



Figure 17: RM 708.30 – Main Channel

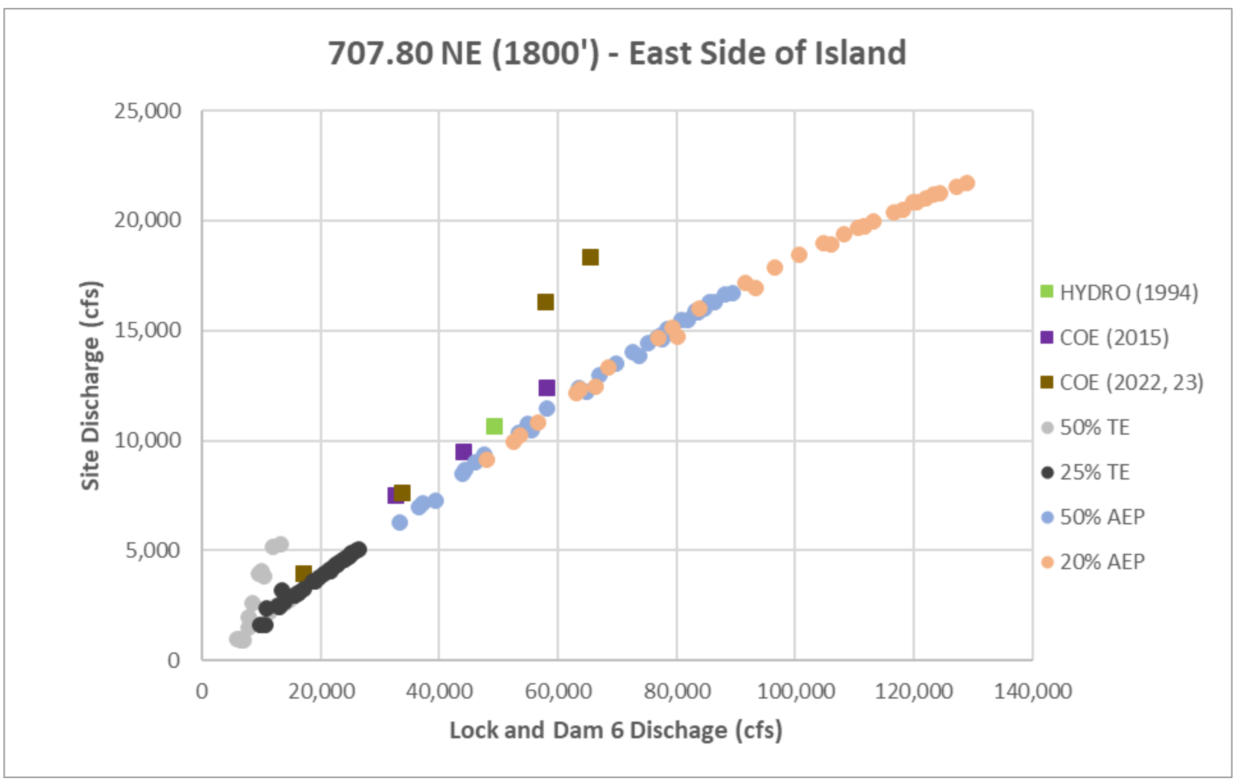



Figure 18: RM 707.80 NE (1800') – East Side of Island

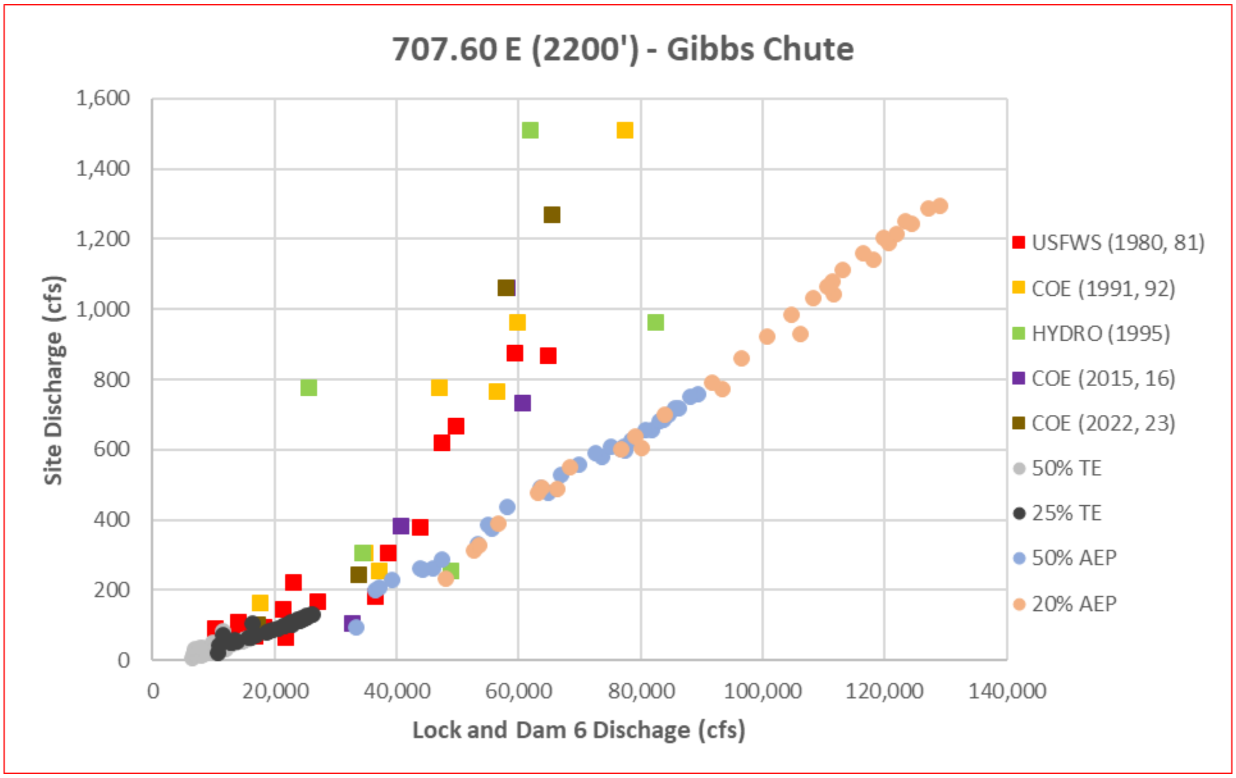



Figure 19: RM 707.60 E (2200') – Gibbs Chute

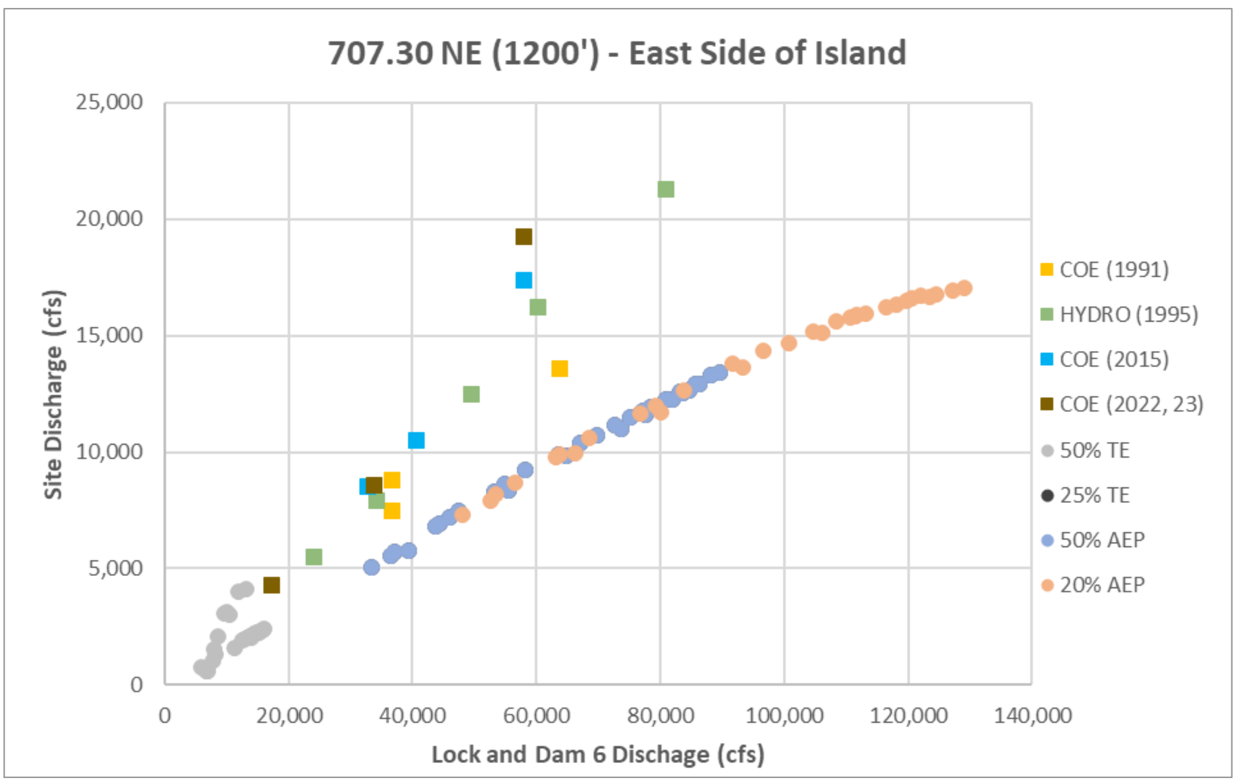



Figure 20: RM 707.30 NE (1200') – East Side of Island

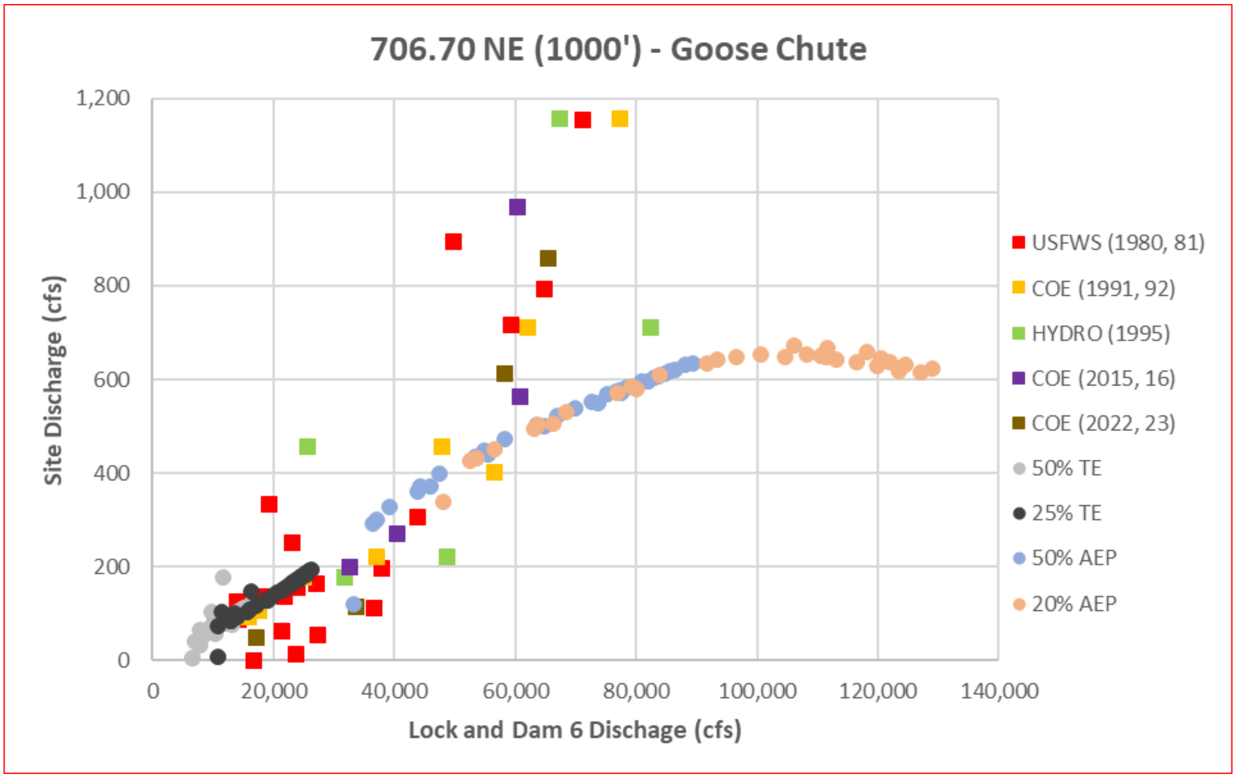



Figure 21: RM 706.70 NE (1000') – Goose Chute

