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Mississippi River Hydrodynamic and Delta Management Study (MRHDM)–Geomorphic Assessment

Charles D. Little, Jr. and David S. Biedenharn

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Mississippi River Hydrodynamic and Delta Management Study (MRHDM)–Geomorphic Assessment

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Final report

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Abstract

This report documents the geomorphic assessment component of the Mississippi River Hydrodynamic and Delta Management Feasibility Study. The overall objectives of the geomorphic assessment were to utilize all available data to document the historical trends in hydrology, sedimentation, and channel geometry in the lower Mississippi River and to summarize the local changes observed at locations where repetitive datasets exist and at key reaches determined during the study. The assessment focused on, but was not limited to, the river reach downstream of the Old River Control Complex and the time period from 1960 to the present (2013). The geomorphic assessment tasks included 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 defined, and the morphologic trends during different time periods were evaluated. The geomorphic assessment highlighted the importance of considering spatial and temporal variability when assessing morphological trends. Morphological trends on the Lower Mississippi River typically occur over decadal timescales. Consequently, there is considerable uncertainty with assessments that only cover short time periods. Therefore, investigators must be cautious when assuming that short-term, recent trends will predict future conditions.

Contents

Figures and Tables

Figures

Tables

Preface

This study was conducted for the U.S. Army Engineer District, New Orleans, and the State of Louisiana as part of the Mississippi River Hydrodynamic and Delta Management Study. The project managers for the U.S. Army Engineer District, New Orleans, were Bill Hicks and Daimia Jackson, and the Plan Formulator was Cherie Price. The study managers for the State of Louisiana were Carol Parsons Richards and Austin Feldbaum. Ehab Meselhe from the Water Institute of the Gulf and Barb Kleiss from the Corps of Engineers, Mississippi Valley Division, were the Technical Leads.

The U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), along with The Biedenharn Group conducted this study from April 2012 to February 2014. The principal investigators for this study were Charlie Little of the ERDC-CHL River Engineering Branch and David Biedenharn of The Biedenharn Group. The ERDC-CHL portion of the study was conducted under the direct supervision of Loren Wehmeyer, Chief, ERDC-CHL River Engineering Branch; Ty V. Wamsley, Chief, ERDC-CHL Flood and Storm Protection Division; and William Martin/José Sánchez, Director, ERDC-CHL.

During the time of the study, COL Kevin J. Wilson/COL Jeffrey R. Eckstein served as Commander and Executive Director of ERDC. Dr. Jeffery P. Holland served as ERDC Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Background

The *Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Study* (U.S. Army Corps of Engineers (USACE), New Orleans District (MVN) 2004), was recommended to Congress by a Chief of Engineers report dated 31 January 2005 that called for a coordinated, feasible solution to the identified critical water resource problems and opportunities in coastal Louisiana. The Mississippi River Hydrodynamic and Delta Management Feasibility Study combines two of the six large-scale and long-term restoration concepts outlined in the *LCA 2005 Report*: the Mississippi River Hydrodynamic Study and the Mississippi River Delta Management Study. The feasibility study has as its primary focus the development of tools that can evaluate both the existing conditions of the Mississippi River and any potential local and system-wide impacts of proposed changes to the system (e.g., additional diversions). The Mississippi River Hydrodynamic component of the feasibility study focuses on impacts to the Mississippi River. This component will evaluate the Mississippi River system from Old River Control Complex (ORCC) to the Gulf of Mexico, develop a comprehensive numerical modeling system to assess potential restoration alternatives, and determine the availability of fresh water, sediment, and nutrients for restoration usage without compromising flood control and navigation missions. The Mississippi River Delta Management component of the feasibility study focuses on impacts to the receiving areas. The geomorphic assessment task of the Mississippi River Hydrodynamic Study component of the feasibility study is described in this report.

2 Objectives

The overall objectives of the geomorphic assessment were to utilize all available data to document the historical trends in hydrology, sedimentation, and channel geometry in the lower Mississippi River and to summarize the local changes observed at locations where repetitive datasets exist and at key reaches that were defined during the study. The assessment focuses on, but is not limited to, the river reach downstream of the ORCC and the time period 1960 to the present (2013).

3 Methodology

The geomorphic assessment included seven inter-related tasks:

- data compilation
- geometric data analysis
- gage and discharge data analysis
- dredge data analysis
- sediment data analysis
- events timeline
- integration.

The methodology used for each of these tasks is described in this chapter.

3.1 Data Compilation

A comprehensive search of available data was conducted, and pertinent data for the assessment were collected and assembled. Close coordination took place with representatives from the State of Louisiana and the U.S. Army Corps of Engineers (USACE) to ensure all historical and on-going studies and data-collection efforts were considered. Types of data that were gathered include the following:

- channel survey data (comprehensive hydrographic surveys, channel condition surveys, and other miscellaneous surveys of river-channel geometry)
- aerial photography and topographic maps
- gage and discharge data at all Mississippi River stations in the study area as well as Vicksburg and Natchez
- suspended-sediment data at all Mississippi River stations
- bed-material data
- dredge records from MVN
- results from previous river-engineering studies.

3.1.1 Hydrographic surveys

Hydrographic surveys of the study reach provide a time series of bathymetric data that can be used to determine geometric changes of the river channel. The hydrographic surveys collected for this study were comprehensive surveys from MVN, channel condition surveys from MVN, and multi-beam surveys from MVN, U.S. Army Engineer Research and Development Center (ERDC), and the State of Louisiana. Table 1 provides a listing of the hydrographic surveys used in the study along with pertinent information of each survey.

3.1.2 River gage and discharge data

Daily stage and discharge data, along with irregular discharge measurements, were assembled for the majority of the main Mississippi River gauging stations within the study reach. The daily stage and discharge data were downloaded from the USACE RiverGages.com website and the U.S. Geological Survey (USGS) website. The historical discharge measurements were obtained from MVN, either through the annual gage and discharge publications or directly provided by the district. Much of this data had been previously assembled as part of prior studies on the lower Mississippi River. Table 2 lists the primary gage and discharge data obtained for the study.

3.1.3 Sediment data

Sediment data in the form of suspended sediment measurements were assembled for gauging stations on the Mississippi River within the study reach. These data were obtained from USACE sources as well as downloaded from the USGS website. Bed-material data were collected by the data collection team as part of a longitudinal study of the Mississippi River for comparison to a historical data set (Nordin and Queen 1992). Table 3 lists the sediment data assembled for the geomorphic assessment.

3.1.4 Dredge records

Annual maintenance dredge reports were obtained from MVN for the period of fiscal year 1970 through fiscal year 2011. Data in these reports included dredge volume by River Mile (RM) on a daily basis for the dredge contracts. These reports were used to determine volumes and location of dredge activities within the study reach.

Table 1. Hydrographic surveys used in geomorphic assessment.

Description	Date	Extent	Vertical Datum	Source
MVN[1] comprehensive hydrographic survey	1961–1963	Entire MVN reach of MS[2] River	MSL[3]	MVN .dgn files and hard-copy maps
MVN comprehensive hydrographic survey	1973–1975	Entire MVN reach of MS River	MSL	MVN .dgn files and hard-copy maps
MVN comprehensive hydrographic survey	1983–1985	Entire MVN reach of MS River	NGVD27[4]	MVN .dgn files and hard-copy maps
MVN Comprehensive hydrographic survey	1992–1993	Entire MVN reach of MS River	NGVD27	MVN .dgn files and hard-copy maps
MVN Comprehensive hydrographic survey	2003–2004	Entire MVN reach of MS River	NAVD88[5]	MVN .dgn files and hard-copy maps
MVN multi-beam survey (partial)	2012	RM[6] 318–RM 234	NAVD88	MVN XYZ files
Channel condition survey	9/09, 10/10, 7/11, 8/12	Smithland Crossing	NAVD88	MVN
Channel condition survey	9/09, 9/10, 7/11, 8/12	Bayou Sara Crossing	NAVD88	MVN
Channel condition survey	10/09, 8/10, 8/11, 7/12	Wilkerson Pt. Crossing	NAVD88	MVN
Channel condition survey	8/09, 9/10, 9/11, 8/12	Baton Rouge Front	NAVD88	MVN
Channel condition survey	10/09, 10/10, 6/11, 7/12	Redeye Crossing	NAVD88	MVN
Channel condition survey	9/09, 7/12	Sardine Pt. Crossing	NAVD88	MVN
Channel condition survey	9/09, 9/10, 3/12	Medora Crossing	NAVD88	MVN
Channel condition survey	10/09, 9/10, 7/11, 7/12	Grenada Crossing	NAVD88	MVN
Channel condition survey	9/09, 3/10, 11/11, 7/12	Bayou Goula Crossing	NAVD88	MVN
Channel condition survey	9/09, 9/10, 11/11, 3/12	Alhambra Crossing	NAVD88	MVN
Channel condition survey	8/08, 10/11, 8/12	Philadelphia Pt. Crossing	NAVD88	MVN
Channel condition survey	10/09, 9/10	Smoke Bend Crossing	NAVD88	MVN
Channel condition survey	10/08, 10/11, 8/12	Rich Bend Crossing	NAVD88	MVN
Channel condition survey	10/09, 9/10, 10/11, 6/12	Belmont Crossing	NAVD88	MVN
Channel condition survey	8/08, 7/12	Fairview Crossing	NAVD88	MVN
Multi-beam survey	Aug/Nov 2011	RM 57–RM 68	NAVD88	State of LA[7]

[1]MVN=U.S. Army Corps of Engineers, New Orleans District

[2]MS=Mississippi

[3]MSL=Mean Sea Level

[4]NGVD1927=National Geodetic Vertical Datum of 1927

[5]NAVD88=National Vertical Datum of 1988

[6]RM=River Mile

[7]LA=Louisiana

Table 2. Gage and discharge data obtained for geomorphic assessment.

Location	Type	Date	Source
Old River Control	Daily stage and Q[1]	1977–2010	MVN[2]
Mississippi River @ Tarbert Landing	Daily Q and measured Q	1960–present	MVN and Old River Hydropower report
Mississippi River @ Red River Landing	Daily stage	1960–present	MVN
Mississippi River @ Bayou Sara	Daily stage	1960–present	MVN
Morganza Floodway	Daily Q	1973, 2011	MVN
Mississippi River @ Baton Rouge	Daily stage	1960–present	MVN
Mississippi River @ Baton Rouge	Measured Q	2004–present	USGS[3]
Bonnet Carré Floodway	Daily Q	Operation years	MVN
Mississippi River @ Carrollton	Daily stage	1960–present	MVN
Mississippi River @ Belle Chasse	Measured Q	2008–present	USGS
Baptiste Collette	Measured Q	1960–present	MVN
Mississippi River @ Venice	Daily stage	1960–present	MVN
Grand Pass	Measured Q	1960–present	MVN
West Bay Diversion	Measured Q	2004–present	MVN
Cubits Gap	Measured Q	1960–present	MVN
Head of Passes	Daily stage	1960–present	MVN
Pass a Loutre, South Pass, Southwest Pass	Measured Q	1960–present	MVN

[1]Q=discharge

[2]MVN=U.S. Army Corps of Engineers, New Orleans District

[3]USGS=U.S. Geological Survey

Table 3. Sediment data obtained for the geomorphic assessment.

Location	Type	Date	Source
Mississippi River @ Tarbert Landing, LA[1]	Measured suspended sediment	1975–2011	MVN[2]
Mississippi River @ St. Francisville, LA	Measured suspended sediment	1978–2012	USGS[3]
Mississippi River @ Baton Rouge, LA	Measured suspended sediment	1975–2012	USGS
Mississippi River @ Belle Chasse, LA	Measured suspended sediment	1978–2012	USGS
Mississippi River Vicksburg, MS[4], to Head of Passes	Bed material	1932 and 1989	Nordin and Queen (1992)

[1]LA=Louisiana

[2]MVN=U.S. Army Corps of Engineers, New Orleans District

[3]USGS=U.S. Geological Survey

[4]MS=Mississippi

3.2 Geometric Data Analysis

Analysis of the Mississippi River channel geometry for the study reach was conducted with hydrographic survey data obtained from the comprehensive decadal surveys as well as other multi-beam surveys previously documented in Table 1. 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 is a dynamic system 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 and dredging. Observance of the river channel at a given location over time may indicate significant variability as the river responds to the various hydrologic cycles. Even the location or height of dunes/dune fields on the river bed 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 from successive surveys were determined from comparative cross sections located in the crossing and pool sections of the river. Volumetric change between surveys was determined for relatively short segments along the study reach. These volumetric changes were utilized in the development of the sediment budget for the lower river downstream of Tarbert Landing. Profiles of the channel invert for both the crossing sections and the pool sections were assessed, as well as profiles of channel conveyance computed at top bank elevation. Profiles of channel top widths and width/depth ratios were also investigated. Survey contour maps and bed-elevation-change maps were also created and are available as Geographic Information System (GIS) grid files.

Additionally, comparative cross sections and volumetric changes were determined in greater detail for the reach in the vicinity of the Old River Control Complex (ORCC). The low sill control structure at ORCC began operation in 1963; thus, the structure represents a river diversion that has been in place for approximately the entire study period. The geometric and volumetric changes that are identified for this reach provide an opportunity to glean unique insights into the effects of a river diversion on river morphology.

3.2.1 Hydrographic survey data

The decadal hydrographic surveys used in the geomorphic assessment contain bathymetric data collected along transects spaced approximately 1,000 feet (ft) apart along the river channel. These data were incorporated as XYZ data into the GIS database for the geometric analysis. A triangular irregular network (TIN) surface was developed in the GIS from the XYZ data, and contour maps for the main river channel were developed from the TIN. Figure 1 shows an example of a survey TIN and the hydrographic bathymetric data. Note that the 1983–1985 survey for much of the study area was taken during a low-water period, and spatial coverage of the entire channel is incomplete in areas.

Each survey TIN was converted to a grid file in the GIS, and the grid files of successive surveys were subtracted to determine the bed elevation change between surveys. Figure 2 shows an example of a bed-elevation-change grid file.

Figure 1. Example of hydrographic survey bathymetric data and contour map.

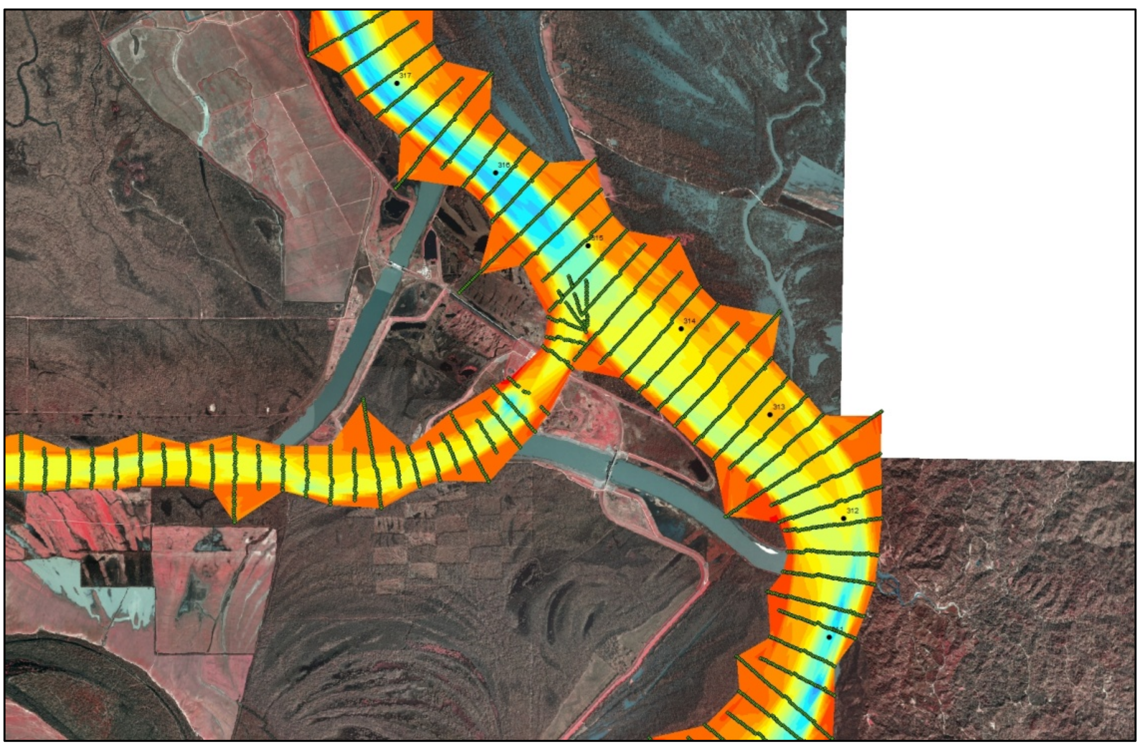
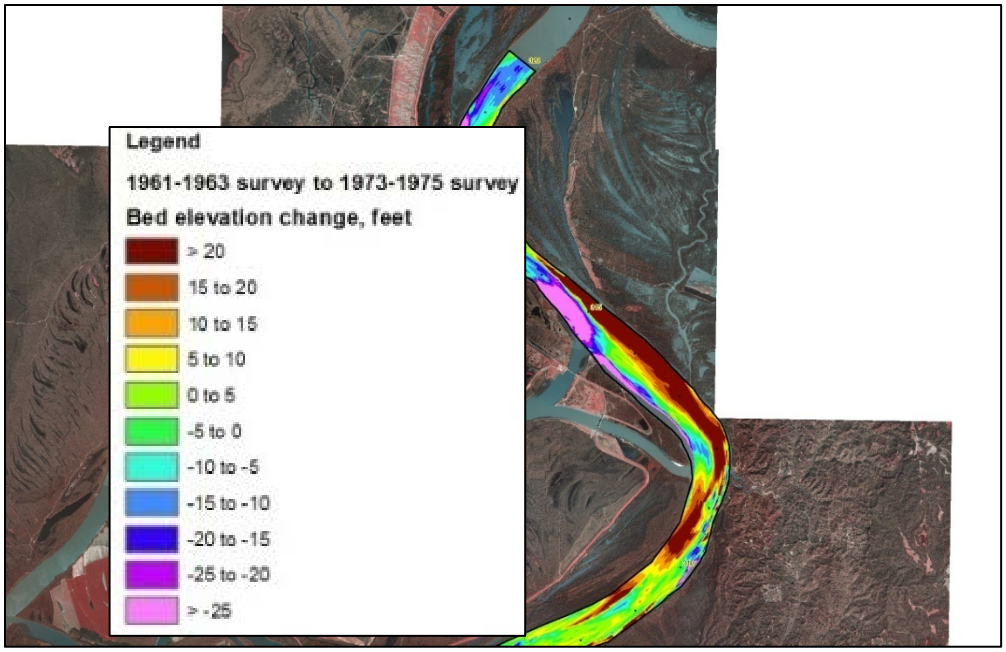


Figure 2. Example of bed elevation change between successive surveys.



3.2.2 Cross section data

Cross section locations were established in the GIS at the principal river crossings and pools along the study area. The cross sections were used in the GIS to extract geometric data from the surveys and to conduct comparisons of the channel dimension at a specific location over time. The river-crossings-section locations were determined through inspection of the survey contour maps to identify the most consistent channel-crossing pattern over time. Information at these river crossings is considered important for visualizing stability in the river system as these crossings generally establish the slope of the river. The pool sections were similarly identified through contour-map inspection and are generally located in the bends of the river. In addition to the crossing and pool locations throughout the entire study reach, more closely spaced cross sections were created in the vicinity of ORCC from approximately RM 318 to RM 287. These cross sections were established to achieve a more detailed visualization of channel dimension adjustment associated with a major river diversion. The location of the crossing and pool cross sections are shown in Figures 3–5 and Figures 6–8, respectively, and also listed in Table 4. The location of the detailed ORCC cross sections is shown in Figure 9 and listed in Table 5.

Figure 3. Cross section locations for crossings, ORCC to Baton Rouge.

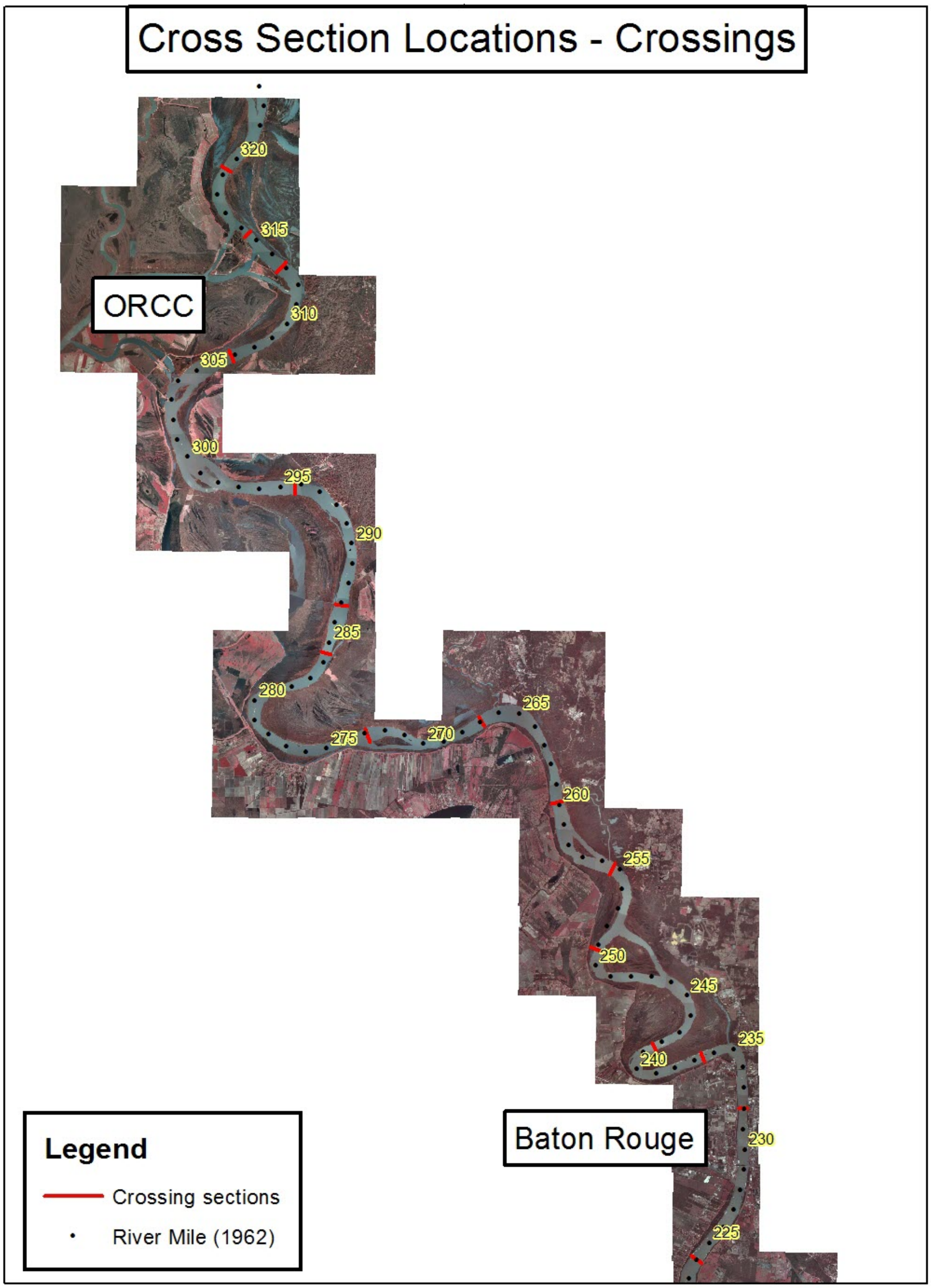


Figure 4. Cross section locations for crossings, Baton Rouge to New Orleans.

