Technical Report M55

Montgomery Point Lock and Dam HSR MODEL
White River Miles 4.0 – 0.0

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

By
Ashley N. Cox
Jasen L. Brown, P.E.
Robert D. Davinroy, P.E
Ivan H. Nguyen
Jason J. Floyd
Dana Fischer
Jason Mewes

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APPLIED RIVER ENGINEERING CENTER
FOOT OF ARSENAL STREET
ST. LOUIS, MISSOURI 63118

Sponsored by and Prepared for:
U.S ARMY CORPS OF ENGINEERS – LITTLE ROCK DISTRICT

In Cooperation With:
AMERICAN COMMERCIAL LINES
JANTRAN INC.
KIRBY INLAND MARINE
PINE BLUFF SAND & GRAVEL CO.

Final Report – April, 2011

INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a study of the flow and sediment transport response upstream of the Montgomery Point Lock and Dam (MPLD) reach of the White River between River Miles (RM) 4.0 and 0.0 near Watson, Arkansas. This study was funded by the U.S. Army Corps of Engineers, Little Rock District. 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 outdraft at MPLD.

The study was conducted between August, 2010 and April, 2011 using a physical hydraulic sediment response (HSR) model at the Applied River Engineering Center, St. Louis District in St. Louis, Missouri. The model study was performed by Mrs. 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
Jasen Brown, P.E.	Hydraulic Engineer	St. Louis District
Dave Gordon, P.E.	Chief of Hydraulic Design Section	St. Louis District
Ivan Nguyen	Hydraulic Engineer	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Dana Fischer	AREC Co-op	St. Louis District
Jason Mewes	AREC Co-op	St. Louis District
Glen Raible, P.E.	Chief of Hydrologic and Hydraulics Branch	Little Rock District
Henry Himstedt, P.E.	Chief of Hydraulics & Technical Services Branch	Little Rock District
Gil Wootten	Chief of Operations Technical Support Branch	Little Rock District
Brad Shoemaker	Chief of Navigation and Maintenance	Little Rock District
Nick Mitchell	Deputy Operations Project Manager, PBPO	Little Rock District
Kathrene Fletcher	Lock and Dam Equipment Mechanic (Leader)	Little Rock District
Paul Brown	Chief of Contract Support Branch	Little Rock District
Troy Bailey	Lockmaster at Pine Bluff	Little Rock District
Steve Brewer	Hydraulic Engineer	Little Rock District
Ashly Zink	Civil Engineer	Little Rock District
Keith Garrison	Member	Arkansas Waterways Commission
Shannon Hughes	River Field Port Captain	Kirby Inland Marine
John Hoopaugh	Captain/Manager: Transportation Division	Pine Bluff Sand & Gravel Co.
Scott McGeorge	President	Pine Bluff Sand & Gravel Co.
Andrew McKinnie	Pilot	Pine Bluff Sand & Gravel Co.
Don Bratton	Representative	Pine Bluff Sand & Gravel Co.
John Janoush	Vice President	JanTran Inc.
Jamie Willis	Marine Superintendent	American Commercial Lines
Brian Damotte	Pilot	American Commercial Lines

TABLE OF CONTENTS

BACKGROUND

1. Problem Description

The Montgomery Point Lock and Dam (MPLD) was put into service on August 24, 2004. Since the opening of the lock, there have been 5 significant allisions. This is a considerable amount of allisions in only 7 years. See Plate 2 for a general schematic of the MPLD complex.

Tows navigate through the MPLD differently in pool condition and open river. During pool condition, the gates are up and holding pool, with tows passing through the lock chamber. Navigation is less problematic during pool condition than at open river due to lower velocities. There have been no significant allisions or problems when tows lock through at MPLD.

At open river, the gates are down and tows utilize the navigation pass. During open river barge tows pass through the 300 foot wide navigation pass on the north side of the lock's guide wall. However, as the tows travel downstream through the bend between Miles 2.0 – 1.0, they get pushed or pinned into the Right Descending Bank (RDB). As a result, pilots have difficulties realigning their barge tows into the navigation pass. The White River's navigable channel is approximately 350 feet in width at Mile 0.9, narrowing to about 225 feet at the north side of the guide wall near Mile 0.73. During open river, this crossing requires tows to carefully navigate around the lock guide wall and properly align themselves before navigating through the spillway pass in just 0.2 miles. This presents operational concerns for commercial traffic and the structural integrity of the lock. Outdraft is most prevalent during swift water conditions (ie the White River flows are above average and the Mississippi River is falling about 1-2 feet a day). Accidents have occurred when there has been 2.2 feet to 4.6 feet of differential from Lock 1 tailwater (approximately RM 10.1) to the headwater of MPLD and when flows range from 60,000 to 80,000 cubic feet per second (cfs). These accidents include allisions with the abutment pier, the guide wall, and the upstream tower.

2. Study Purpose and Goals

The purpose of this study was to find a solution to reduce or eliminate outdraft at MPLD and produce a report that communicates the results of the HSR analysis of various river engineering measures.

The goals of this study were to:

i. Investigate and provide analysis on the existing flow mechanics causing the outdraft and navigation alignment 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 outdraft just upstream of the lock. In order to determine the best alternative, two criteria were used to evaluate each alternative.

   a. The alternative should reduce or eliminate the outdraft at MPLD.
   b. The alternative should maintain the navigation channel requirements of at least 12 foot of depth and 300 foot of width.

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

3. Study Reach

The study comprised a four mile stretch of the White River, between RM 4.0 – 0.0 in Desha County near Watson, Arkansas. The White River and Mississippi River confluence occurs 0.6 miles downstream of MPLD. Plate 1 is a location and vicinity map of the study reach. Discussed below are a variety of features found within the reach.

The Montgomery Point Lock and Dam and existing river training structures from RM 2.5 - 0.0 were designed from an alternative tested in a large-scale physical model performed by the Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi. Their lock and dam design was put into service on August 24, 2004. As a result of the new lock and dam, the previous navigation channel was shifted from the RDB north towards the center of the river between RM 0.9 – 0.2. The movement of the navigation channel has created significant outdraft when there are moderate to high flows on the White River and the Mississippi River is falling.

