Data Collection and Analysis in Support of the Mid-Breton Sediment Diversion Project (POSTER SESSION)

Brad Barth, Operations Assist Administrator, Coastal Protection and Restoration Authority, Baton Rouge, Louisiana, bradley.barth@la.gov
Rebecca Quan, Coastal Engineer, Baird & Associates, Oakville, Ontario, rquan@baird.com
Qimiao Lu, Associate Principal, Baird & Associates, Oakville, Ontario, qlu@baird.com
Rob Nairn, Principal, Baird & Associates, Oakville, Ontario, rnairn@baird.com
Jim Lewis, Senior Hydraulic Engineer, Ibid, lewis@baird.com
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

Abstract

To support the design of the Mid-Breton Sediment Diversion Project, data related to the hydrodynamics, sediment transport, and morphology of the project site was collected from both publicly available sources and through an extensive series of field data campaigns. Field data was collected under a variety of flow conditions ranging from approximately 8,500 m^3/s (300,000 cfs) to 34,000 m^3/s (1,200,000 cfs) during both rising and falling limb periods between 2018 and 2022. Several methods of processing the collected data were developed to gain a better understanding of the complex physical processes at the project site and were used in the development of the numerical models.

Introduction

To address land loss in coastal Louisiana, the Coastal Protection and Restoration Authority (CPRA) initiated several sediment diversion projects to restore and sustain land. The Mid-Breton Sediment Diversion (MBrSD) Project is one of the projects intended to divert sediment-laden water from the Lower Mississippi River (LMR) into Breton Sound. Baird has provided hydrologic and hydraulic support to the engineering design led by Stantec.

The proposed diversion is located at Jesuit Bend, approximately at River Mile 68 in the LMR. The bend has a large point bar on the east side at Will's Point to which the proposed intake is to be connected. The hydraulic, sediment transport, and morphology dynamics in the bend are very complex and feature strong secondary flows, large sand wave movements, and underwater slope sliding. To better understand these complex physical processes, data was collected from publicly accessible sources and extensive field survey campaigns were conducted to support the numerical modeling and design of the Mid-Breton Sediment Diversion Project.

Data Collection and Field Surveys

Data Collection from Public Sources

Hydrological and sediment data in the LMR, Breton Sound, and the Gulf of Mexico were collected from public data sources provided by the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), and the United States Army Corps of Engineers (USACE). The collected data included historical bathymetry, river discharge, water levels (or stages), turbidity, sediment concentration, and other information on levees, existing diversions, soil classifications, vegetation data, subsidence, sea level rise, etc. The objective of collecting data in the LMR was to understand the historical variation of hydraulics and sediment transport in the river and to provide boundary conditions for the numerical model development described in Tun *et al.* (2022).

Water levels from 19 gages along the LMR between Baton Rouge and the Mississippi Delta were obtained from USACE. In the Breton Sound, water level data from 14 stations were obtained from CPRA. Water level data from the Gulf of Mexico was downloaded from NOAA's Center for Operational Oceanographic Products and Services. Hourly water levels and tidal constituents were downloaded from Pilots Station East near the mouth of the Mississippi River. The water level data was used to support the development of the numerical models (Tun *et al.*, 2022).

Daily discharge, water quality sample data that includes sediment data from water samples and bed sediment, and turbidity data from USGS stations in the LMR were also obtained. A total of six gages between Baton Rouge and the Mississippi River Delta were available. These data were used to understand sediment dynamics in the LMR and to develop the sediment rating curves.

Seven historical bathymetry datasets were collected from the USACE hydrographic contour database and NOAA. Bathymetric contours from 1992 and onwards were available in digital format, while the older surveys were obtained as images that required georeferencing and tracing of the contours. The digitized contours were converted into continuous surfaces using a Triangulated Irregular Network (TIN) for morphological evolution analysis.

