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Technical Assessment of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers: Geomorphic Assessment

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Technical Assessment of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers

Geomorphic Assessment

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Abstract

This report documents the geomorphic assessment component of the Old River, Mississippi River, Atchafalaya River, and Red River System Technical Assessment. The overall objectives of the geomorphic assessment are to utilize all available data to document the historic trends in hydrology, sedimentation, and channel geometry for the rivers in the vicinity of the Old River Control Complex and to summarize the changes observed at locations where repetitive datasets exist and at key reaches that are determined during the study. The geomorphic assessment tasks include data compilation, geometric data analysis, gage and discharge analysis, dredge record analysis, sediment data analysis, development of an events timeline, and integration of results. Geomorphic reaches were developed, and the morphological trends during different time periods were identified. The geomorphic assessment highlighted the importance of considering spatial and temporal variability when assessing morphological trends.

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Preface

The investigation documented in this report was conducted for the US Army Corps of Engineers, Mississippi Valley Division (MVD), as part of the Mississippi River and Tributaries Project, under Project No. 478534, and published through the Mississippi River Geomorphology and Potamology (MRG&P) Program. At the time of publication of this report, the MRG&P Program director was Dr. James W. Lewis. The MVD commander was MG Diana M. Holland, and the MVD director of programs was Mr. Edward E. Belk.

The work was performed by the River and Estuarine Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory and the Geotechnical Engineering and Geosciences Branch of the Geosciences and Structures Division, US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory.

At the time of publication of this report, Mr. David P. May was chief of the River and Estuarine Branch; Dr. Cary A. Talbot was chief of the Flood and Storm Protection Division; Mr. Christopher G. Price was chief of the Geotechnical Engineering and Geosciences Branch; Mr. James L. Davis was chief of the Geosciences and Structures Division. The deputy director of the Coastal and Hydraulics Laboratory was Mr. Keith W. Flowers, and the director was Dr. Ty V. Wamsley. The deputy director of the Geotechnical and Structures Laboratory was Mr. Charles W. Ertle, II, and the director was Mr. Bartley P. Durst.

The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

1 Introduction

1.1 Background

The Lower Mississippi River Basin, in particular Vicksburg, MS, and south, has undergone tremendous transformation in the last 120 yr^{1,2}. These natural and anthropogenic modifications to the basin, both in-channel and on land, have led to significant alterations in the performance of the Mississippi River and its tributaries. These rivers are still reacting to these changes. More recently, a level of consistency has been imposed on part of this dynamic system through the construction of the Old River Control Complex (ORCC), which regulates the proportion of flow from the Mississippi River diverted into its distributary the Atchafalaya River via the ORCC Outflow Channel. The ORCC consists of the Low Sill Structure (construction completed in 1959, beginning operation in 1963), Overbank Structure (1959), Lock (1962), Dam (1963), Auxiliary Structure (1986), and Hydropower Installation (1990). By regulating the flow from the Mississippi River to the Atchafalaya River, the ORCC has kept the main channel of the Mississippi River in its current course instead of assuming the Atchafalaya alignment. The ability of the ORCC to maintain this delicate balance is of paramount importance due to the public safety and economic considerations for the populations downstream.

The Old River, Mississippi River, Atchafalaya River, and Red River (OMAR) System Technical Assessment is a review of the historic behavior of this area, a review of the ORCC and the surrounding systems to assess critically the performance of the ORCC, the effect of this performance on the immediately surrounding basin, and to predict both future performance and impacts. This comprehensive assessment will consist of data collection, modeling, development of a comprehensive understanding, and provide sound engineering recommendations. This

¹ For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

² For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

report details the geomorphic assessment portion of the comprehensive OMAR System Technical Assessment.

1.2 Objective

The objectives of the geomorphic assessment are to utilize available data to document the historic trends in hydrology, sedimentation, and channel geometry of the rivers in the vicinity of the ORCC and to summarize the local changes observed at locations where repetitive datasets exist and at key reaches that are determined during the study. This report focuses primarily on a period from 1900 to 2019.

1.3 Approach

The analysis documented in this report compiled various datasets for geomorphic analyses of each river reach. Section 2 describes the data compilation and the methods used to process the various datasets.

2 Methodology

The geomorphic assessment included 11 interrelated tasks. The methodology used for each of these tasks is described in this section.

Two terms used in describing the methods and the results of the analyses below are *aggradation* and *degradation*. For this report, these terms will be used to indicate a reach-scale loss or gain of channel capacity respectively and thus whether the channel is changing or is stable. These changes in capacity reflect an integration of processes including channel geometry changes (width, depth, or some combination of the two), roughness changes (e.g., vegetation), anthropogenic changes (e.g., levee construction), and more. The individual analyses below are often only commenting on one or a few of the many possible variables. However, it is believed that integrating these analyses over time allows conclusions to be drawn about trends. The terms *deposition* and *erosion* are often used as synonyms for aggradation and degradation; for the purpose of this report, a distinction is drawn that the former will be used to describe localized phenomena while the latter will describe reach-scale trends.

An important concept within the framework of natural channel reach stability is that of *dynamic equilibrium*. Dynamic equilibrium is the idea that the fluxes of sediment entering and exiting a reach are approximately in balance, and thus the system is not, as a trend, storing or losing sediment. This results in relatively consistent trends in stage and discharge for the reach, and thus a conceptualized stability. Within the reach itself, significant sediment transport or sediment location adjustment may be taking place, but the changes in the bed and banks are counteracting each other so that the overall trend reflects little change to the overall reach hydraulic parameters. Natural channels are constantly adjusting towards a dynamic equilibrium condition while at the same time regularly undergoing perturbations that would redefine what that dynamic equilibrium condition would be. As such, dynamic equilibrium is an idealized trend dependent on the period of analysis and reach length, as in truth, a perfect balance is never reached or maintained.

2.1 Data compilation

A comprehensive search of available data was conducted, and pertinent data for the assessment were collected and assembled. Types of data that

were gathered included hydrographic surveys, aerial photography, stage and discharge data, reach lengths, suspended sediment data, bed sediment data, dredging data, geospatial data, historical information, and results from previous river engineering studies.

2.1.1 Hydrographic surveys

Hydrographic survey data for channels within the vicinity of the ORCC were made available in digital and hardcopy form by the Vicksburg and New Orleans Districts (MVK and MVN, respectively). In cases where hardcopy surveys were provided (or digital scans of hardcopy surveys), digital images of the surveys were loaded into Geographic Information System software, geo-referenced to the correct location, and then elevation measurements were digitized by entering vertical survey values for individual points placed at the correct locations.

The surveys used as part of the geometric data analysis are shown in Table 1. Red River surveys were not used as part of the assessment due to the lack of multiple digital datasets to allow for comparison. All hydraulic parameters calculated for the geometric analysis were referenced to a common Low Water Reference Plane (LWRP), in this case, the Lower Mississippi LWRP of 2007 (in NGVD29). Spot checks in the differences between NGVD29 and NAVD88 within the study area revealed negligible differences (<0.4 ft.). Differences in pre-NGVD29 datum are of a similar magnitude.

Table 1. Hydrographic surveys obtained for the geomorphic assessment.

River	Survey Year
Mississippi River	1915, 1948, 1963–64, 1974–75, 1983–88, 1992–94, 2003–04, 2013
Atchafalaya River	1976, 1989, 1998, 2010, 2019
Old River	1963–64, 1974–75, 1988–89, 2003–04, 2013

2.1.2 River gage and discharge data

Discharge measurements along with daily stage and computed discharge data were assembled for gages in the study area. A map of gage locations is provided later in the report in Figure 2. The stage and discharge data were provided by the Water Control Operations offices from MVK and MVN,

downloaded from the USACE RiverGages.com website or scanned from annual or cumulative gage and discharge publications available at the US Army Engineer Research and Development Center (ERDC) Library, Mississippi Valley Division office, or MVN office and digitized. Much of these data were assembled as part of previous studies. The period from 1900 to 2019 was the period of focus for the daily data; for the discharge measurements, the record was extended where data were sufficiently available. The data may not be continuous for an individual gage, due to missing data, gage errors, etc. The primary gage and discharge data obtained for the study are shown in Table 2 – Table 4.

Table 2. Gage and discharge data for the Mississippi River for the geomorphic assessment.

Location	Type	Date
Vicksburg (River Mile [RM] 437.0)	Daily stage and Q, measured Q	1900–2019; 1928–2019; 1858–2019
Natchez (RM 363.3)	Daily stage and Q, measured Q	1900–2019; 1936–2019; 1858–2019
Union Point (Previously Coochie) (RM 317.2)	Measured Q	1962–2019
Knox Landing (RM 313.7)	Daily stage	1955–2019
Tarbert Landing* (RM 306.3)	Daily Q and measured Q	1930–2019; 1911–2019
Red River Landing (RM 302.4)	Daily stage and measured Q	1900–2019; 1881–1963
Bayou Sara (RM 265.4)	Daily stage	1900–2015 [#]
Baton Rouge (RM 228.4)	Daily stage	1900–2019

*—Discharges measured at Tarbert Landing, stages used from Red River Landing (stages not historically measured at Tarbert Landing); referenced hereafter as Tarbert Landing – Red River Landing.

[#]—Bayou Sara stages stop in 2015; given the proximity of the two gages, a linear relationship between the Bayou Sara and St. Francisville stages was used to interpolate and extrapolate missing Bayou Sara stages from 2009 to 2019.

Table 3. Gage and discharge data for the Atchafalaya River for the geomorphic assessment.

Location	Type	Dates
Barbre Landing (RM 0)	Daily stage	1900–2019
Simmesport (RM 4.9)	Daily stage and Q, measured Q	1905–2019; 1928–2019; 1889–2019
Melville (RM 29.5)	Daily stage	1900–2019
Krotz Springs (RM 39)	Daily stage	1932–2019
Whiskey Bay Pilot Channel (in Old Channel, adjacent to RM 55.4)	Daily stage	1959–2019

Table 4. Gage and discharge data for the Old River Outflow Channel, Red River, and Black River for the geomorphic assessment.

Location	Type	Dates
Old River Outflow	Daily stage [^] and Q ^{&} , Measured Q [%]	1963–2019; 1961–2019
Fulton (RM 345.5)	Measured Q	1931–2019
Shreveport (RM 228.8)	Measured Q	1891–2019
Alexandria (RM 88.2)	Daily stage and Q, measured Q	1900–2019; 1928–2019; 1858–2019
Acme	Daily stage, daily Q (see note below)	1932–2019; 1963–2019

[^]–Daily stages taken from Low Sill Outflow Channel

[&]–Calculated combined daily discharges provided by MVN

[%]–Discharges from USGS¹ gage “Old River below Hydropower Channel” (previously “Old River near Knox Landing” gage)

2.1.3 Suspended sediment data

Sediment data in the form of suspended sediment measurements were assembled for gaging stations on the Mississippi, Red, and Old Rivers within the study reach. These data were obtained from US Army Corps of Engineers (USACE) sources as well as downloaded from the US Geological

¹ US Geological Survey

Survey (USGS) National Water Information System website. The sediment data assembled for the geomorphic assessment is shown in Table 5. Note that the pump sampler data are not isokinetic (i.e., a sample is not collected at a constant speed to prevent collection distortions); however, given the pump sampler (i.e., a pump-based, stationary device for collecting suspended sediment samples) locations immediately downstream of the structures, the water column would be expected to be considered fully mixed in these locations.

Table 5. Sediment gages.

Location	Channel	Date
Union Point (previously Coochie) (RM 317.2)	Mississippi River	1967–1998
Tarbert Landing (RM 306.3)	Mississippi River	1958–2015
Simmesport (RM 4.9)	Atchafalaya River	1950–2019
Melville (RM 29.5)	Atchafalaya River	1979–2019
Red River north of Simmesport, LA (formerly RED R ABOVE OLD R OUTFLOW CHAN ABOVE SIMMESPORT) (~RM 29.5)	Red River	1973–2019
Old River below Hydropower Channel (previously Old River near Knox Landing)	Old River Outflow Channel	1973–2019
Hydropower Plant Pump Sampler	Hydropower Outflow Channel	1991–2018
Low Sill Structure Pump Sampler	Low Sill Structure Outflow Channel	1991–2018
Auxiliary Structure Pump Sampler	Auxiliary Structure Outflow Channel	1991–2018

2.1.4 Bed sediment data

Bed sediment data on the Mississippi River had previously been collected and analyzed in Gaines and Priestas (2016) and Nordin and Queen (1992). Bed sediment data on the Atchafalaya River had previously been collected and analyzed by Nordin et al. (1995); a new collection to update the previous work on the Atchafalaya was carried out under the Task 3: Field Data Collection component of the OMAR System Technical Assessment to compare to the historical dataset. Limited bed sediment data for the Red

River was collected as part of the field investigation; additional sources for bed sediment data for the Red River were not investigated.

2.1.5 Boring logs

Logs for borings adjacent to the Atchafalaya River were collected from MVN for evaluating material types anticipated to be present in the river's bed and banks. Boring logs are available for the Mississippi and Red Rivers along revetment alignments as well; for this study, the boring logs along the Atchafalaya River were used specifically to identify potential material layers that would limit erodibility.

2.1.6 Dredging data

Historic dredging data were gathered from MVK and MVN. These data were used to determine volumes and location of dredge activities within the study reach.

2.1.7 Bed-load data

Multibeam bathymetric surveys were collected at points throughout the OMAR System Technical Assessment area by ERDC Coastal and Hydraulics Laboratory (CHL) personnel as part of Task 3: Field Data Collection.

2.2 Geospatial data

Numerous pieces of geospatial data were critical for developing a comprehensive understanding of the system. The most relevant pieces of information (the main channels of OMAR, ORCC components, gages, levees, revetment, and dikes) were included on maps to inform and help orient readers of this report. This information was gathered from USACE sources. Aerial imagery from the ESRI Corporation was used as a background for orientation. Beyond just providing a sense of location, these features (Figure 1 – Figure 5) on these maps are important with respect to the morphological behavior of the system.

Figure 1. ORCC features and surrounding channels.

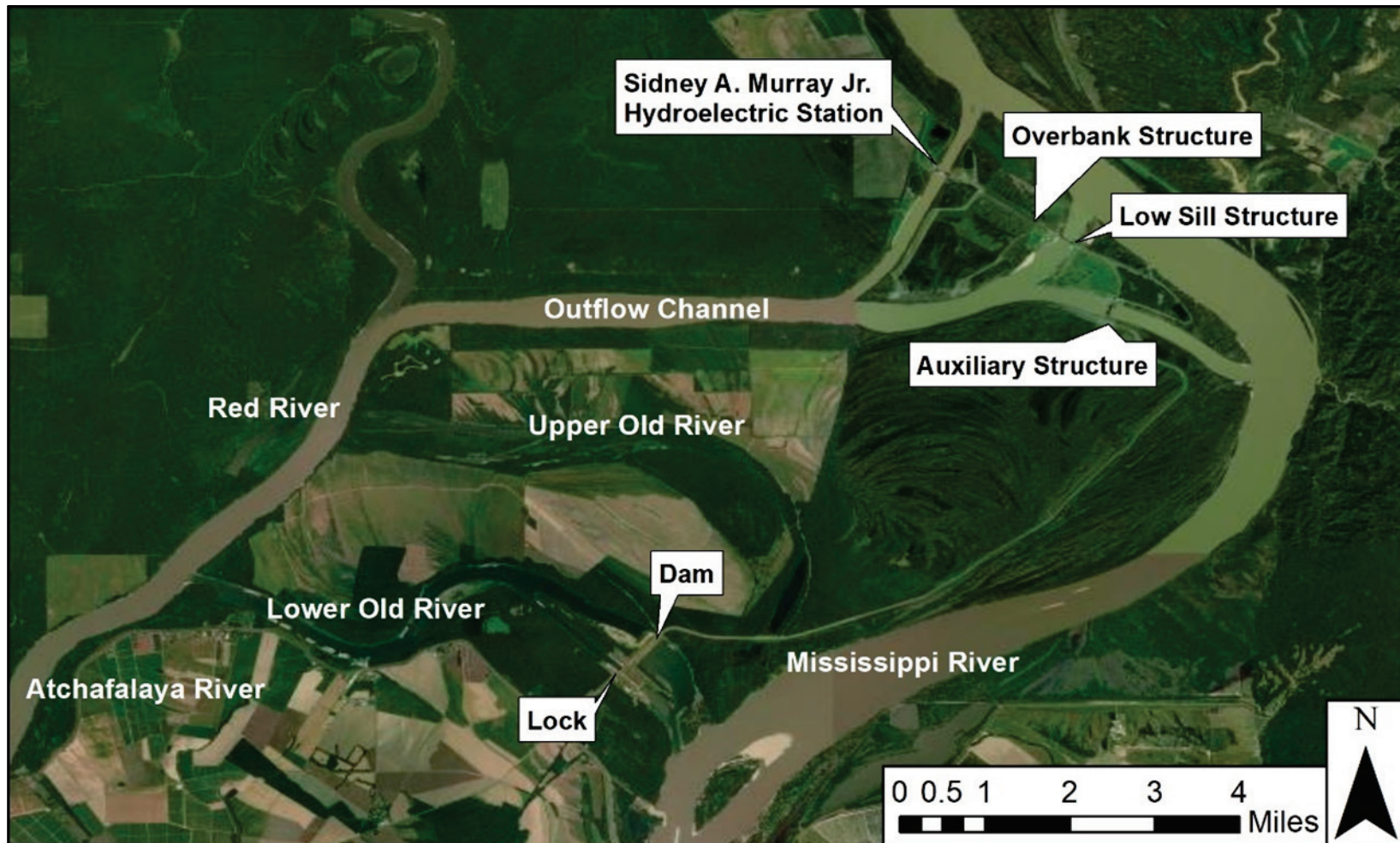


Figure 2. OMAR gages and main channels.



Figure 3. OMAR levees and main channels.



Figure 4. OMAR revetments.

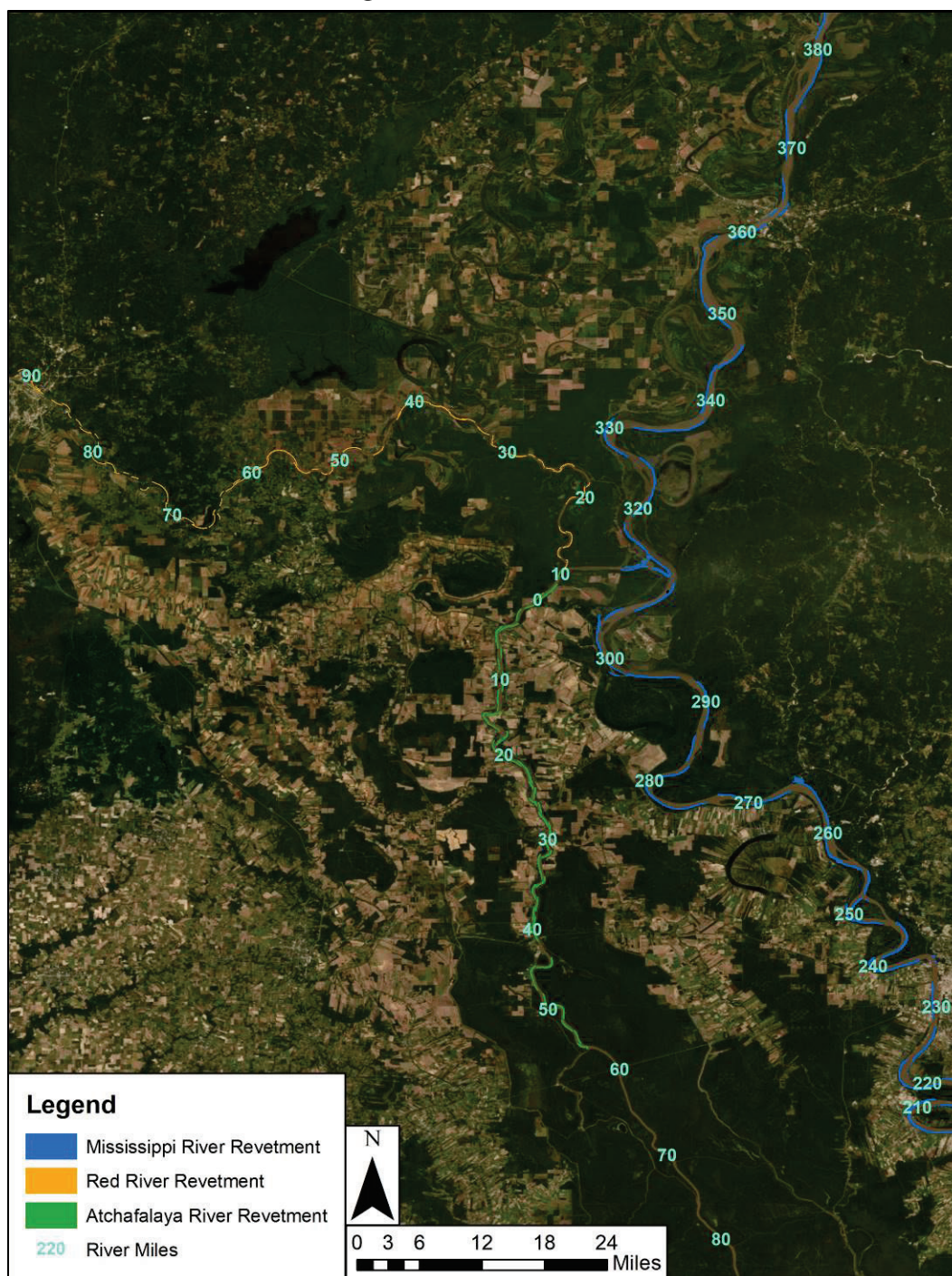
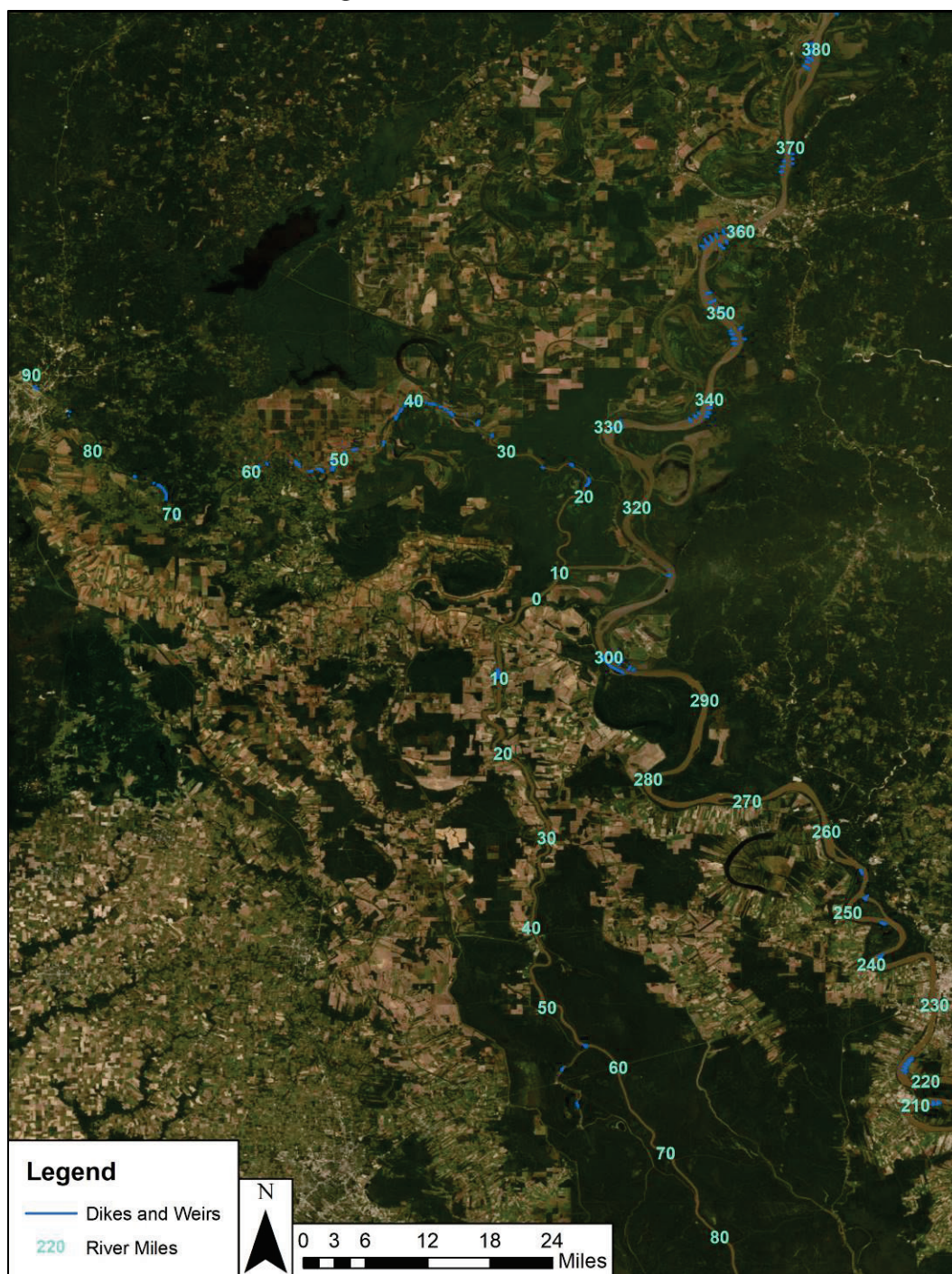


Figure 5. OMAR dikes and weirs.



2.3 Geometric data

Analysis of the channel geometry for the study reach was conducted with hydrographic surveys. Data from these repetitive surveys were used to document river changes over the study time period and to identify any long-term trends in morphology. The Lower Mississippi River and its tributaries are dynamic systems that can potentially undergo significant change in channel dimension. These changes are influenced by the occurrence of large floods, prolonged periods of extreme high water or drought, as well as anthropogenic activities such as river training structure construction, dredging, and dam construction. Observance of the river channel at a given location over time may indicate significant variability in dimension as the river responds to the various hydrologic cycles. Even the size of bedforms on the riverbed can result in variability observed from successive hydrographic surveys. This analysis endeavors to differentiate between the natural variability of the dynamic river system and any system-wide, long-term morphologic trends.

Channel geometry changes (cross-sectional area, width, hydraulic depth, conveyance, and width/depth ratio) from successive surveys were determined from comparative cross sections located in the major crossings and pool sections of the river. Volumetric change between surveys was determined for relatively river-mile-long segments along the study reach.

The analysis of the geometric data for the study area is documented separately in the OMAR Assessment: Volume 3 (Little and Biedenharn 2022).

2.4 Specific gage

Analysis of the specific gage record is a critical tool for a geomorphologist to understand the long-term stability or instability of a reach (Watson et al. 2013). By tracking the change in water surface elevation for consistent values from discharge measurements, geomorphologists can gain a sense of whether the channel near the gage is approximately at equilibrium, aggrading, or degrading. Specific gage records were developed for gages on the Mississippi, Atchafalaya, and Red Rivers. This section lists the gages used for the specific gage analysis along with the methodology for the specific gage analysis.

The list of gages used in the specific gage analysis is presented in Table 6 – Table 8. Due to the limited number of gages where discharge measurements were taken, linking instantaneous stage measurements with discharge measurements was not always possible. Instead, daily stage data at a gage were frequently analyzed with discharge measurements taken at another gage location. The discharge gage selected for use in these situations was based on a combination of proximity, contributing portion of the watershed, and gage record length.

Table 6. Gages used in the development of the Mississippi River specific gage records.

Stage Gage	Discharge Gage	Time Period
Vicksburg (RM 437.0)	Vicksburg (RM 437.0)	1858–2019
Natchez (RM 363.3)	Natchez (RM 363.3)	1934–2019
Union Point* (RM 317.2)	Union Point# (RM 317.2)	1962–2018
Knox Landing (RM 313.7)	Natchez (RM 363.3)	1959–2019
Red River Landing (RM 302.4)	Red River Landing (RM 302.4) (pre-1964) / Tarbert Landing (RM 306.3) (1964 on)	1881–2019
Bayou Sara% (RM 265.4)	Tarbert Landing (RM 306.3)	1907–2019
Baton Rouge (RM 228.4)	Tarbert Landing (RM 306.3)	1907–2019

– Flows previously collected at Coochie; flows adjusted to Union Point.

* – Stages previously collected at Knox Landing; stages adjusted to Union Point.

% – Bayou Sara stages interpolated and extrapolated as identified in Section 2.1.2.

Table 7. Gages used in the development of the Atchafalaya River specific gage records.

State Gage	Discharge Gage	Time Period
Barbre Landing (RM 0)	Simmesport (RM 4.9)	1912–2019
Simmesport (RM 4.9)	Simmesport (RM 4.9)	1889–2019
Melville (RM 29.5)	Simmesport (RM 4.9)	1920–2019
Krotz Springs (RM 39)	Simmesport (RM 4.9)	1932–2019
Whiskey Bay Pilot Channel (in Old Channel, adjacent to RM 55.4)	Simmesport (RM 4.9)	1959–2019

Table 8. Gages used in the development of the Red River and Old River outflow channel specific gage records.

Stage Gage	Discharge Gage	Time Period
Fulton (RM 345.5)	Fulton (RM 345.5)	1931–2019
Shreveport (RM 345.5)	Shreveport (RM 345.5)	1891–2019
Alexandria (RM 345.5)	Alexandria (RM 345.5)	1879–2019
Old River Outflow^	Old River Outflow^	1961–2019

^ - Measurements now collected at USGS gage “Old River below Hydropower Channel” (previously “Old River nr Knox Landing” gage)

The specific gage analyses were developed using the R programming language. The tool allows for the development of specific gage analyses by using the Direct Step Method or the Rating Curve Method. For the Direct Step Method, only stage values resulting from a chosen range of the preferred target measured discharges are used to develop the plot. For the Rating Curve Method, all data within a specific year (either calendar year or water year) are used to develop a best-fit rating curve (based on a selected fitting methodology), and stages corresponding to the preferred target discharges are selected from the curve. For these analyses, the Rating Curve Method was the primary method selected using annual

calendar year rating curves (the Direct Step method was used at select locations as a check). Data were analyzed over the calendar year. The tool allows for the selection of different models when fitting a rating curve to the data for a specific year; the model that fits a 2nd-Order Polynomial to the stage based on a logarithmic value of discharge (“2nd-Order Polynomial of H on Log Q” in the tool) was chosen. Filtering can be done to remove data from poorly fitting rating curves from the analysis. Filtering for these analyses was done by requiring a coefficient of determination, or R^2 value, of 0.9 or higher. Results from the tool were saved as text files for standardized plotting in Microsoft Excel.

2.5 Slope and stream power

Measuring the sediment transport through a large river reach is problematic. Instead, geomorphologists often use surrogate means for quantifying or characterizing the sediment transport capacity of a reach. One such measure used is the concept of stream power, the energy dissipation along the bed and banks of a river for a unit length of the river. Another way to think of stream power is the energy available to transport sediment through a reach. The higher the energy, the higher the potential to mobilize (and keep mobilized) bed and banks sediments. The equation for stream power is

$$\Omega = \rho g Q S$$

where

Ω	=	stream power
ρ	=	density of water
g	=	acceleration due to gravity
Q	=	discharge
S	=	channel slope.

In a typical river reach, the density of water and discharge can be measured with reliable methods. Likewise, the channel slope can be estimated for a reach by dividing the difference in water surface elevation between the entrance and exit of reach by the average reach length. Thus, stream power can be calculated. Given that the discharge and channel slope, and thus the stream power, is constantly changing, it is useful to aggregate stream power calculations to a useful timescale.

Note that stream power is just a proxy for sediment transport capacity and not a true measure of the rate of sediment moving through a reach. Bed material size and availability can impact the relationship between stream power and sediment transport. Significant engineering in a reach (such as the creation of the navigation pools as seen on the Red River) can also complicate the relationship. Furthermore, finding a yearly slope for a dynamic property such as sediment transport, which can vary widely over a day, let alone a year, is a large simplification to make the data digestible. For these reasons, it is important to generally focus on overall trends as compared to individual data points and determine those trends from a sufficient number of data points. This can be difficult, as stream power's direct dependence on flow, and thus the variability of the hydrograph, can exhibit more fluctuations from 1 yr to the next than slope.

For the purpose of this study, the daily calculations of slope were averaged to yearly values and the daily calculations of stream power summed to yearly values. Years with fewer than 350 days of stream power measurements were filtered out to build a more consistent comparison while still allowing for the stray missing value. The gages and time periods used for the slope and stream power calculations are listed in Table 9, Table 10, and Table 11.

Table 9. Gages and time periods used in the development of the Mississippi River slope and stream power.

Upstream Gage	Downstream Gage	Daily Discharge	Time Period
Vicksburg (RM 437)	Natchez (RM 363.3)	Vicksburg (RM 437)	1900–2019
Natchez (RM 363.3)	Knox Landing (313.7)	Natchez (RM 363.3)	1957–2019
Knox Landing (313.7)	Red River Landing (302.4)	Tarbert Landing (RM 306.3)	1957–2019
Red River Landing (302.4)	Bayou Sara (265.4)	Tarbert Landing (RM 306.3)	1900–2014
Bayou Sara (265.4)	Baton Rouge (228.4)	Tarbert Landing (RM 306.3)	1900–2014

Table 10. Gages and time periods used in the development of the Atchafalaya River slope and stream power.

Upstream Gage	Downstream Gage	Daily Discharge	Time Period
Barbre Landing (RM 0)	Simmesport (RM 4.9)	Simmesport (RM 4.9)	1930–2017
Simmesport (RM 4.9)	Melville (RM 29.5)	Simmesport (RM 4.9)	1929–2018
Melville (RM 29.5)	Krotz Landing (RM 39)	Simmesport (RM 4.9)	1932–2018
Krotz Landing (RM 39)	Whiskey Bay Pilot Channel (in Old Channel, adjacent to RM 55.4)	Simmesport (RM 4.9)	1963–2018

Table 11. Gages and time periods used in the development of the Red River and Old River slope and stream power.

Upstream Gage	Downstream Gage	Daily Discharge	Time Period
Acme (RM 0.1 on Black River, adjacent to Red River ~RM 34.3)	Barbre Landing (RM 0)	Simmesport–Old River Outflow	1980–2015
Old River (Low Sill Outflow Channel)	Barbre Landing (RM 0)	Old River Outflow	1980–2015

As previously referenced in this report, slope was estimated for a reach by dividing the difference in water surface elevation between the entrance and exit of a reach by the average reach length. However, average length is subject to change, in small ways due to shifting morphology and large ways due to natural and man-made channel cutoffs. Because of these changing lengths, different length values were developed for different periods by tracing the approximate channel centerline from maps and aerial imagery as available. Also note that the slope and stream power results are sensitive to the distance between the gages, which adds another level of uncertainty to the slope and stream power results.

Slope and stream power calculations were performed using the R programming language. Results from the tool were saved as text files for standardized plotting in Microsoft Excel. Note that the slope and stream

power calculations using the Knox Landing gage should be viewed with some reservation given the gage's proximity to the ORCC.

2.6 Sediment data

There are a number of different ways to analyze sediment data; the methods of analysis chosen for this report are detailed in the following.