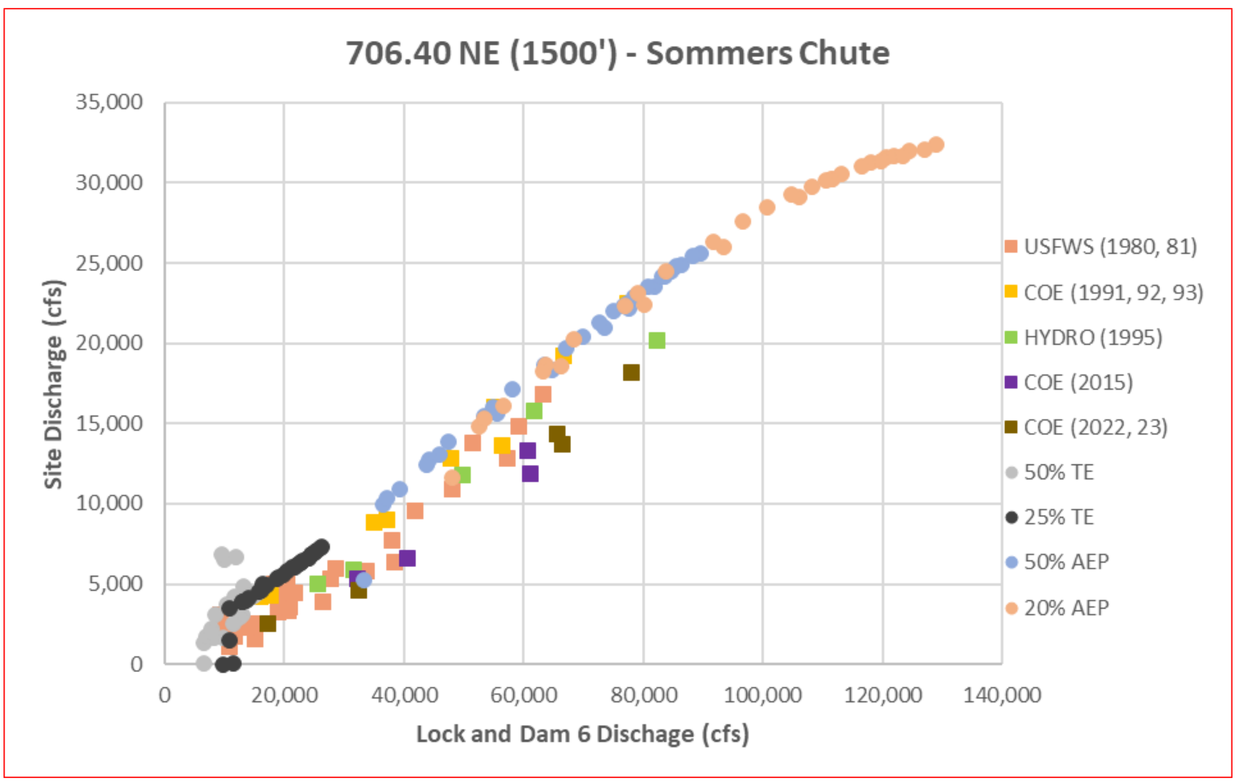



Figure 22: RM 706.40 NE (1500') – Sommers Chute

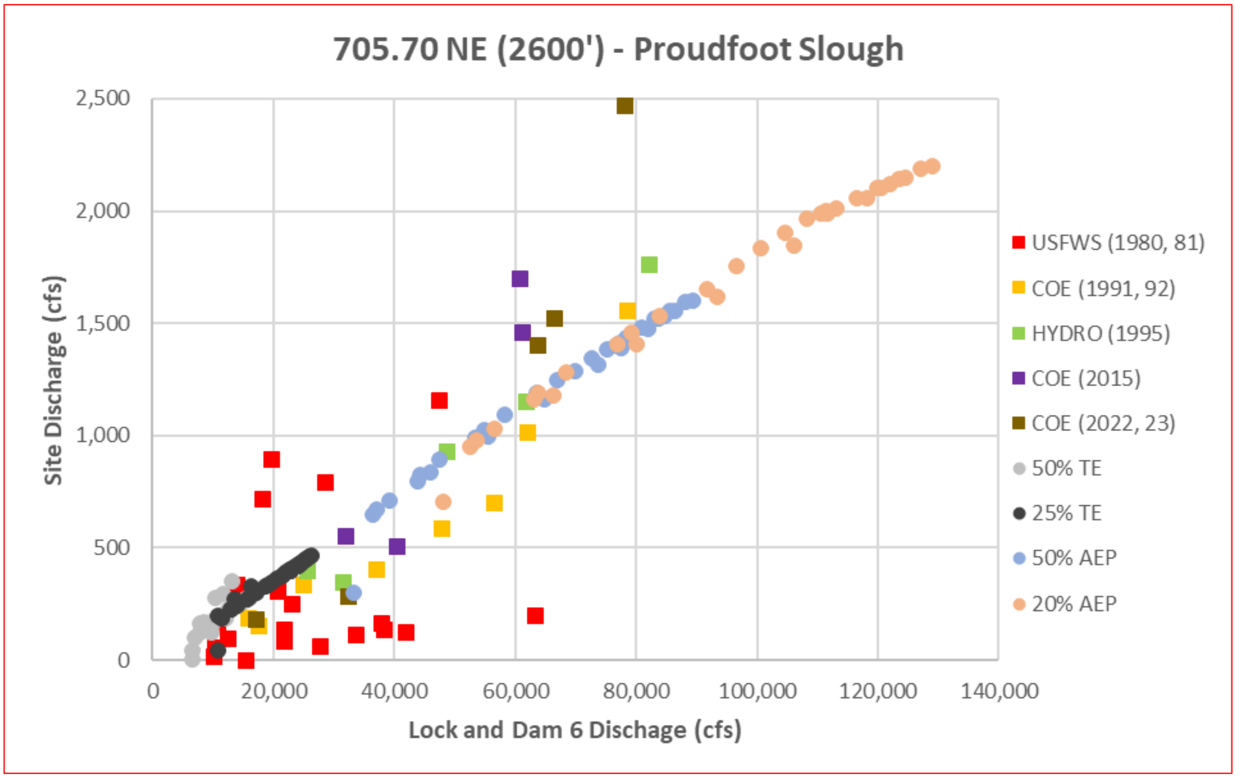



Figure 23: RM 705.70 NE (2600') – Proudfoot Slough

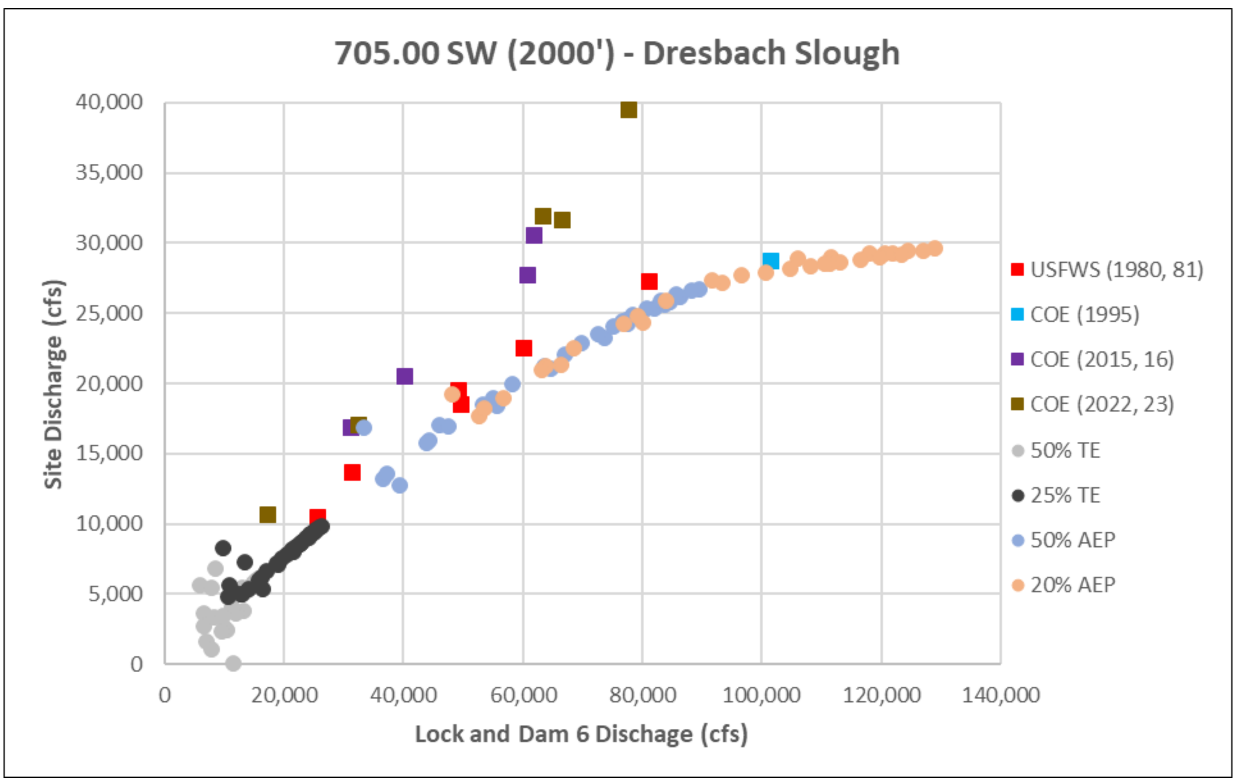



Figure 24: RM 705.00 SW (2000') – Dresbach Slough

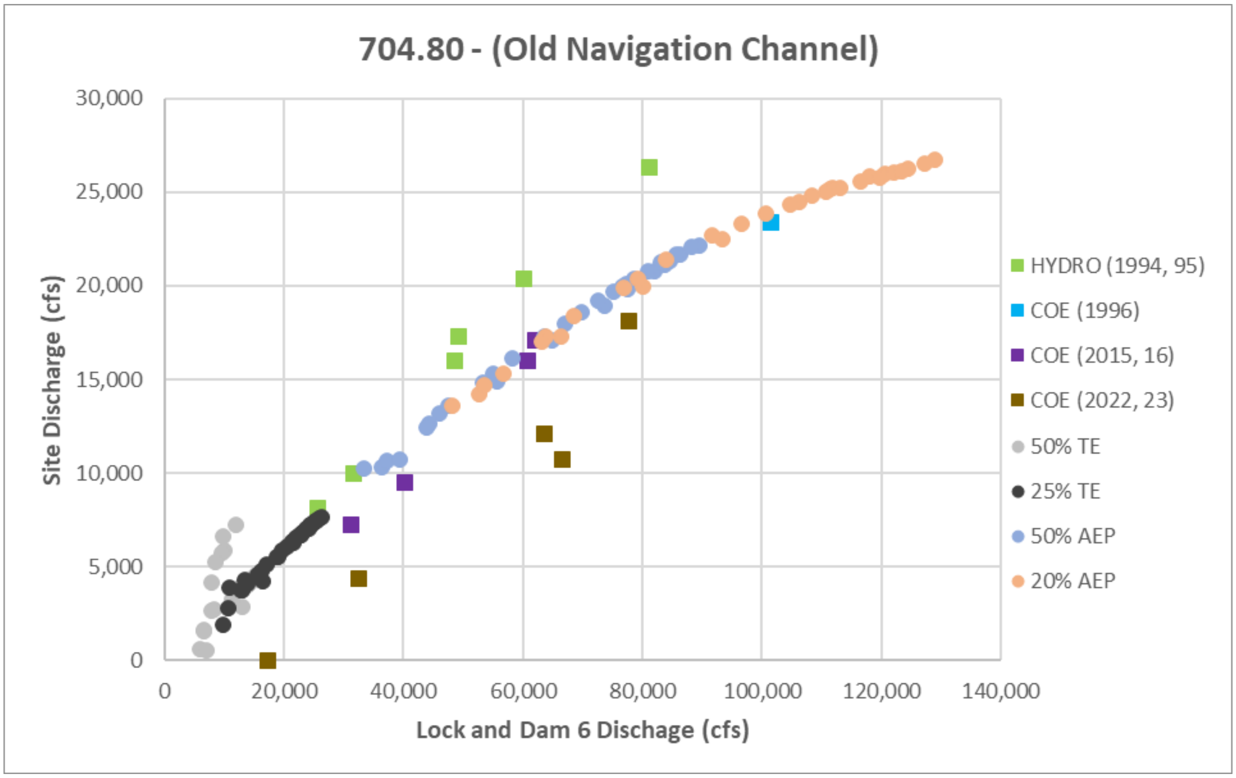



Figure 25: RM 704.80 – (Old Navigation Channel)

