Model Application for Design of the Mid-Breton Sediment Diversion Project (Oral Presentation)

Brad Barth, Operations Assist Administrator, Coastal Protection and Restoration Authority, Baton Rouge, Louisiana, bradley.barth@la.gov
Matthew Hoy, Senior Principal, Stantec, St. Louis, Missouri, matthew.hoy@stantec.com
Scott Peyton, Vice President, Stantec, Cincinnati, Ohio, scott.peyton@stantec.com
Adam Witt, Senior Water Resources Engineer, Stantec, Sacramento, California, adam.witt@stantec.com
Qimiao Lu, Associate Principal, W.F Baird and Associates, Oakville, Ontario, qlu@baird.com
Rob Nairn, Principal, Ibid, rnairn@baird.com
Rebecca Quan, Coastal Engineer, Ibid, rquan@baird.com

Abstract

The Mid-Breton Sediment Diversion Project (MBrSD or Project) is being proposed to address the problem of large-scale land loss in coastal Louisiana. The Project design connects the left descending (east) bank of the Mississippi River near River Mile 68 above Head of Passes to the Breton Sound Basin by modifying the existing Mississippi River Levee to include four primary components: an intake channel, a gate structure, a conveyance channel, and an outfall channel. The Project is currently in the 60% Design Phase, with design completion scheduled for early 2024, and a Final EIS and permitting decision to follow in late 2024. Construction is expected to begin in early 2025. The design team has performed numerical model runs to evaluate design variations for the various components of the Project. These model runs have been performed to optimize the hydrodynamic performance of the structure, establish erosion armoring requirements, estimate delta development to inform tailwater conditions, and assess morphologic change in the river due to diversion operation. This paper will focus on the application of the numerical and physical models described in previous sessions to support testing of various geometric variations and selection of the recommended design configuration.

Introduction

The MBrSD Project consists primarily of a gated diversion channel and outfall transition that will transport water and sediment from the Lower Mississippi River (LMR) to Breton Sound. A suite of numerical and physical models described in a companion paper (Tun *et al,* 2023, Baird 2021) were developed, calibrated, and validated to model the complex physical processes at the site, including river hydrodynamics, flooding, storm surge, secondary currents, diversion channel hydraulics, sediment transport, bed load characteristics, morphology, and land building in Breton Sound. The suite of models was used for design support, including development of design concepts and subsequent evaluation of design criteria, performance, and near-field project impacts.

To progress the design of the Project, the system was segmented into four components: intake, conveyance channel, diversion structure, and outfall (Figure 1). Individual design concepts were developed for each component, and the results were evaluated relative to one another to determine the preferred configuration.

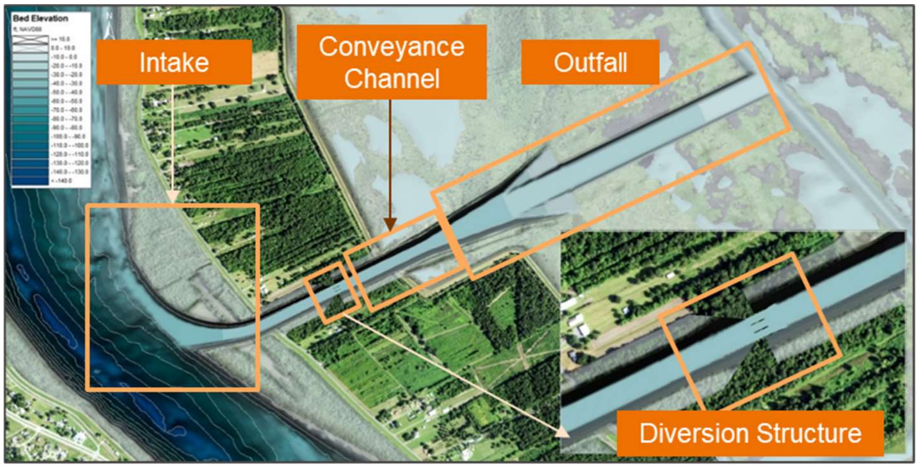


Figure 1. Major components of Project for design refinement

Design Refinement of Primary Components

The primary design parameter is to provide a design flow capacity of 50,000 cfs when the LMR flow is at 1,000,000 cfs in Year 0 and maximize sediment delivery. To meet this parameter, the design refinement process was conducted progressively from the intake to the outfall.