2.6.1 Suspended sediment

The methods that sediment is transported in a river system can be defined multiple ways. From a geomorphic stability standpoint, the most critical transport rate is that of bed material load, the rate of transport of material that makes up the bed (as opposed to wash load, the sediment that stays in suspension for throughout its time in the channel). However, there are no total bed material load measurements available. For measurement purposes, it is common to rely on a different means of division for sediment, the transport mechanism, that gives suspended load (sediment moving via suspension) and bed load (sediment moving by sliding, rolling, or saltating in contact with the bed). Suspended sediment sampling integrates a sediment transport process that is highly variable both spatially and temporally. This often leads to significant spread in results, to the point that plotting on a logarithmic scale is used to understand the variability better. However, suspended sediment concentration, and thus suspended load determination, is the easiest sediment division to measure, and thus, decades of measurements exist throughout a number of systems. In comparison, there are relatively few measurements of bed load rate on major waterways, and for bed material load, functionally almost none. The suspended material measured as the suspended load has little correlation to the makeup of the bed, and therefore its usefulness as a corollary for the bed material load that drives significant geomorphic change must be viewed with caution. There are of course exceptions, such as slackwater, estuarine, or deltaic areas such as the Atchafalaya River's Wax Lake or the Bird's Foot Delta of the Mississippi River, where suspended sediment is the bed material because it falls out of suspension.

The sand load component of the suspended load is used frequently to represent the bed material. There are cases where this may be appropriate. However, there are also frequently cases where some fraction of the sand load remains in suspension and thus does not interact with the bed in a

meaningful way. Determining which portion of the sand load truly is engaging with the bed, and thus reflects bed material load, requires site-specific analysis that is outside of the scope of generalized trends sought in this analysis.

A significant problem when attempting to develop spatial and temporal trends using measured suspended sediment data is the lack of standardization of methodology both among gages and for individual gages (e.g., type of sampler, weight of sampler, sampling depth). This lack of standardization has not been authoritatively catalogued for all of the gages within the study reach, but significant efforts have been undertaken at certain locations to identify the existing issues; more is still needed. Because of the standardization issues and the potential for a corollary relationship between suspended load and bed material load, the existing suspended load measurements at the most critical gages were analyzed to develop very liberal estimates for suspended load moving into, through, and out of the ORCC reach.

Treatment of the suspended sediment data began by combining datasets from US Geological Survey and USACE sources. To resolve conflicts, data with transposed concentrations (fine vs. coarse) were removed. Further removal was done based on deviation for daily discharge values. Where conflicts remained, records with the most complete history (e.g., type of collector documented) and with the concentrations not calculated were favored.

Once a dataset had been prepared, 4th-order polynomial rating curves were fit to the concentration data. Regression curves based on time-weighting with a half-window of 5 yr were used to build out the measurement dataset further synthetically. Each rating curve was required to have at least 25 observations for use. Once the rating curves were established, daily discharge data were used with the rating curves to calculate a daily load. The daily discharge in some cases already existed for that site. For other sites, the daily discharge data were calculated as the sum or difference of other daily discharge data (e.g., the daily discharge for the Red River Above Simmesport gage (formerly the Red River near Simmesport) was taken as the difference of the Simmesport daily discharge and the Old River Outflow daily discharge). Once daily loads were calculated, the average annual load was calculated for a defined period. Only annual loads with at least 350 days of observations were

used, to have similarly representative years. Because of the number of observations, some average annual loads were calculated from as few as 3-years' worth of data, whereas others were calculated from as many as 10-years' worth of data.

2.6.2 Bed material and bed load

The mobile material that makes up the bed of a channel can provide clues as to a reach's geomorphic stability. Looking at changes in the bed material composition from one time period to the next can indicate a change of materials sources, a change in bed material transport mechanisms, or a change in the magnitude of those mechanisms. These assumptions must be made understanding certain caveats. Material transport is dependent on the discharge, and thus bed material composition collected at one discharge under many circumstances would be expected to change under a different discharge (but may not, in the cases a bed consisting of a non-erodible material or a bed that has armored). Even for a similar discharge, the bed material may be different, due to sediment source exhaustion. Localized hydraulic effects across the channel cross section can also make a significant difference in bed material composition, such as the differences experienced in a bend from a bar to the thalweg. As such, any sampling effort represents a single snapshot in time, and it is best to look at bed material information for generalized trends on the feature- or reach-scale.

As a second indicator, knowledge of the bed material gives a sense of its erodibility; when coupled with a knowledge of flow rates, and thus an approximate sense of shear stresses, estimates of how much material will be transported can be developed. With an understanding of material mobility, assumptions can be made about changes in the channel cross section.

Data from two collection efforts of bed material were available on both the Mississippi and the Atchafalaya Rivers, allowing for comparisons between the two periods. Three statistical particle sizes were calculated: the median particle size, or D50; the particle size for which 16% of the material was finer, also known as the 16th percentile or D16; and the particle size for which 84% of the material was finer, also known as the 84th percentile or D84. The D16 and D84 were chosen as they represent one standard deviation from the median for a normal distribution. Given the variability described above in bed material, comparisons between the two collection

efforts were analyzed for general trends in grain class (e.g., silt/clay, very fine sand, fine sand).

Multibeam bathymetric surveys, collected over a short, known timeframe can be processed in such a way as to determine the rate of change of bed volume, or bedload rate. This was done for multiple locations within the OMAR System Technical Assessment reach using the ISSDOTv2 methodology (Abraham et al. 2011; Abraham et al. 2015). The bedload rate gives a measure of how actively the bed of the river is changing. This can be attributed to either the volume of sediment transported or the speed at which it is transported. Trends in bedload rate indicate whether the amount of sediment moving past a particular point are increasing, decreasing, or staying relatively constant. When these trends are known throughout a system, the differences in these trends between the points can indicate sediment storage or removal in a reach.

2.6.3 Boring logs

Boring logs are used to provide contextual clues as to reach stability beyond the surface information that can be collected from bed and bank samples. In particular, the temporary, mobile sediments of the bed may be covered by just a few inches of competent layers that are actually defining the channel's ability to deepen. To investigate locations where subsurface materials may be governing stability, boring logs were loaded into the Strater boring log management/visualization software. These logs were then compared to the thalweg depth to provide estimates as to the material present at the thalweg elevation.

The boring logs were provided by the MVN.

2.7 Dredging records

Dredging records provide a history of when and to what amount of material removal was necessary to maintain authorized dimensions on a navigation channel. Although records can be analyzed for trends to help determine if a particular channel reach was aggradational, there is uncertainty when analyzing dredging records, and therefore the results must be viewed with caution.

2.8 Site visit

A site visit was conducted to the Atchafalaya, Red, Black, and Old Rivers on November 18–19, 2021. The purpose of the visit was to visually inspect the river systems for indicators of short- or long-term geomorphic change or evidence of cause-and-effect relationships. A secondary purpose was the collection of bank and bed sediment samples. The trip report from site visit is included in Appendix B. Major findings are summarized below in Section 3.6 of the report.

2.9 Events timeline

A chronology of the major river engineering activities within the study reach was developed for the study time period. The chronology was based on histories of the basin (Reuss 1998) and the ORCC (Barnett, Jr. 2017) and USACE project documentation. Information gleaned from this task was primarily used to add insight to the interpretation of the results from other analyses presented in this report.

2.10 Integration

The integration component of the geomorphic assessment blends the results from all of the analyses conducted as part of the geomorphic assessment and forms the basis for the comprehensive understanding of the study reaches. The primary analyses relied on for forming a geomorphic understanding of the study area were the geometric analysis and specific gage records; the other analyses were used to supplement these analyses. The results from each analysis are combined to establish the trends in river morphology and sedimentation from an historic perspective. In some cases, the trends indicated by the different techniques agree. However, in many instances, the techniques may produce conflicting results. The confidence placed on a specific technique may vary depending on the reach in question or the time period being considered.

3 Results

The following subsections highlight individual analyses undertaken by type of analysis, followed by a breakdown by reaches if needed.

3.1 Geometric data

The results below are reach-scale summaries taken from the report detailing the geometric analysis. The report is featured in its entirety in Volume 3. A comparative analysis of geometric trends was not possible for the Red River at this time due to the lack of digital forms of historic bathymetric surveys. The time periods chosen reflect the availability of comprehensive surveys for comparison.

3.1.1 Mississippi River geometric analysis

3.1.1.1 *Natchez to Vicksburg*

The morphological trends for the Vicksburg to Natchez reach display some variability in the geometric parameters and channel volume over the time period (1915–2013) but are generally stable over the period. The period 1915 to 1948 is characterized by aggradation, the period 1948 to 1975 by slight degradation to being in dynamic equilibrium, and 1975 to 2013 by slight aggradation. The time periods chosen reflect the availability of comprehensive surveys for comparison.

3.1.1.2 *ORCC Low Sill Structure Inlet to Natchez*

The morphological trends for the Natchez to the ORCC Low Sill Structure Inlet (RM 314) reach typically display more variability in the geometric parameters and channel volume over the time period (1915–2013). Median values of cross-sectional area, hydraulic depth, and channel volume from 1915 to 1963 generally indicate slight aggradation to in dynamic equilibrium during this period. The reach appears slightly degradational to being in dynamic equilibrium from 1963 to 1988 and slightly aggradational to being in dynamic equilibrium from 1988 to 2013.

3.1.1.3 Baton Rouge to ORCC Low Sill Structure Inlet

The predominant morphological trends for the ORCC Low Sill Structure Inlet to Baton Rouge reach during the time period (1915–2013) are that the reach was aggradational from 1915 to approximately 1975, then less aggradational to being in dynamic equilibrium from then to 2013.

Reduction in median values of cross-sectional area, hydraulic depth, and channel volume from 1915 to 1975 indicate general aggradation during this period. This aggradational trend is consistent with the findings of Winkley (Winkley 1977), which found the loss of depth at Red River Landing and below back to 1880. Although values fluctuate from 1994 to 2013, the median values of these parameters are generally stable to slightly decreasing, indicating a channel near dynamic equilibrium but still slightly aggradational.

3.1.1.4 Mississippi reach summary

A reach summary based on the geometric data analyses was compiled for easy visual comparison of reach trends (Figure 6).

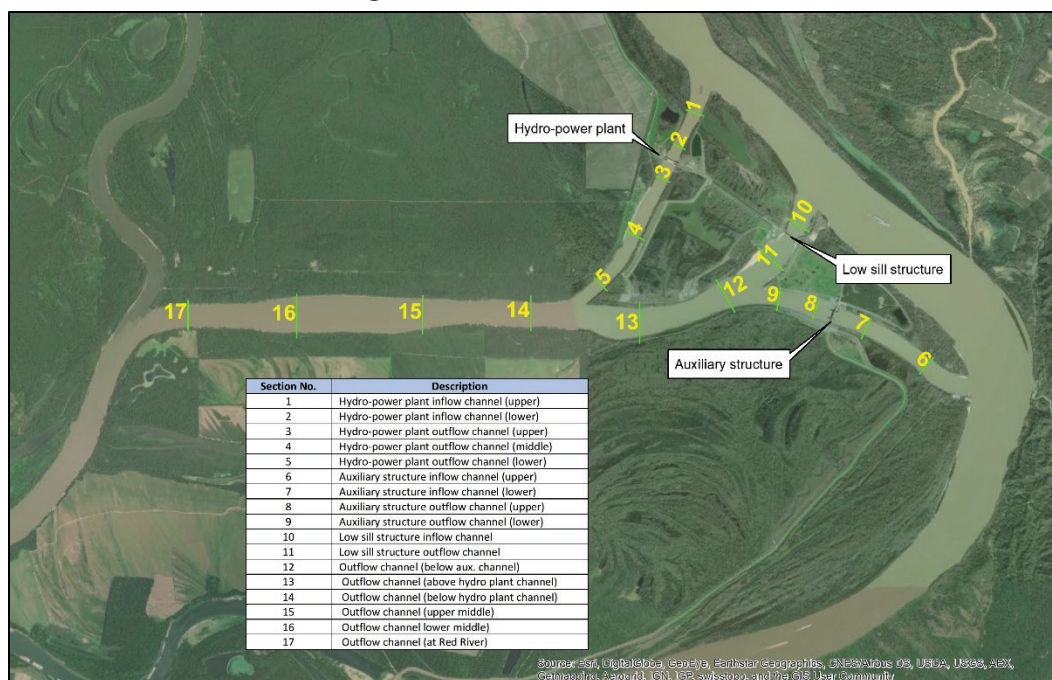
Figure 6. General geomorphic trend summary for Mississippi River reaches.

General Geomorphic Assessment by Reach Based on Geometric Parameter and Volumetric Analyses								
Reach No.	Reach Description	Survey Time Periods						
		1915 to 1948	1948 to 1963	1963 to 1975	1975 to 1988	1988 to 1994	1994 to 2004	2004 to 2013
3	Natchez, MS to Vicksburg, MS (RM 363-435)	Aggradation	Transitional Aggradation to DE	Transitional Degradation to DE	Aggradation	Dynamic Equilibrium	Dynamic Equilibrium	Dynamic Equilibrium
2	ORCC low sill structure inlet to Natchez, MS (RM 314-363)	Aggradation	Aggradation	Transitional Degradation to DE	Transitional Degradation to DE	Dynamic Equilibrium	Dynamic Equilibrium	Dynamic Equilibrium
1	Baton Rouge to ORCC low sill structure inlet (RM 230-314)	Aggradation	Aggradation	Aggradation	Dynamic Equilibrium	Dynamic Equilibrium	Dynamic Equilibrium	Dynamic Equilibrium
		Aggradation	Transitional Aggradation to DE	Dynamic Equilibrium	Transitional Degradation to DE	Degradation		

3.1.2 Old River geometric analysis

Given the limited channel lengths, specific cross sections were analyzed for Old River. The locations of these cross sections are presented in the following Figure 7.

Figure 7. Old River cross sections.



3.1.2.1 Hydropower Plant inflow and outflow channels

The time period begins with the first survey (1992) subsequent to opening of the hydropower plant and continuing through 2013. Observed trends of cross-sectional area, hydraulic depth, and channel volumes indicate the inflow and outflow channel for the hydropower plant experienced degradation from 1992 to 2004, with the outflow channel showing the most degradation. Channel volume for the outflow channel nearly doubled referenced to the LWRP and increased approximately 30% referenced to bankfull conditions. This time period encompassed the majority of the observed channel adjustment, as trends from 2004 to 2013 showed little to no change, suggesting that the channel is approaching a state of dynamic equilibrium. Of interest is the relative size to which the channels have adjusted, with the outflow channel volume increasing to approximately twice that of the inflow channel (detailed more in the geometric analysis in Volume 3).

3.1.2.2 Low Sill Structure inflow and outflow channels

The time period begins with the first survey (1963) subsequent to opening of the Low Sill Structure and continuing through 2013. Observed trends in cross-sectional area, hydraulic depth, and channel volume indicate the

inflow channel for the Low Sill Structure has generally experienced aggradation from 1963 to 2013. Cross-sectional area and hydraulic depth for the inflow channel have decreased over the time period, and widths have slightly decreased as well.

Conversely, the Low Sill Structure outflow channel from the structure to the auxiliary structure outflow channel has undergone general degradation over the time period, although the trends in geometric parameters and channel volume are more variable. The variability in observed channel geometry may be a result of the change in operation frequency of the low sill structure since the Auxiliary Structure and Hydropower Plant were placed in operation. Note that this segment of the outflow channel conveys flows released from the Low Sill Structure. The remainder of the ORCC Outflow channel will be addressed later as a single reach.

3.1.2.3 Auxiliary Structure inflow and outflow channels

Based on the observed trends of the geometric parameters and channel volume for the period from 1992 to 2013, the inflow channel of the Auxiliary Structure has demonstrated periods of aggradation and degradation. This is most likely due to the inflow channel acting as a sediment trap and the ensuing sediment flushing activities. There is some uncertainty in the trends, as the channel volume tends to show less variability than the geometric parameters. In general, the Auxiliary Structure outflow channel indicates little change over the time period and is at or near a state of dynamic equilibrium.

3.1.2.4 Full outflow channel

The original outflow channel below the Low Sill Structure has been divided into three segments since the construction of the auxiliary structure and the Hydropower Plant. The segments are the Low Sill Structure to the confluence of the Auxiliary Structure outflow channel, the auxiliary outflow channel to the confluence of the hydropower plant outflow channel, and the hydropower outflow channel to the Red River. Since the addition of the structures, the three segments of the outflow channel have been subject to various combinations of water and sediment loads, dependent on structure operation. Only the segment from confluence of the Hydropower Plant outflow channel to the Red River has experienced the total load of water and sediment passed through the ORCC.

For the full outflow channel from the Low Sill Structure to the Red River, the general trend over the time period 1963 to 2013 has been a slowing rate of degradation to approaching the point of stopping, with the exception 1983 to 1992 when slight aggradation was observed. Overall, the channel volume of the full outflow channel referenced to bankfull conditions has increased approximately 75% from 1963 to 2013.

As mentioned earlier, the channels of the ORCC are greatly influenced by local effects from the structures and variations in structure operation activities. Attribution of observed changes in channel geometry to either local effects or long-term, reach-scale morphology trends is problematic.

3.1.3 Atchafalaya River geometric analysis

Reach-scale summaries were prepared in the geometric report (Volume 3 for three reaches on the Atchafalaya: Old River (RM 0) to the Whiskey Bay Pilot Channel (RM 55.4), the Whiskey Bay Pilot Channel to Grand Lake (RM 101), and Grand Lake to Morgan City, LA (RM 121). Given the focus of this report, only the results for the upstream reach, Old River to the Whiskey Bay Pilot Channel, are reported below.

The variability in trends displayed for the Old River to the Whiskey Bay Pilot Channel reach is very subtle, and in general, the reach is in or near a state of dynamic equilibrium for the survey time period of 1976 to 2019. The trends of cross-sectional area, hydraulic depth, and channel volume indicate slight aggradation to dynamic equilibrium from 1976 to 1998, and slight degradation to dynamic equilibrium from 1998 to 2019. Overall, this reach has been generally stable over the entire time period (1976 to 2019), with very slight periods of degradation and aggradation.

A study was conducted in 1951 by USACE for the Mississippi River Commission (USACE 1951) that focused on engineering and geological investigations of the enlargement of Old River and the Atchafalaya River. Due to very similar methodologies, the trends from the analysis could be extended even further back, as the 1951 effort utilized data from 1880 to 1950. The results of the 1951 study indicate the average cross-sectional area for the reaches from Old River to Whiskey Bay Pilot Channel increased from 1880 to 1950.

A reach summary based on the geometric data analyses was compiled for easy visual comparison of reach trends (Figure 8).

Figure 8. General geometric trend summary for Atchafalaya River reaches.

General Geomorphic Assessment by Reach Based on Geometric Parameter and Volumetric Analyses									
Reach No.	Reach Description	Survey Time Periods							
		1880 to 1916	1916 to 1931	1931 to 1950	1950 to 1976	1976 to 1989	1989 to 1998	1998 to 2010	2010 to 2019
1	Old River to Head of Whiskey Bay Pilot Channel (RM 0-56)								

	Aggradation
	Transitional Aggradation to DE
	Dynamic Equilibrium
	Transitional Degradation to DE
	Degradation

3.1.4 Mississippi River in the vicinity of ORCC reach

Given of the focus on the function of the ORCC, the decision was made to analyze the cross-sections in the immediate vicinity of the ORCC, taken as RM 317 to RM 311. The cross-sectional area at low water shows a decreasing trend in the median value from 1948 to 1988 (Figure 9). This fits with the larger reach analysis of the Lower Mississippi River from Vicksburg to ORCC and ORCC to Baton Rouge of being aggradational or slightly aggradational. Starting in 1988, the cross-sectional area, outside of an increase in 1994, does not show a significant trend towards aggradation or degradation. A similar trend is observed for the cross-sectional area at bankfull: a decrease in the median value from 1948 to 1988 followed by an increase in 1994 (Figure 10). However, 2004 and 2013 have interquartile behavior that is slightly higher than 1988 at bankfull.

Figure 9. Mississippi River RM 317–311, cross-sectional area at low water reference.

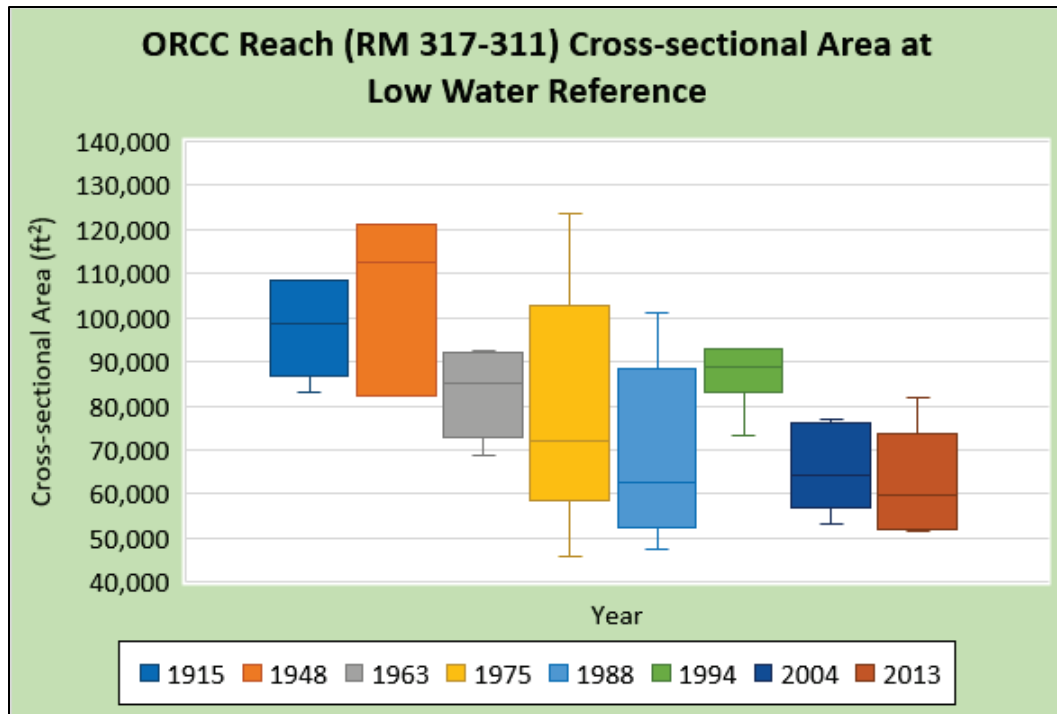
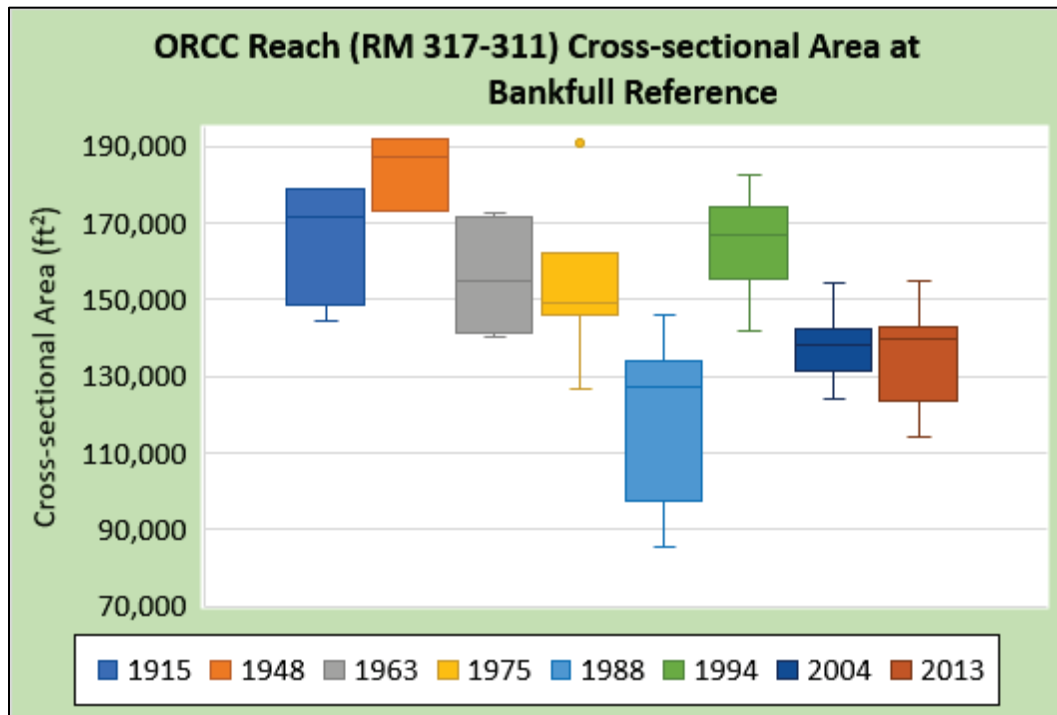


Figure 10. Mississippi River RM 317–311, cross-sectional area at bankfull reference.



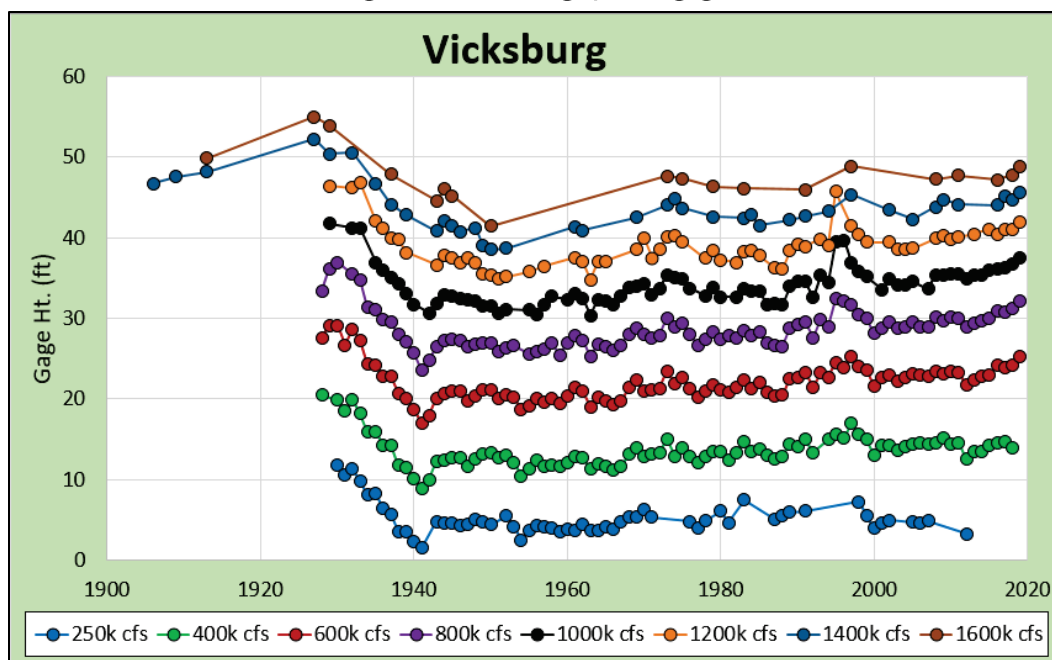
3.2 Specific gage

Note that on the topic of specific gage analysis is that stage changes for the same gage could be the result of different processes dependent on the flow: lower flows will still be within the banks of the channel whereas higher flows will have spilled onto the floodplain. As such, it is often important to consider that point out-of-bank flows occur. This point can change over time due to channel incision.

3.2.1 Mississippi River specific gage

The specific gage record for the Vicksburg gage is shown in Figure 11. Limited data are available at all but the higher flows to discern via specific gage analysis what was occurring before the 1930s at the Vicksburg gage. Starting in the 1930s and continuing into the early 1940s at the lower flows and approximately 1950 at the upper flows, the specific gage analysis indicates a system that was highly degradational. Much of the degradation reflects the initial response to the channel cutoff program on the Mississippi River between 1929 and 1942. After approximately 1950, the gage is slightly aggradational at all but the lowest flow.

Figure 11. Vicksburg specific gage.



The Natchez specific gage analysis (Figure 12) shows similar trends to the Vicksburg gage; an initial, albeit more subtle, degradational period in the late 1930s into the early 1940s, followed by a sustained aggradational period. One difference worth noting is that the lowest flow analyzed, 250,000 cfs, which stayed at relative dynamic equilibrium to potentially being degradational on the Vicksburg gage, is instead aggradational on the Natchez gage.

The Direct Step Method was also used to understand better the variability that may be hidden because of method selection. The Natchez direct step specific gage is shown in Figure 13. The Direct Step method captures that there is variability most noticeably in the 600,000 cfs to 1,200,000 cfs range. This results in the initial degradational trend becoming somewhat obscured, but the trend of a sustained aggradation after that period remains clear.

Figure 12. Natchez specific gage.

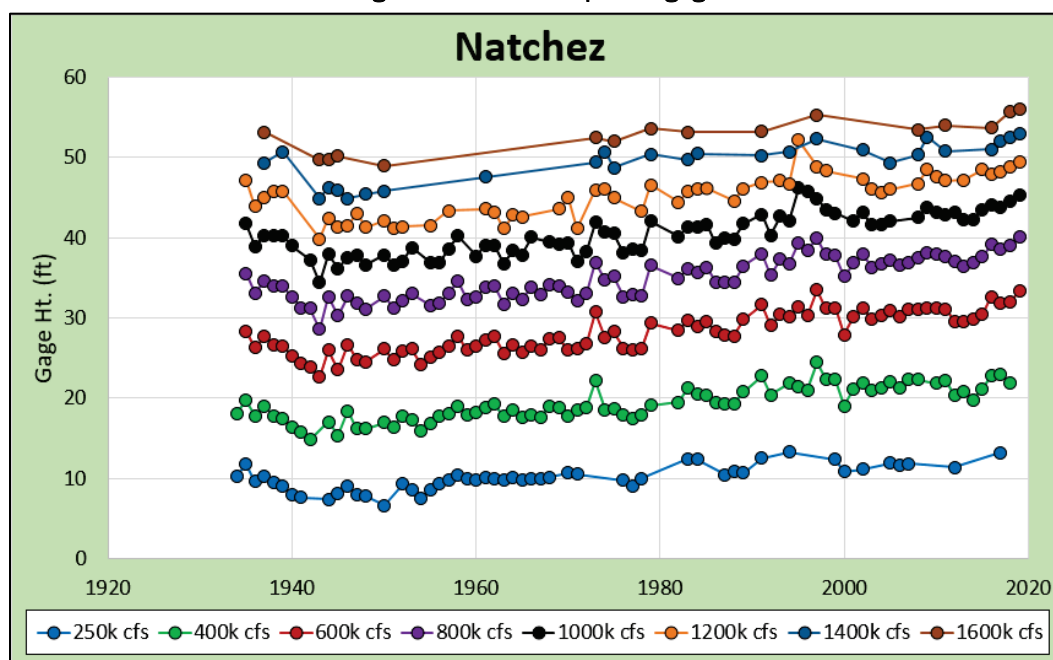
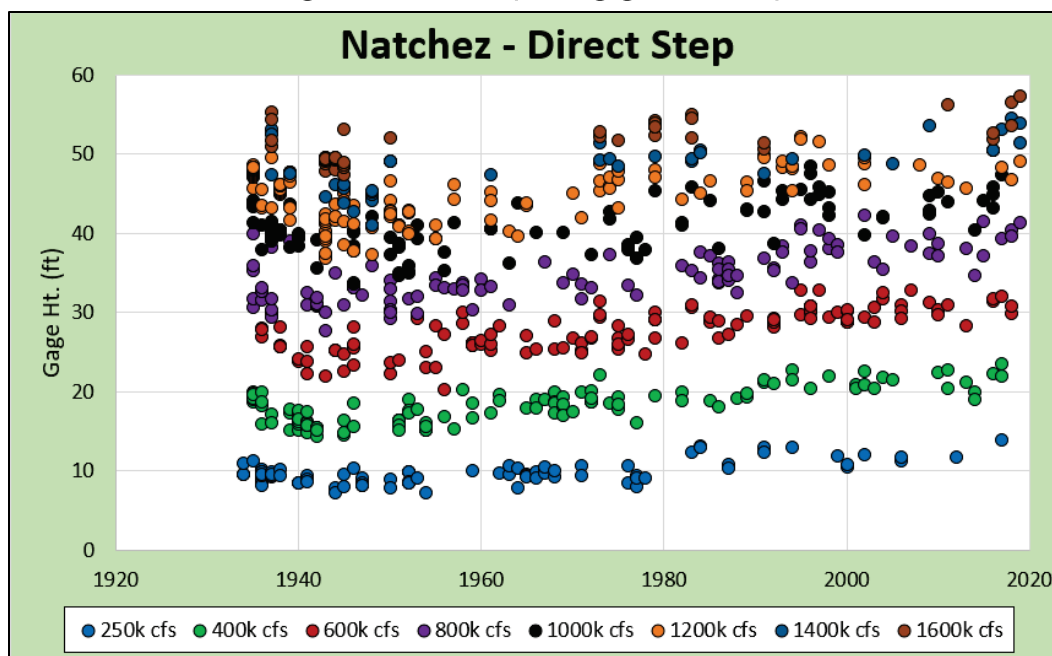


Figure 13. Natchez specific gage–Direct Step.



The combined Tarbert Landing–Red River Landing specific gage analysis (Figure 14) indicates an overall trend of aggradation over the last approximately 130 yr. Note the abrupt stage increases associated with the 1973 flood. Although the overall trends at this gage are aggradational, there is a period between the early 1940s and early 1970s that the mid–range to higher flows (above approximately 800,000 cfs) experienced a slight downward trend, which has yet to be fully explained.

The Direct Step Method for gage analysis (Figure 15) was once again done along with the Rating Curve method for the combination of the Tarbert Landing and Red River Landing gages to understand the variability. The Direct Step Method shows again more variability in the 600,000 cfs to 1,000,000 cfs range. The trends remain the same.

Figure 14. Tarbert Landing —Red River Landing combined specific gage.