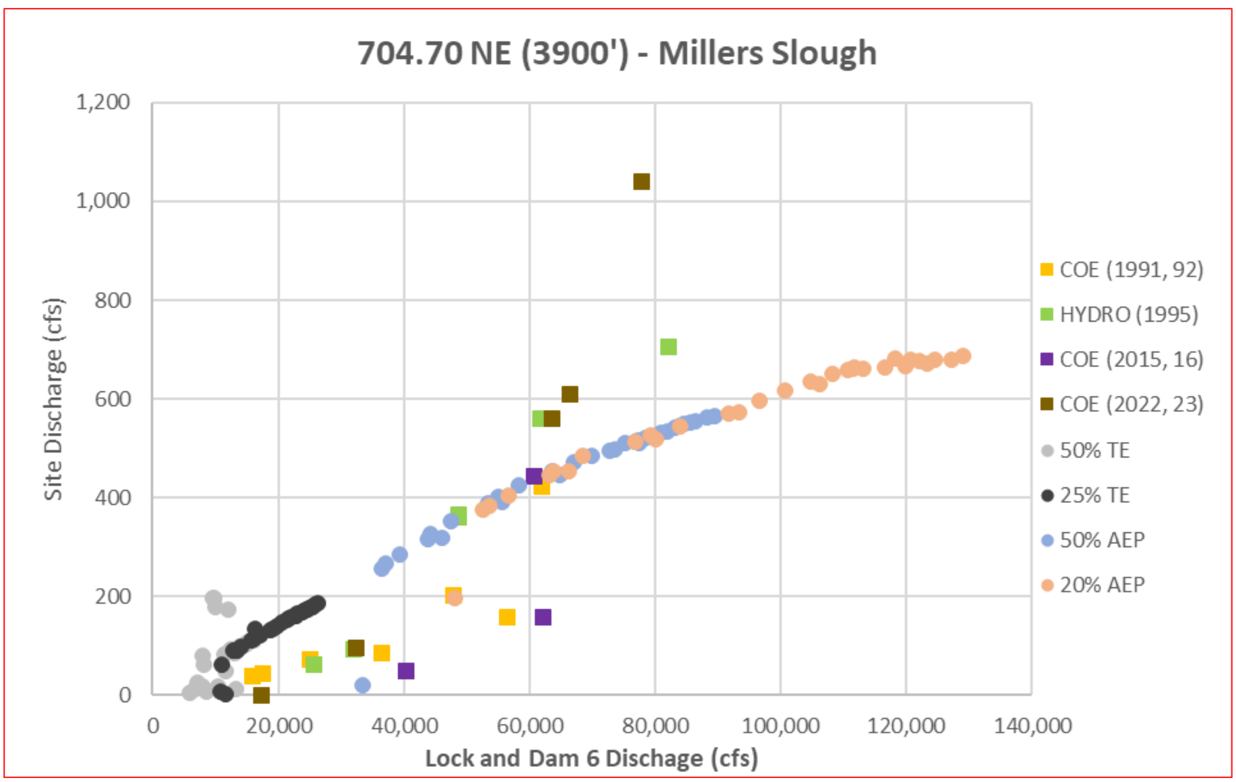



Figure 26: RM 704.70 NE (3900') – Millers Slough

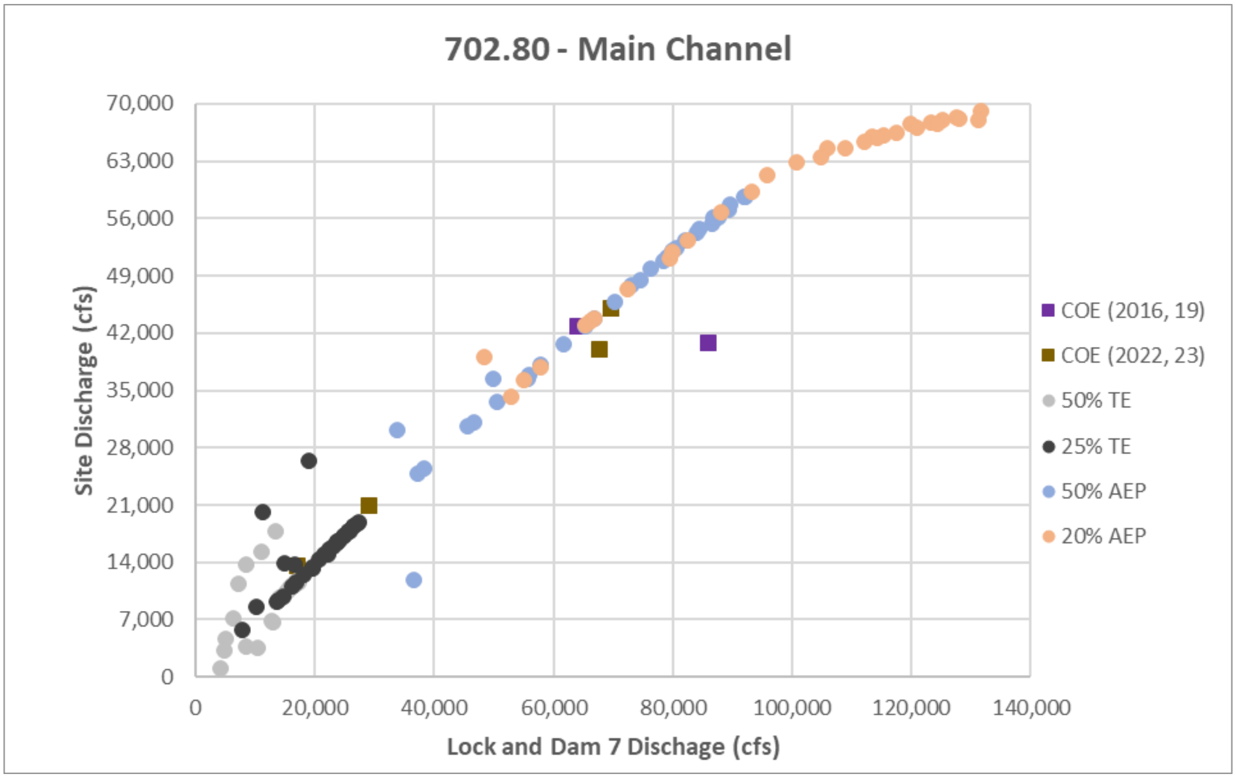



Figure 27: RM 702.80 – Main Channel

## 2.3 Model Results

The velocity results are included below in Figure 28 through Figure 32. These result plots are showing maximum values from the simulation.