The lock and dam structure, located at RM 0.6, consists of a 110 foot wide by 600 foot long miter-gated lock chamber, two 524 foot long floating guide walls, a 300 foot wide bottom lift hinged-crest gated navigable pass concrete spillway, and a 200 foot wide fixed crest concrete overflow spillway as seen on Plate 2. The channel structures consist of a 470 foot kicker dike located on the Left Descending Bank (LDB) at RM 2.6, and four weirs located along the Right Descending Bank (RDB) at RM 0.9, 0.85, 0.78, and 0.74 as well as intermittent channel revetments.

For most of the year, MPLD operates at open river with all of the gates down and tows utilize the navigation pass. The gates are raised, and the lock chamber used, (ie pool condition) when the tailwater of MPLD falls to an elevation of 115 foot National Geodetic Vertical Datum of 1929 (NGVD29). The tailwater elevation is controlled by the Mississippi River. The Montgomery Point upper pool must be operated within the limits of 115 to 119 foot NGVD29. The upper limit of the pool is derived from the elevation of a raised gate at 115 foot NGVD29 and the design maximum allowable head over the top of a raised gate at approximately 4 feet. To operate within pool limits, the Mississippi River elevation controls the position of the gates and the White River flow controls the number of gates raised. For example, when White River flow is approximately 19,000 cfs, all ten gates are raised in order to maintain a pool elevation of 119 foot NGVD29. However, if flow on the White River is approximately 53,000 cfs, only 5 gates are raised to maintain a pool elevation of 119 ft MSL. The lock chamber miter gates can only open when the river elevation is below 127 ft MSL.

The effects of construction are still visible on the LDB between RM 1.0 to 0.2. During construction a cofferdam was built near the RDB, and as a result, the White River was widened on the LDB side to route the river around the cofferdam and allow navigation to pass. No longer useful, the temporary navigation channel was replaced with a large earthen dam constructed from the LDB out towards the spillway as seen on Plate 3. The rest of the temporary channel slowly accreted sediment and has slack water areas upstream and downstream of the earthen dam.

Although the banks are mainly a sandy material, there is only minor bank line erosion for most of the White River Entrance Channel (RM 10.0-0.0), as the planform has been well revetted. The Little Rock District has plans to place additional bank stabilization near RM 4.9 - 4.5L and RM 3.6 - 3.3R. There have been no significant changes to the planform since 1961.

The property on both sides of the White River from RM 4.0 - 0.0 is private forested land. The area is flat with water spilling into the overbank areas near elevation 140 foot NGVD29. There are cypress and willows from elevation 140 to about 145 foot NGVD29. The bottom land hardwoods, mostly cottonwoods, exist from elevation 145 to 155 foot NGVD29. When the water surface reaches an elevation of 150 foot NGVD29, the area is inundated.

A. Study Reach Channel Characteristics and General Trends

i. Bathymetry

Hydrographic surveys of the White River, within the HSR Model extents, are shown on Plates 4 - 16. The plates show range line and multi-beam surveys from 2003 to 2010. Plates 17 – 22 show pre-dredge conditions and post-dredge conditions in October 2010. For this study, the bathymetric data was referenced to the Construction Reference Plane (CRP) elevation of 120 foot (NGVD29).

Recent surveys were used to determine general trends because they showed the most recent construction and the resultant river bed changes. The MPLD complex and other river training structures built in 2004 were the last navigation items constructed, so the surveys following should be relatively consistent. The following bathymetric trends remained relatively constant from 2005 to 2010 after comparison of the above mentioned hydrographic surveys:

Table 2: Study Reach Bathymetry Trends

River Miles	Description
4.0-3.7	The thalweg was located on the RDB with depths between -30 ft and -40 ft CRP.
3.7-3.4	A crossing was observed between RM 3.7 – 3.4.
3.4-2.6	The thalweg was located on the LDB with depths between -25 ft and -40 ft CRP.
2.6-2.2	A crossing was observed between RM 2.6 – 2.2 due to the LDB kicker dike.
2.2-0.74	The thalweg was located on the RDB with depths between -25 ft and -40 ft CRP. A large bar was located near RM 1.3 to 0.7 on the LDB.
0.74-0.6	A crossing was observed after weir 0.74R, underneath the floating guide wall, and stopped just upstream of the navigation pass spillway.
0.6-0.0	Downstream of the spillway, there was a large scour pattern from RM 0.6 - 0.2 with depths between -30 ft and -55 ft CRP. Shoaling occured behind the earthen dam and revetment on the LDB RM 0.5 – 0.3. The thalweg crossed from the middle of the channel to the RDB from RM 0.2 - 0.0.

Note: In October 2010, 70,090 cubic yards were dredged near RM 0.8-0.7 on the LDB side of the channel. This was done to ensure enough depth for tows to use the navigation pass. This was the first time since the construction of MPLD that the area upstream of the lock had been dredged. There was also 24,734 cubic yards dredged on the RDB and 21,142 cubic yards dredged on the LDB downstream of the lock near RM 0.3-0.1.

ii. Velocity

ADCP (Acoustic Doppler Current Profile) surveys of the White River, in the HSR Model extents, are shown on Plates 23 - 26. ADCP defines the velocity magnitude and direction of the water. The plates show ADCP surveys from 2008 to 2010.

A comparison of velocity distribution using several cross sections of the channel was necessary to evaluate and compare flow trends. In order to compare the general velocity trends between the river and model, the velocities in each cross section were normalized. Normalization involved dividing the magnitudes from each transect by the highest magnitude in that particular transect. This created a velocity scale from 0 to 1 for both the collected river ADCP and the model LDV data. The normalized data showed the magnitude distribution between the highest and lowest velocities in each cross section. The direction was unchanged and showed directional issues like eddies and outdraft.

Table 3: Study Reach Velocity Trends

River Miles	Description
4.0-3.7	The higher energy of the river was located near the RDB.
3.7-2.6	The highest velocities crossed to the LDB. Around RM 3.1, the highest velocities deflected off the LDB and stayed toward the middle of the channel.
2.6-2.2	The higher energy of the river was forced to the RDB by the kicker dike at RM 2.3.
2.2-0.74	The highest velocities deflected off the RDB near RM 1.7 and migrated near the LDB at RM 1.5. The higher energy dissipated slightly, but velocities increased again near RM 1.0 on the RDB. After the first weir, the direction of flow was altered and the slightly higher velocities stayed toward the middle of the channel, while the slightly slower velocities stayed near the RDB side and the lock. In the slack water on the LDB from RM 1.0 - 0.74, there was a weak eddy.
0.74-0.6	Slower velocities on the RDB created an eddy between the RDB, floating guide wall, and closed lock gate. Velocities also moved underneath the guide wall. The higher velocities were slightly angled towards the LDB, increased by the flows coming underneath the guide wall. At the navigation pass, high velocities were directed toward the navigation pass pier.
0.6-0.0	After the spillway, the main energy stayed in the middle of the channel from RM 0.6 - 0.0. A small eddy developed in the slack water behind the earthen dam from RM 0.6 - 0.25. At RM 0.1 to 0.0 velocities increased near the RDB.