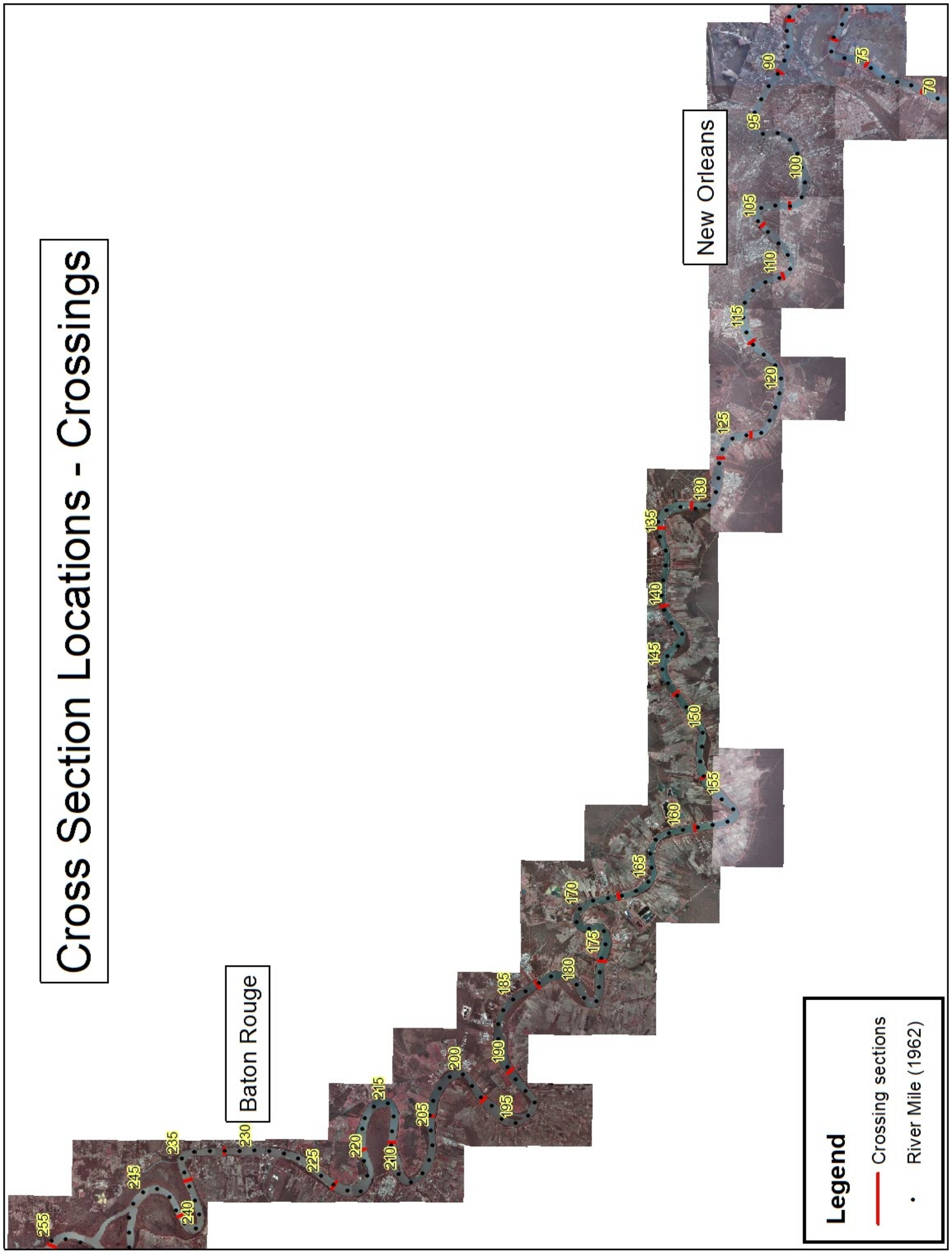


Figure 5. Cross section locations for crossings, New Orleans to Head of Passes.

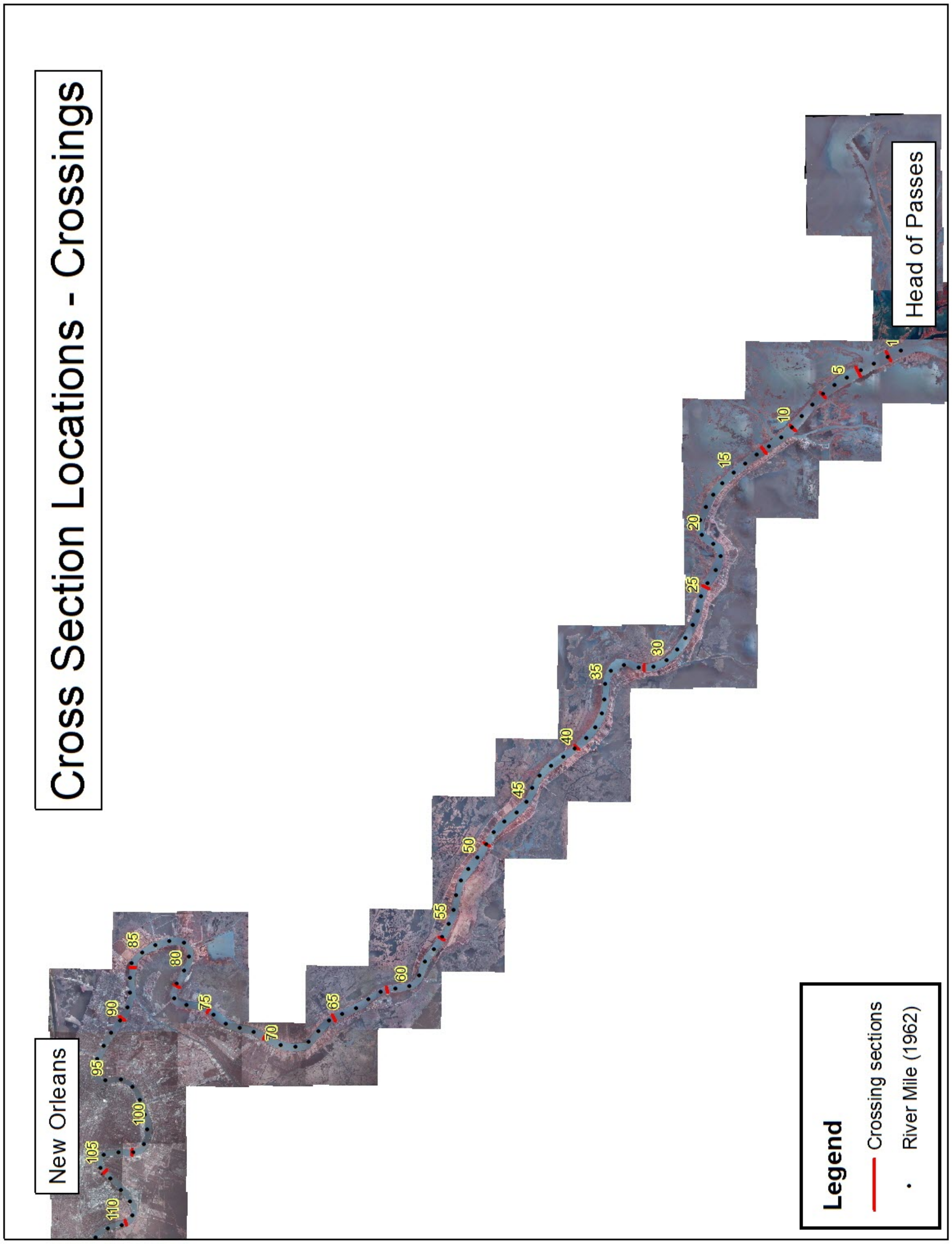
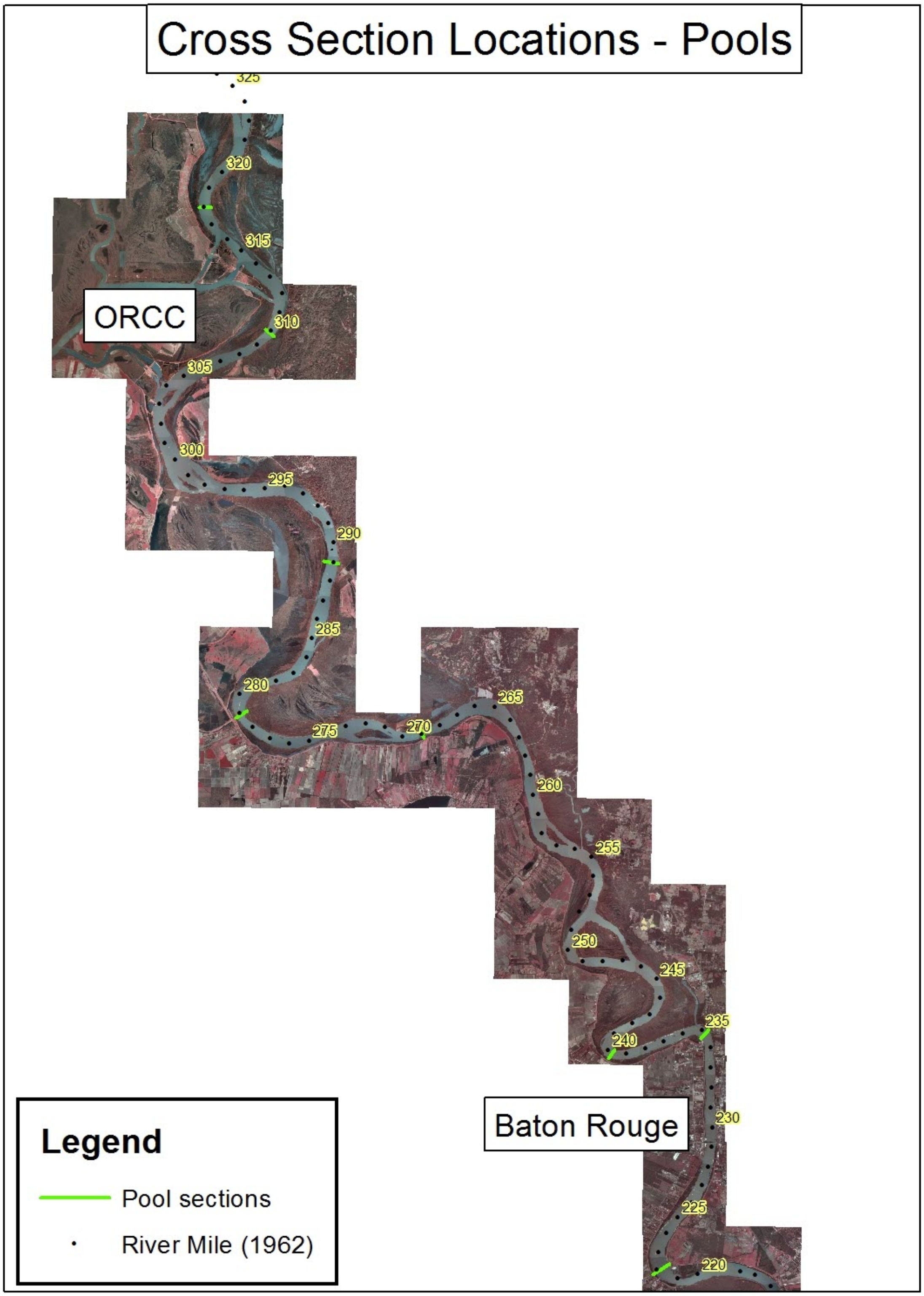


Figure 6. Cross section locations for pools, ORCC to Baton Rouge.



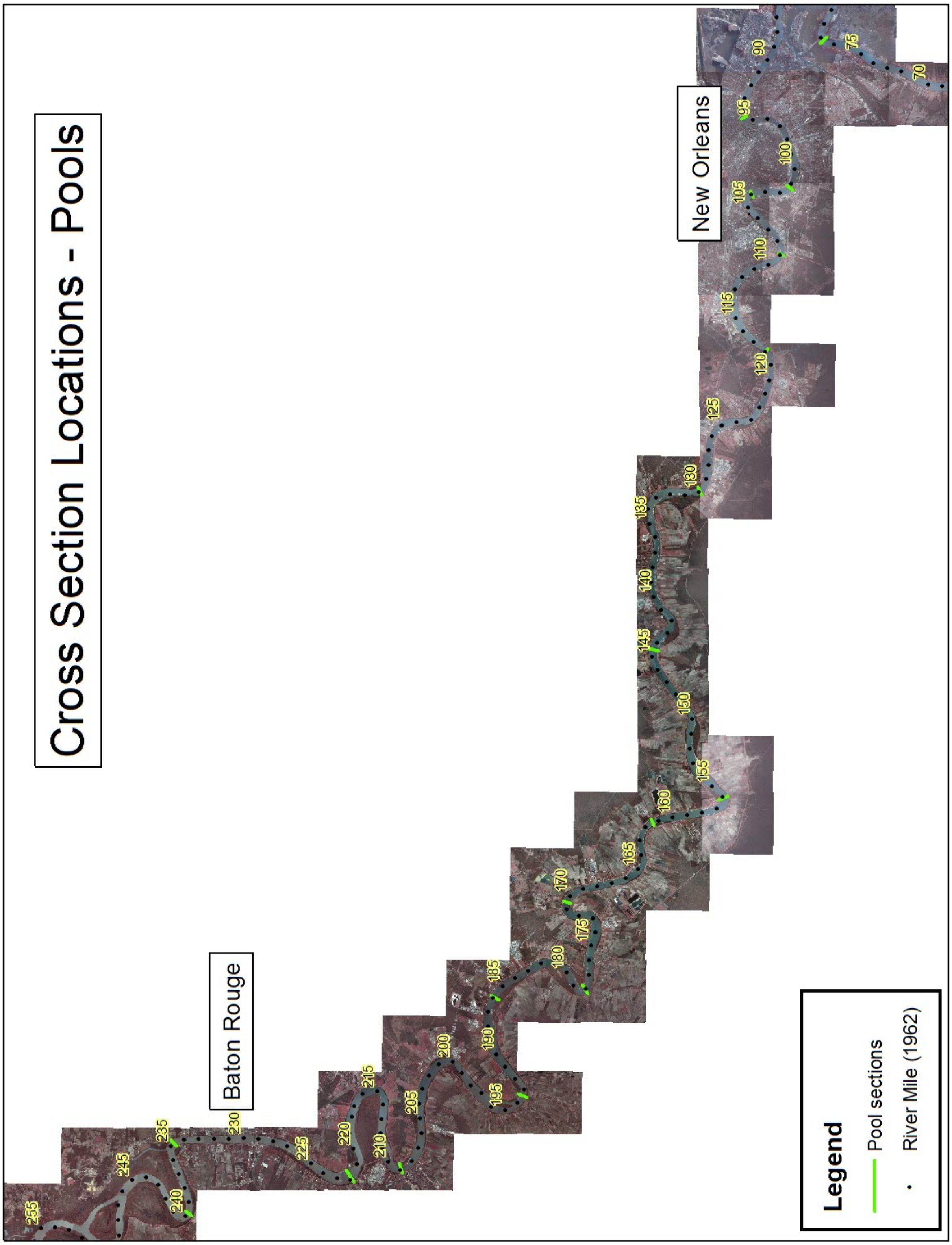


Figure 7. Cross section locations for pools, Baton Rouge to New Orleans.

Figure 8. Cross section locations for pools, New Orleans to Head of Passes.

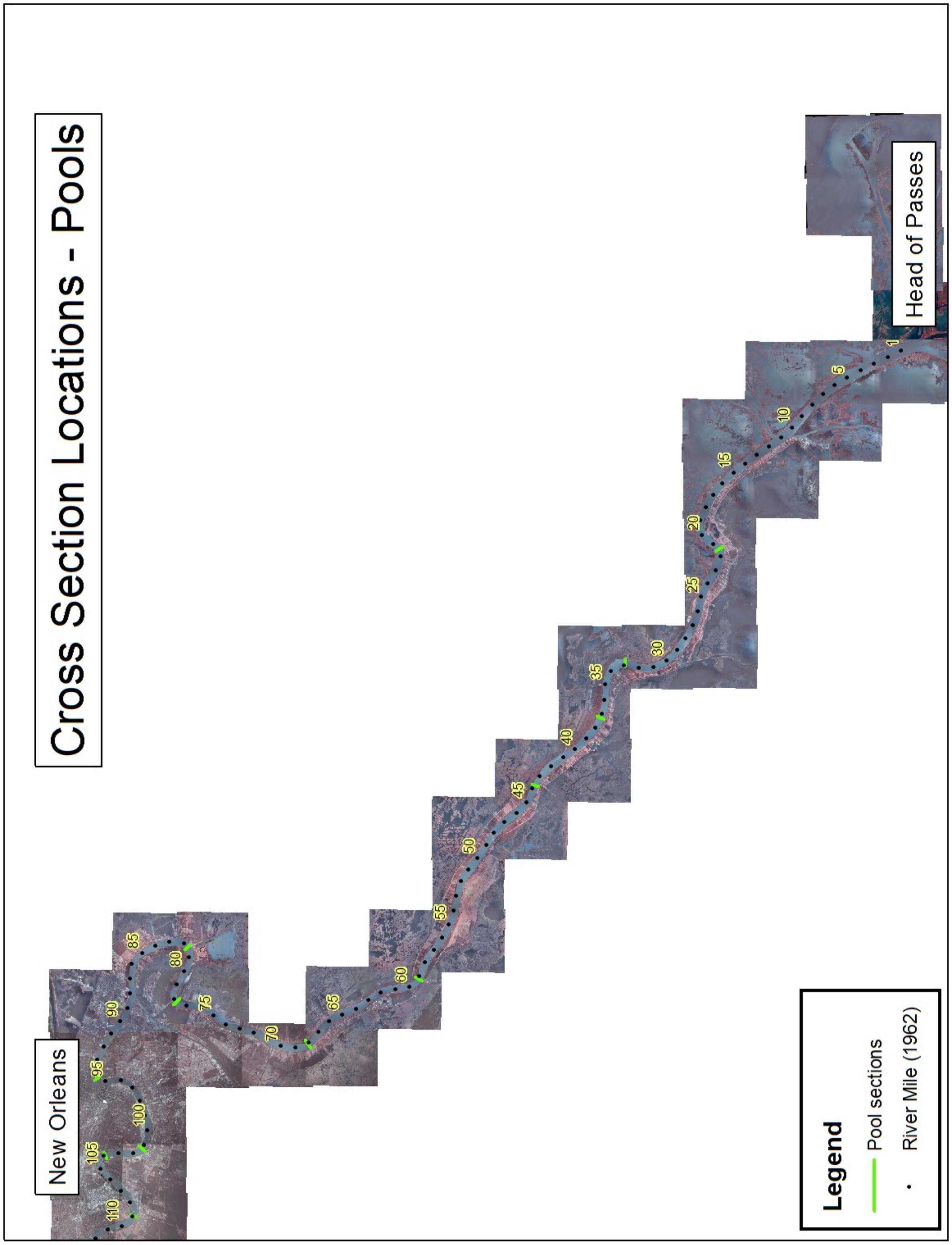


Table 4. River Mile (RM) locations of cross sections at crossings and pools.

Crossing Sections			Pool Sections	
RM 319.3	RM 212.1	RM 102.1	RM 318.0	RM 109.0
RM 315.6	RM 204.1	RM 90.0	RM 309.9	RM 104.0
RM 313.2	RM 197.8	RM 86.3	RM 289.0	RM 101.3
RM 306.8	RM 190.4	RM 78.9	RM 278.9	RM 94.3
RM 294.4	RM 183.2	RM 75.4	RM 269.9	RM 81.6
RM 286.9	RM 175.3	RM 71.3	RM 239.8	RM 77.8
RM 284.4	RM 167.3	RM 65.6	RM 234.8	RM 68.2
RM 281.2	RM 159.2	RM 61.6	RM 222.0	RM 59.2
RM 273.0	RM 153.1	RM 56.2	RM 209.0	RM 43.8
RM 267.0	RM 146.9	RM 49.0	RM 193.5	RM 37.3
RM 260.2	RM 139.8	RM 39.9	RM 186.0	RM 33.0
RM 255.3	RM 134.4	RM 31.4	RM 178.2	RM 21.6
RM 250.8	RM 131.2	RM 24.5	RM 170.6	
RM 241.5	RM 126.7	RM 12.6	RM 161.5	
RM 236.6	RM 123.9	RM 10.1	RM 156.2	
RM 232.0	RM 115.7	RM 7.0	RM 144.6	
RM 224.0	RM 109.7	RM 4.3	RM 130.0	
RM 219.4	RM 105.4	RM 2.0	RM 118.0	

Bathymetric data from each hydrographic survey were extracted at all cross section locations and imported into spreadsheets for processing and analysis. Comparative cross section plots were generated to illustrate the changes in channel dimension at each location. Figure 10 shows an example of a comparative cross section plot. Plots for all cross sections can be found in Appendix A. These plots were used to identify any trends or excessive changes in channel geometry; however, natural variability of the channel often makes discerning actual trends difficult.

Figure 9. Location of detailed cross section at ORCC.

