Technical Report M62

Vancill Towhead HSR MODEL
River Miles 72.00 – 65.00

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation improvement study of the Mississippi River at Vancill Towhead from River Mile (RM) 72.0 to RM 65.0. This study was funded by the Regulating Works Project for the Middle Mississippi River and Avoid and Minimize (A&M) Program. The objective of the model study was to produce a report that outlined the results of an analysis of various river engineering measures, intended to reduce or eliminate the need for repetitive channel maintenance dredging between RM 68.00 and RM 67.00 and enhance the environmental diversity at Vancill Towhead without negatively affecting the navigation channel.

The study was conducted between October 2011 and September 2012 at the Applied River Engineering Center (AREC), U.S. Army Corps of Engineers, St. Louis District. The study was performed by Mr. Ivan H. Nguyen, Hydraulic Engineer, under direct supervision of Mr. Robert D. Davinroy, P.E., Chief of River Engineering Section for the St. Louis District. See Table 1 for other personnel involved in the study.

Table 1: Other Personnel Involved in the Study

Name	Position	District/Company
Leonard Hopkins, P.E.	Chief of Hydrologic and Hydraulic Branch	St. Louis District
Ashley Cox	Hydraulic Engineer	St. Louis District
Jasen Brown, P.E.	Acting Project Manager	St. Louis District
Eddie Brauer, P.E.	Hydraulic Engineer	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Sarah Markenson	Real Estate	St. Louis District
Adam Rockwell	Cartographic Technician	St. Louis District
Shawn Kempshall	River Surveyor	St. Louis District
Lance Engle	Dredge Project Manager	St. Louis District
Brian Johnson, P.E.	Chief of Environmental Planning Section	St. Louis District
David Gordon, P.E.	Chief of Hydraulic Design	St. Louis District
Mike Rodgers, P.E.	Project Manager	St. Louis District
Dawn Lamm	Hydraulic Design	St. Louis District
Peter Russell, P.E.	Hydraulic Design	St. Louis District
Romanda Walker	Public Affairs	St. Louis District
Kathryn Mccain	Ecologist	St. Louis District
Atwood Butch	Fisheries Biologist	Illinois Department of Natural Resource (IDNR)
Matthew Mangan	Biologist	U.S. Fish and Wildlife
Ed Henleben	Ingram Barge Company	River Industry Action Committee (RIAC)
Dave Knuth	Fishery Biologists	Missouri Department of Conservation (MDC)
Ryan Christensen	Chief Coast Guard St. Louis	U.S. Coast Guard

Dave Ostendorf	Fishery Biologists	Missouri Department of Conservation (MDC)
Mark Boone	Program Advisor	Missouri Department of Conservation (MDC)
Janet Sternberg	Policy Coordinator	Missouri Department of Conservation (MDC)
Shannon Hughes	Port Captain	Kirby Inland Marine
Terry Hoover	Employees/Safety Manager	Ingram Barge Company
Michael Canada	Employee	Ingram Barge Company

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BACKGROUND

1. Study Reach

The study reach was located between Cape Girardeau County in Missouri and Union County in Illinois. The study comprised a 7 mile stretch of the Mississippi River, between RM 72.00 to RM 65.00. The towhead, located along the left descending bank (LDB) of the Mississippi River between RM 67.60 to RM 67.30, covers an area of 11.4 acres. Plate 1 is a location and vicinity map of the study reach.

A. Features and Structures

Plate 2 is a 2010 aerial photograph illustrating the planform and nomenclature of the Middle Mississippi River between RM 72.00 and RM 65.00. There was a quarry with a fleeting operation located on the right descending bank (RDB) at RM 71.50. The bluff line was located along the RDB. The Preston Levee system was located on the LDB side of the river. The Proctor and Gamble facility was located directly downstream of the quarry at RM 69.50. Below the facility was a Biological Monitoring Area called The Trail of Tears. The Trail of Tears is a Missouri state park which extends to the end of the study reach. A majority of the property on the LDB side of the Mississippi River was used for agriculture.

At the time of this study, the study reach had a total of 48 structures: 42 dikes, 5 weirs and 1 L-dike. Refer to Table 2 for a more detailed history of the river training structures. The RDB was revetted between RM 69.50 to RM 66.80 and at the fleeting area adjacent to the quarry, while the LDB was not. However, round-outs along the LDB were revetted. There were two pile dikes located in the study reach. Pile Dike 67.80L was located across the upstream end of Vancill Towhead while Pile Dike 69.80L was located on Neely Landing inside the bend. Three exchange points for navigation traffic were located in the study reach, along the RDB and LDB at RM 68.20, and along the LDB at RM 66.70. Exchange points are locations along banklines where barges can temporarily stop to yield incoming traffic.

Table 2: Study Reach River Structure History

River Training Structures	Length (feet)	Description
Dike 71.90L	840	Constructed between 1939 to 1967, Dike Extended in 1991
Dike 71.70L	677	Dike Repair in 1984
Dike 71.40L	640	Dike Constructed in 1991
Dike 71.30L	470	Dike Extended in 1976
Dike 71.30R	200	Spur Dike
Dike 71.20R	290	Spur Dike
Dike 71.00L	500	Dike Constructed in 1992
Dike 71.00R	325	Spur Dike
Dike 70.70R	530	Dike Extended in 1977
Dike 70.60L	600	Dike Repair in 1976
Weir 70.45L	680	Weir Constructed in 1999
Weir 70.35L	680	Weir Constructed in 1999
Dike 70.30L	630	Dike Repair in 1991
Dike 70.30R	700	Dike Extended in 1977
Weir 70.25L	950	Weir Constructed in 1999
Weir 70.15L	975	Weir Constructed in 1999
Dike 70.10L	890	Spur Dike
Weir 70.00L	1000	Weir Constructed in 1999
Dike 69.80L	300	Pile Dike
Dike 69.90R	580	Dike Repair in 1977
Dike 69.50L	800	Dike Repair in 1977
Dike 69.50R	500	Dike Extended in 1977
Dike 69.10L	550	Dike Extended in 1977
Dike 69.10R	525	Constructed in 1977. Dike repaired and extended in 1991.
Dike 68.80L	500	Constructed in 1999 and 230 feet in length

Dike 68.50L	500	Dike Repair in 1977
Dike 68.30L	480	Dike Repair in 1977
Dike 67.80L	600	Pile Dike (Mostly buried under sediment)
Dike 67.50R	225	Dike Raised in 1983
Dike 67.40R	340	Dike Extended in 1983
Dike 67.30L	960	Dike Raised and Extended in 1983
Dike 67.20R	475	Dike Raised in 1983
Dike 67.10L	700	Dike Constructed in 1991
Dike 67.00R	490	Dike Raised in 1983
Dike 66.90R	220	Spur Dike
Dike 66.80L	350	Reconstruct Flank Dike in 1999
Dike 66.70R	1500	Dike Extended in 1995 (L-shaped Dike)
Dike 66.60R	50	Spur Dike
Dike 66.50L	275	Dike Constructed in 1992
Dike 66.30L	150	Dike Constructed in 1991
Dike 66.00L	350	Dike Raised and Extended in 1977
Dike 66.00R	600	Dike Constructed in 1977; Raise and Extend in 1992
Dike 65.90L	375	Dike Constructed in 1977; Raise and Extend in 1984
Dike 65.80L	425	Spur Dike
Dike 65.80R	550	Dike Extended in 1983
Dike 65.60L	375	Dike Constructed in 1992 and 440 feet in length
Dike 65.30L	600	Spur Dike
Dike 65.30R	700	Dike Constructed in 1992

B. Vancill Towhead and Side Channel

Vancill Towhead's side channel was located along the LDB between RM 67.70 and RM 67.40 with an average width of approximately 150 feet, ranging from 80 feet to 220 feet. There were two dikes, Pile Dike 67.70L and Dike 67.30L that controlled the amount of flow and sediment through the side channel. Pile Dike 67.80L, located just upstream of Vancill Towhead, measured 600 feet in length, but was mostly buried under sediment (See Plate 3). Dike 67.30L, located just downstream of Vancill Towhead, had scour occurring off the tip.

Plate 4 shows helicopter photographs of Vancill Towhead taken in May 2003 during high water when flow was able to pass through the side channel. However during low water shown in Photograph 4, debris and sediment clogged the entrance and reduced the amount of water passing through the channel.

Adjacent to Vancill Towhead, surveys show adequate navigation depths. However, in reality the channel shoals considerably. The surveys reflect the channel being artificially maintained by dredging. An example where the crossing has shoaled prior to dredging is shown on Plate 5 in the 2011 pre-dredge hydrographic survey.

C. Real Estate

Property owners on the Illinois bankline include; Joe Rumfelt owned from RM 72.50 to RM 71.00, Westvaco Corporation owned from RM 70.00 to RM 68.00, Joe D. Livesay owned from RM 68.00 to RM 66.00 (including Vancill Towhead), and the American Land Conservancy (a non-profit organization) owned from RM 65.00 to the end of study reach. Property owners on the Missouri bankline included; the Missouri State Park Board owned from RM 72.00 to RM 69.60, Proctor and Gamble owned from RM 69.50 to RM 69.10, and Bainbridge Corporation (c/o Patrick McSpadden) owned from RM 69.00 to RM 63.00. The quarry located at RM 71.50 along the RDB is owned by MMD Stone, LLC.

2. Problem Description

To maintain the navigation channel, from 2003 to 2010, between RM 68.00 and RM 67.00, approximately 1.7 million cubic yards were dredged at a cost of $3.8M. See Plate 6 for dredging and disposal locations. Repetitive dredging is the current solution for maintaining an appropriate navigation channel at this location. Any reduction in dredging at this location while maintaining the navigation channel will increase the efficiency of waterways transportation.

3. <u>Study Purpose and Goals</u>

The purpose of this study was to find a solution to reduce or eliminate repetitive channel maintenance dredging from RM 68.00 to RM 67.00, enhance the environmental diversity at Vancill Towhead, and produce a report that communicates the results of the Hydraulic Sediment Report (HSR) model study to all project stakeholders.

The goals of the study were to:

i. Investigate and provide analysis on the existing flow mechanics causing the sedimentation problems.

ii. Evaluate a variety of remedial measures utilizing an HSR Model with the objective of identifying the most effective and economical plan to reduce or eliminate sedimentation from RM 68.00 to RM 67.00. In order to determine the best alternative, 4 criteria were used to evaluate each alternative.

    a. The alternative should reduce or eliminate sedimentation between RM 68.00 and RM 67.00.

    b. The alternative should maintain the navigation channel requirement of at least 9 foot of depth and 300 foot of width.

    c. The alternative should avoid and minimize impacts to the existing environmental conditions present between RM 71.00 and 67.00.

        i. The alternative should introduce additional flow and sediment transport along the LDB between RM 68.00 and RM 67.00.

iii. Communicate to other engineers, river industry personnel, and environmental agency personnel the results of the HSR model tests and the plans for improvement.

iv. Maintain a side channel that can provide flow between RM 68.00 and RM 67.00.