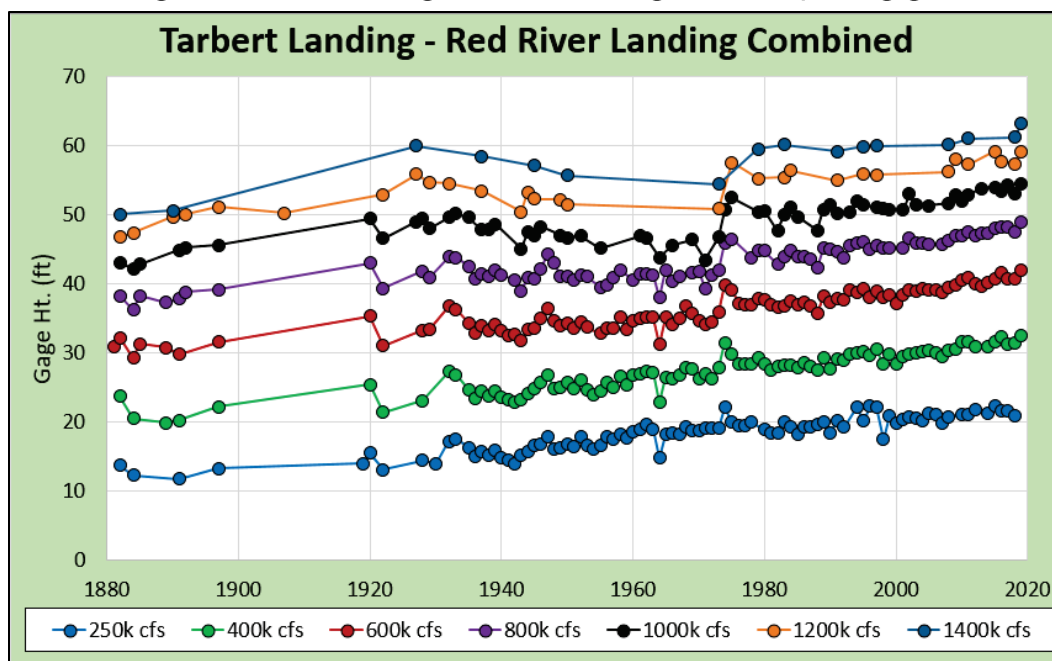
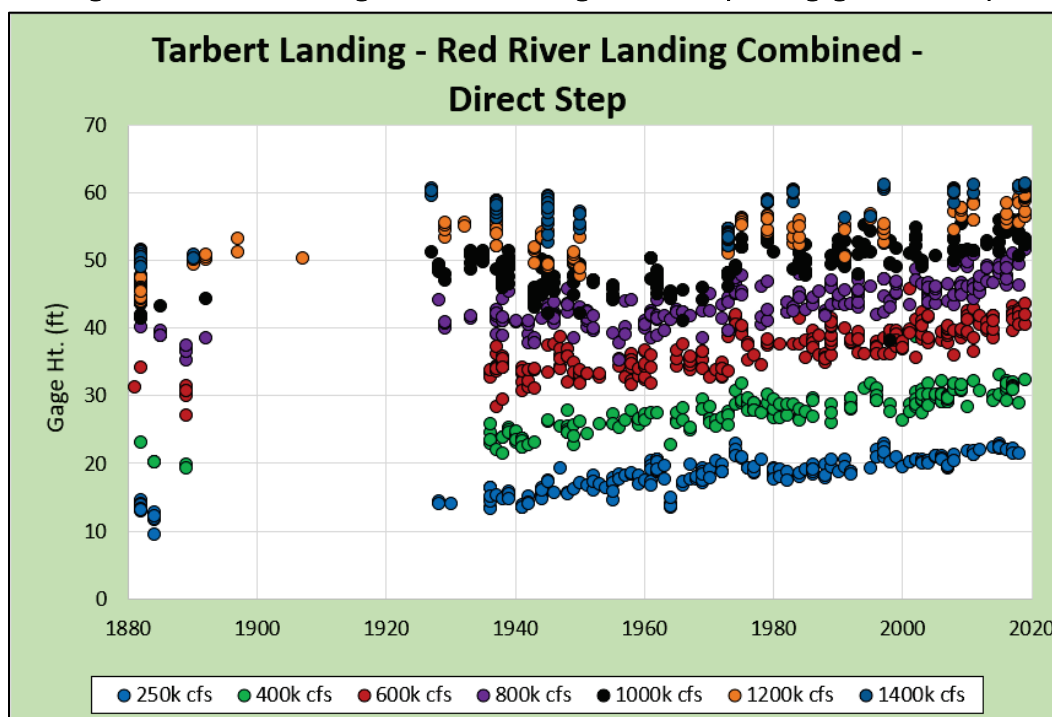


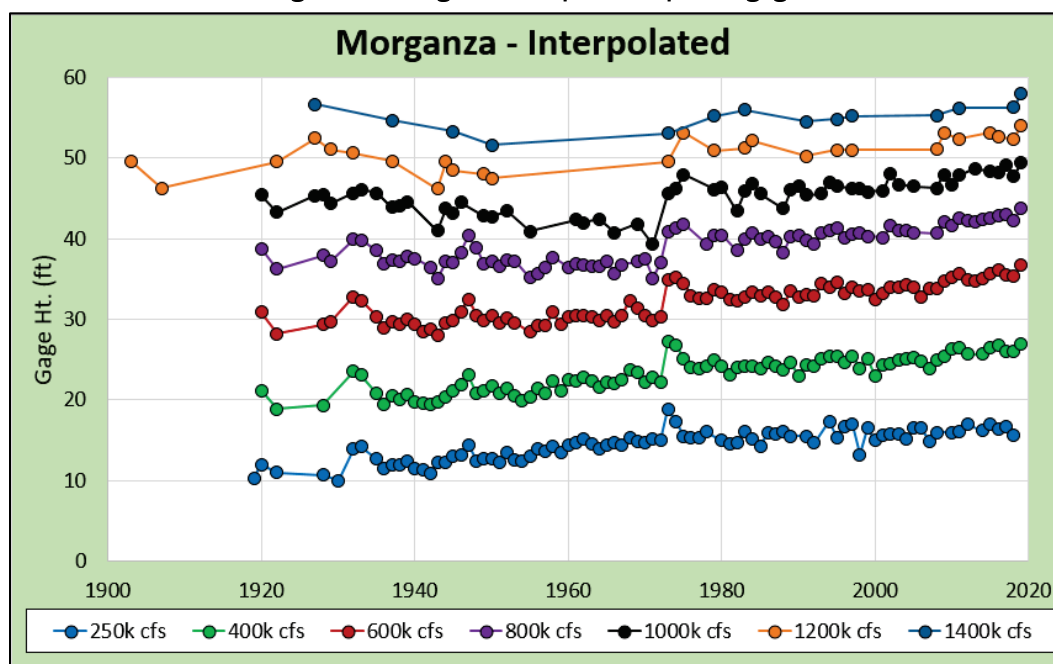
Figure 15. Tarbert Landing—Red River Landing combined specific gage—Direct Step.



One of the charge questions for the OMAR System Technical Assessment asks, “What are the impacts of sedimentation on operations of ORCC and the Morganza Structure?” To answer the latter half of that question better, a specific gage analysis was developed for the Mississippi River at Morganza (Figure 16). This was done by linearly interpolating the stage between Red River Landing and Bayou Sara (with the Bayou Sara gage extended from 2015 to 2019 based on a correlation to the St. Francisville gage) for River Mile 280 (the location of Morganza) and using the measured discharges from Red River Landing and Tarbert Landing. The gage primarily used for making Morganza operational decisions is gage MFI-4 located at the northern extent of the Morganza forebay; it is important to recognize there will be local water surface affecting the actual gage performance at the structure leading to differences from the results of this interpolation effort.

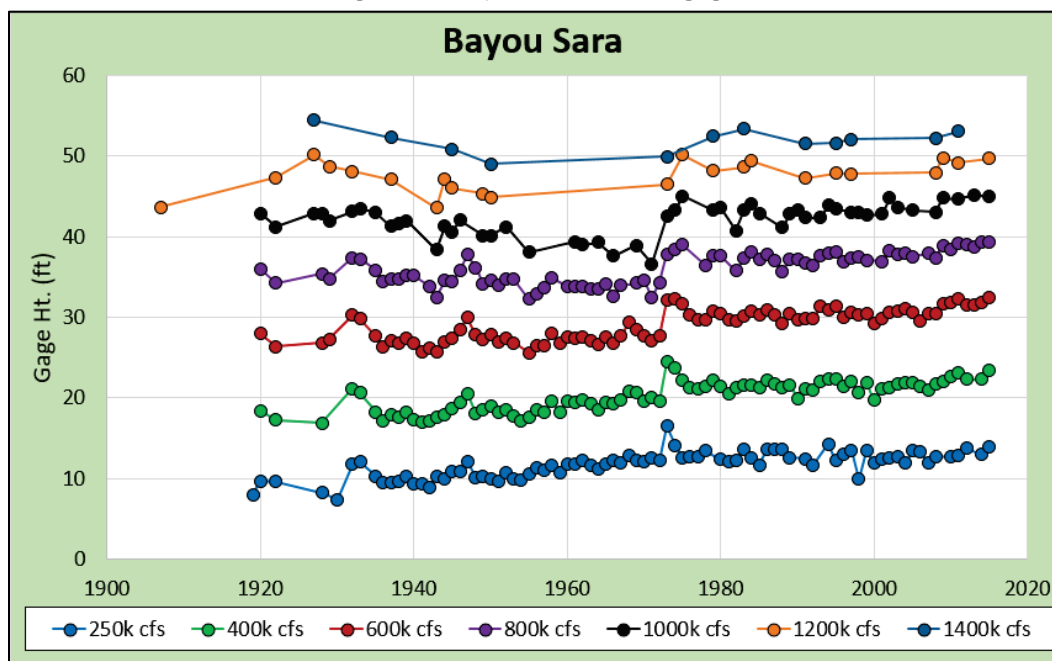
The specific gage analysis suggests stages have been slightly increasing in recent years, but the level of increase is difficult to determine due to the limited period, and thus would not be expected to be statistically significant.

Figure 16. Morganza interpolated specific gage.



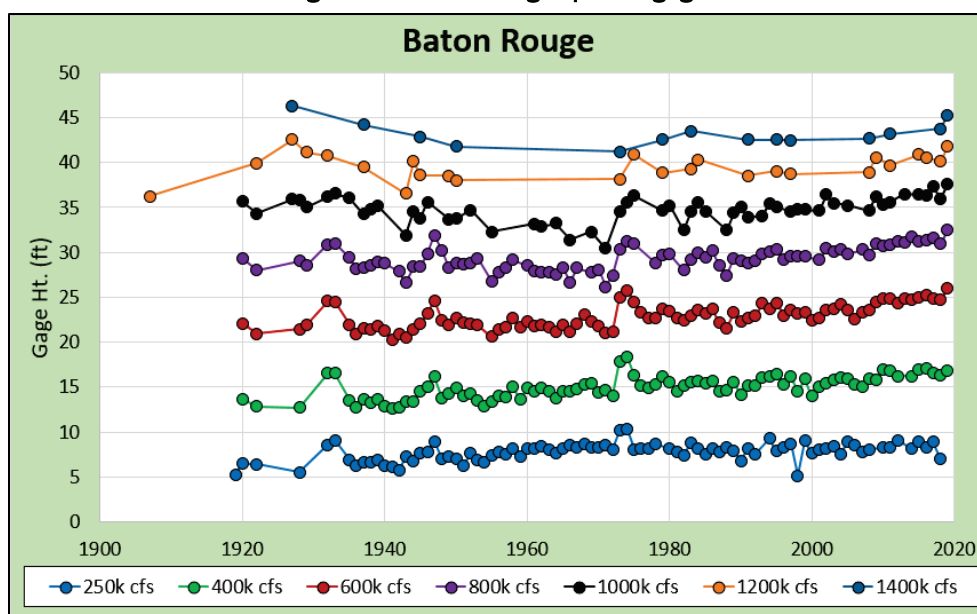
The trends of the Bayou Sara specific gage analysis (Figure 17) are similar to the Tarbert Landing–Red River Landing analysis. One change to Bayou Sara from Tarbert Landing–Red River Landing is in the lower flows; the Bayou Sara lower flows are more indicative of the lower portions of the cross section of the reach being in dynamic equilibrium as compared to still being aggradation as at Tarbert Landing–Red River Landing.

Figure 17. Bayou Sara specific gage.



The Baton Rouge specific gage analysis (Figure 18) shows similar trends to the Bayou Sara analysis.

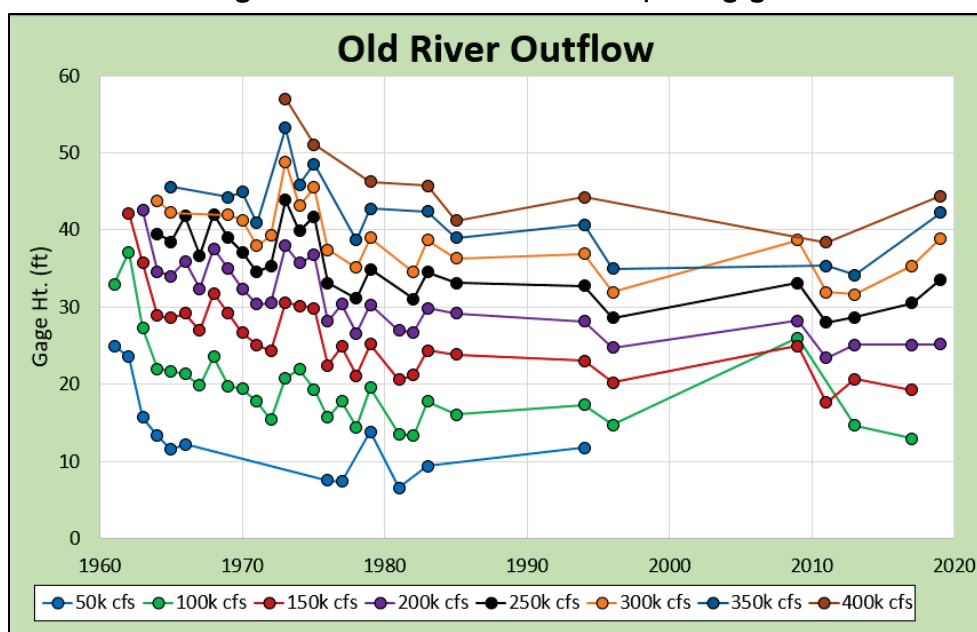
Figure 18. Baton Rouge specific gage.



3.2.2 Old River specific gage

The Old River outflow specific gage analysis (Figure 19) shows a general, though noisy, trend of degradation until the early 1980s. The gage record depicts the stage increases associated with the 1973 flood. From the early 1980s on, the limited data points impact the feasibility of detecting the precise trends.

Figure 19. Old River outflow channel specific gage.



3.2.3 Atchafalaya River specific gage

The Simmesport specific gage analysis shown in Figure 20 demonstrates a degradational trend from approximately the 1930s until the 1980s, followed by a period of dynamic equilibrium from the 1980s to the present. This trend extends even further back to the 1890s for the lower flows. The magnitude of the stage decreases (approximately 25 ft for multiple flows) is considerable.

The Direct Step Method for gage analysis (Figure 21) was done along with the Rating Curve method for the Simmesport gage. There is not as much variability in the results as those seen on the Direct Step Method plots for the Mississippi River gages. The trends remain the same.

Figure 20. Simmesport specific gage.

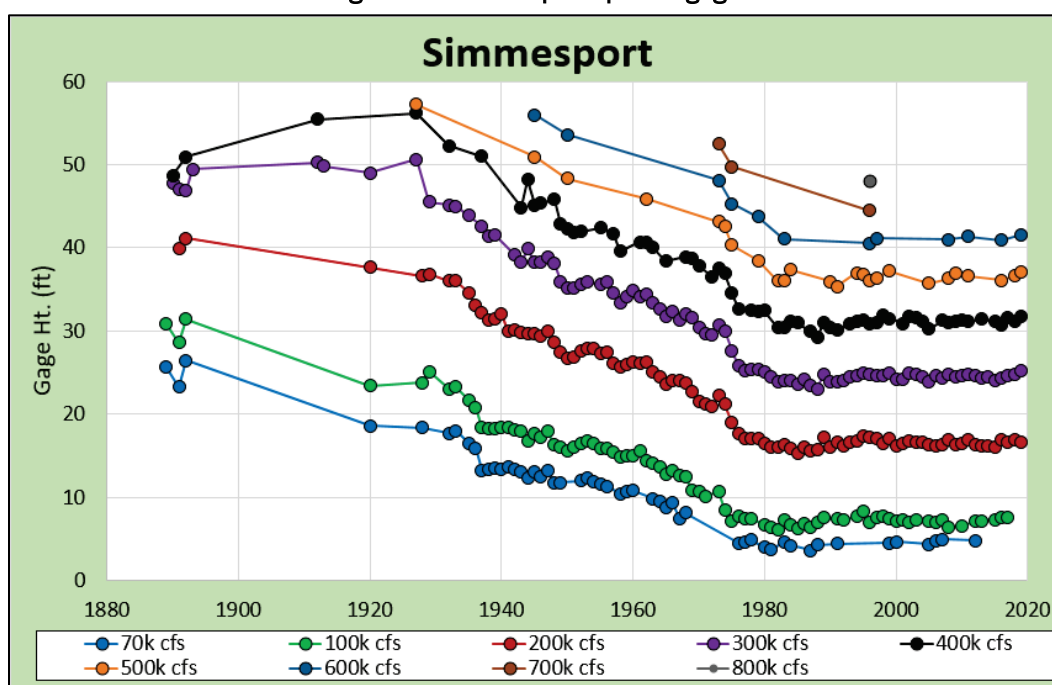
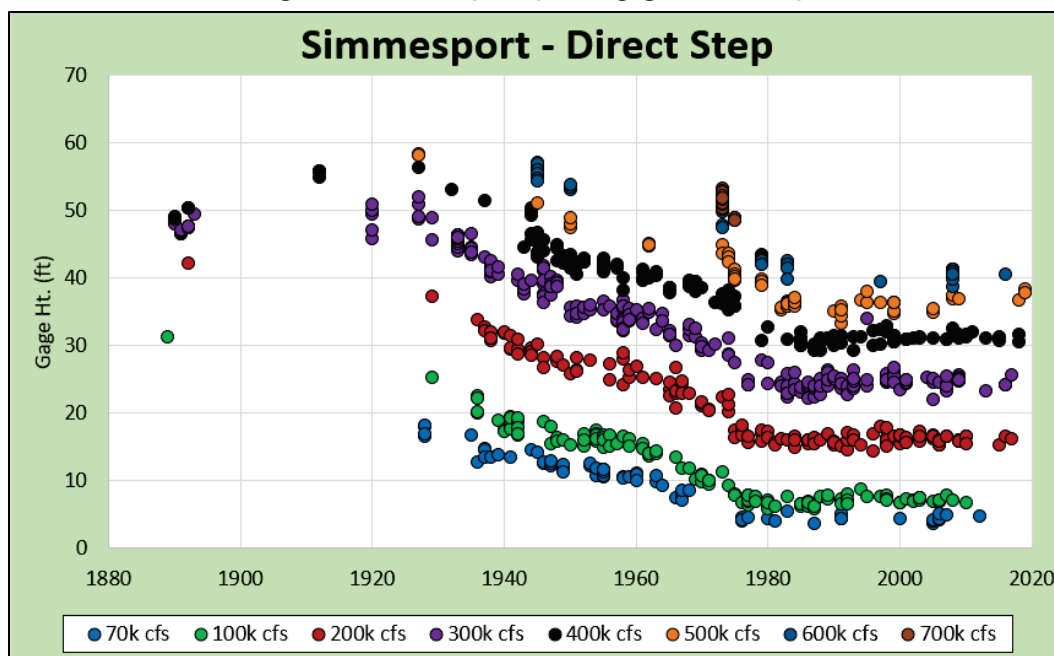
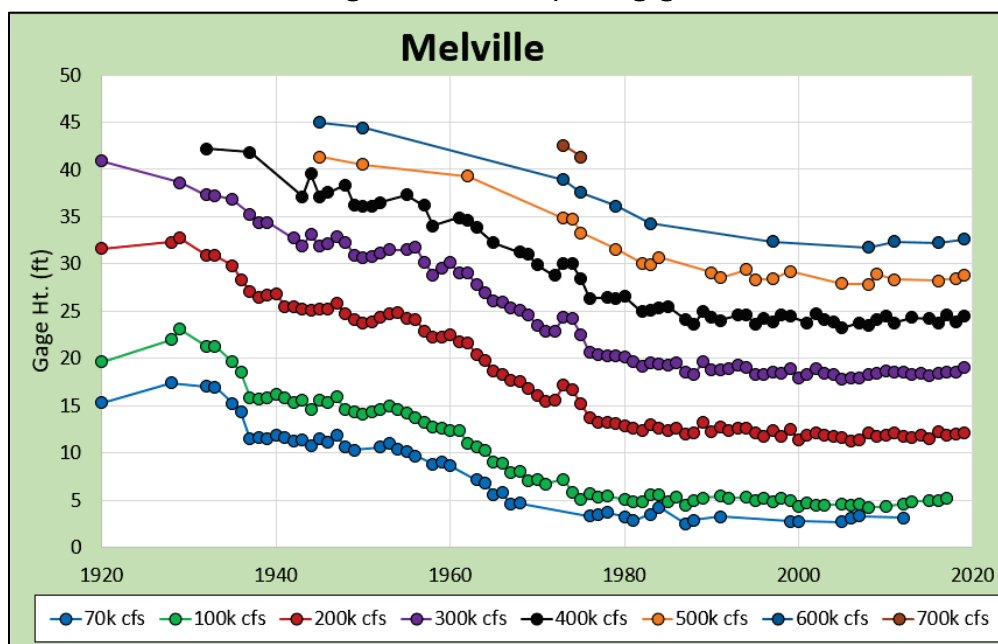


Figure 21. Simmesport specific gage-Direct Step.



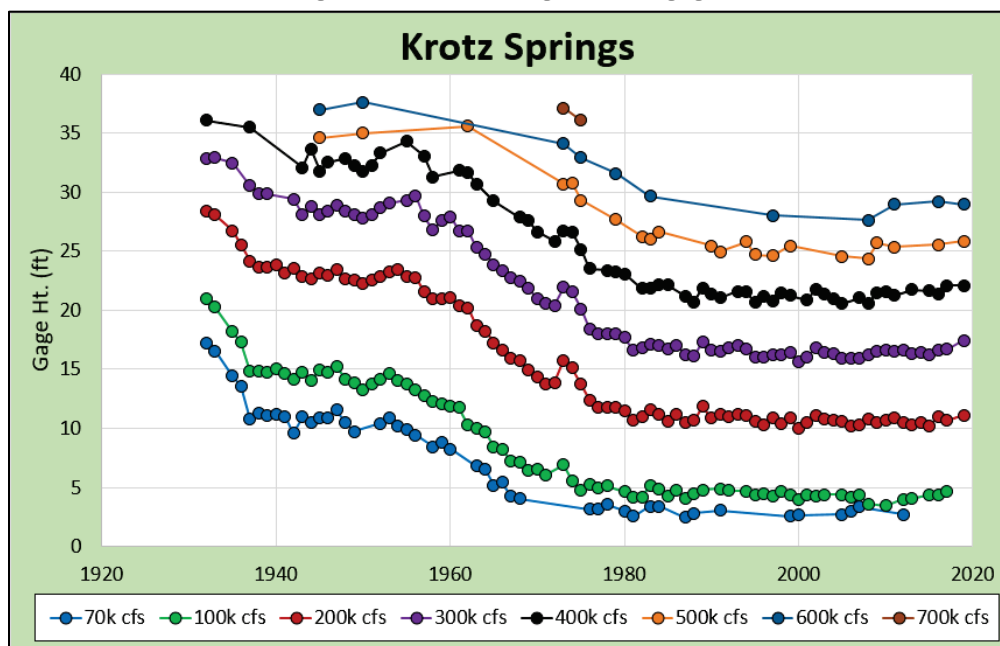
The Melville specific gage analysis (Figure 22) follows the same trends of the upstream gages. Like the Simmesport gage, the Melville gage shows a pronounced drop in the mid-to-late 1930s. The transition from a degradational regime to that of dynamic equilibrium is not as abrupt for the Melville gage as it is for the Simmesport gage.

Figure 22. Melville specific gage.



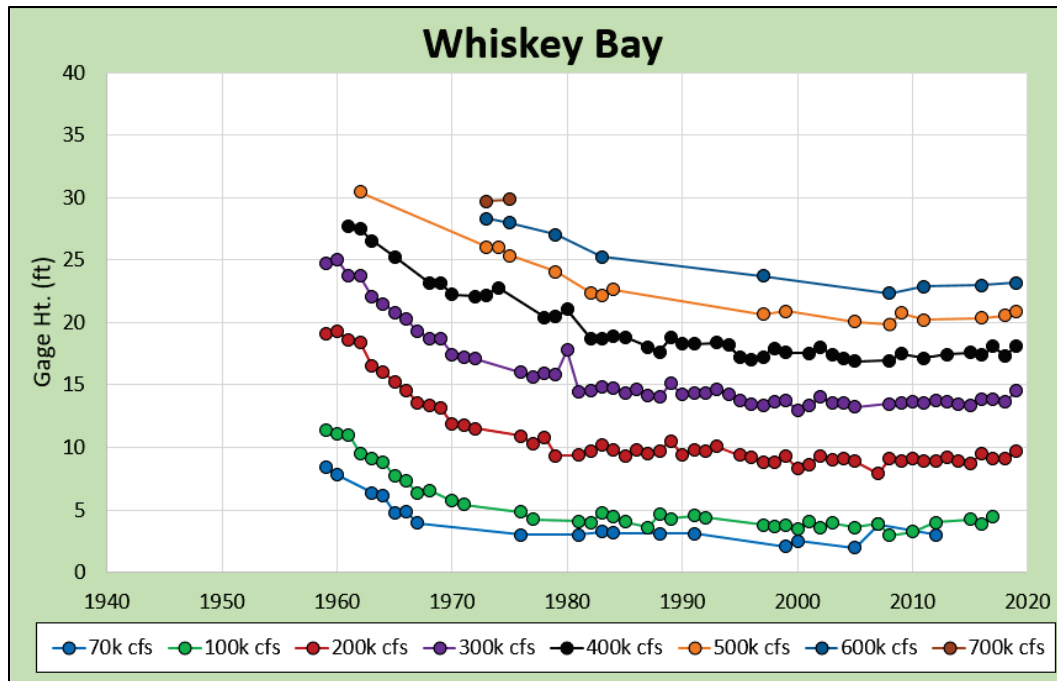
The Krotz Springs specific gage analysis (Figure 23) has the same general trends as the two upstream gages but shows a more pronounced plateau (representing a channel more in dynamic equilibrium than degradational) in the stage readings from the late-1930s to the early 1960s than the upstream gages. Degradation then continues until the early 1980s, after which the channel appears to be in a state of dynamic equilibrium.

Figure 23. Krotz Springs specific gage.



The Whiskey Bay specific gage analysis shown in Figure 24 demonstrates the same trends as the three upstream gages but with the smoother transition from being degradational to that of dynamic equilibrium seen similarly on the Melville gage.

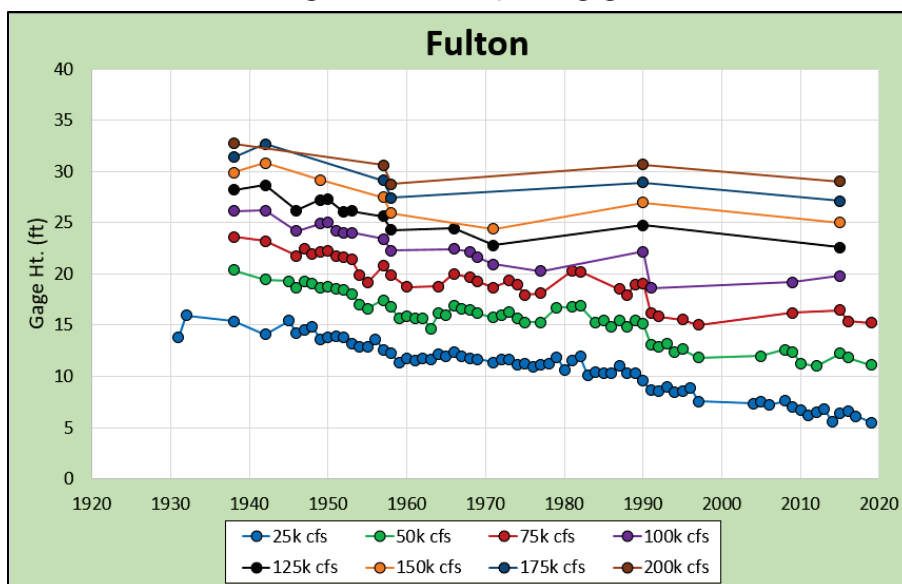
Figure 24. Whiskey Bay specific gage.



3.2.4 Red River specific gage

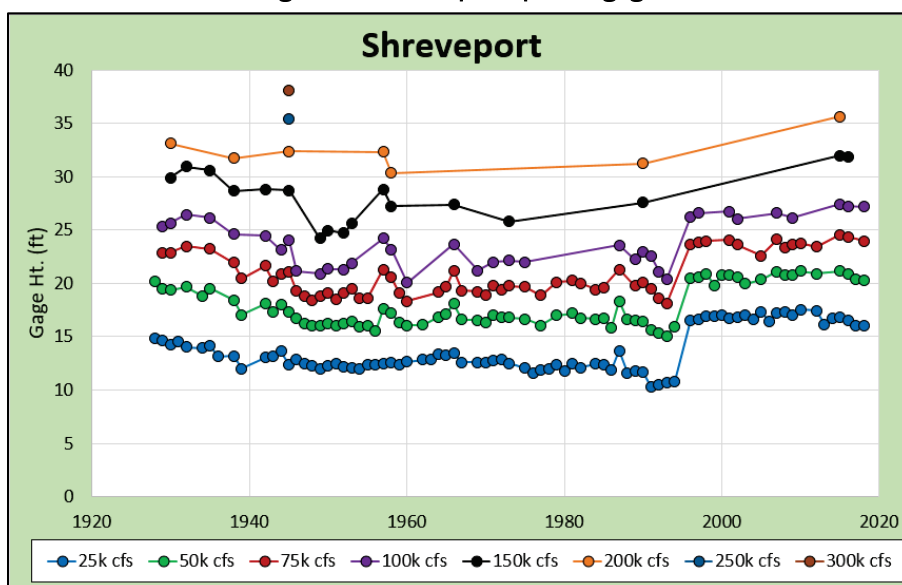
The Fulton gage is located upstream of the J. Bennett Johnston Waterway Project and therefore is very far upstream of the OMAR System Technical Assessment area. However, the Fulton gage does speak to the overall geomorphic trends of the Red River and thus was analyzed. The Fulton specific gage analysis (Figure 25) indicates a reach that has been degradational for the period that data were available, with the lower stages dropping approximately 10 ft in approximately 80 yr. Limited points for the higher stages preclude the determination if the behavior for out-of-bank flows is different.

Figure 25. Fulton specific gage.



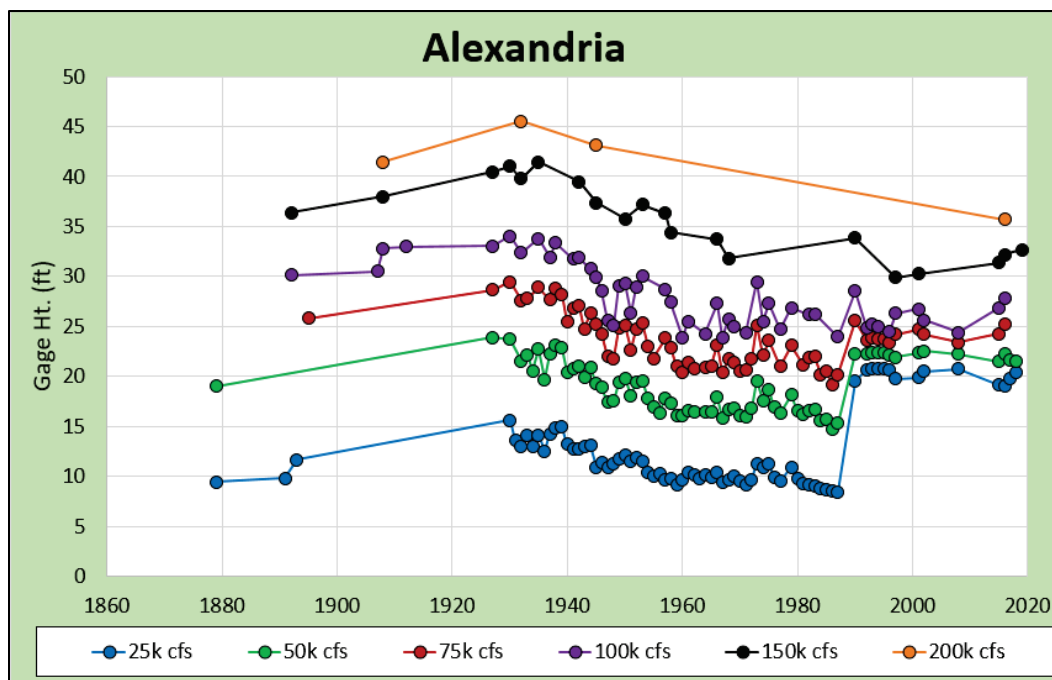
The Shreveport gage, like the Fulton gage, is outside of the OMAR System Technical Assessment area but serves as another data point for the geomorphic trends of the Red River. The Shreveport specific gage analysis (Figure 26) shows the same degradational trend before the construction of Red River Lock and Dam No. 5 (Joe D. Waggoner, Jr., Lock and Dam) as that seen on the Fulton gage but at a lower rate of degradation (approximately 5 ft in approximately 65 yr). The effects of Lock & Dam No. 5 are also clearly shown since it was put into operation in 1995.

Figure 26. Shreveport specific gage.



The Alexandria specific gage record shown in Figure 27 shows similar degradational trends to the upstream gage prior to the opening of Red River Lock and Dam No. 2 (John H. Overton Lock and Dam) in 1989. The degradation rate at Alexandria pre-damming is the highest of the three gages, with the stage decreasing approximately 10 ft in approximately 60 yr.

Figure 27. Alexandria specific gage.

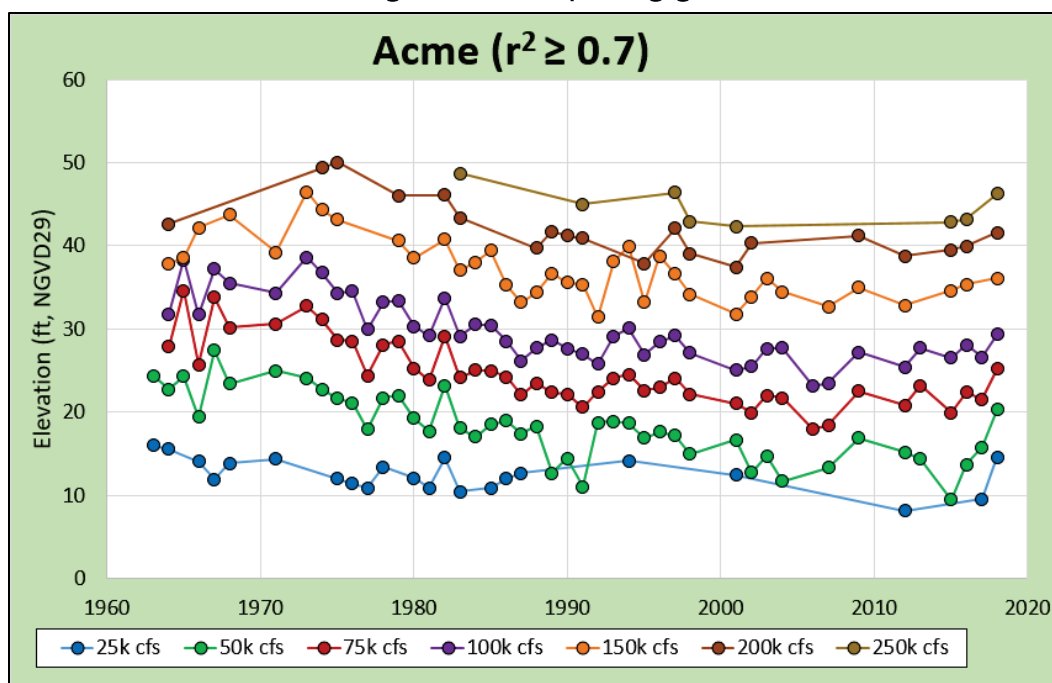


A synthetic specific gage analysis was developed for the Black River at Acme to understand the behavior of the Red River below Red River Lock and Dam No. 1 (L. C. Boggs Lock and Dam) better. The gage at Acme is just upstream of the Black River's confluence with the Red River, and thus trends experienced by the combined flow of the Red River and Black River could reasonably be expected to be reflected in the Acme gage's behavior. The specific gage is synthetic in that flow measurements were not collected for the period analyzed. Instead, the discharge at this point was taken as the difference between the Simmesport daily discharge and the Old River Outflow Channel daily discharge, representing a combined discharge from the Red and Black Rivers. As a further complication, the lower Red River can experience significant backwater effects from the portion of the Mississippi River flow diverted through the Old River Outflow Channel. To account for this, the difference between the Acme and Barbre Landing gages was calculated for each day. For days where the difference between the two gages was less than 3 ft, the stages and discharges were removed,

as the channel was understood to be effected by backwater conditions. One final complication encountered when developing the specific gage analysis was that the procedure of filtering the values developed from the Specific Gage Tool by an r^2 value of 0.9 was found to leave little data for analysis. For this specific gage analysis, an r^2 value of greater than or equal to 0.7 was used instead of 0.9.