Intake

The primary objectives of the intake design refinement were to improve hydraulics by reducing losses and eddies, reduce the potential for scour around the intake, and increase sediment delivery to Breton Sound. The MISED model (Tun *et al,* 2023) was run at a river flow of 1 M cfs in a short-term simulation to evaluate and compare preliminary concepts for intake refinement. The primary geometric variables modified included the alignment of the intake, the cross-sectional shape (i.e., curvature and width), and the location and length of guide berms on either side of the intake. A plan view of depth averaged flow speed contours for a design concept is shown in Figure 2. Intake hydraulics and sediment extraction were improved by increasing the curvature of the north and south bank, narrowing the width of the intake, and increasing berm height relative to the 30% design. Once the final concept was established, a constructability review was used to optimize berm size and location.

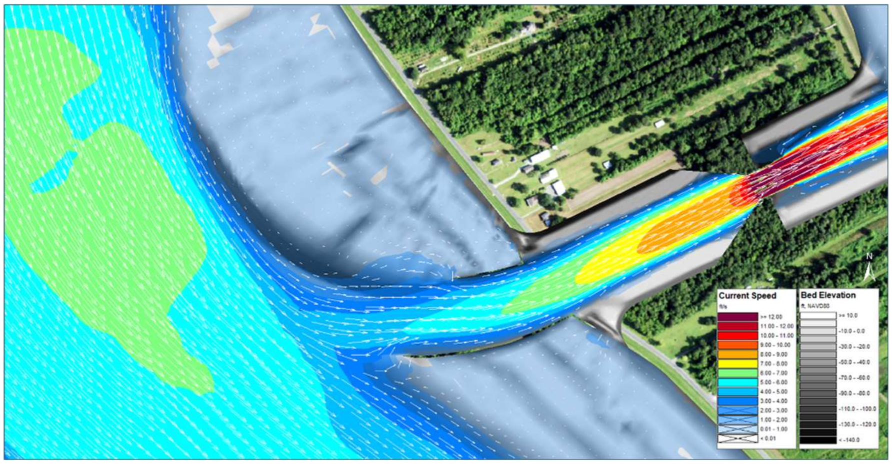


Figure 2. Plan view of current speed at the intake for a 1,000,000 cfs condition

Diversion Structure

The primary objectives of the diversion structure refinement were to evenly distribute flow across all gates, maintain stable transition hydraulics and minimize hydraulic losses through the diversion structure, and evaluate the impact of downstream guidewall length on flow speed and sedimentation. A mix of numerical and physical models were used at an LMR condition of 1 M cfs and 1.25 M cfs, primarily in a short-term simulation to evaluate and compare preliminary concepts. The primary geometric variables modified included curved intake guidewalls (Figure 3), longer downstream guidewalls (Figure 4), longer piers, and alternative pier nose shapes (Figure 5). Diversion structure hydraulics were improved by adding curved upstream guidewalls and elliptical pier nose shapes, and longer guidewalls produced less sedimentation.