4. Geomorphology

To understand the planform of the river near Vancill Towhead, an investigation was conducted on the historical changes, both man-made and natural, that lead up to the present day condition. Plate 7 shows geomorphic planform changes between RM 77.00 and RM 62.00, encompassing the years from 1817 to 2003, and was sourced from "Geomorphology Study of the Middle Mississippi River" produced by the St. Louis District (2005).

The 1928 aerial photo Plate 8 of the project area showed Vancill Towhead had four separate islands compared to one island in 2010. There was an island approximately 3000 acres located in the middle of the navigation channel at RM 71.00. At Willard Landing, there were multiple islands along the LDB. The overall width of the channel was decreased due to river training structures along both banklines. Therefore, the Mississippi River channel in the area of Vancill Towhead from 1928 to 2010 had six islands to now only one. The difference between 1928 and 2010 aerial photos can be seen on Plate 9.

The 1986 Aerial photograph (Plate 10) showed Vancill Towhead as a large sandbar. There was a small vegetated island attached upstream of the sandbar. The difference between 1986 and 2010 aerial photos can be seen on Plate 11. Since 1928, there have been no significant changes to the planform for this reach of the Mississippi. Plates 12-15 show historic aerial photographs taken from 1939 to 1982.

5. Channel Characteristics and General Trends

A. Bathymetry

Range line and multi-beam hydrographic surveys of the Mississippi River for 2010, 2007 and 2005 within the HSR Model extents, are shown on Plates 5, 16 and 17. Plates 18 – 26 show pre-dredge conditions from 2003 – 2011. For this study, the bathymetric data was referenced to the Low Water Reference Plane (LWRP).

Recent surveys were used to determine general trends because they showed the most recent construction and the resultant river bed changes. The following bathymetric trends remained relatively constant from 2005 - 2010 after comparison of the above mentioned hydrographic surveys:

Table 3: Study Reach Bathymetry Trends

River Miles	Description
71.00 – 70.50	Scour occurred off the tips of Dike 71.00L and Dike 70.60L with depths as low as -50 feet LWRP.
70.50 – 70.00	The thalweg located along the LDB with depths ranged between -40 feet and -10 feet LWRP.
70.00 – 69.10	The thalweg crossed from the LDB to the RDB with depths approximately -10 feet LWRP. This crossing was shallow and dredging has been required to maintain the navigation depths.
69.10 – 68.00	The thalweg was located along the RDB with depths that ranged between -30 feet and -10 feet LWRP.
68.00 – 67.00	Shoaling occurred in the middle of the channel and the LDB with depths that ranged between -5 feet and 0 feet LWRP. Dredging has been required.
67.00 – 66.00	The thalweg located along the RDB with depths that ranged between -20 feet and -10 feet LWRP.

B. Velocity

An ADCP (Acoustic Doppler Current Profiler) survey of the Mississippi River, between RM 68.50 and RM 66.75 at Vancill Towhead, is shown in Plate 27. ADCP defines the velocity magnitude and direction of the flowing water. The plate shows an ADCP survey from November 2011.

A comparison of velocity distribution using several cross sections of the channel was necessary to evaluate and compare flow trends in the model to river flow trends. However, the value of the comparison is limited, due to only one year of velocity data collected. In order to compare the general trends between river and model, the velocity on each cross section were normalized. Normalization involved dividing the magnitudes from each transect by the highest magnitude in that particular transect. This creates a velocity scale from 0 to 1 for both the collected river ADCP and the model Laser Doppler Velocimeter (LDV) data. The normalized data showed the magnitude distribution between the highest and lowest velocities in each cross section (Plate 28). The direction was unchanged and showed velocity patterns such as eddies and outdraft.

Table 4: Study Reach Velocity Trends

River Miles	Description
68.30 – 67.80	The highest magnitudes of the river were located near the middle of the channel and the RDB. Magnitudes were slower on the LDB.
67.80 – 67.30	The highest magnitudes occurred along the dike field along the RDB. Magnitudes were slower on the LDB.
67.30 – 66.80	After passing through the dike field, the highest magnitudes began to migrate to the middle of the channel. However, within the RDB dike field still had some slow magnitudes. The LDB had the slowest magnitudes.

C. Site Data

On October 25, 2011, personnel from the Applied River Engineering Center visited Vancill Towhead reach to examine bank lines, structures and any data that could not otherwise be gathered in the office. At the Chester, IL gage, the river stage was 6.79 feet (347.84 feet in elevation). The following observations were made:

- Vancill Towhead: There was no major erosion along the RDB.
- Side Channel: The entire side channel was exposed. However, there was a big scour hole at RM 67.50 where there was water. The side channel appeared to have the same elevation as Vancill Towhead.
- Dike 67.80L and Dike 69.80L upstream of Vancill Towhead were confirmed to be pile dikes.

Photographs from the site visit can be seen on Plates 29 and 30.

HSR MODELING

A discussion of HSR modeling theory is included in Appendix C.

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the conditions in the river at the time of the model study. Replication of the model was achieved during calibration and involved a three step process.

First, planform "fixed" boundary conditions of the study reach, i.e. banklines, islands, side channels, tributaries and other features were established according to the 2010 high resolution aerial photography. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries.

Second, "loose" boundary conditions of the model were developed. Bed material was introduced into the channel throughout the model to an approximate level plane. The combination of the fixed and loose boundaries served as the starting condition of the model.

Third, steady state discharge simulation tests were run through the model. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The mobile bed developed from a static, flat, arbitrary bed into a fully-formed, dynamic, and three dimensional bed response. The resulting bed configuration was surveyed numerous times during the calibration tests and compared to recent river bathymetry. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bed bathymetry were similar to observed recent river bathymetry, and the tests were repeatable, the model was considered replicated and alternative testing then began.

2. Scale and Bed Materials

The HSR model employed a horizontal scale of 1 inch = 700 feet, or 1: 8400, and a vertical scale of 1 inch = 52 feet, or 1:624, for 13.46 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those observed in the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.40.

3. Appurtenances

The HSR model insert planform was constructed according to the 2010 high-resolution aerial photography of the study reach. The insert was then mounted in a standard HSR model flume. The riverbanks of the model were constructed from dense polystyrene foam, clay, and polymesh to develop proper bendway mechanics. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.008 inch/inch. River training structures in the model were constructed of galvanized steel mesh to generate appropriate scaled roughness. Plate 31 is a photograph of the Vancill Towhead HSR model used in this study.

4. Flow Control

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to control the flow of water and sediment into the model. For all model tests, flow entering the model was held steady at 2.1 Gallon per Minutes (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the actual river, this steady state flow was used to replicate existing conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. <u>Data Collection</u>

Data from the HSR model was collected with a three dimensional (3D) laser scanner and flow visualization.

A. 3-D Laser Scanner

The river bed in the model was surveyed with a high definition, 3D laser scanner that collects a dense cloud of xyz data points. These xyz data points were then georeferenced to real world coordinates and triangulated to create a 3D surface. The surface was then color coded by elevation using standard color tables that are also used in color coding prototype surveys. This process allowed a direct comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

B. Flow Visualization

Flow visualization is a tool used to monitor the flow patterns in a HSR model. The preferred method at the Applied River Engineering Center is to dye the water black and seed the water surface with dry white sediment (Poly-Urea-grit) at the model entrance. The dry sediment floats on the top of the water surface and provides a visual representation of surface flow patterns in the model. A high definition video camera is used to record approximately 30 seconds of the sediment floating through the study area. The recording is processed with software that reduces the original recording to approximately 20% of the original speed. The video speed reduction allows viewer to more easily track the flow patterns.

C. Laser Doppler Velocimeter (LDV)

The magnitude (speed) and direction of flow in the model was measured with the LDV. The data was then processed to produce velocity vector transects. Each velocity vector transect was normalized to the highest vector magnitude in the transect. The resulting normalized vectors were then sized and color coded using standard vector arrow sizes and color tables used in displaying prototype velocity surveys (also normalized). This allowed for a direct comparison between HSR model velocity surveys and prototype velocity surveys.

6. Replication Test

Once model replication was achieved through the calibration process, the resultant bathymetry served as a benchmark for the comparison of all future model alternative tests. In this manner, the actions of any alternative, such as new channel improvement structures, realignments, side channel modifications, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences, positive or negative, between the alternative and the replication by comparing the surveys of the two and also carefully observing the model while the testing was taking place.

A. Bathymetry

Bathymetric trends were recorded from the model using a 3-D laser scanner. Calibration was achieved after numerous favorable bathymetric comparisons of the prototype surveys were made to several of the model. The resultant bathymetry served as the bathymetry replication test for the model and is shown on Plate 32.

Results of the HSR model replication test bathymetry and a comparison to the 2005 through 2010 prototype surveys indicated the following trends:

Table 5: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
71.00 – 70.50	The model and the prototype surveys showed scour occurring off the tips of Dike 71.0L and Dike 70.60L with depths as low as -50 feet LWRP.
70.50 – 70.00	The thalweg was located along the LDB and had depths that ranged between -30 feet and -10 feet LWRP in both the model and prototype surveys.

70.00 – 69.10	The thalweg crossed from the LDB to the RDB with depths approximately -10 feet LWRP in both model and prototype. This crossing was shallow in the model survey when compared to the prototype surveys.
69.10 – 68.00	The thalweg located along the RDB with depths that ranged between -30 feet and -10 feet LWRP was observed in both the model and prototype surveys.
68.00 – 67.00	Shoaling occurred with depths that ranged between -5 feet and 0 feet LWRP in the middle of the channel. Scour occurred off the dike field along the RDB. Sediment deposition occurred along the LDB where Vancill Towhead located with depths of at least +5 feet LWRP. The model and prototype surveys showed similar trends.
67.00 – 66.00	The thalweg was located along the RDB and scour was observed off Dike 67.00R. Both model and prorotype surveys showed that the thalweg was located along the RDB and had depths that ranged between -20 feet and -10 feet LWRP.