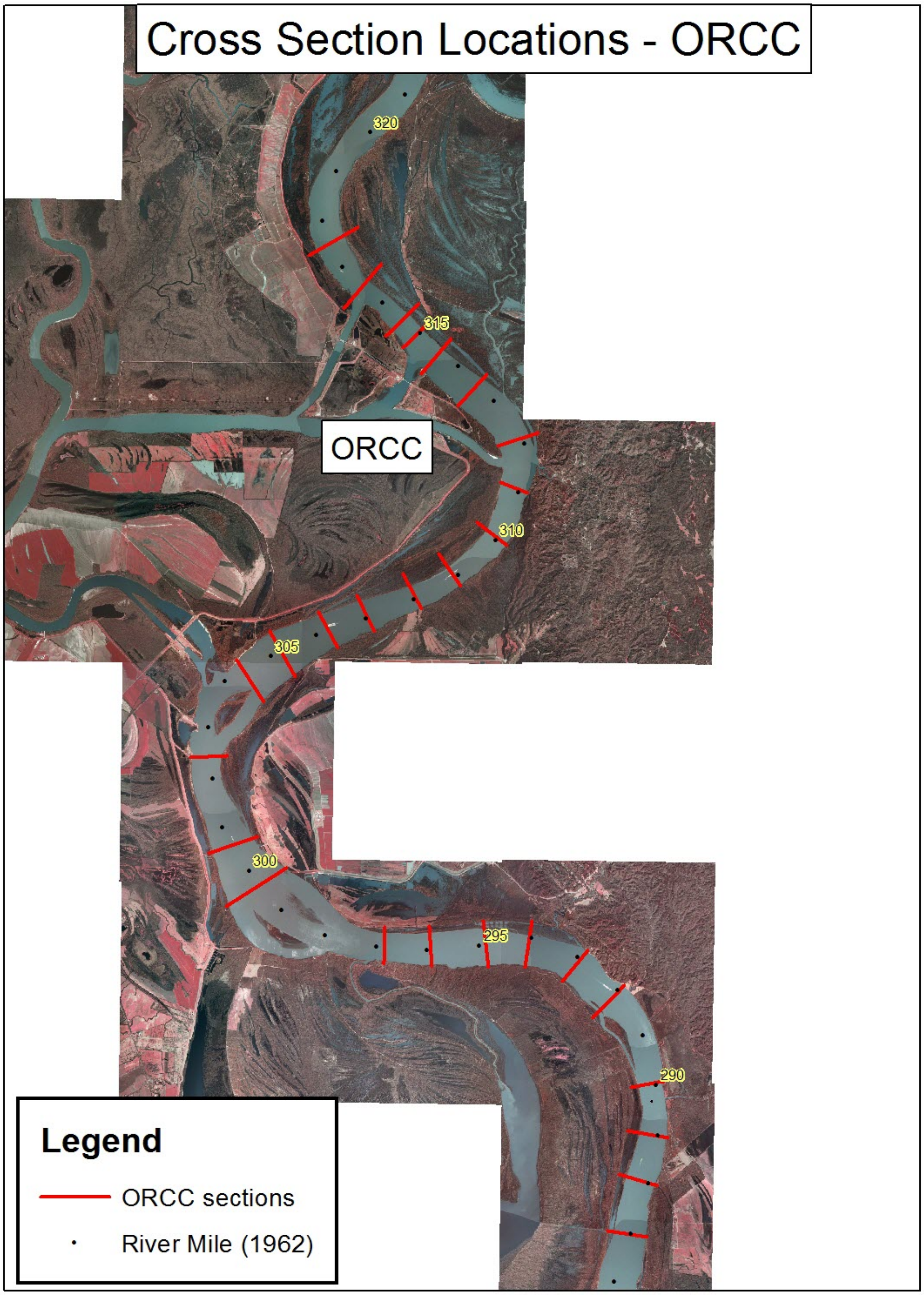
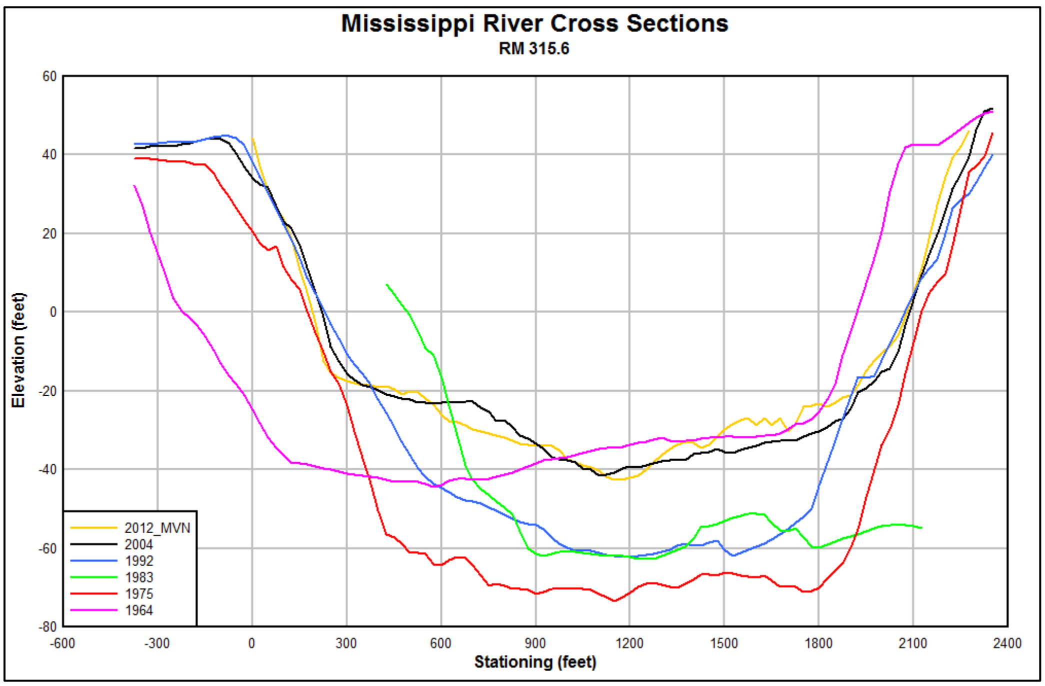


Table 5. RM locations of detailed cross sections at Old River Control Complex (ORCC).

Location of ORCC Cross Sections			
RM 317.6	RM 311.0	RM 304.4	RM 294.0
RM 316.6	RM 310.0	RM 302.4	RM 293.0
RM 315.5	RM 308.9	RM 300.6	RM 292.0
RM 315.0	RM 308.0	RM 299.7	RM 290.0
RM 314.5	RM 307.0	RM 296.9	RM 289.0
RM 313.5	RM 306.2	RM 295.9	RM 288.0
RM 312.1	RM 305.2	RM 294.9	RM 287.0

Figure 10. Example comparative cross section plot, RM 315.6.



The cross section data were used to compute cross-sectional area, hydraulic conveyance and top width/depth ratios at each section location. Cross-sectional area and hydraulic conveyance were computed for the section below top bank elevation, and approximate top bank widths and maximum depths relative to top bank elevation were determined to compute the width/depth ratios. These values were plotted versus river mile to determine how the characteristics of the river, in terms of these parameters, change longitudinally throughout the study reach. Results are discussed later in this report.

Additionally, the cross section data were used to determine a representative channel invert elevation that was used to construct a longitudinal thalweg profile. The representative channel invert elevation used for the profile was defined as the minimum average bed elevation for any continuous 500 ft-wide section of the cross section. Each cross section was analyzed to determine the average bed elevation for a 500 ft-wide swath as this swath was *moved* across the channel. The minimum of these average bed elevations was selected as the representative channel invert elevation. This process was used to filter out narrow, deep holes in the river cross section that may not be representative of average bed conditions. Longitudinal thalweg profiles for both the crossing sections and the pool sections were constructed from this data. Results are discussed later in this report.

3.2.3 Volumetric data

Whereas cross section data at specific locations provide a means to assess relative changes in channel dimension for successive surveys, volumetric data computed over relatively short reaches of the river provide a sense of spatial change in the channel. Polygons were constructed in the GIS that captured the bank-to-bank area of the river for relatively short reach lengths of approximately 10 miles for the entire study reach. A *lid* elevation equal to the average top bank was determined for each polygon. Tools within the GIS were used to compute the volume for each polygon between the lid elevation (approximate top bank) and the TIN surface for each hydrographic survey. The difference in volume for successive hydrographic surveys represents the volume of erosion or deposition in the polygon for the time period between the surveys. For surveys that had a different vertical datum, the volumes were adjusted based on the volume for each polygon resulting for the average datum shift at the polygon. The polygons for the entire study reach are shown in Figures 11–13 and listed in Table 6. As was the case for the cross section analysis, detailed polygons were constructed in the vicinity of the ORCC to gain more detailed information on the erosion and deposition patterns associated with a major river diversion. These polygons were generally 1 RM in length. Figure 14 shows the detailed ORCC volume polygons.

Figure 11. Volume polygon locations, ORCC to Baton Rouge.

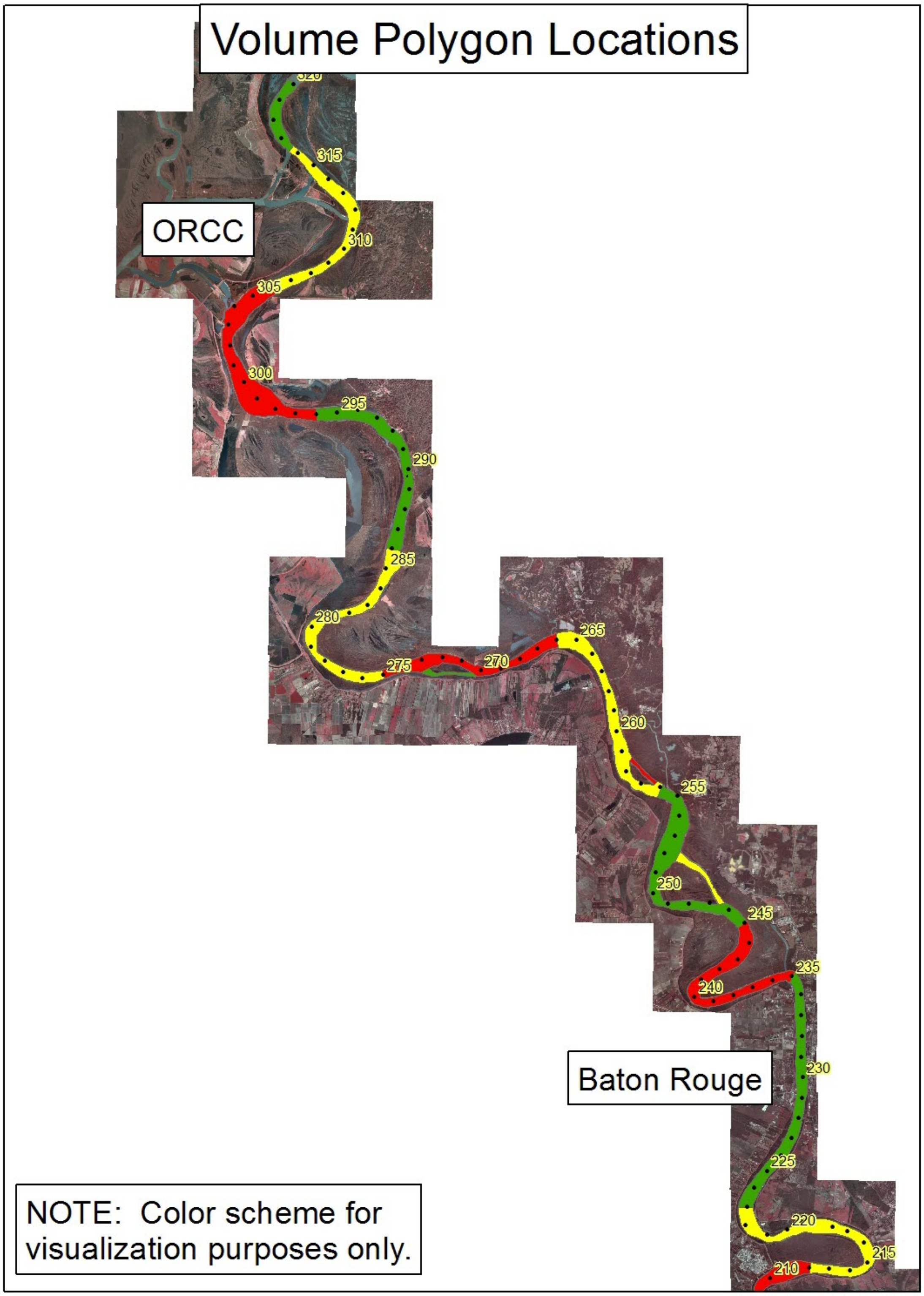


Figure 12. Volume polygon location, Baton Rouge to New Orleans.

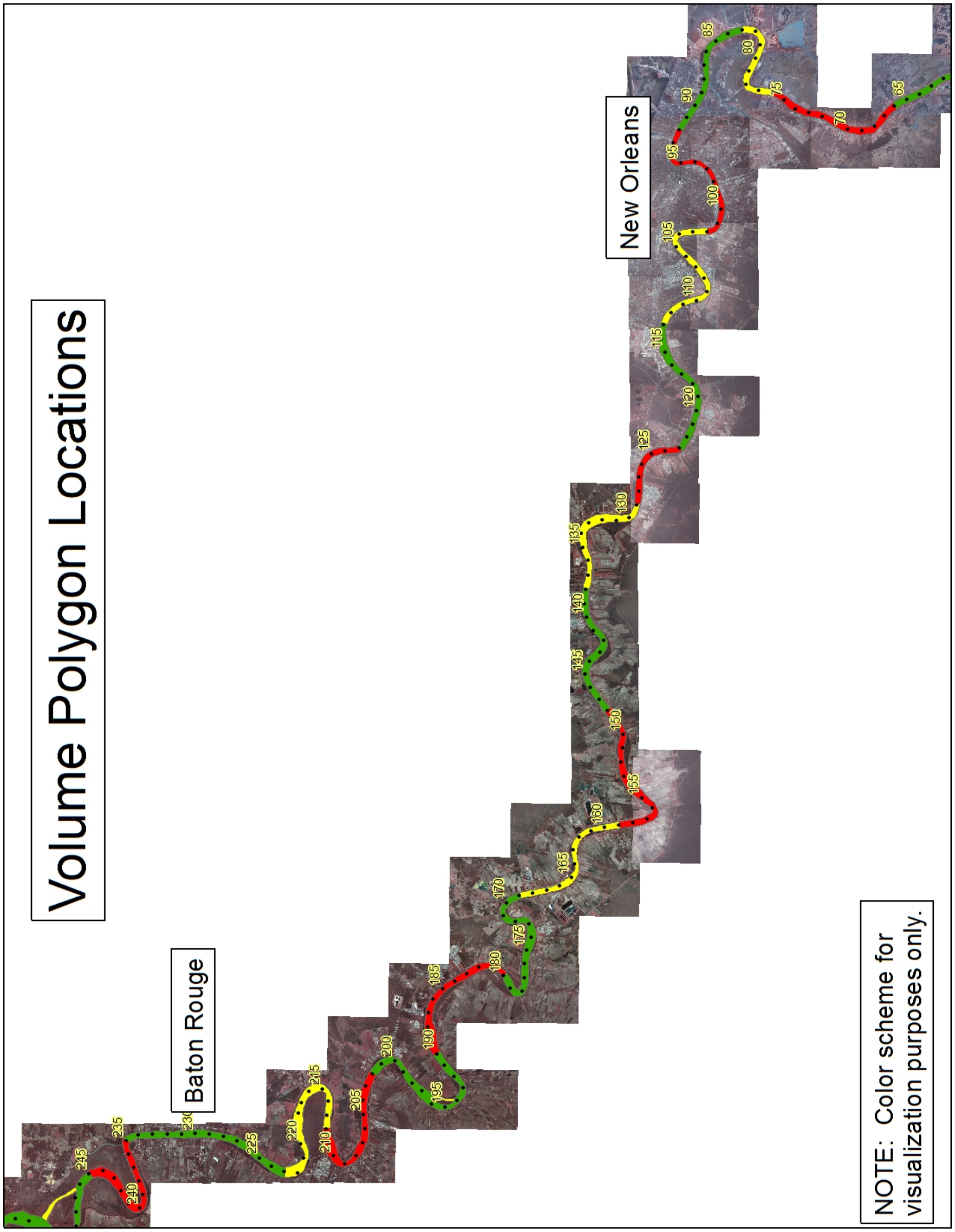


Figure 13. Volume polygon locations, New Orleans to Head of Passes.

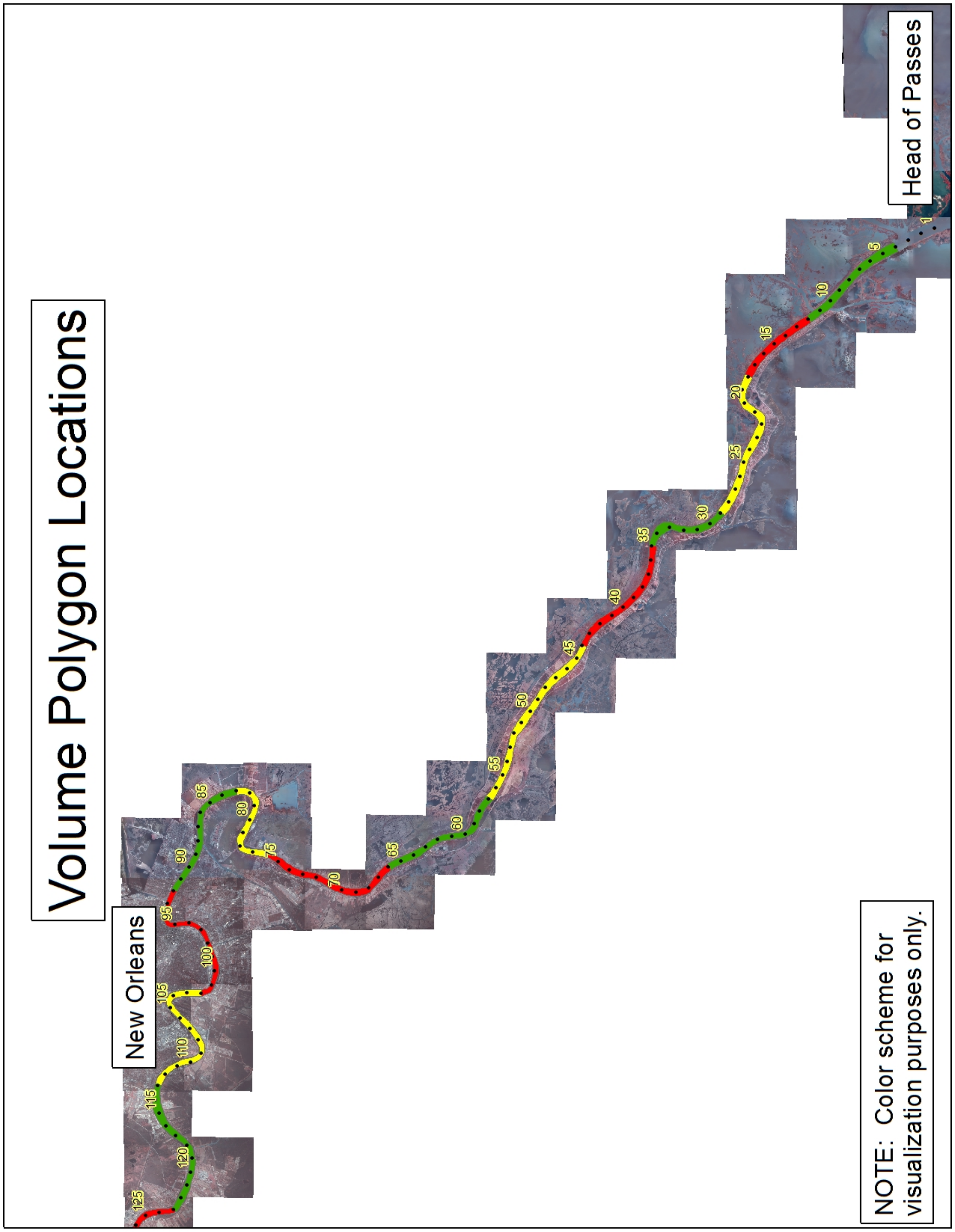


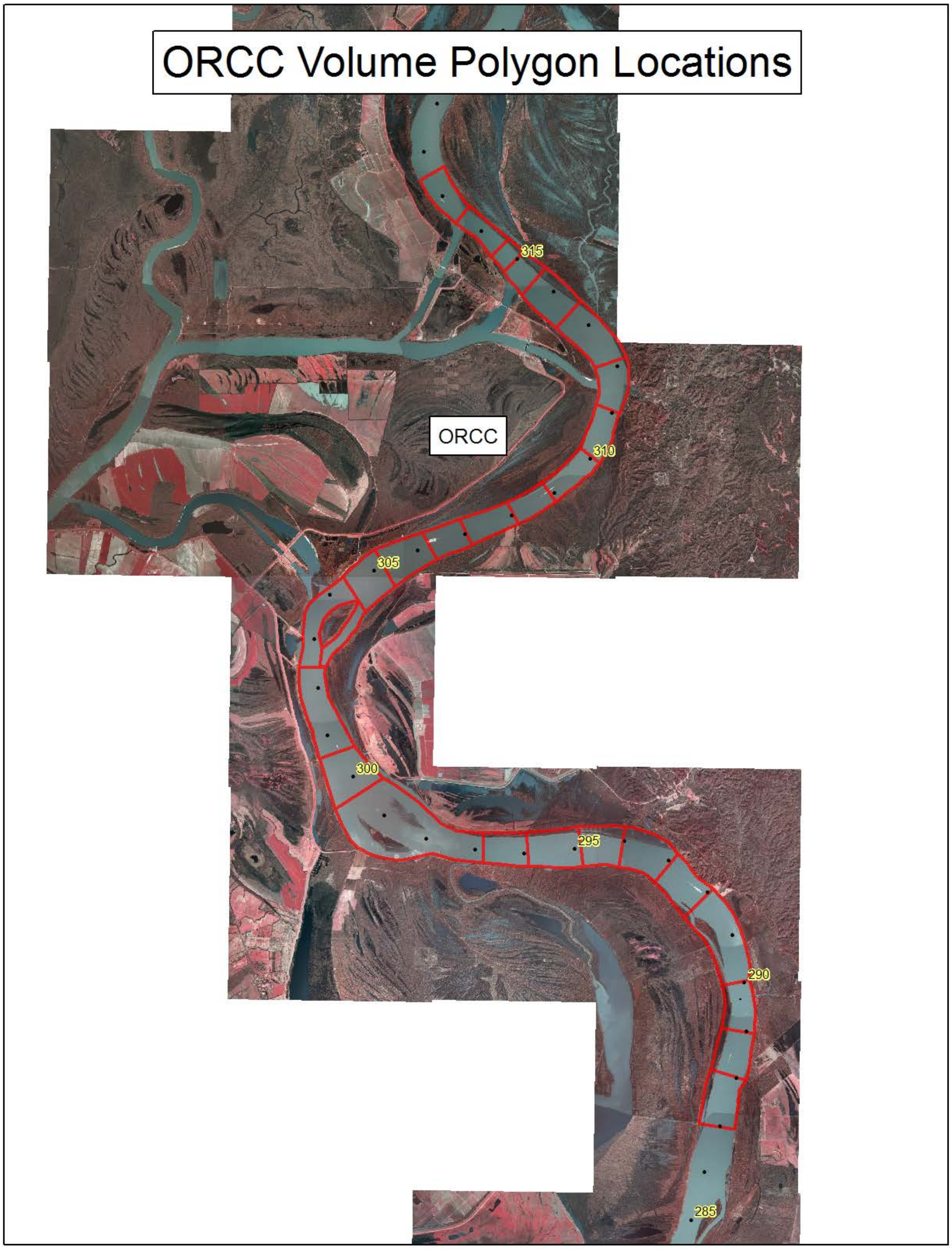
Table 6. Volume polygon locations by RM.

Polygon	RM	Polygon	RM	Polygon	RM
1	320–316.4	12	212–202	23	102–92
2	316.4–306.3	13	202–190	24	92–83
3	306.3–296	14	190–180	25	83–76
4	296–286	15	180–169	26	76–66
5	286–275	16	169–159	27	66–57
6	275–266	17	159–148	28	57–44
7	266–256	18	148–138	29	44–35
8	256–245	19	138–129	30	35–29
9	245–235	20	129–123	31	29–18
10	235–223	21	123–113	32	18–12
11	223–212	22	113–102	33	12–4

The average annual erosion/deposition volume for successive hydrographic surveys was computed by dividing the volume change by the length of the polygon in river miles and the number of years between surveys. The average annual erosion/deposition rates were used to create maps of sedimentation rates for the study reach, which are provided in Appendix B. Additionally, the computed volume changes were converted to an average annual bed displacement for each polygon by dividing the volume change by the polygon area. The average annual bed displacements were then plotted by river mile to provide another description of bed-change trends over time. These trends were compared to the trends observed with the comparative cross sections as well as the specific gage trends to gain an understanding of the stability of the river channel over time.