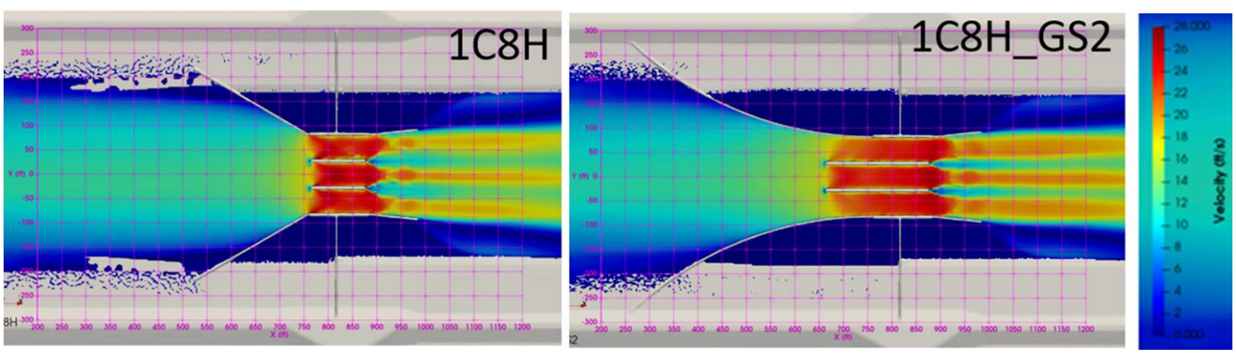


Figure 3. CFD modeled depth average velocity contours of straight guidewalls (left) and curved guidewalls (right) at conveyance of approximately 66,000 cfs.

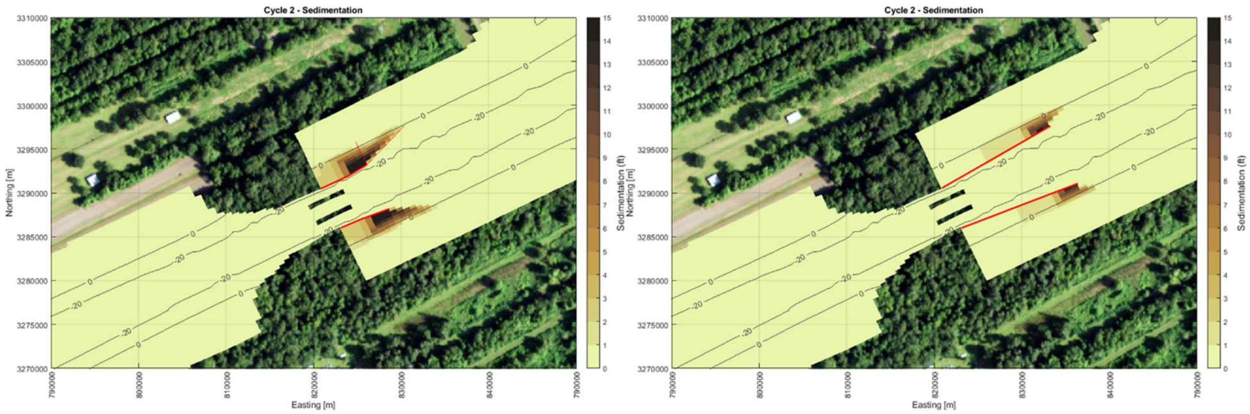


Figure 4. Modeled sedimentation after 2 years behind the downstream short (left) and long (right) guidewalls.

Figure 5. Pier nose shape alternatives tested in physical model: rounded (left), ellipse (middle), octagonal (right)

Conveyance Channel

The primary objectives of the conveyance channel refinement were to reduce depth average velocity in the conveyance channel (to reduce armoring cost), and more evenly spread flow laterally in the conveyance channel to reduce jetting effects from the gates. Model runs were performed in CFD at an LMR condition of 1.25M cfs and conveyance of approximately 66,000 cfs for concepts that modified conveyance channel cross-sectional geometry, including shallower side slopes and benches at lower relative elevations (Figure 6). The CFD model results confirmed none of the concepts appreciably reduced depth average velocity in the conveyance channel relative to the baseline configuration, primarily due to the inability of the high velocity core to spread laterally and effectively occupy the increased cross-sectional area.