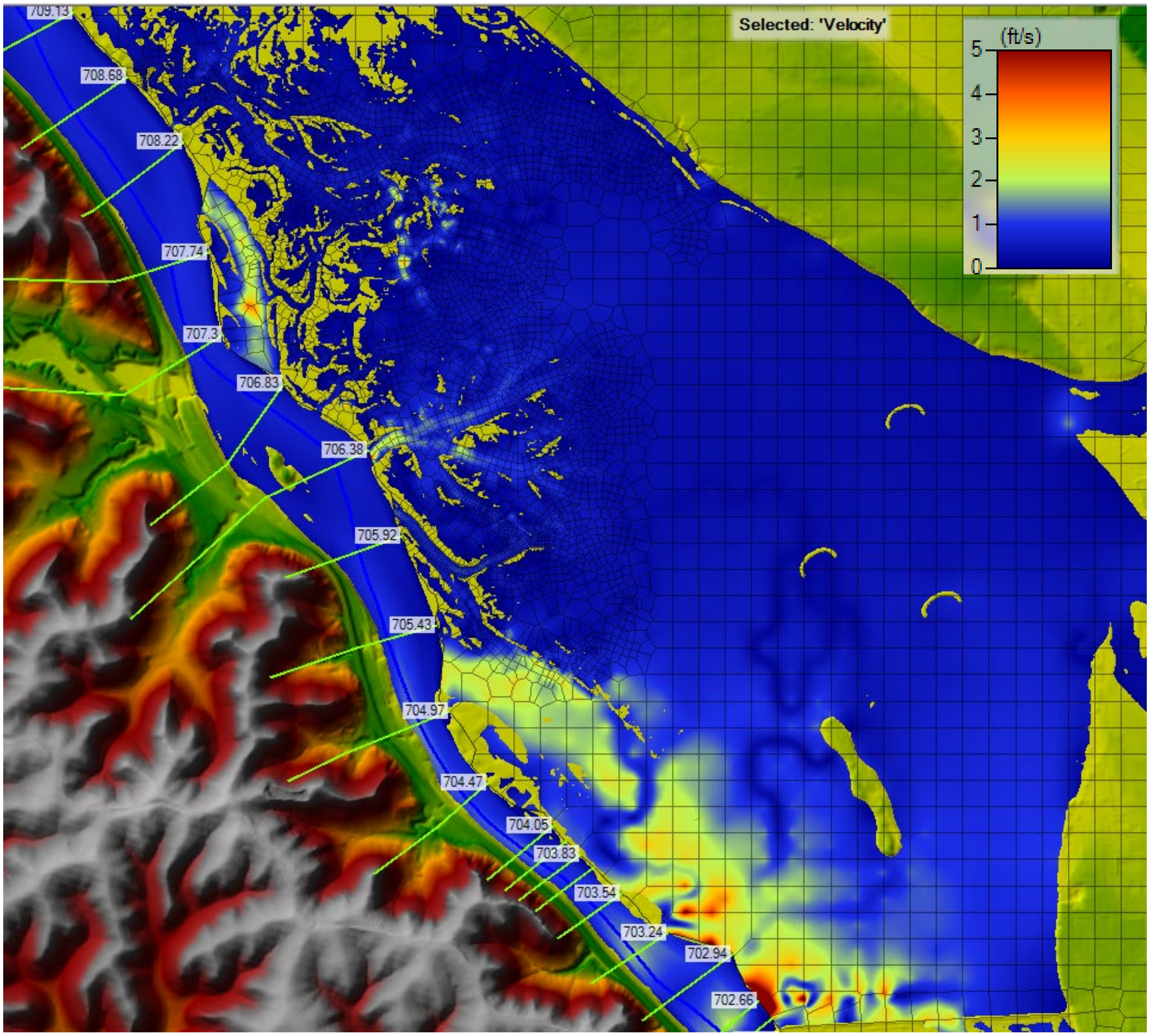



Figure 28: Velocity Results: 50% Time Exceeded Event

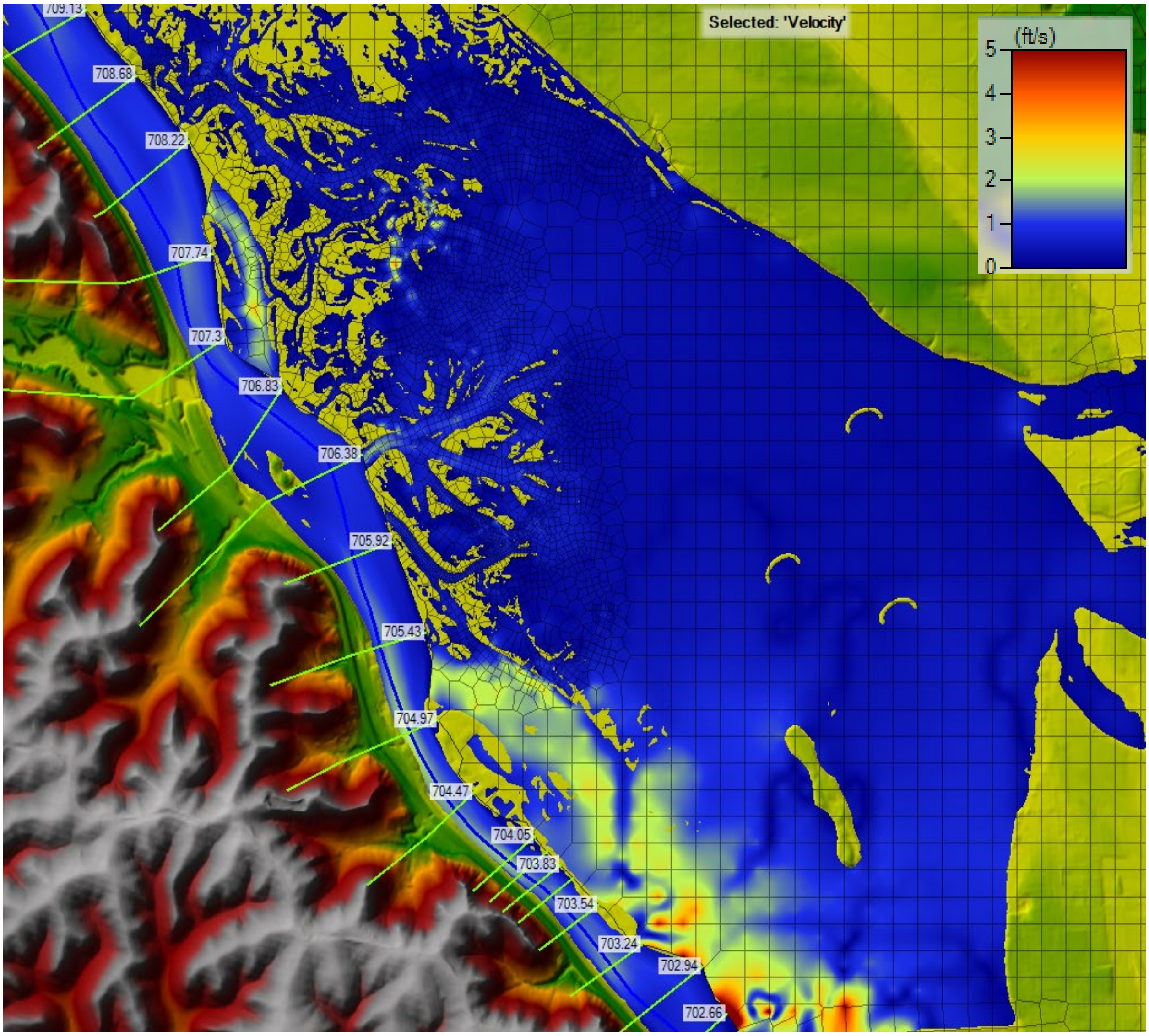



Figure 29: 25% Time Exceeded Event

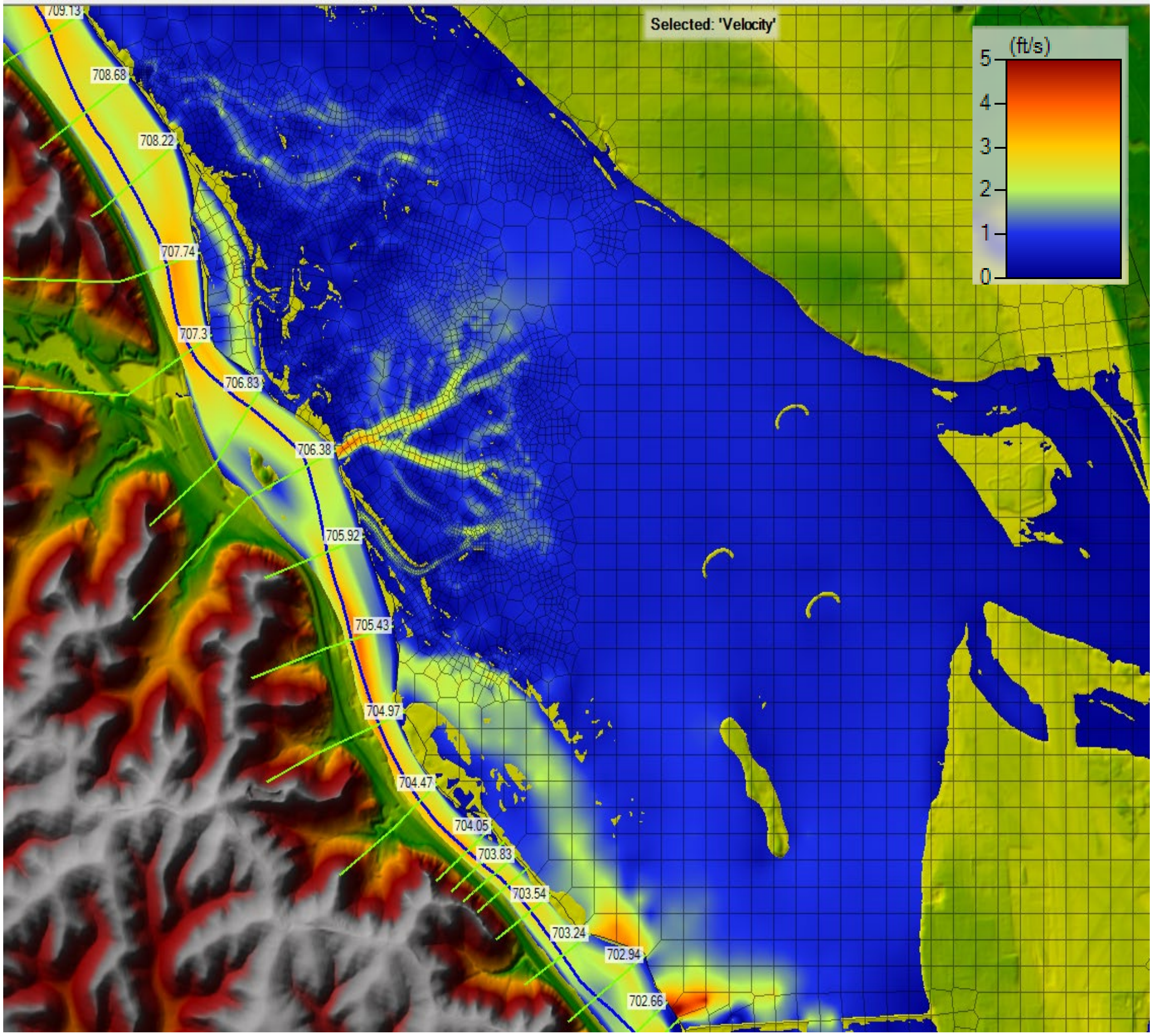



Figure 30: Velocity Results: 50% AEP Event

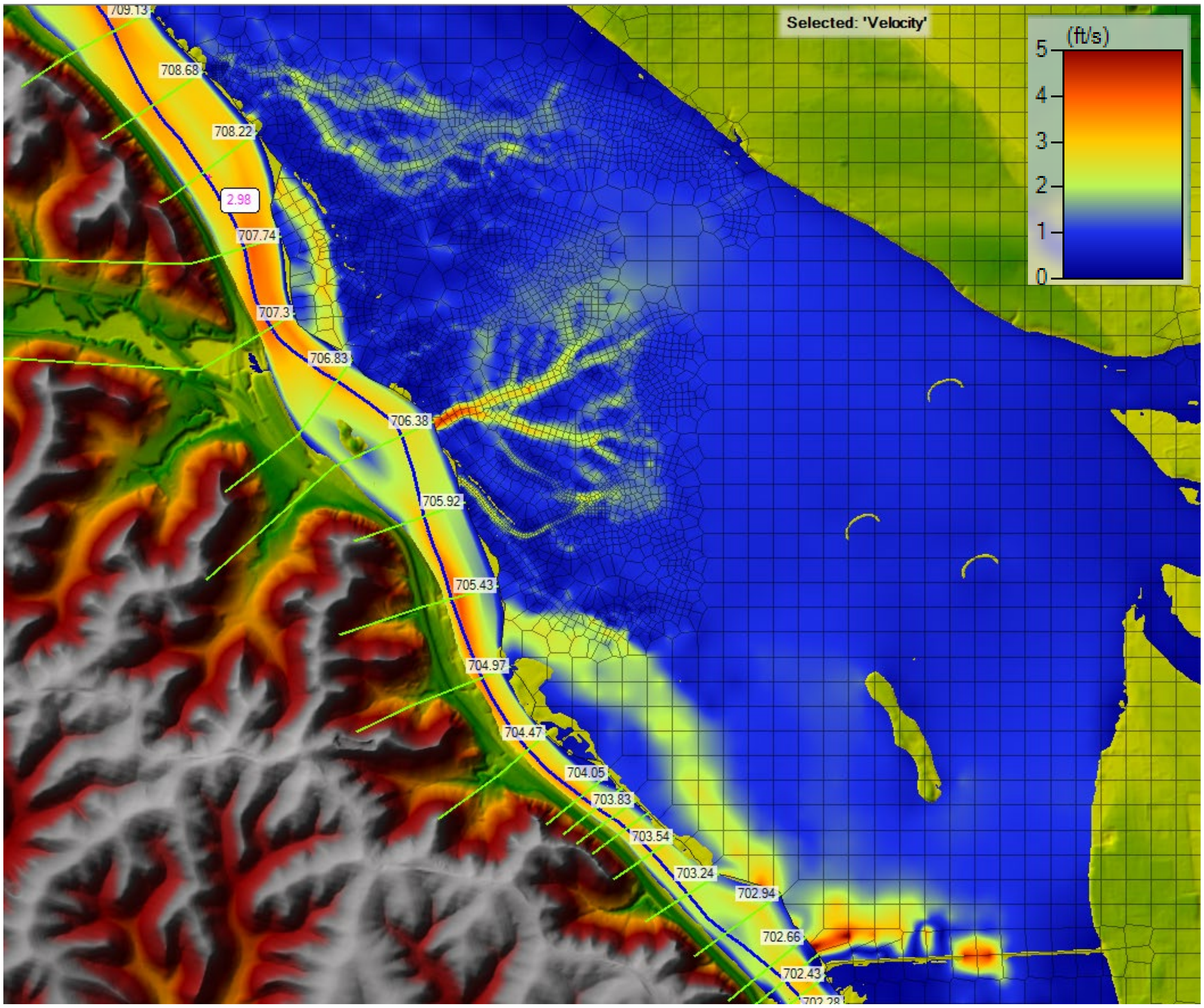



Figure 31: Velocity Results: 20% AEP Event

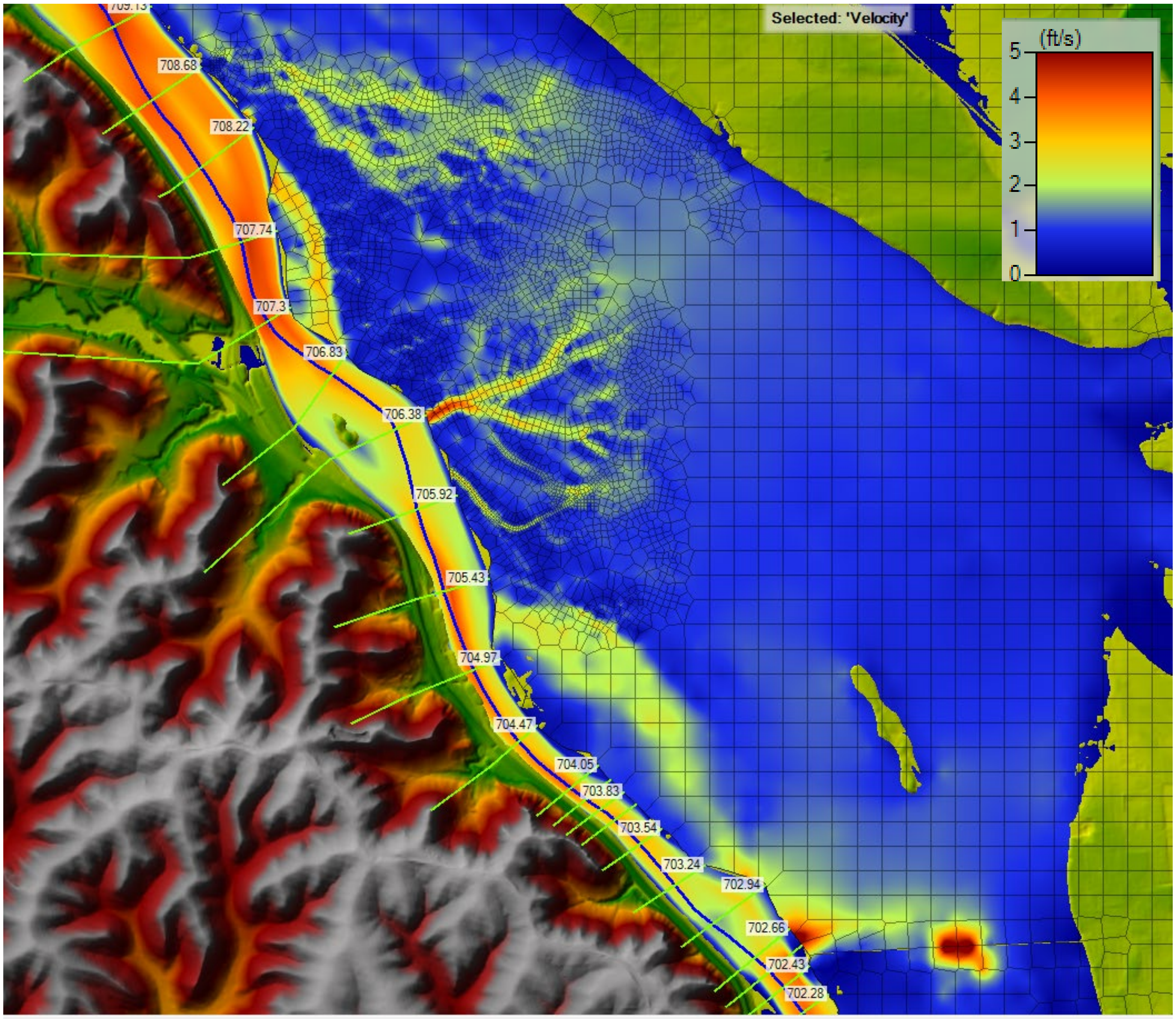



Figure 32: Velocity Results: 1% AEP Event

## 2.4 Hydraulic Modeling Conclusion

The model used in this analysis was truncated from the UMR FRM hydraulic model to include the area immediately upstream and downstream of Lake Onalaska. The geometry of the truncated model was altered to include a more refined 2D area between the side channels connecting the main channel of the Mississippi River and Lake Onalaska. To solve model instabilities, a 2D area near the Black River was also added.