The primary use of the computed volumetric changes by survey was to inform the sediment budget developed for the study reach. The sediment budget utilized suspended sediment data and daily discharge data for streamgage stations along the river to determine the erosion and deposition trends by reach. The erosion/deposition volumes for the polygons that encompassed the reach between computation points of the sediment budget were summed to determine the reach average changes for comparison to the sediment budget. The volume-change data provided a means to verify the results of the sediment budget and when combined with the specific gage results, formed the basis of the stability assessment for the study reach.

Figure 14. Location of ORCC detailed volume polygons.



3.3 Gage and Discharge Analysis

Perhaps one of the most useful tools available to the river engineer or geomorphologist for assessing the historical stability of a river system is the specific gage record. Specific gage records were developed at a number of stations within the study area. This section provides a list of the gages used in the specific gage analysis as well as a discussion of the application and limitations of specific gage records.

3.3.1 Gaging stations

Table 7 provides a list of the gages and time periods used in the development of the specific gage records. The measured discharges at Tarbert Landing were coupled with the stage records at Red River Landing, Bayou Sara, Baton Rouge, and Donaldsonville to develop the specific gage records at these sites. A 1-day lag was applied for the flows at Baton Rouge and Donaldsonville based on methodology routinely used by MVN. Daily stage records were available at Algiers Lock and West Pointe a LaHache. These stages were coupled with the 1978–2012 discharge measurements made by USGS at Belle Chasse.

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

Stage Gage	Discharge Gage	Time Period
Red River Landing (RM 302.4)	Tarbert Landing	1963–2011
Bayou Sara (RM 265.4)	Tarbert Landing	1963–2011
Baton Rouge (RM 228.4)	Tarbert Landing	1963–2011
Donaldsonville (RM 173.6)	Tarbert Landing	1963–2011
Algiers Lock (RM 88.3)	Belle Chasse	1978–2012
West Pointe a LaHache (RM 48.7)	Belle Chasse	1978–2012

3.3.2 Specific gage analysis: methodology, interpretation, and limitations

This section discusses the methodology, interpretation, and limitations of specific-gage record analysis.

Methodology. The outcome of specific gage analysis is a graph of the stage (water-surface elevation above a fixed datum) for one or more selected discharges at a gauging station, plotted as a function of time. The channel is assumed to be stable (i.e., neither aggrading nor degrading), demonstrated by a line fitted through the stage data showing no significant upward or downward trend. Given the empirical basis for specific gage analysis, a key issue is the availability of reliable, measured data that chronicle the relationship between measured stages and measured discharges semi-continuously throughout the period being analyzed. In this context, it is important to note that published mean daily discharges are estimated values and that only the stage is measured daily (or more frequently). Consequently, an important limitation to the utilization of stage and discharge records for specific gage analysis is that only measured data should be used, and extrapolation is unacceptable.

There are two accepted approaches to performing a specific gage analysis: (1) the rating curve method and (2) the direct step method. Both methods have advantages and disadvantages but can produce reliable outcomes when properly applied. Data from the Red River Landing gage (1976–2010) were used to demonstrate the two methods (Figures 15 and 16). The first step in the rating curve method is to establish the stage-discharge relationship based on measured stages and measured discharges for each year during the period of record. Annual rating curves were developed for each year of record in Figure 15, using a polynomial regression analysis to provide objective and repeatable annual stage-discharge rating curves that minimize subjectivity.

Figure 15. Specific gage record for Red River Landing (1975–2010) using the rating curve method.

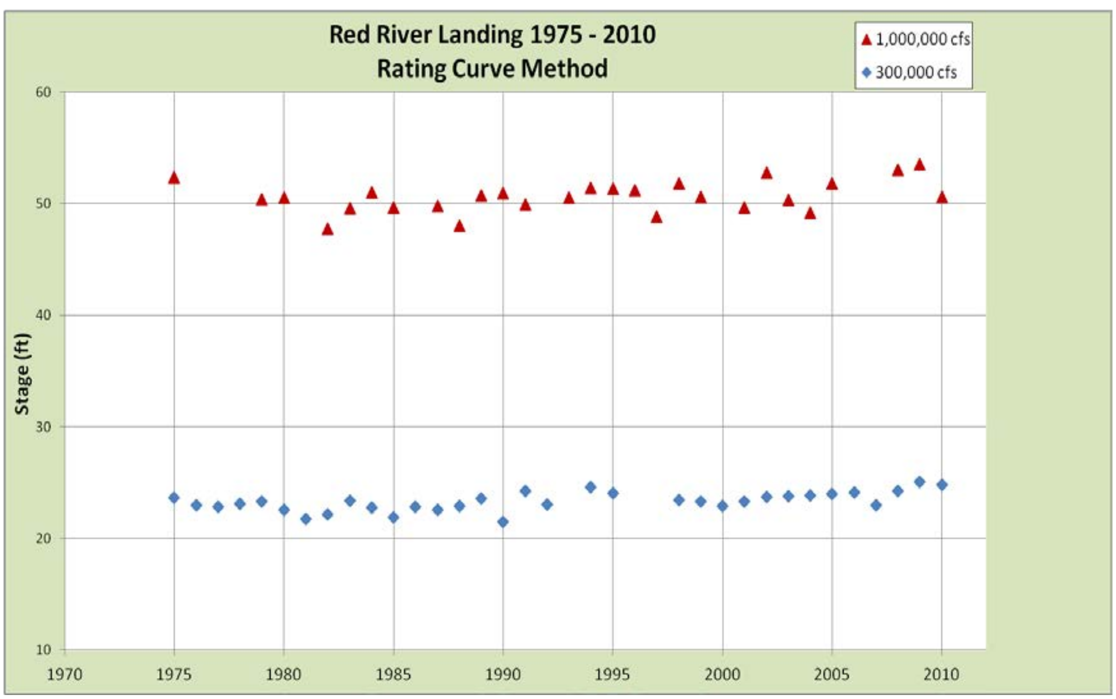
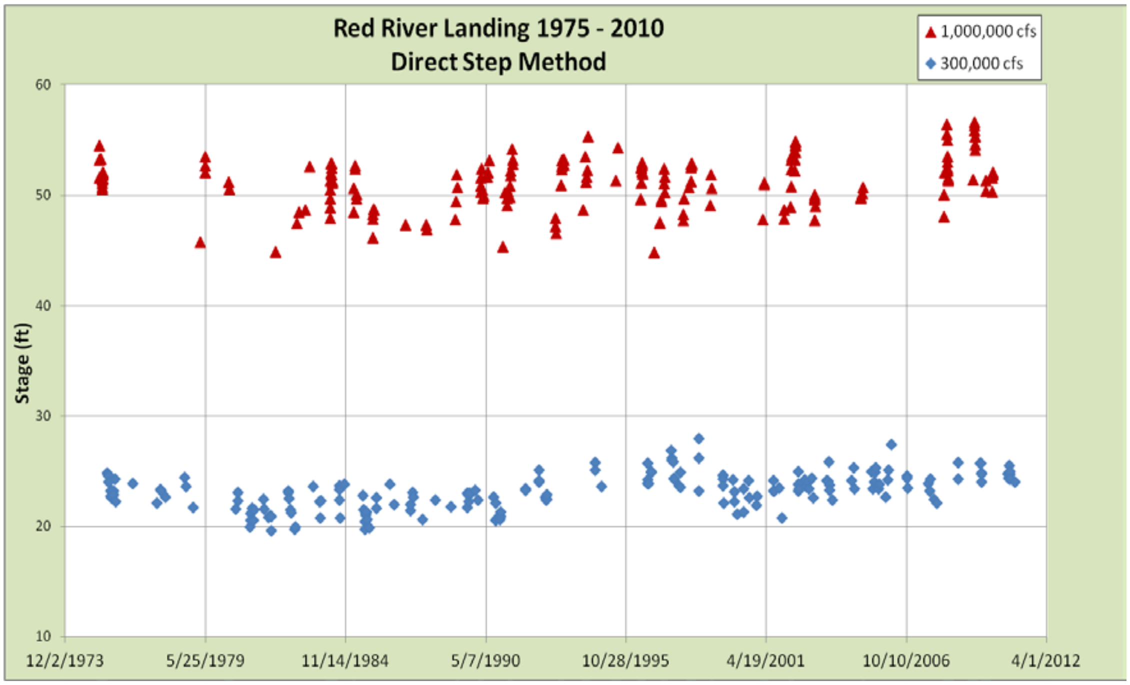


Figure 16. Specific gage record for Red River Landing (1975–2010) using the direct step method.



In Figure 15, stages are only plotted for years when measured discharges encompassed those used for the specific gage analysis. This explains why in most specific gage analyses there are gaps in the data series for the highest and/or lowest discharges. Stage values should not be generated by extrapolation of annual rating curves because additional points generated this way cannot add to the strength or statistical significance of the specific gage record for that discharge but may mask real trends in the measured data. A disadvantage of the rating curve method is that developing individual rating curves for each year in a long period of record is time consuming, and a degree of subjectivity exists in selecting the type of regression analysis employed.

In the direct step method, data are acquired directly from records of measured stages and measured discharges rather than via an annual rating curve fitted to those data (Figure 16). Specific discharges used in the analysis are the mid-points of bins in the range of discrete measurements of flow, usually at ±5% increments. A range of ±5%, a total bin width of 10%, is recommended to reflect the error band associated with field measurements classified as *good* by the U.S. Geological Survey (USGS) (Turnipseed and Saur 2010). The stages observed for each of the measured discharges in the bin are then plotted as a function of the date (year) of observation to produce the specific gage record for that discharge. Unlike the rating curve method, the direct step method may generate multiple points for a single year, depending on the number of times that flows within a given bin were gaged during that year. An advantage of the direct step method is that variability between measurements within a given year is evident in the specific gage plot. The primary advantage of the direct step method is that the measured data are utilized. For example, hysteresis is common in rating curves for the Mississippi River, and this is captured by the direct step method but may be eliminated in the annual rating curve. One disadvantage of the direct step method is that there may be gaps in the record for some years due to lack of gaged measurements being made that year for one or more of the specific discharges selected in the analysis.

For either method, the final step in the specific gage analysis is to fit a regression line to the points for the discharges in the time series. The specific gage records were developed using both methods, and the resulting trends were similar. For this study, only the direct step method is presented.

Interpretation. Performing a specific gage analysis using either the rating curve or direct step method is relatively simple and straightforward. However, interpreting the results of a specific gage analysis is not only more complicated but also presents more challenges, demanding that the investigator blends consistent treatment of the results with sound judgment. For example, it may be unwarranted to use trends established from the specific gage record for a single gauging station to infer that changes are taking place at the reach scale. Unless the trend exhibited at one station is corroborated by evidence from other stations and sources, the possibility that it is associated with a local change in channel form and process cannot be discounted.

A common error is to place too much emphasis on short-term fluctuations in stage, which are unreliable as evidence of physical changes to form or function of the river. Even for rivers in stable regime, specific gage records exhibit short-term stage fluctuations due to natural variability in the fluvial system. Consequently, trends that are not sustained for more than a few years cannot be interpreted as evidence of either morphological evolution or response to perturbation.

While close visual inspection of a specific gage record is an essential first step in its interpretation, statistical analyses are necessary to establish whether trends identified in data are significant. The two statistical parameters commonly employed for this purpose are the coefficient of determination (R^2) and the probability (p-value) that the slope of a regression line fitted to the data is significantly different from zero. R^2 is a measure of the proportion of the change in the Y variable (stage) that is explained by change in the X variable (time). For example, an R^2 of 0.8 implies that 80% of change through time in stage can be explained by the passage of time. Conversely, an R^2 of 0.2 implies that only 20% of the observed change in stage can be explained by time.

The p-value is the probability that the slope of a least squares regression line fitted to the data is the product of random chance rather than the outcome of the influence of the X (independent) variable on the Y (dependent) variable. As it is highly unlikely that the slope of the regression line will be precisely zero, it is necessary to select a critical p-value against which to compare the slope. The critical p-value is set by the analyst, based on the level of significance at which one wishes to reject the null hypothesis. The null hypothesis states that although the slope is not zero, the difference from zero is not statistically significant. For this study, the following criteria were used for setting the critical p-value and interpreting its meaning with respect to historical trends in stages:

1. For p-values greater than 0.1, the null hypothesis is accepted, and it is concluded that the slope of the regression line is not significantly different from zero (i.e., stage does not change as a function of time).
2. For p-values less than 0.01, the null hypothesis is rejected, and it is concluded that the slope of the regression line is significantly different from zero (i.e., stage does change as a function of time).
3. For p-values in the range of 0.01 to 0.1, the test is inconclusive. While stage does change as a function of time, the rate of change is insufficient to be confident that it is not the result of random chance.

While selection of these values (0.01 and 0.1) represents common practice for statistical tests of significance in trend lines, values actually used to support the contention that stage does (or does not) change through time may be set by the analyst.

<u>Limitations</u>. Specific gage analyses have long been recognized as an excellent tool for identifying historical stability (or instability) in the channel at a gauging station. For example, Blench (1969) wrote thus:

"There is no single sufficient test whether a channel is in-regime. However, for rivers, the most powerful single test is to plot curves of 'specific gage' against time; if the curves neither rise nor fall consistently the channel is in-regime in the vicinity of the gaging site for most practical purposes." However, there are limits to what can reliably be concluded from specific gage analysis, and these must be recognized, accepted, and borne in mind at all times. These limits may be defined by four statements of principle (Watson et al. 2013):

1. A specific gage record represents only the condition of the channel in the vicinity of the particular gauging station.
2. Specific gage analysis examines past trends and changes and does not a priori give any indication of future trends or changes.
3. Reliable interpretation of a specific gage record requires sound statistical treatment of the data, coupled with river-engineering experience.
4. The existence of natural variability and other sources of uncertainty in the data (e.g., measurement error, temperature effects) must be recognized.

Consequently, while specific gage analysis has long been, and remains, a valuable tool when attempting to identify causal links between engineering measures and fluvial responses, it is not a panacea. The results of a specific gage analysis should never be considered in isolation. The approach is better suited to assessing channel stability and change when used with other methods, techniques, and models appropriate to the geographical location, period of record, and quality of data available. It follows that while specific gage analysis can help identify historical trends of stage change, it cannot alone prove the cause of any apparent changes in stage with time.

3.4 Dredge Records Analysis

Annual maintenance dredging reports were obtained from the MVN for the time period 1970 to present. The annual dredge volumes listed in these reports are based on post-dredge surveys of the dredged areas and represent the official reported volumes for each contract rather than the actual production volumes reported in the dredge contractor log. For the time period 1980 to present, the volumes are reported by general locations such as crossings in the deep draft navigation channels, Southwest Pass, etc. The annual dredge volumes were determined for all major river crossings where periodic maintenance dredging has occurred. Dredge volumes for Southwest Pass and the Mississippi River above Head of Passes were reported by ERDC (Sharp et al. 2013) and are referenced here.

The dredge volumes were investigated to determine trends in maintenance dredging quantity and frequency during the study time period. The dredge history for the crossing locations was used to qualitatively inform the interpretation of the results of the geometric data analysis in terms of observed cross section changes. It should be noted that the dredge material from the crossing locations is typically discharged into the deep pool area immediately downstream of the crossing. Reported annual dredge volumes can also be a function of available funding and may not accurately reflect the volume of material deposited in a given year, potentially limiting the interpretation of relationships between dredge volume and observed geometric change.

3.5 Sediment Data Analysis

An integral component of the geomorphic assessment is the development of a sediment budget for the study reach. This involves the comparison of annual sediment loads for the various stations along the study reach using measured suspended sediment data. Allison et al. (2012) conducted a sediment budget for the study reach for the years 2008–2010. This study documented the utility of a sediment budget to identify patterns of sediment storage and delivery. The goals of this present study are to complement and expand upon the sediment budget conducted by Allison et al. (2012) by extending the study time period and by the development of a Probabilistic Sediment Budget (PSB) that incorporates the uncertainty in the measured sediment data into the analysis. The development of the PSB approach is described in this section.

3.5.1 Gauging stations utilized

The gauging stations used for this analysis included Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse. These are the same four stations used by Allison et al. (2012). Tarbert Landing is maintained by the USACE while the other three are USGS stations.

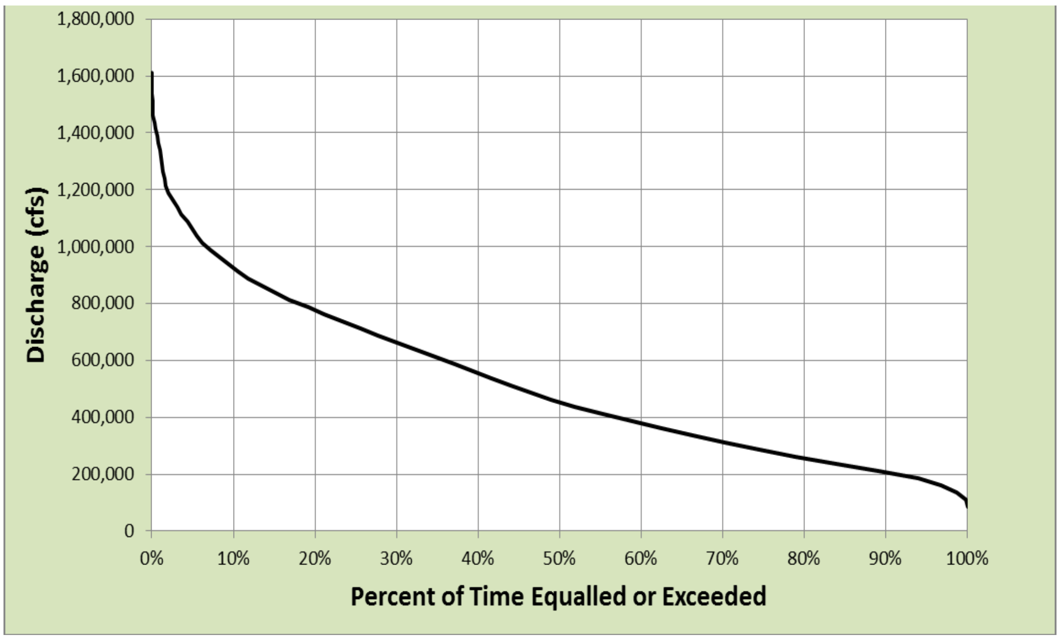
3.5.2 Flow records

A record of computed daily discharges for the entire time period is required for the development of the sediment budget. Ideally, this would be based on measured discharge data at each station. Unfortunately, Tarbert Landing is the only long-term discharge gage that covers the entire time period (1973–2012). Therefore, some means of developing the flow record at the other stations was needed. Two methods were considered. The first method was to use the computed daily discharge data at Tarbert landing and then lag these data to the downstream stations. Adjustments were also made for discharges through Morganza and Bonnet Carré floodways. At St. Francisville, no lag adjustments were made. At Baton Rouge and Belle Chasse, the flows were lagged one day and two days, respectively, based on methodology routinely used by MVN. The second method used was to develop stage-discharge relationships at the gages using the limited measured discharge at the study gage with the long-term daily stage data from a nearby gage. For example, measured discharge and computed daily discharge are only available at Belle Chasse from 2009 to 2012. Therefore, a stage-discharge relationship was developed using these data and the daily stage data at New Orleans where a long-term stage record exists. The resulting regression equation was then used to develop computed daily discharge at Belle Chasse using the daily stage data at New Orleans for the entire time period from 1973 to 2012. A similar method was used for Baton Rouge and St. Francisville.

The sediment budget results using the lagged flow approach and the stage relation approach were compared and found to produce very similar results. While there were minor differences in the annual sediment load calculations, the overall trends were essentially the same. It should be emphasized that there is uncertainty in both methods and that both methods have advantages and disadvantages. The advantages of the lagged approach are that it provides a long-term record of flows based on Tarbert Landing, and therefore, uncertainty associated with measurement differences between gauging stations is not an issue. The primary disadvantages in this approach are the uncertainty introduced in the determination of the correct lag time (particularly the farther downstream the flows are lagged) and the uncertainty with respect to the Morganza and Bonnet Carré flows or other unknown losses between stations. The primary advantage of the stage relation approach is that it uses measured discharge data at each station. The primary disadvantages include the uncertainty in the computed stage-discharge relationships and the potential for uncertainty associated with measurement differences between stations. Additionally, the stage-discharge relationships, developed for a relatively short time period in recent years, may not be representative of the early time periods. Weighing all these factors, and recognizing that the results were so similar, it was determined that the lagged approach would be used for this study.

Using the lagged approach, daily discharge values were developed for all four stations for the period of record being considered. Next, a flow-duration curve for this time period was developed for each station. The flow-duration approach used discharge bins of 25,000 cubic feet per second (cfs). Figure 17 shows an example flow-duration curve for Tarbert landing.

Figure 17. Tarbert Landing flow-duration curve for 1973–2012.



3.5.3 Sediment rating curves

Sediment concentration-discharge relationships were developed at the following four gauging stations: Tarbert Landing (1975–2011), St. Francisville (1978–2012), Baton Rouge (1975–2012), and Belle Chasse (1978–2012). The data were segmented into fines (<0.063 millimeter (mm)) and sands (=>0.063 mm). For the sand concentration analysis, the regressions were developed for the entire time periods shown in parentheses above. Developing a regression for this entire time period is acceptable because no significant increasing or decreasing trends in sand concentration were observed during this time period (see Section 4.4.1). Although decreasing trends in the fine concentrations have been observed from the 1950s to the 1990s, no significant trends were observed in the post-1990 period (see Section 4.4.1). Therefore, the fine sediment analysis only covered the period from 1990 to 2012. All variables were heavily right-skewed, and discharge data were strongly heteroscedastic (i.e., data scatter increased with larger values). Rating curves were constructed using a log-

log relationship for sediment concentration and discharge in order to meet assumptions of residual normality and homoscedasticity (Walling 1977). Natural logarithms were used to simplify correction of transformation bias in subsequent steps. Approximation of the normal distribution was indicated by a Shapiro-Wilk statistic of $W \geq 0.95$ (Douglass and Douglass 2004).

Logarithmic transformation cannot be performed on values of zero. Some of the datasets (particularly the sand concentration data) used in this study, however, contained sediment concentrations equal to zero. In order to keep these observations in the regression analysis, 1.0 was added to each value before taking the natural log. Adding a constant to every observation has no effect on the calculation of least squares for regression, but it must be taken into account for back-transformation to the original scale and/or proper interpretation of regression coefficients.

A linear relationship for sediment concentration and river discharge tended to overestimate values at higher discharges. Therefore, a second-order polynomial function was fit to each dataset and significance of the quadratic term was assessed:

$$\mathrm{Y} = \theta + \theta_1 \mathrm{X} + \theta_2 \mathrm{X}^2 + \varepsilon \tag{1}$$

where:

Y = ln (concentration)
X = ln (discharge)
θ, θ_1 and θ_2 = regression coefficients
ε = random error term with mean of zero.