Field Survey Campaigns

Field data is firsthand information required to understand the physical processes at the project site. The data is also required for model calibration and validation. A total of 14 field data collection campaigns were conducted under river flow conditions ranging from approximately 8,500 m^3/s (300,000 cfs) to 34,000 m^3/s (1,200,000 cfs) during both rising and falling limb periods between 2018 and 2022 (Figure 1). The data collected from the campaigns include Acoustic Doppler Current Profiler (ADCP) transects for current and backscatter measurements; isokinetic water sampling for vertical profiles of suspended sediment concentration and grain size distribution; bed sediment grab samples for grain-size distribution analysis; and extensive multi-beam hydrographic surveys for estimations of bed sediment load, sand wave characteristics, and morphologic change.

Data Processing and Analysis

Secondary Flows

Secondary flow in a river bend has significant impact on local sediment transport. The secondary flow at the project site is strong due to the pronounced river bend. Flow at the surface moves towards the outer bend of the river and a helical flow pattern moves along the riverbed and is directed upwards towards the east bank (i.e., where the diversion is proposed). It is important to understand how secondary flows impact the dynamics of sediment transport and how sediment will be transported into the diversion channel. ADCP transects data collected at all 14 field survey events were used to identify and quantify the secondary flow pattern at the project site.

The ADCP measurements were projected onto a straight transect line fitted to the track line data. The bearing of the transect line is generally perpendicular to the direction of primary flow. The horizontal secondary flow component was determined by projecting the resultant u (positive to east) and v (positive to north) velocity components on to the transect line. This horizontal secondary flow component was plotted with the vertical w component to represent secondary flow in the river cross-sections. The vectors shown in Figure 2 indicate the secondary flow direction in a river cross-section.