Note: See Appendix C for the cross sectional comparison

B. Velocity

Once favorable bathymetric trends were observed in the model, a Laser Doppler Velocimeter (LDV) profile was collected from the replication test conditions in the model to compare with ADCP data collected on the river. After comparisons of the prototype ADCP were made to LDV surveys of the model and the trends were similar, this further verified that the model was replicated. The resultant LDV normalized velocity distributions served as the velocity replication test for the model and is shown on Plate 33. A comparison of the 2011 normalized velocities and the normalized model velocities is on Plate 34. LDV measurement locations were determined based upon previously collected ADCP transects in the prototype but limited to a ten inch by ten inch grid. The equivalent area was approximately 1,000 acres. (This was due to the traverse extents of the LDV). Velocities from the HSR model replication test were compared to the 2011 prototype ADCP surveys and indicated the following trends:

Table 6: Model and Prototype Velocity Trend Comparison

River Miles	Description
68.30 – 67.80	In both the model and the prototype highest velocity magnitudes were located near the middle of the channel and along the RDB. The LDB had the lowest velocities between Dike 68.30L and Dike 67.80L.
67.80 – 67.30	The location of the highest velocities in the model and the prototype began to cross from the middle of the channel towards the RDB. The highest velocities occurred at the dike field along the RDB. The LDB had the slowest velocities.
67.30 – 66.80	The location of the highest velocities in the model and the prototype were located in the middle of the channel. The LDB and RDB had the slowest velocities in the dike field.

7. Design Alternative Testing

The testing process consisted of modeling alternative measures in the HSR model followed by analyses of the bathymetry and velocity results. The goal was to reduce or eliminate repetitive maintenance dredging from RM 68.0 to RM 67.0. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry (deposition and scouring). Only the most promising alternatives were then evaluated against model replication test velocity (LDV) data (alignment) and flow visualization (environmental diversity).

Alternative 1:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Extend Dike	67.80	LDB	200	+18.5
Construct Dike	67.60	LDB	1,500	+18.5
Restore Dike	67.30	LDB	960	+18.5
Restore Dike	67.10	LDB	700	+18.5
Restore Dike	66.70	RDB	1,500	+18.5
Restore Dike	66.50	LDB	425	+18.5
Restore Dike	66.30	LDB	260	+18.5
Restore Dike	66.00	LDB	340	+18.5

Results: Bathymetry Analysis (Plate 35)

Reduced Dredging RM 68.00 – RM 67.00	Alleviate Boat Ramp Deposition	Flow and Sediment Transport Side Channel
No	Yes	No
Additional Comments	There were no significant bathymetry changes between RM 71.30 to RM 68.00. The channel became shallower along the RDB (from -12 feet to -7 feet LWRP) between RM 67.80 to RM 67.00. Scour occurred at the tip of Dike 67.60L. The channel deepened (from -15 feet to -25 feet LWRP) along the RDB near the boat ramp located.	

Alternative 2:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.55	RDB	700	-15
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed

Results: Bathymetry Analysis (Plate 36)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. However, Weir 69.55 was buried under sediment. The channel slightly deepened (from -7feet to -12 feet LWRP) along the RDB between RM 68.00 to RM 67.00. There were no significant changes between RM 67.00 to RM 65.30.	

Alternative 3:

Type of Structure	River Mile	LDB / RDB	Dimensions (feet)	Elevation (Feet LWRP)
Construct Weir	69.55	RDB	700	-15
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	68.05	LDB	650 x 650	+18.5
Construct Chevron	67.80	LDB	650 x 650	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed

Results: Bathymetry Analysis (Plate 37)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 and RM 68.60. However, Weir 69.55 was buried under sediment. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed to the left of the two chevrons. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 4:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	68.05	LDB	650 x 650	+18.5
Construct Chevron	67.80	LDB	650 x 650	+18.5
Notch Dike*	67.30	LDB	325	Existing Bed
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed

* Notch dike 200 feet from the LDB, -15 feet LWRP deep and 300 feet wide.

Results: Bathymetry Analysis (Plate 38)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1400 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed behind chevrons and notched dike. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 5:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	68.05	LDB	650 x 650	+18.5
Construct Chevron	67.80	LDB	650 x 650	+18.5
Construct Chevron	67.30	LDB	650 x 650	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Shorten Dike	67.30	LDB	400	Existing Bed

Results: Bathymetry Analysis (Plate 39)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1500 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed behind chevrons and shortened dike. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 6:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	68.10	LDB	300 x 300	+18.5
Construct Chevron	67.70	LDB	300 x 300	+18.5
Construct Chevron	67.30	LDB	300 x 300	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Shorten Dike	67.30	LDB	400	Existing Bed

Results: Bathymetry Analysis (Plate 40)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1500 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed behind chevrons and shortened dike. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 7:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	67.85	LDB	300 x 300	+18.5
Construct Chevron	67.55	LDB	300 x 300	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Shorten Dike	67.30	LDB	400	Existing Bed

Results: Bathymetry Analysis (Plate 41)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 500 feet) along the RDB between RM 68.00 to RM 67.00. Flow and sediment transport was observed behind chevrons and shortened dike. The secondary side channel extended to RM 67.00 creating shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp located).	

***** Secondary Side Channel

Alternative 8:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Chevron	68.20	LDB	300 x 300	+18.5
Construct Chevron	67.75	LDB	300 x 300	+18.5
Construct Chevron	67.35	LDB	300 x 300	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Shorten Dike	68.30	LDB	180	Existing Bed
Shorten Dike	67.30	LDB	400	Existing Bed

Results: Bathymetry Analysis (Plate 42)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 500 feet) along the RDB between RM 68.00 to RM 67.00. Flow and sediment transport was observed along the LDB. The secondary side channel extended to RM 67.00 creating shallow water habitat. There were no significant changes between RM 67.00 to RM 65.30.	

***** Secondary Side Channel

Alternative 9:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Weir	68.35	RDB	700	-15
Construct S-Dike	68.30	LDB	700	+18.5
Construct Chevron	68.20	LDB	300 x 300	+18.5
Construct Chevron	67.75	LDB	300 x 300	+18.5
Construct Chevron	67.35	LDB	300 x 300	+18.5
Construct Dike	67.85	LDB	350	+18.5
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Shorten Dike	68.30	LDB	50	Existing Bed
Shorten Dike	67.80	LDB	250	Existing Bed
Shorten Dike	67.30	LDB	450	Existing Bed

Results: Bathymetry Analysis (Plate 43)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1500 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed along the LDB. However, there was flow. S-Dike 68.30L created scour off the tip immediately downstream. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp). Deposition building in the channel near RM66.00.	

Alternative 10:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Weir	68.35	RDB	700	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed

Results: Bathymetry Analysis (Plate 44)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 500 feet) along the RDB between RM 68.00 to RM 67.00. There were no significant bathymetry changes between RM 68.00 to RM 65.30.	

Alternative 11:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Weir	68.35	RDB	700	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	200	Existing Bed
Construct J-Hook	68.00	LDB	500	+18.5
Construct J-Hook	67.75	LDB	500	+18.5
Construct J-Hook	67.60	LDB	500	+18.5
Shorten Dike	67.80	LDB	200	Existing Bed
Shorten Dike	67.30	LDB	300	Existing Bed

Results: Bathymetry Analysis (Plate 45)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 800 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed to the LDB side of the three J-Hooks. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 12:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	700	-15
Construct Weir	69.15	RDB	700	-15
Construct Weir	68.95	RDB	700	-15
Construct Weir	68.75	RDB	700	-15
Construct Weir	68.55	RDB	700	-15
Construct Weir	68.35	RDB	700	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Construct J-Hook	68.40	LDB	500	+18.5
Construct J-Hook	68.00	LDB	500	+18.5
Construct J-Hook	67.60	LDB	500	+18.5
Construct J-Hook	67.35	LDB	500	+18.5
Construct J-Hook	67.15	LDB	500	+18.5
Shorten Dike	67.80	LDB	200	Existing Bed
Shorten Dike	67.30	LDB	300	Existing Bed

Results: Bathymetry Analysis (Plate 46)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed on the LDB side of the five J-Hooks. However, there was flow. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 13:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir*	69.00	RDB	6600	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	200	Existing Bed

*The purpose of this zig-zag weir was to raise the river bed elevation

Results: Bathymetry Analysis (Plate 47)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	Weir 69.00R reduced scouring at the bend along the RDB between RM 69.20 to RM 68.60. The Weir directed the flow along the RDB. Therefore, the channel slightly deepened (from -7 feet to -12 feet LWRP) between RM 68.00 to RM 67.00. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 14:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed

Results: Bathymetry Analysis (Plate 48)

Reduced Dredging at RM 68.00 – 67.0	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 500 feet) along the RDB between RM 68.00 to RM 67.00. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 15:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Construct Chevron	68.10	LDB	300 x 300	+18.5
Construct Chevron	67.75	LDB	300 x 300	+18.5
Construct Chevron	67.40	LDB	300 x 300	+18.5
Shorten Dike	67.30	LDB	325	Existing Bed

Results: Bathymetry Analysis (Plate 49)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1500 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed behind chevrons and shortened dike. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 16:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct Chevron	68.10	LDB	300 x 300	+18.5
Construct Chevron	67.75	LDB	300 x 300	+18.5
Construct Chevron	67.30	LDB	300 x 300	+18.5
Construct Dike	67.75	RDB	100	+18.5
Extend Dike	68.80	LDB	50	+18.5
Extend Dike	68.50	LDB	50	+18.5
Shorten Dike	67.30	LDB	325	Existing Bed

Results: Bathymetry Analysis (Plate 50)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1500 feet) along the RDB between RM 68.00 to RM 67.00. No sediment transport was observed behind chevrons and shortened dike. However, there was flow. The dike extensions did not help with sediment transport. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp located).	

Alternative 17:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	200	Existing Bed
Shorten Dike	68.30	LDB	125	Existing Bed
Construct Rootless Dike*	68.20	LDB	200	+18.5
Construct Rootless Dike*	68.10	LDB	200	+18.5
Construct Dike	68.05	LDB	150	+18.5
Construct Rootless Dike*	67.85	LDB	200	+18.5
Shorten Dike	67.80	LDB	225	Existing Bed
Construct Two Rootless Dike**	67.70	LDB	200	+18.5
Construct Rootless Dike****	67.60	LDB	200	+18.5
Construct Rootless Dike***	67.50	LDB	200	+18.5
Construct Dike*	67.40	LDB	200	+18.5
Remove Dike****	67.30	LDB	600	Existing Bed
Construct Rootless	67.30	LDB	200	+18.5

Dike*****				
Construct Rootless Dike*	67.20	LDB	200	+18.5

* Located 600 feet from the bankline

** Rootless Dikes located 250 feet and 900 feet from the bankline

***Rootless Dike located 50 feet from the bankline

****Remove 300 feet from Dike 67.30 starting at the bankline. Remove 300 feet away from Dike 67.30 starting at 550 feet from the bankline.