The Acme specific gage follows the trend of the other specific gage analyses on the Red River in showing a degradational trend from the 1960s to the 1980s. The Acme specific gage suggests this degradational trend continued until approximately 2000 (Figure 28), past the completion of the lock and dam system on the Red River (Lock and Dam No. 1 was put into operation in 1984). Past approximately 2000, the analysis suggests the channel was approximately in dynamic equilibrium, with the most recent points suggesting the channel may be aggradational. As with other analyses, it is recommended to wait to see if the most recent points represent a true trend or a temporary deviation before drawing a conclusion.

Figure 28. Acme specific gage.



3.3 Slope and stream power

Slope and stream power can be important surrogates for understanding sediment transport through a reach. These relationships were developed

for reaches within the OMAR study reach as outlined in Table 9 through Table 11.

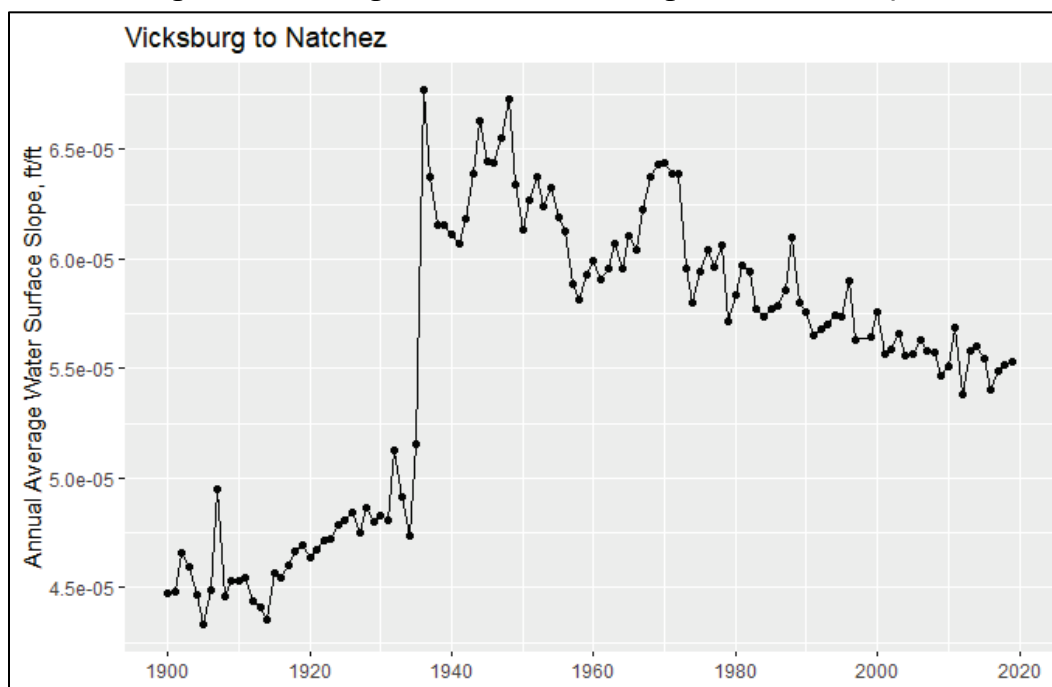
3.3.1 Mississippi River slope and stream power

3.3.1.1 Slope

Annual average water surface slope and stream power plots were generated for five reaches of the Mississippi: Vicksburg (RM 437) to Natchez (RM 363.3) (abbreviated “Vck-Ntc”); Natchez to Knox Landing (RM 313.7) (abbreviated “Ntc-KnL”); Knox Landing to Red River Landing (RM 302.4) (abbreviated “KnL-RRL”); Red River Landing to Bayou Sara (RM 265.4) (abbreviated “RRL-ByS”); and Bayou Sara to Baton Rouge (RM 228.4) (abbreviated “ByS-Btn”).

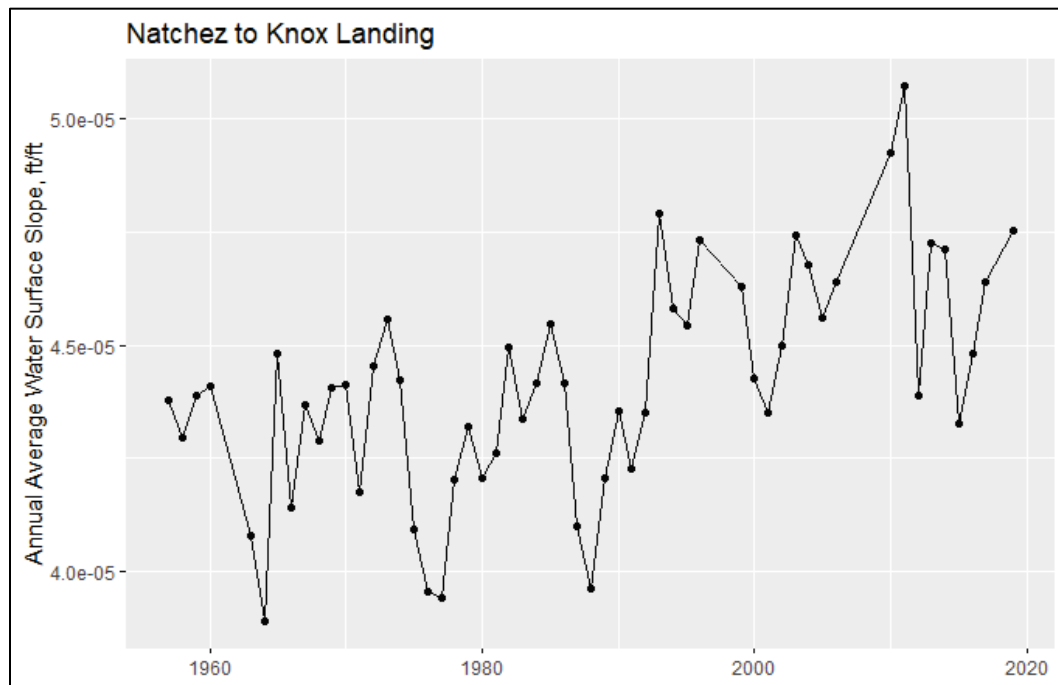
The annual average water surface slope for the Vicksburg-to-Natchez reach for the period 1900 to 2019 (Figure 29) was trending slightly upward until a significant jump in 1936. These slope increases are consistent with the multiple cutoffs constructed in this reach. Post 1936, the annual average water slope experienced annual variations, yet a continuing decreasing trend.

Figure 29. Vicksburg-to-Natchez annual average water surface slope.



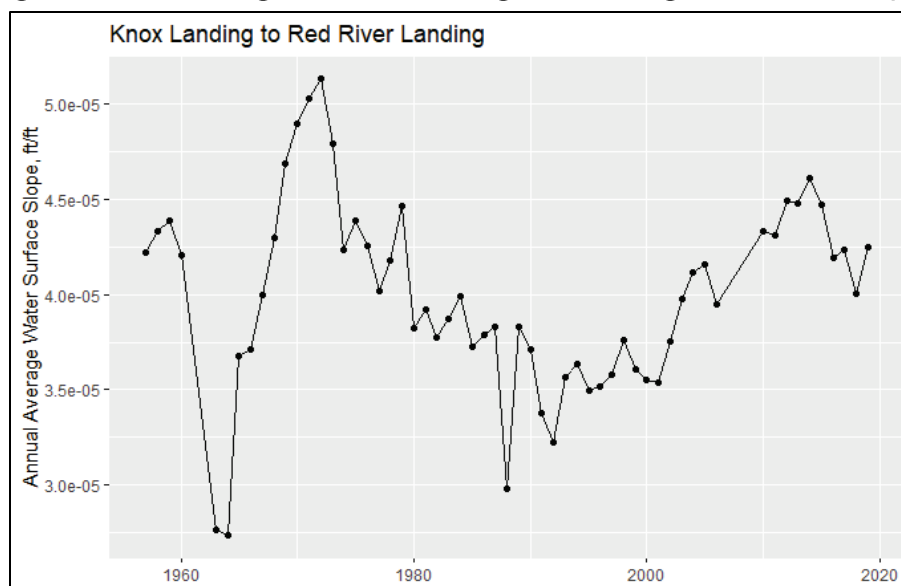
The general trend for the average annual slope between Natchez and Knox Landing experienced annual variations but has been increasing for the available period of record (1957–2019) (Figure 30).

Figure 30. Natchez-to-Knox Landing annual average water surface slope.



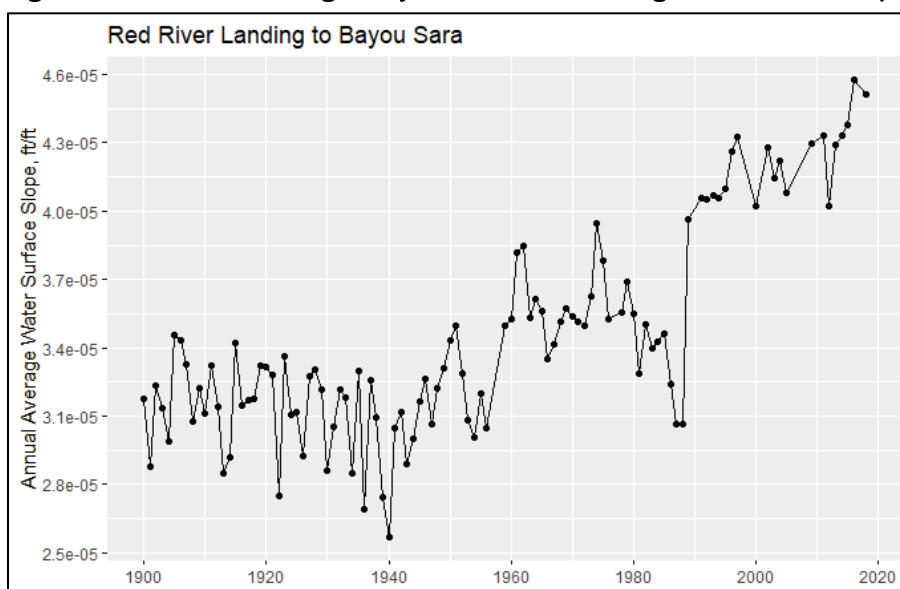
The annual average water surface slope for the Knox Landing-to-Red River Landing reach (Figure 31) includes annual variations throughout the 1957 to 2019 period of record. The slope through this reach decreased dramatically between 1960 and 1963 (right after the construction of the Old River Low Sill Structure and the construction period for the Old River Lock). The annual average slope rebounded and continued to increase until beginning to decrease again in 1973 (correlating with the 1973 Mississippi River Flood) and continuing to decrease until the early 1990s. The average annual slope began an increasing trend between the early 2000s and approximately 2015, with a slight decrease after that.

Figure 31. Knox Landing-to-Red River Landing annual average water surface slope.



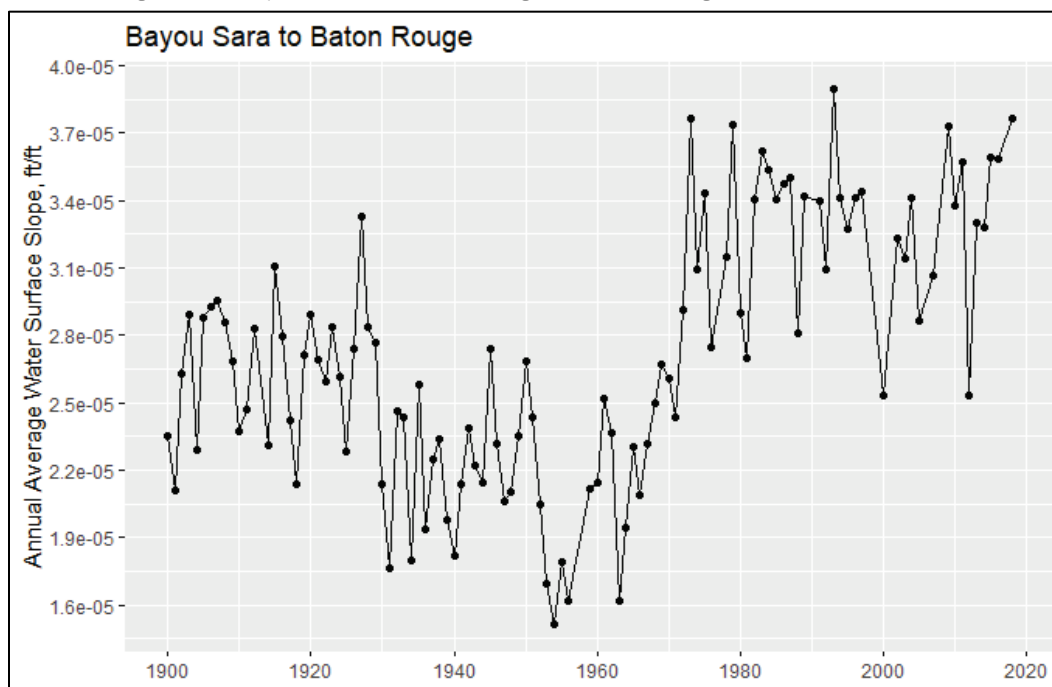
The average annual slopes for the Red River Landing-to-Bayou Sara reach for the 1900 to 2019 period of record is shown in Figure 32. The slopes experienced annual variations throughout the period of record. The general trend for the Red River Landing to Bayou Sara for the average annual slope is decreasing until the early 1940s. The trend then begins increasing until the mid-1970s, and then begins to decrease again. A dramatic jump occurs in 1989, followed by an increasing trend. The reason for the dramatic jump in 1989 was investigated, but the exact cause was not identified.

Figure 32. Red River Landing-to-Bayou Sara annual average water surface slope.



The average annual water surface slope from Bayou Sara to Baton Rouge (Figure 33) like the other reaches shows annual variations throughout the 1900 to 2019 period of record. Specifically, the slope shows a decreasing trend until a dramatic jump in the early 1970s that correlates to the 1973 Mississippi River flood. Post flood, the slope is higher than previously recorded.

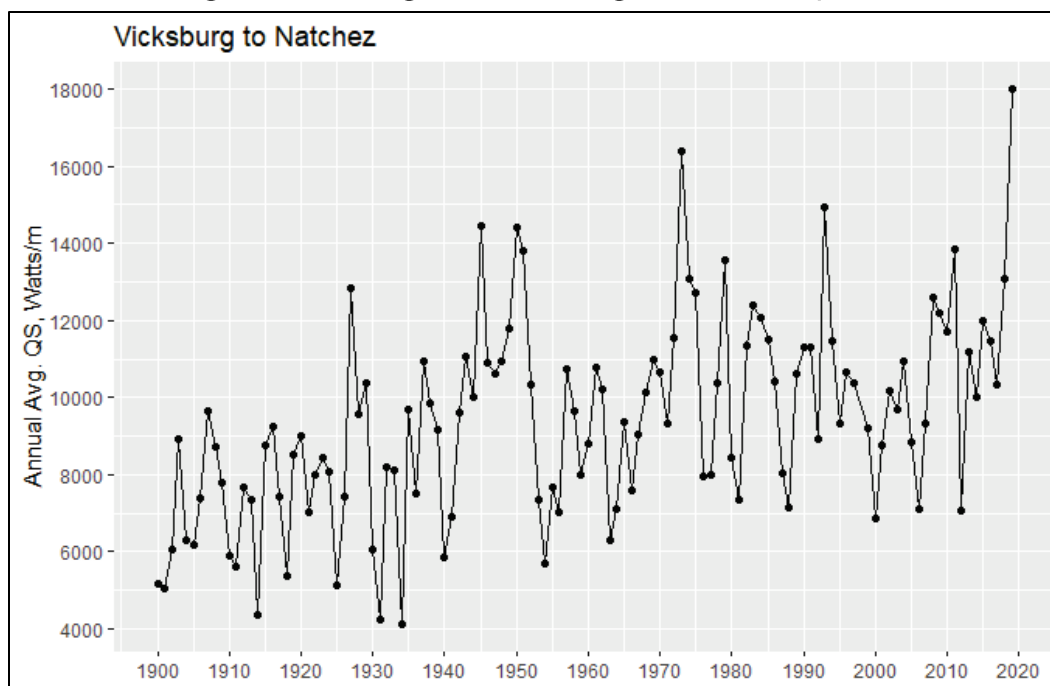
Figure 33. Bayou Sara-to-Baton Rouge annual average water surface slope.



3.3.1.2 Stream power

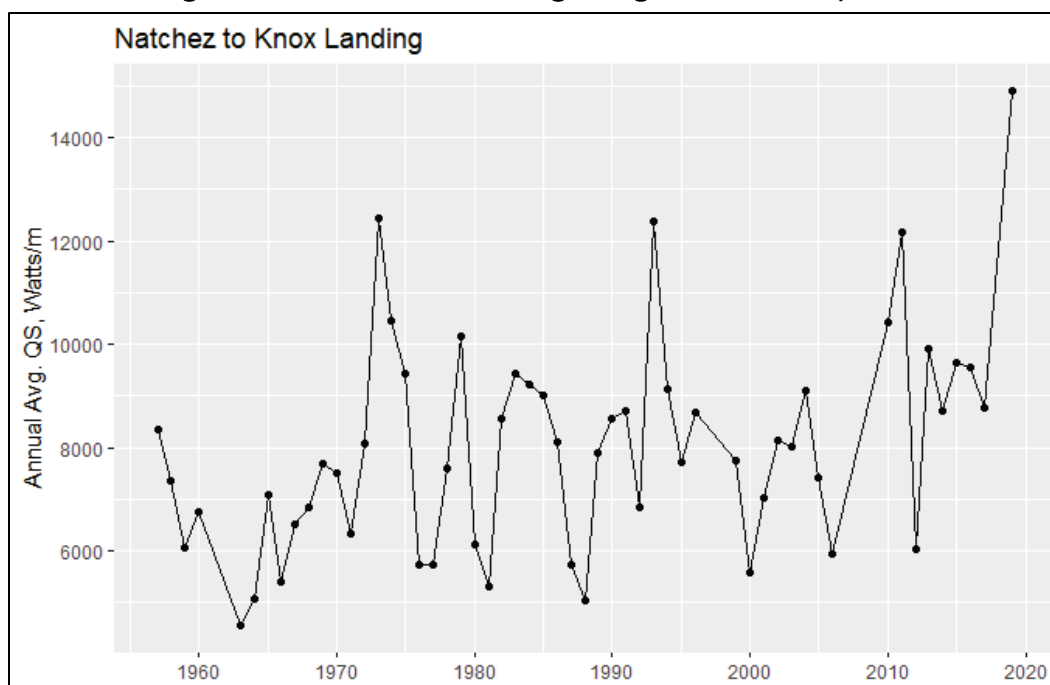
The general trend for average annual stream power (Figure 34) has been increasing for the Vicksburg-to-Natchez reach during the 1900 to 2019 period of record. Sudden jumps in stream power are identifiable; these generally correlate to Lower Mississippi River floods that were either large or had a long duration (1927, 1973, 1993, and 2019). The 2011 flood does not show a large peak when compared to the other historic floods because, while historic, the flood had a limited duration. Also note that the 2019 flood dwarfs all other flood in the record in average annual stream power due to its extremely long duration (not its flow or stage).

Figure 34. Vicksburg-to-Natchez average annual stream power.



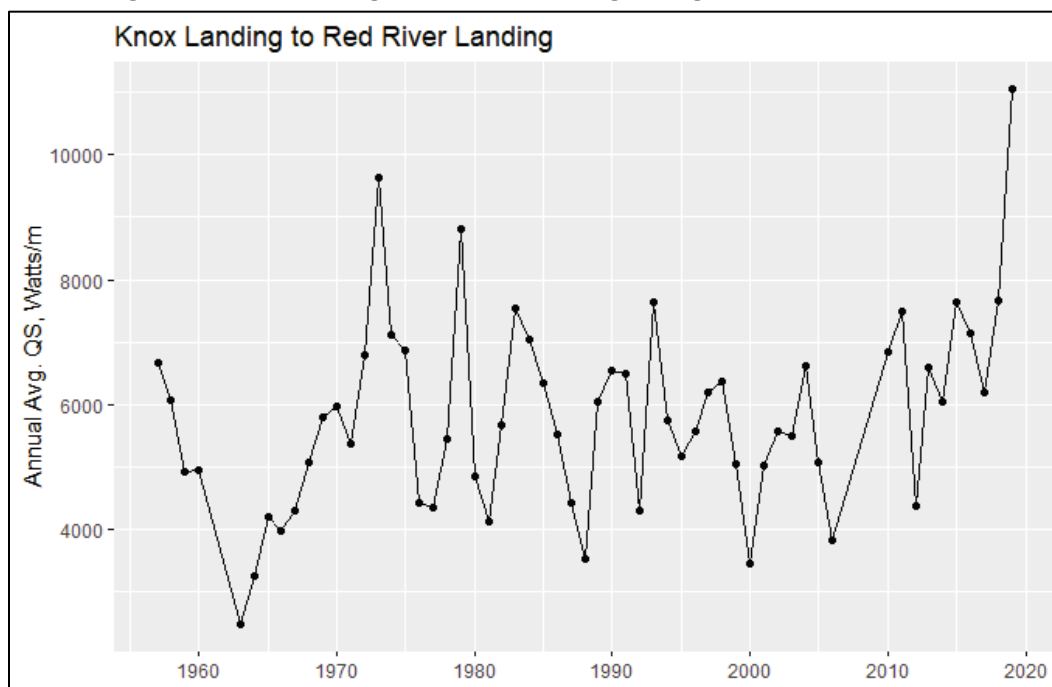
The average annual stream power for the Natchez to Knox Landing (Figure 35) has been generally flat when analyzed for a general trend. Peaks do exist as outliers—these peaks are identifiable as floods of note on the Mississippi River (1973, 2011, and 2019) along with 1993.

Figure 35. Natchez-to-Knox Landing average annual stream power.



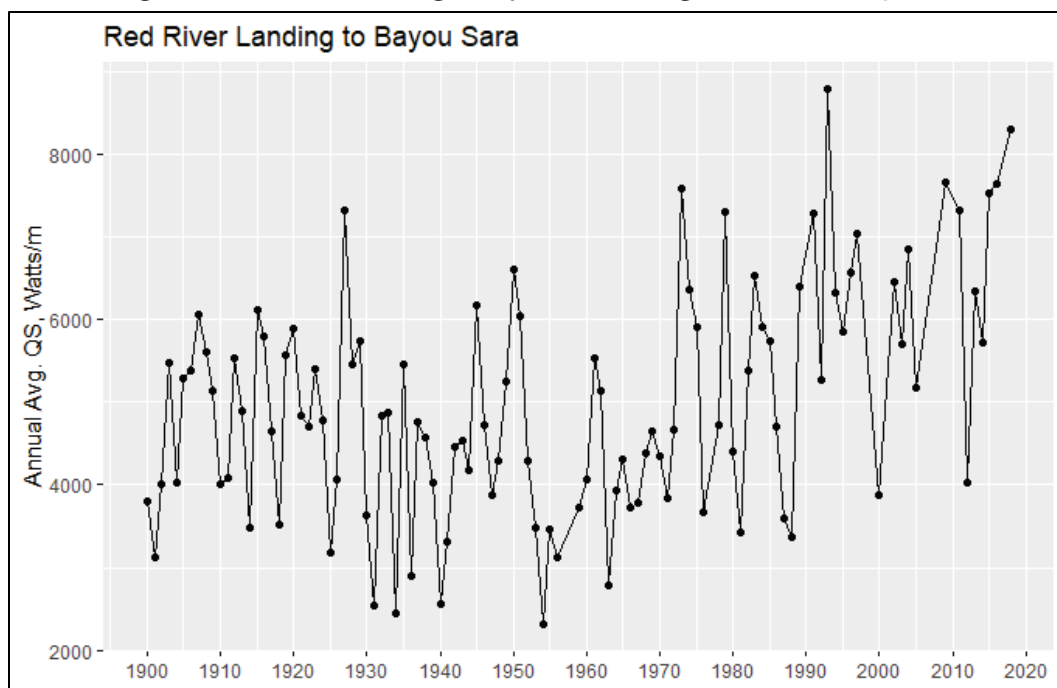
The average annual stream power for the Knox Landing-to-Red River Landing reach (Figure 36) includes annual variations for the 1957 to 2019 period of record and shows similar behavior to the reach upstream, in that it was generally flat. However, the peaks are not the same; for Natchez to Knox Landing, both 1979 and 2011 are peaks, but in the Knox Landing-to-Red River Landing reach, 1979 presents as a peak, but 2011 does not.

Figure 36. Knox Landing-to-Red River Landing average annual stream power.



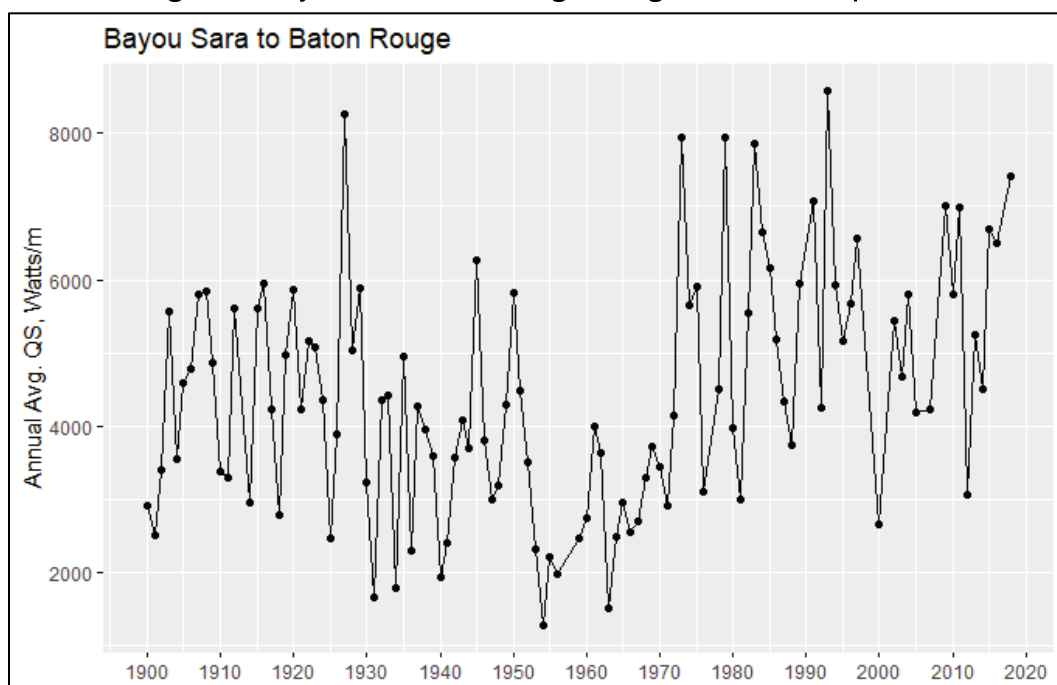
The general trend for the average annual stream power from Red River Landing to Bayou Sara (Figure 37) includes annual variations through the 1990 through 2019 period of record and was decreasing until a change point was reached around 1971. After the change point (identified past that point as a higher average level), it is difficult to discern a general trend. Note that there is generally less volatility in the values for the early 1950s to the early 1970s; this period is commonly associated with a drought period on the Mississippi River.

Figure 37. Red River Landing-to-Bayou Sara average annual stream power.



The reach from Bayou Sara to Baton Rouge (Figure 38) shows annual variation for the 1900 to 2019 period of record and shows very similar general trends to those of the Red River Landing-to-Bayou Sara reach.

Figure 38. Bayou Sara-to-Baton Rouge average annual stream power.



Facet box plots at 20 yr intervals were created of the reaches for easier comparison of upstream to downstream trends. The average annual slope (Figure 39) and average annual stream power (Figure 40) both decrease from upstream to downstream as anticipated.

Figure 39. Annual average water surface slope for Mississippi River.

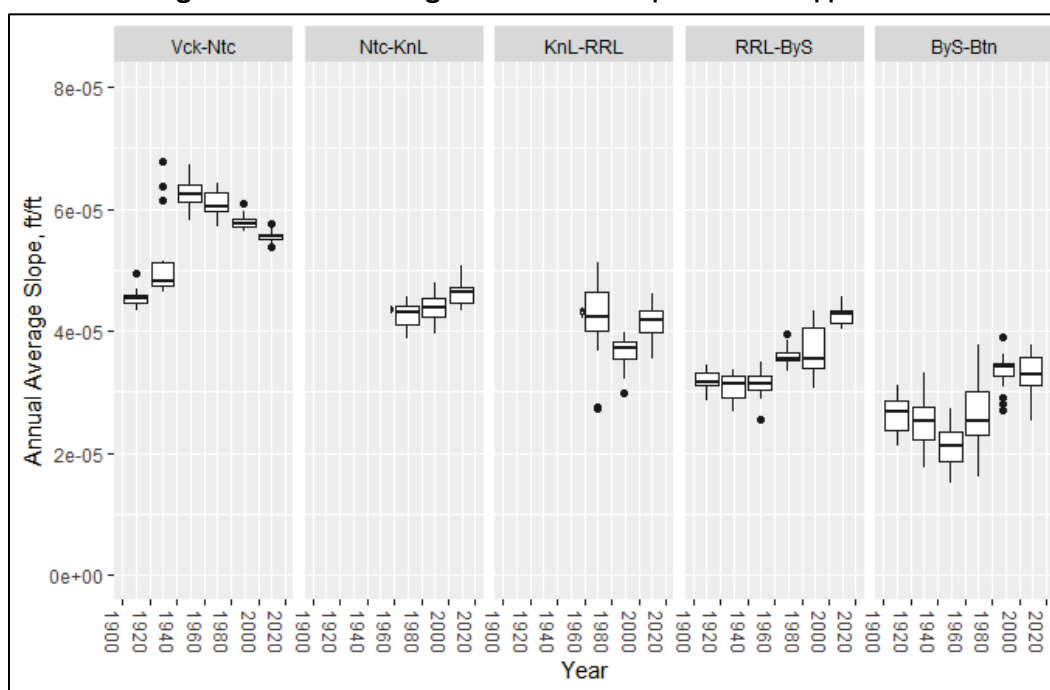
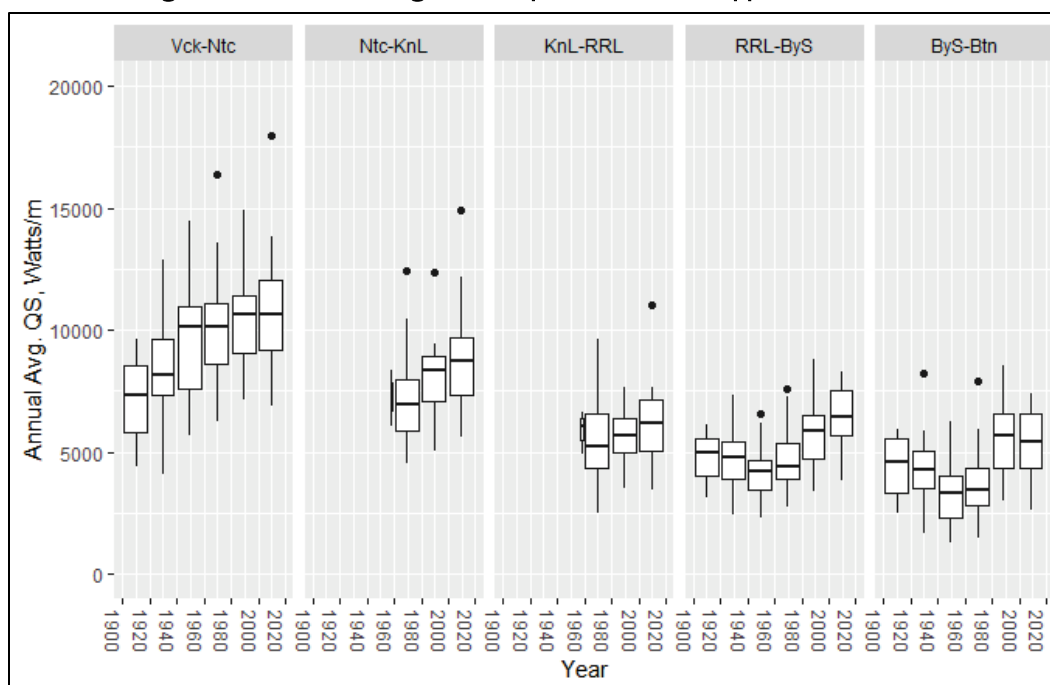


Figure 40. Annual average stream power for Mississippi River reaches.



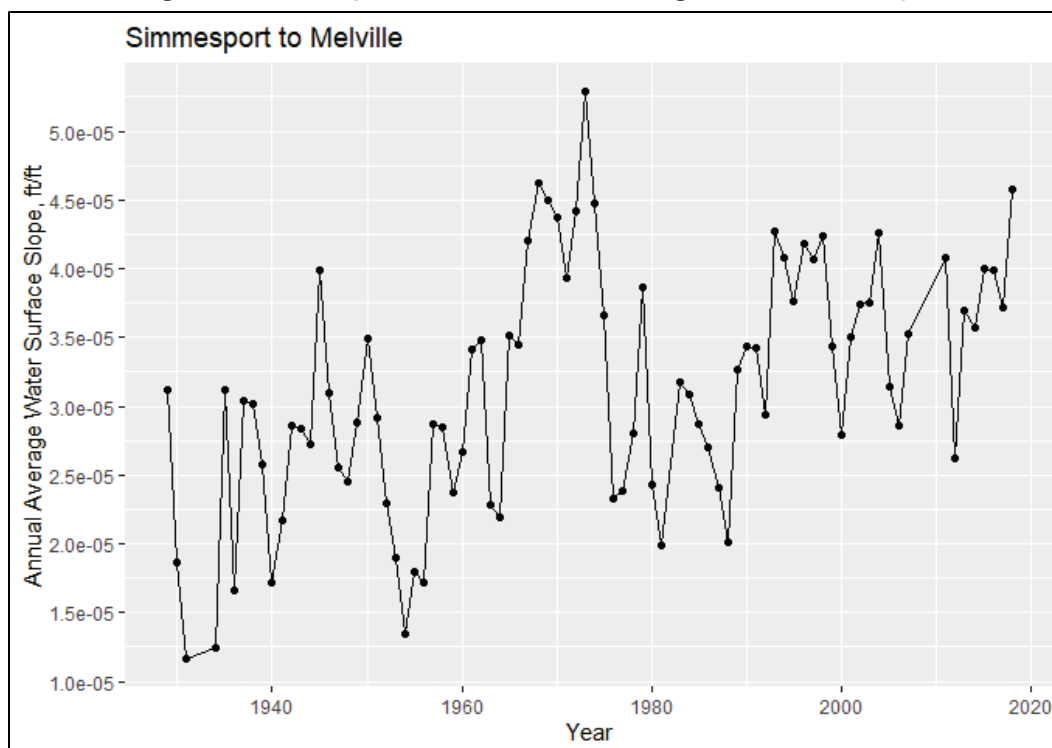
3.3.2 Atchafalaya river slope and stream power

3.3.2.1 Slope

Annual average water surface slope and stream power plots were generated for two upstream reaches of the Atchafalaya River: Simmesport (RM 4.9) to Melville (RM 29.5) (abbreviated “Simmes-Mel”); and Melville to Krotz Springs (RM 41.3) (abbreviated “Mel-Krotz”).

