Technical Report M64

WESTPORT HSR MODEL
Mississippi River Miles 260.00 – 252.00

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a flow and sediment transport study in the Westport Island reach of the Mississippi River between River Miles (RM) 260.00 and 252.00 of the St. Louis District near Hamburg, Illinois and Elsberry, Missouri. This study was funded by the U.S. Army Corps of Engineers, St. Louis District's Upper River Dike and Revetment 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 repetitive channel maintenance dredging from River Mile (RM) 257.00 to RM 253.00.

The study was conducted between October, 2011 and May, 2013 using a physical Hydraulic Sediment Response (HSR) model at the Applied River Engineering Center, U.S. Army Corps of Engineers, St. Louis District in St. Louis, Missouri. The model study was performed by Ashley Cox, Hydraulic Engineer, under direct supervision of Mr. Robert 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.	Hydrologic and Hydraulic Branch Chief	St. Louis District
Rob Davinroy, P.E.	Chief of River Engineering Section	St. Louis District
Jasen Brown, P.E.	Hydraulic Engineer	St. Louis District
Edward Brauer, P.E.	Hydraulic Engineer	St. Louis District
Dave Gordon, P.E.	Chief of Hydraulic Design Section	St. Louis District
Michael Rodgers, P.E.	Project Manager for River Works Projects	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Brian Johnson	Chief of Environmental Compliance Section	St. Louis District
Lance Engle	Dredging Project Manager	St. Louis District
Sarah Markenson	Real Estate	St. Louis District
Dana Fischer	AREC Co-op	St. Louis District
Butch Atwood	Mississippi River Fisheries Biologist	Illinois Dept. of Natural Resources
Matt Mangan	Biologist	U.S. Fish and Wildlife Service
David Ostendorf	Resource Staff Scientist	Missouri Dept. of Conservation
Bernie Heroff	Port Captain	American River Transportation Co./ RIAC
Shannon Hughes	River Field Port Captain	Kirby Inland Marine
Danny Brown	Resource Staff Scientist	Missouri Dept. of Conservation
Dan Shrake	Pilot	ADM
Scott Hussel	Pilot	ADM

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BACKGROUND

1. Study Purpose and Goals

The purpose of this study was to find a solution to reduce or eliminate chronic dredging from RM 257.00 to RM 253.00 and produce a report that communicates the results of the Hydraulic Sediment Response (HSR) model study.

The goals of this 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 257.00 to RM 253.00. Six criteria were used to evaluate each alternative.

   a. The alternative should reduce or eliminate sedimentation at RM 257.00.
   b. The alternative should reduce or eliminate sedimentation at RM 256.00.
   c. The alternative should reduce or eliminate sedimentation at RM 255.00.
   d. The alternative should reduce or eliminate sedimentation at RM 253.50.
   e. The alternative should maintain the navigation channel requirements of at least 9 foot of depth and 300 foot of width.
   f. The alternative should avoid and minimize negative impacts to environmental features within the reach.

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

2. Study Reach

The study comprised an 8 mile stretch of the Mississippi River, between RM 260.00 – 252.00, passing through Lincoln County, Missouri and Calhoun County, Illinois near Hamburg, Illinois. Plate 1 is a location and vicinity map of the study reach.

The Westport Island study reach is located approximately 13 miles downstream of Lock and Dam 24 and 10 miles upstream of Lock and Dam 25. The study reach is in Pool 25 and encompasses Mosier Landing, which is the "hinge point" for the pool. The St. Louis District navigation pools are maintained based upon hinge point limits. As the flows increase and the upper limits of the hinge point is approached, the pool level is lowered to compensate until the flows start decreasing or max drawdown is reached. As the flows decrease and the lower limits of the hinge point is approached, the pool level is raised to compensate until the flows start increasing. The lower limit at the hinge points are defined by the lowest river level allowable for a safe and dependable navigation channel and in coordination with dredging efforts. The upper limit is defined by the highest river level that can be maintained by the dam because the land above this limit isn't owned by the U.S. government, thus not authorized to be inundated by the project. The hinge point limits for Mosier Landing are 434.0 ft to 437.0 ft NGVD 29 (but could be exceeded if at maximum drawdown).

A majority of the property on both sides of the Mississippi river was used for agriculture and wildlife refuges. Hamburg, Illinois is located on the left descending bank (LDB) side of the river near RM 258.50. The Clarence Cannon National Wildlife Refuge and the Prairie Slough State Wildlife Conservation area are located on the Missouri side of the river. The Upper Mississippi River State Wildlife Management Area is located on the Illinois side of the river. The Elsberry Levee system was located on the right descending bank (RDB) side of the river. The bluff line in Illinois was the floodplain boundary on the LDB.

There are also multiple mussel bed locations in this study reach, including Thomas Chute RM 260, Kelly Island RM 257, Westport Chute RM 257, in between

Schwanigan and Eagle Islands RM 253.8, and throughout the main channel. There used to be several commercial mussel beds located in the reach, however some beds may no longer exist. Some dives have been conducted within the past ten years to investigate mussel beds. See Plate 2 for mussel bed locations.

There were a total of 28 river training structures and revetment within the entire study reach and are shown on Plate 3. See Table 2 for the river training structures' history and existing conditions. Revetment was in place on parts of Mosier Island, Westport Island, Kelly Island, Schwanigan Island, the island downstream of Eagle Island, the LDB island near RM 252.50, and Sterling Island, as well as the LDB near RM 261.00, the RDB near RM 258.00, the LDB near RM 255.70, and the LDB near RM 254.00.

Table 2: Study Reach River Structure History

River Training Structure	Length (ft)	Description
Dike 258.90R	1,200	Constructed in 1923. Currently buried.
Dike 258.60R	1,020	Constructed in 1924. Repaired in November 1974. (Stone)
Dike 258.30R	985	Constructed prior to the 1938 (Pre-Lock and Dam 26) aerial photograph. (Stone)
Dike 258.00R	1,500	Constructed prior to the 1942 map. (Logs) Repaired in September 1985.
Dike 257.70R	665	Constructed in September 1985. (Stone) Repaired in June 1988.
Dike 257.60R (Closure)	1,050	Constructed prior to the 1942 map. (Stone)
Dike 257.40L	700	Constructed prior to the 1938 aerial photograph. (Stone) MRSs were constructed on top of the degraded structure in 2005.
MRS 257.40L	80	Constructed in July 2005. (Stone) Two rows, second row on top of existing remnant dike (257.4L), first row 50 ft upstream of second row. In each row, there was 100 ft of spacing between roundpoints.
Dike 257.30R	500	Constructed prior to the 1942 map. (Stone)
Dike 257.20L	1,305	Constructed prior to the 1938 aerial photograph. (Stone) MRSs were constructed on top of the degraded structure in 2005.
MRS 257.20L	80	Constructed in January 2005. (Stone) Two rows, first row on top of existing remnant dike (257.2L),