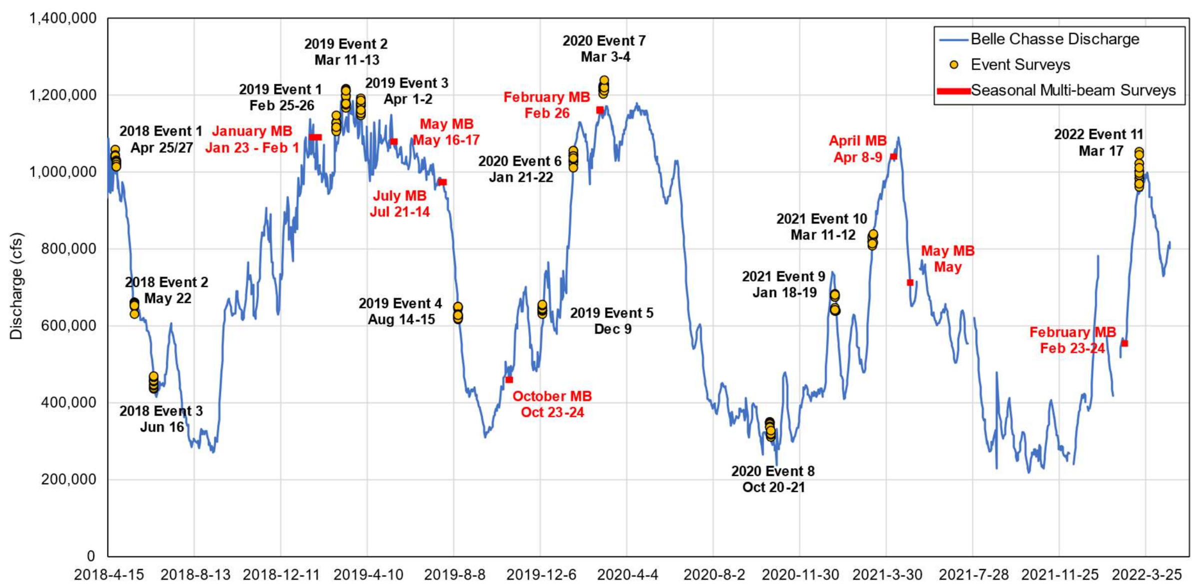

Figure 1. Field surveys conducted from 2018 to 2022

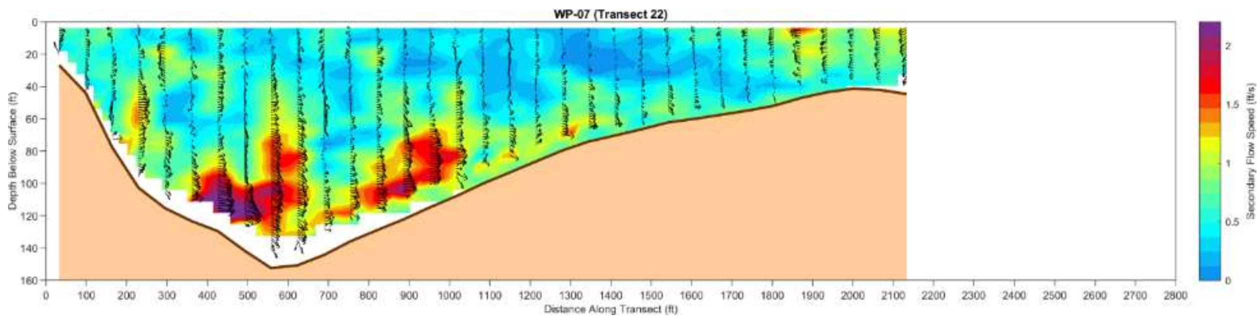

Figure 2. Secondary flow processed from the ADCP transect data during 2018 Event 1

Suspended Sand Concentration from ADCP Backscatter

Studies (Topping et al., 2007; Ramirez and Allison, 2013) indicate that suspended sand concentration has a strong correlation with the backscatter data acquired from ADCP signals. To estimate the suspended sand concentration using ADCP backscatter data, a relationship between suspended sand concentration and ADCP backscatter data was developed for the site. Isokinetic samples were taken at 10%, 30%, 50%, 70%, and 90% depths at several points along each transect line. Measured sand concentration from the isokinetic samples were plotted against ADCP backscatter readings taken at the same time and location as the isokinetic samples. Based on a similar analysis by Ramirez and Allison (2013), an exponential curve was fit to the data. An example is shown in Figure 3 for 2019 Event 5. The developed fit line was then used to estimate the suspended sand concentration using the ADCP transect data.

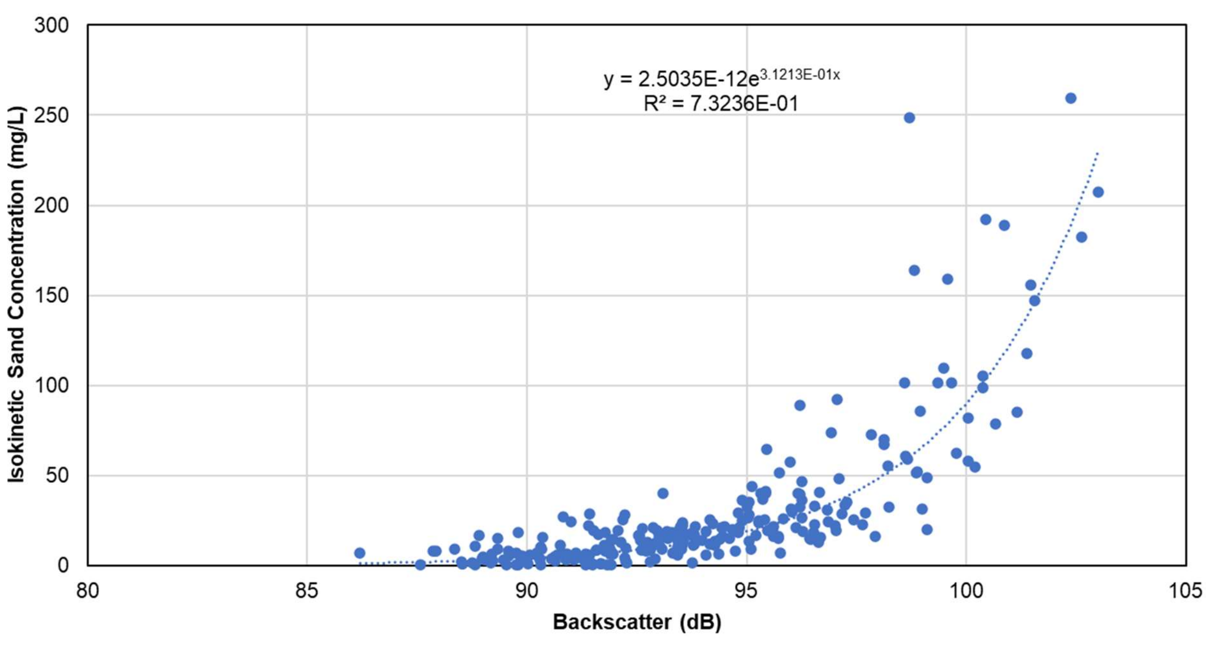

Figure 3. Relationship of ADCP backscatter data and isokinetic sand concentration measured in 2019 Event 5