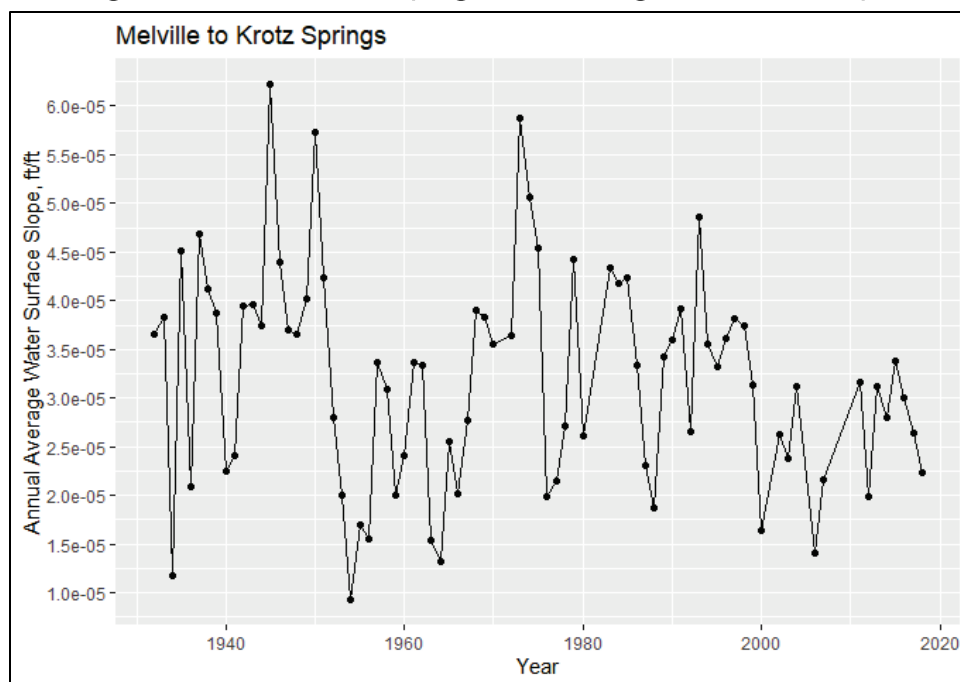
As shown in Figure 41, the annual average water surface slope for the Simmesport-to-Melville reach includes annual variations during the 1929 to 2018 period of record and shows an indeterminate trend until the approximately the mid-1960s, followed by a jump period from 1964 to 1973 followed by a dramatic decrease from 1973 to 1976. From 1976 on, the annual average water slope has been trending upward. The slopes of the last 30 yr have been higher than the slopes before the mid-1960s.

Figure 41. Simmesport-to-Melville annual average water surface slope.



The annual average water surface slope for the Melville-to-Krotz Springs reach (Figure 42) shows considerable cyclic behavior and variability for the 1932 to 2018 period of record with a generally decreasing trend.

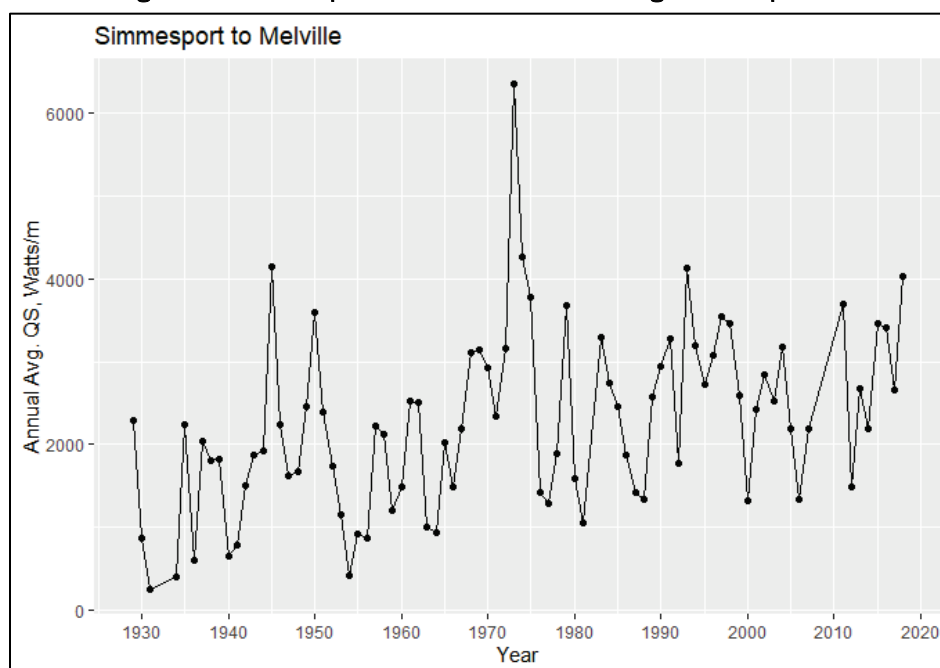
Figure 42. Melville-to-Krotz Springs annual average water surface slope.



3.3.2.2 Stream power

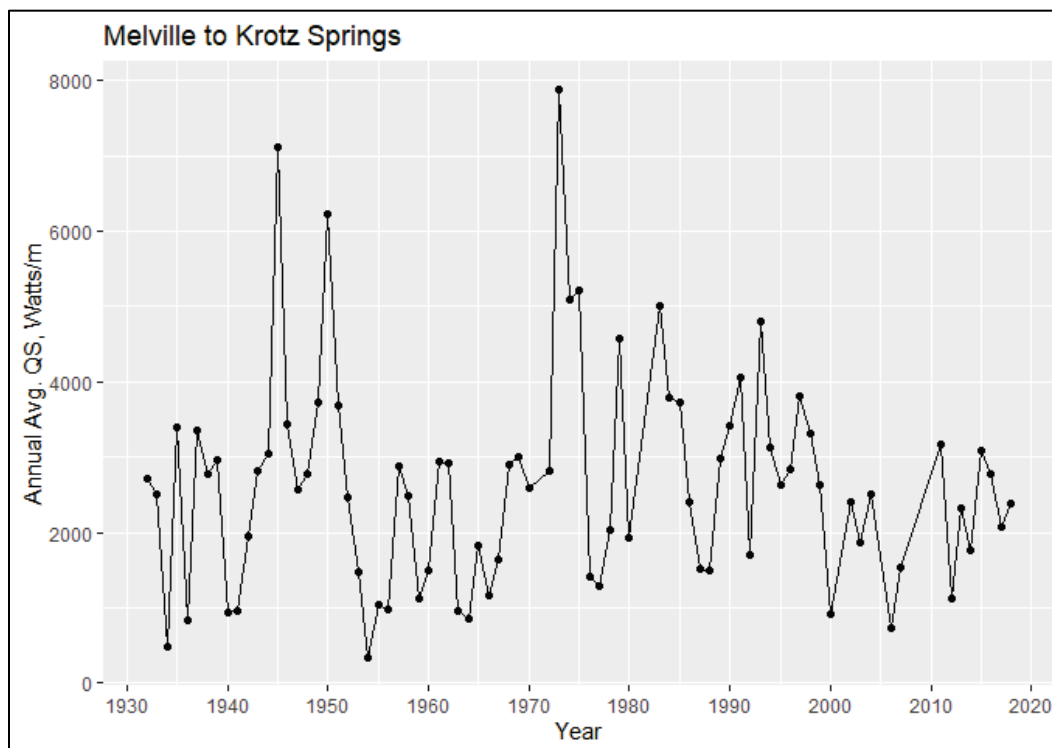
The annual average stream power for Simmesport to Melville (Figure 43) shows annual variability over the 1929 to 2018 period of record with a generally increasing trend. The peak streamflow year is the Flood of 1973.

Figure 43. Simmesport-to-Melville annual average stream power.



The annual average stream power for Melville to Krotz Springs (Figure 44) shows annual variation for the 1932 to 2018 period of record but a generally constant flat trend.

Figure 44. Melville-to-Krotz Springs annual average stream power.



Facet box plots at 20 yr intervals were created of the reaches for easier comparison of upstream to downstream trends. Figure 45 shows the box plots for the water surface slopes. The two reaches show slightly opposing trends. The Simmesport-to-Melville reach has experienced a fairly dramatic increase in slopes, particularly between the 20 yr prior to 1960 and the 20 yr after 1960, the slope trends in the Melville to Krotz Springs reach are more subtle but do show a slight decrease in slopes in the post-2000 period.

The average annual stream power box plots are shown in Figure 46. As expected, the stream power trends are similar to the slope trends, although depicting these trends becomes more difficult due to the added component of discharge. Much of the comparison of the two reaches does fall within the interquartile ranges of the box plots.

Figure 45. Annual average water surface slope for Atchafalaya River reaches.

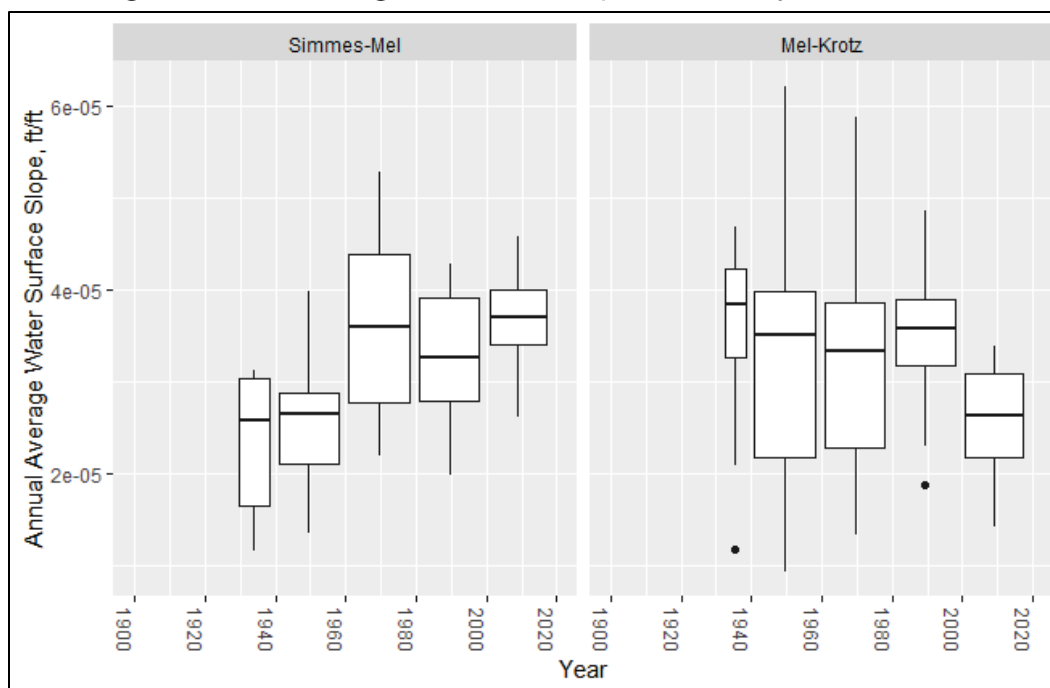
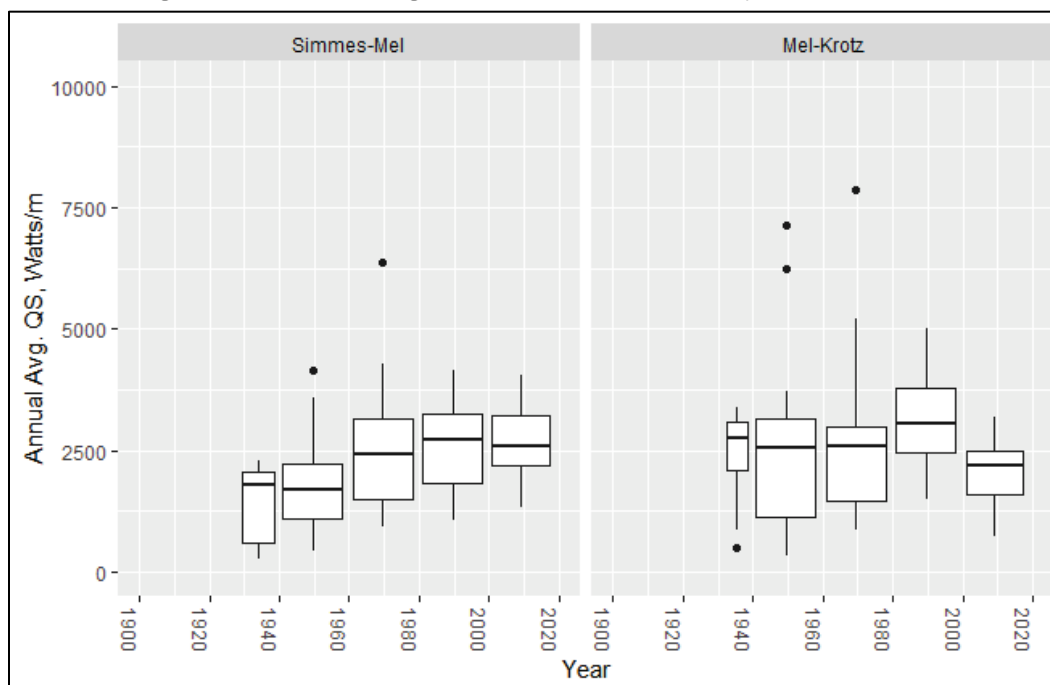


Figure 46. Annual average stream power for Atchafalaya River reaches.



3.3.3 Stream power summary

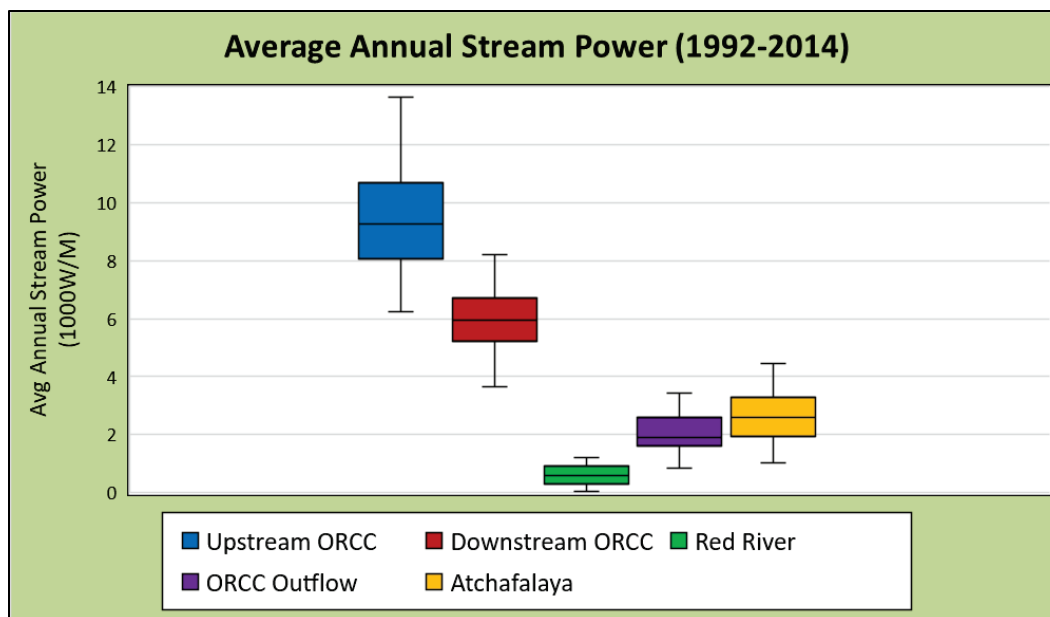
Average annual stream power was developed in the vicinity of the ORCC for the period between 1992 and 2014 with the results shown in Figure 47. For the Mississippi River, two reaches were identified: (1) upstream of the ORCC, which was determined as the average of the Vicksburg to Natchez and Natchez to Knox Landing data, and (2) downstream of the ORCC, which was determined as the average of the Knox Landing-to-Red River Landing and Red River Landing-to-Bayou Sara data (Figure 47). Inflow to the Atchafalaya River was represented by two reaches: (1) the Red River, which was represented by the Acme to Barbre Landing reach data, and (2) the ORCC Outflow reach which was represented by the ORCC Outflow channel below Hydropower-to-Barbre Landing data (Figure 47). The Atchafalaya River reach was represented by the Simmesport-to-Melville data (Figure 47). Note that the use of the Barbre Landing gage as the downstream gage for both upstream inflow reaches is problematic due to its location approximately 3.5 mi downstream of the Old River outflow channel. The actual boundary for the two reaches should be at the Red River–Old River outflow confluence, but since there is no gage there, the only recourse was to use the Barbre Landing gage. This boundary condition combined with the backwater issues upstream along the Red River increases the uncertainty in the slope and stream power relationships for the Red River/Old River/Atchafalaya River as compared to the Mississippi River.

As shown in Figure 47, there is a significant loss of stream power on the Mississippi River downstream of the ORCC compared to upstream of the ORCC. In fact, there is a loss of stream power of almost 40% in this time period. This decrease in stream power was both a result of the loss of water diverted through the ORCC, and a decrease in the slope downstream of the ORCC.

As expected, the stream power on the Atchafalaya side of the ORCC is significantly smaller than on the Mississippi River (Figure 59). It is also interesting that the stream power on the Red River is also only approximately 30% of the stream power for the ORCC Outflow channel.

This reduced stream power is the result of both a decrease in discharge and slope of the Red River compared to the ORCC.

Figure 47. Average annual stream power in the vicinity of the ORCC for the 1992–2014 time period.



3.4 Sediment data

Sediment transport through the OMAR reaches, particularly into the Old River Outflow Channel, is of critical importance. Latimer and Schweizer (1951a) recognized this would be an issue, writing in their 1951 report the following:

"The angle of diversion from the Mississippi River is in the concave side of a bend, The Mississippi River, in this bend, has a depth of about 70 feet below mean sea level. Old River, immediately below the point of diversion, has a shallower depth which serves as a sill or weir and tends to prevent the heavier bed load from entering the Old River channel, The lower portion of the flow carrying the bed load should pass down the Mississippi River rather than into Old River, The diversion into Old River, in general, is being supplied from the upper layers of flow which carry only finer suspended material, and it would appear that an increase in discharge through Old River would result in an increase in the suspended load that is now being transported into the lower Atchafalaya Basin below the end of the leveed channel with no great increase in bed load."

3.4.1 Suspended sediment

The records of the suspended sediment stations in the vicinity of the ORCC were analyzed. This requires that all stations have the same hydrologic period, which due to data limitations at different gages limits the time periods available for study. For this analysis, the time period from 1992 to 2014 was selected. The stations used on the Mississippi River for this analysis included Union Point and Tarbert Landing (Figures 48 and 49). The Red and Black Rivers were represented by the Red River Above Simmesport gage, and the Old River Below Hydropower Channel gage (herein referred to as the ORCC Outflow gage) was used to represent the sediment delivered out of the ORCC (Figures 48 and 49). The Simmesport gage was used for the Atchafalaya River (Figures 48 and 49).

The total, fine (particle size < 0.0625 mm), and sand (> 0.0625 mm) suspended load were calculated at each of the selected suspended sediment gaging locations for the period from 1992 to 2014.

As stated in Section 2.6.1, considerable uncertainty exists for the suspended sediment data, both from the wide variability of suspended sediment data itself and from the effects of changing procedures at individual gages and between gages. The level of uncertainty this produces is significant, and therefore the results should be viewed as providing approximate order of magnitude estimates of the sediment loads. For this reason, the results are presented in box plot fashion, which provides some visualization of the data variability. The results for the fine and sand loads are shown in Figure 48 and Figure 49.

As shown in Figure 48 and Figure 49, there appears to be a slight decrease in all sediment loads between Union Point and Tarbert Landing. On the west side of the ORCC, the results suggest that the inflows of sediment from the Red River and ORCC match reasonably well with the loads measured at Simmesport (Figure 48 and Figure 49). One of the OMAR System Technical System Assessment charge questions asked, “How much sediment is being supplied by the Red River to the Atchafalaya River?” For the period 1992–2014, it appears that the average annual supply of sands from the Red River was in the range of approximately 7 million tons/yr of sands, which is approximately 58% of the total sands provided to the Atchafalaya River. It is interesting that for the 1992–2014 period, the Red

River supplied almost 60% of the sand load to Atchafalaya River, but only approximately 30% of the flow.

Figure 48. Average annual fine sediment loads in the vicinity of the ORCC for the period 1992–2014.

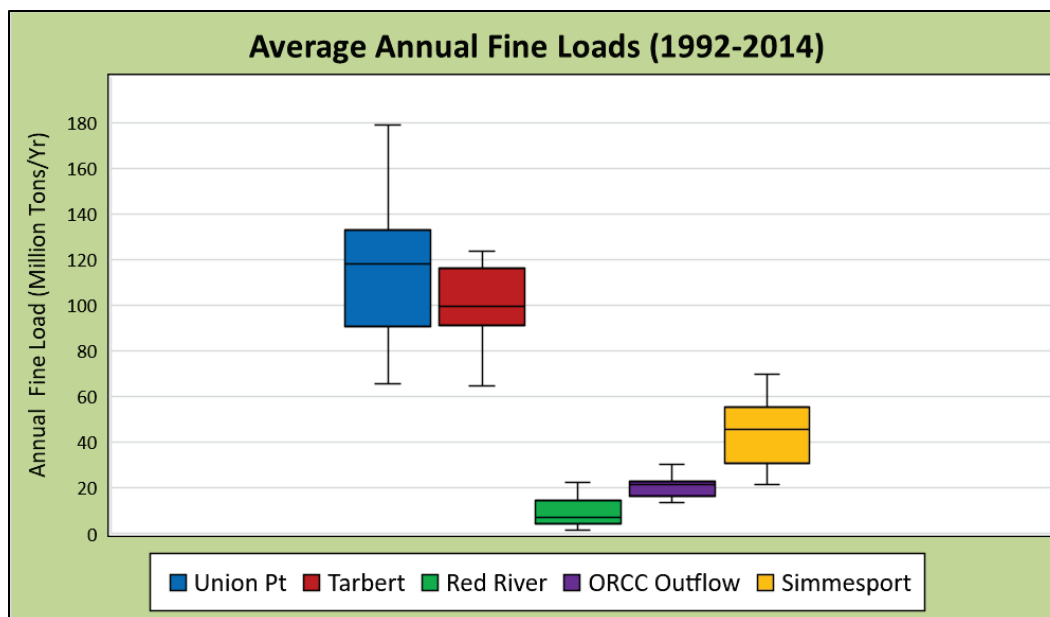
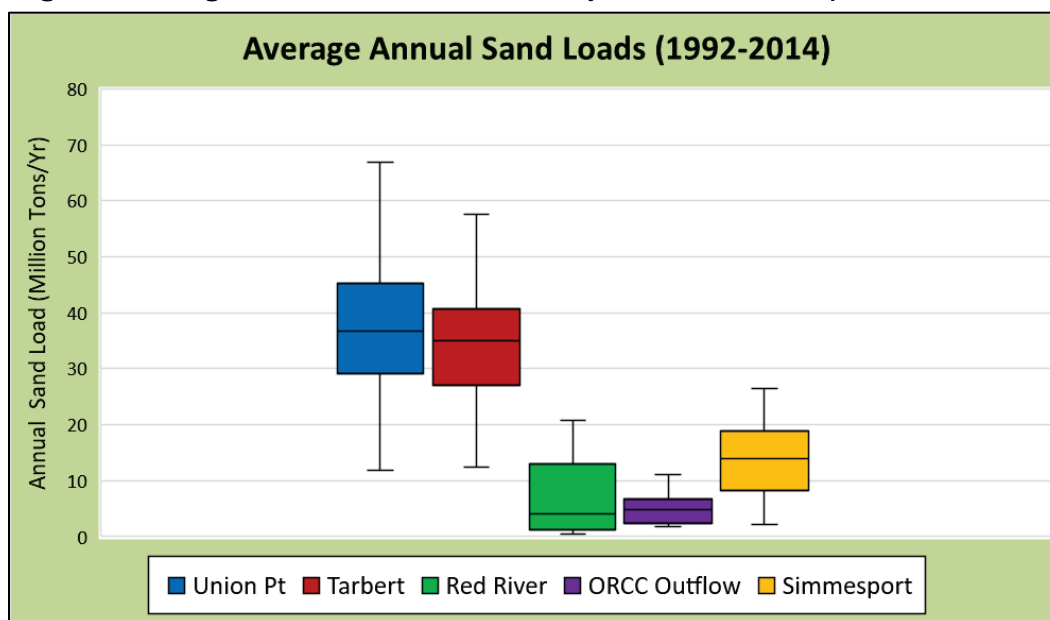


Figure 49. Average annual sand loads in the vicinity of the ORCC for the period 1992–2014.



The measured sediment data from the pump samplers located immediately downstream of the ORCC structures (hydropower, low sill, and auxiliary) were used to generate rating curves for the concentration versus the discharge through each structure. These rating curves were then

combined with the daily discharge data for each structure to calculate daily loads. These loads were then added together to determine a yearly load for the period 1992–2014. Note that the pump sampler data are not directly comparable with the conventional methods used at the other sites in this study and there is often some criticism that these data are not as reliable as the conventional data. These limitations are recognized, but this is a massive data set that should be considered. With respect to the variability in the data, the R^2 values of the regressions range from approximately 0.55 to 0.68 for the sand loads. While these are low values, they are not out of the bounds for R^2 values often observed with conventional sediment measurements.

The pump sample results for the fine loads and sand loads are shown in box plot fashion in Figure 50 and Figure 51. For comparison, the results from the ORCC Outflow gage are also shown in Figure 50 and Figure 51. The pump sample data for the fine loads are generally higher than the ORCC Outflow loads. However, the sand loads are of comparable magnitudes, with the pump sample data possibly being slightly higher. Considering both the ORCC Outflow and pump data, it appears that the sand loads through the ORCC are likely in the range of approximately 2.5 to 7 million tons/yr for the 1992 to 2014 period, with an average annual value of approximately 5 million tons/yr. This represents only approximately 13% of the sand loads measured at Union Point.

Figure 50. Annual fine loads for the ORCC pump samples and the ORCC Outflow gage.

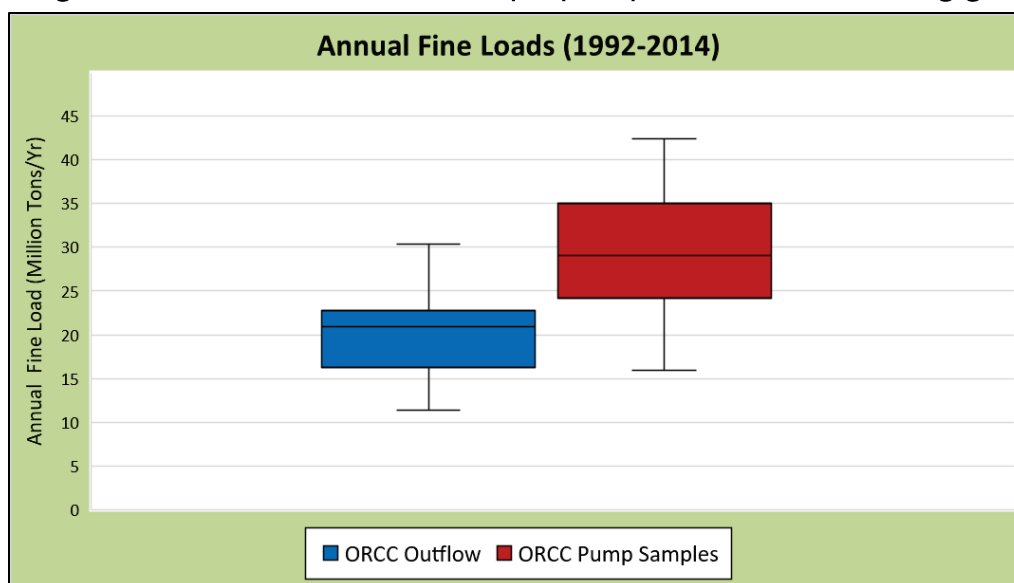
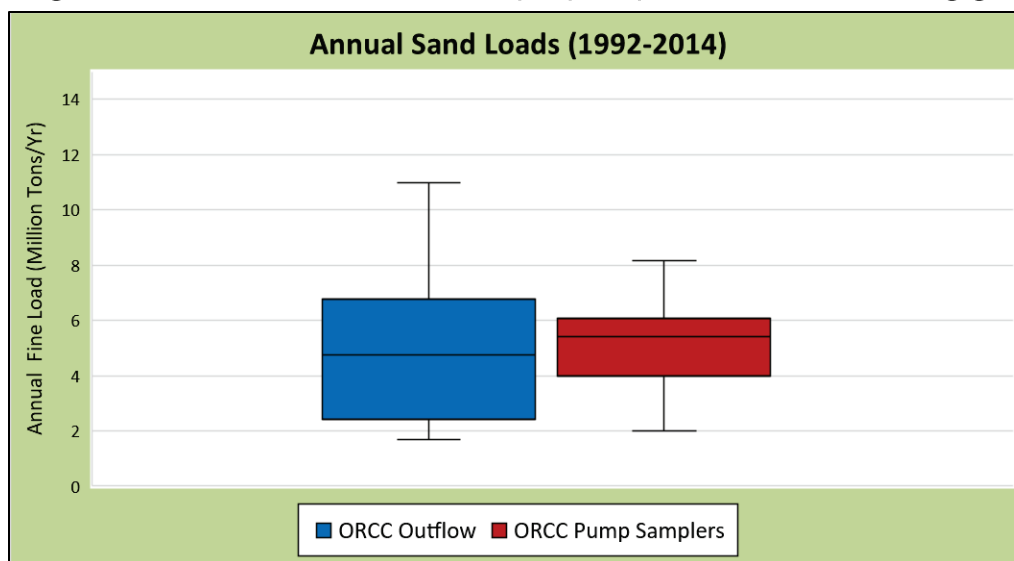


Figure 51. Annual sand loads for the ORCC pump samples and the ORCC Outflow gage.



One of the OMAR Assessment charge questions was “How much sediment could be diverted by USACE operations if the hydroelectric station was not operated?” This type of hypothetical question is difficult to answer with any certainty in a geomorphic assessment and may be more suitably addressed in the modeling efforts. However, a scenario was developed to provide some order of magnitude insight with respect to only using the Auxiliary and Low Sill structures. This approach assumed that all flow that would normally be passed through the hydropower unit would be re-distributed, with the Low Sill and Auxiliary structures receiving 35% and 65% of the flow, respectively. Regression curves were developed from the daily pump sample data for the sand loads at all three structures (Figure 52–Figure 54). Daily sand load data were developed by applying the regression equations to the daily flows at each structure. This was accomplished for both the existing conditions and the *no hydropower* scenario. Note that computing linear regressions with log transformed data would produce underpredicted results unless a bias correction factor is applied. However, since this exercise was not focused on the absolute load values, but rather was only used to show the relative percent differences between the scenarios, the lack of a bias correction was not necessary. The results suggest that diverting all flows through the Low Sill and Auxiliary structures could increase the diversion of sands, possibly on the order of approximately 90%. While this represents a large percentage increase in the amount of sand being diverted, this increased load is still small compared to the sand loads on the Mississippi River. Again, it must be emphasized that there is significant

uncertainty in these results and that this exercise was intended only to provide broad scale insight into the charge question.

Figure 52. Pump sampler sand load data for the Hydropower Structure from 1991 to 2019.

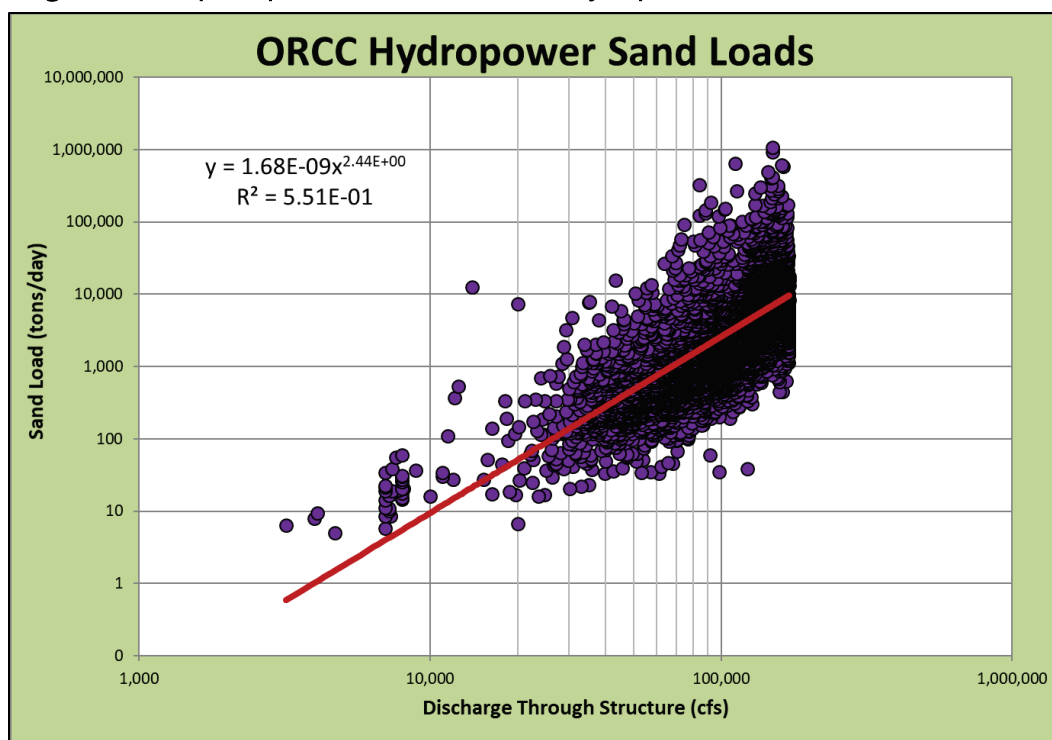


Figure 53. Pump sampler sand load data for the Auxiliary Structure from 1991 to 2019.