*****Located 1000 feet from the bankline

Results: Bathymetry Analysis (Plate 51)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet) along the RDB between RM 68.00 to RM 67.00. Flow and sediment were observed along the LDB between the rootless dike field. There were multiple scour holes. The secondary side channel extended to RM 67.00 creating shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

***** Secondary Side Channel

Alternative 18:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Remove Dike	69.50	RDB	200	Existing Bed
Remove Dike	69.10	RDB	100	Existing Bed
Construct Dike	68.05	LDB	50	+18.5
Construct Dike	67.75	RDB	150	+18.5
Construct Dike	67.60	LDB	150	+18.5
Construct Dike	67.20	LDB	150	+18.5
Extend Dike	69.50	LDB	50	+18.5
Extend Dike	68.50	LDB	50	+18.5
Extend Dike	68.30	LDB	50	+18.5
Extend Dike	67.80	LDB	50	+18.5

Results: Bathymetry Analysis (Plate 52)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The constriction of the channel at Vancill Towhead, due to three rootless dikes, resulted in less deposition from RM 68.00 to RM 67.00, increasing the width of the navigation channel. Dike extension did not widen navigation channel and had no affect on river bathymetry. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 19:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Extend Dike	69.50	LDB	50	+18.5
Extend Dike	68.80	LDB	50	+18.5
Extend Dike	68.50	LDB	50	+18.5
Extend Dike	68.30	LDB	50	+18.5
Construct J-Hook	68.00	LDB	400	+18.5
Construct J-Hook	67.70	LDB	400	+18.5
Construct J-Hook	67.40	LDB	400	+18.5
Construct Dike	67.95	RDB	150	+18.5
Construct Dike	67.75	RDB	150	+18.5

Results: Bathymetry Analysis (Plate 53)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.95R and Dike 67.75R protected the bankline. The constriction of the channel at Vancill Towhead due to three J-Hook Dikes resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet). No flow or sediment was observed along the LDB. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 20:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct S-Dike	68.10	350	LDB	+18.5
Construct S-Dike	67.80	350	LDB	+18.5
Construct S-Dike	67.40	350	LDB	+18.5
Construct Dike	67.80	150	RDB	+18.5
Construct Dike	67.70	350	LDB	+18.5
Shorten Dike	67.30	250	LDB	Existing Bed

Results: Bathymetry Analysis (Plate 54)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	There were no significant bathymetry changes between RM 71.30 to RM 68.00. The constriction of the channel due to the S-Dikes resulted in less deposition from RM 68.00 to RM 67.00, increasing the width of the navigation channel. Dike 67.70L and 67.30L were used to constrict the flow on the LDB side of the three S-Dikes. The secondary side channel extended to RM 67.00 creating shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

***** Secondary Side Channel

Alternative 21:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct S-Dike	68.10	LDB	550	+18.5
Construct S-Dike	67.80	LDB	550	+18.5
Construct S-Dike	67.40	LDB	550	+18.5
Construct Dike	67.80	RDB	350	+18.5
Construct Dike	67.70	LDB	150	+18.5
Shorten Dike	67.30	LDB	240	Existing Bed

Results: Bathymetry Analysis (Plate 55)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.80R protected the RDB. The constriction of the channel due to the S-Dikes resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). A secondary channel was observed along the LDB to the left of the three S-Dike structures. Secondary side channel extend to RM 67.00 creating shallow water habitats. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

*****Secondary side channel

Alternative 22:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct S-Dike	68.10	LDB	550	+18.5
Construct S-Dike	67.80	LDB	550	+18.5
Construct S-Dike	67.40	LDB	550	+18.5
Construct Dike	67.70	LDB	350	+18.5
Construct Dike	67.80	LDB	200	+18.5
Shorten Dike	67.30	LDB	250	Existing Bed

Results: Bathymetry Analysis (Plate 56)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.80R was there to protect the bankline. S-Dikes were moved 100 feet toward the LDB compared to Alternative 21. The constriction of the channel due to the S-Dikes resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). No sediment transport was observed behind three S-Dikes. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (where the boat ramp located).	

Alternative 23:

Type of Structure	River Mile	LDB / RDB	Dimensions ($Feet^2$)	Elevation (feet in LWRP)
Construct Island*	68.15	LDB	30,000	+18.5
Construct Island*	68.00	LDB	30,000	+18.5
Construct Island*	67.80	LDB	30,000	+18.5
Construct Island*	67.70	LDB	30,000	+18.5
Construct Island*	67.50	LDB	30,000	+18.5
Construct Island*	67.40	LDB	30,000	+18.5
Construct Island*	67.30	LDB	30,000	+18.5

* Volume required for each island is approximately 450,000 $feet^3$. Average dredge volume at Vancill is roughly 190,000 yd^3 or 5,000,000 $feet^3$. No phased construction necessary.

Results: Bathymetry Analysis (Plate 57)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	There were no significant bathymetry changes RM 71.30 to RM 68.00. The constriction of the channel due to the small islands resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp)	

Alternative 24:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct Island*	68.15	LDB	30,000 $feet^2$	+18.5
Construct Island*	68.00	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.80	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.70	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.50	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.40	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.30	LDB	30,000 $feet^2$	+18.5

* Volume required for each island is approximately 450,000 $feet^3$. Average dredge volume at Vancill is roughly 190,000 yd^3 or 5,000,000 $feet^3$. No phased construction necessary.

Results: Bathymetry Analysis (Plate 58)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. The constriction of the channel due to the small islands resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. No sediment transport was observed between islands. However, there was flow. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

Alternative 25:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct Island	68.15	LDB	30,000 $feet^2$	+18.5
Construct Island	68.00	LDB	30,000 $feet^2$	+18.5
Construct Island	67.80	LDB	30,000 $feet^2$	+18.5
Construct Island	67.70	LDB	30,000 $feet^2$	+18.5
Construct Island	67.50	LDB	30,000 $feet^2$	+18.5
Construct Island	67.40	LDB	30,000 $feet^2$	+18.5
Construct Island	67.30	LDB	30,000 $feet^2$	+18.5
Construct Dike	67.70	RDB	200	+18.5
Shorten Dike	68.30	LDB	180	Existing Bed
Shorten Dike	67.30	LDB	350	Existing Bed

* Volume required for each island is approximately 450,000 $feet^3$. Average dredge volume at Vancill is roughly 190,000 yd^3 or 5,000,000 $feet^3$. No phased construction necessary.

Results: Bathymetry Analysis (Plate 59)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.70R protected the bankline. The constriction of the channel due to the small islands resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet). More flow was observed along the LDB. Flow and sediment transport was observed between islands. The secondary side channel extended to RM 67.00, creating shallow water habitat. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

***** Secondary Side Channel

Alternative 26:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct S-Dike	68.15	LDB	550	+18.5
Construct S-Dike	67.70	LDB	550	+18.5
Construct S-Dike	67.30	LDB	550	+18.5
Construct Island*	68.00	LDB	30,000 feet^2	+18.5
Construct Island*	67.80	LDB	30,000 feet^2	+18.5
Construct Island*	67.50	LDB	30,000 feet^2	+18.5
Construct Island*	67.40	LDB	30,000 feet^2	+18.5
Shorten Dike	68.30	LDB	180	Existing Bed
Shorten Dike	67.30	LDB	350	Existing Bed
Construct Dike	67.70	RDB	200	+18.5

* Volume required for each island is approximately 450,000 feet^3. Average dredge volume at Vancill is roughly 190,000 yd^3 or 5,000,000 feet^3. No phased construction necessary.

Results: Bathymetry Analysis (Plate 60)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.70R protected the bankline. The constriction of the channel due to the small islands and S-Dikes resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1000 feet). More flow was observed along the RDB. No sediment transport was observed between islands. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 27:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct S-Dike	68.15	LDB	550	+18.5
Construct S-Dike	67.80	LDB	550	+18.5
Construct S-Dike	67.30	LDB	550	+18.5
Construct Dike	67.80	RDB	200	+18.5
Shorten Dike	67.80	LDB	375	Existing Bed
Shorten Dike	67.30	LDB	550	Existing Bed
Shorten Dike	67.10	LDB	100	Existing Bed

Results: Bathymetry Analysis (Plate 61)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	There were no significant bathymetry changes between RM 71.30 to RM 68.00. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 800 feet). Flow and sediment transport was observed to the left of S-Dike structures and along the LDB. There was a scour hole with depth approximately -20 feet LWRP located between S-Dike 67.30L and Dike 67.30. The secondary side channel extended to RM 67.00, creating shallow water habitat. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

* Secondary Side Channel

Alternative 28:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct S-Dike	68.15	LDB	550	+18.5
Construct S-Dike	67.70	LDB	550	+18.5
Construct S-Dike	67.30	LDB	550	+18.5
Construct Dike	67.70	RDB	200	+18.5
Shorten & Raise Dike	67.80	LDB	400	Existing Bed
Shorten Dike	67.30	LDB	550	Existing Bed

Results: Bathymetry Analysis (Plate 62)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards the LDB between RM 68.50 and RM 67.50. Dike 67.70R protected the RDB. The constriction of the channel due to S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 800 feet). More flow was observed along the LDB. No sediment transport was observed behind S-Dike structures. However, there was flow. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 29:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Extend Weir	70.45	LDB	350	-15
Extend Weir	70.35	LDB	350	-15
Extend Weir	70.25	LDB	350	-15
Extend Weir	70.15	LDB	350	-15
Extend Weir	70.00	LDB	350	-15

Results: Bathymetry Analysis (Plate 63)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
No	No	No
Additional Comments	The extended weirs had no affect from RM 70.00 to RM 69.00. There were no significant bathymetry changes between RM 69.00 to RM 65.30. However, scour off the tip of Dike 67.30L was larger.	