The model was calibrated to observed stage data from 2019 and 2020 and provided significantly more accurate results compared to the original model. Operating curves were also used as a form of calibration.

Five theoretical events were created using a typical hydrograph ranging in size from low flow (50% Time Exceeded) to a large flood (1% AEP). These model results were used to create discharge transect plots to compare the results of the models with observed data taken periodically throughout the area. These results were excellent in the Main Channel of the Mississippi while in the side channels the results were more mixed. These mixed results were believed to be due to old bathymetry data (collected 1992-1995) in the side channels. This hypothesis was tested by modifying the terrain to be deeper at Gibbs Chute. The original and deepened channel are shown in Figure 32.

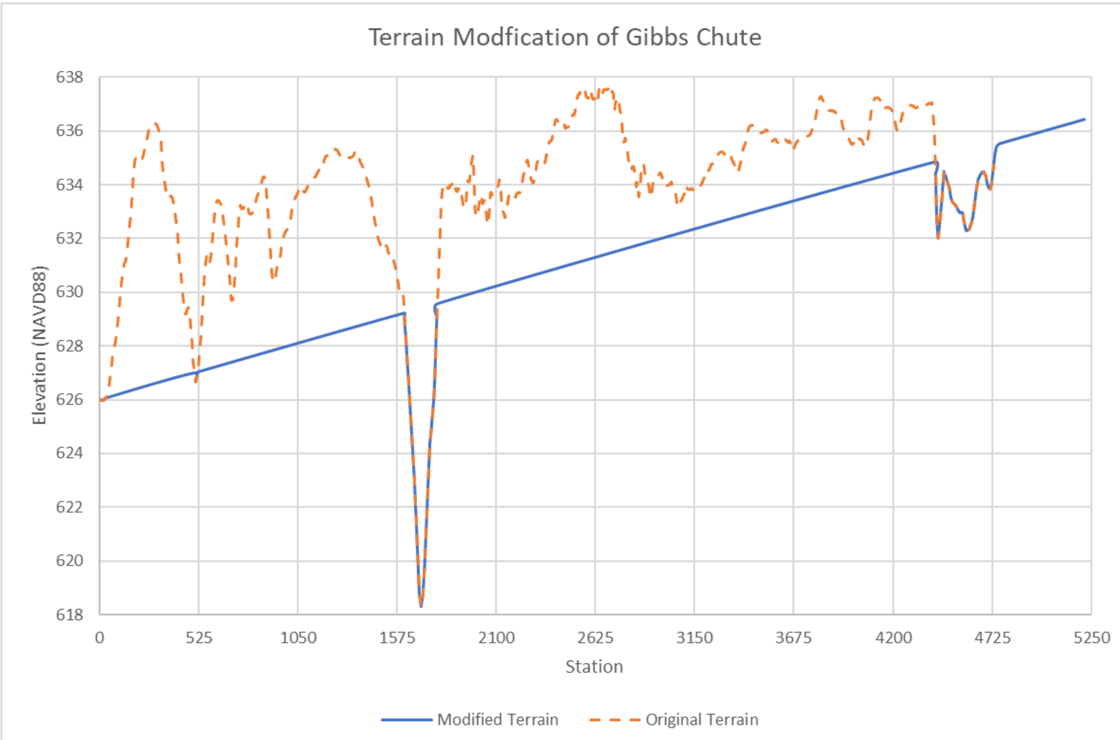



Figure 33: Modified Vs. Original Terrain of Gibbs Chute

The channel was also widened. The difference between the original channel and modified channel is shown in Figure 34.