Parker and Troutman (1989) proposed that the parameter θ_2 may have a physically significant interpretation in terms of sediment supply, as follows:

$\theta_2 = 0$, sediment increases at a constant (linear) rate (i.e., unlimited sediment supply)

$\theta_2 < 0$, sediment increases at a decreasing rate (i.e., limited sediment supply)

$\theta_2 > 0$, sediment increases at an increasing rate (i.e., increasing sediment supply at higher discharges).

For both the sands and the fine regressions, the quadratic terms (θ_2) were less than zero, possibly indicating a sediment-supply-limiting phenomenon. Figure 18 shows the sand concentration-discharge relationships for the four stations. Figure 19 shows the fine concentration-discharge relationships for the four stations.

Back-transformation of the arithmetic mean of log-transformed data yields the geometric mean (i.e., median) in the original scale. Consequently, use of uncorrected anti-logged predicted values from least squares regression in the logarithmic scale leads to underestimation by the model as the geometric mean is smaller than the arithmetic mean for right-skewed data. The degree to which the model underestimates the concentration depends on the variability in the data. A correction factor (CF) proposed by Ferguson (1986a) for the log_{10}-linear relationship with normally distributed residuals was modified for the log_e-quadratic relationship:

$$CF = exps\left(\frac{s^2}{2}\right) \tag{2}$$

$$\text{with } s^2 = \sum_{i=1}^{n}\left(lnCi - ln\hat{C}i\right)^2 / (n-3) \tag{3}$$

where:

s^2 = unbiased estimator of the error variance (σ^2)
$(logCi - \widehat{logCi})$ = the residual (i.e., observed-predicted concentration) in the log-scale
n = the sample size.

Because the denominator accounts for the estimation of three parameters (θ,θ_1, θ_2), the squared standard error of estimate (s^2) for the regression is an unbiased estimator of σ^2 (Sprugel 1983; Ferguson 1986a). Adaptation of the correction factor to the quadratic form was straightforward because the error term in a polynomial function, as in a linear function, is additive. This correction factor was appropriate because the residuals from the quadratic regression met the assumptions of least squares regression (Ferguson 1986b). However, to evaluate these parametric assumptions, the results were compared with those using a nonparametric correction factor proposed by Koch and Smillie (1986). Both methods yielded similar correction factors, and the Ferguson approach was employed thereafter.

Figure 18. Sand concentration-discharge relationships for (a) Tarbert Landing, (b) St. Francisville, (c) Baton Rouge, and (d) Belle Chasse.

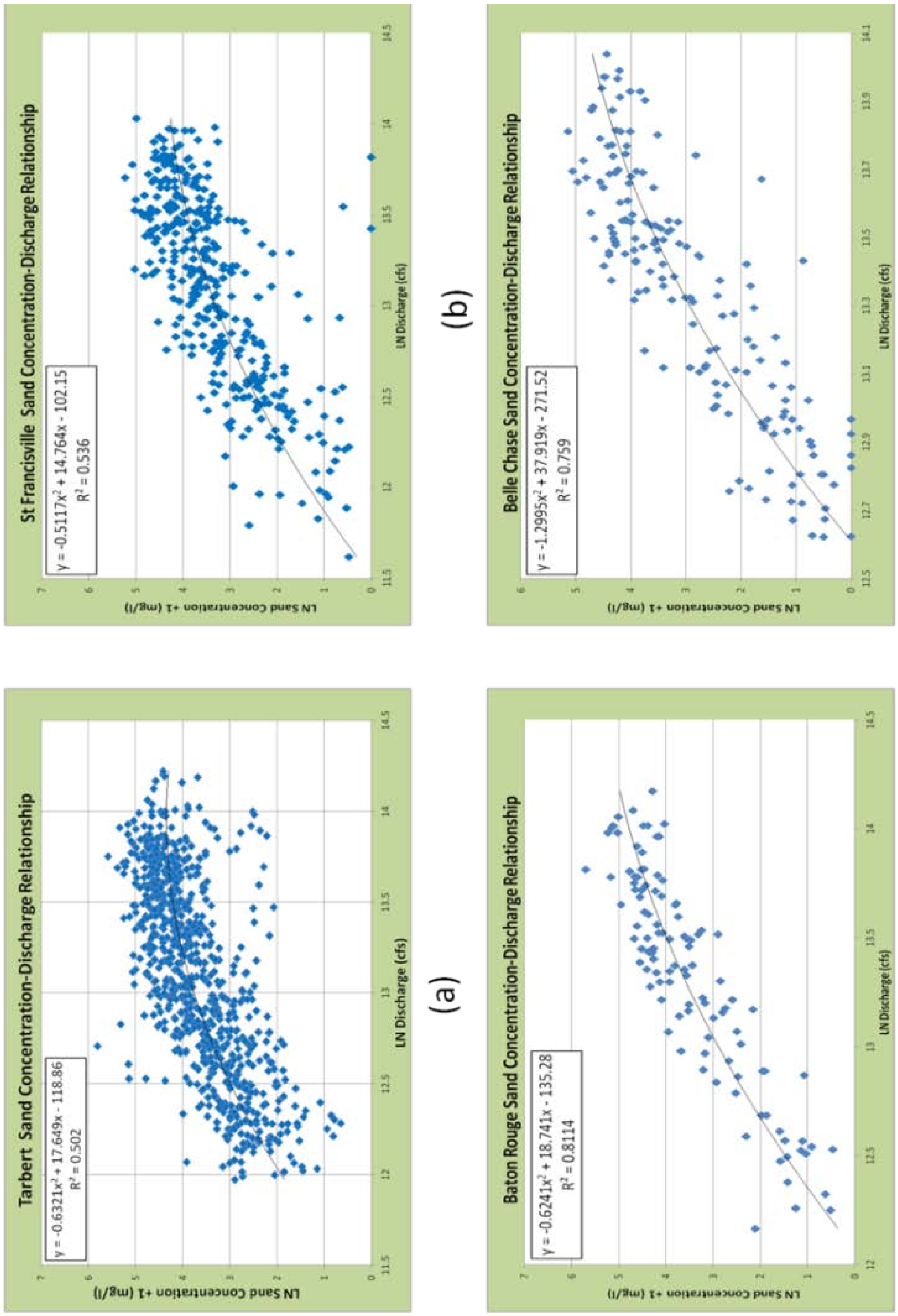
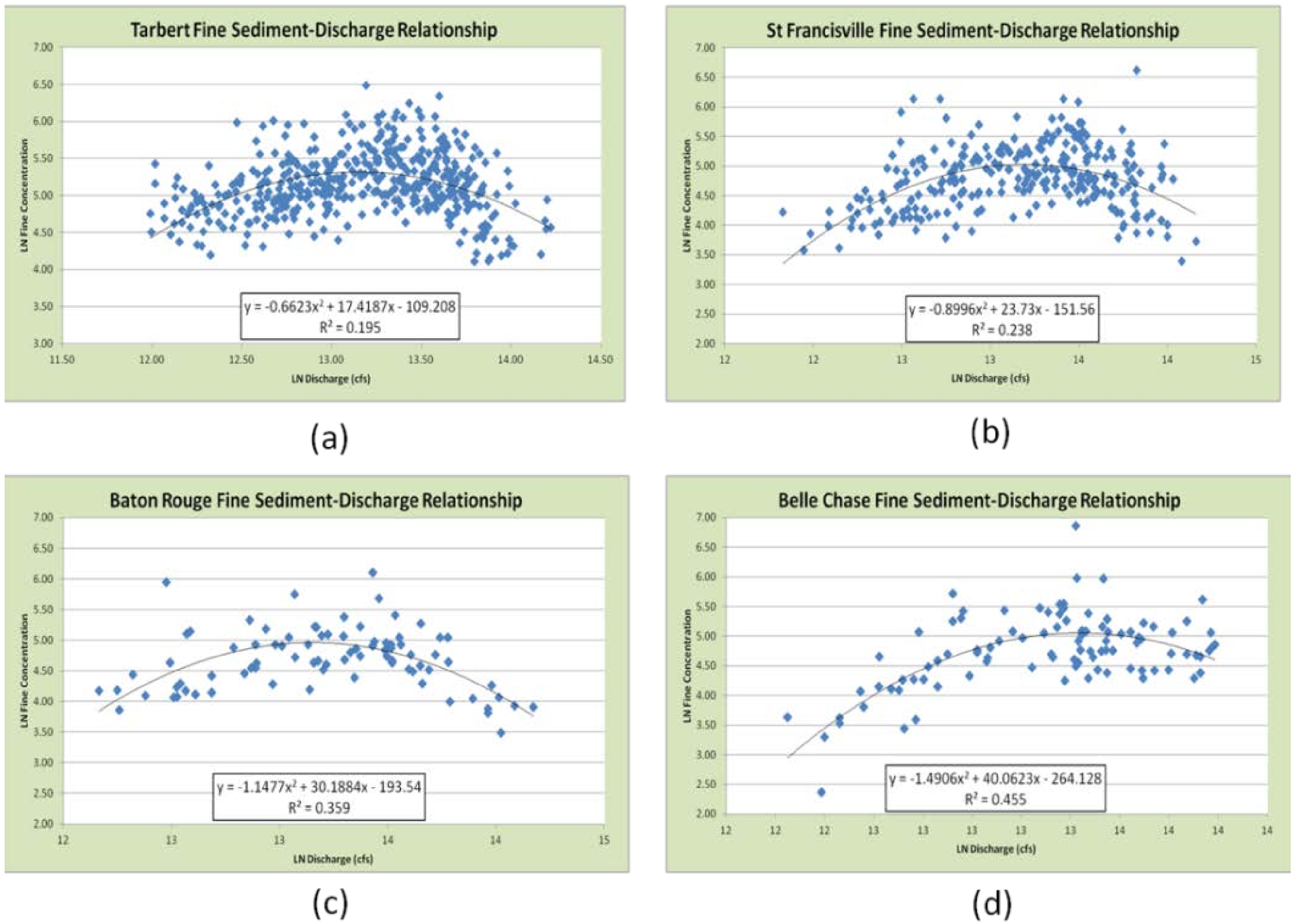


Figure 19. Fine concentration-discharge relationships for (a) Tarbert Landing, (b) St. Francisville, (c) Baton Rouge, and (d) Belle Chasse.



3.5.4 Sediment budget

The flow-duration curves were coupled with the sediment-discharge relationships to produce the annual sediment loads at each of the four stations. Subtracting the values between adjacent stations provides an estimate of the amount of sediment that is deposited or scoured between the gages on an annual basis. A traditional sediment budget such as this reflects the annual sediment load based on the mean regression of the sediment data. However, this approach fails to capture the complete structure of the concentration-discharge relationship (Sivakumar and Wallender 2004). As shown in Figures 18 and 19, there is much scatter around the mean regression of the sediment data. Therefore, a Monte Carlo approach based on the statistical properties of each dataset of regression residuals was adopted as a means to capture the uncertainty in the data and to produce a probabilistic sediment budget. The first step in this approach was to calculate the residuals for the sediment-regression equations for each station. The residuals are simply the difference between the mean value of the concentration predicted by the regression curve and the actual observed concentration value. Log_e-quadratic relationships were modeled in SAS 9.3 using the General Linear Model Procedure, and approximation of the normal distribution by the model residuals was assessed using the Univariate Procedure (SAS Institute 2012). Figure 20 shows an example plot of the residuals for the Tarbert Landing sand concentration data.

Figure 20. Residual concentration plot for Tarbert Landing sand data.

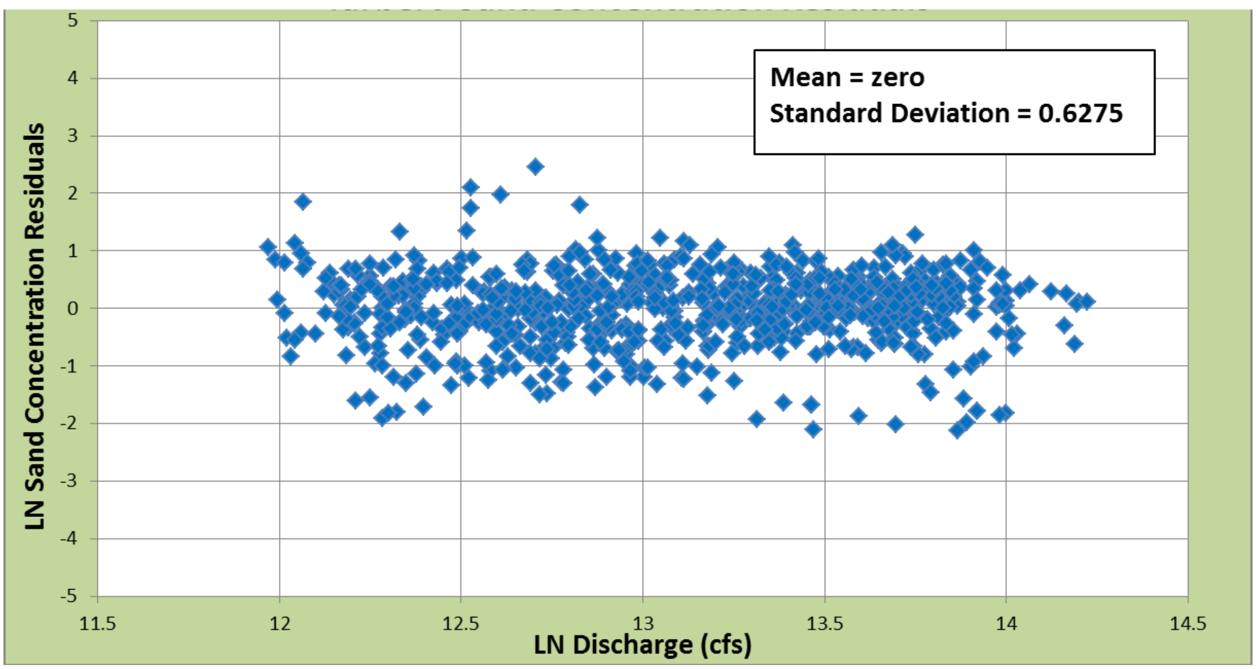


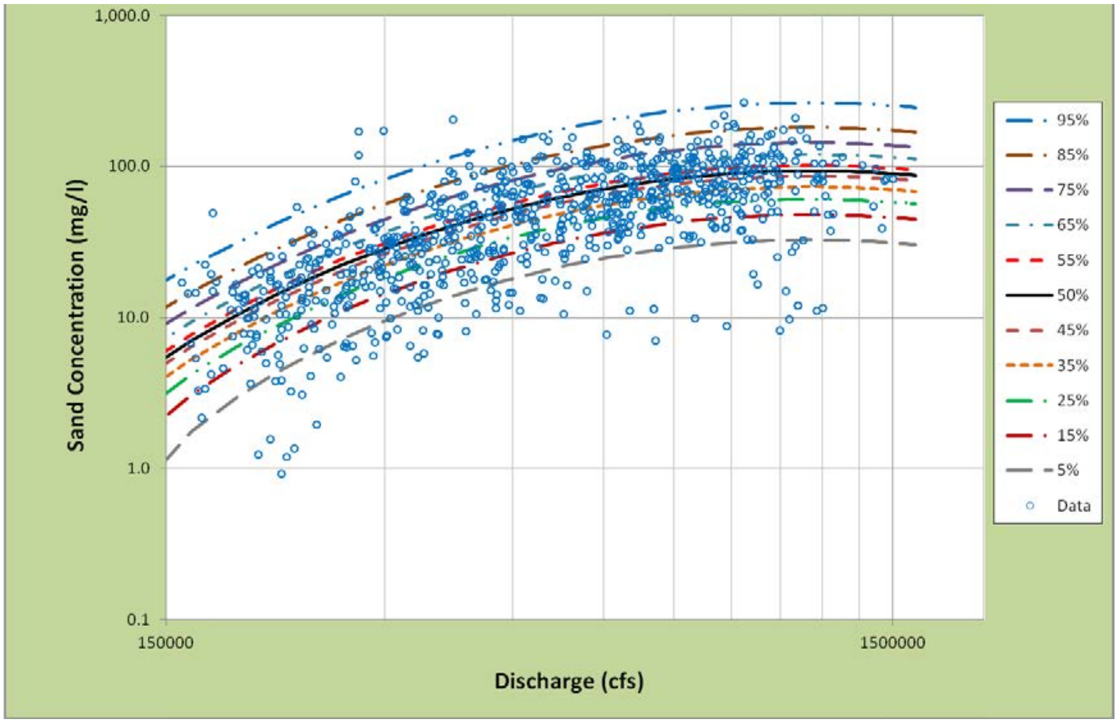
Table 8. Example of generation of adjusted sediment concentrations.

		Random Number 1	Random Number 2	Random Number 3	—	Random Number 9,998	Random Number 9,999	Random Number 10,000
		-0.985	**-0.069**	**0.067**	—	**-1.449**	**0.065**	**-0.511**
Discharge (cfs)	Predicted Mean LN Sand Concentration (milligrams/liter)	Adjusted Sand Concentration (milligrams/liter)	Adjusted Sand Concentration (milligrams/liter)	Adjusted Sand Concentration (milligrams/liter)	—	Adjusted Sand Concentration (milligrams/liter)	Adjusted Sand Concentration (milligrams/liter)	Adjusted Sand Concentration (milligrams/liter)
87,500	0.133	0.000	0.064	0.200	---	0.000	0.198	0.000
112,500	0.914	0.000	0.844	0.981	---	0.000	0.978	0.402
137,500	1.479	0.494	1.410	1.547	---	0.031	1.544	0.968
162,500	1.912	0.926	1.842	1.979	---	0.463	1.976	1.400
187,500	2.254	1.268	2.184	2.321	---	0.805	2.318	1.742
212,500	2.532	1.546	2.463	2.599	---	1.083	2.596	2.020
237,500	2.762	1.777	2.693	2.830	---	1.314	2.827	2.251
262,500	2.956	1.971	2.887	3.024	---	1.508	3.021	2.445
287,500	3.122	2.136	3.052	3.189	---	1.673	3.186	2.610
312,500	3.264	2.279	3.195	3.331	---	1.815	3.329	2.753
----------	----------	----------	----------	----------	---	----------	----------	----------
1,387,500	4.327	3.341	4.257	4.394	---	2.878	4.391	3.815
1,412,500	4.323	3.337	4.253	4.390	---	2.874	4.387	3.811
1,437,500	4.318	3.332	4.249	4.385	---	2.869	4.383	3.806
1,462,500	4.313	3.328	4.244	4.380	---	2.864	4.378	3.802
1,487,500	4.308	3.322	4.238	4.375	---	2.859	4.372	3.796
1,512,500	4.302	3.317	4.233	4.370	---	2.853	4.367	3.791
1,537,500	4.297	3.311	4.227	4.364	---	2.848	4.361	3.785
1,562,500	4.291	3.305	4.221	4.358	---	2.842	4.355	3.779
1,587,500	4.284	3.299	4.215	4.352	---	2.836	4.349	3.773
1,612,500	4.278	3.293	4.209	4.345	---	2.829	4.343	3.767

As shown in Figure 20, the data are approximately normally distributed about the mean of zero, satisfying the assumptions of least squares regression. The random number generation analysis tool in Excel was used to generate 10,000 randomly generated residuals conforming to a normal probability distribution with a variance unique to each regression. Ten-thousand values were generated to ensure that a reasonable range of possible values was analyzed. Each random number when added to the predicted mean value produces a new concentration value that falls within the scatter of the data. This was accomplished for each discharge bin. Table 8 lists an example of the calculations for the sand concentrations at Tarbert Landing. The data in the first column are the representative discharges for each discharge bin for the flow-duration data. The second column contains the predicted mean value for the Log_e of the sand concentration from the regression curve for each discharge bin. The remaining columns contain the random numbers and the adjusted concentrations. Each random number is added to the predicted mean concentration value in the second column for each discharge bin to produce an adjusted concentration value for that random number (i.e., a randomized location within the scatter of data at that discharge value). For example, in the fourth column, the random number is –0.069, which when added to the mean concentration (0.133) for the first discharge bin, produces a concentration value of 0.064. It should be noted that in the smallest discharge bins, the adjusted concentration result is sometimes negative. In these instances, the adjusted value is simply set to zero. This is considered to be a reasonable assumption since this occurs only in the smaller discharge bins where there is typically little-to-no sand moved. This process simulates 10,000 new sand concentration-discharge values that are normally distributed about the mean curve with a standard deviation descriptive of the variability at that station. Figure 21 graphically presents scenarios representing the median and exceedance frequencies at 10% increments between 5% and 95%.

The next step in the process was to calculate the annual sediment loads for all 10,000 scenarios. Each Log_e concentration value was back-transformed to the standard linear scale and then multiplied by the Ferguson bias correction factor. The concentration values in each bin were then multiplied by the representative discharge for that bin and the average number of days per year (from the flow-duration curve) that the flows in that bin occur to produce the annual sediment load for each bin in tons/year. These values were then summed up to produce the total annual

Figure 21. Sequences of sand concentration-discharge curves at Tarbert Landing for the exceedance frequencies between 5% and 95%.



sediment load in tons/year for each of the 10,000 scenarios. Table 9 lists examples of the annual load calculations for Tarbert Landing. Using the rank and percentile tool in Excel, the percentile rank was then determined for all 10,000 scenarios. Figure 22 presents an example graph of the percentiles for the annual sand loads at Tarbert Landing. A key aspect of the PSB approach is that it provides the user with the flexibility to examine a range of possible results rather than simply relying on the mean value. As shown in Figure 22, this approach generates some extreme loads at both the upper and lower percentile ranges. These loads are the result of the upper and lower percentile curves in Figure 21. Although these loads are theoretically possible, it is highly unlikely that they would occur. It is more likely that there is some range of values on either side of the median (50%) value that provides a more realistic range of practical results. Defining the boundaries for this practical outcome range is inherently subjective and requires engineering judgment. For this study, the 35th and 65th percentile curves were selected to represent the lower and upper boundaries of the practical range. As indicated in Figure 21, these curves are fairly close to the median value curve, representing a rather conservative range. Therefore, sand concentrations that fall within this range are considered very likely to occur. Using the 35th to 65th percentile range, the range of annual sand load results at Tarbert Landing would range from approximately 28 million tons/year (tons/yr) to 46 million tons/yr.

Table 9. Example calculations for the annual sands loads for Tarbert Landing.