Alternative 30:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Extend Weir	70.45	LDB	350	-15
Extend Weir	70.35	LDB	350	-15
Extend Weir	70.25	LDB	350	-15
Extend Weir	70.15	LDB	350	-15
Extend Weir	70.00	LDB	350	-15
Construct Weir	69.35	RDB	800	-15
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct Weir	68.55	RDB	800	-15
Construct Weir	68.35	RDB	800	-15
Construct Chevron	68.00	LDB	300x300	+18.5
Construct Chevron	67.70	LDB	300x300	+18.5
Construct Chevron	67.30	LDB	300x300	+18.5
Construct Dike	67.70	RDB	200	+18.5
Construct Rootless Dike *	67.65	LDB	200	+18.5
Shorten Dike	67.80	LDB	200	Existing Bed
Shorten Dike	67.30	LDB	450	Existing Bed
Shorten Dike	67.10	LDB	325	Existing Bed

* Start at Vancill Towhead

Results: Bathymetry Analysis (Plate 64)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The extended weirs resulted in deepening (from -10 feet to -15 feet LWRP) between RM 70.00 and RM 69.00. The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. Dike 67.70R protected the RDB. The constriction of the channel due to three chevrons resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. Flow and sediment transport was observed behind the three chevrons. The secondary side channel extended further downstream to RM 66.75, creating more shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 31:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	LDB	800	-15
Construct Weir	69.15	LDB	800	-15
Construct Weir	68.95	LDB	800	-15
Construct Weir	68.75	LDB	800	-15
Construct Weir	68.55	LDB	800	-15
Construct Weir	68.35	LDB	800	-15
Construct Dike	67.70	RDB	200	+18.5
Construct S-Dike	68.10	LDB	500	+18.5
Construct S-Dike	67.80	LDB	500	+18.5
Construct S-Dike	67.50	LDB	500	+18.5
Construct Island*	68.10	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.80	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.60	LDB	30,000 $feet^2$	+18.5
Shorten Dike	67.80	LDB	100	Existing Bed
Shorten Dike	67.30	LDB	450	Existing Bed

* Volume required for each island is approximately 450,000 $feet^3$. Average dredge volume at Vancill is roughly 190,000 yd^3 or 5,000,000 $feet^3$. No phased construction necessary.

Results: Bathymetry Analysis (Plate 65)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. Dike 67.70R protected the RDB. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. Flow and sediment transport was observed behind the S-Dike structures. The secondary side channel extended to RM 67.00, creating shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

***** Secondary Side Channel

Alternative 32:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	LDB	800	-15
Construct Weir	69.15	LDB	800	-15
Construct Weir	68.95	LDB	800	-15
Construct Weir	68.75	LDB	800	-15
Construct Weir	68.55	LDB	800	-15
Construct Weir	68.35	LDB	800	-15
Construct Dike	67.70	RDB	200	+18.5
Construct S-Dike	68.10	LDB	500	+18.5
Construct S-Dike	67.70	LDB	500	+18.5
Construct S-Dike	67.50	LDB	500	+18.5
Construct Island*	68.00	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.70	LDB	30,000 $feet^2$	+18.5
Construct Island*	67.60	LDB	30,000 $feet^2$	+18.5
Shorten Dike	67.80	LDB	100	Existing Bed
Shorten Dike	67.30	LDB	350	Existing Bed
Shorten Dike	67.10	LDB	200	Existing Bed

* Volume required for each island is approximately 450,000 $feet^3$. Average dredge volume at Vancill was roughly 190,000 yd^3 or 5,000,000 $feet^3$. No phased construction necessary.

Results: Bathymetry Analysis (Plate 66)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. Dike 67.70R protected the RDB. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. Flow and sediment transport was observed behind the S-Dike structures. The secondary side channel extended further downstream to RM 66.75, creating more shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

***** Secondary Side Channel

Alternative 33:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.15	RDB	800	-15
Construct Weir	68.95	RDB	800	-15
Construct Weir	68.75	RDB	800	-15
Construct S-Dike	68.10	LDB	500	+18.5
Construct S-Dike	67.80	LDB	500	+18.5
Construct S-Dike	67.50	LDB	500	+18.5
Repair Dike	67.80	LDB	380	+18.5
Repair Dike	67.10	LDB	230	+18.5
Remove Dike	67.30	LDB	750	Existing Bed
Revetment	67.30	LDB	300	+18.5
Revetment	67.10	LDB	300	+18.5

Results: Bathymetry Analysis (Plate 67) and Velocity Analysis (Plate 68)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	Three weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). More flow was observed along the LDB. Flow and sediment transport was observed behind the S-Dike structures. Secondary side channel extend further downstream to RM 66.75 creating more shallow water habitats. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp located). Higher velocities were observed along the RDB where most of the flow concentrated. Slower velocities were observed around S-Dike structures and downstream from them.	

***** Secondary Side Channel

Alternative 34:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	LDB	800	-15
Construct Weir	69.15	LDB	800	-15
Construct Weir	68.95	LDB	800	-15
Construct Weir	68.75	LDB	800	-15
Construct Weir	68.55	LDB	800	-15
Construct Weir	68.35	LDB	800	-15
Construct S-Dike	68.10	LDB	500	+18.5
Construct S-Dike	67.70	LDB	500	+18.5
Construct S-Dike	67.40	LDB	500	+18.5
Construct SCED	67.75	LDB	450	+18.5
Shorten Dike	68.30	LDB	200	Existing Bed
Shorten Dike	67.80	LDB	200	Existing Bed
Shorten Dike	67.30	LDB	200	Existing Bed
Shorten Dike	67.10	LDB	200	Existing Bed
Notch Dike*	67.80	LDB	250	Existing Bed
Notch Dike *	67.30	LDB	250	Existing Bed
Notch Dike *	67.10	LDB	300	Existing Bed

*Dike notched from the bankline.

Results: Bathymetry Analysis (Plate 69)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	No
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). Flow was observed behind the S-Dike structures and Vancill Towhead but no sediment transport or secondary side channel. More shallow water habitat was created. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

Alternative 35:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct SCED**	67.70	LDB	1800	+18.5
Remove Dike	67.80	LDB	650	Existing Bed
Notch Dike*	67.30	LDB	300	Existing Bed
Notch Dike*	67.10	LDB	300	Existing Bed
Shorten Dike	67.30	LDB	100	Existing Bed
Shorten Dike	67.10	LDB	50	Existing Bed

* Dike notched from the bankline.

** SCED = Side Channel Enhancement Dike

Results: Bathymetry Analysis (Plate 70)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No**
Additional Comments	There were no significant bathymetry changes between RM 71.30 to RM 68.00. Scouring occurred along the RDB of the SCED with depths approximately -12 feet LWRP. The SCED 67.70L successfully captured flow from the main channel and directed it to Vancill Towhead side channel. However, no sediment transport was observed. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

**Only flow increased in side channel behind Vancill Towhead

Alternative 36:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.35	LDB	800	-15
Construct Weir	69.15	LDB	800	-15
Construct Weir	68.95	LDB	800	-15
Construct Weir	68.75	LDB	800	-15
Construct Weir	68.55	LDB	800	-15
Construct Weir	68.35	LDB	800	-15
Remove Dike	68.30	LDB	500	Existing Bed
Remove Dike	67.80	LDB	600	Existing Bed
Construct Rootless Dike*	68.30	LDB	350	+18.5
Construct Rootless Dike*	67.80	LDB	350	+18.5
Construct Chevron	67.70	LDB	300 x 300	+18.5
Construct Chevron	67.50	LDB	300 x 300	+18.5
Shorten Dike	67.30	LDB	420	Existing Bed

*Dike angled downstream and located 300 feet away from the bankline

Results: Bathymetry Analysis (Plate 71)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	No	No**
Additional Comments	The weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The constriction of the channel due to two chevrons and two rootless dikes resulted in less deposition from RM 68.00 to RM 67.00. However, there was a deposition bar in the middle of the channel between RM 68.0 and RM 67.0. The navigation channel deepened (from -7 feet to -9 feet LWRP) and widened (from 0 feet to 1200 feet). Flow was observed behind two chevrons, two rootless dikes and Vancill Towhead but no sediment transport. More shallow water habitat was created. There were no significant bathymetry changes between RM 67.00 to RM 65.30.	

**Only flow increased in side channel behind Vancill Towhead

Alternative 37:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (feet in LWRP)
Construct Weir	69.15	LDB	800	-15
Construct Weir	68.95	LDB	800	-15
Construct Weir	68.75	LDB	800	-15
Construct S-Dike	68.10	LDB	500	+18.5
Construct S-Dike	67.80	LDB	500	+18.5
Construct S-Dike	67.50	LDB	500	+18.5
Construct SCED	67.75	LDB	550	+18.5
Notch Dike	67.80	LDB	150	Existing Bed
Repair Dike	67.80	LDB	200	+18.5
Shorten Dike	67.10	LDB	300	Existing Bed
Remove Dike*	67.30	LDB	1000	Existing Bed

Results: Bathymetry Analysis (Plate 72)

Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
Yes	Yes	Yes*
Additional Comments	Three weirs reduced scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg was located along the RDB instead of crossing over towards in the LDB between RM 68.50 to RM 67.50. The constriction of the channel due to the S-Dike structures resulted in less deposition from RM 68.00 to RM 67.00. The navigation channel deepened (from -7 feet to -12 feet LWRP) and widened (from 0 feet to 1200 feet). Flow and sediment transport was observed behind the S-Dike structures in a secondary channel, but the side channel behind Vancill only experienced a slight increase in flow. The secondary side channel extended further downstream to RM 66.75, creating more shallow water habitat. The channel also deepened (from -15 feet to -25 feet LWRP) between RM 67.00 and RM 66.30 along the RDB (near the boat ramp).	

***** Secondary Side Channel

CONCLUSION

8. Evaluation and Summary of Test Results

In order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The most important consideration was that the alternative had to sufficiently reduce or eliminate the dredging at RM 68.00 to RM 67.00. The second condition was that the alternative had to maintain the navigation channel requirements of at least 9 foot of depth and 300 feet foot of width. The third condition was that the alternative should introduce additional flow and sediment transport along the LDB to enhance the aquatic diversity at Vancill Towhead. Lastly, the alternative had to reduce deposition at the boat ramp inside the L-Dike 66.70R. Although there were a number of alternatives that showed reduced deposition in the problem areas while maintaining the navigation channel requirements, they were not recommended. These alternatives were not recommended primarily because the alternative did not successfully improve the environmental conditions at Vancill Towhead.

Table 7: Summary of Test Results

Alternative	Reduced Dredging at RM 68.00 – 67.00	Alleviate Boat Ramp Deposition	Side Channel Flow and Sediment Transport
1		x	
2	x		
3	x	x	
4	x	x	
5	x	x	
6	x	x	
7	x	x	x*
8	x		x*
9	x	x	

10	x		
11	x	x	
12	x	x	
13	x		
14	x		
15	x	x	
16	x	x	
17	x	x	x*
18	x		
19	x		
20	x	x	x*
21	x	x	x*
22	x	x	
23	x	x	
24	x	x	
25	x	x	x*
26	x	x	
27	x	x	x*
28	x	x	
29			
30	x	x	x*
31	x	x	x*
32	x	x	x*
33	x	x	x*
34	x	x	x**
35	x		x**
36	x		
37	x	x	X*

* Flow and sediment transport for secondary side channel

**Flow increased in side channel behind Vancill Towhead

9. Recommendations

Alternative 33, Plate 67, was recommended as the most desirable alternative because of its ability to solve the dredging problem at Vancill Towhead. This alternative also alleviates sediment deposition at the boat ramp along the RDB at RM 66.65, while having no significant impacts on the navigation channel. Bathymetry results show that the thalweg between RM 68.00 and RM 67.00 was directed along the RDB by three S-Dikes. The thalweg depths increased in the main channel and more scour occurred near Dike 66.70R and the boat ramp.