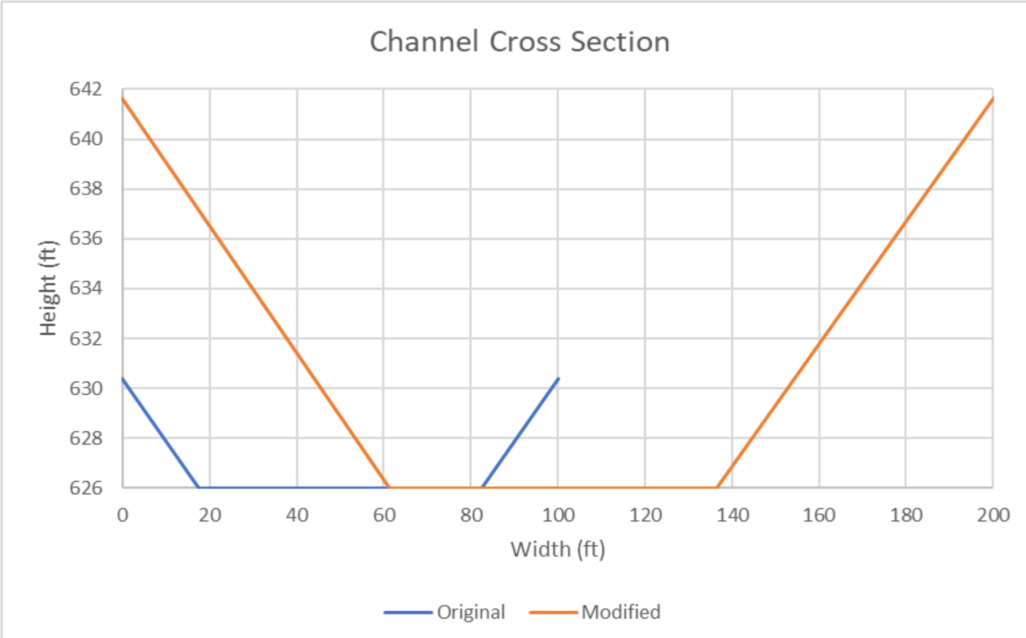



Figure 34: Channel Cross Section

The terrain modification of this channel appeared to improve the calibration of this side channel compared to the most recent observed data (2022-2023). This is shown in Figure 35.

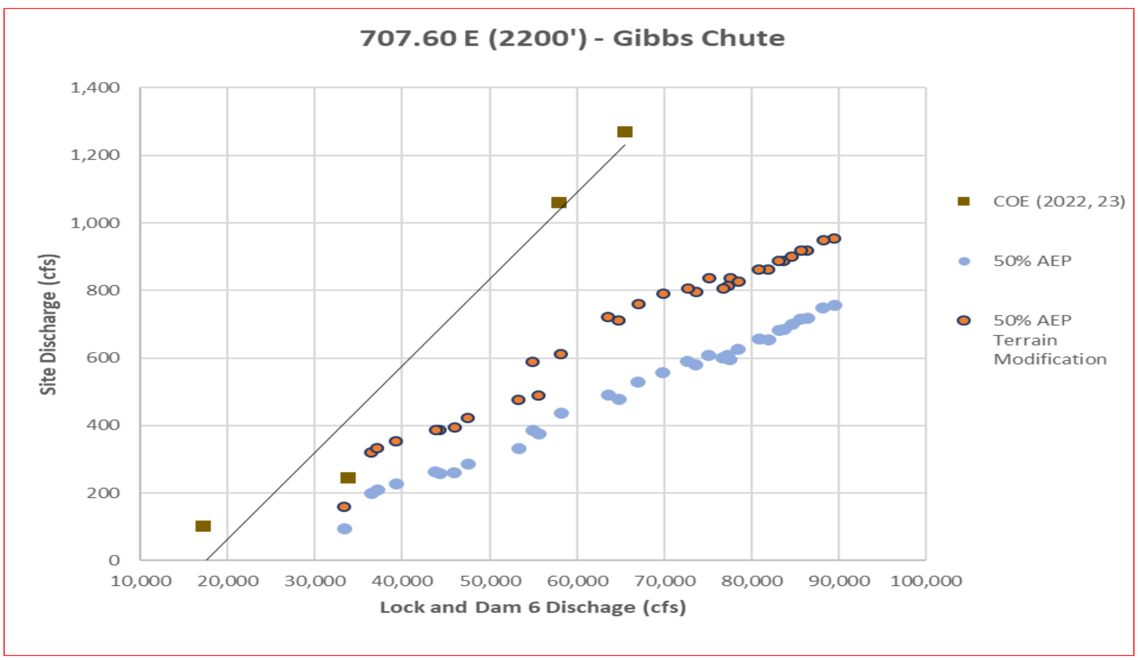



Figure 35: Terrain Modification to Gibbs Chute

# 3 Sediment Transport and Geomorphology

Sedimentation in the Upper Mississippi River (UMR) has been a major concern throughout the implementation of ecosystem restoration project on the UMR. Land use changes have contributed to high sediment delivery to tributaries and the channelization of some tributaries have also increased the rate that the tributaries deliver the sediment to the UMR. In off-channel backwaters common in Pool 7, accumulation of sediment may result in loss of depth and encroachment of terrestrial vegetation into formerly aquatic areas.