		second row 50 ft downstream of first row. In each row, there was 100 ft of spacing between roundpoints.
Bullnose 257.10L	375	Seen in 2006 Aerials. (Stone)
MRS 256.70L	80	Constructed in 2009. (Stone) Two rows, first row approximately 100 ft downstream of existing remnant dike (256.7L), second row 50 ft downstream of first row. In each row, there was 100 ft of spacing between roundpoints.
Dike 256.70L	700	Constructed prior to the 1938 aerial photograph. (Stone) Seen in 2006 Aerials.
Dike 256.70L (Closure)	825	Constructed prior to the 1938 aerial photograph. (Stone) Seen in 2006 Aerials.
Dike 256.50L	390	Constructed prior to the 1938 aerial photograph. (Stone) Dike extended in June 1988. Dike was raised in 2008.
Dike 256.30L	500	Constructed prior to the 1942 map. (Stone) Dike raised and extended in June 1988
Dike 255.70L	850	Constructed prior to the 1942 map. (Stone)
MRS 255.70L	80	Constructed in 2008. (Stone) Two rows, first row on top of existing remnant dike (255.7L), second row 50 ft downstream of first row. In each row, there was 100 ft of spacing between roundpoints.
Dike 255.60R	500	Constructed in 1899 (original piles). Repaired in June 1988 (Stone).
Dike 255.30R	675	Constructed in 1899 (original piles). Repaired in June 1988 (Stone).
Dike 255.10R	500	Constructed in 1899 (original piles). Currently buried.
Dike 254.60R (Closure)	1,150	Constructed prior to the 1942 map. (Stone) Currently buried.
Dike 254.50R	920	Constructed prior to the 1942 map. (Stone) Currently buried.
Dike 253.80L	440	Constructed prior to the 1938 aerial photograph. (Stone) Repaired in June 1988.
Dike 253.50L	520	Constructed prior to the 1938 aerial photograph. (Stone) Degraded riverward 400 ft of dike to elevation 422. The stone was placed on dike align and raised to elevation 429 in June 1988.
Dike 253.20R	160	Constructed prior to the 1942 map. (Stone)
Dike 253.10L	1,480	Constructed prior to the 1938 aerial photograph. (Stone)

*Note: A Multiple Roundpoint Structure (MRS) consists of vertical rock piles that are 100 ft apart, in offset rows (typically 2 rows) that are 50 ft apart.

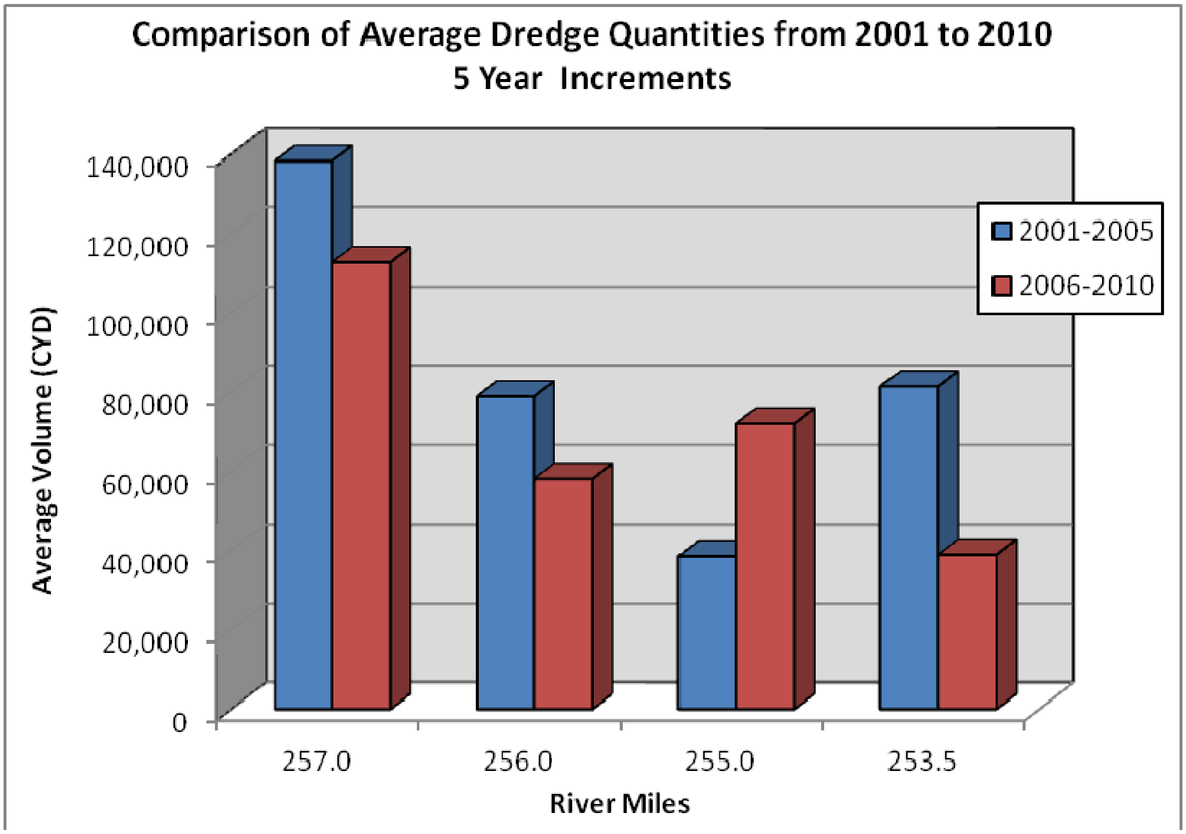
A. Geomorphology

An investigation was conducted on the historical changes, both natural and manmade, that resulted in the present day condition of the Westport Island reach. Plate 4 shows the geomorphic planform changes from RM 261.00 to RM 251.00, between the years from 1938 to 2009. Lock and Dam 25 has been operational since 1939 and Lock and Dam 24 has been operational since 1940. There were no aerial photographs or planform maps prior to 1938; therefore 1938 was used as a starting point for analyzing planform changes. The most recent noteworthy change in the planform occurred between 1942 and 1968-1971, when the RD bankline near RM 259.50 shifted riverward, resulting in a constriction of the channel. Sedimentation behind the dike field on the RDB, extended up to 500 ft towards the LDB. Minor changes have occurred to island shapes and side channels between 1938 and 2009. See Plates 5 – 11 for historic images.