Sediment Rating Curve

Long-term records of river discharge, suspended sediment concentration (SSC), and sand fraction in the LMR are required to evaluate the diversion performance, the delta development in the receiving basin, and the impact of point-bar stability over a period of 50 years. The measured data and studies (Gaweesh and Meselhe, 2016; Little and Biedenharn, 2014) indicate that SSC in the LMR has a strong hysteresis feature in which SSC in falling limbs is significantly lower than that in the rising limb. To estimate a time series of SSC in the river for model boundary conditions, a two-level regression model (or sediment rating curve) was developed to hindcast the long-term daily SSC for sand and fines using daily discharge data and daily turbidity data where available (Baird, 2020). The developed sediment rating curve was well calibrated against the measured data and was also well validated by the on-going measured data (Figure 4).

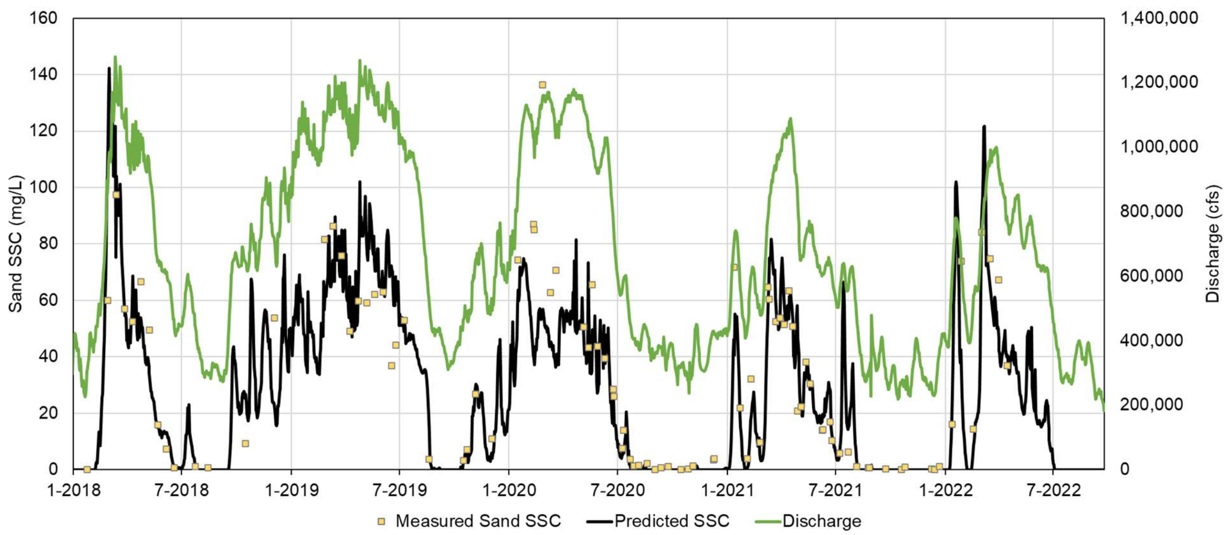

Figure 4. Measured and predicted sand SSC predicted by Baird's sediment rating curve. The model was calibrated by using the measured data before September 30, 2019. The model was validated well against the data measured after September 30, 2019

Sediment Load Estimation

To estimate sediment load, ADCP transect backscatter was converted to suspended sand concentration using the developed backscatter-sand SSC relationships. Suspended sediment concentrations were extended to the bed (where backscatter data was not available) using the Rouse profile (van Rijn, 1993). To fill in the ADCP blanking distance, the concentration at the first available depth was extended to the water surface. The suspended sediment concentration of fines was assumed to be homogenous over the entire transect, which were typically observed in the measured data. The SSC and speed were multiplied and depth-integrated to obtain the suspended sand and fine sediment loads, and the results were used to understand the sediment load variation in the river and the shift of sediment load through the point bar.