Discharge (cfs)	Mean Curve Sand Load (tons/yr)	Scenario 1 Sand Load (tons/yr)	Scenario 2 Sand Load (tons/yr)	Scenario 3 Sand Load (tons/yr)	–	Scenario 9,998 Sand Load (tons/yr)	Scenario 9,999 Sand Load (tons/yr)	Scenario 10,000 Sand Load (tons/yr)
87,500	0	0	0	0	-	0	0	0
112,500	448	0	398	500	-	0	497	148
137,500	5,745	1,082	5,247	6,263	-	53	6,241	2,766
162,500	22,462	5,942	20,697	24,296	-	2,293	24,221	11,909
187,500	52,568	15,757	48,634	56,654		7,626	56,487	29,052
212,500	142,578	45,500	132,203	153,353	-	24,059	152,914	80,562
237,500	218,897	72,460	203,247	235,152	-	40,117	234,489	125,348
262,500	293,254	99,378	272,534	314,775		56,557	313,898	169,400
287,500	321,371	110,668	298,852	344,759	-	64,131	343,806	186,767
312,500	406,547	141,621	378,233	435,954	-	83,108	434,756	237,304
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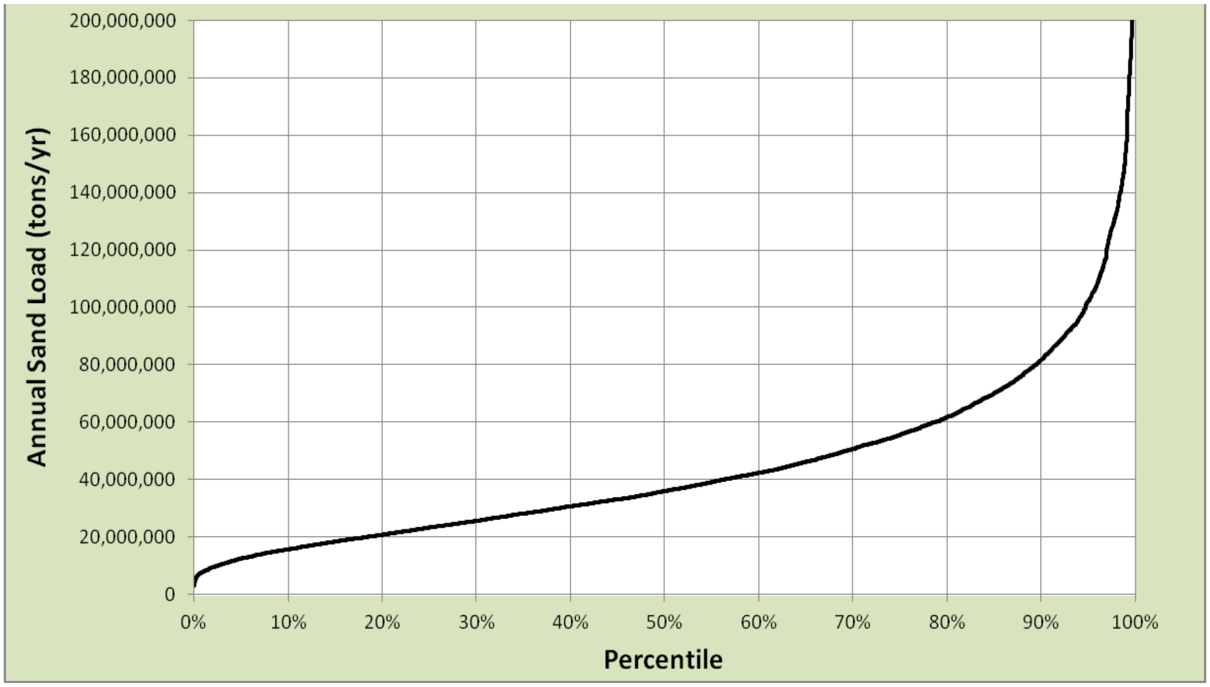
1,387,500	207,140	75,580	193,079	221,743	-	46,522	221,148	123,095
1,412,500	218,704	79,791	203,857	234,123	-	49,110	233,495	129,962
1,437,500	239,259	87,281	223,017	256,129	-	53,714	255,441	142,171
1,462,500	233,240	85,075	217,405	249,687	-	52,351	249,016	138,588
1,487,500	54,457	19,861	50,760	58,297	-	12,220	58,141	32,356
1,512,500	18,356	6,694	17,109	19,650	-	4,118	19,597	10,905
1,537,500	37,102	13,528	34,583	39,719	-	8,321	39,612	22,042
1,562,500	18,739	6,832	17,467	20,061	-	4,202	20,007	11,132
1,587,500	9,460	3,448	8,818	10,127	-	2,120	10,100	5,620
1,612,500	38,188	13,917	35,594	40,882	-	8,557	40,772	22,683
Total Annual Load (tons/yr)	35,751,909	12,942,670	33,314,179	38,283,762	-	7,904,949	38,180,552	21,180,605

Figure 22. Percentiles for the 10,000 scenarios of annual sand loads at Tarbert Landing.



With a traditional sediment budget, the mean values for the annual sediment loads at two adjacent stations are simply subtracted from each other. However, with the PSB, there are thousands of potential combinations of values that can be considered. The change in the annual sediment load for the three reaches (Tarbert Landing to St. Francisville, St. Francisville to Baton Rouge, and Baton Rouge to Belle Chasse) is determined for each of the 10,000 scenarios by subtracting the annual loads for each scenario. Table 10 lists an example of the calculations for the Tarbert Landing to St. Francisville reach. The percentile rank is then determined for all 10,000 scenarios of annual load changes. Figure 23 presents an example graph of the percentiles for the annual sand load changes for the Tarbert Landing to St. Francisville reach. The next step is to determine the boundaries of the practical outcome range that corresponds to the selected percentile range from the individual station curves, which for this study are the 35th and 65th percentile values. This is accomplished by subtracting the 35th and 65th percentile values at St. Francisville from the 65th and 35th percentile values at Tarbert Landing, respectively. This provides the maximum and minimum values for the annual sand load change within the 35th and 65th percentile curves. Table 11 lists the results for this example. As shown in Table 11, the minimum and maximum values for the annual sand load change within the 35th to 65th percentile range are -10.1 million tons/yr and 24.5 million tons/yr, respectively. These values can then be used to define a range of practical outcomes along the percentile curve as indicated by the vertical red lines in Figure 23. Note that this results in a range from approximately the 29th to 72nd percentile on the annual sand load change curve in Figure 23.

Table 10. Example calculations for the annual sand load change for the Tarbert Landing to St. Francisville reach.

	Annual Sand Loads (tons/yr)			Annual Sand Change (tons/yr)
Scenario	Tarbert Landing	St. Francisville	—	Tarbert Landing Minus St. Francisville
1	12,942,670	22,272,777	---	–9,330,106
2	33,314,179	17,384,431	---	15,929,748
3	38,283,762	88,955,715	---	–50,671,953
4	10,867,328	12,745,617	---	–1,878,289
5	11,114,993	24,017,510	---	–12,902,517
6	89,857,494	29,761,734	---	60,095,760
7	15,226,524	22,105,954	---	–6,879,431
8	122,531,266	5,686,419	---	116,844,847
---------------	--------------------	----------------------	---	----------------------------------
9,993	34,880,982	75,840,889	---	–40,959,907
9,994	50,063,321	17,608,849	---	32,454,473
9,995	28,479,510	120,140,622	---	–91,661,111
9,996	37,320,550	10,735,718	---	26,584,832
9,997	72,749,595	40,161,355	---	32,588,240
9,998	7,904,949	19,426,770	---	–11,521,821
9,999	38,180,552	16,849,812	---	21,330,740
10,000	21,180,605	50,056,180	---	–28,875,574

Figure 23. Percentiles for the 10,000 scenarios of annual sand load change between Tarbert Landing and St. Francisville.

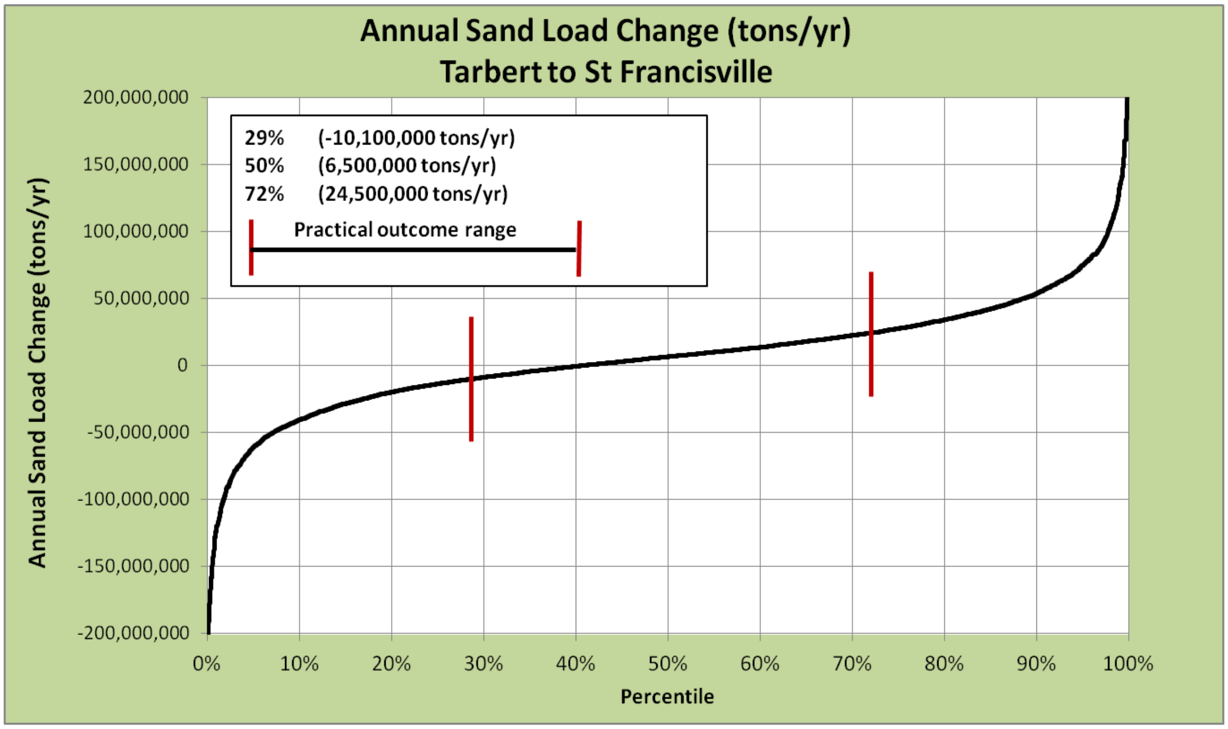
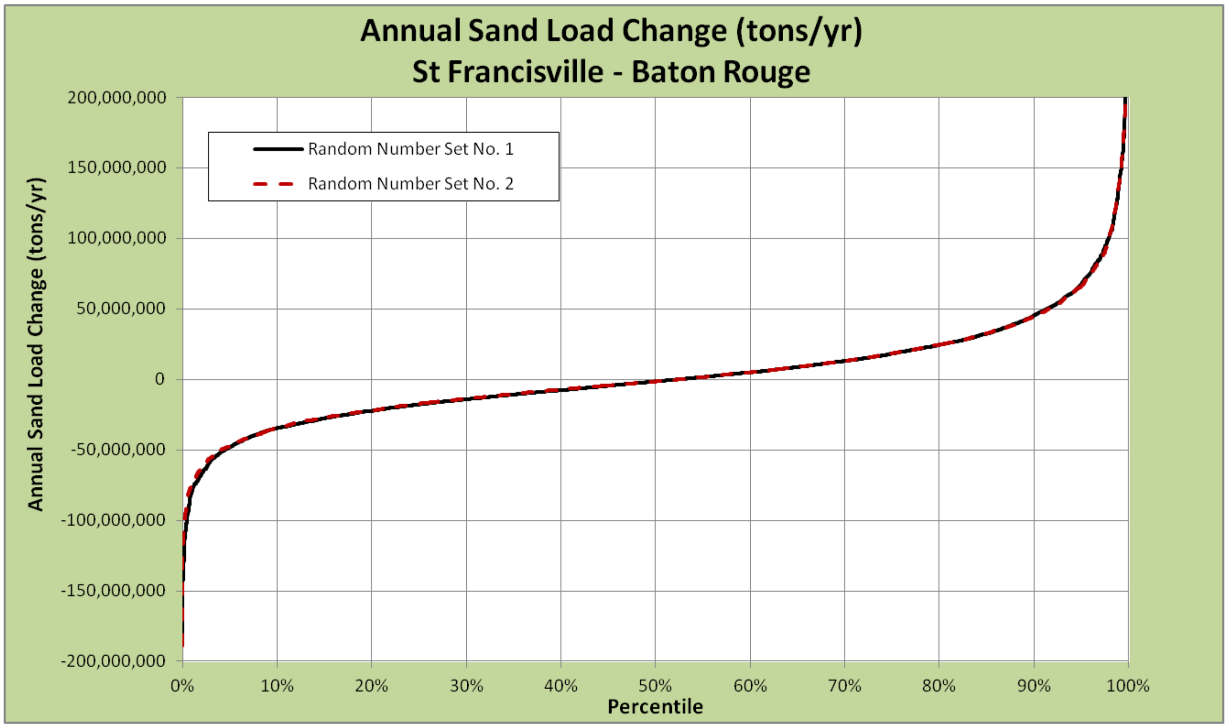


Table 11. Calculation of annual sand load change between Tarbert Landing and St. Francisville for the 35th and 65th percentiles.

Percentile	Tarbert Landing Annual Sand Load (tons/yr)	St. Francisville Annual Sand Load (tons/yr)	Tarbert–St. Francisville Sand Load Change (tons/yr)	
			Minimum (35%–65%	Maximum (65%–35%)
35th	28,100,000	21,600,000	–10,100,000	24,500,000
65th	46,100,000	38,200,000		

A test was conducted to determine how sensitive the results were to the random number generation. Figure 24 provides an example of the test for the St. Francisville to Baton Rouge reach. A completely different set of 10,000 random numbers was generated for St. Francisville and Baton Rouge using the statistical parameters (mean and standard deviation) for each station, and a new PSB analysis was conducted. Figure 24 presents the results for the annual sand load changes between St. Francisville and Baton Rouge for these two different sets of random numbers. Although the individual values for each scenario were different, the percentile values were almost identical. This suggests that the PSB approach is not sensitive to the random number generation.

Figure 24. Annual sand load change between St. Francisville and Baton Rouge for two sets of random numbers.



3.5.5 Effective discharge analysis

Wolman and Miller (1960) identified that the flow doing most bed-material transport over a period of years may be taken to represent the dominant or *channel forming* discharge. The peak in a histogram of bed-material load versus discharge developed using the principles of magnitude and frequency analysis defines the flow doing the most transport. Andrews (1980) termed this flow the *effective discharge*. The first step in the effective discharge calculation is to select a specific period of record and then divide the flows into a number of classes. Next, a sediment transport-discharge rating curve is developed. The total amount of sediment (bed material) transported by each flow class is then calculated. This is achieved by multiplying the frequency of occurrence of each flow class by the median sediment load for that flow class. A more detailed description of this methodology is described in the *Federal Interagency Stream Corridor Restoration Handbook* (Federal Interagency Stream Restoration Working Group (FISRWG) 1998) and by Biedenharn et al. (2001).

Effective discharge analysis was conducted at Tarbert Landing for various time periods to assess temporal trends in the effective discharge results. The time periods analyzed include 1955–1972, 1973–1992, 1992–2012, and 1973–2012. The sand regressions were combined with the flow-duration data to produce effective discharge curves for each time period.

3.6 Events Timeline

A chronology of the major river engineering, hydrologic, and anthropogenic events within the study reach was developed for the study time period. The chronology was largely based on the chronology reported by ERDC in the West Bay Sediment Diversion Effects report (Sharp et al. 2013). The West Bay report chronology was augmented with additional information on dike and revetment construction obtained from MVN. Information gleaned from this task was primarily used to add insight into the interpretation of the results from other analyses presented in this report.

3.7 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 reach. The results from each analysis are combined to establish the trends in river morphology and sedimentation from a historical perspective. In some cases, the trends indicated by the different techniques are in agreement. However, in many instances, the techniques may produce conflicting results. The techniques utilized in the geomorphic assessment (channel geometry comparisons, specific gage records, and sediment budgets) each have inherent uncertainty that can vary spatially and temporally. Consequently, the confidence placed on a specific technique may vary depending upon the reach in question or the time period being considered.

4 Results

4.1 Geometric Data Analysis Results

The geometric data analysis reveals that the lower Mississippi River is constantly changing in response to extreme hydrologic events and river-engineering activities. These changes can range from significant episodes of channel erosion and deposition to very subtle changes over time. It is evident that there is natural variability in the river system between survey time periods that does not represent a discernible long-term trend or change in river morphology. The geometric data analysis focused on identification of long-term changes in the system; however, morphological changes on a local scale can be investigated for site-specific areas with the maps and products developed in the analysis.

4.1.1 Comparative cross sections analysis

Comparative channel cross section plots for the various surveys at crossing and pool locations along the study reach were investigated to determine notable changes in channel depth, width, and shape. The comparative plots indicate areas of both stable and variable channel dimensions. Channel depth fluctuations of 10–15 ft were not uncommon between successive surveys, and identification of trends in geometry change was often difficult due to this natural variability of the channel. Appendix A displays the cross sections for the crossing locations.

The cross section plots for the crossing locations generally indicated more variability from survey to survey than the plots for the pool sections. Figures 25 and 26 present examples of this variability. Figure 25 shows the cross section plots at RM 319.3 above Head of Passes (AHP), located upstream of Old River Control Complex and near the upstream end of the study reach. Channel depths are shown to vary over an approximate 20 ft range with no discernible trend or pattern, but the general shape of the section is consistent. Figure 26 shows the cross section variation at RM 78.9 AHP, the crossing just upstream of English Turn. This plot indicates a shift in the channel thalweg location since the 1963 survey. Although the thalweg position has shifted, the thalweg has deepened such that the channel in 2004 is near the 1963 depth.

Figure 25. Comparative cross sections for the Mississippi River crossing at RM 319.3 above Head of Passes (AHP).

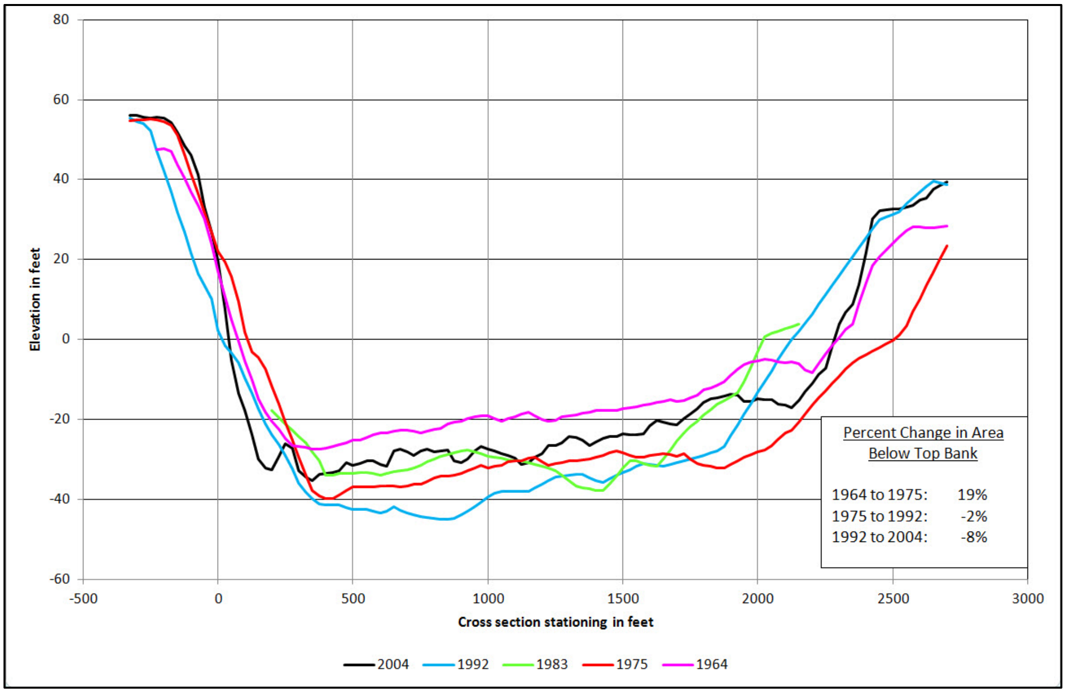
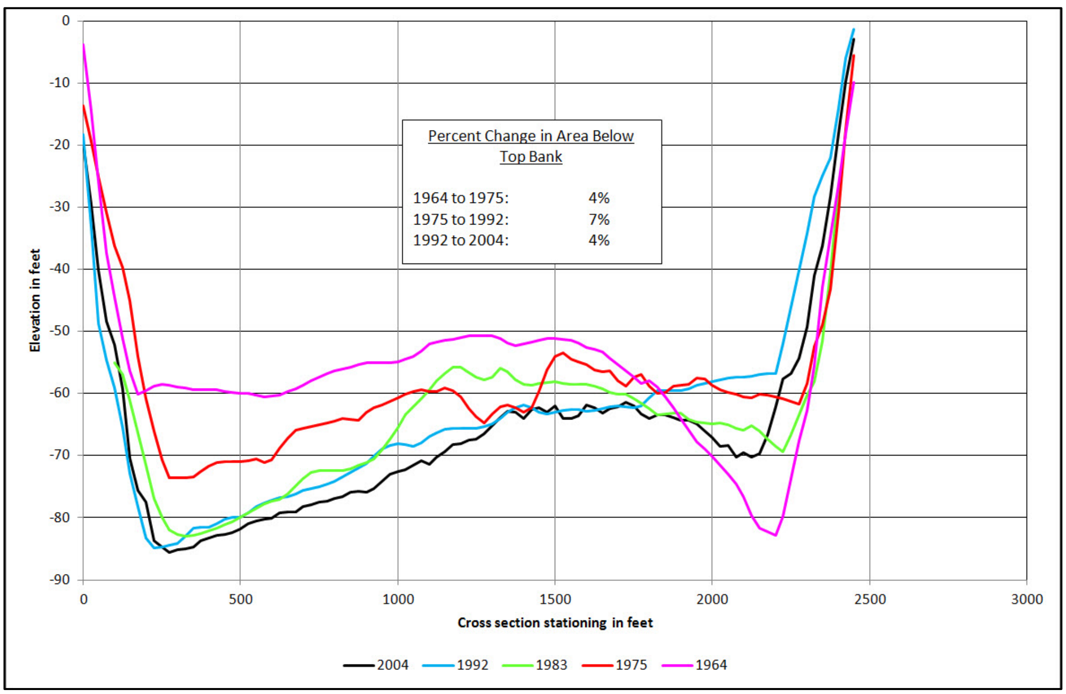


Figure 26. Comparative cross sections for the Mississippi River crossing at RM 78.9 AHP.



Figures 27 and 28 present examples of observed stability in the crossings geometry. Figure 27 presents the comparative cross sections for the crossing at RM 236.6 just upstream of Baton Rouge harbor. The cross sections indicate the channel bed fluctuates as much as 10 ft between successive surveys, yet the overall dimension and shape of the section are stable. The percent change in cross-sectional area below top bank elevation between surveys is no more than 2%. Figure 28 shows the comparative cross sections for the crossing at RM 126.7 just downstream of the Bonnet Carré floodway. The crossing at this location has shown little movement spatially over time, and the bed elevation and cross section shape are very stable over time. This location coincides with a study reported by Allison et al. (2013) of water and sediment surveys conducted in the vicinity of Bonnet Carré floodway during the Mississippi River record flood of 2011. Allison observed as much as 6 to 7 meters (m) of accretion downstream of the floodway as a result of floodway operation from early May to late June 2011. Subsequent bathymetric surveys conducted by Allison in 2012 as part of the Mississippi River Hydro study indicate that most of the accreted area has since been eroded. The comparative cross sections, along with Allison's findings, indicate that the river downstream of the floodway will remove material deposited during the relatively infrequent operation of the floodway and readjust to some stable, equilibrium state.