B. Dredging/Problem Description?

Dredging in the Mississippi River is commonly used to provide required navigation dimensions of depth, width, alignment, or a combination thereof. In the Westport Island reach, repetitive channel maintenance dredging is required for all three dimensions. Between 2001 and 2010, dredging has occurred nearly every year at RM 257.00, RM 256.00, RM 255.00, and RM 253.50 (See Plate 11B). During that time frame, at RM 257.00, an average of 125,531 cubic yards (CY) were dredged annually at a cost of $222,692. At RM 256.00 an average of 68,500 CY were dredged annually at a cost of $125,558. At RM 255.00 an average of 55,342 CY were dredged annually at a cost of $142,791. At RM 253.50 an average of 60,161 CY were dredged annually at a cost of $122,097. See Graph 1 for a comparative analysis of the dredge material removed in the Westport Island reach over the past ten years. The total quantity dredged has slightly decreased over the past five years.

Graph 1: Study Reach Dredge Removal Data



C. Channel Characteristics and General Trends

i. Bathymetry

Range line and multibeam hydrographic surveys of the Mississippi River from 1997 to 2011 within the HSR Model extents are shown on Plates 12 – 18. Plates 19 – 23 show pre-dredge conditions from 2007 – 2011. Since pre-dredge surveys from 1993 to 2006 showed similar trends, only the most recent surveys were included in the report. For this study, the reference plane for the bathymetric data was feet below minimum pool for Pool 25 (MP=Minimum Pool).

Recent surveys were used to determine general trends because they showed the most recent construction and the resultant river bed changes. A comparison of the abovementioned hydrographic surveys revealed that the following bathymetric trends remained relatively constant from 1997 - 2011:

Table 3: Study Reach Bathymetry Trends

River Miles	Description
260.00 – 258.00	Main Channel: The thalweg was on the LDB and remained there until confluence scour occurred at the downstream end of Mosier Island at RM 259.00. There was significant scour in the middle of the channel from RM 258.50 – RM 258.00, with depths between -30 and -45 ft MP. Thomas Chute: There was some scour on the RDB near RM 260.00. The thalweg crossed to the LDB, the energy decreased, and deposition occurred at the end of the side channel.
258.0 – 257.0	Main Channel: After the flow scoured at the head of Westport Island, the flow split around the Island and into Westport Chute. Thus deposition occurred from RM 257.50 – RM 257.00. Some flow split around Kelly Island and down the side channel. There was deposition behind the MRS's on the LDB. A small bar formed on the RDB behind Dike 257.30. Westport Chute: Deposition occurred at the entrance to the side channel. There was scour off the western side of the tip of Westport Island. The thalweg stayed on the RDB with depths between -15 to -30 ft MP. It then crossed at RM 257.00. Some flow was split around Kickapoo Island. Kelly Island Side Channel: Lack of diversity with depths between 0 to -10 ft MP. There was a scour hole behind the closure structure at RM 256.70L.
257.0 – 255.5	Main Channel: The thalweg crossed to the RDB near RM 256.30. The crossing was narrow and shallow (-6 to -14 ft MP). There was a scour hole off the tip of Dike 255.60R. There was deposition downstream of the MRS 255.70L. There was a scour hole just downstream of MRS 255.70L from flow exiting the side channel behind Kelly Island. Westport Chute: The thalweg stayed on the LDB with depths between -15 to -30 ft MP. Energy was lost around RM 256.00 to RM 255.50.
255.5 – 254.0	Main Channel: The thalweg crossed to the LDB near RM 254.4. The crossing was narrow and shallow (-6 to -14 ft MP). There was deposition on the RDB near RM 255.30 to RM 254.00 near the islands. Westport Chute: The thalweg stayed near the RDB until RM 254.50. It then crossed to the LDB (or the back west side of Eagle Island). Flow from the side channel running northeast to southwest added to the flow. Schwanigan and Eagle Island Side Channel Complex: Lack of diversity with depths between 0 to -10 ft MP.
254.0 – 251.0	Main Channel: The thalweg crossed to the RDB near RM 253.80. The thalweg stayed on the RDB through RM 251.0. There was some scour

	near RM 252.90 due to some flow exiting the side channel. There was also scour along Sterling Island near RM 251.50. There was deposition along the LDB dikes and small islands. Westport Chute: The thalweg was on the LDB with depths between -15 to -30 ft MP. Some flow exited the side channel just upstream of Sterling Island. The thalweg continued on the LDB and then crossed near RM 252.20 and split around a small island. The thalweg was on the RDB from RM 252.00 to RM 251.00.

ii. Flow Split Data

The Westport reach has deep side channels and many islands. Flow is monitored to determine flow splits in vital areas. The side channels, mainly Westport Chute, remain as deep as the main channel. Since nearly a third of the overall flow in this reach passes through the side channels, the main channel has multiple dredging issues every year. As seen in Tables 4 and 5, there are minor increases in flow through the chutes and decreases in flow through the main channel. At this point in time there is not enough data to determine if varying flow splits are the definitive cause of all the dredging issues. Flow splits should continue to be monitored in similar conditions annually. See Graphic 1 for a generalized schematic of the existing flow mechanics in the study reach.