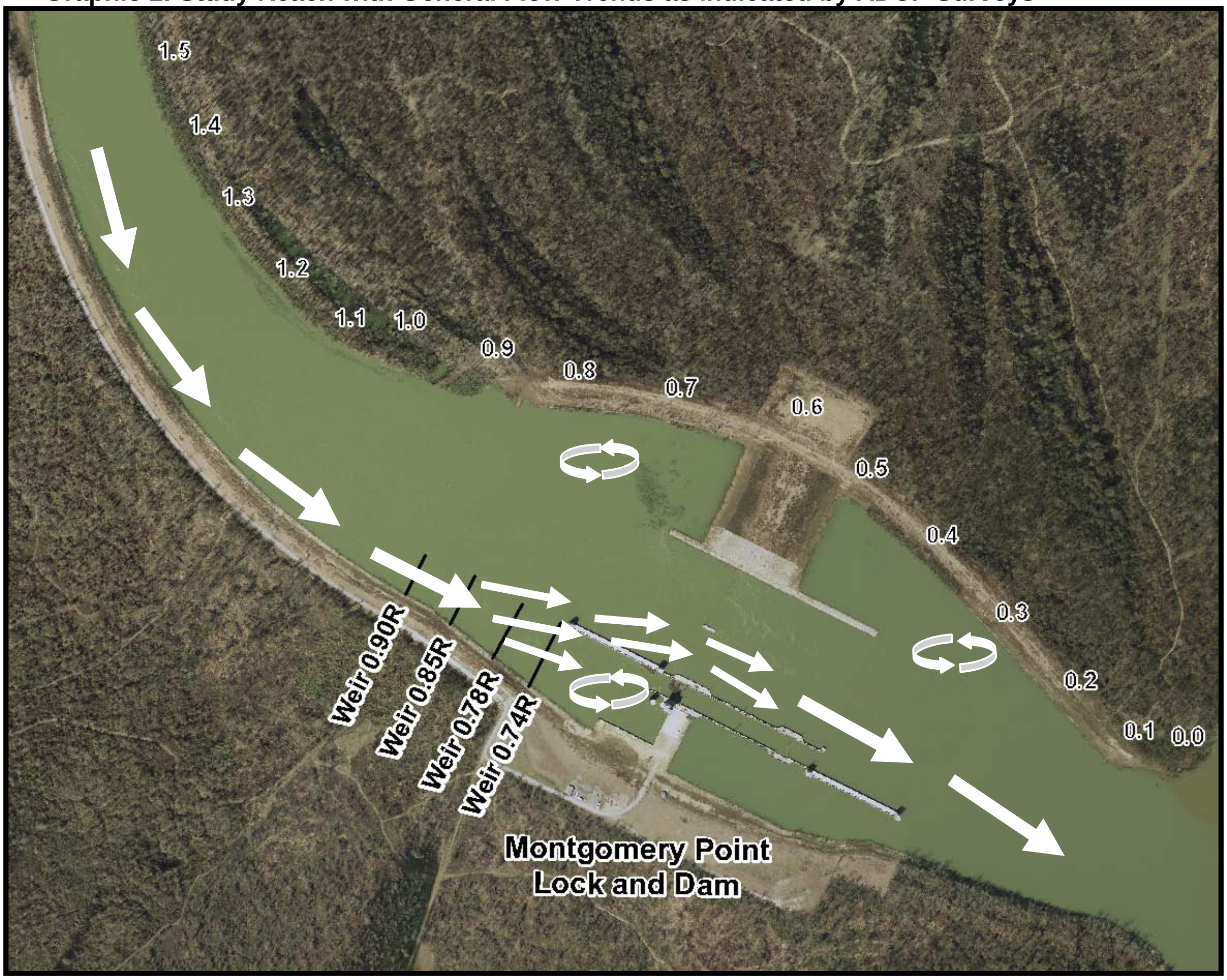
iii. Site Data

Pictures of the study reach were provided by the St. Louis District surveying team, Little Rock District, as well as W. Scott McGeorge the President of Pine Bluff Sand and Gravel Co. in Pine Bluff, AR. The surveying team took pictures on June 4, 2010 when they collected single beam and ADCP data; these pictures were taken from a boat. The Little Rock District provided aerial photos taken on October 5, 2007. Scott McGeorge provided pictures he took from an airplane on January 13, 2010. The pictures can be seen on Plates 27 - 28.

iv. Analysis of Existing Flow Mechanics

After thoroughly investigating the model reach, it was apparent that the flow exiting the bend at RM 1.0 was only slightly influenced by the weirs and split near the floating guide wall. The weirs do not have much of an effect on the flow because they have minimal section (approximately 5 foot) and are at an angle perpendicular to the bank line and the lock and dam. Generally weirs are angled such that the end of the weir in the channel is upstream of the portion of the weir tied into the bankline. The upstream angled weirs disperse high velocities across its section and direct some flow towards the inside of the bend or channel. Because most of the energy was directed towards the LDB, during high water tows are pulled toward the navigation pass pier. As a result of the split flow at the guide wall, an eddy forms near the RDB, guide wall, and miter gate. The flow directed towards the eddy was still strong enough to influence tows in that direction as well. During high water, flows rushing under the guide wall towards the LDB have been strong enough to slightly twist the floating guide wall. Overall, the flow just upstream of the lock has been extremely difficult to predict, and as a result, conditions have been difficult to navigate. See Graphic 1 for a generalized schematic of the existing flow mechanics based upon ADCP surveys.

Graphic 1: Study Reach with General Flow Trends as Indicated by ADCP Surveys



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 established 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. These boundaries were based off of documentation (such as plans and specifications) provided by the Little Rock District.

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.

One important parameter to note was that in calibration, non-erodible bed material of higher specific gravity was used in a localized area on the model riverbed to represent the revetment and armoring located just upstream of the navigation tower near RM 0.6. 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 = 300 feet, or 1:3,600, and a vertical scale of 1 inch = 50 feet, or 1:600, for a 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 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 routed into dense polystyrene foam and modified during calibration with clay and polymesh. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.01 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 29.