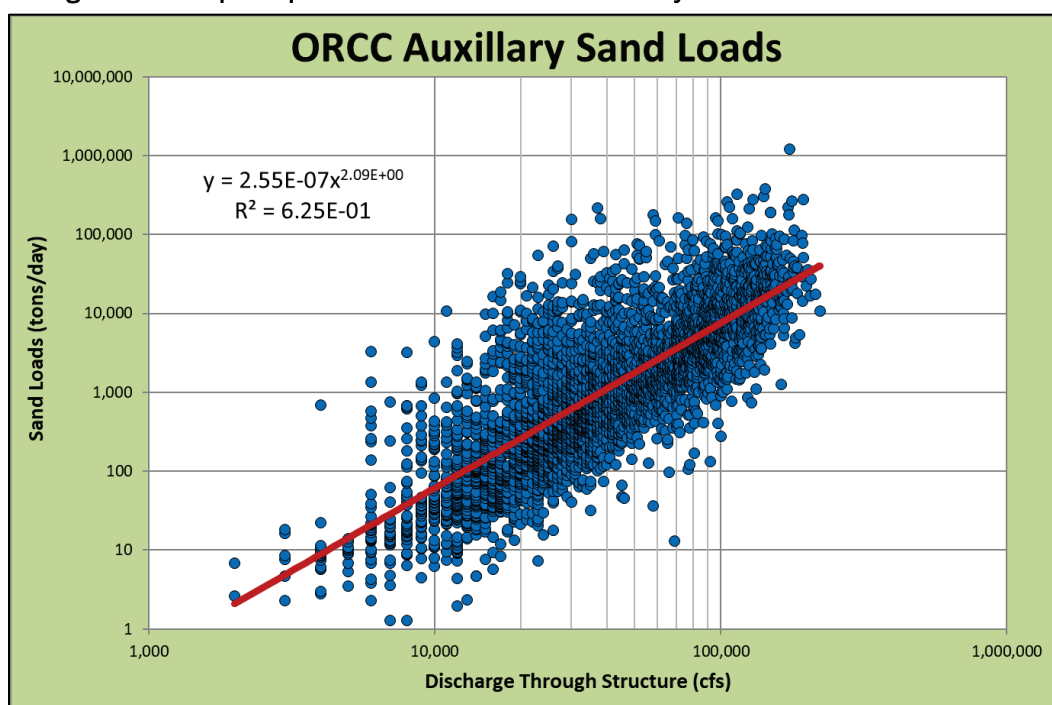
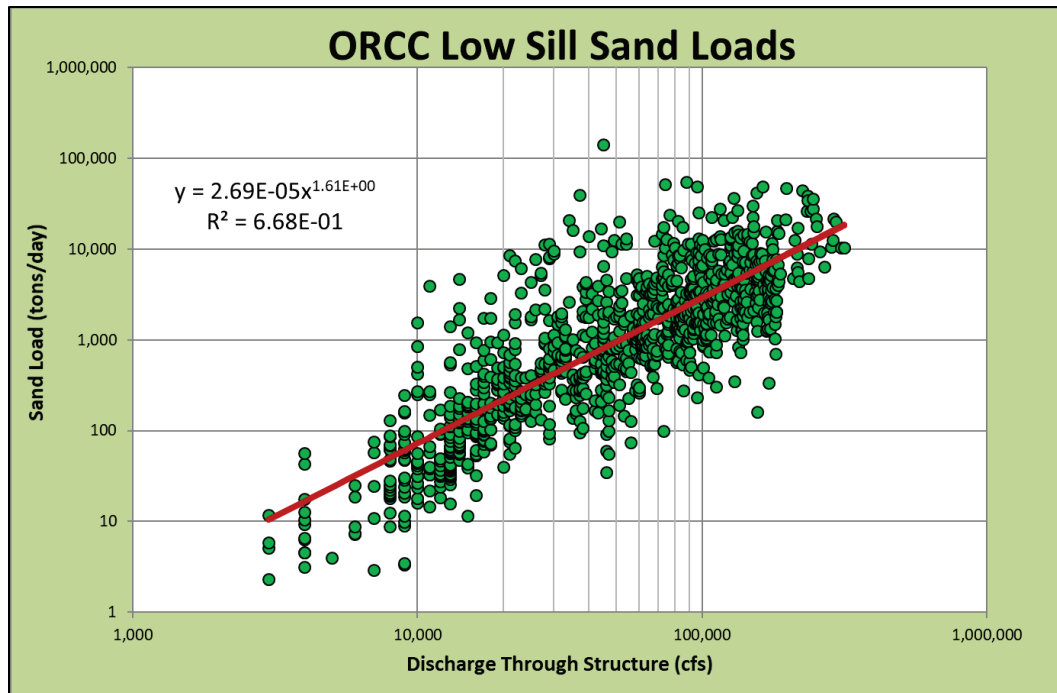


Figure 54. Pump sampler sand load data for the Low Sill Structure from 1991 to 2019.



3.4.2 Bed material

The top layer bed material comparisons for the Mississippi River are shown below in Figure 55 to Figure 57 and for the Atchafalaya River in Figure 58 to Figure 60. The sampling methodology used for the Mississippi River samples is described in Gaines and Priestas (2016). The sampling methodology used for the Atchafalaya River samples is described in Nordin et al. (1995). The material sizes appear similar for both rivers between the two collections.

Figure 55. Mississippi River D16 comparison.

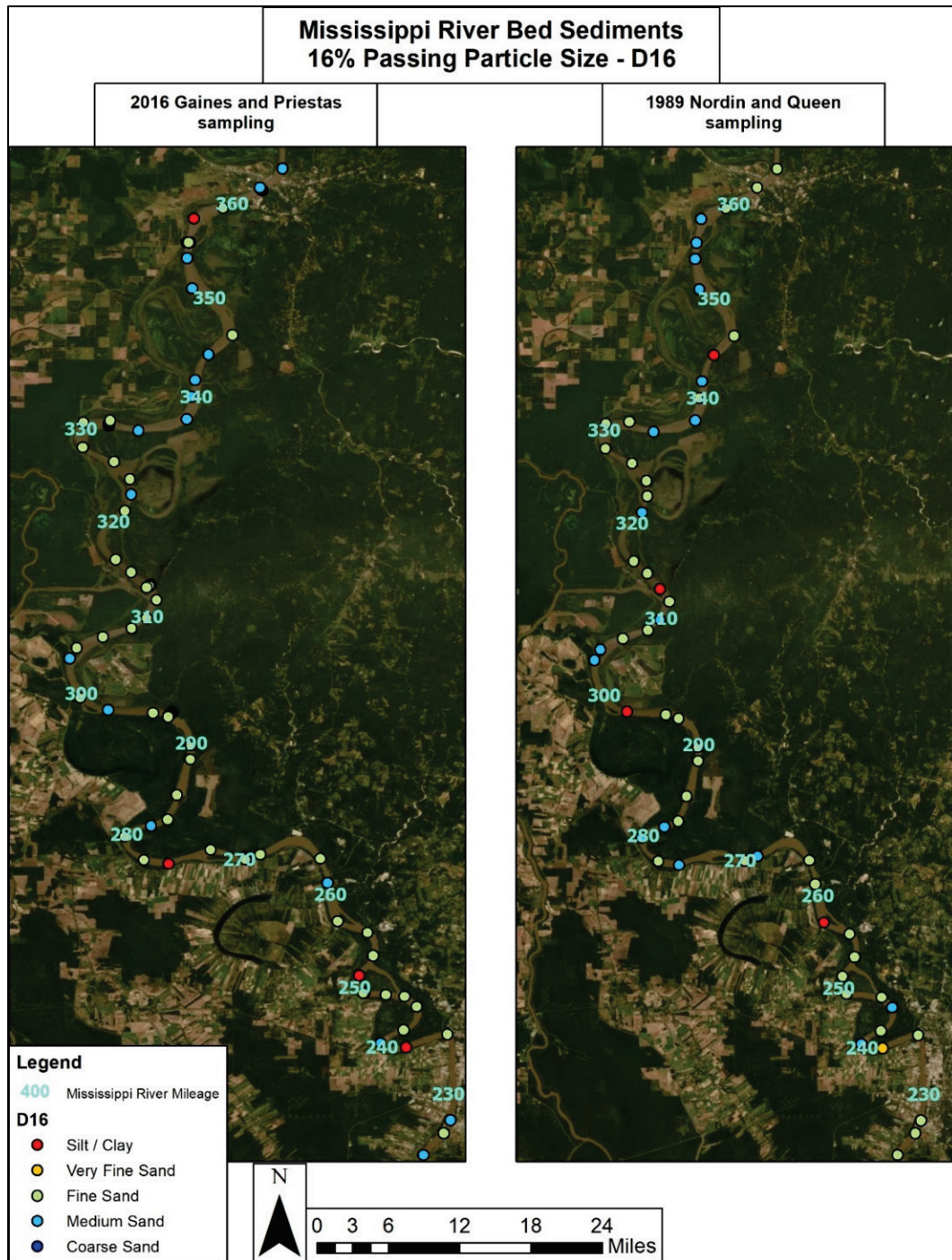


Figure 56. Mississippi River D50 comparison.

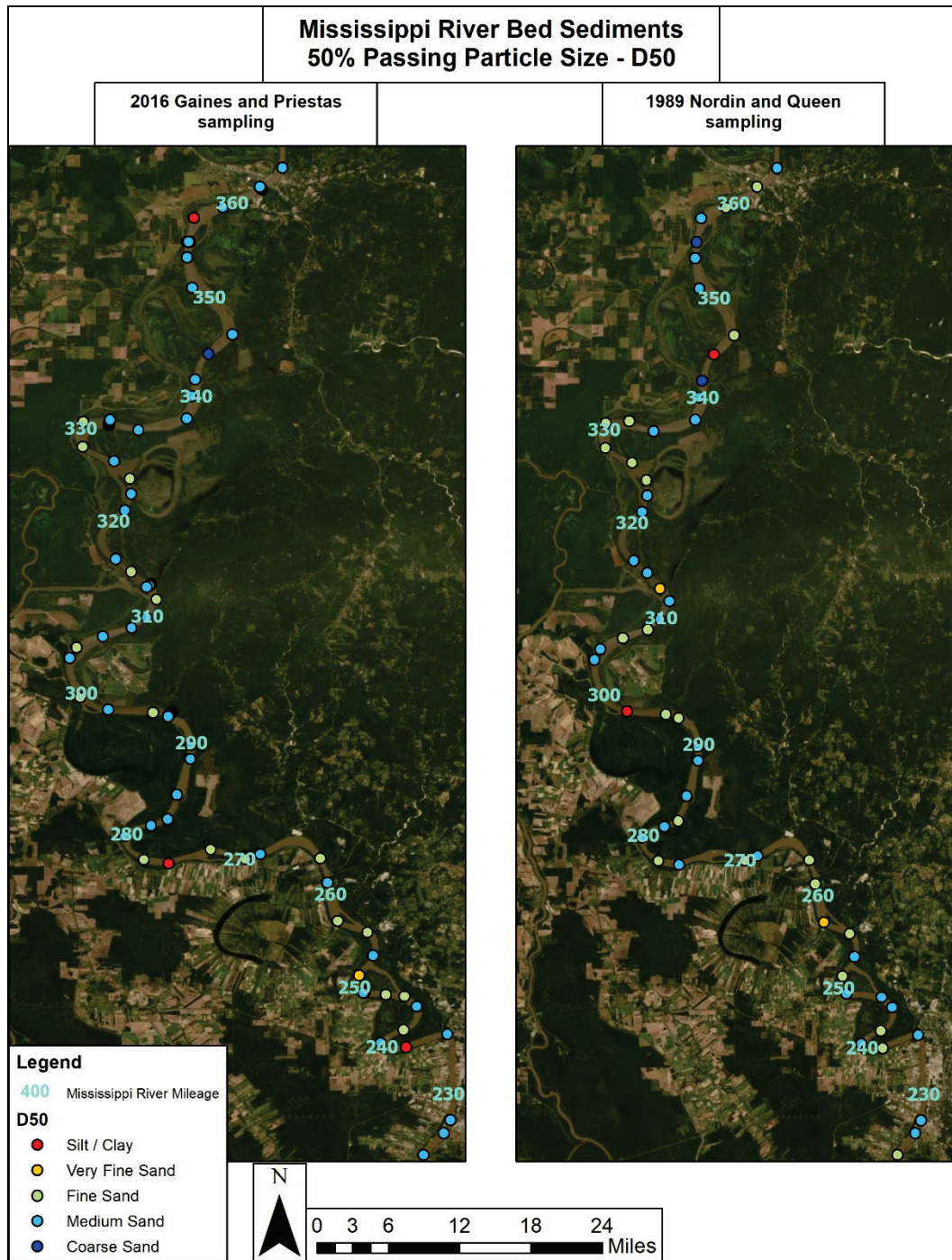


Figure 57. Mississippi River D84 comparison.

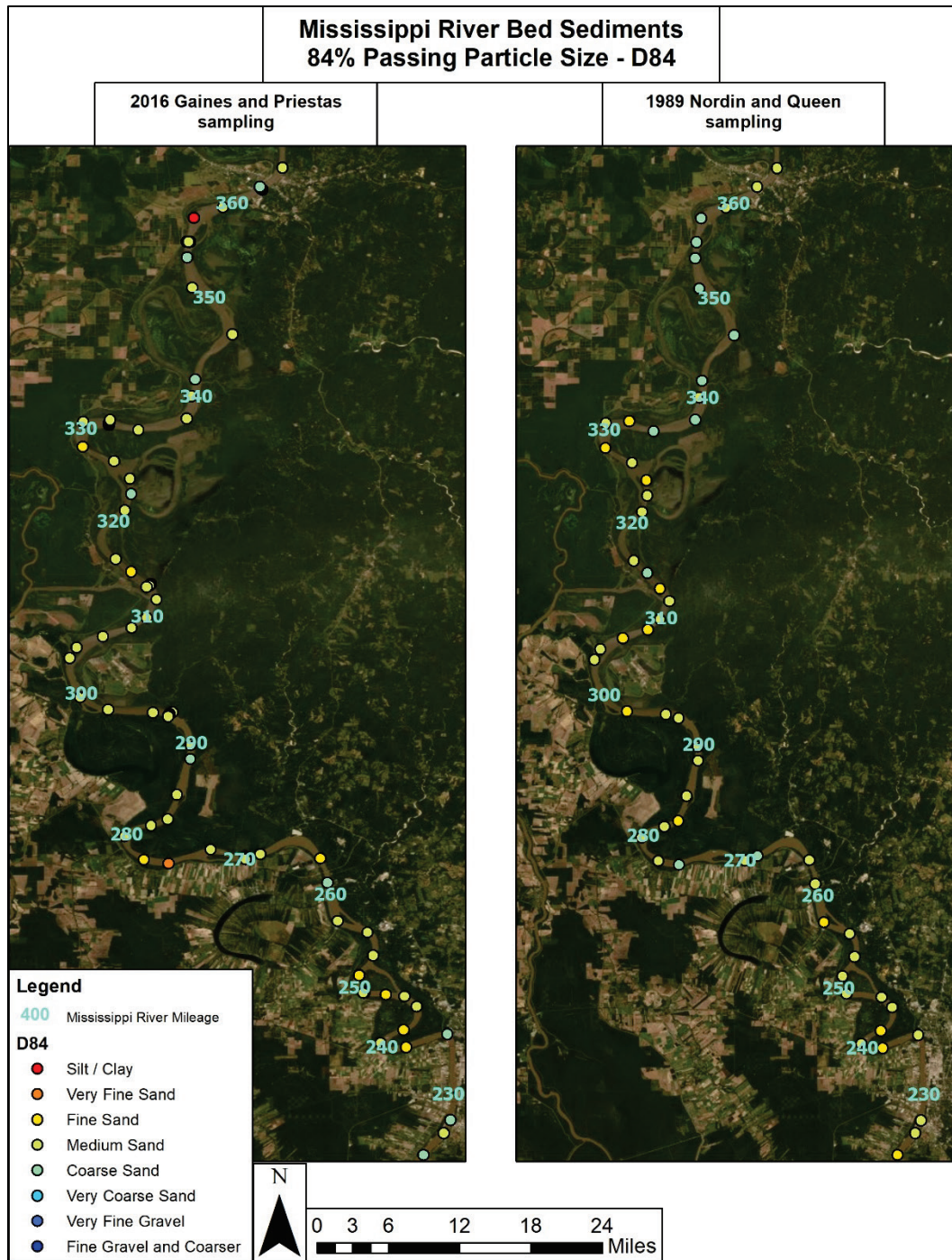


Figure 58. Atchafalaya River D16 comparison.

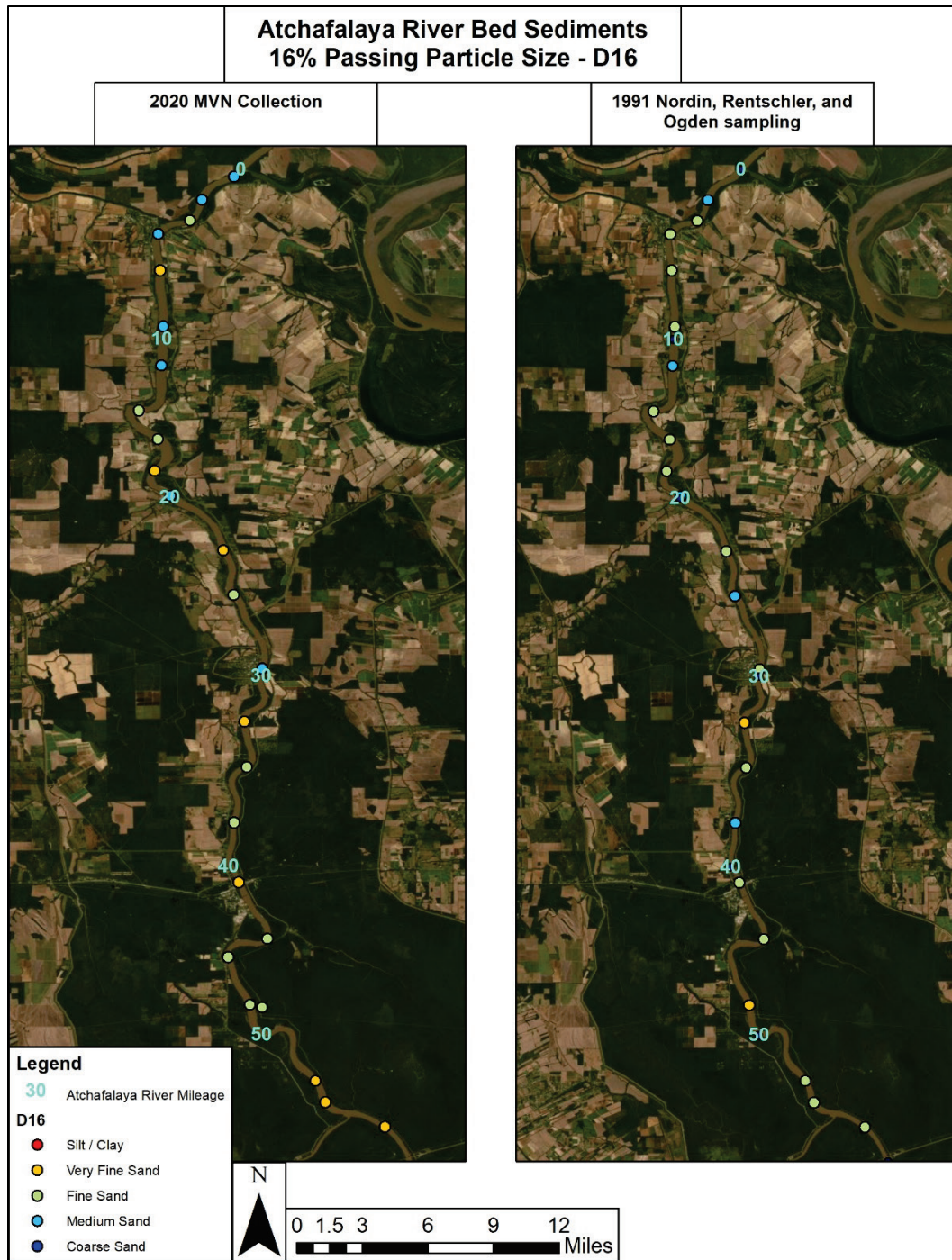


Figure 59. Atchafalaya River D50 comparison.

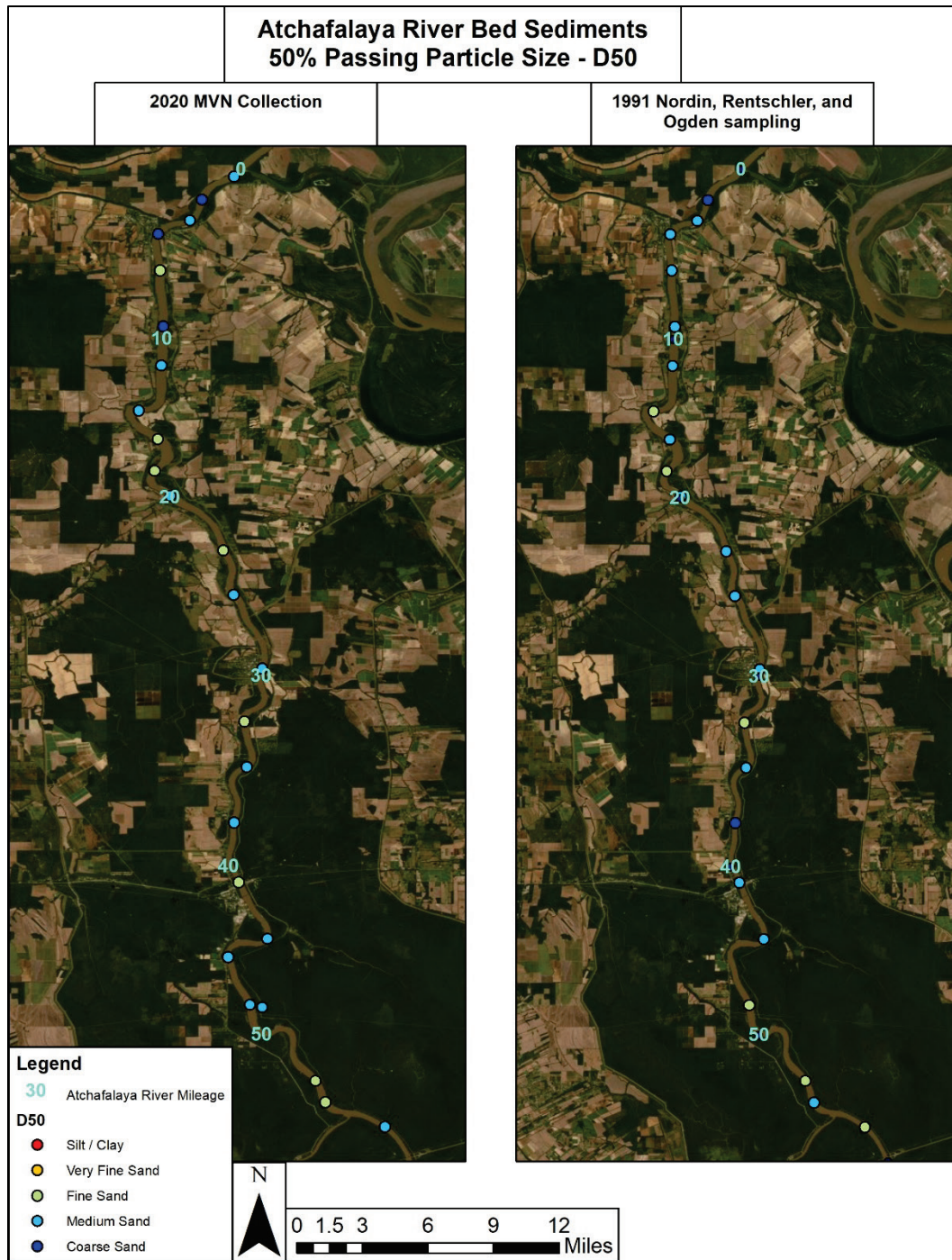
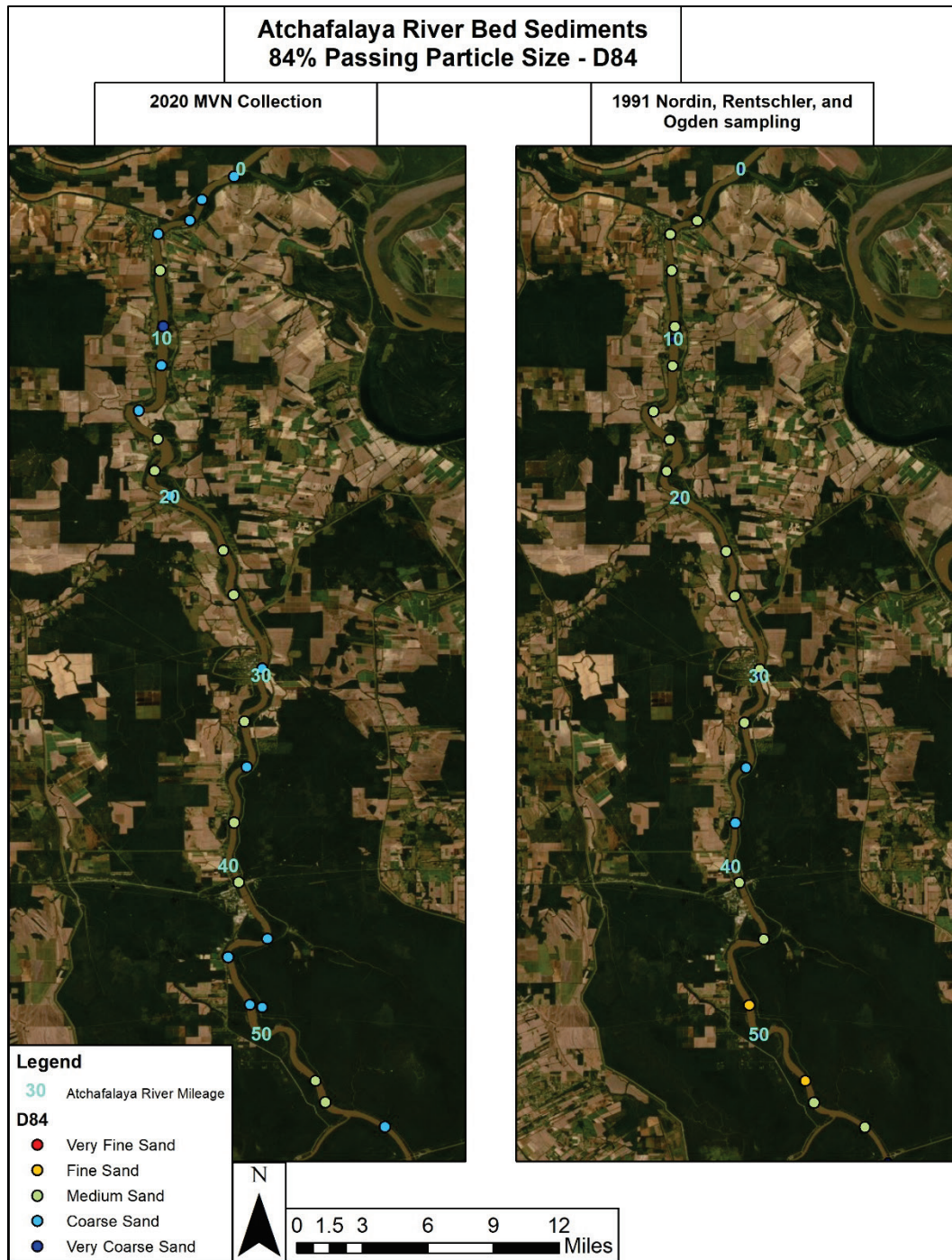


Figure 60. Atchafalaya River D84 comparison.



3.4.3 Atchafalaya boring logs

The geometric and specific gage analyses for the Atchafalaya River suggest that the upper reach of the river has adjusted to the current flow and sediment regimes. However, an alternative explanation exists that the Atchafalaya River, through non-erodible boundaries, no longer has the ability to adjust and thus artificially presents as stable. To investigate this, boring logs on each side of the channel from approximately RM 4 to RM 10 (Figure 62 and Figure 63, with the legend using the Unified Soil Classification in Figure 61) were compared to the approximate elevation of the thalweg so that estimates of the composition of the bed sediments below the mobile layer at the thalweg could be drawn (Figure 62 and Figure 63). The review of the boring logs suggests that larger portions of the reach investigated would have a bed material that would be in poorly graded sands. Thus, the bed should still have the capability to degrade if there were an existing unsatisfied sediment demand, reinforcing the assumption that the reach is in dynamic equilibrium and not artificially presenting as such.

Figure 61. Legend for Atchafalaya boring logs.

Boring Log Legend			
	CH		OH
	CL		OL
	CI		PT
	GC		SC
	GM		SI
	GP		SM
	GW		SP
	MH		SW
	ML		WD
	NS		

Figure 62. Borings vs. thalweg elevation for Atchafalaya River for approximate RM 4–10, west bank.

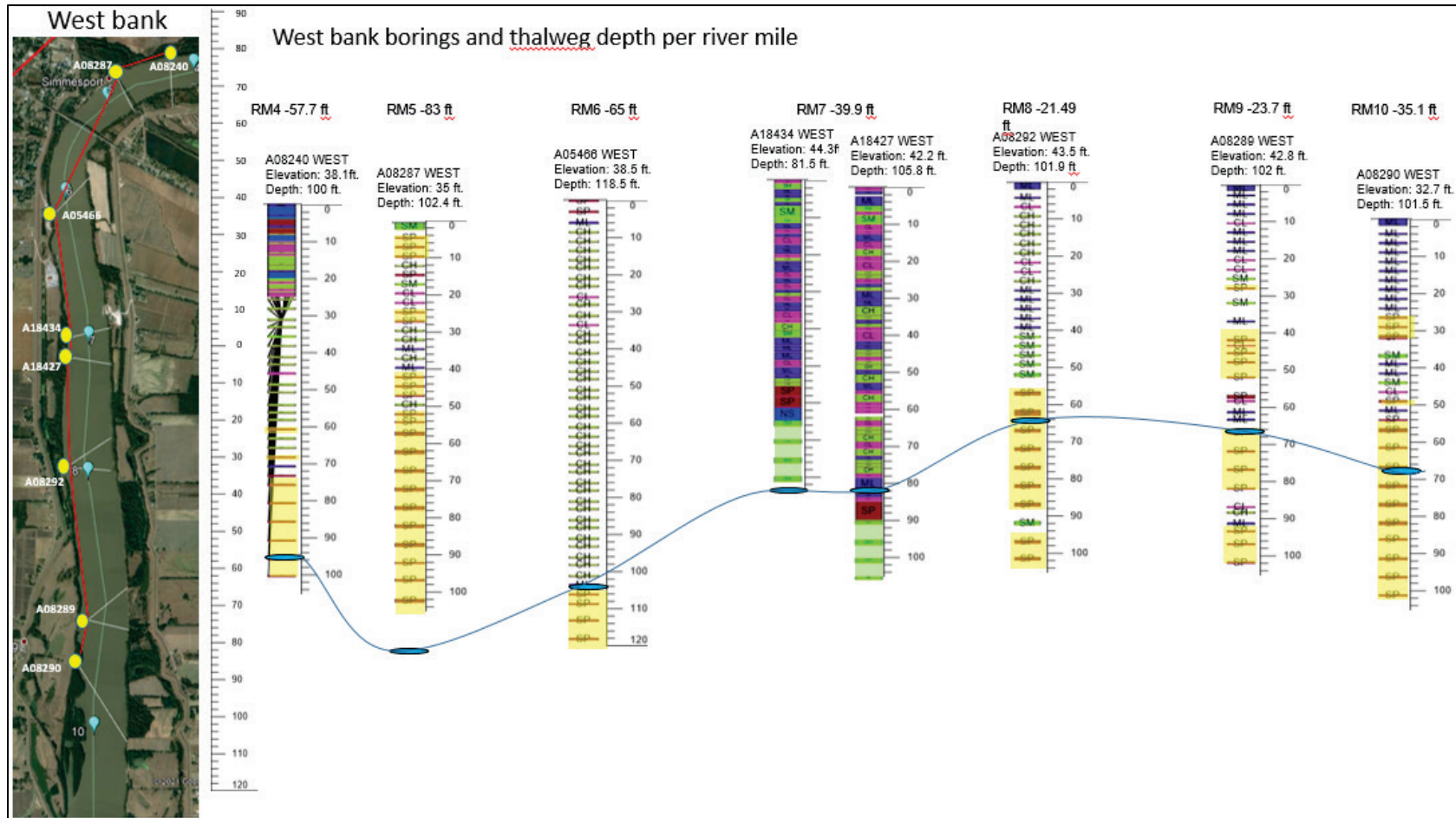
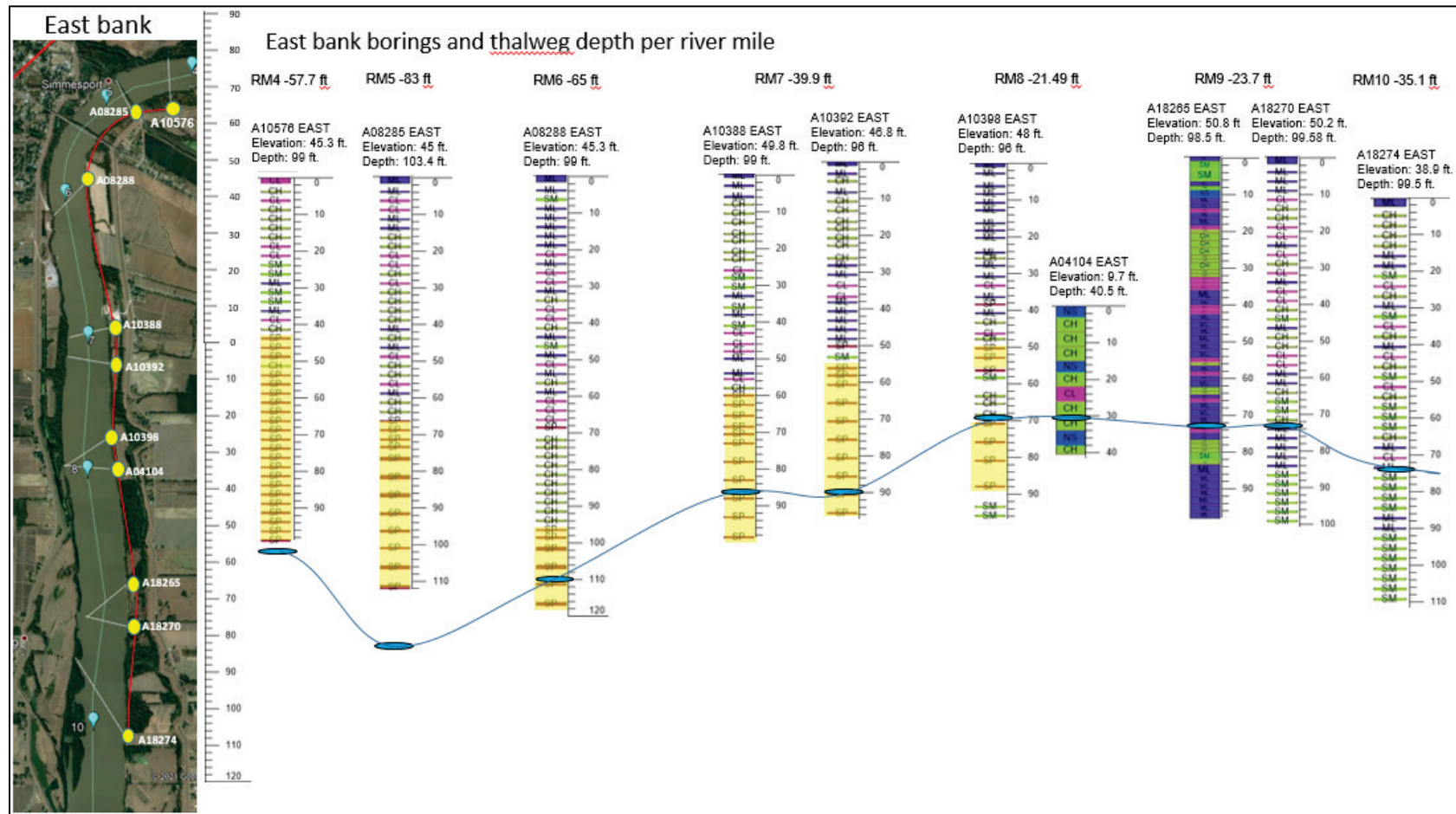


Figure 63. Borings vs. thalweg elevation for Atchafalaya River for approximate RM 4–10, east bank.



3.4.4 Bedload data

Bedload measurements were taken at different flow rates in 2010, 2011, 2016, and 2019. Measurements were taken at different locations; a map of those locations is presented in Figure 64 (numbering remaining consistent with prior publications, only measurements needed for overall sediment budget shown). Definitive conclusions could not be drawn from the limited bedload measurements available, though there is evidence of material switching transport mechanism due to the loss of flow (i.e., coarser suspended load becoming bed load). Additional measurements of bedload are recommended to try to further establish trends; this includes the development of bedload rating curves on the Mississippi River at locations farther from the ORCC.

Figure 64. Bedload measurement sites.