The goal to improve the environmental diversity at Vancill Towhead involved increasing the flow and sediment transport through the side channel. However, the location of the side channel entrance being so far away from the thalweg made the task nearly impossible. Therefore the approach taken in the recommended alternative created a secondary side channel with river training structures. Overall, this alternative would eliminate the repetitive dredging, maintain the navigation channel and enhance the environmental diversity near Vancill Towhead.

The recommended design included the following:

- Construct Weir 69.15L
    - Construct weir 800 feet long
    - Top elevation of the weir will be -15 feet LWRP
- Construct Weir 68.95L
    - Construct weir 800 feet long
    - Top elevation of the weir will be -15 feet LWRP
- Construct Weir 68.75L
    - Construct Weir 800 feet long
    - Top elevation of the weir will be -15 feet LWRP
- Construct Diverter Dike 68.10L (S-Dike)

- Construct Diverter Dike 750 feet long
- Top elevation of the dike will be +18.5 feet LWRP

- Construct Diverter Dike 67.80L (S-Dike)
  - Construct Diverter Dike 750 feet long
  - Top elevation of the dike will be +18.5 feet LWRP
- Construct Diverter Dike 67.50L (S-Dike)
  - Construct Diverter Dike 750 feet long
  - Top elevation of the dike will be +18.5 feet LWRP
- Repair Dike 67.80L
  - Repair Dike 380 feet long
  - Top elevation of the dike will be +18.5 feet LWRP
- Shorten Dike 67.30L
  - Shorten Dike 750 feet long
  - Top elevation of the dike will be existing bed.
- Shorten Dike 67.10L
  - Remove Dike 230 feet long
  - Top elevation of the dike will be existing bed.
- Revetment 600 feet
  - Two revetment locations (RM 67.325 – RM 67.275 and 67.125 – RM 67.075)

10. <u>Interpretation of Model Test Results</u>

In the interpretation and evaluation of the model test results, it should be remembered that these results are qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodible variables. Water surfaces were not analyzed and flood flows were not simulated in this study.

This model study was intended to serve as a tool for the river engineer to guide in assessing the general trends that could be expected to occur in the Mississippi River from a variety of imposed design alternatives. Measures for the final design may be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirements.

FOR MORE INFORMATION

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APPENDICES

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Plate	50	Alternative 16
Plate	51	Alternative 17
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Plate	53	Alternative 19
Plate	54	Alternative 20
Plate	55	Alternative 21

Plate	56	Alternative 22
Plate	57	Alternative 23
Plate	58	Alternative 24
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Plate	61	Alternative 27
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B. Vancill Towhead HSR Model Meeting Minutes

MEETING NOTES

SUBJECT: Information gathering and discussion of design alternatives for the Vancill Towhead HSR Model.

This document is meant to summarize the information discussed in the Vancill Towhead HSR model meeting held on February 27, 2012 from 2PM to 3PM. See Enclosure 1 for a list of meeting attendees.

Ivan Nguyen was the lead river engineer for this model and led the discussion. He pointed out the repetitive dredging location in the Vancill Towhead reach that was being addressed by this HSR model, between River Mile (RM) 68.00 and RM 67.00. He pointed out that dredging generally takes place in the middle of the river channel and disposal is generally along the left descending bank (LDB) side of the channel. See Enclosure 2 for a map of the dredging area.

Matt Mangan of the US Fish and Wildlife Service (USFWS) stated that in the reach being studied, there was a gravel bar along the right descending bank (RDB) at RM 70.30. He also noted that some pallid sturgeons were found at the downstream end of the Vancill Towhead bar.

Missouri Department of Conservation (MDC) and Illinois Department of Natural Resources (IDNR) representatives, along with USFWS representatives, will be paying extra attention to the results of this model study because this area was originally intended to be the “control” site for the Herculaneum Project (NESP). However, due to limited NESP funding, Corps personnel may decide that the Vancill Towhead reach will utilize the Herculaneum reach as its control site. This decision will likely come after the results of the HSR model study are communicated.

The 3 environmental agencies present at the meeting were also interested in this area as it is a potential site for flexible dredge disposal pipe island creation. If an idea is put forward that greatly reduces or eliminates the need for repetitive dredging at Vancill Towhead, this area will drop off the list of candidates for flexible dredge pipe island creation. This river reach also contains the Trail of Tears State Park boat ramp. This boat ramp is behind the trail dike 66.7R and is frequently inaccessible due to sedimentation buildup behind the end of the trail dike.

Representatives of the navigation industry pointed out that fleeting and loading operations should be accounted for adjacent to Tower Rock Quarry along the LDB at RM 71.60.

Ivan pointed out to Ed Henleben and others that he was aware of 3 exchange points for navigation traffic in the area. They are along the RDB and LDB at RM 68.20 and along the LDB at RM 66.70. No other exchange points were noted in this river reach.

Enclosure 1

Carondelet and Vancill Towhead HSR Model Study

February 27th at 1PM

Rodgers, Michael	
Butch Atwood	Butch Atwood
Brown, Danny	[signature]
Jim Mick	
Collins, Joyce	
Matthew_Mangan	[signature]
Robert.Hrabik	
Sternburg, Janet	
Engle, Lance	✓ [signature]
Frerker, Charles F	
Gordon, David	
Johnson, Brian L	[signature]
Lamm, Dawn	Dawn Lamm
Schimpf, Andrew	
Terry, Rottler	
Henleben, Ed ✓	[signature]
Hughes, Shannon	Shannon Hughes
QC Harris	
Tim. Robinson	
Bequette, Terry	
Markenson, Sarah	[signature]
Mark.Boone	
Dave Knuth	[signature]
Bernard.Heroff	
Chris Kennedy	
Zobrist, Tyson	

HASSLER, PAUL ✓ [signature]

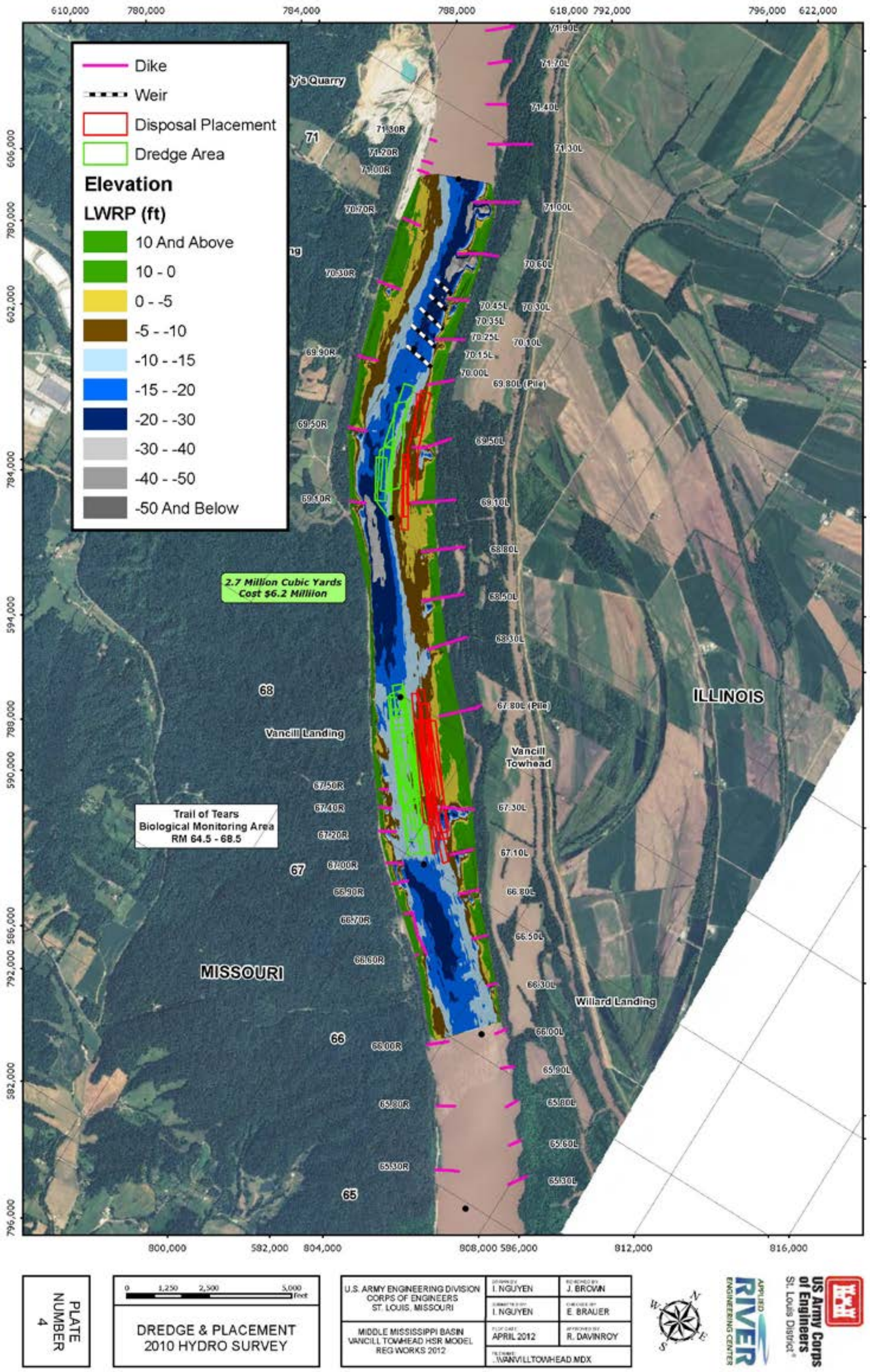
CHRISTENSEN, RYAN USCG [signature]

David Ostendorf MDC

GARY PATTERSON [signature]

Kat McCain USACE [signature]

Enclosure 2



Dike
Weir
Disposal Placement
Dredge Area
Elevation
LWRP (ft)
10 And Above
10 - 0
0 - -5
-5 - -10
-10 - -15
-15 - -20
-20 - -30
-30 - -40
-40 - -50
-50 And Below
2.7 Million Cubic Yards
Cost $6.2 Million
Trail of Tears
Biological Monitoring Area
RM 64.5 - 68.5
Vancill Landing
Vancill Towhead
Willard Landing
ILLINOIS
MISSOURI
PLATE NUMBER 4
DREDGE & PLACEMENT
2010 HYDRO SURVEY
U.S. ARMY ENGINEERING DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
MIDDLE MISSISSIPPI BASIN
VANCILL TOWHEAD HSR MODEL
REG WORKS 2012
I. NGUYEN
J. BROWN
E. BRAUER
APRIL 2012
R. DAVINROY
US Army Corps of Engineers
St. Louis District
APPLIED RIVER ENGINEERING CENTER

C. <u>Cross Section Comparison</u>

To verify the predictive capabilities of the HSR model used for this study, cross sections were developed for the replication model condition and three prototype bathymetries, the 2005, 2007 and 2010 river surveys. At these cross sections, the cross-sectional areas and percent differences were calculated. The cross sections were modeled and area calculations were performed using Bentley's Inroads and Microstation software. The cross sections were cut at 2000 feet intervals along the sailing line for the same locations for all four surveys. See Plate 73.