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 1.63 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. 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.

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 surveys of the model. The resultant bathymetry served as the bathymetry base test for the model and is shown on Plate 30.

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

Table 4: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
4.0-3.7	The model and the prototype surveys showed the thalweg on the RDB. The model base test survey had slightly more depth than the prototype survey.
3.7-3.4	In both the model and the prototype, the crossing was observed between RM 3.7-3.4. The model crossing was deeper than in the prototype. The bar at the inside of the bend developed near RM 3.5 in the prototype and extended to RM 3.0. In the model, the bar formed near RM 3.5 and only extended to RM 3.2. The bar in the prototype surveys was typically higher in elevation than in the model base test.
3.4-2.6	The model and the prototype surveys both showed the thalweg on the LDB from RM 3.4 to 2.6. In both surveys, the flow deflected off the LDB kicker dike and crossed to the RDB bank near RM 2.4.

2.6-2.2	In both the model and the prototype, a crossing was observed between RM 2.6 – 2.2 due to the LDB kicker dike and the thalweg remained along the RDB from RM 2.4 to 0.6.
2.2-0.74	The thalweg was located on the RDB in the model and prototype. A bar formed on the inside of the bend behind the kicker dike near RM 2.3 and extended to RM 0.7 in both the model and the prototype.
0.74-0.6	In the model and prototype surveys the crossing from the RDB towards the LDB occurred after weir 0.74R. This crossing continued underneath the floating guide wall and stopped just upstream of the navigation pass.
0.6-0.0	Downstream of the structure, a large scour pattern occurred in both the model and the prototype. The scour extended to RM 0.3 in both the model and the prototype, but the scour pattern in the model was slightly larger and deeper than in the prototype. Downstream of the scour, the thalweg moved from the center of the channel toward the RDB until RM 0.1 in both the model and the prototype surveys.

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 31.

The profile for the LDV was determined based upon the previously collected prototype transects, but limited to a ten inch by ten inch grid. (This was due to the traverse extents of the LDV). The LDV could have been moved for additional data collection, however this was not pursued for every alternative due to time and budget restrictions. Another LDV profile was introduced upstream from RM 1.8 - 1.2 to evaluate the alignment in the bend near the end of the study. This upstream data collection was only used for the three alternatives that most successfully met the study goals. Results of the HSR model replication test were compared to the 2008, 2009, and 2010 prototype ADCP surveys and indicated the following trends:

Table 5: Model and Prototype Velocity Trend Comparison

River Miles	Description
1.8-0.74	From RM 1.8 to 0.9, the model and the prototype both showed higher velocities existed near the RDB. The higher velocities were more concentrated in the model than in the prototype. Near the large sand bar on the LDB, approximately RM 1.0 – 0.74 a weak eddy developed in the model and prototype. In both the model and the prototype, after the first weir (RM 0.91R) the higher velocities were less concentrated by the RDB. The higher velocities spread toward the center of the channel. At the head of the floating guide wall in the model and prototype, the velocities split, with a majority of the higher velocities observed on the north side of the guide wall.
0.74-0.6	In both the model and the prototype the slower velocities stayed near the RDB side and the lock, where a weak eddy formed. It was more evident in the prototype that water was traveling underneath the guide wall. In the model and the prototype just upstream of the navigation pass, it was clear that the velocities were slightly directed towards the LDB and the abutment pier. This outdraft is the main focus of the HSR model study.
0.6-0.45	Downstream of the spillway in both the model and the prototype, the main energy remained in the middle of the channel from RM 0.6 to 0.45.

In addition to monitoring the bed changes with the 3-D Laser Scanner for each alternative, the LDV was used to monitor the outdraft.

3. 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 alter the model velocity distribution in a manner intended to reduce outdraft in front of the lock. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry and model replication test velocity (LDV) data. The effects on outdraft were analyzed by looking at the magnitude and direction of the velocity upstream and just downstream of the lock in the alternative test compared to the magnitude and direction of velocity upstream and just downstream of the lock in the replication test.

Alternative 1:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.15	RDB	460	98
Weir	1.10	RDB	425	98
Weir	1.05	RDB	350	98
Weir	1.00	RDB	265	98
Weir	0.95	RDB	280	98

Results: *Bathymetry (Plate 32) and Velocity (Plate 33) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
No	Yes	There was no significant change in bathymetry and velocity.

Alternative 2:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Dike	1.60	LDB	100	130
Dike	1.55	LDB	100	130
Dike	1.50	LDB	120	130
Dike	1.45	LDB	165	130
Dike	1.40	LDB	205	130
Dike	1.35	LDB	260	130

Results: *Bathymetry (Plate 34) and Velocity (Plate 35) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	There was very little change in bathymetry. The dike field straightened the direction of flow between RM 1.0 - 0.74L, which replaced the weak eddy. Outdraft was slightly weakened just upstream of the navigation pass and abutment pier.

Alternative 3:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.20	RDB	265	98
Weir	1.15	RDB	275	98
Weir	1.10	RDB	250	98
Weir	1.05	RDB	220	98
Weir	1.00	RDB	220	98
Weir	0.95	RDB	235	98

Results: *Bathymetry (Plate 36) and Velocity (Plate 37) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.2 - 0.95, was gradually reduced in width from 0 ft to nearly 50 ft. The magnitude of the outdraft was only slightly reduced.

Alternative 4:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98
Weir (new)	0.90	RDB	240	98
Remove existing				~90
Weir (new)	0.85	RDB	265	98
Remove existing				~90

Results: *Bathymetry (Plate 38) and Velocity (Plate 39) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
No	No	The LDB bar, between RM 1.2 - 1.0, was gradually reduced in width from 0 ft to nearly 50 ft. There was no significant change in velocity.

Alternative 5:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Dike	1.60	LDB	150	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Dike	1.35	LDB	310	130

Results: *Bathymetry (Plate 40) and Velocity (Plate 41) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.2 - 0.75, was gradually reduced in width from 0 ft to nearly 50 ft. The dikes minimized the eddy on the LDB and increased the magnitude of flow along the northwest side of the thalweg from RM 1.1 - 0.65.