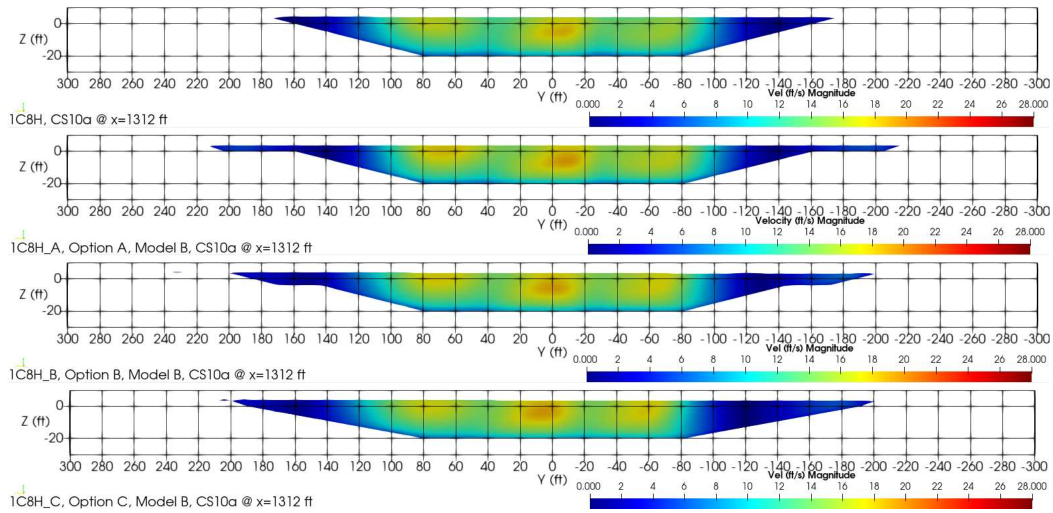
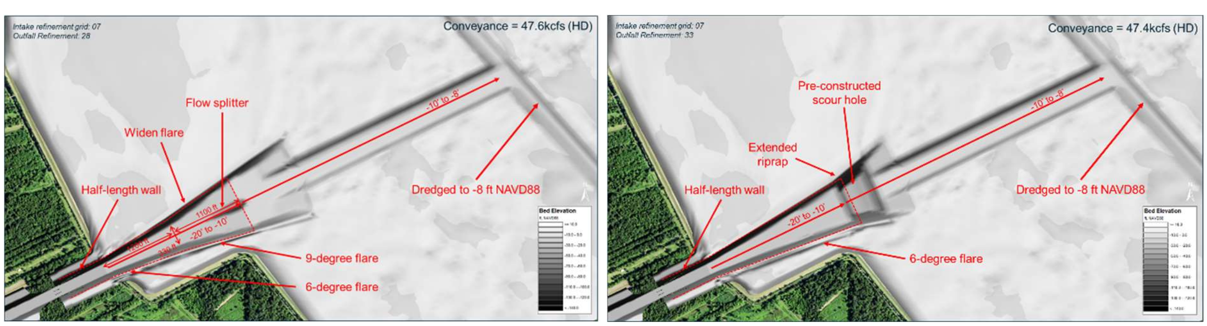


Figure 6. Cross-sectional contours of velocity magnitude in the conveyance channel for the baseline (top), lowered bench to El 0' (second), lowered bench to El -4' (third), and shallower side slopes from 4:1 to 5:1 (bottom).

Outfall

The primary objectives of the outfall design refinement were to reduce sedimentation in the flare, reduce the potential for scour hole development in the unarmored channel, and identify an appropriate flow transition to the pilot channel that connects the flared end of the diversion to Oak River in Breton Sound. Concept geometries were developed that balanced the need to lower velocity in the outfall to reduce scour with the need to maintain enough stream power to carry sediment into Breton Sound and limit sedimentation in the outfall. Numerical models were first used at an LMR condition of 1 M cfs and 1.25 M cfs to evaluate the hydrodynamics of design concepts that increased the flow area by flaring the outfall width in stages, decreased the flow area by increasing the outfall slope, spreading the flow using a flow splitter built from riprap, and pre-constructing a scour hole to dissipate energy (Figure 7). A hydraulic and morphological model was used to simulate aggradation and degradation in the outfall and Breton Sound over a 3-year simulation period to determine if undesirable scour occurred at the end of the armored portion of the outfall. The combination of hydrodynamic and morphological modeling indicated a widened flare with a steeper slope relative to the base condition reduced the velocity at the end of the flare and lowered the scour potential. The flow speed and scouring rate at the location of the scour hole were further reduced by the pre-constructed scour hole.