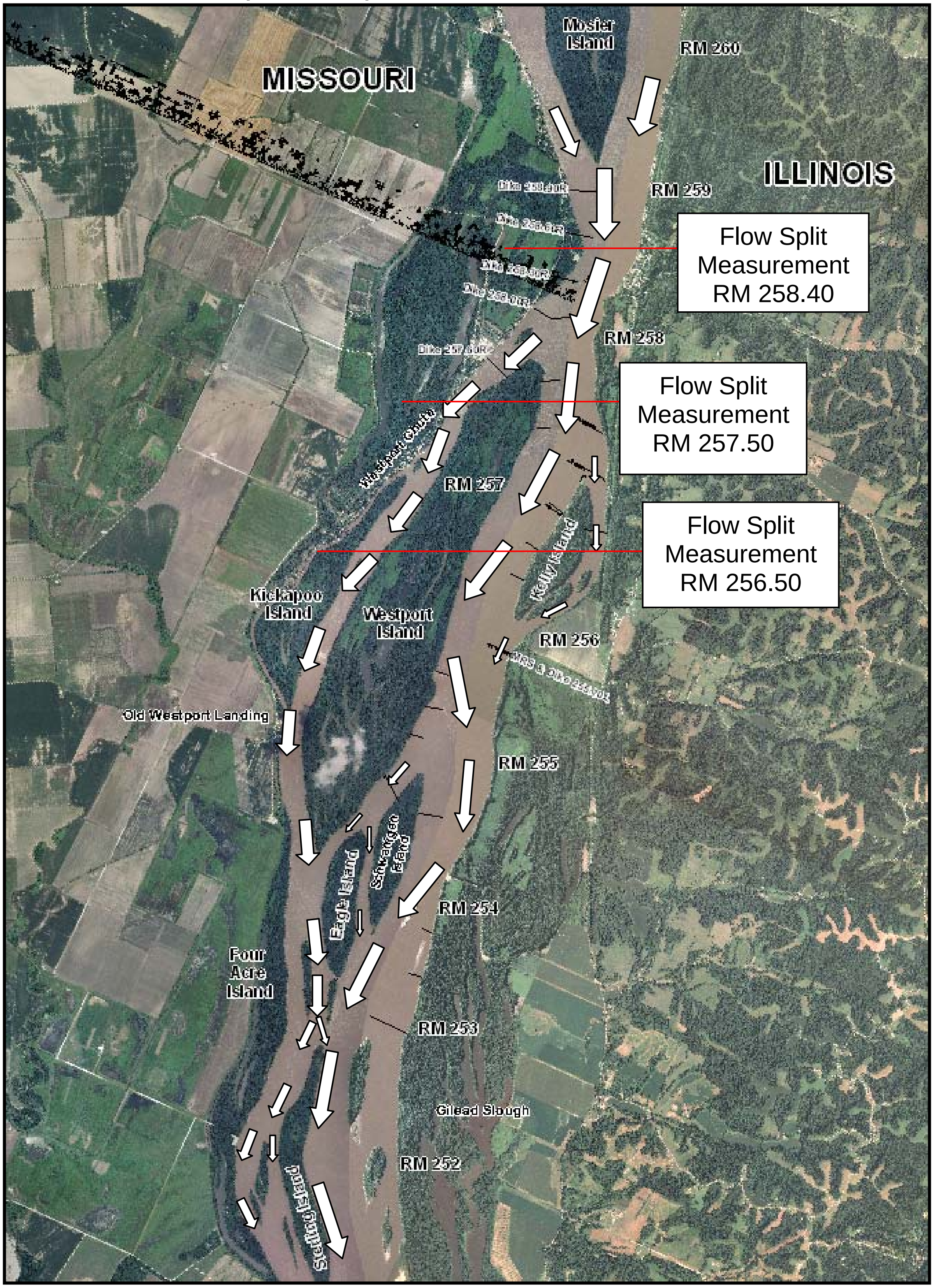
Table 4. Flow Splits for River Mile 257.50

Date	Total Flow at RM 258.4	Main Channel (Measured)	Right Chute (Measured)	Left Chute (Measured)	Main Channel	Right Chute	Left Chute
June 2010	238,459	176,733	61,726		74%	26%	
June 2011	246,482	179,568	66,914		73%	27%	

Table 5. Flow Splits for River Mile 256.5

Date	Total Flow at RM 258.4	Main Channel (Measured)	Right Chute (Measured)	Left Chute (Measured)	Main Channel	Right Chute	Left Chute
June 2010	238,459	141,156	66,914	30,389	59%	26%	13%
June 2011	246,482	146,259	66,914	33,309	59%	27%	14%

Graphic 1: Study Reach with General Flow Trends



*Note: Larger arrows represent more flow, smaller arrows represent less flow.

iii. Site Data

On October 24, 2011, a site visit was conducted at the Westport Island reach to examine bank lines, structures, and an in person view of the study area. At the Mosier gage, the river stage was 34.8 ft (434.8 ft in elevation). Lock and Dam 25 was holding pool. The water covered some degraded structures. The tops of newly constructed and repaired structures could be seen. The following observations were made:

- Dike 258.90R: Structure was not visible.
- Dike 258.60R: Rock structure was visible. There was a large round out just downstream – see Plate 25.
- Dike 258.30R: Structure was not visible.
- Dike 258.00R: Rock structure was visible by the bank, then lowered as it went further into the channel. (Multi-beam was conducted in December of 2011 and showed that part of the structure was degraded near the navigation channel. See Plate 18).
- Dike 257.70R: Structure was not visible. Effects (swirls in water where structure was supposed to be) from underwater structure were barely visible.
- Dike 257.60R: Structure was not visible. Effects from underwater structure were seen.
- MRS 257.40L: Rock structure was visible. The first row (most upstream) had seven MRS's, but the first MRS (riverside) was barely visible. The second row had 6 MRS's.
- Dike 257.40L: Structure was not visible.
- Dike 257.30R: Structure was not visible. Effects from underwater structure were barely visible.
- MRS 257.20L: Rock structure was visible. The first row (most upstream) had one MRS on the river side. The middle row had seven MRS's. The third row (most downstream) had seven MRS's.
- Dike 257.20L: Structure was not visible.
- Bullnose 257.10L: Structure was not visible.

- MRS 256.70L: Rock structure was visible. The first row (most upstream) had one MRS. The second row (most downstream) had seven MRS's, but the first two on the riverside were barely visible.
- Dike 256.70L: Structure was not visible. Effects from underwater structures were barely visible.
- Dike 256.50L: Rock structure was visible. The structure had some kind of notch by Kelly Island.
- Dike 256.30L: Rock structure was visible. The structure had some kind of notch by Kelly Island.
- MRS 255.70L: Rock structure was visible. Both rows had eight MRS's.
- Dike 255.70L: Structure was not visible.
- Dike 255.60R: Structure was not visible. Effects from underwater structures were barely visible.
- Dike 255.30R: Rock structure was visible.
- Dike 255.10R: Structure was not visible.
- Dike 254.60R: Structure was not visible.
- Dike 254.50R: Structure was not visible.
- Dike 253.80L: Rock structure was visible.
- Dike 253.50L: Rock structure was visible.
- Dike 253.10L: Rock structure was visible.

Pictures from the site visit can be seen on Plates 24 – 25.

HSR MODELING

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the general 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 modeled according to the most recent available high resolution aerial photographs. 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 replicated. 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, model tests were run using steady state discharge. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The bed progressed from a static, flat, arbitrary bed into a fully-formed, dynamic, three dimensional mobile bed response. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bathymetry were similar to observed recent river bathymetry, and the tests were repeatable, the model was considered calibrated and alternative testing began.

In calibration, non-erodible bed material of higher specific gravity was used in a localized area on the model riverbed to represent the gravel bars on the LDB from RM 261.00 to RM 258.00 and the rock bluff near RM 258.00. Because the non-erodible was required for calibration, the non-erodible remained in the model throughout the rest of the study (ie during alternative testing).

2. Scales and Bed Materials

The model employed a horizontal scale of 1 inch = 800 feet, or 1:9,600, and a vertical scale of 1 inch = 48 feet, or 1:576, for a 16.6 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 planform insert was constructed according to the 2009 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 routed into dense polystyrene foam and modified during calibration with clay and polymesh. Leveling feet on the legs of the supportive table controlled the slope of the model. The measured slope of the insert and flume was approximately 0.014 inch/inch. River training structures in the model were made of galvanized steel mesh to generate appropriate scaled roughness. A picture of the HSR model can be seen on Plate 26.