Alternative 6:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Dike	1.60		130	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Dike	1.35	LDB	310	130
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98
Weir (new)	0.90	RDB	240	98
Remove Existing				~90
Weir (new)	0.85	RDB	265	98
Remove Existing				~90

Results: *Bathymetry (Plate 42) and Velocity (Plate 43) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.1 - 0.8, was gradually reduced in width from 0 ft to nearly 50 ft. The dikes dispersed the energy across the channel from RM 1.2-0.75. As a result, the eddy was minimized and the magnitude of flow was increased along the northwest side of the thalweg from RM 1.1 - 0.65. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 7:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Dike	0.70	RDB	170	130

*Note: Approximately 190 feet from river side tip of dike to southern edge of floating guide wall.

Results: *Bathymetry (Plate 44) and Velocity (Plate 45) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
No	No	There was increased scour upstream and downstream of the proposed dike. There was no change in velocity near the navigation pass. Velocity was decreased on the south side of the floating guide wall, but the eddy was stronger.

Alternative 8:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.40	RDB	330	98
Weir	1.35	RDB	315	98
Weir	1.30	RDB	295	98
Weir	1.25	RDB	275	98
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98

Results: *Bathymetry (Plate 46) and Velocity (Plate 47) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	There was no significant change in bathymetry. As a result of the weirs, the magnitude of flow was increased along the northwest side of the thalweg from RM 1.1 - 0.65. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 9:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Dike	1.60	LDB	150	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Weir	1.40	RDB	330	98
Dike	1.35	LDB	310	130
Weir	1.35	RDB	315	98
Weir	1.30	RDB	295	98
Weir	1.25	RDB	275	98
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98

Results: *Bathymetry (Plate 48) and Velocity (Plate 49) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.1 - 0.8, was gradually reduced in width from 0 ft to nearly 50 ft. The dikes dispersed the energy across the channel from RM 1.2 - 0.75. As a result, the eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 10:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.70	RDB	290	98
Weir	1.65	RDB	335	98
Weir	1.55	RDB	365	98
Weir	1.50	RDB	385	98
Weir	1.45	RDB	395	98
Weir	1.40	RDB	330	98
Weir	1.35	RDB	315	98
Weir	1.30	RDB	295	98
Weir	1.25	RDB	275	98
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98

Results: *Bathymetry (Plate 50) and Velocity (Plate 51) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
No	Yes	There was no significant change in bathymetry and velocity.

Alternative 11:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Weir	1.25	RDB	505	102
Weir	1.20	RDB	490	102
Weir	1.15	RDB	470	102
Weir	1.10	RDB	515	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 52) and Velocity (Plate 53) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant change in bathymetry. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 12:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.74	RDB	*	102
Remove Existing Weir	0.74	RDB	490	~90

*The armoring would range from approximately 100 ft wide to 350 ft wide at certain locations and would be nearly 3,000 ft long.

Results: *Bathymetry (Plate 54) and Velocity (Plate 55) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.7 - 0.7, was gradually reduced in width from 0 ft to nearly 90 ft. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 13:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.64	RDB	*	102

*The armoring would range from approximately 100 ft wide to 350 ft wide at certain locations and would be nearly 3,400 ft long.

Results: *Bathymetry (Plate 56) and Velocity (Plate 57) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	The LDB bar, between RM 1.75 - 0.7, was reduced in width anywhere from 0 ft to nearly 150 ft. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 14:

Little Rock District may want to further widen the resulting navigation channel from Alternative 13. Alternative 14 could be phase 2 of Alternative 13. After the bed has reacted to Alternative 13 and created more scour on the inside of the point bar, the next step would be to widen the armoring approximately 75-100 ft towards the LDB.

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.64	RDB	*	102

*The armoring would range from approximately 175 ft wide to 450 ft wide at certain locations and would be nearly 3,400 ft long.

Results: *Bathymetry (Plate 58) and Velocity (Plate 59) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	The LDB bar, between RM 1.75 - 0.7, was reduced in width anywhere from 0 ft to nearly 150 ft. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft. There were no significant improvements from Alternative 13.

Alternative 15:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.30-0.64	RDB	*	102

*The armoring would range from approximately 85 ft wide to 400 ft wide at certain locations and would be nearly 3,800 ft long.

Results: *Bathymetry (Plate 60) and Velocity (Plate 61) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.75 - 0.7, was reduced in width anywhere from 0 ft to nearly 100 ft. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft. There was not a significant improvement to bathymetry or outdraft compared to Alternative 13.

Alternative 16:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.64	RDB	*	98

*The armoring would range from approximately 100 ft wide to 350 ft wide at certain locations and would be nearly 3,400 ft long.

Results: *Bathymetry (Plate 62) and Velocity (Plate 63) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The LDB bar, between RM 1.75 - 0.75, was reduced in width anywhere from 0 ft to nearly 130 ft. The eddy was minimized and the magnitude of flow was increased on the northwest side of the thalweg. However, because of the reduced height of the armoring (98 ft vs. 102 ft) it was not as effective in reducing the width of the sand bar or minimizing outdraft as Alternative 13. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. This would make a shorter crossing and tows would have a longer time and distance to adjust to the existing outdraft.

Alternative 17:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Part of Existing Dikes & Revetment	2.4 -2.3	LDB	800 ft Remaining of Revetment *	130

*****Total: Remove 1,219 ft of dike and revetments

Results: *Bathymetry (Plate 64) and Velocity (Plate 65) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
No	Yes	The scour off the revetment at RM 2.6L occurred further upstream as a result of the shortened revetment. Therefore, the crossing occurred further upstream as well, reducing the width of the depositional bar that forms at RM 2.25 – 1.85 LDB anywhere from 0 ft to 100 ft. There was increased scour in the bend near RM 1.6 RDB. There were no significant changes to the LDB depositional bar from RM 1.2 – 0.7 LDB or to the velocity.

Alternative 18:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Part of Existing Dikes & Revetment	2.4 -2.3	LDB	800 ft Remaining of Revetment *	130
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.64	RDB	*	98

*****Total: Remove 1,219 ft of dike and revetments

*The armoring would range from approximately 100 ft wide to 350 ft wide at certain locations and would be nearly 3,400 ft long.

Results: *Bathymetry (Plate 66) and Velocity (Plate 67) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The scour off the revetment at RM 2.6L occurred further upstream as a result of the shortened revetment. Therefore, the crossing occurred further upstream as well, reducing the width of the depositional bar that forms at RM 2.25 – 2.0 LDB anywhere from 0 ft to 100 ft. The LDB bar, between RM 1.75 - 0.75, was reduced in width anywhere from 0 ft to nearly 130 ft. The velocity readings showed that there would be higher flows directed towards the RDB from RM 1.1 - 0.85. Flow was still dispersed towards the center of the channel. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. The outdraft appeared to be reduced right at the floating guide wall, creating a more straight approach to the navigation pass.