Results

From the collected data and the results from the data processing methods described above, observations of local conditions were made and are summarized below:

Water Level

The water level at the project site in the LMR is mainly driven by river discharge with some tidal influences. The water level rises as the river discharge increases. The existing daily average water level at the project site varies from 0.15 m to 3.1 m NAVD88 (0.5 ft to 10.3 ft NAVD88), based on the measured stage at Belle Chasse and Alliance from 2008 to 2022. The impact of tides on water level variation decreases as the river discharge increases. The water levels in Breton Sound are mainly driven by tide and winds.

Currents

The current speed at the project site in the river increases as the river discharge increases but the flow patterns are generally similar for all flow conditions. The surface current speed at the bend is about 0.8 m/s (2.5 ft/s) at a river flow of 8,500 m^3/s (300,000 cfs) and reaches about 3 m/s (10 ft/s) at a river flow condition of 34,000 m^3/s (1,200,000 cfs). The zone of highest flow speeds in the vicinity of the project site is located over the point bar.

Flow separation occurs at the control point of Will's Point (Figure 5). A large eddy with strong upwelling is observed downstream of the separation point. The eddy size increases as the river flow increases. The batture is flooded when the river flow is larger than approximately 22,700 m^3/s (800,000 cfs). The currents on the batture are reversed resulting from a large eddy driven by the flow separation at the control point of Will's Point.

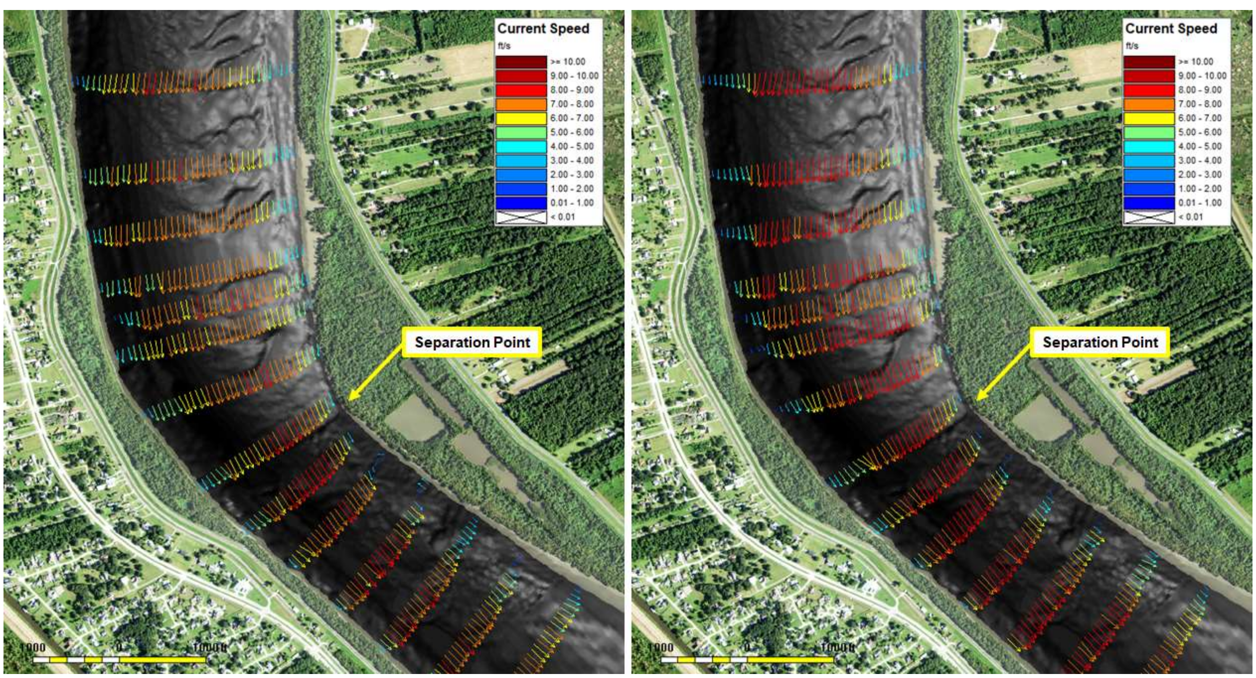

Figure 5. Measured current speed vectors near the water surface during 2019 Event 1 (30,200 m^3/s, left) and 2019 Event 2 (32,000 m^3/s, right)