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 1.07 Gallons per Minute (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the river, this steady state flow was used to replicate existing general conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. Data Collection

Data from the HSR model was collected with a three dimensional (3D) laser scanner. The operation of this equipment is described below.

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 were also used in color coding prototype surveys. This process allowed a direct comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

6. Replication Test

Once the model adequately replicated general prototype trends, 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, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative test and the replication test by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place.

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 surveys of the model. The resultant bathymetry served as the bathymetry base test for the model and is shown on Plate 27.

Results of the HSR model base test bathymetry and a comparison to the 1997 through 2011 prototype surveys indicated the following trends:

Table 4: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
260.00 – 258.00	Main Channel: The thalweg was on the LDB and remained there until confluence scour occurred at the downstream end of Mosier Island. There was not as much depth in the model compared to the prototype.

	There was significant scour in the middle of the channel near RM 258.30, with depths between -30 and -40 ft MP. Thomas Chute: There was some scour on the RDB near RM 260.00. The thalweg stayed more on the LDB, but was less concentrated as energy decreased, and deposition occurred at the end of the side channel. There was not as much deposition in the model as there was in the prototype.
258.00 – 257.00	Main Channel: After the flow scoured at the head of Westport Island, the flow split around the Island and into Westport Chute. Thus deposition occurred from RM 257.50 – RM 257.00. Some flow split around Kelly Island and down the side channel. There was deposition behind the MRS's on the LDB. A small bar formed on the RDB behind Dike 257.30. Westport Chute: Deposition occurred at the entrance (RDB side) to the side channel. There was scour off the western side of the tip of Westport Island. The thalweg stayed on the RDB with depths between -15 to -30 ft MP. It then crossed around RM 257.00. Some flow was split around Kickapoo Island. Kelly Island Side Channel: Not very diverse with depths between 0 to -10 ft MP.
257.00 – 255.50	Main Channel: The thalweg crossed to the RDB near RM 256.30. The crossing was shallow and narrow (-6 to -10 ft MP). There was a scour hole near Dike 255.60R. There was deposition downstream of the MRS 255.70L. There was a minimal scour off the tip of MRS 255.70L from flow exiting the side channel behind Kelly Island. Westport Chute: The thalweg stayed on the LDB with depths between -15 to -30 ft MP. There was a crossing near RM 255.50.
255.50 – 254.00	Main Channel: The thalweg crossed to the LDB near RM 254.50. The crossing was narrow and shallow (-6 to -15 ft MP). There was deposition on the RDB near RM 255.20 to RM 254.00 near the islands. Westport Chute: The thalweg stayed near the RDB until RM 254.00. It then crossed to the LDB (or the back west side of Eagle Island). Flow from the side channel that runs northeast to southwest added to the flow. Schwanigan and Eagle Island Side Channel Complex: Not very diverse with depths between 0 to -10 ft MP.
254.0 – 251.0	Main Channel: The thalweg crossed to the RDB near RM 253.80. the thalweg stayed on the RDB through RM 251.00. There was some scour near RM 252.90 due to some flow exiting the side channel. There was scour along Sterling Island near RM 251.50, but it was not as deep as the prototype.

	Westport Chute: The thalweg was on the LDB with depths between -15 to -30 ft MP. Some flow exited the side channel just upstream of Sterling Island. The thalweg continued on the LDB and then crossed near RM 252.20 and split around a small island. The thalweg was on the RDB from RM 252.00 to RM 251.00.

7. Design Alternative Tests

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 eliminate or reduce shoaling near RM 257.00, RM 256.00. RM 255.00, and RM 253.50. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry (deposition).

Alternative 1:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	257.70	RDB	NA	437

Results: *Bathymetry (Plate 28) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The raised dike forced more flow into Westport Chute, thus increasing deposition in the main channel at all dredging locations.

Alternative 2:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	257.30	RDB	NA	437

Results: *Bathymetry (Plate 29) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The raised dike only slightly reduced some shoaling near RM 257.00. Downstream no significant bathymetry changes occurred.

Alternative 3:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	258.30	RDB	NA	437

Results: *Bathymetry (Plate 30) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Minimal	No	No	No	The raised dike slightly reduced the deposition at RM 257.00. The crossing slightly deepened at RM 256.00. There was increased scour near Dike 255.60R and the crossing occurred sooner. Downstream no significant bathymetry changes occurred.

Alternative 4:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	258.00	RDB	NA	437

Results: *Bathymetry (Plate 31) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Minimal	Yes	Minimal	No	The raised dike reduced deposition near RM 257.00 and Westport Chute slightly shallowed in some locations (near RM 257.5-257.00). However, there was increased depth (approximately 4 ft) through the channel between Westport and Schwanigan Island. There was increased depth in Westport Chute near RM 252.00. The crossing slightly deepened near RM 256.00 and the deposition was reduced near RM 256.00. There was increased scour near Dike 255.60R and the crossing occurred sooner. There was reduced deposition at RM 255.00. There was no change in shoaling at RM 253.50.

Alternative 5:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	258.30	RDB	NA	437
Raise Existing Dike	257.70	RDB	NA	437
Raise Existing Dike	257.60	RDB	NA	437

Results: *Bathymetry (Plate 32) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	Minimal	Yes	The raised dikes forced flow to the main channel. However, a lot of energy was expended near the dikes which resulted in constant deposition at RM 257.00. As a result of increased flow through Kelly Island Chute, the deposition at RM 256.00 slightly worsened. There was more depth around MRS 255.70L. The sandbar has been reduced near the navigation side of Schwanigan Island, as a result of the crossing widening. Westport Chute has shallowed, and then clogged at the downstream end near RM 254.00. The deposition has been significantly reduced at RM 253.50. There were no significant bathymetry changes downstream.

Alternative 6:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Raise Existing Dike	257.60	RDB	• 420 ft from Mo bank towards notch • 275 ft notch • 355 ft from notch to Westport Island	437 height of existing structure 437

Results: *Bathymetry (Plate 33) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The raised dike did not reduce the flow through Westport Chute and enhance the navigation channel. The deposition slightly worsened in the navigation channel as a result of the side channel having increased flow and depth. Also, there was increased depth (approximately 4 ft) through the channel in between Westport and Schwanigan Island. This deepened Westport Chute from Eagle Island downstream to the exit.

Alternative 7:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,355	Same height as existing closure structure 257.60R

Results: *Bathymetry (Plate 34) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The angled closure structure at the head of Westport Island did not reduce the flow or sediment transport in Westport Chute. There were no significant bathymetric changes.