Situations were observed where a shift in the channel thalweg resulted in a different channel shape but with no appreciable change in cross section area. Figure 29 shows the comparative cross sections for RM 219.4 AHP at the Sardine Point crossing. The plot indicates that the channel thalweg shifted from the left descending bank in 1963 to the right descending bank in 1992. However, the percent change in cross-sectional area between successive surveys is minimal. Figure 30 shows the comparative contour maps for the area.

Since the comparative cross sections were extracted from the survey TINs at a set location, caution must be exercised when interpreting the changes in depth and shape. Shifts in crossing or pool location from survey to survey can give the illusion that significant changes in depth have occurred, but in reality the pool location has shifted slightly upstream or downstream. In cases such as this, the controlling elevation at the crossing may not have actually changed. Figure 31 shows an example of this. The comparative cross section plot for the crossing at RM 123.9 AHP seems to indicate deposition as much as 50 ft has occurred since 1975. However, inspection of the bed elevation change maps for this location reveals the pool shifted downstream after 1975, as shown in Figure 32. The apparent changes at this cross section reflect a shift in pool location rather than a change in the controlling elevation of the crossing.

Figure 27. Comparative cross sections for the Mississippi River crossing at RM 236.6 AHP.

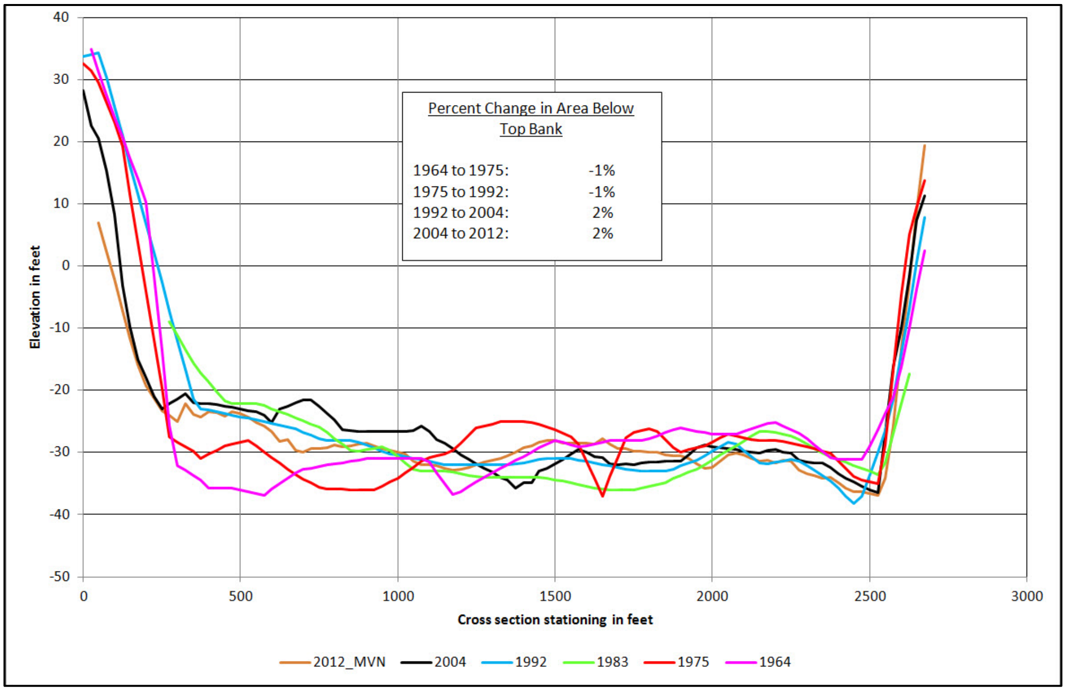


Figure 28. Comparative cross sections for the Mississippi River crossing at RM 126.7 AHP.

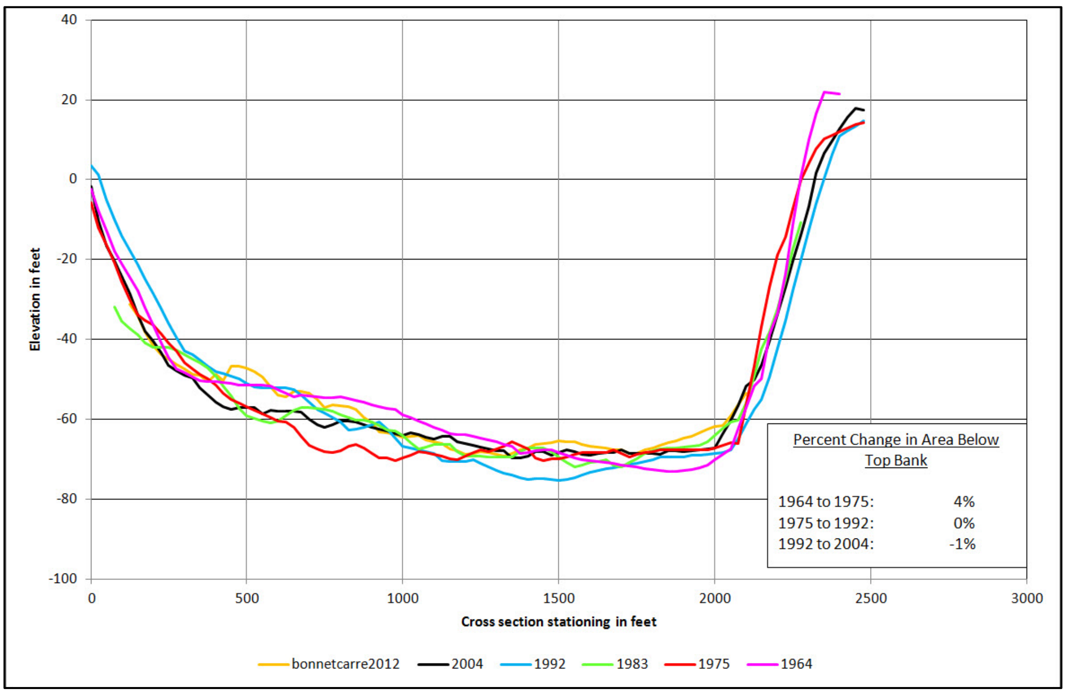
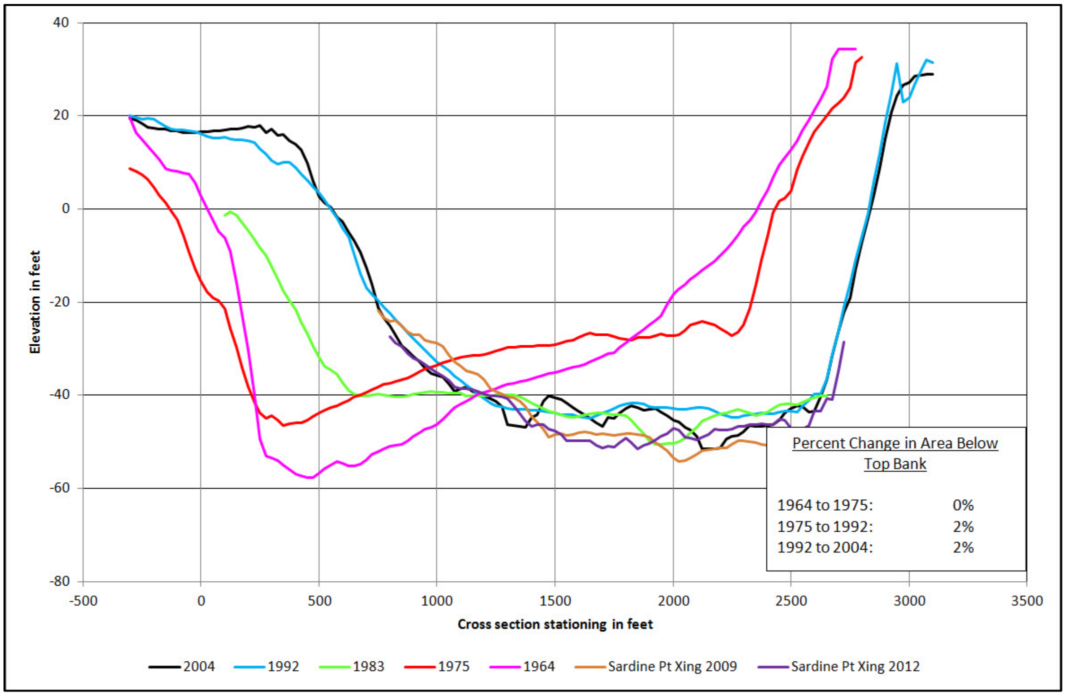


Figure 29. Shift in the Mississippi River channel thalweg with no appreciable change in cross-sectional area at RM 219.4 AHP.



Cross-sectional area below the top bank elevation was computed for each crossing section. The percent change from survey to survey was computed and is listed in Table 12. The 1983 survey was not used for these computations because the limited spatial coverage of the survey did not provide a full section up to top bank elevation. The percent change in cross section area from the 1963–1975 surveys in excess of 15% indicates an erosion of the channel (positive percent change) for the sections upstream of the ORCC low sill structure entrance channel. This change was also noted in the bed-change maps for this time period. This is due to the drawdown effect from the low sill structure being placed in operation in 1963, as well as the increased outflow during the 1973 flood due to structural damage. This will be addressed in more detail later in the report as part of the ORCC detailed analysis. Percent changes for the reach between ORCC and Baton Rouge indicate a pattern of deposition (negative percent change) to no change. The greatest change indicating excessive deposition occurred for the cross section at RM 224.0 AHP located at Redeye Crossing, which has historically been the most problematic crossing in terms of required maintenance dredging for navigation. The percent changes for the reach downstream of Donaldsonville, Louisiana, near RM 175.0 AHP to Head of Passes indicate predominantly erosion (positive percent change) throughout the reach. A possible explanation for this response is that the period of the late 1950s to

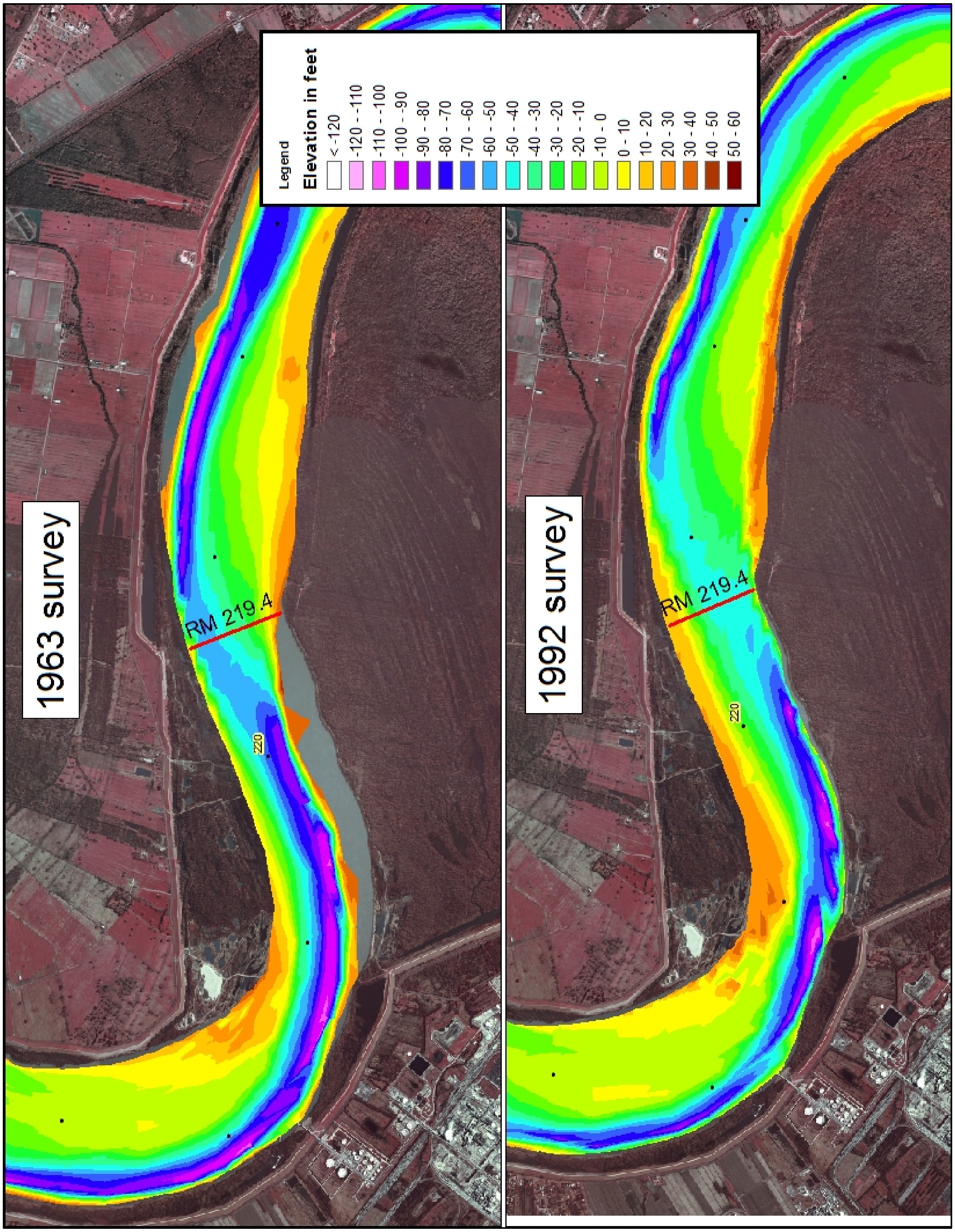
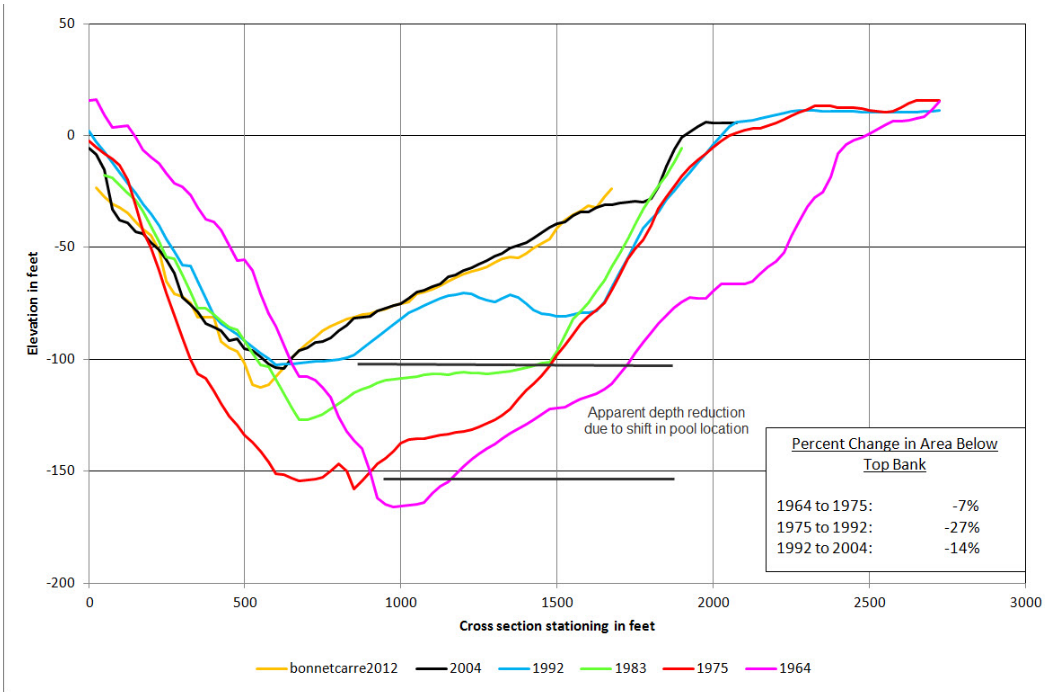


Figure 30. Shift in the Mississippi River thalweg location at Sardine Point, RM 219.4 AHP.

Figure 31. Example of false indication of deposition in the Mississippi River due to a shift in pool location at RM 123.9 AHP.



the early 1970s was characterized by relatively low-to-moderate hydrologic extremes, with no major flood events occurring during that time. During this time, this reach of the river may have adjusted to a lower hydrologic regime where some of the crossings and pools were filled with sediment. The major floods of 1973 and 1975 were of such magnitude that this reach of the river was significantly altered through channel enlargement. Additionally, anecdotal information suggests that coarse bed material was dredged from this reach of river and used as fill material for construction of nearby Interstate 10 during the 1960s and 1970s. Regardless of the cause, this reach experienced a fairly uniform enlargement of the channel during the time period.

Percent changes in cross-sectional area from the 1975–1992 surveys for the crossing sections at RM 315.6 and 313.2 AHP indicate a potential response due to the opening of the auxiliary structure at ORCC. The percent change of 15% for section at RM 313.2 AHP indicates erosion of the channel that may be due to drawdown at the auxiliary structure after operation began in 1986. However, the section at RM 315.6 AHP upstream of the low sill structure shows a deposition trend that may have resulted from less frequent operation of the low sill structure. The percent changes for the remainder of the reach downstream of ORCC to Baton Rouge

Figure 32. Shift in pool location between surveys can give false indication of depth change.

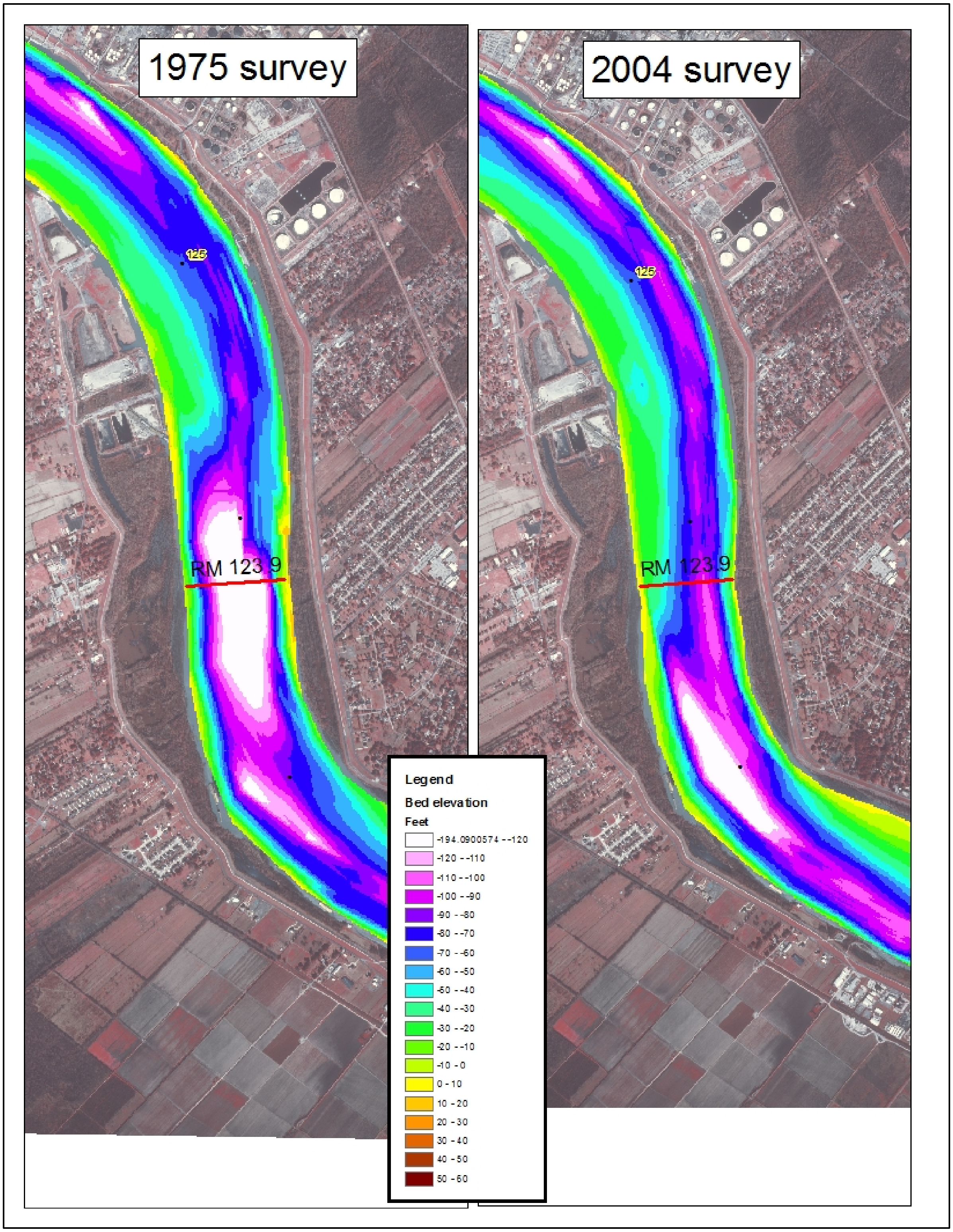


Table 12. Percent change in cross-sectional area for Mississippi River crossing sections.

RM of Crossing Section	Percent Change in Cross-Sectional Area below Top Bank Elevation			
	1963–1975	1975–1992	1992–2004	2004–2012
319.3	19.2%	–1.9%	–8.1%	
315.6	22.5%	–16.7%	–16.3%	–3.2%
313.2	–2.3%	15.0%	–11.9%	0.2%
306.8	–7.4%	3.7%	–0.1%	0.2%
294.4	–1.0%	–0.8%	–7.4%	0.0%
286.9	–8.6%	–4.7%	4.8%	
284.4	–0.3%	4.4%	–0.4%	–1.5%
281.2	–2.3%	3.6%	–2.9%	–15.5%
273.0	–12.7%	0.1%	4.1%	–3.6%
267.0	0.5%	4.0%	–0.6%	–4.5%
260.2	1.7%	3.9%	2.1%	2.2%
255.3	–10.5%	1.8%	17.3%	–7.2%
250.8	–13.9%	0.1%	5.8%	
241.5	–2.2%	–1.6%	0.9%	–3.1%
236.6	–0.7%	–1.1%	1.6%	2.4%
232.0	3.2%	0.6%	–1.1%	
224.0	–16.0%	10.7%	–0.7%	
219.4	–0.1%	1.6%	1.5%	
212.1	–11.7%	16.7%	–2.8%	
204.1	–5.5%	5.1%	–4.3%	
197.8	–2.4%	3.1%	–2.5%	
190.4	–0.4%	4.9%	–2.6%	
183.2	0.5%	3.0%	–2.8%	
175.3	1.8%	4.0%	–6.4%	
167.3	7.6%	5.3%	–4.7%	
159.2	6.8%	5.4%	–2.2%	
153.1	14.3%	–1.5%	–2.1%	
146.9	12.9%	2.7%	–3.9%	
139.8	0.9%	6.5%	–3.8%	
134.4	6.5%	–6.4%	–1.6%	
131.2	2.1%	–1.9%	–4.3%	

RM of Crossing Section	Percent Change in Cross-Sectional Area below Top Bank Elevation			
	1963–1975	1975–1992	1992–2004	2004–2012
126.7	3.6%	0.3%	–0.6%	
123.9	–6.6%	–27.0%	–14.1%	
115.7	10.2%	5.8%	–0.2%	
109.7	6.3%	–5.8%	–1.7%	
105.4	–4.1%	–3.9%	2.6%	
102.1	9.3%	–2.1%	–0.2%	
90.0	7.2%	–0.4%	5.3%	
86.3	12.3%	–5.2%	0.3%	
78.9	4.1%	6.6%	4.2%	
75.4	8.3%	2.6%	0.5%	
71.3	15.0%	2.1%	–1.1%	
65.6	8.7%	6.6%	–1.5%	2.5%
61.6	12.6%	–4.8%	4.6%	0.2%
56.2	3.0%	8.4%	–0.9%	
49.0	8.2%	4.7%	–0.3%	
39.9	4.8%	5.0%	0.6%	
31.4	14.4%	–2.3%	–0.3%	
24.5	7.4%	–3.5%	1.7%	
12.6	8.6%	5.3%	–4.2%	0.6%
10.1	2.0%	5.6%	–7.1%	–5.6%
7.0	11.3%	–9.2%	–7.1%	–3.3%
4.3	12.5%	–9.3%	–9.2%	–8.8%
2.0	8.6%	–6.4%	–10.8%	–4.0%

Legend for percent change in cross-sectional area. Positive change indicates erosion; negative change indicates deposition.