The initial comparison was between the replicated model scan and the 2005 bathymetry. The cross sections were generated with a vertical distortion of 15 feet horizontal for 1 foot vertical, which dictated using 15 as a correction factor for the area calculations. See Plate 74. The results of the area calculations are presented on the next page in Table 8. The average difference between the cross-sectional areas, model to prototype, was 4.9%. Tables 9 and 10 show the comparison between the replicated model scan to the 2007 and 2012 bathymetry. The average differences between the cross-sectional areas were 5.7% and 6.2% respectively. The average difference in cross-section between the replicated model scan and three prototype bathymetric surveys was 5.6%. See Table 14.

Cross sections were generated in the same manner comparing the 2005 and 2010 bathymetries to get a measure of the natural variation of the channel. Table 11 shows the average percent difference was 6.4%. Table 12 shows the cross sectional comparison between the 2005 and 2007 bathymetries. The average difference was 8.2%. Table 13 shows the cross sectional comparison between the 2007 and 2010 bathymetries. The average difference was 5.3%. The average variation in cross sectional area was 6.6%. The natural variation of the channel compared within 1% to the replication model. See Table 15.

Table 8: **Cross Section Comparison Model Replication Scan and 2005 Bathymetry**

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2005 Survey (feet²)	True Model Replication (feet²)	True 2005 Survey (feet²)	
20+00	782220	677047	52148	45136	14.4%
40+00	650843	626161	43390	41744	3.9%
60+00	641241	633756	42749	42250	1.2%
80+00	716914	673283	47794	44886	6.3%
100+00	690817	693504	46054	46234	0.4%
120+00	670843	683037	44723	45536	1.8%
140+00	647292	617704	43153	41180	4.7%
160+00	631279	629587	42085	41972	0.3%
180+00	649537	620843	43302	41390	4.5%
200+00	844305	765023	56287	51002	9.9%
220+00	789509	689958	52634	45997	13.5%
240+00	737780	734482	49185	48965	0.4%
260+00	702433	688090	46829	45873	2.1%
				Average	**4.9%**

Table 9: Cross Section Comparison Model Replication Scan and 2007 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2007 Survey (feet²)	True Model Replication (feet²)	True 2007 Survey (feet²)	
20+00	782220	861285	52148	57419	9.6%
40+00	650843	775443	43390	51696	17.5%
60+00	641241	682556	42749	45504	6.2%
80+00	716914	764660	47794	50977	6.4%
100+00	690817	723451	46054	48230	4.6%
120+00	670843	634807	44723	42320	5.5%
140+00	647292	658012	43153	43867	1.6%
160+00	631279	664513	42085	44301	5.1%
180+00	649537	663892	43302	44259	2.2%
200+00	844305	824203	56287	54947	2.4%
220+00	789509	700536	52634	46702	11.9%
240+00	737780	736005	49185	49067	0.2%
260+00	702433	699819	46829	46655	0.4%
				Average	**5.7%**

Table 10: Cross Section Comparison Model Replication Scan and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2010 Survey (feet²)	True Model Replication (feet²)	True 2010 Survey (feet²)	
20+00	782220	731704	52148	48780	6.7%
40+00	650843	769083	43390	51272	16.7%
60+00	641241	690214	42749	46014	7.4%
80+00	716914	731099	47794	48740	2.0%
100+00	690817	683010	46054	45534	1.1%
120+00	670843	730676	44723	48712	8.5%
140+00	647292	689795	43153	45986	6.4%
160+00	631279	653078	42085	43539	3.4%
180+00	649537	599446	43302	39963	8.0%
200+00	844305	787782	56287	52519	6.9%
220+00	789509	714249	52634	47617	10.0%
240+00	737780	741536	49185	49436	0.5%
260+00	702433	720021	46829	48001	2.5%
				Average	**6.2%**

Table 11: Cross Section Comparison between 2005 Bathymetry and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2005 Survey (feet²)	2010 Survey (feet²)	True 2005 Survey (feet²)	True 2010 Survey (feet²)	
20+00	677047	731704	45136	48780	7.8%
40+00	626161	769083	41744	51272	20.5%
60+00	633756	690214	42250	46014	8.5%
80+00	673283	731099	44886	48740	8.2%
100+00	693504	683010	46234	45534	1.5%
120+00	683037	730676	45536	48712	6.7%
140+00	617704	689795	41180	45986	11.0%
160+00	629587	653078	41972	43539	3.7%
180+00	620843	599446	41390	39963	3.5%
200+00	765023	787782	51002	52519	2.9%
220+00	689958	714249	45997	47617	3.5%
240+00	734482	741536	48965	49436	1.0%
260+00	688090	720021	45873	48001	4.5%
				Average	**6.4%**

Table 12: Cross Section Comparison Between 2005 Bathymetry and 2007 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2005 Survey (feet²)	2007 Survey (feet²)	True 2005 Survey (feet²)	True 2007 Survey (feet²)	
20+00	677047	861285	45136	57419	24.0%
40+00	626161	775443	41744	51696	21.3%
60+00	633756	682556	42250	45504	7.4%
80+00	673283	764660	44886	50977	12.7%
100+00	693504	723451	46234	48230	4.2%
120+00	683037	634807	45536	42320	7.3%
140+00	617704	658012	41180	43867	6.3%
160+00	629587	664513	41972	44301	5.4%
180+00	620843	663892	41390	44259	6.7%
200+00	765023	824203	51002	54947	7.4%
220+00	689958	700536	45997	46702	1.5%
240+00	734482	736005	48965	49067	0.2%
260+00	688090	699819	45873	46655	1.7%
				Average	**8.2%**

Table 13: Cross Section Comparison between 2007 Bathymetry and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2007 Survey (feet²)	2010 Survey (feet²)	True 2007 Survey (feet²)	True 2010 Survey (feet²)	
20+00	861285.000	731704.000	57419	48780	16.3%
40+00	775443.000	769083.000	51696	51272	0.8%
60+00	682556	690214	45504	46014	1.1%
80+00	764660	731099	50977	48740	4.5%
100+00	723451	683010	48230	45534	5.8%
120+00	634807	730676	42320	48712	14.0%
140+00	658012	689795	43867	45986	4.7%
160+00	664513	653078	44301	43539	1.7%
180+00	663892	599446	44259	39963	10.2%
200+00	824203	787782	54947	52519	4.5%
220+00	700536	714249	46702	47617	1.9%
240+00	736005	741536	49067	49436	0.7%
260+00	699819	720021	46655	48001	2.8%
				Average	**5.3%**

Table 14: Average Percent Difference between Model Replication and Prototype Surveys

Model Replication & 2005 Survey	Model Replication & 2007 Survey	Model Replication & 2010 Survey	Average Percent Difference
4.9%	5.7%	6.2%	5.6%

Table 15: Average Percent Difference between Prototype Surveys

2005 Survey & 2010 Survey	2005 Survey & 2007 Survey	2007 Survey & 2010 Survey	Average Percent Difference
6.4%	8.2%	5.3%	6.6%

D. HSR Modeling Theory

The principle behind the use of a hydraulic sediment response model is similitude, the linking of parameters between a model and prototype so that behavior in one can predict behavior in the other.

There are two different types of similitude; mathematical similitude and empirical similitude. Mathematical similitude is founded on the scale relationship between all linear dimensions (geometric similarity), a scale relationship between all components of velocity (kinematic), or both geometric and kinematic similarity with the ratio of all common point forces equal (dynamic similarity).

In contrast to mathematical similitude, empirical similitude is based on the belief that the laws of mathematical similitude can be relaxed as long as other more fundamental relationships are preserved between the model and the prototype. All physical models used in the past by USACE employed, to some degree, empirical similitude. Numerous definitions of what relationships must be preserved have been put forward concerning physical sediment models. These relationships often deal with the scalability of elements of sediment transport processes or surface or structure roughness. Hydraulic sediment response models depend on similitude in the morphologic response, i.e. the ability of the model to replicate known prototype parameters associated with the bed response in the river under study. Bed response includes thalweg location, scour and deposition within the channel and at various river structures, and the overall resultant bed configuration. These parameters are directly compared to what is observed from prototype surveys.

Detailed cross-sectional analysis of prototype and model surveys defining bed response and bed configuration have shown that HSR model variation from the prototype is often approximately that of the natural variation observed in the prototype. This correspondence allows hydraulic engineers to use the HSR model with confidence and introduce alternatives in the model to approximate the bed response that can be expected to occur in the prototype.

HSR models were developed from empirical large scale coal bed models utilized by the USACE Waterways Experiment Station (Environmental Research and Development Center). These models were used by MVS from 1940 to the mid 1990s. For a more thorough explanation of the HSR model development, please refer to the following link:

http://www.wes.army.mil/Welcome.html

E. Flow Visualization Results

Flow visualization is a tool used to monitor the flow patterns in an HSR model. The preferred method at the Applied River Engineering Center is to dye the water and seed the water surface with dry white sediment (Poly-Urea grit) at the model entrance. The dry sediment floats on the top of the water surface and provides a visual representation of surface flow patterns in the model. A high definition video camera is used to record approximately 60 seconds of the sediment floating through the study area. The recording is processed with software that reduces the recording to approximately 20% of the original speed. The video speed reduction allows viewers to more easily track the flow patterns.

The first condition recorded was the replication test, or existing conditions as seen in Figure 1 below. (Please note that there is a DVD available with this report to view the videos.)