Alternative 19:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Part of Existing Dikes & Revetment	2.4 -2.3	LDB	800 ft Remaining of Revetment *	130
Dike	1.60	LDB	150	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Weir	1.40	RDB	330	98
Dike	1.35	LDB	310	130
Weir	1.35	RDB	315	98
Weir	1.30	RDB	295	98
Weir	1.25	RDB	275	98
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98

***Total**: Remove 1,219 ft of dike and revetments

Results: *Bathymetry (Plate 68) and Velocity (Plate 69) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	The scour off the revetment at RM 2.6L occurred further upstream as a result of the shortened revetment. Therefore, the crossing occurred further upstream as well, reducing the width of the depositional bar that forms at RM 2.25 – 2.0 LDB anywhere from 0 ft to 100 ft. The LDB bar, between RM 1.1 - 0.8, was gradually reduced in width from 0 ft to nearly 90 ft. The velocity readings showed that there would be higher flows directed towards the RDB from RM 1.1 - 0.85. Flow was still dispersed towards the center of the channel, but not as high of magnitudes as Alternative 18. This showed promise, because tows could drift toward the middle of the channel and not hug the RDB. The outdraft appeared to be reduced right at the floating guide wall, creating a more straight approach to the navigation pass.

Alternative 20:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Part of Existing Dikes & Revetment	2.4 -2.3	LDB	800 ft Remaining of Revetment *	130
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Weir	1.25	RDB	505	102
Weir	1.20	RDB	490	102
Weir	1.15	RDB	470	102
Weir	1.10	RDB	515	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

*****Total: Remove 1,219 ft of dike and revetments

Results: *Bathymetry (Plate 70) and Velocity (Plate 71) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	The scour off the revetment at RM 2.6L occurred further upstream as a result of the shortened revetment. Therefore, the crossing occurred further upstream as well, reducing the width of the depositional bar that forms at RM 2.25 – 2.0 LDB anywhere from 0 ft to 100 ft. The LDB bar from RM 1.7 - 1.55 was reduced in width from 0 ft to 150 ft. The LDB bar, between RM 1.2 - 0.8, was gradually reduced in width from 0 ft to nearly 150 ft. The velocity readings showed that there would be higher flows directed towards the RDB from RM 1.1 - 0.9, but not as significant as Alt 19. Flow was still dispersed towards the center of the channel. The outdraft appeared to be reduced from RM 0.8 - 0.6, creating a more straight approach to the navigation pass.

Alternative 21:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95

Results: *Bathymetry (Plate 72) and Velocity (Plate 73) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Minimal	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8 – reducing the width of the navigation channel to approximately 310 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.9 anywhere from 0 ft to 100 ft. There was increased scour in the bend near RM 1.6 RDB. The velocity readings showed that there would be higher flows directed towards the RDB from RM 1.1 - 0.85; much worse than Alternative 16. Flow was still dispersed towards the center of the channel. The outdraft appeared to be reduced from RM 0.7 - 0.6, creating a more straight approach to the navigation pass.

Alternative 22:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Armor Bed	1.25-0.64	RDB	*	98

*The armoring would range from approximately 100 ft wide to 350 ft wide at certain locations and would be nearly 3,400 ft long.

Results: *Bathymetry (Plate 74) and Velocity (Plate 75) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8 – reducing the width of the navigation channel to approximately 310 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 150 ft. The scour slightly increased in the bend near RM 1.75 RDB, but was dispersed by the weirs downstream. The velocity readings showed that there would be higher flows directed towards the RDB from RM 1.1 - 0.85. Flow was still dispersed towards the center of the channel. The outdraft appeared to be reduced from RM 0.7-0.6, creating a more straight approach to the navigation pass. The flow that pushes the tows toward the outside of the bend from RM 1.2 - 0.85 was worse than Alternative 16, but the outdraft from RM 0.7 - 0.6 had a more straight alignment.

Alternative 23:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Dike	1.60	LDB	150	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Weir	1.40	RDB	330	98
Dike	1.35	LDB	310	130
Weir	1.35	RDB	315	98
Weir	1.30	RDB	295	98
Weir	1.25	RDB	275	98
Weir	1.20	RDB	275	98
Weir	1.15	RDB	305	98
Weir	1.10	RDB	290	98
Weir	1.05	RDB	250	98
Weir	1.00	RDB	250	98
Weir	0.95	RDB	240	98

Results: *Bathymetry (Plate 76) and Velocity (Plate 77) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8 – reducing the width of the navigation channel to approximately 310 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 130 ft. The scour slightly increased in the bend near RM 1.65 RDB, but was dispersed by the weirs downstream. Flow was dispersed towards the center of the channel. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass.

Alternative 24:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Weir	1.25	RDB	505	102
Weir	1.20	RDB	490	102
Weir	1.15	RDB	470	102
Weir	1.10	RDB	515	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 78) and Velocity (Plate 79) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8 – reducing the width of the navigation channel to approximately 310 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 150 ft. The scour slightly increased in the bend near RM 1.7 RDB, but was dispersed by the weirs downstream. Flow was dispersed towards the center of the channel. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass. This alternative appeared to reduce the outdraft slightly better than Alternative 23.

Alternative 25:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.95	RDB	220	102
Weir	1.80	RDB	445	102
Weir	1.75	RDB	490	102
Weir	1.65	RDB	480	102
Weir	1.55	RDB	470	102
Weir	1.45	RDB	480	102
Weir	1.35	RDB	460	102
Weir	1.30	RDB	480	102
Weir	1.25	RDB	505	102
Weir	1.20	RDB	490	102
Weir	1.15	RDB	470	102
Weir	1.10	RDB	515	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 80) and Velocity (Plate 81) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width at RM 1.8. The point bar was reduced as a result of the two upstream weirs and the navigation channel width measured approximately 410 ft. Scour on the RDB started further downstream at RM 2.0 and was dispersed by the weirs. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 190 ft. The scour slightly increased in the bend near RM 1.7 RDB, but was dispersed by the weirs downstream. The overall bathymetry results were better than Alt. 27 because of the increase in navigation channel widths upstream of the lock. An additional LDV profile was run further upstream to monitor the flows from RM 1.8 - 1.2. The velocity distribution over the cross section increased greatly compared to the replication test. This was especially visible from RM 1.58 - 1.25. Flow was again dispersed towards the center of the channel around RM 1.1 downstream. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass. This alternative appeared to reduce the outdraft slightly better than Alternative 23.