Secondary flow is directed towards the east bank near the riverbed but flows towards the west bank at the water surface. This flow pattern is similar for different flow conditions, but the magnitude of the flow speed decreases as river discharge decreases. In periods of high discharge (i.e., greater than 28,300 m^3/s (1,000,000 cfs)), secondary flow reaches speeds of 0.6 m/s (2 ft/s). A comparison of the flow patterns in 2018 and 2019-2021 showed that the moored ships in Cedar Grove Anchorage can impact local hydrodynamic patterns downstream. The moored ships reduce the secondary flow speed on the west bank.

Suspended and Bed Sediment

The sediment dynamics in the LMR are complex. The hysteresis behavior and bed sediment starvation have been confirmed by the surveys in 2018 and 2019. Four distinctive periods of SSC response to the river discharge were identified from a review of the field survey and gage data. As evident from the field measurements in 2019, the bed sediment grain size over the point bar becomes coarser during the sustained high flow condition and this can be explained by the process of bed sediment starvation (i.e., all of the fines had been winnowed from the bed during the extended period of high flow). About 83% of sediment (about 80% of fines and 98% for sand) are carried by river flows larger than 12,700 m^3/s (450,000 cfs) which is the proposed trigger discharge for diversion operation.

Figure 6 shows the cross-sectional distribution of suspended sand concentration, velocity, and suspended load at WP-07 during 2019 Event 3. The top plot shows the distribution of suspended sand concentration in the cross-section which was estimated from ADCP transect backscatter. The middle plot shows the distribution of flow speed in the cross-section measured by ADCP, and the bottom plot shows the unit-width total sediment load along the cross-section. This data was used for numerical model calibration and validation (Tun *et al.*, 2022).

The concentration of suspended fines at the project site is approximately the same or slightly lower than the average measured at Belle Chasse, while the concentration of suspended sand over the point-bar is greater than the average measured at Belle Chasse. Higher sand concentration at the project site is likely the result of local sand resuspension from the point bar. The total sediment load decreases along the west side of the river. The total sediment load increases along the east side of the river (near the project site) with peak loads occurring near the separation point.

The collected bed sediment samples show that the point bar is dominated by fine sand. On the western edge of the point bar, the bed sediment is predominantly medium sand, finer bed sediment is found on the east edge of the point bar near the batture. Bed sediment information was used as input to the numerical models.