Sediment transport in the project area is affected by upstream sediment loads and local hydraulic conditions. Variation in upstream sediment loads occur due to seasonal patterns of river discharge and sediment mobilization. The hydraulic characteristics of the project area can best be described as a connected system with flow entering the project area through openings at the following: Bullet Chute, No Name Chute, Gibbs Chute, Goose Chute, Sommers Chute, Proudfoot Slough, and Millers Slough.

To better understand sediment transport and geomorphology in the project area, both fine material and coarse material sediment deposition rates were analyzed.

## 3.1 Fine Sediment Rates

A study was completed as part of the Upper Mississippi River Restoration Program's Long Term Resource Monitoring that estimated sedimentation rates at several transects in Pools 4 and 8 (Rogala, Kalas, & Burdis, 2020). This study is titled *Rates and Patterns of Net Sedimentation from 1997-2017 in Backwaters of Pools 4 and 8 of the Upper Mississippi River*. The first study completed as part of this effort was completed in 2002 (Rogala, Boma, & Gray, 2003). Sedimentation rates were estimated through this effort on a short-term scale from 1997-2002 (5 years). Approximately 20 years later (1997-2017) the transects were re-analyzed which provided recent sedimentation rates that would be less influenced by short-term variability.

Historically, there have been several other sedimentation rate studies completed along the Upper Mississippi River. There are several shortcomings regarding these past studies which are listed below (Rogala, Kalas, & Burdis, 2020).

1. Many of the studies were completed immediately upstream of the dams only.
2. Most of the studies sampled in areas of known sedimentation, so rates were likely overestimated.
3. Most of the studies are outdated and do not provide recent estimates (>25 years old).
4. Past studies provide little information on spatial variability.

For the reasons listed above, the Lake Onalaska sedimentation rate estimates will utilize this most recent report for Pool 8. Lake Onalaska is located in Pool 7, but Pool 8 is just one pool downstream of the project area and this report/data is the most current and includes spatial variability.

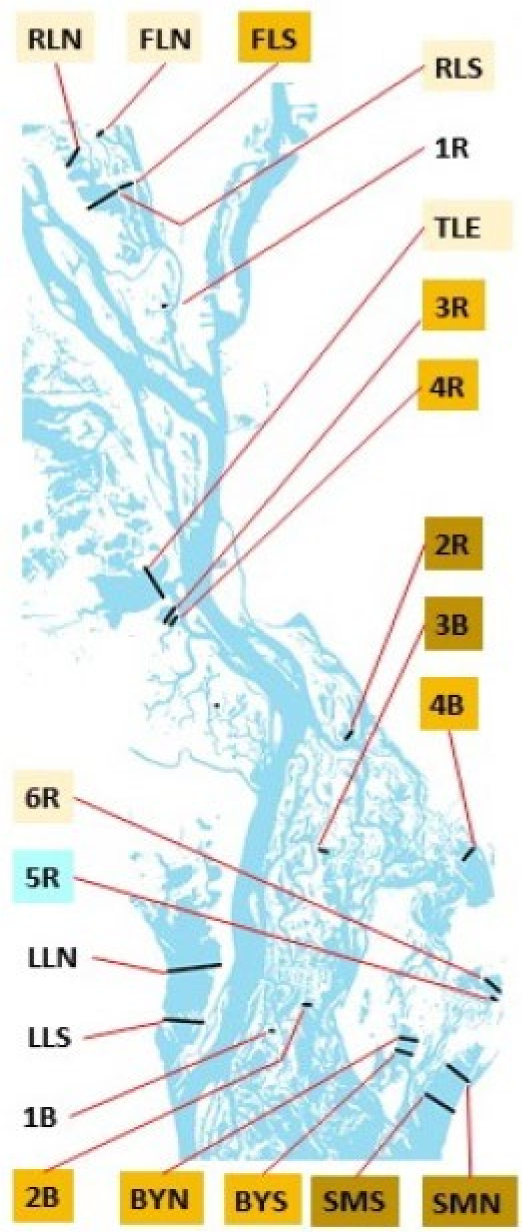
According to the report, pool-wide mean rates of backwater sedimentation in aquatic portions of the sampling transects during this 20-year period were 0.51 cm/yr (0.20 in/yr) in Pool 8. When considering portions of transects defined by bed elevation, rates were lowest in nearshore terrestrial areas with mean rates of 0.15 cm/yr (0.06 in/yr) in Pool 8. Rates as high as 0.62 cm/yr (0.24 in/yr) were found in areas deeper than 0.5 meters (1.64 feet) in Pool 8.

Mean sedimentation rates calculated in this study were generally in line with the rates observed in previous studies for the Upper Mississippi River. Table 6 below shows the previous study rates. This table includes a sedimentation rate from a study specifically completed in Pool 7. This study reported a sedimentation rate in Pool 7 or 0.2 cm/yr (0.08 in/yr) which is lower than this more recent study completed in Pool 8. The Pool 7 study is much older than the more recent Pool 8 study and the values provided from Pool 8 are generally more conservative, so the Pool 8 values were used to estimate sedimentation rates.

Table 5: Sedimentation Rates from Previous Studies on the Upper Mississippi River (Rogala, Kalas, & Burdis, 2020)

| Study | Location | Method / Period | Rates (cm $yr^{-1}$) |
|---|---|---|---|
| McHenry et al. (1984) | Impounded areas in Pools 4-10 | Cesium-137 dating / 1954-1975 | 1 - 4 |
| Korschgen et al. (1987) | Large lake in Pool 7 | Bathymetric maps / 50 years since impoundment | 0.2 |
| Eckblad et al. (1977) | Large lake in Pool 9 | Cesium-137 dating / 1964 - 1974 | 1.69 |
| Rogala et al. (1997) | Lakes of Pool 8 | Coring to parent material / 58 years since impoundment | 0 - 1.5 |
| Rogala and Boma (1996) | Lakes in Pools 4, 8, and 13 | Repeated surveys / 1990-1996 | 0.29, 0.12, 0.80 |

All Pool 8 transects, and mean sedimentation rates (cm/yr) are shown in Figure 36 below. Using all of the Pool 8 transects, the average sedimentation rate is approximately 0.55 cm/yr (0.22 in/yr).




| pool | transect | mean | std |
|---|---|---|---|
| 4 | BLN | 0.04 | 0.31 |
| 4 | 1R | -0.23 | 0.17 |
| 4 | 3B | -1.37 | 3.45 |
| 8 | SMS | 1.34 | 1.55 |
| 8 | 3B | 1.30 | 0.66 |
| 8 | SMN | 1.12 | 0.47 |
| 8 | 2R | 1.01 | 0.14 |
| 8 | 2B | 0.93 | 0.33 |
| 8 | BYS | 0.92 | 0.40 |
| 8 | 4R | 0.76 | 0.18 |
| 8 | BYN | 0.71 | 0.18 |
| 8 | FLS | 0.64 | 0.11 |

| pool | transect | mean | std |
|---|---|---|---|
| 8 | 4B | 0.61 | 0.20 |
| 8 | 3R | 0.60 | 0.14 |
| 8 | RLN | 0.49 | 0.18 |
| 8 | 6R | 0.41 | 0.07 |
| 8 | RLS | 0.34 | 0.48 |
| 8 | TLE | 0.33 | 0.37 |
| 8 | LLS | 0.18 | 0.48 |
| 8 | FLN | 0.11 | 0.04 |
| 8 | 1B | 0.07 | 0.27 |
| 8 | 1R | -0.03 | 0.14 |
| 8 | LLN | -0.05 | 0.52 |
| 8 | 5R | -0.28 | 0.25 |

Figure 36: Pool 8 Sedimentation Rate Transects (Rogala, Kalas, & Burdis, 2020)

## 3.2 Coarse Sediment Rates

The coarse sediment analysis completed as part of this project utilized the 1D/2D HEC-RAS Project Design Model described in Section 2 above. From this model, discharges were extracted for the 50% AEP event for the side channels. Historically, discharge measurements have been collected along the Main Channel and backwater channels near the project area using an Acoustic Doppler Current Profiler (ADCP). The most recent measurements were taken in 2022 and 2023. These measurements are compiled into an observed discharge rating curve relating the L&D 6 discharge to the discharge measurement site. The locations of these measurements are shown below in Figure 37. The discharge location names are listed below.