Alternative 8:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,900	Same as Existing Closure Structure 257.60R

Results: *Bathymetry (Plate 35) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The angled closure structure was raised 6 feet and extended to the RDB. This did not increase the effectiveness of the structure. The structure actually increased the flow through the side channel, thus increasing the amount of deposition in the main channel.

Alternative 9:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,900	5 ft higher than Alternative 8

Results: *Bathymetry (Plate 36) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The raised structures forced more flow towards the LDB, which slightly deepened the navigation channel and slightly reduced flow through Westport Chute. However, there were no significant changes to the bathymetry in the depositional locations.

Alternative 10:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Chevron	257.75	RDB	300 x 300	437

Results: *Bathymetry (Plate 37) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	There was no increased depth in the main channel as a result of the split flow around the chevron. There were no significant bathymetry changes.

Alternative 11:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Large Bullnose with Notch	257.50	RDB	1,950 (200 ft Notch)	437

Results: *Bathymetry (Plate 38) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The bullnose diverted more flow into Westport Chute. As a result, the main channel acquired more deposition.

Alternative 12:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Dike	259.50	RDB	330	437
Construct Dike	259.30	RDB	330	437
Construct Dike	259.10	RDB	430	437

Results: *Bathymetry (Plate 39) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	Minimal	Yes	The flow exited Thomas Chute (RM 258.90R) towards the Missouri bankline, which altered the confluence scour pattern and allowed the sandbar on the main channel side of Mozier Island to extend downstream. There was still deposition at RM 257.00 and RM 256.00. There was an increase in depth near the sandbar at RM 255.0R and RM 253.50. Westport Chute remained fairly constant.

Alternative 13:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	1,355	418
Construct Weir	258.30	LDB	955	418
Construct Weir	258.20	LDB	975	418
Construct Weir	258.10	LDB	950	418
Construct Weir	257.90	LDB	975	

Results: *Bathymetry (Plate 40) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a lot of flow towards the main channel, thus reducing much of the dredging issues throughout the reach. However, Westport Chute completely clogged with sediment.

Alternative 14:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Off Bank	258.80	LDB	1165	418
Revetment (or	258.65	LDB	940	418
Notched Dike)	258.50	LDB	1070	418

*Note: Upstream notch near RM 258.70L is approximately 215 ft wide and downstream notch near RM 258.50L is approximately 230 ft wide.

Results: *Bathymetry (Plate 41) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	A small amount of flow was diverted from Westport Chute and into the main channel, but there was no benefit. Deposition still occurred at all four problem locations.

Alternative 15:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Off Bank	258.80	LDB	1165	437
Revetment or	258.65	LDB	940	437
Notched Dike	258.50	LDB	1070	437
Construct Weir	258.20	LDB	975	418
Construct Weir	258.10	LDB	950	418
Construct Weir	257.90	LDB	975	418

*Note: Upstream notch near RM 258.70L is approximately 215 ft wide and downstream notch near RM 258.50L is approximately 230 ft wide.

Results: *Bathymetry (Plate 42) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The structures diverted a lot of flow to the main channel, thus reducing much of the deposition. However, Westport Chute lost a lot of depth and silted in at the downstream end.

Alternative 16:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Rootless Dike	259.25	RDB	240	437
Construct Dike	259.05	RDB	430	437

*Note: Rootless dike starts 80 ft from the Missouri bankline.

Results: *Bathymetry (Plate 43) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	There were no significant changes in bathymetry.

Alternative 17:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,900	Same height as existing closure structure 256.70R
Construct Weir	258.20	LDB	975	418
Construct Weir	258.10	LDB	950	418
Construct Weir	257.90	LDB	975	418

Results: *Bathymetry (Plate 44) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a majority of the flow towards the main channel, which removed most of the deposition. The average main channel depth was -12 to -14 ft LWRP. However, the side channel gained a lot of deposition.

Alternative 18:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,900	Raised 10 ft higher than Alt. 17
Construct Weir	258.20	LDB	975	418
Construct Weir	258.10	LDB	950	418
Construct Weir	257.90	LDB	975	418

Results: *Bathymetry (Plate 45) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	No	No	The height of the closure structure caused too much constriction near RM 258.00, resulting in a majority of the flow and all of the sediment diverting towards the main channel. The constriction caused the flow to back up upstream of the choke point (RM 258.00), causing sediment to deposit in slack water areas by Hamburg, IL. The small amount of flow that rushed over the new and existing closure structures in the chute had enough energy to continue sediment transport and scour out the bed. The bed in Westport Chute was continually deepened as a result of sediment deprivation.

Alternative 19:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Closure Structure	257.75	RDB	1,900	Raised 7 ft higher than Alt. 17
Construct Weir	258.20	LDB	975	418
Construct Weir	258.10	LDB	950	418
Construct Weir	257.90	LDB	975	418

Results: *Bathymetry (Plate 46) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
No	No	Minimal	Minimal	The raised closure structure in combination with the weirs backed the water and sediment up above the choke point where it settled out in the pocket near Hamburg, IL. The weirs directed more flow towards the main channel, but still left deposition at the first two problem areas and slightly reduced the deposition at the two most downstream problem areas.

Alternative 20:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418

Results: *Bathymetry (Plate 47) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The shortened weirs directed less flow towards the main channel than the longer weirs in Alternative 13. They did guide enough water to the main channel to reduce deposition near RM257.00. The bed was still shallow at the downstream end of the first problem area. The deposition was reduced near RM 256.00, 255.00 and 253.50. Even though less flow was entering Westport Chute causing it to become slightly shallower, there was still enough energy to maintain depths from -6 to -26 ft MP.

Alternative 21:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Construct J Hook	257.00	LDB	420	437
Construct J Hook	256.60	LDB	420	437

Results: *Bathymetry (Plate 48) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The shortened weirs in combination with the J hooks reduced much of the dredging near RM 257.00. However, there was still some deposition near RM 256.60. The overall increased flow in the main channel helped reduce deposition at RM 255.00 and 253.50. A slightly different alignment from RM 255.00 to RM 254.00 would exist. The tows would stay closer to Schwanigan Island (RDB) or the middle of the channel, as opposed to crossing from the RDB over to the LDB, resulting in a straighter alignment. There might be need to remove the dike at RM 254.50R covered by deposition, if it has not degraded to a low enough elevation for navigation to pass over it.

Alternative 22:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Construct Chevron	257.80	RDB	300x300	437
Construct J Hook	257.00	LDB	420	437
Construct J Hook	256.60	LDB	420	437

Results: *Bathymetry (Plate 49) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	No	Yes	The weirs directed some flow to the main channel, but the chevron increased flow to the main channel. The chevron took the slightly reduced flow to Westport Chute and split that flow, sending it back to the main channel. This caused Westport Chute to fill in. As a result, the dredging issues at RM 257.00, 256.00, and 253.50 were greatly improved.