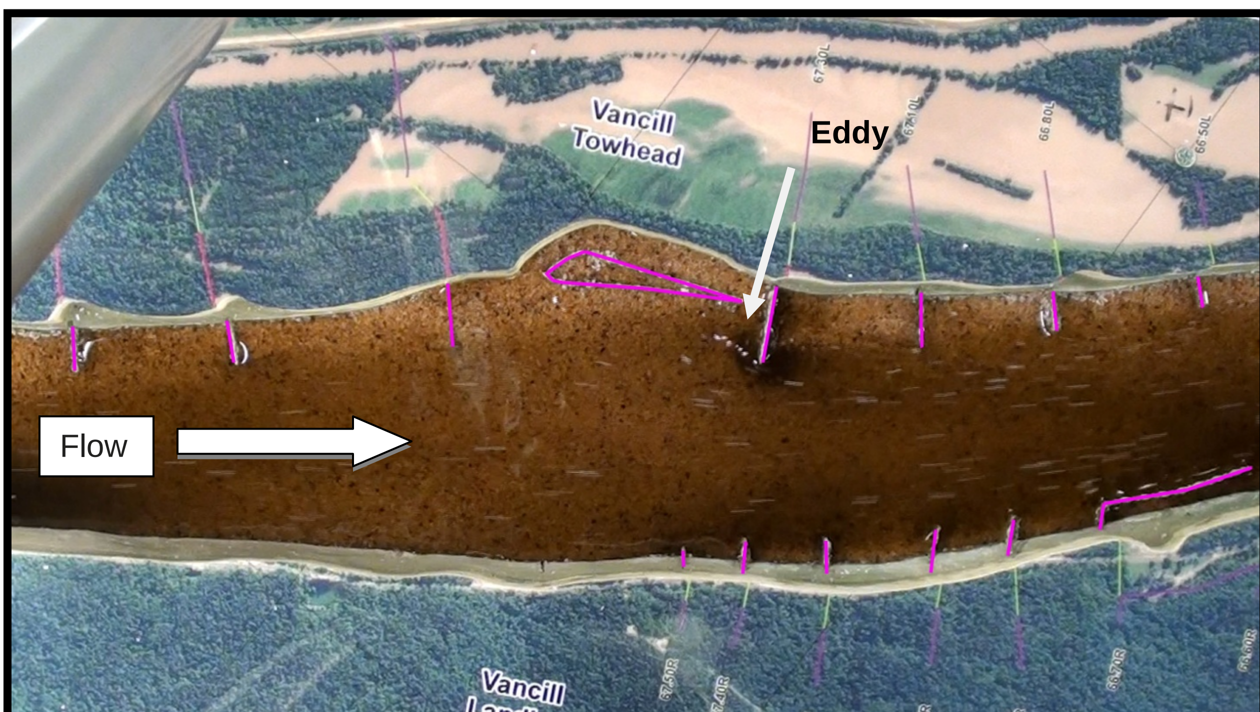


Figure 1: Flow Visualization of Existing Conditions

The flow exited a bend at RM 69.00 and maintained a straight path just upstream of Figure 1's extents. As seen in the snapshot of the existing conditions, the resultant flow was concentrated along the RDB in Figure 1. Immediately downstream, flow began to disperse across the channel. There was an eddy caused by Dike 67.30L located just downstream of Vancill Towhead. No sediment movement was observed in the side channel. All structures are highlighted in pink for increased visibility.

The next condition recorded was post construction with the recommended alternative (Alternative 33) of constructing Weirs 69.15R, 68.95R and 68.75; constructing S-Dike 68.10L, 67.80L and 67.50L, repairing Dike 67.80L; shortening 67.30L and 67.10L; and revetment.

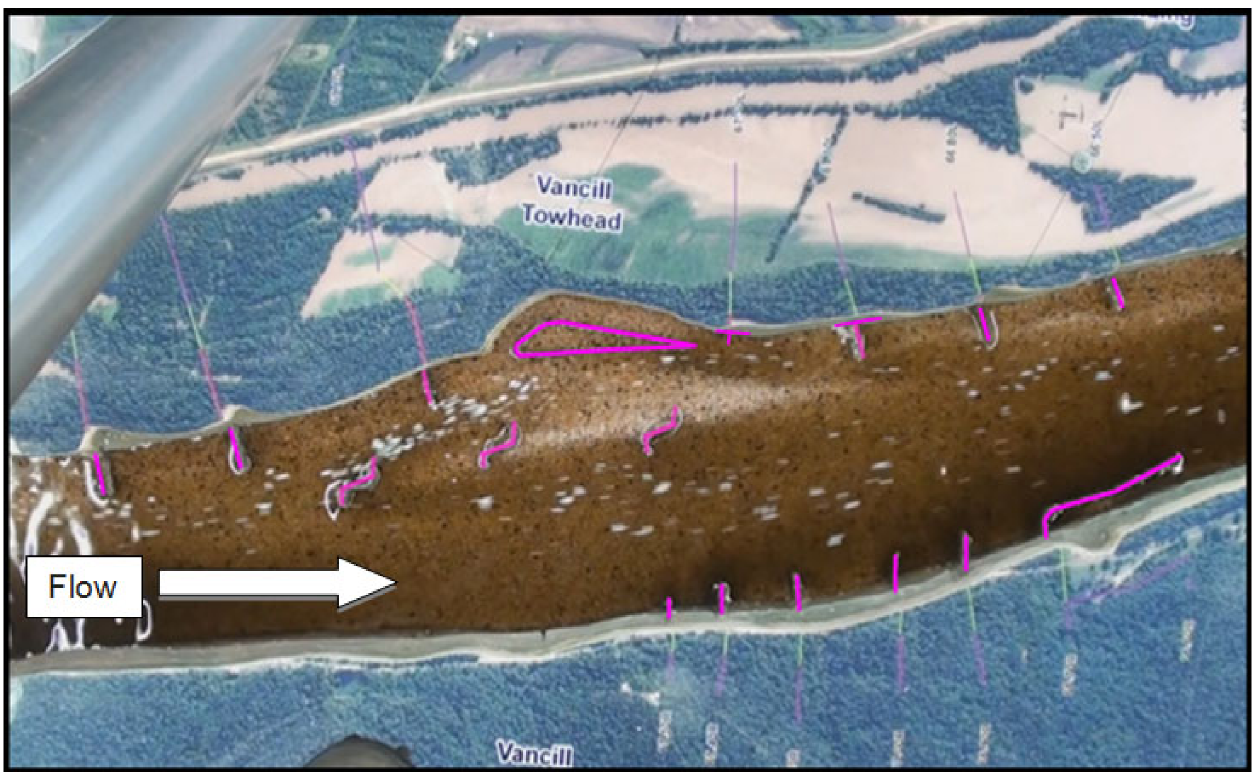


Figure 2: Alternative 33 Flow Visualization

Again, the flow exited a bend at RM 69.00 and maintained a straight path just upstream of Figure 2’s extents. As seen in the snapshot of the post construction conditions, the flow was split sending the majority of the flow through the main channel. A secondary side channel was created between three S-Dike structures. Compared to the existing conditions, there was increased flow and sediment transport along the LDB.

F. S-Dike Structure (Diverter Dike)

Chevrons, dike structures designed as a blunt nosed arch shape, have typically been used to redistribute flow and sediment to maintain the navigation channel. River engineers at the Applied River Engineering Center have found that S-Dike structures not only redistribute flow and sediment, but have the ability to control the energy coming off of the right side or the left side of the structure. S-Dike structures are useful for creating secondary side channels because they angle upstream to capture water from the main channel and direct it towards the area of interest, while providing enough roughness and constriction to maintain a navigable channel. The S-dike showed that it will cause minimal erosion along the bankline because an eddy was formed at the tip. The figure below shows a more detailed drawing of the structure. As flow and sediment hit the structure, depending on the orientation of the dike, a portion of the flow and sediment will be taken from the main source of flow towards a lower energy area on the opposite side of the dike.

Figure 4: S-Dike (LDB) Details

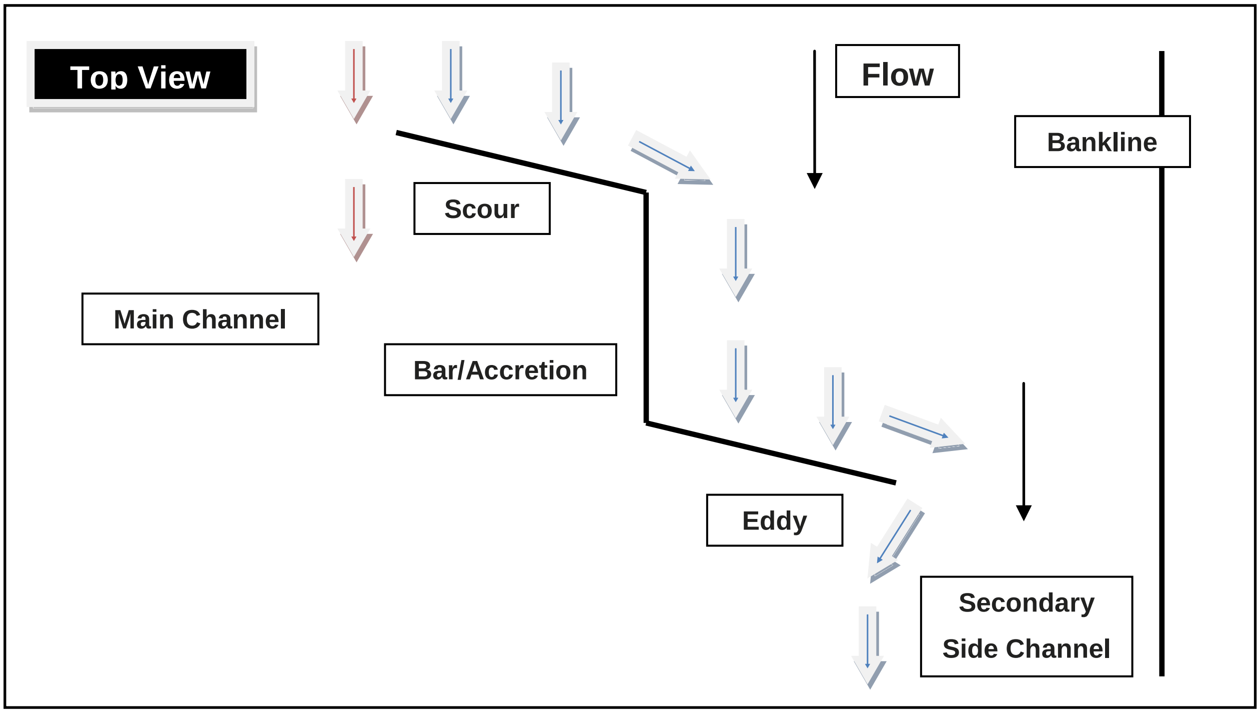


Figure 5: S-Dike (RDB) Details