- Bullet Chute – RM 708.70 NE (2000’)
- No Name Chute – RM 708.50 NE (1900’)
- Gibbs Chute – RM 706.60 E (2200’)
- Goose Chute – RM 706.70 NE (1000’)
- Sommers Chute – RM 706.40 NE (1500’)
- Proudfoot Slough – RM 705.70 NE (2600’)

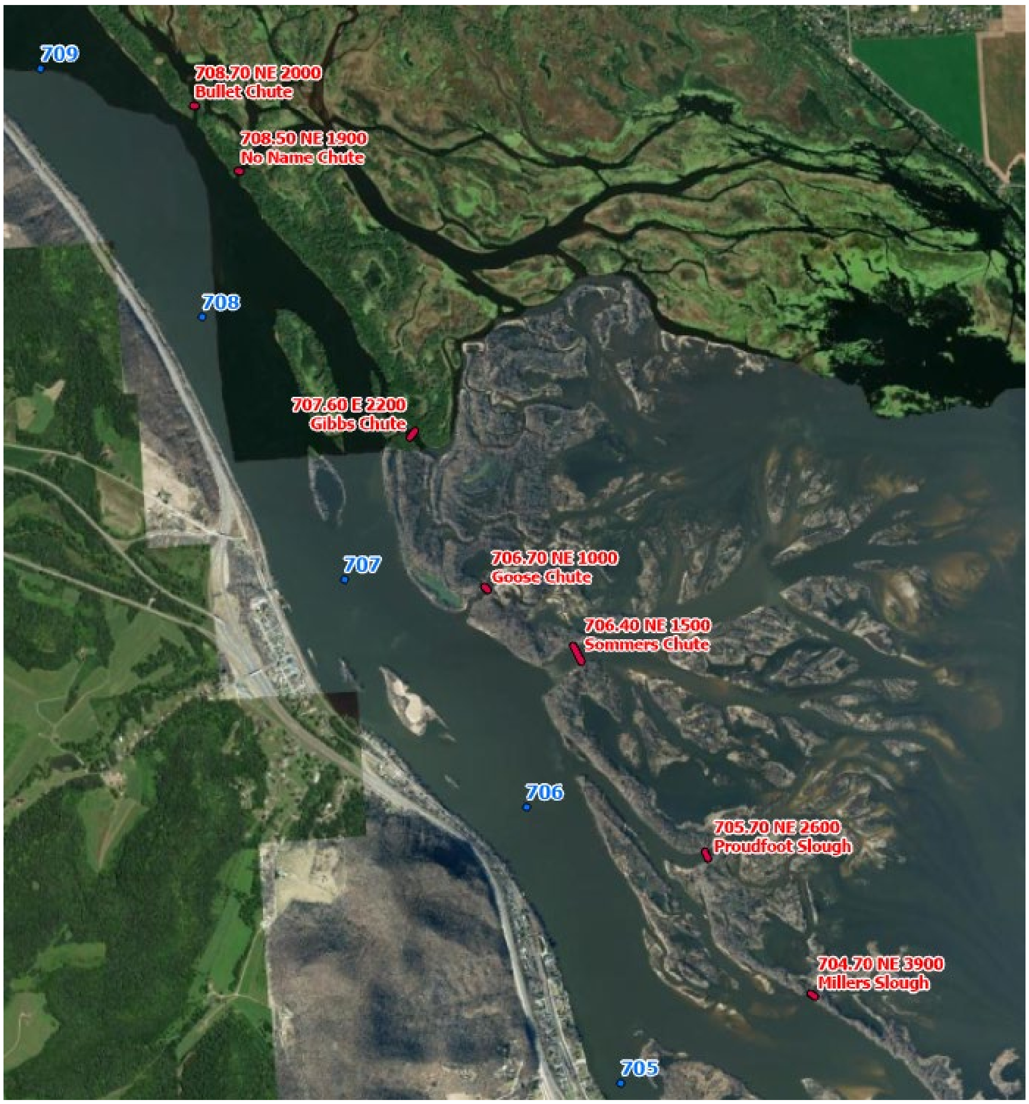



Figure 37: Pool 7 ADCP Discharge Measurement Locations near Project Area

The comparison for the discharges at six of the discharge measurement locations are shown in Table 6 below. These discharges transect measurement locations will be used to calculate the water exchange ratio (WER) between the Main Channel and the side channels of interest.

Table 6: 50% AEP Observed and Modeled Discharge Values

| 50% AEP Event Discharges | | |
|---|---|---|
| **Secondary Channel** | **Observed Discharge (cfs)** | **Modeled Discharge (cfs)** |
| **Bullet Chute** | 2169 | 330 |
| **No Name Chute** | 1965 | 2013 |
| **Gibbs Chute** | 1932 | 756 |
| **Goose Chute** | 1246 | 634 |
| **Sommers Chute** | 21338 | 25600 |
| **Proudfoot Slough** | 2650 | 1603 |
| **Millers Slough** | 1126 | 566 |

The modeled data does not match well for most of the side channel discharge transect locations. This is due to the lack of current bathymetry in the study area. Because of this, the observed discharge values will be used for the following calculations.

Using the observed discharges for the secondary channels and the observed total river discharge (L&D 6: 93,000 cfs), the WER ratio was calculated for each secondary channel. These values are shown below in Table 7.

Table 7: WER for Secondary Channels

| Observed Water Exchange Ratios (WER) | | | |
|---|---|---|---|
| **Secondary Channel** | **Secondary Channel Observed Discharge (cfs)** | **Total River 50% AEP Event Discharge (cfs)** | **Water Exchange Rate (WER) - Qside/Qtotal** |
| **Bullet Chute** | 2169 | 93000 | 0.0233 |
| **No Name Chute** | 1965 | 93000 | 0.0211 |
| **Gibbs Chute** | 1932 | 93000 | 0.0208 |
| **Goose Chute** | 1246 | 93000 | 0.0134 |
| **Sommers Chute** | 21338 | 93000 | 0.2294 |
| **Proudfoot Slough** | 2650 | 93000 | 0.0285 |
| **Millers Slough** | 1126 | 93000 | 0.0121 |

To estimate sediment loads for the analysis, the St. Paul District Bed Material Sediment Budget was utilized (Hendrickson, 2003). This district-wide bed material sediment budget was created in 2003 to estimate the effects of navigation channel dredging, off-channel sediment deposition, and tributary sediment loads on sediment transport on the UMR. Bed material refers to sand-size sediment that can be found on the bed of the main channel but can also be transported as bed load or suspended load. This bed material budget was based on interpretation of available sediment transport information at U.S. Geological Survey (USGS) gaging stations, long-term channel dredging data, studies of sediment transport and deposition, and measured hydraulic characteristics on the UMR.

A side channel sediment load equation for the 50% AEP event was developed and is used in the St. Paul District Bed Material Sediment Budget (Hendrickson, 2003). This equation uses a channel's WER and the sediment load in the main channel to estimate the sediment load in the side channel of interest. According to the St. Paul District Bed Material Budget. The equation is included below.

$$Q_{Sediment-Side} = WER^{1.4} * \ Q_{Sediment-Main}$$

The values for the Main Channel Sediment Load and the calculated Side Channel Sediment Load are included below in Table 8.

Table 8: Calculated Side Channel Sediment Load

| Observed Water Exchange Ratios (WER) | | | |
|---|---|---|---|
| **Secondary Channel** | **Water Exchange Rate (WER) - Qside/Qtotal** | **Main Channel Sediment Load just US of Secondary Channel Location (tons/year)*** | **Side Channel Sediment Load (tons/year)** |
| **Bullet Chute** | 0.0233 | 162,618 | 843 |
| **No Name Chute** | 0.0211 | 162,013 | 732 |
| **Gibbs Chute** | 0.0208 | 140,608 | 620 |
| **Goose Chute** | 0.0134 | 139,726 | 334 |
| **Sommers Chute** | 0.2294 | 139,444 | 17756 |
| **Proudfoot Slough** | 0.0285 | 111,601 | 766 |
| **Millers Slough** | 0.0121 | 111,077 | 230 |

**Note: There are other side channels between the chutes of interest listed in this table that contribute to the amount of sediment leaving the main channel. Thus, the main channel sediment load and side channel sediment load listed here do not show exact continuity.*

### 3.3 Sediment Transport Conclusion

While there is uncertainty in the bed material loads and deposition rates in the project area, the results from the analyses discussed above show that both fine and coarse sedimentation rates and sediment loads, specifically in the secondary channels connecting the Mississippi River and Lake Onalaska, will affect the project area in the future. Reducing sediment loads through the secondary channels could be beneficial to reduce the dynamic sediment deposition seen within these secondary channels.

# 4 Conclusion

This study includes hydraulic modeling and sediment load calculations to provide a better idea of the dynamics of the side channels listed above to inform future NESP efforts.

A hydraulic model was created to analyze the hydraulic properties of the side channels connecting the Main Channel of the Mississippi River and Lake Onalaska. The geometry used in this hydraulic model was taken from a basin wide model, UMR Phase IV, and truncated to the project area. A modification to the original geometry was made around the confluence of the Black River to improve model stability. This model was then calibrated, and it was found that the new model provided more accurate results when compared to the original model.

The model was used to create discharge transect plots throughout the project area. The results of these were very good in the main channel but were more mixed in the side channels. A sensitivity analysis in the hydraulic model showed that updated bathymetry data in the side channels could improve both the results of the discharge transect plots and the associated sediment rate calculations.

The hydraulic model was also used to conduct sediment analysis in the project area. A fine materials sedimentation rate of 0.22 inches per year was found in the side channels. A coarse-grained material load for the side channels was found to range between 330 and 1,800 tons per year, depending on the side channel.

This study could be refined with supplementary data such as bathymetry data as well as site-specific discharge and velocity data. Additionally, further refinements of the estimated sediment loads could be completed following a literature review. However, this is not likely to significantly affect the results.

Overall, this report provides a good basis for the existing conditions in Lake Onalaska that will be very helpful for future NESP efforts. The hydraulic model and sediment analysis can be utilized for the proposed condition estimations efficiently for a future NESP planning study.

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