Alternative 23:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Construct J Hook	257.00	LDB	420	437
Construct J Hook	256.80	RDB	420	437
Construct J Hook	256.60	LDB	420	437

Results: *Bathymetry (Plate 50) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The weirs in combination with the J hooks reduced much of the dredging at RM 257.00. However, there was still some deposition near RM 256.60. The overall increased flow in the main channel helped reduce deposition at RM 255.00 and 253.50. A slightly different alignment from RM 255.00 to RM 254.00 would exist. The tows would stay closer to Schwanigan Island (RDB) or the middle of the channel, as opposed to crossing from the RDB over to the LDB, resulting in a straighter alignment. There might be need to remove the dike at RM 254.50R covered by deposition, if it has not degraded to a low enough elevation for navigation to pass over it.

Alternative 24:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Extend Dike*	256.50	LDB	375	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 51) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The shortened weirs in combination with the dike extensions reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at all the dredging locations. This alternative would keep the existing alignment.

Alternative 25:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 52) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at all the dredging locations. This alternative could keep the existing alignment, or adjust to have a straighter alignment near RM 254.50.

Alternative 26:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Remove MRS	255.70	LDB	~845	Existing bed elevation

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 53) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Minimal	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at all the dredging locations. Removing the MRS did not significantly increase flow in the side channel complex behind Eagle Island.

Alternative 27:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Shorten MRS	255.70	LDB	~420	Existing bed elevation

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 54) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at all of the dredging locations. Removing half of the MRS did not significantly increase flow in the side channel complex behind Eagle Island and was less efficient at reducing deposition at RM 256.0.

Alternative 28:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Restore Dike	254.50	RDB	915	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 55) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at all of the dredging locations. The restored dike has enabled more flow to enter the side channel complex and increased the side channel depth from Eagle Island and on downstream. There would still be minor deposition near RM 253.00.

Alternative 29:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Construct Dike	254.70	RDB	770	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 56) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	No	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at most of the dredging locations. The SCED enabled more flow to enter the side channel complex and increased the side channel depth from Eagle Island and on downstream. There would still be deposition near RM 253.50.

Alternative 30:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Construct Dike	254.70	RDB	770	437
Extend Dike	253.50	LDB	435	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 57) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	No	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The shortened weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The overall increased flow in the main channel helped reduce deposition at most of the dredging locations. The SCED enabled more flow to enter the side channel complex and increased the side channel depth from Eagle Island and on downstream. The dike extension at RM 253.50 did not substantially reduce the deposition at RM 253.50.

Alternative 31:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	418
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Construct Dike	254.70	RDB	770	437
Construct Weir	254.20	LDB	455	418
Construct Weir	254.10	LDB	525	418
Construct Weir	254.00	LDB	610	418

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 58) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The SCED enabled more flow to enter the side channel complex and increased the side channel depth from Eagle Island and on downstream, as well as relieved deposition in the main channel. The weirs at RM 254.00 alleviated much of the dredging at RM 253.50.

<u>Alternative 32:</u>

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Construct Dike	254.70	RDB	770	437
Construct Weir	254.20	LDB	455	418
Construct Weir	254.10	LDB	525	418
Construct Weir	254.00	LDB	610	418
Extend Dike	253.50	LDB	435	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 59) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	This alternative had the same bathymetry results as the previous alternative. Dike 253.50 was extended to see if it improved the depths in the channel and near the waiting point, but it was not very effective.

Alternative 33:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Extend Dike*	256.50	LDB	375	437
Construct Dike	254.70	RDB	770	437

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 60) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	No	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The braided channel around Four Acre Island did get shallower, but then it regained some depth behind Sterling Island. The SCED did not capture enough flow to make any significant changes to the bathymetry of the side channel, but it did alleviate some of the deposition in the main channel. The overall increased flow in the main channel helped reduce deposition at all the dredging locations. This alternative would keep the existing alignment.

<u>Alternative 34:</u>

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Extend Dike*	256.50	LDB	375	437
Construct Dike	254.70	RDB	770	437
Remove Dike	255.10	RDB	500	Existing Bed Elevation

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 61) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	No	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. Unlike Alternative 31, the SCED, in combination with removal of Dike 255.10R, still did not capture enough flow to make any significant changes to the bathymetry of the side channel. The overall increased flow in the main channel helped reduce deposition at all the dredging locations. More structures would be needed to further reduce dredging at RM 253.50.

<u>Alternative 35:</u>

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Construct Weir	258.40	LDB	960	418
Construct Weir	258.30	LDB	740	418
Construct Weir	258.20	LDB	740	418
Construct Weir	258.10	LDB	700	418
Construct Weir	257.90	LDB	680	418
Extend Dike*	257.20	LDB	195	437
Extend Dike*	256.70	LDB	185	437
Construct Trail Dike			645	437
Construct Dike	254.70	RDB	730	437
Construct Weir	254.20	LDB	455	418
Construct Weir	254.10	LDB	525	418
Construct Weir	254.00	LDB	610	418

*Note: The extensions will be solid, perpendicular dikes extending from the most riverward MRS.

Results: *Bathymetry (Plate 62) Analysis*

Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Additional Comments
Yes	Yes	Yes	Yes	The weirs directed a small amount of flow to the main channel, while still allowing flow back to Westport Chute, maintaining a relatively deep side channel. The weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The upstream angled dike enabled more flow to enter the side channel complex and increased the side channel depth, as well as relieved deposition in the main channel. However, the dike did not increase depths in the side channel as well as the SCED. The weirs at RM 254.00 alleviated much of the dredging at RM 253.50.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Alternatives	Reduced Deposition at RM 257.00	Reduced Deposition at RM 256.00	Reduced Deposition at RM 255.00	Reduced Deposition at RM 253.50	Positive Overall Impact on Study Reach
Alternative 1	No	No	No	No	No
Alternative 2	No	No	No	No	No
Alternative 3	Minimal	No	No	No	No
Alternative 4	Minimal	Yes	Minimal	No	No
Alternative 5	No	No	Minimal	Yes	No
Alternative 6	No	No	No	No	No
Alternative 7	No	No	No	No	No
Alternative 8	No	No	No	No	No
Alternative 9	No	No	No	No	No
Alternative 10	No	No	No	No	No
Alternative 11	No	No	No	No	No
Alternative 12	No	No	Minimal	Yes	No
Alternative 13	Yes	Yes	Yes	Yes	No
Alternative 14	No	No	No	No	No
Alternative 15	Yes	Yes	Yes	Yes	No
Alternative 16	No	No	No	No	No
Alternative 17	Yes	Yes	Yes	Yes	No
Alternative 18	No	No	No	No	No
Alternative 19	No	No	Minimal	Minimal	No
Alternative 20	Yes	Yes	Yes	Yes	Yes
Alternative 21	Yes	Yes	Yes	Yes	Yes
Alternative 22	Yes	Yes	No	Yes	No
Alternative 23	Yes	Yes	Yes	Yes	Yes
Alternative 24	Yes	Yes	Yes	Yes	Yes
Alternative 25	Yes	Yes	Yes	Yes	Yes
Alternative 26	Yes	Yes	Minimal	Yes	No
Alternative 27	Yes	Yes	Yes	Yes	No
Alternative 28	Yes	Yes	Yes	Yes	Yes
Alternative 29	Yes	Yes	Yes	No	No
Alternative 30	Yes	Yes	Yes	No	No