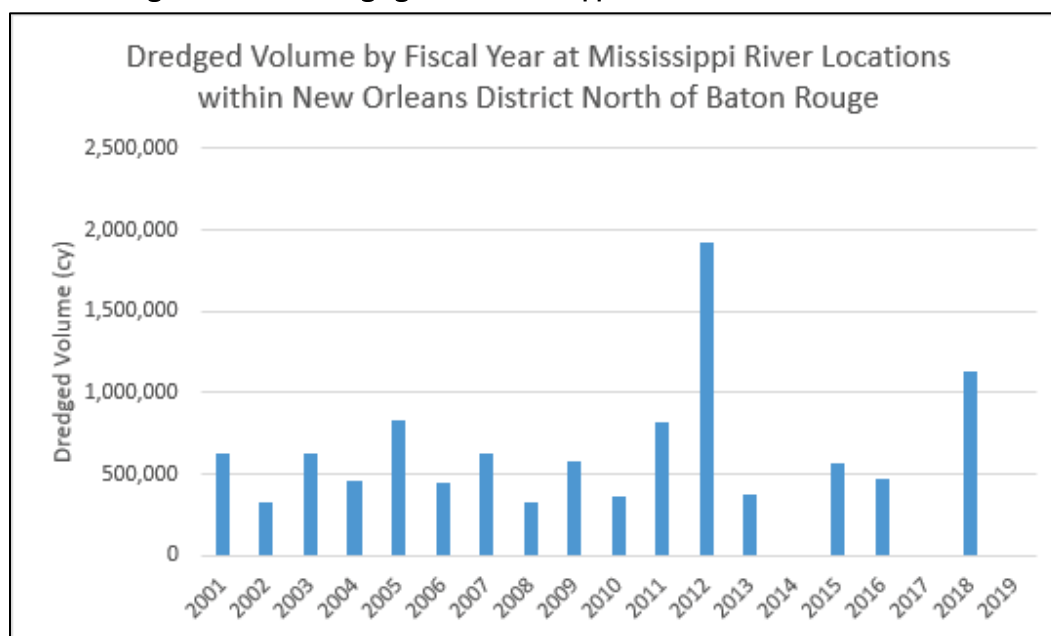


3.5 Dredging records

Dredging records were requested from the MVK and MVN for the past 20 yr (dredging seasons, starting in 2000 to ending in 2020). No dredging is known to have occurred on the Mississippi River within the MVK area of responsibility south of Vicksburg during that time period.

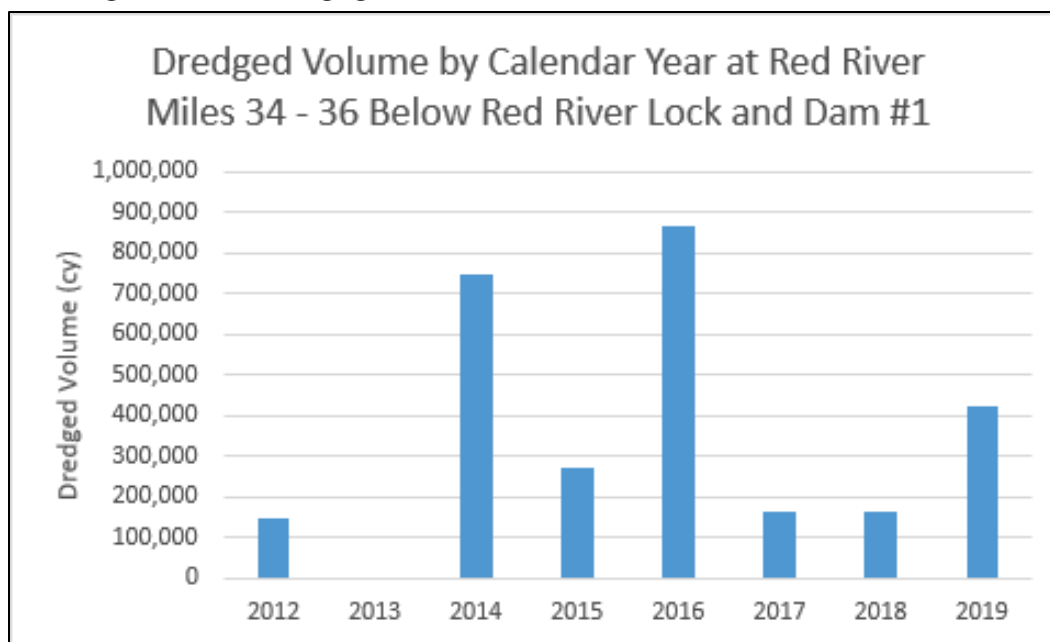
The MVN has dredged at five locations on the Mississippi River within the OMAR Assessment reach as defined by this report (Baton Rouge and north) between Fiscal Year (FY) 2001 (starting in October 2000) and FY 2019 (ending in September 2019). Those locations are Fort Adams Crossing (RM 311-314), Smithland Crossing (RM 299.7), Tunica Bend (RM 293), Bayou Sara Crossing (RM 266), and Wilkerson Point (RM 235). The dredging volume has been relatively consistent, with FY 2012 being identifiable as an outlier; this is understandable considering that the fall and winter in 2011–2012 was a known historic drought that followed a historic flood during the spring of 2011 (Figure 65).

Figure 65. MVN dredging on the Mississippi River within the OMAR reach.



No dredging is known to have occurred on the Atchafalaya between the Red River and the Whiskey Bay Pilot Channel for the time period analyzed. Dredging does occur in the approach channels of the Old River Lock and on the Lower Old River just upstream of the confluence with the Red and Atchafalaya. The only location MVK dredges on the Red River other than in the lock approach channels is a stretch of river between RM 34 and RM 36 (Figure 66). This reach extends from slightly below the confluence with the Black River to downstream of Lock and Dam No. 1 (Lindy C. Boggs Lock and Dam).

Figure 66. MVK Dredging on the Red River below Red River Lock and Dam No. 1.



3.6 Site visit

A team of ERDC CHL and MVN personnel conducted a site visit to the Red River, Black River, Old River Outflow Channel, and Atchafalaya River on November 18 and 19, 2020. The reaches visited were the Red River from the tailwater of Lock and Dam No. 1 (Lindy C. Boggs Lock and Dam) to Old River, the Black River from just upstream of Acme to the confluence with the Red River, the Old River Outflow Channel from the confluence of the Hydropower Outflow Channel to the Red River, and the Atchafalaya River from the Red River to the upstream end of the Whiskey Bay Pilot Channel. The purpose of the visit was to visually inspect the river systems for indicators of short- or long-term geomorphic change or evidence of cause-and-effect relationships. A secondary purpose was the collection of bank and bed sediment samples.

The following are the major findings from the trip report:

- Multiple bank erosion sites were identified on the Atchafalaya River, but these were generally localized and usually restricted to the outside bank of tight meanders with radius of curvature to width ratios less than about 3, or at downstream ends of revetments. This erosion did not appear to be indicative of reach-scale bank instability. Toe scour appeared to be the failure mechanism at multiple revetment sites.

- Little ongoing Operations and Maintenance of existing revetments has occurred on the Red downstream of Lock and Dam No. 1 and on the Atchafalaya from its head down to the Whiskey Bay Pilot Channel.
- Multiple sites exhibited signs of terracing, supporting adjustment to widespread historical downcutting identified in other analyses.
- The bank materials varied from medium sands to clays; typically, one material would dominate with lenses of the other. This matches with the materials identified in the analysis of the boring logs on the Atchafalaya River.

3.7 Events timeline

A timeline chart of the major events that have occurred during the study time period that were considered influential in terms of morphology in vicinity of the ORCC is shown in Appendix A. A color-coded table providing additional information is also included in Appendix A.

Images can be incredibly useful to understand some of the large planform (i.e., viewed directly from above, as looking down on a map) changes and construction elements that have historically occurred as detailed in the events timeline. Three such images are included below. Figure 67 shows the area at Old River over multiple times, including the influence of Shreve's Cutoff. Sill dams were constructed at different times on the Atchafalaya River to reduce channel enlargement and on the Red River to direct more flow down the Mississippi River; their approximate locations can be seen in Figure 68. Figure 69 shows the percentage of the Mississippi River flows captured by the Atchafalaya River changing over time (Latimer and Schweizer 1951). The accelerating pace of this change was the driving force for construction of the Low Sill and Overbank structures (and thus, the ORCC) to control the flow distribution between the Mississippi and Atchafalaya Rivers.

Figure 67. Old River evolution (from Latimer and Schweizer [1951b]).

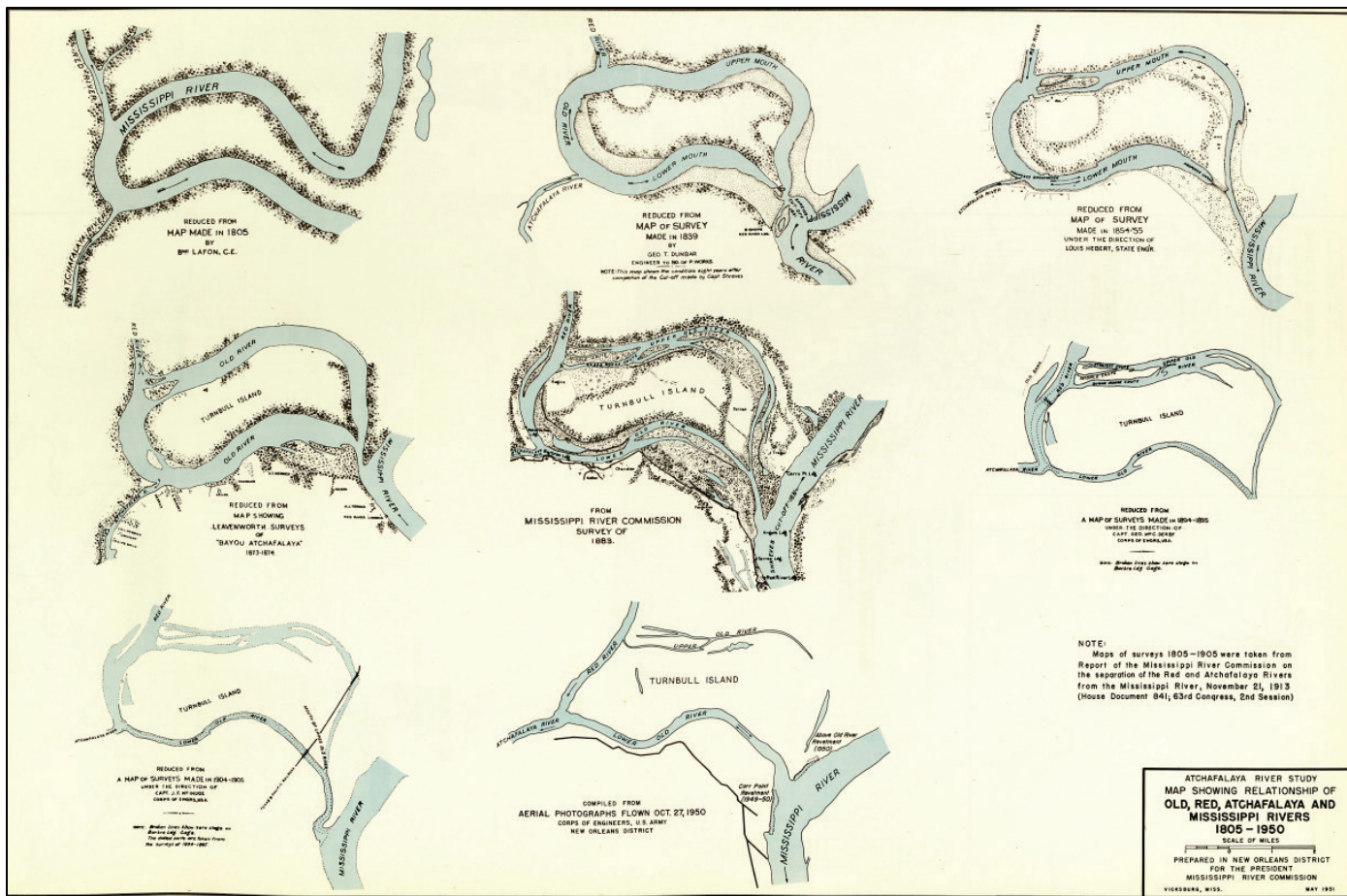


Figure 68. Red and Atchafalaya Dams locations (adapted from Reuss [1998]).

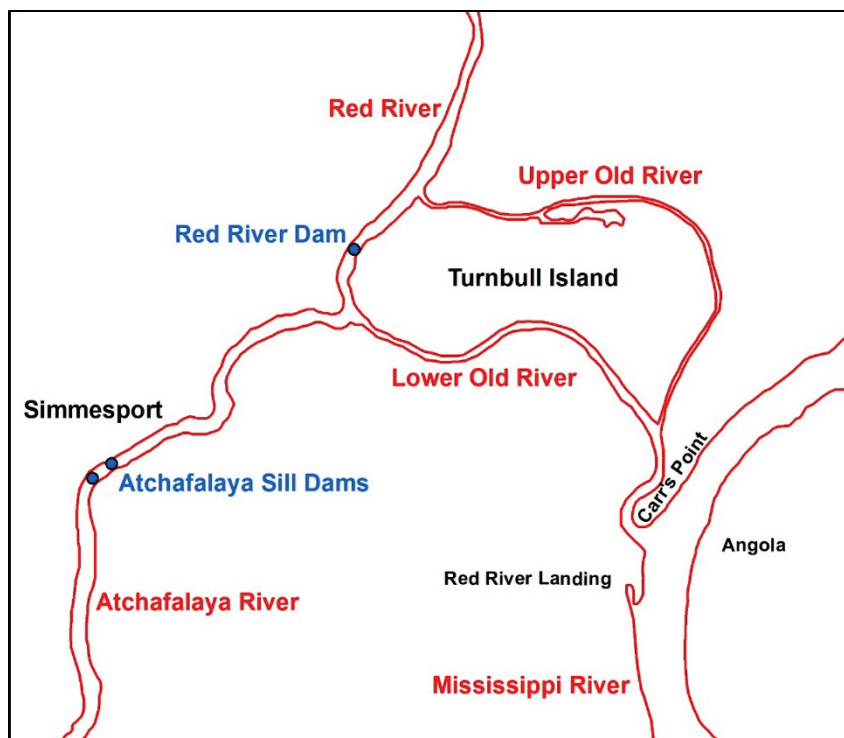
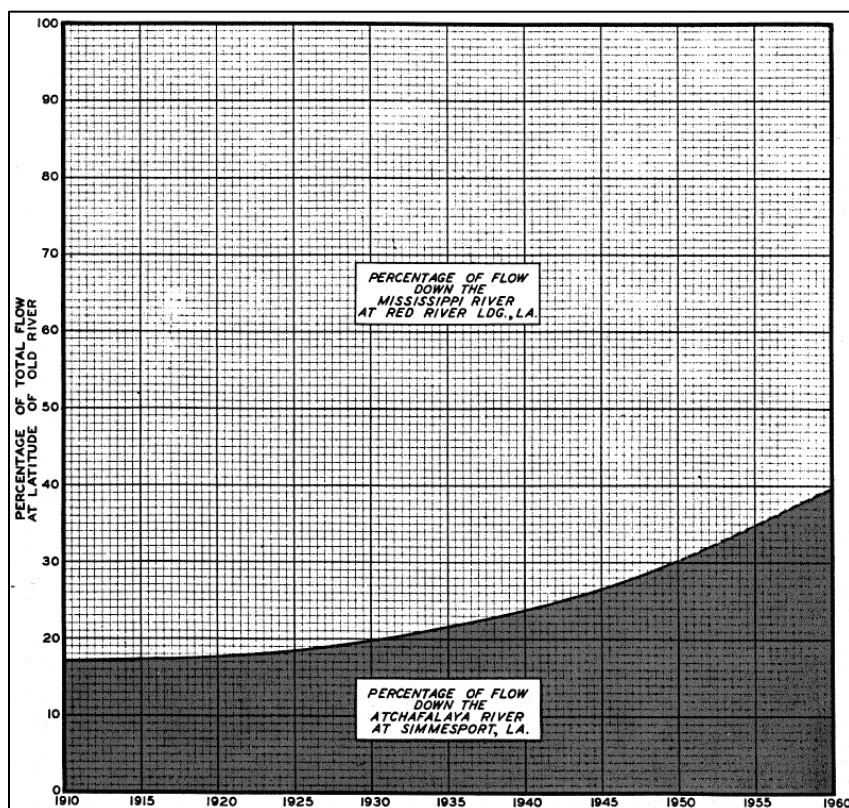


Figure 69. Percentage of flow capture of the Mississippi River by the Atchafalaya River (from Latimer and Schweizer [1951b]).



4 Integration

4.1 Mississippi River Reach – Vicksburg to Old River Control Complex (ORCC)

Prior to the 1930s, this reach was experiencing slight aggradation as indicated by specific gage records and channel geometry analysis. This aggradational trend agrees with the observations of Winkley (1977). The USACE cutoff program (an engineered shortening of the Mississippi River to reduce flood heights and provide a more efficient navigation channel) altered this aggradational regime. Between 1929 and 1936, one natural and four artificial cutoffs shortened this reach by almost 50 mi. This led to an increase in cross-sectional area at bankfull stages and an identifiable drop in stages in the specific gage records until the early 1940s. Since the early 1940s, the geometric analysis trends for both low flow and bankfull conditions generally show a slight loss in cross-sectional area. The specific gage trends generally support this trend as well, with the lower flows showing a trend of aggradation slowing towards dynamic equilibrium beginning in the 1980s. For higher flows, the trend of slight aggradation continues from the early 1940s to the present. The Vicksburg to Natchez reach shows a dropping annual average water surface slope since the mid-1930s, which also supports the slightly aggradational trend.

4.2 Mississippi River reach – ORCC to Baton Rouge

The geometric analysis reveals this reach to be aggradational from the mid-1910s/1920s until the early-1970s, losing approximately 25% of its average cross-sectional area at low water. This loss of area is reflected in the specific gage records, which indicate stage increases during this period. Note that even though the flow diversion through Old River was increasing during this time period, the planform and cross-section geometry of the Mississippi River in the vicinity of Old River would not be expected to divert significant bed material load into Old River (Latimer and Schweizer, 1951). High flows in 1973 and 1975 resulted in a dramatic increase in stages, after which the reach has remained slightly aggradational but at a somewhat lower rate than it was previously.

The stream power shows a significant drop downstream of the ORCC, suggesting a loss of carrying capacity for sediment downstream of the distributary connection. This decrease in stream power is a function of

both the loss of water and a reduced slope. This is supported by a drop in the calculated total suspended sediment loads as well.

4.3 ORCC inflow and outflow

The geometric analysis points to the ORCC inflow channels and connections to the main outflow channel as typically being slightly aggradational since approximately 1988. The inflow channels being aggradational is understandable given that the Mississippi River both upstream and downstream of the ORCC has been slightly aggradational for the same period.

The ORCC Outflow channel has been degradational since 1963. This process, according to the geometric analysis, has been slowing to the point of potentially reaching dynamic equilibrium, as seen in the cross-sectional area for most cross sections from 2004 to 2013. The specific gage analysis for the Old River Outflow channel gage supports this trend as well between the early 1960s and the early 1980s. After the early 1980s, the specific gage analysis lacks sufficient points for trend determination.

4.4 Atchafalaya River reach – Old River to Whiskey Bay Pilot Channel

The general trend for the Atchafalaya River for the reach upstream of the Whiskey Bay Pilot Channel is that the Atchafalaya River went through a period of significant degradation dating back to at least 1880, but that process has slowed to the point that the reach has been approximately in dynamic equilibrium since the 1980s. This is demonstrated in the geometric analysis, which finds geometric trends fluctuating between slightly aggradational, slightly degradational, or at dynamic equilibrium for the current analysis period (1976 to present). The specific gage trends show the same trend across multiple gages, a significantly degradational system until the early 1980s, when the system approximately reaches dynamic equilibrium. This degradation has known historical causes, including the clearing of the Atchafalaya River and Red River rafts in the mid-1800s, increasingly diverted flows from the Mississippi, and the channel capacity dredging of the 1930s to 1960s. Revetments were placed in this reach of the Atchafalaya starting in 1954 and continuing until 2011, reducing the possibility of lateral channel migration and driving the channel towards vertical change if it needed to adjust. An analysis of boring logs in close

vicinity to the channel suggest that the bed of the Atchafalaya has not reached a non-erodible layer and should still have the ability to deepen if needed, further supporting the trend of dynamic equilibrium.

4.5 Red River reach – Alexandria to confluence

Limited digital bathymetric data were available for the Red River reach at the time of this report, precluding an analysis of geometric trends. From the specific gage records for the gages with measured flow data on the Red River, it is known that the Red River was degradational (from Fulton to Alexandria) prior to the construction of the locks and dams as part of the J. Bennett Johnston Waterway. A synthetic specific gage analysis developed for the Black River at Acme gage (just upstream from the confluence with the Red) suggests that the reach below Red River Lock and Dam No. 1 (L. C. Boggs Lock and Dam) was degradational following the construction of the lock and dam until a point early in the 2000s. The specific gage trends fit within the historical context of timber raft removal and rock removal allowing for more flow (and thus, potentially, more sediment mobilization) on the Red River, among other events. Additional analysis is warranted of geomorphic trends on Red River.

4.6 Summarized integration

The overall trends for each reach for different time periods based on the synthesis of the different analyses is below in Figure 70. The Mississippi River analysis is split into two reaches, Vicksburg to ORCC and ORCC to Baton Rouge. The Vicksburg-to-ORCC reach shows an overall slightly aggradational trend from 1920 to 2020 with a short period of degradation stretching 1930 to 1940. The ORCC-to-Baton Rouge reach shows a trend of aggradation from 1920 to 1980 with a trend of slightly aggradational from 1980-2020. The Old River Outflow reach shows a trend of degradation from 1960 to 1980 and changes to a slightly degradational trend from 1980 to 2020. For the Atchafalaya River, the Old River-to-Whiskey Bay reach was used as the boundary for the trend summary. The Old River-to-Whiskey Bay reach shows a trend of degradation from 1920 to 1980 and a trend of dynamic equilibrium from 1980 to 2020. For the Red River, the Alexandria-to-the Confluence of the Red River and Atchafalaya River reach was used as the boundary for the trend summary. The Atchafalaya-to-the confluence reach shows a trend of degradation

Figure 70. Reach trend summary.

Channel - Reach	Stability Assessment for Given Time Periods					
	1920 to 1940		1940 to 1960	1960 to 1980	1980 to 2000	2000 to 2020
Mississippi - Vicksburg to ORCC	SA	D	SA	SA	SA	SA
Mississippi - ORCC to Baton Rouge	A		A	A	SA	SA
Old - Old River Outflow	-		-	D	SD	SD
Atchafalaya - Old River to Whiskey Bay	D		D	D	DE	DE
Red - Alexandria to Confluence	-		D	SD	SD	-

A	Aggradation
SA	Slightly Aggradational
DE	Dynamic Equilibrium
SD	Slightly Degradational
D	Degradation
-	Not Applicable / Not Analyzed

5 Charge Questions

At the inception of the OMAR Assessment, a number of charge questions were developed and assigned to the various OMAR Assessment teams. The Geomorphic Assessment team was charged with addressing the following charge questions: (1) How much sediment is currently being diverted through the ORCC; (2) How much sediment is being supplied by the Red River to the Atchafalaya River; (3) What are the impacts of sedimentation on the operation of the ORCC and the Morganza Structure; (4) How much sediment could be diverted by USACE operations if the hydroelectric station was not operated; and (5) How much sediment must be diverted to bring the Mississippi at ORCC into dynamic equilibrium? As part of the geomorphic assessment, an attempt was made to address each of these charge questions. However, note that any answers to these sediment-related questions must be viewed within an approximately order of magnitude range due to the large uncertainty in the base sediment data. Each of the five charge questions is discussed in the following sections.

5.1 How much sediment is currently being diverted through the ORCC?

The measured suspended sediment data from the pump sampler data and the ORCC Outflow site were examined for the time period from 1992 to 2014. Based on these data, the average annual sand load being diverted through the ORCC is estimated to be in the range of approximately 2.5 to 7 million tons/yr, with an annual average of approximately 5 million tons/yr. The diversion of fine sediment is estimated to be in the range of approximately 17 to 34 million tons/yr. These estimates do not include any bedload measurements.

5.2 How much sediment is being supplied by the Red River to the Atchafalaya?

It was not possible to define an exact value of the sediment supplied by the Red River to the Atchafalaya River. However, analysis of the measured suspended sand data suggests that the sand supplied from the Red River is slightly greater than that from the ORCC. The contributions from the Red River are obviously greatly influenced by the particular flow period, but for the 1992 to 2014 period, the Red River supplied about 58% of the sand load to the Atchafalaya River. Obviously, the relative percentage of sand

supplied will vary for a given flow period. Also note that for the 1992–2014 period, the Red River supplied almost 60% of the sand load to Atchafalaya River but only supplied approximately 30% of the flow.

5.3 What are the impacts of sedimentation on the operation of the ORCC and the Morganza structure?

Specific gage data (Figure 16) suggest long-term trends of stage increases at the higher flows in the vicinity of the Morganza Structure. Note that these long-term stage increases are the result of a number of factors, such as sedimentation and changes in overbank roughness.

5.4 How much sediment could be diverted by USACE operations if the hydroelectric station were not operated?

A scenario was developed to provide an approximately order of estimate of the effects of using only the Auxiliary and Low Sill Structures. This approach used the pump sampler sediment data at the three structures and assumed that all flow and sediment would be passed through the Low Sill and Auxiliary Structures. For this scenario, the distribution of water through the Low Sill and Auxiliary Structures was 35% and 65%, respectively. The results suggest that diverting all flows through the Low Sill and Auxiliary Structures could increase the diversion of sands, possibly on the order of approximately 90%. While this represents a large percentage increase in the amount of sand being diverted, this increased load is still small compared to the sand loads at Union Point.

5.5 How much sediment must be diverted to bring the Mississippi River at ORCC into dynamic equilibrium?

The Mississippi River in this reach (both upstream and down of the ORCC) is in a slightly aggradational regime, and this regime is anticipated to continue for some time into the future. Increasing the diversion of bed material could reduce this aggradational trend to some degree. However, this aggradational regime is largely driven by broader system-wide processes and trying to alter these processes to achieve dynamic equilibrium through local adjustments at the ORCC will be difficult. It is also important to recognize that the Atchafalaya River has been in a state of dynamic equilibrium since the early 1980s, and any change in the sediment diversion could disrupt this regime.

6 Recommendations

- Synchronous lidar and multibeam survey collection after significant flood events is recommended to capture the evolution of the channel and the overbank.
- The anthropogenic geomorphic changes on the Red River have been dramatic, starting with the history of raft clearing to the more recent history of channel realignment for the creation of the J. Bennett Johnson Waterway. The scope of these changes is not well understood and made more complex by the switch from a free-flowing to a pooled environment. Likewise, geomorphic changes on the Ouachita-Black River system are not fully understood. It is recommended that geomorphic analyses be carried out on both the Red River and the Ouachita-Black River systems to gain a better understanding of potential long-term impacts on the Atchafalaya River.
- Differences in procedure between gages and even changes in procedure for individual gages made like comparison of suspended sediment data difficult. It is recommended that suspended sediment data collection methodology be standardized between USGS gages and USACE gages throughout the Lower Mississippi River. This will require another round of procedure changes, but in doing so, this will greatly increase the value of the data collected for basin-wide analysis. As a secondary recommendation, an intensive historical (to find and document procedure changes) and statistical effort should be undertaken to determine what value can be derived from the currently available historical data.

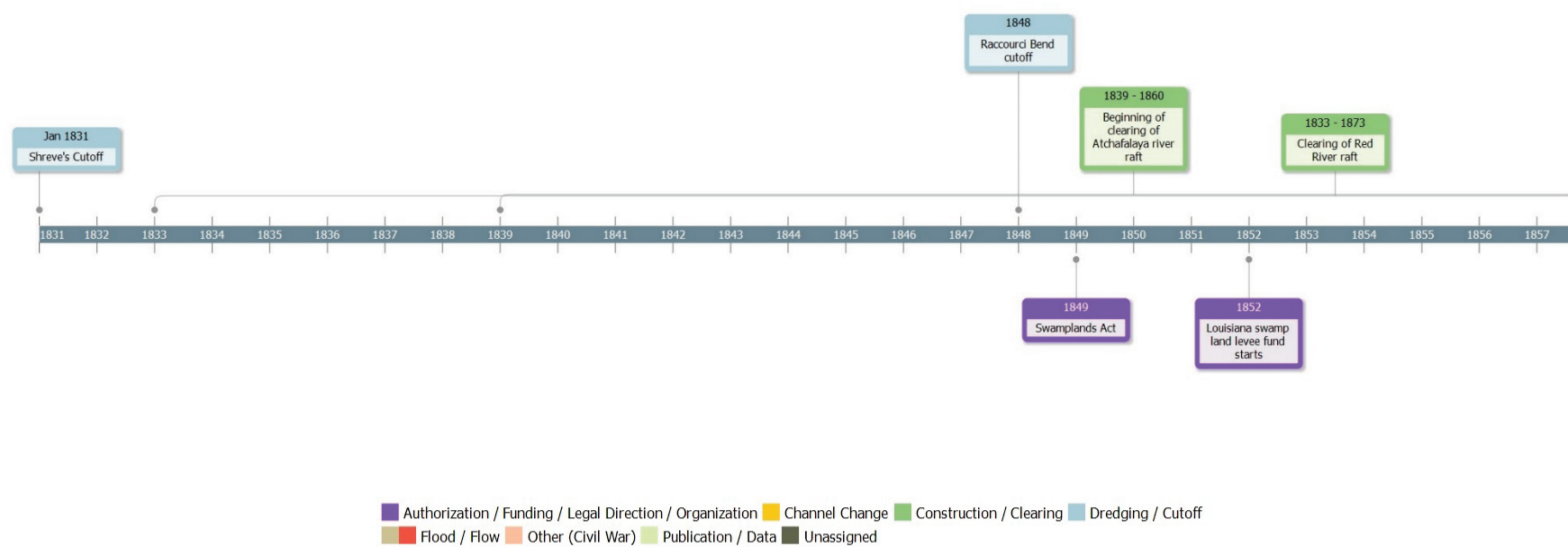
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Appendix A: Explanation Table and Events Timeline

Figures A-1 through A-7 present explanations of the historical timeline events.

Figure A-1. Events timeline 1831–1857.



Created with Timeline Maker Pro v4. Produced on Sep 23 2021.

Figure A-2. Events timeline 1857–1883.

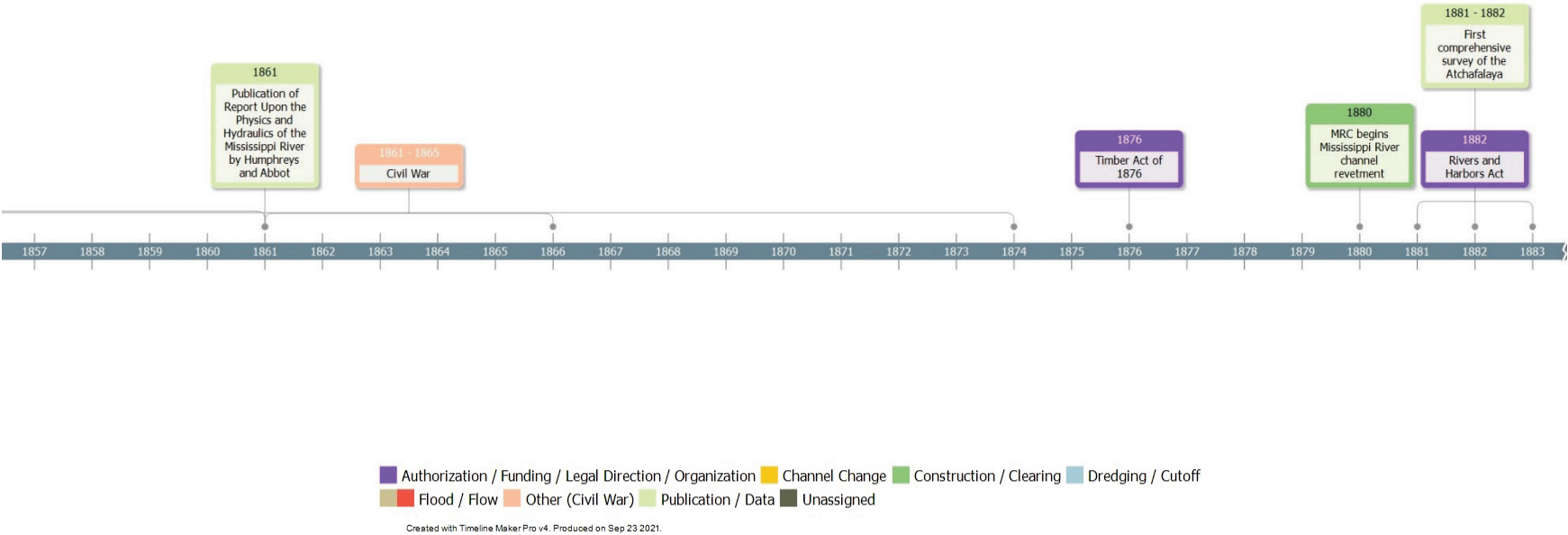
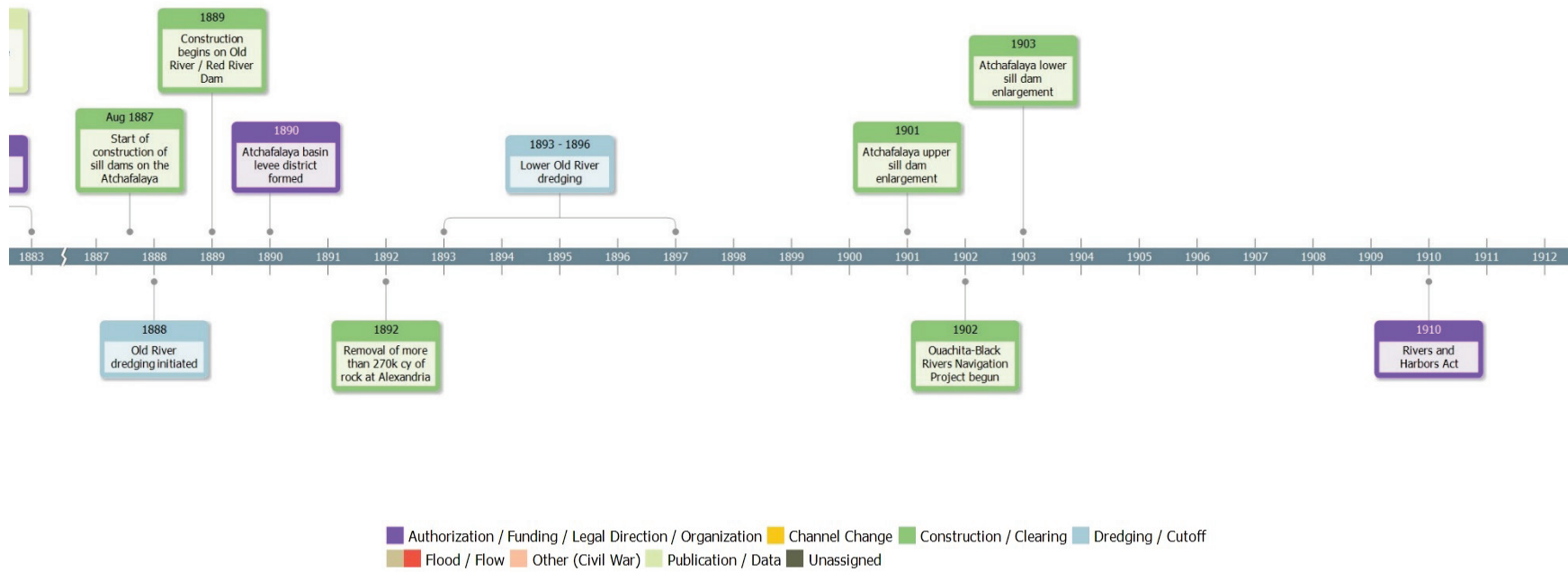
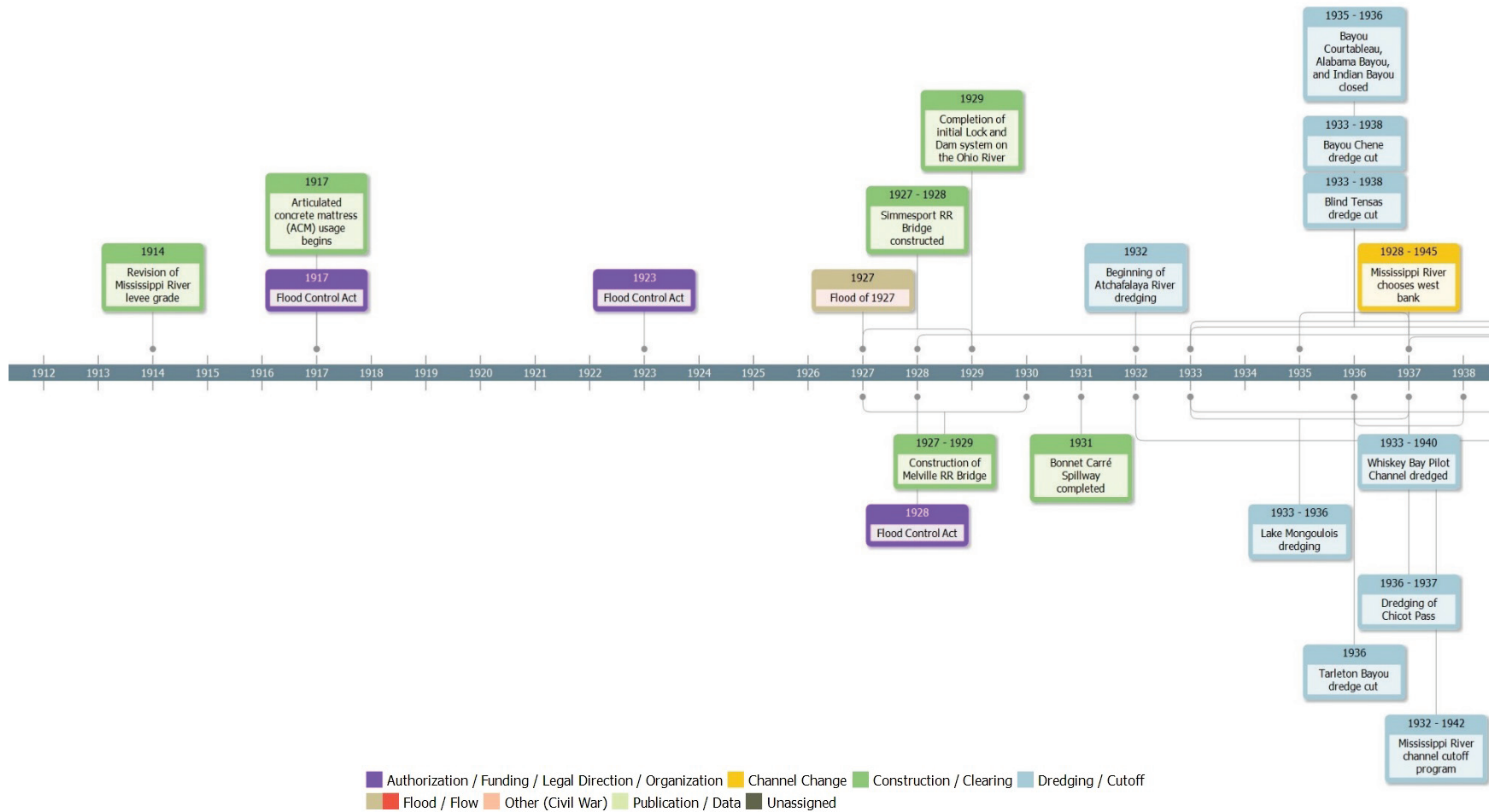


Figure A-3. Events timeline 1883–1912.