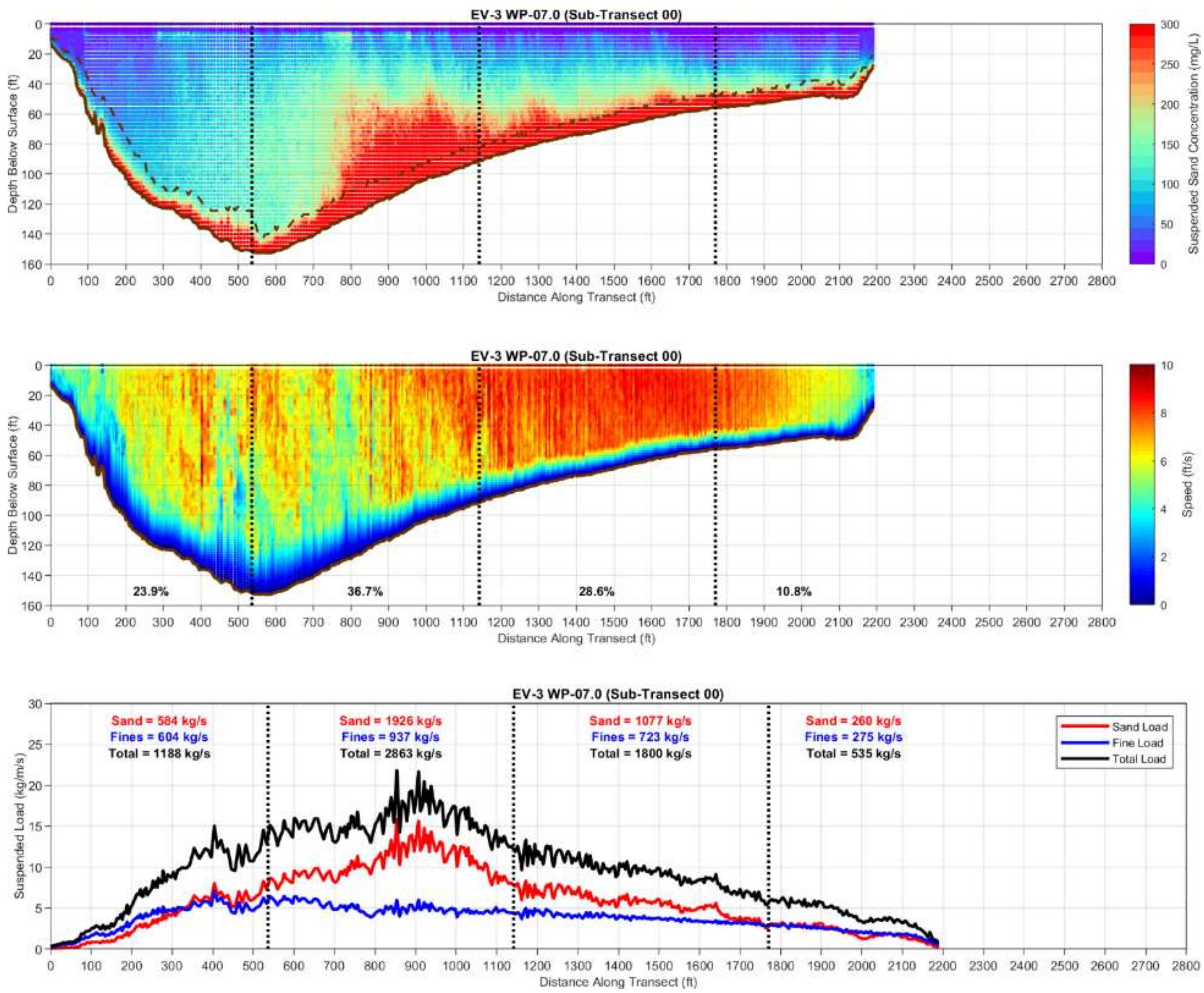

Figure 6. Suspended sand concentration converted from ADCP transect backscatter (top), ADCP measured speed (middle), and suspended sediment load (bottom) for 2019 Event 3 WP-07

Morphology

A comparison of historical bathymetry was completed to understand the morphological evolution at the project site. Construction of the Jesuit Bend revetment over many years has led to dynamically stable morphological conditions related to the riverbed in the vicinity of the project (i.e., there is stability over a period of years but fluctuations on shorter time frames and seasonally). Since 1992, there have been large bed changes to the distal end of the point bar extending approximately 180 m (600 ft) upstream and downstream of the separation point, featuring alternating erosion and accretion around a relatively stable mean position. The intermittent and rapid erosion is the result of underwater point bar adjustments as observed in measured bathymetry changes in the 2018 and 2019 surveys (Figure 7).

Based on a review of multiple survey datasets, erosion of the point bar occurs during the falling limbs and accretion occurs during the rising limbs, at least for the recent wet hydrological years, as observed from the field survey of 2019/2020. This likely results from the hysteresis behavior of the sediment load in the river. The average bed elevation on the point bar was lowered in the wet years, as revealed from the measured bathymetry data in these three years. However, there is no data yet to indicate how the bed elevation varies in dry years, but it is expected to rise to maintain the dynamic equilibrium that has been evident back to the early 1990s from the decadal river surveys.