Alternative 31	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Alternative 32	Yes	Yes	Yes	Yes	No
Alternative 33	Yes	Yes	Yes	No	No
Alternative 34	Yes	Yes	Yes	No	No
Alternative 35	Yes	Yes	Yes	No	Yes

In order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The first and most important consideration was that the alternative had to reduce or eliminate sedimentation at RMs 257.00, 256.00, 255.0, and 253.50. The second condition was that the alternative had to maintain the navigation channel requirements of at least 12 foot of depth and 300 foot of width. The third condition was that the alternative should avoid and minimize negative impacts to environmental features within the reach. Although there were a number of alternatives that showed minimal improvements in reducing deposition at all four problem areas while maintaining the navigation channel requirements, they were not recommended. These alternatives were not recommended primarily because they had negative impacts to the environmental features in the reach, specifically Westport Chute. Some of the alternatives that met the criterion but were not chosen were alternatives 20, 21, 23, 24, 25, 28, 32, 34 and 35.

2. Recommendations

Alternative 31, Plates 58, was recommended as the most desirable alternative because of its observed ability to significantly alleviate the dredging at RM 257.00, 256.00, 255.00, and 253.50. The weirs directed a small amount of flow to the main channel, while still allowing flow to Westport Chute, maintaining a relatively deep side channel. The weirs in combination with the dike extensions and trail dike reduced much of the dredging near RM 257.00. The angled dike at RM 254.7R reduced deposition in the main channel. An additional benefit was that it enabled more flow to enter the side channel complex and increased the side channel depth from Eagle Island and on downstream. The weirs at RM 254.00 alleviated much of the dredging at RM 253.50. Overall, this alternative greatly reduced the deposition throughout the reach while maintaining the environmental features of the reach. No proposed structures will be built on mussel beds, based upon old mussel bed surveys. Also, all of the side channels behind Westport Island complex and Kelly Island show there will be no significant bathymetry changes, leaving substantial depth for environmental habitat as well as boat access for locals. The alignment of the main channel should not change. The proposed cost estimate shows that the structures should pay for themselves within 6 years.

The recommended design included the following:

- Construct Weir at RM 258.40 (L)
  - Construct Weir 960 feet long
  - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 258.30 (L)
  - Construct Weir 740 feet long
  - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 258.20 (L)
  - Construct Weir 740 feet long
  - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 258.10 (L)
  - Construct Weir 700 feet long
  - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 257.90 (L)
  - Construct Weir 680 feet long
  - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Extend Dike at RM 257.20 (L)
  - Extend 195 feet from the most riverward MRS. (Extension will be solid, perpendicular dike.)
  - Top elevation of the Dike extension will be +15 feet (MP) or 436 feet in elevation
- Extend Dike at RM 256.70 (L)
  - Extend 185 feet from the most riverward MRS. (Extension will be solid, perpendicular dike.)
  - Top elevation of the dike extension will be +15 feet (MP) or 436 feet in elevation
- Construct Trail Dike from Dike Extension at RM 256.70 (L)
  - Construct Trail Dike 645 feet long
  - Top elevation of the Trail Dike will be +15 feet (MP) or 436 feet in elevation
- Construct SCED (Side Channel Enhancement Dike) at RM 254.70 (R)
  - Construct SCED 770 feet long

    - Top elevation of the SCED will be +15 feet (MP) or 436 feet in elevation
- Construct Weir at RM 254.20 (L)
    - Construct Weir 455 feet long
    - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 254.10 (L)
    - Construct Weir 525 feet long
    - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation
- Construct Weir at RM 254.00 (L)
    - Construct Weir 610 feet long
    - Top elevation of the Weir will be -15 feet (MP) or 406 feet in elevation

3. Interpretation of Model Test Results

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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APPENDIX

A. Report Plates

1. Location and Vicinity Map
2. Dike Locations and 2009 Aerial Photograph – 1:43,000
3. Mussel Bed Locations – 1:43,000
4. Westport Geomorphology Planform 1938 – 2009 – 1:40,000
5. Pre-L&D 26 (1938) Aerial Photograph – 1:43,000
6. 1942 Map Overlay – 1:43,000
7. 1939 -1956 Hydrographic Survey Overlay – 1:43,000
8. 1968 -1971 Hydrographic Survey Overlay – 1:43,000
9. 1976 -1977 Hydrographic Survey Overlay – 1:43,000
10. 1982 -1983 Hydrographic Survey Overlay – 1:43,000
11. 1986 -1987 Hydrographic Survey Overlay – 1:43,000

11B. Dredging Locations- 1:43,000

12. September 1997 Main Channel Hydrographic Survey – 1:43,000
13. December 1999 Main Channel Hydrographic Survey – 1:43,000
14. August 2004 Main Channel Hydrographic Survey – 1:43,000
15. 2007 Main Channel 2006 Side Channel Hydrographic Surveys – 1:43,000
16. July-August 2011 Main Channel Hydrographic Survey – 1:43,000
17. December 2011 Main & Side Channel Hydrographic Surveys – 1:43,000
18. December 2011 Main Channel Multibeam Hydrographic Survey – 1:6,000
19. 2007 Pre-Dredge Hydrographic Survey – 1:24,000
20. 2008 Pre-Dredge Hydrographic Survey – 1:24,000
21. 2009 Pre-Dredge Hydrographic Survey – 1:24,000
22. 2010 Pre-Dredge Hydrographic Survey – 1:24,000
23. 2011 Pre-Dredge Hydrographic Survey – 1:24,000
24. Westport Field Photographs
25. Westport Field Photographs
26. Westport HSR Model
27. Replication Test: Bathymetry Results – 1:43,000
28. Alternative 1: Bathymetry Results – 1:40,000
29. Alternative 2: Bathymetry Results – 1:40,000
30. Alternative 3: Bathymetry Results – 1:40,000

B. May 29th, 2013 Westport HSR Model Meeting Minutes

C. HSR Model Theory

D. Westport HSR Model Public Meeting Minutes