*****Upstream LDV profile was performed based upon bathymetry and downstream LDV profile's results.

*Please see bathymetry, channel widths, and velocity comparisons versus the Replication Test on Plates 88 and 89.

Alternative 26:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.75	RDB	490	102
Weir	1.55	RDB	470	102
Weir	1.35	RDB	460	102
Weir	1.25	RDB	505	102
Weir	1.15	RDB	470	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 82) and Velocity (Plate 83) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8 – reducing the width of the navigation channel to approximately 310 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 150 ft. The scour slightly increased in the bend near RM 1.7 RDB, but was dispersed by the weirs downstream. The reduction in number of weirs did not have a significant effect – the bathymetry and velocity results were very similar to Alternative 24. Flow was dispersed towards the center of the channel. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass. This alternative appeared to reduce the outdraft slightly better than Alternative 23.

Alternative 27:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.95	RDB	220	102
Weir	1.80	RDB	445	102
Weir	1.75	RDB	490	102
Weir	1.55	RDB	470	102
Weir	1.35	RDB	460	102
Weir	1.25	RDB	505	102
Weir	1.15	RDB	470	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85	RDB	535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 84) and Velocity (Plate 85) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width to a sharp point at RM 1.8. The point bar was reduced as a result of the two upstream weirs and the navigation channel width measured approximately 410 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 140 ft. The scour slightly increased in the bend near RM 1.7 RDB, but was dispersed by the weirs downstream. The bathymetry improved from the replication test, but was not as good as Alt. 25 (increased width in navigation channel). The reduction in number of weirs did not negatively effect the velocity; the results were very similar to Alt. 24. An additional LDV profile was run further upstream to monitor the flows from RM 1.8 - 1.2. The velocity distribution over the cross section increased greatly compared to the replication test. This was especially visible from RM 1.5 - 1.25. Flow was again dispersed towards the center of the channel around RM 1.1 downstream. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass. This alternative appeared to reduce the outdraft slightly better than Alternative 23.

*****Upstream LDV profile was performed based upon bathymetry and downstream LDV profile's results.

Alternative 28:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in NGVD29)
Remove Existing Dikes & Revetment	2.6 -2.3	LDB	Total: Remove 2019 ft	~95
Weir	1.95	RDB	220	102
Weir	1.80	RDB	445	102
Weir	1.75	RDB	490	102
Dike	1.60	LDB	150	130
Dike	1.55	LDB	150	130
Dike	1.50	LDB	170	130
Dike	1.45	LDB	235	130
Dike	1.40	LDB	255	130
Dike	1.35	LDB	310	130
Weir	1.25	RDB	505	102
Weir	1.15	RDB	470	102
Weir	1.00	RDB	495	102
Remove Existing Weir	0.90	RDB		~90
Weir (new)	0.85		535	102
Remove Existing				~90
Remove Existing Weir	0.78	RDB		~90
Weir (new)	0.74	RDB	735	102
Remove Existing				~90

Results: *Bathymetry (Plate 86) and Velocity (Plate 87) Analysis*

Reduced Outdraft	Positive Impact or No Change in Bathymetry	Additional Comments
Yes	Yes	There was no significant scour in the crossing at RM 2.4 - 2.0. As a result of no dike/revetment at 2.6L, the depositional bar began at RM 2.2 and gradually increased in width around RM 1.8. The point bar was reduced as a result of the two upstream weirs and the navigation channel width measured approximately 410 ft. Scour on the RDB started further downstream at RM 2.0. The width of the LDB depositional bar gradually decreased at RM 1.7 – 0.7 anywhere from 0 ft to 145 ft. The scour slightly increased in the bend, but was dispersed by the weirs downstream. The bathymetry improved from the replication test, but was not as good as Alt. 25 (increased width in navigation channel). An additional LDV profile was run further upstream to monitor the flows from RM 1.8 - 1.2. The velocity distribution over the cross section increased greatly compared to the replication test. It was not as effective as Alternative 27, as a result of the dikes restricting the cross section. Flow was again dispersed towards the center of the channel around RM 1.1 downstream. At RM 0.85R, the flows are relatively straight and seem to promote a more safe approach to the navigation pass. This alternative did not increase the velocity distribution across the channel as well as Alternative 25 or 27.

*****Upstream LDV profile was performed based upon bathymetry and downstream LDV profile's results.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Alternatives	Reduced Outdraft	Positive Impact or No Change in Bathymetry	Positive Overall Impact on Study Reach
Alternative 1	No	Yes	No
Alternative 2	Minimal	Yes	Yes
Alternative 3	Minimal	Yes	Yes
Alternative 4	No	No	No
Alternative 5	Minimal	Yes	No
Alternative 6	Minimal	Yes	Yes
Alternative 7	No	No	No
Alternative 8	Minimal	Yes	Yes
Alternative 9	Minimal	Yes	Yes
Alternative 10	No	Yes	No
Alternative 11	Yes	Yes	Yes
Alternative 12	Minimal	Yes	Yes
Alternative 13	Yes	Yes	Yes
Alternative 14	Yes	Yes	Yes
Alternative 15	Minimal	Yes	Yes
Alternative 16	Minimal	Yes	Yes
Alternative 17	No	Yes	No
Alternative 18	Minimal	Yes	Yes
Alternative 19	Minimal	Yes	Yes
Alternative 20	Yes	Yes	Yes
Alternative 21	Minimal	Yes	No
Alternative 22	Yes	Yes	Yes
Alternative 23	Yes	Yes	Yes
Alternative 24	Yes	Yes	Yes
Alternative 25	**Yes**	**Yes**	**Yes**
Alternative 26	Yes	Yes	Yes
Alternative 27	Yes	Yes	Yes
Alternative 28	Yes	Yes	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 sufficiently reduce or eliminate the outdraft at MPLD. 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. Although there were a number of alternatives that showed minimal improvements to outdraft while maintaining the navigation channel requirements, they were not recommended. These alternatives were not recommended primarily because the alternative did not successfully straighten the flows near the guide wall to the navigation pass. Some of the alternatives that met the criterion but were not chosen were alternatives 11, 13, 14, 20, 22, 23, 24, 26, 27, and 28.