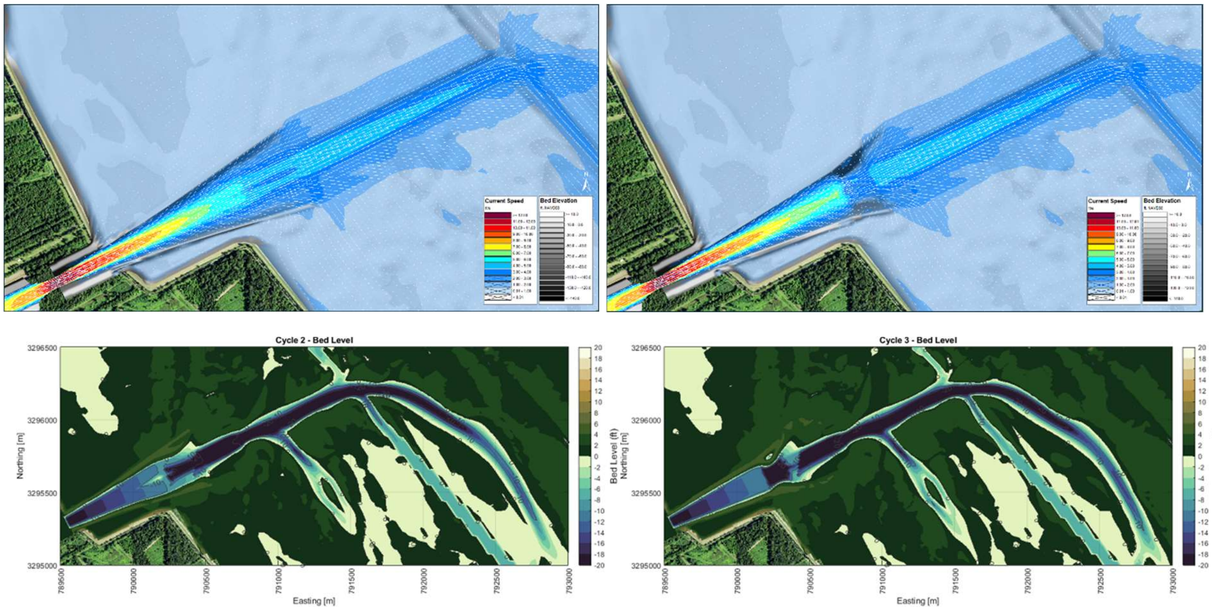


Figure 7. Plan view of outfall geometry concepts (top), modeled flow speed at a conveyance of 50,000 cfs (middle), and modeled bed elevation changes after 2-3 years of operation (bottom). Concepts include 1C8H07_R28 (left, increased slope, wider flare, and splitter) and 1C8H07_R33 (right, increased slope and pre-constructed scour hole).

Conclusions

A comprehensive set of numerical and physical models were used to simulate individual components of the Project and evaluate their ability to meet objectives and design criteria. The models were essential tools supporting the design refinement process of concept development, evaluation, refinement, and sensitivity analysis. The collective results of all modeling results, supported by an uncertainty assessment, were used to develop a recommended configuration for each design component.

References

Baird. 2021. Mid-Breton Sediment Diversion Project -Hydraulics and Modeling Assessment for 30%

Tun, Y., Lu, Q., Quan, R., Scott, F., Nairn, R. 2023. " A Comprehensive Modeling System for Mid-Breton Sedimentation Diversion Project”. SEDHYD 2023 Conference.