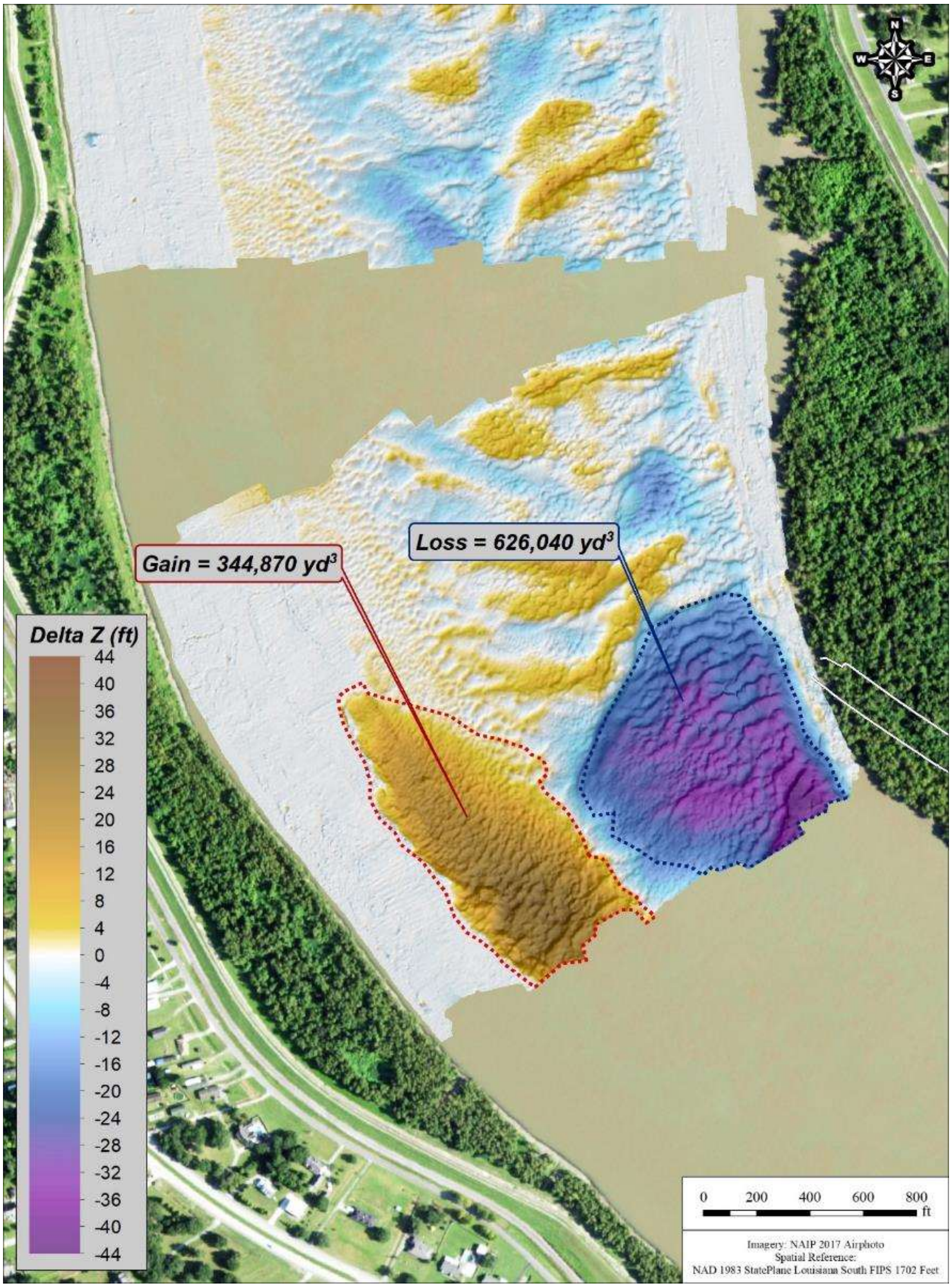

Figure 7. 2018 point bar adjustment area volume – 2018 Event 2 minus 2018 Event 1

Conclusions and Discussions

Physical data from both publicly available sources and from project-specific field data collection programs were essential in obtaining an understanding of the complex hydrodynamic, sediment transport, and morphology processes at the site of the proposed Mid-Breton Sediment Diversion Project. The understanding helped to develop, calibrate, and validate numerical models and to guide the design of the diversion. Future continuous monitoring at the USGS gages and bed changes in the project site, particularly in dry years, will be helpful for future diversion operation and for the better understanding of morphodynamics in the river.

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