2. Recommendations

Alternative 25, Plates 80 - 81, was recommended as the most desirable alternative because of its observed ability to significantly reduce the outdraft at MPLD. This alternative could considerably reduce the navigation issues by creating a better alignment than the existing conditions in the bend (RM 1.8-1.2) and just upstream of the lock (RM 1.2-0.7). According to the LDV results, the velocities around the bend from RM 1.1 – 0.75 were more dispersed across the navigation channel, as well as the angle at which flow was directed towards the navigation pass and the abutment pier was notably reduced or straightened. This alternative also increased the width of the channel from RM 1.7 - 0.7, creating a slightly wider navigation channel. This would allow pilots the freedom to navigate their tows more towards the center of the channel, instead of hugging the RDB line. Side by side comparisons of the replication test and Alternative 25 results can be seen on Plates 88 and 89. Overall, this alternative greatly enhanced the navigation safety for industry with a more straight alignment and reduced outdraft while providing a self maintaining channel.

The recommended design included the following:

- RM 2.6-2.3L: Remove existing Dikes and Revetments to present river bed elevation or 95 ft (NGVD29)
- RM 1.95R: Construct new 220 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.80R: Construct new 445 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.75R: Construct new 490 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.65R: Construct new 480 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.55R: Construct new 470 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.45R: Construct new 480 ft weir
  - Structure top elevation =102 ft (NGVD29)
- RM 1.35R: Construct new 460 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.30R: Construct new 480 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.25R: Construct new 505 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.20R: Construct new 490 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.15R: Construct new 470 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.10R: Construct new 515 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 1.00R: Construct new 495 ft weir
  - Structure top elevation = 102 ft (NGVD29)
- RM 0.90R: Remove existing weir to present river bed elevation or 90 ft (NGVD29)
- RM 0.85R: Remove existing weir to present river bed elevation or 90 ft (NGVD29)
  - o Construct new 535 ft weir
    - Structure top elevation = 102 ft (NGVD29)
- RM 0.78R: Remove existing weir to present river bed elevation or 90 ft (NGVD29)
- RM 0.74R: Remove existing weir to present river bed elevation or 90 ft (NGVD29)
  - o Construct new 735 ft weir
    - Structure top elevation = 102 ft (NGVD29)

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 White 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

For more information about HSR modeling or the Applied River Engineering Center, please contact Robert Davinroy, P.E., Ashley Cox, or Jasen Brown, P.E. at:

Applied River Engineering Center
U.S. Army Corps of Engineers - St. Louis District
Hydrologic and Hydraulics Branch
Foot of Arsenal Street
St. Louis, Missouri 63118

Phone: (314) 865-6326, (314) 865-6331, or (314) 865-6322
Fax: (314) 865-6352

E-mail: Robert.D.Davinroy@usace.army.mil
Ashley.N.Cox@usace.army.mil
Jasen.L.Brown@usace.army.mil

Or you can visit us on the World Wide Web at:

http://www.mvs.usace.army.mil/eng-con/expertise/arec/welcome_page_2.html

APPENDIX

A. Report Plates

1. Location and Vicinity Map
2. MPLD Complex – 1:3,500
3. 2010 Aerial Photograph – 1:13,000
4. August 2003 Hydrographic Survey – 1:13,000
5. June 2004 Hydrographic Survey – 1:13,000
6. August 2004 Hydrographic Survey – 1:13,000
7. October 2004 Hydrographic Survey – 1:13,000
8. May 2005 Hydrographic Survey – 1:13,000
9. June 2005 Hydrographic Survey – 1:13,000
10. March 2006 Hydrographic Survey – 1:13,000
11. May 2007 Hydrographic Survey – 1:13,000
12. June 2007 Hydrographic Survey – 1:13,000
13. July 2007 Hydrographic Survey (RM 1.75-0.0) – 1:13,000
14. July 2007 Hydrographic Survey (RM 1.25-0.25) – 1:13,000
15. June 2010 Hydrographic Survey – 1:13,000
16. September 2010 Hydrographic Survey – 1:13.000
17. August 2004 Pre-Dredge Hydrographic Survey – 1:13,000
18. September 2004 Post-Dredge Hydrographic Survey – 1:13,000
19. October 2010 Pre-Dredge Hydrographic Survey – 1:13,000
20. October 2010 Post-Dredge Hydrographic Survey – 1:13,000
21. October 2010 Pre-Dredge Hydrographic Survey – 1:13,000
22. October 2010 Post-Dredge Hydrographic Survey – 1:13,000
23. May 2008 Normalized ADCP – 1:13,000
24. September 2008 Normalized ADCP – 1:13,000
25. June 2009 Normalized ADCP – 1:13,000
26. June 2010 Normalized ADCP – 1:13,000
27. Montgomery Point L&D Field Photographs
28. Montgomery Point L&D Field Photographs
29. Montgomery Point Lock and Dam HSR Model
30. Replication Test: Bathymetry Results – 1:13,000
31. Replication Test: LDV Results – 1:13,000

65. Alternative 17: LDV Results – 1:13,000
66. Alternative 18: Bathymetry Results – 1:13,000
67. Alternative 18: LDV Results – 1:13,000
68. Alternative 19: Bathymetry Results – 1:13,000
69. Alternative 19: LDV Results – 1:13,000
70. Alternative 20: Bathymetry Results – 1:13,000
71. Alternative 20: LDV Results – 1:13,000
72. Alternative 21: Bathymetry Results – 1:13,000
73. Alternative 21: LDV Results – 1:13,000
74. Alternative 22: Bathymetry Results – 1:13,000
75. Alternative 22: LDV Results – 1:13,000
76. Alternative 23: Bathymetry Results – 1:13,000
77. Alternative 23: LDV Results – 1:13,000
78. Alternative 24: Bathymetry Results – 1:13,000
79. Alternative 24: LDV Results – 1:13,000
80. Alternative 25: Bathymetry Results – 1:13,000
81. Alternative 25: LDV Results – 1:13,000
82. Alternative 26: Bathymetry Results – 1:13,000
83. Alternative 26: LDV Results – 1:13,000
84. Alternative 27: Bathymetry Results – 1:13,000
85. Alternative 27: LDV Results – 1:13,000
86. Alternative 28: Bathymetry Results – 1:13,000
87. Alternative 28: LDV Results – 1:13,000
88. Replication Test vs. Alternative 25: Bathymetry Results – 1:9,800
89. Replication Test vs. Alternative 25: LDV Results – 1:9,800

B. April 5, 2011 MPLD HSR Model Meeting Minutes