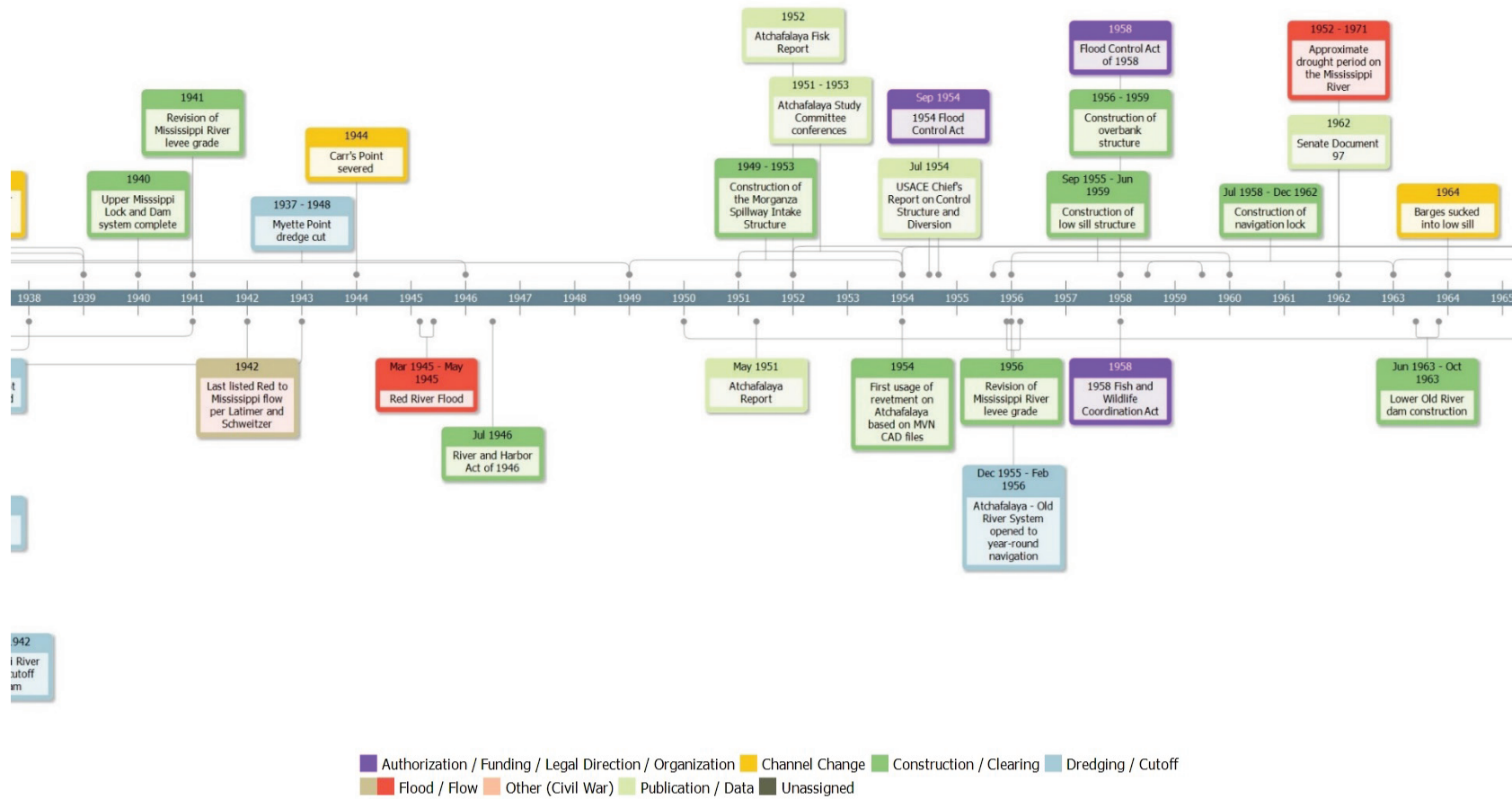
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Figure A-4. Events timeline 1912–1938.



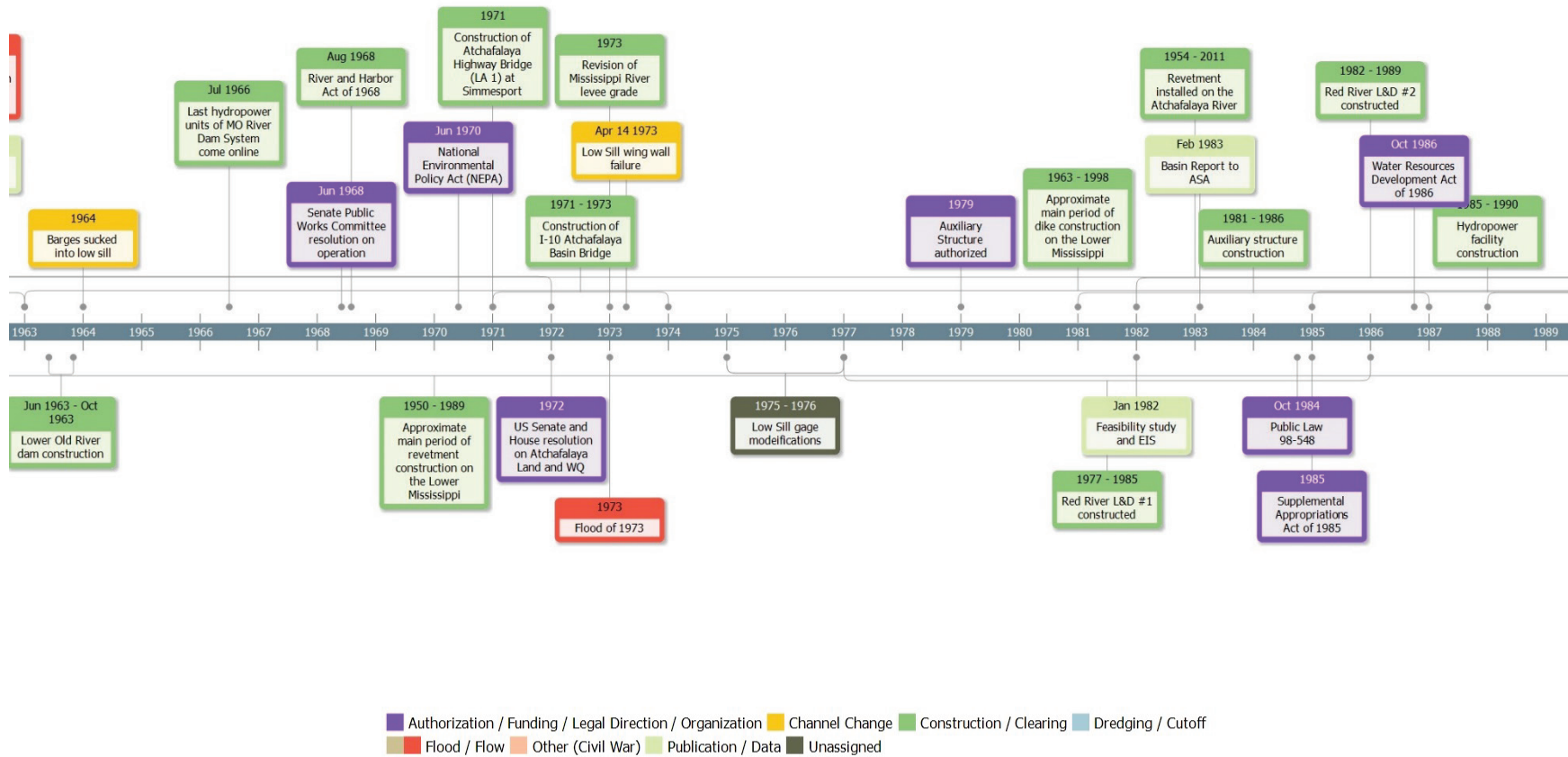
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Figure A-5. Events timeline 1938–1965.



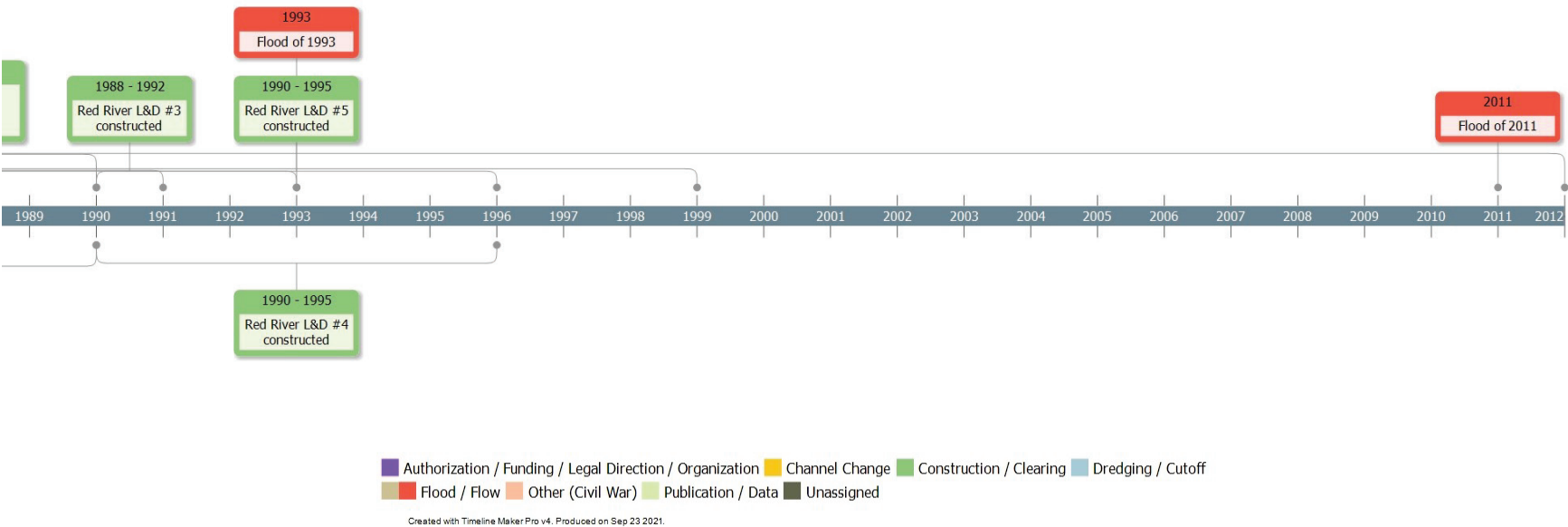
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Figure A-6. Events timeline 1963–1989.



Created with Timeline Maker Pro v4. Produced on Sep 23 2021.

Figure A-7. Events timeline 1989–2012.



River	Year	Month if provided	Event	Explanation / Effect
Mississippi	1831	Jan	Shreve's Cutoff	Shortened Mississippi by ~ 18 mi
Red	1830s		Clearing of Red River Raft	Multiple estimates of length of raft (>100 mi, ~160mi). Started north of Natchitoches in 1830s. Non-continuous. Estimated to exist for hundreds of years with lower end decaying and passing downstream. Potential cause of change to Moncla Gap. Done by Shreve (Latimer & Schweitzer 1951 list date as 1828, others as 1833-38); Raft finally fully removed in 1873. Abington has three removal periods (1833-38, 1841-43, and 1872-3). New raft started to form ~4 months after initial removal (2300 ft to >20 mi from 1838 to 1841). Third raft started to form months after removal (30 mi long by 1972). Post-last removal, logs were cleared quickly and overflow channels closed to increase main channel flow.
Atchafalaya	1839		Beginning of clearing Atchafalaya raft	~30 miles in length in at upper end (Latimer and Schweitzer 1951). ~40 mi in length, 30 mi from head in Comeaux 1970. Series of rafts over distance. Raft cleared in ~1860 (by ~1855 to Latimer & Schweitzer)
Mississippi	1848		Raccourci Bend Cutoff	Shortened Mississippi by ~ 19 mi; new main Mississippi by mid-1850s
-	1849, 1850		Swampland Acts	Transfer federal swampland to states for sale and reclamation
-	1852		Louisiana swamp land levee fund starts	Reworked in 1859, stopped in 1861
-	1861		Publication of <i>Report upon the Physics and Hydraulics of the Mississippi River</i> by Humphreys and Abbot	"Levees-only" strategy
-	1861-5		Civil War	Significant destruction of existing Atchafalaya Basin levees
-	1876		Timber act of 1876	Deforestation of cypress swamplands begins
Mississippi	1880-1		MRC begins Mississippi channel revetment	
Atchafalaya	1881-2		First comprehensive survey of the Atchafalaya	Done by Major G.W. Howell - USACE
-	1882		Rivers and Harbors Act	Mississippi River Commission begins to coordinate Mississippi River levee design.
Atchafalaya	1887	August	Start of construction of sill dams on the Atchafalaya	Constructed to prevent Red River capture by the Atchafalaya. Only 2 Atchafalaya sills constructed; first close to Simmesport (finished 12/21/1888) and then with 0.25 mile to follow (2nd actually 0.33 mi, finished 8/27/1889); in 1890s, MRC decided that enlargement had halted and did not build the rest: dam 1 maintained by RR until 1934
Old	1888		Old River dredging initiated	
Red	1889		Construction begins on Old River / Red River Dam	Dam designed on Red River to move flows into Upper Old River; work stopped in 1891 due to dredging ineffectiveness on Old River; Dam partially opened in 1892 for navigation traffic; abandoned in 1896
Atchafalaya	1890		Atchafalaya Basin levee district formed	Constructed levees on the Mississippi and Atchafalaya. By 1900, had 30 mi of levee on the Atchafalaya. The levee exceeded the 1897 flood by 3 ft. By 1916, 40 mi on the RDB and 46 on the LDB of the Atchafalaya.
Red	1892-1893		Removal of more than 270k cy of rock at Alexandria	Allows knickpoint to continue working up Red River
Old	1893-6		Lower Old River dredging	Cutter head dredge Ram keeps lower Old River open
Atchafalaya	1901		Atchafalaya sill dam enlargement	Upper sill dam enlarged to 560 ft, lower to 440 ft
Black	1902		Ouachita-Black Rivers Navigation Project begun	Construction of 6 Locks and Dams completed in 1924 (presently 4)
Atchafalaya	1903		Low sill dam enlargement	Lower sill dam enlarged to 560 ft
-	1910		Rivers and Harbors Act	Dredging of a 240 ft wide by 20 ft deep nav channel at Atchafalaya Bay, filled shortly after
Mississippi	1914		Revision of Mississippi River levee grade	Post-1912-13 floods, update to the Mississippi River Commission's levee grade and section
-	1917		Flood Control Act	Established federal need to assist with flood recovery and federal-local cost share for levee construction; Up to \$45 million dollars in spending with no more that \$10 million dollars in anyone year
Mississippi	1917		ACM usage begins	First cases in the Vicksburg Harbor and Arkansas River, then eslewhere
-	1923		Flood Control Act	Continuation of 1917 Flood Control Act to allow up to \$10 million dollars annual spending on flood control
-	1927		Flood of 1927	
Atchafalaya	1927 - 1928		Simmesport RR Bridge constructed	Sill dam 1 enlarged on upstream end; bridge built on extension
Atchafalaya	1927 - 1929		Construction of Melville RR Bridge	
-	1928		Flood Control Act	Authorization for MR&T - \$325 million over - including the authority for the floodways under the Jadwin plan (right for easement purchases to follow)
Mississippi	late 1920s-1940s		Mississippi River chooses west bank	Per Latimer & Schweitzer, MI River channel would vary between E and W bank in the vicinity of RR Landing before Simmesport RR Bridge. After construction of an incline to unload RR material, the channel stabilized on the W bank. Increased W bank attack led to Carr's Point severing in 1944
Mississippi	1929		Completion of initial Lock and Dam system on the Ohio River	Series of 51 locks and dams
Mississippi	1931		Bonnet Carré Spillway completed	Designed to divert 250,000 cfs of the Project Flood to Lake Pontchartrain

River	Year	Month if provided	Event	Explanation / Effect
Atchafalaya	1932		Beginning of Atchafalaya river dredging	Dredging to improve Atchafalaya capacity from ~200k cfs to ~600k cfs as part of Atchafalaya floodway plan; as of 1938, capacity estimated at ~500k cfs. 91 M cy removed between 1932 and 1941.
Mississippi	1932 - 1942		Mississippi River channel cutoff program	Sixteen cutoffs (15 engineered, 1 natural) led to the shortening of the Mississippi between Memphis and Old River by ~ 150 mi
Atchafalaya	1933 - 1940		Whiskey Bay Pilot Channel dredged	Shortened Atchafalaya by ~7.25 mi; dredged ~23.3M cy (per Fisk)
Atchafalaya	1935 - 1936		Bayou Courtableau, Alabama Bayou, and Indian Bayou closed	Part of the Atchafalaya dredging program; closed distributaries to concentrate flow
Atchafalaya	1936 - 1937		Dredging of Chicot Pass	10 miles of Chicot pass dredged for navigable depth and effective sediment passage; ~18.8M CY
Atchafalaya	1933 - 1938		Blind Tensas Dredging Cut	RM 68; ~4.6M CY
Atchafalaya	1933 - 1936		Lake Mongoulois	RM 70-74; ~9.2M CY
Atchafalaya	1933 - 1938		Bayou Chene Cut	RM 74; ~7.3M CY
Atchafalaya	1936		Tarleton Bayou Cut	RM 76; ~1.3M CY
Atchafalaya	1937 - 1948		Myette Point Cut	RM 95; ~5.7M CY
Mississippi	1940		Upper Mississippi Lock and Dam system complete	With completion of L&D 24, original system for main stem Upper Mississippi control is complete
Mississippi	1941		Revision of Mississippi River levee grade	Update to the levee grade of 1928
	1942		Last listed Red to Mississippi flow per Latimer and Schweitzer	9 days of this flow condition recorded
	1944		Carr's Point severed	Mississippi connection to lower Old River shortened
Red	1945	Mar - May	Red River Flood	As a result, Mississippi to Atchafalaya direction begins to dominate Old River, instead of periodic switching. Last flow of Old River into Mississippi.
Red	1946	July	River and Harbor Act of 1946	Precursor to the modern Red River Navigation Project authorized
Mississippi	1949 - 1953		Construction of the Morganza Spillway Intake Structure	Designed to divert 600,000 cfs of the Project Flood to Atchafalaya River
Atchafalaya	1951	May	Atchafalaya Report	Latimer and Schweitzer conclude that the Atchafalaya will dominate within 25 years without a control structure
	1950 - 1989		Approximate main period of revetment construction on the Lower Mississippi	
Atchafalaya	1951 - 3		Atchafalaya Study Committee Conferences	Panel of government and outside experts to discuss viability of control structure
Atchafalaya	1952		Atchafalaya Fisk Report	Geology of the Atchafalaya and the Problem of the Mississippi River diversion; finds largely the same, that by 1971, a critical stage will be reached in the switch
Mississippi	1952 - 1971		Approximate drought period on the Mississippi River	
-	1954	July	USACE Chief's Report on Control Structure and Diversion	
-	1954	Sept	1954 Flood Control Act	Control structure funding authorized, including future lock funding; funding also authorized to improve nav channel above Morgan City
Atchafalaya	1954 - 2011		Revetment installed on the Atchafalaya River	
	1955 - 6	Dec - Feb	Atchafalaya - Old River System opened to year-round navigation	Year-round navigation from Angola on the Mississippi to Morgan City via clearing shoals at Grand and Six Mile Lakes
Old	1955 - 1959	Sept 55 - June 59	Construction of low sill structure	Began Sept 14
Mississippi	1956		Revision of Mississippi River levee grade	
Old	1956 - 1959	October	Construction of overbank structure	
-	1958		Flood Control Act of 1958	Additional \$28.2 M for project (primarily lock)
-	1958		1958 Fish and Wildlife Coordination Act	Federal Water resource agencies must coordinate with USFWS before submitting reports to Congress
Old	1958 - 1962	July 58 - Dec 62	Construction of navigation lock	Contract award 6/27/58; opened for traffic 3/15/63
-	1962		Senate Document 97	Required multi-purpose planning be considered
Old	1963	June - Oct	Lower Old River Dam construction	June 27, dam beginning; Dam complete October 15
Mississippi	1963 - 1998		Approximate main period of dike construction on the Lower Mississippi	
Old	1964, 1965		Barges sucked into low sill	Extensive downstream scour mentioned both times
Missouri	1966	July	Last hydropower units of MO River Dam System come online	Missouri River Dam System begins full operation
-	1968	June	Senate Public Works Committee resolution on operation	Senate directs USACE to resolve conflicts over amount of water supplied to Atchafalaya via ORCC; after modeling, USACE held meeting in Feb 1970 recommended operation to continue the same
Red	1968	August	River and Harbor Act of 1968	Authorized the modern Red River Navigation Project (J. Bennett Johnston Waterway)
-	1970	January 1	National Environmental Policy Act (NEPA)	Requires federal agencies to assess environmental effects prior to making decision
Atchafalaya	1971 - 1973		Construction of I-10 Atchafalaya Basin Bridge	S of Krotz Springs
Atchafalaya	1971		Construction of Atchafalaya Highway Bridge (LA 1) at Simmesport	

River	Year	Month if provided	Event	Explanation / Effect
-	1972		US Senate and House resolution on Land and WQ	USACE directed to develop plan for land and water quality in Atchafalaya basin with partner agencies and stakeholders. Atchafalaya Basin Agency Management Group (ABAMG) formed in April 1974 to lead effort
-	1973	Mar - May	Flood of 1973	
Mississippi	1973		Revision of Mississippi River levee grade	
Old	1973	April 14	Low sill wing wall failure	Sections of the wing wall fail due to scour from flood of 1973
Old	1975 - 1976		Low Sill gate modifications	Allowed more uniform flow through the gates, increased operational head differential
Red	1977 - 1985		Red River L&D #1 constructed	L.C. Boggs L&D
Old	1979		Auxiliary Structure authorized	
Old	1981 - 1986		Auxiliary structure construction	Construction complete on September 7, 1986
Atchafalaya	1982	January	Atchafalaya River Feasibility Study and EIS	Finalized version of feasibility study (including the heart of the general design memorandum) and EIS for Atchafalaya Basin floodway plan (required by NEPA) submitted to MRC; maintained 70-30 split and called for 29 M cy of dredging in Grand and Six Mile Lake area to help with enlargement / sedimentation; included real estate plans for easements
Red	1982 - 1989		Red River L&D #2 constructed	J.H. Overton L&D
Atchafalaya	1983	Feb	Basin Report to ASA	
-	1984	October	Public Law 98-548	Authorized establishment of Atchafalaya National Wildlife Refuge; established formally in October 1986
Old	1985 - 1990	Aug - Aug	Hydropower facility construction	Powerstation comes online in Feb 1991
-	1985		Supplemental Appropriations Act of 1985	Authorized and appropriated for the Basin report; held up from work due to cost sharing
-	1986	October	Water Resources Development Act of 1986	Re-authorized with cost-share language
Red	1988 - 1992		Red River L&D #3 constructed	
Red	1990 - 1995		Red River L&D #4 constructed	R.B. Long L&D
Red	1990 - 1995		Red River L&D #5 constructed	J.D. Waggonner L&D
-	1993	Apr - Oct	Flood of 1993	
-	2011	May - June	Flood of 2011	

Color-coding Index

Construction / Clearing
Flood / Flow
Authorization / Funding / Legal Direction / Organization
Report / Meeting
Dredging / Cutoff
Other (Civil War)
Channel Change

Appendix B: Trip Report

The following pages present the geomorphology team field trip report for November 2020.

Members of the OMAR Task 2: Geomorphology team along with CHL geomorphologists visited the Atchafalaya, Red, Black, and Old Rivers in the area around the Old River Control Complex (ORCC) on November 18th and 19th, 2020. The investigators on the trip included the following:

David Biedenharn – CEERD-HFR
Deborah Centola – MVN-ED-H
Travis Dahl – CEERD-HFR
Keaton Jones – CEERD-HFR
Tim Lauth – CEERD-HFR
Marie Mathews – CEERD-HFR
Autumn Murray – CEERD-HFR

The visit was conducted using CHL's buoy tender/landing craft boat: the boat captain was Mike Kirklin, assisted by De'Arius Christmas, both from CHL's Field Data Collection and Analysis Branch.

The weather for both days was generally sunny with some clouds; temperatures varied from lows in the mid 30s to highs in the upper 70s. There was no precipitation either day. Boat traffic was low both days – the team saw two tows and the occasional fishing boat. There was no significant wind.

The below are the stage readings from the relevant gages for the two days of the trip:

	Red River L&D 1 DS	Acme	Old River Aux. Outflow	Simmesport	Melville	Krotz Springs	Whiskey Bay
11/18/2020 0600	9.41	9.61	12.00	9.01	6.21	5.78	5.43
11/19/2020 0600	9.78	9.38	11.96	8.53	5.76	5.38	5.07

As a reference, the historic daily recorded low at Simmesport was 0.70 ft, the recorded high was 59.13 ft.

The overall purpose of the trip was visually inspect the river systems for indicators of short- or long-term geomorphic changes or evidence of cause-and-effect relationships. While on the trip, the team collected bank and bed sediment samples to better characterize sediments in the system. These sediment samples would also support potential numerical modeling of bank stability/failure in the system; the team also spent time trying to choose sites for this modeling. Lastly, the team investigated sites previously identified by MVN as being locations of concern due to bank erosion and failure.

The team put the boat in from the Simmesport boat ramp both days. On the first day, the team traveled upriver to the downstream side of Red River Lock and Dam #1, then down the Red and up the Black to a grain elevator site, traveled back down the Red to the upper Old River east to the ORCC, and then reversed course back down to Simmesport. On the second day, the team traveled downstream on the Atchafalaya to the Whiskey Bay Pilot Channel slightly past the old Atchafalaya channel, then traveled back upstream to go into the old Atchafalaya channel, then continued back upstream to return to Simmesport.

Below are the general findings from the trip:

- The revetment in the Red River was in noticeably worse condition than the revetment downstream (Figure 1). Freddie Pinkard (formerly of MVK, a key designer of the Red River navigation project) was called while on the boat to inquire about the revetments on the Red; he stated that much of the revetment done was trench-fill revetment, so the channel was allowed to erode to the desired dimensions before being revetted. Conversations with MVK staff after the trip supported the visual assessment, stating little O&M had been done in the area.
- Likewise, discussions with MVN staff and provided CADD files later confirmed that little O&M was ongoing on the Atchafalaya (Figure 2). This includes vegetation growth and debris being present on revetment. Revetment is present for large portions of the Atchafalaya above the Whiskey Bay Pilot Channel. Revetment used is a combination of articulated concrete mattress and riprap; there was no clear indication for selection methodology.
- There was no visual indication of widespread or significant bank instability or failure in the Old River outflow channel.
- Toe scour appeared to be the failure mechanism for multiple revetment sites (as identified by sag into the waterline at low water).
- There were signs of ongoing channel evolution on the Atchafalaya despite revetment usage, including armoring of the bank opposite the thalweg (suggesting channel migration) and point bar development on the outside of a bend (suggesting meander migration).
- Multiple erosional bank sites were identified on the Atchafalaya. These sites tended to be scattered and localized. Failures almost always corresponded one or more of the following: 1) an area with little riparian corridor, 2) location adjacent to the end of placed revetment (Figure 3), 3) a failure of revetment, 4) located on the opposite bank of established revetment (suggesting a thalweg shift from one bank to the other after armoring), 5) on the outside of a bend, or 6) proximity of a hydraulic structure (Figure 4). There were no clear visual indications of reach-scale instability.
- Multiple sites (including the inside and outside of bends and straight reaches) exhibited signs of terracing and the establishment of a new, adjusted floodplain level (Figure 5). This would support the specific gage analyses showing significant historic downcutting.
- Two meander bends exhibited erosion and loss of the tip of the meander (the inside of the bend) instead of formation of a more typical point bar (Figure 6). In both cases, these failures appeared to be due to revetment stopping, leaving a vulnerable location, and a geometry locked into place in an overly-tight alignment via revetment.
- Twenty-five samples were taken from various bend and bank locations on the Red, Black, and Atchafalaya. An image of the sampler used for bed samples is attached (Figure 7).
- The bank and bed materials varied from medium sands to clays. Most bank materials consisted of a sand bank with lenses of finer material, or vice versa, though there were fine material-dominated banks, and wholly sand bars. There appeared to be coarsening of the bed material as one traveled downstream.



Figure 1: Failed revetment along the Red River



Figure 2: Revetment along the Atchafalya River



Figure 3: Bank failure adjacent to revetment



Figure 4: Bank failure adjacent to a structure



Figure 5: Potential terraces on the inside of a bend

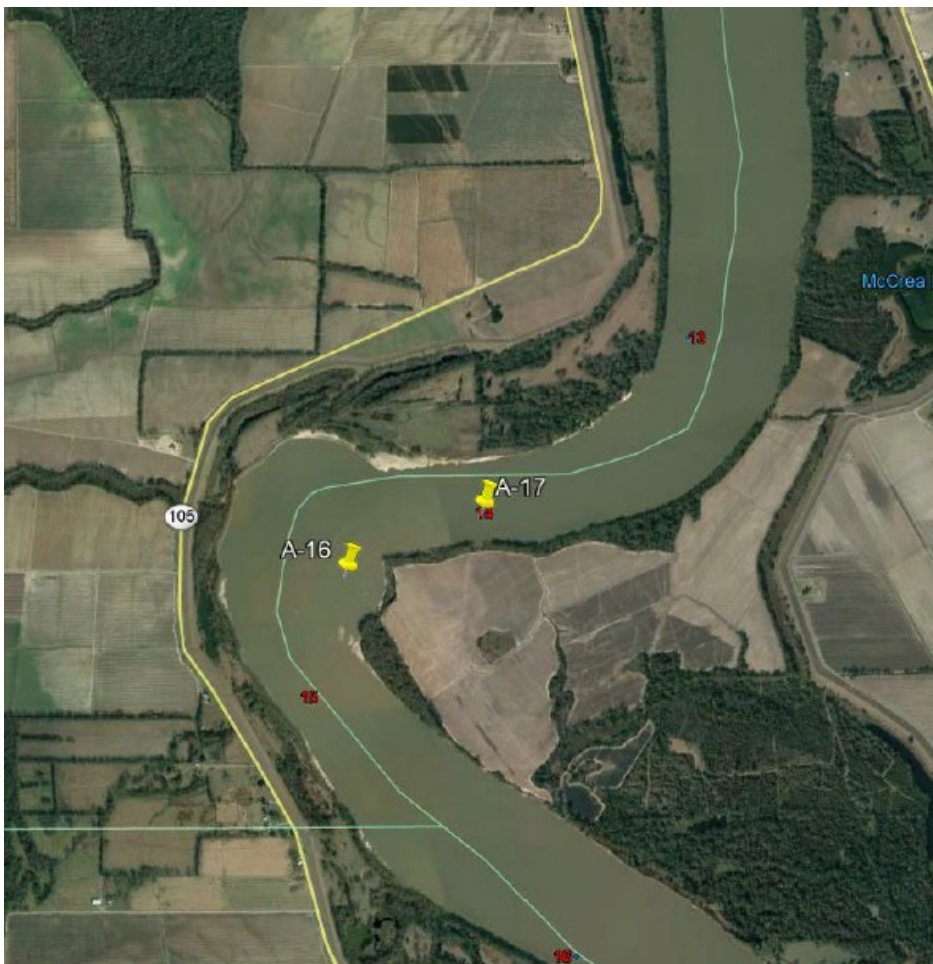


Figure 6: Example of eroded bend tip



Figure 7: Bed Material Sampler

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14. ABSTRACT This report documents the geomorphic assessment component of the Old River, Mississippi River, Atchafalaya River, and Red River System Technical Assessment. The overall objectives of the geomorphic assessment are to utilize all available data to document the historic trends in hydrology, sedimentation, and channel geometry for the rivers in the vicinity of the Old River Control Complex and to summarize the changes observed at locations where repetitive datasets exist and at key reaches that are determined during the study. The geomorphic assessment tasks include data compilation, geometric data analysis, gage and discharge analysis, dredge record analysis, sediment data analysis, development of an events timeline, and integration of results. Geomorphic reaches were developed, and the morphological trends during different time periods were identified. The geomorphic assessment highlighted the importance of considering spatial and temporal variability when assessing morphological trends.						
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