Purple	Greater than 15%
Blue	10% to 15%
Green	5% to 10%
White	5% to –5%
Yellow	–5% to –10%
Orange	–10% to –15%
Red	Greater than –15%

indicate little change. Downstream of Baton Rouge, the percent changes indicate slight channel enlargement to no change. Exceptions to this were noted at RM 224.0 and 212.1 AHP, the locations of Redeye Crossing and Medora Crossing, respectively, where channel enlargement was greater than other places in the reach. An additional exception occurs at RM 123.9 AHP where the excessive decrease in cross section was caused by a shift in the pool location between the surveys that gives a false indication of significant deposition. The percent change observed for the sections at RM 7.0, 4.3, and 2.0 AHP indicates a pattern of deposition downstream of Venice, Louisiana, that was similarly identified by Sharp et al (2013) as part of the West Bay Sediment Diversion Effects study. Channel geometry analysis in that study indicated a deposition trend for the Mississippi River downstream of Venice that began in the late 1970s to early 1980s.

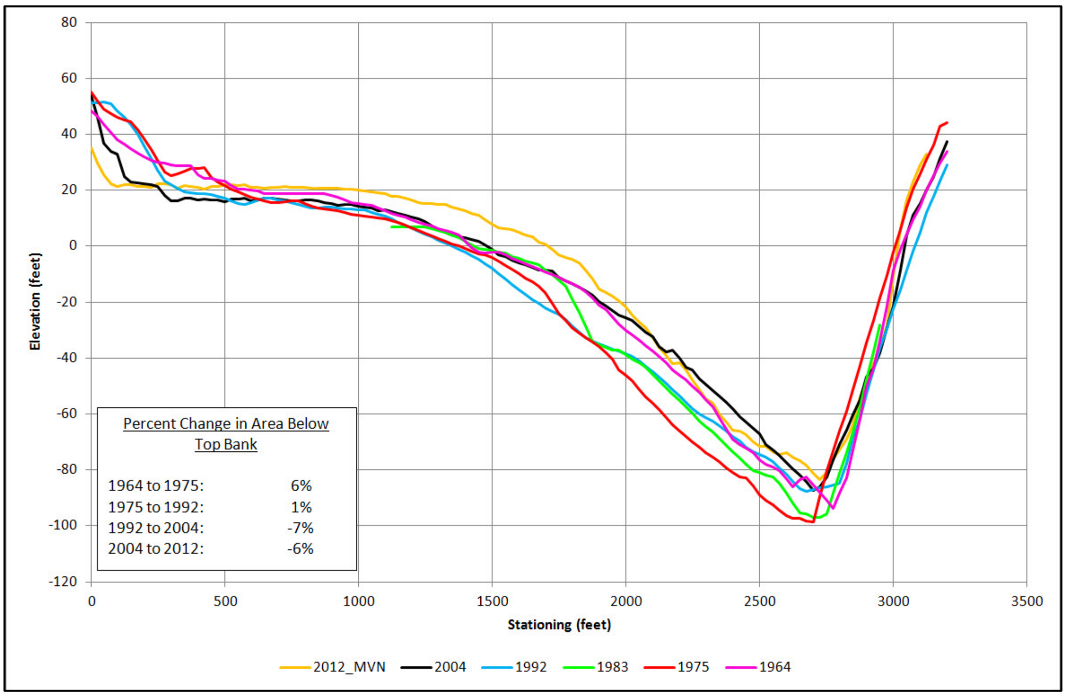
The percent changes in cross-sectional area from the 1992–2004 surveys indicate a continued deposition trend in two locations, in the vicinity of ORCC and downstream of Venice. The reductions in area for the sections at RM 319.3, 315.5, and 313.2 AHP suggest deposition that is most likely attributable to initiation of hydropower operation at ORCC in 1990. Little et al. (2012) reported that the hydropower channel is the least efficient of all the ORCC structures at diverting sand from the Mississippi River. The sediment diversion characteristics of the hydropower facility result in deposition in the Mississippi River immediately downstream of the hydropower channel. In the vicinity of Venice and downstream, the deposition trend continued at rates similar to those observed from the 1975–1992 surveys. For the remainder of the study, reach percent changes in cross-sectional area were minimal.

Percent changes in cross-sectional area from the 2004–2012 surveys are not available for the entire study reach due to the limited coverage of the 2012 surveys. Where sufficient survey coverage does exist, the percent changes in area generally indicate little-to-no change in the vicinity of ORCC and continued deposition near Venice, but at a somewhat lesser rate.

Comparative cross sections for the pool locations within the study reach indicate depths in the pools can fluctuate by 10–20 ft between surveys, but the general dimension and shape of the sections is fairly consistent. Since the pool sections are usually located in a bend of the river, evidence of lateral shift prior to construction of revetments can often be observed. In general, channel dimension at the pool sections was more consistent than observed for the crossing sections. This seems likely, given that erosion and deposition are much more active in the crossings than in the pools. Appendix A shows the comparative cross sections for the pool locations. Examples of the observed channel dimension changes for the pool sections are presented in the following paragraphs.

The comparative cross sections for the pool section at RM 318.0 AHP are shown in Figure 33. This section is located at the most upstream extent of the study reach upstream of ORCC. The dimension of the section is typical of pool locations in a meandering fluvial system. Deposition on the point bar side along with a slight decrease in channel depth is observed from 1975 to 2012, and the percent change in cross-sectional area between surveys indicates a fluctuation within ± 7%.

Figure 33. Comparative cross sections for pool located at RM 318.0 AHP.



The cross section plot for the pool section at RM 309.9 AHP shown in Figure 34 illustrates the lateral changes that have occurred in some locations within the study area. This section is located downstream of the auxiliary structure channel and is in an area where the channel has shifted towards the left descending bank, and the opposite point bar has inflated due to sediment deposition. The magnitude of the lateral shift is approximately 400–500 ft, but channel depths have not significantly increased or decreased beyond normal levels of fluctuation. The Ft. Adams revetment is located in this reach and has stabilized the river against further lateral shift. Additional detailed analysis in the vicinity of ORCC will be presented later in the report.

Figure 34. Comparative cross sections for pool located at RM 309.9 AHP.

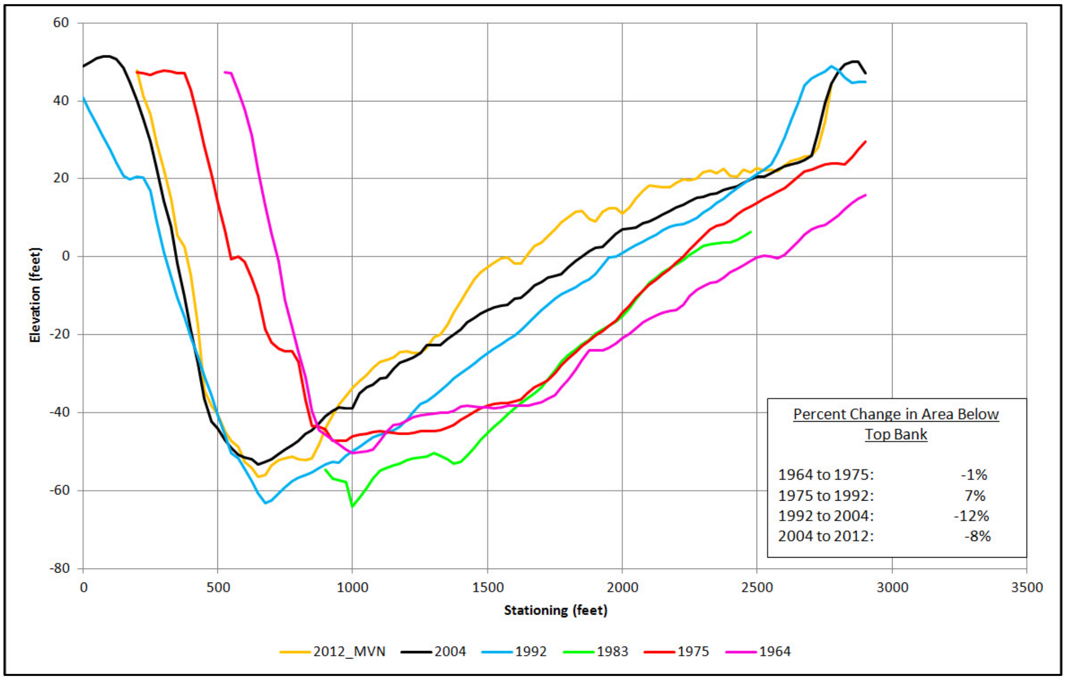


Figure 35 shows the comparative cross sections for the pool section at RM 269.9 AHP just downstream of St. Maurice Towhead and in the vicinity of Red Store Landing revetment. The sections indicate a slight decrease in channel depths from 1963 to 2004 and some deposition along the opposite point bar, but percent changes in cross-sectional area below top bank are minor. The position of the pool at this location has been very stable over the time range of all surveys. This is an example of slight variability in channel dimension that occurs over time.

An example of the variability observed in the channel dimension is shown in Figure 36 for the pool section at RM 239.8 AHP. This pool is located in a very tight bend in the river upstream of Baton Rouge harbor and in the vicinity of the Allendale Bend revetment. The channel depth at this location has fluctuated as much as 25–30 ft over the survey period, and some lateral shift occurred until the 1983 timeframe when the revetment stabilized the location. Also notable is the deflation of the opposite point bar that occurred subsequent to the 1992 survey, which resulted in an approximately 16% increase in cross-sectional area below top bank elevation. However, no definitive trends in channel dimension change are identified.

Figure 35. Comparative cross sections for pool located at RM 269.9 AHP.

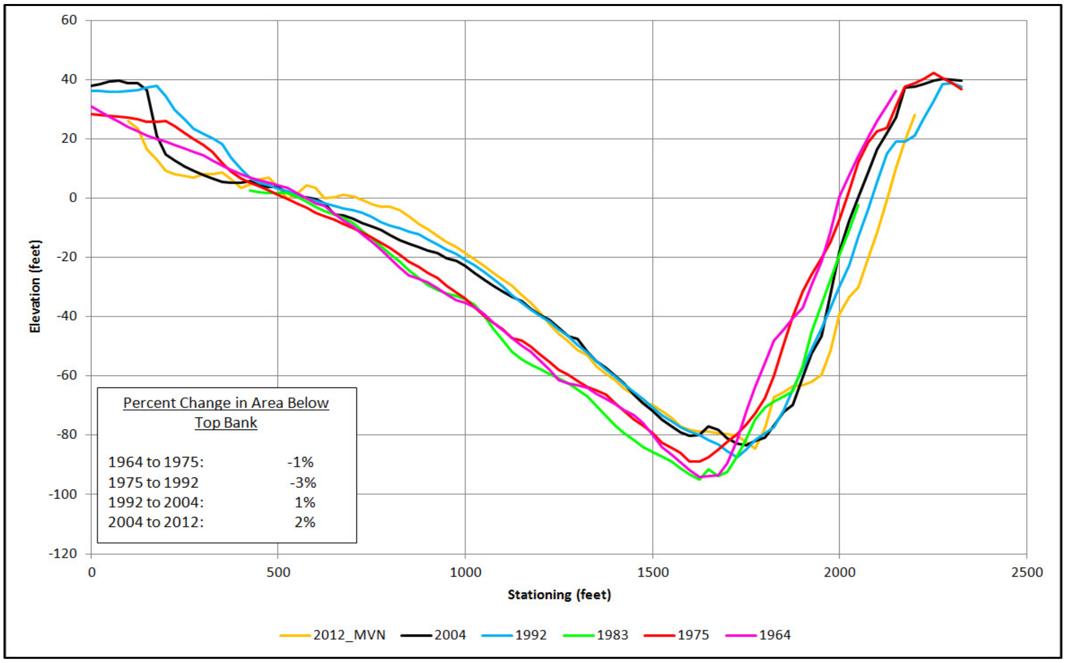
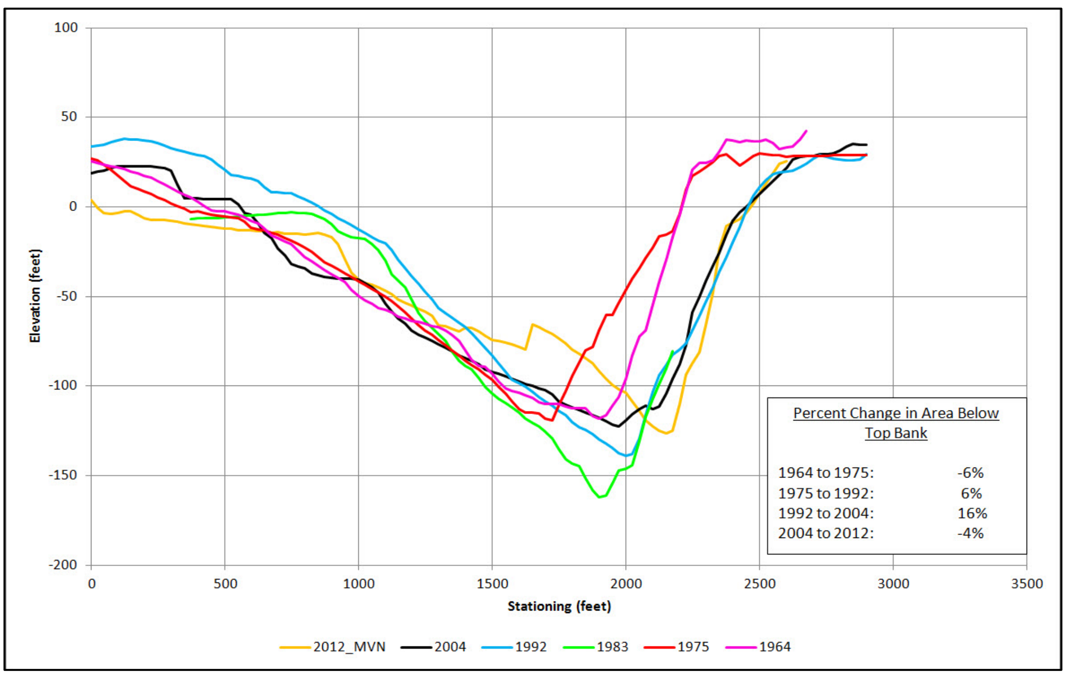
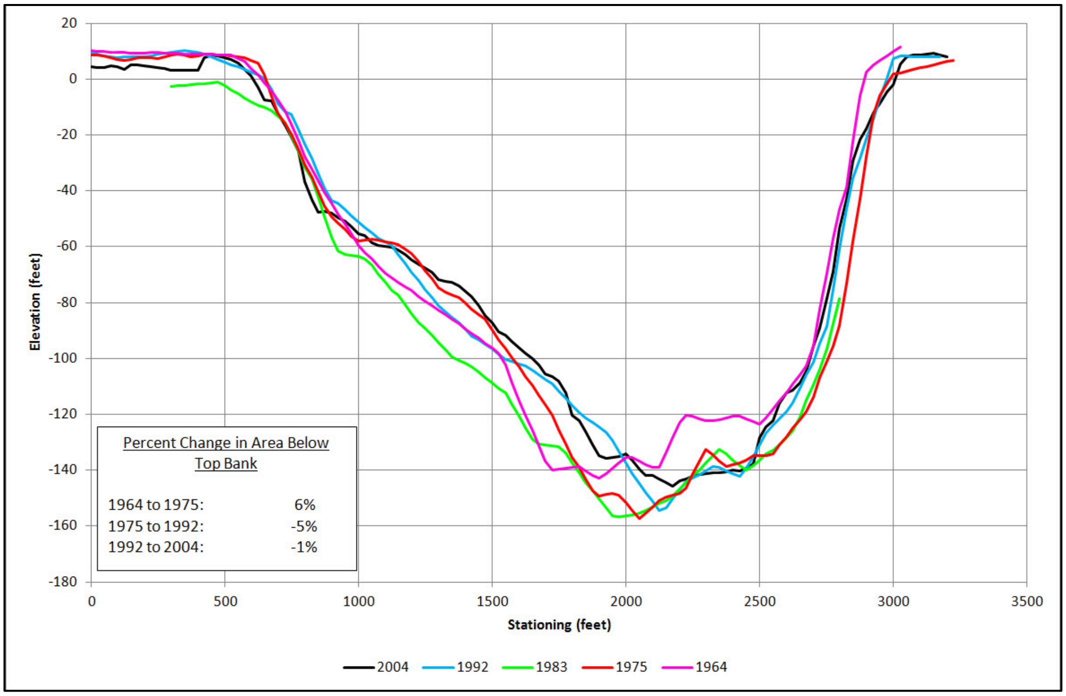


Figure 36. Comparative cross sections for pool located at RM 239.8 AHP.



The comparative cross section plot for the pool section at RM 77.8 AHP at English Turn is shown in Figure 37. The location is in a tight bend in the river where the pool position has been very stable over the survey periods. Channel depths have fluctuated between the surveys, but in general, the overall dimension of the cross section has remained stable.

Figure 37. Comparative cross sections for pool located at RM 77.8 AHP



The percent change in cross-sectional area below top bank elevation for all pool sections was computed and is listed in Table 13. In terms of generalized trends, the percent changes in area between the 1963 and 1975 surveys suggest erosion of the channel downstream from approximately RM 200 AHP. This is similar to the trend observed in the crossing sections. Change in cross-sectional area observed between the 1975 and 1992 surveys does not suggest any particular trend or pattern. Significant change in the form of random erosion and deposition can be seen for the pool at RM 234.8 AHP. This pool is located in the extremely tight bend at Wilkerson Point just upstream of Baton Rouge. Area change between successive surveys is of the greatest magnitude observed at any section, but there is no discernible pattern or trend. This random change suggests the pool temporarily stores sediment that can be flushed during times of high discharge. The area change from the 1992 survey to the 2004 survey indicates a general depositional trend throughout the study reach.

In addition to the comparative cross section geometry analysis, the cross section data were used to construct profiles of the channel invert and the hydraulic conveyance for the study reach. A representative channel invert elevation was determined for each crossing and pool section by computing the minimum average bed elevation over a given 500 ft width of channel. The minimum average elevations were plotted longitudinally to create the

Table 13. Percent change in cross-sectional area for Mississippi River pool sections.

RM of Pool Section	Percent Change in Cross-Sectional Area below Top Bank Elevation			
	1963–1975	1975–1992	1992–2004	2004–2012
318.0	6.3%	1.2%	–7.2%	–6.4%
309.9	–1.4%	7.3%	–11.7%	–8.0%
289.0	–10.3%	5.6%	–6.4%	1.7%
278.9	3.2%	–4.0%		
269.9	–0.5%	–3.0%	0.7%	2.3%
239.8	–5.6%	6.6%	16.2%	–3.5%
234.8	34.0%	–24.2%	–9.7%	16.0%
222.0	–1.9%	–0.9%	–1.1%	
209.0	10.5%	–13.6%	6.0%	
193.5	11.7%	–6.2%	–7.9%	
186.0	6.9%	–1.3%	–2.6%	
178.2	15.8%	1.4%	–1.4%	
170.6	7.1%	–3.9%	–8.3%	
161.5	4.8%	–9.8%	3.3%	
156.2	4.0%	0.9%	–5.6%	
144.6	–1.1%	7.2%	–3.9%	
130.0	3.4%	1.4%	–1.5%	
118.0	–12.2%	12.5%	–5.1%	
109.0	–0.5%	–3.0%	–1.2%	
104.0	19.8%	–8.2%	0.1%	
101.3	7.6%	–3.7%	1.3%	
94.3	2.3%	3.2%	–3.8%	
81.6	3.1%	2.3%	2.2%	
77.8	6.5%	–4.8%	–0.7%	
68.2	6.0%	–3.7%	–1.8%	
59.2	11.8%	3.1%	–9.9%	
43.8	–0.9%	–11.3%	–6.5%	
37.3	–4.9%	12.4%	5.3%	
33.0	3.8%	3.1%	–1.9%	
21.6	10.3%	–4.0%	–6.3%	–2.4%

RM of Pool Section	Percent Change in Cross-Sectional Area below Top Bank Elevation			
	1963–1975	1975–1992	1992–2004	2004–2012
Legend for percent change in cross-sectional area. Positive change indicates erosion; negative change indicates deposition.				
(purple)	Greater than 15%			
(blue)	10% to 15%			
(green)	5% to 10%			
(white)	5% to –5%			
(yellow)	–5% to –10%			
(orange)	–10% to –15%			
(red)	Greater than –15%			

channel invert profile. Figure 38 presents the plot of the representative channel invert for the crossing sections. The profile of the low-water survey conducted by ERDC in 2012 is also shown in the plot. The large, downward spike in the invert profile is caused by the sections at RM 123.9 AHP for the 1963 and 1975 surveys where a shift in the location of the adjacent pool resulted in lower elevations. Although there is variability in the data, the profile indicates that the slope of the river has been consistent over the time range of the surveys. The slope of the river is fairly uniform downstream of ORCC to approximately the location of Belle Chasse. From that point, the slope of the river flattens to approximately RM 35. At this point, there is a distinct change in gradient, and the invert profile assumes an adverse slope of approximately 1 ft per mile downstream to Head of Passes at RM 0 (zero). The point of beginning of the adverse slope generally coincides with the location where the flood control levee along the left descending bank ends, and loss of discharge from the Mississippi River through crevasses and distributaries increases. This break point in gradient may also represent the location where the river approaches a threshold level of minimum energy for sediment transport.

Average invert profiles for both the crossing sections and the pool sections for all surveys are presented in Figure 39. The plot illustrates the relationship in depth between the crossing and the pools within the study reach. The difference in depth between the crossings and pools is as much as 50 ft. This indicates that the crossings provide the principal control on the slope of the river and that the pools have ample sediment storage capacity.

Figure 38. Mississippi River profiles of representative channel invert.

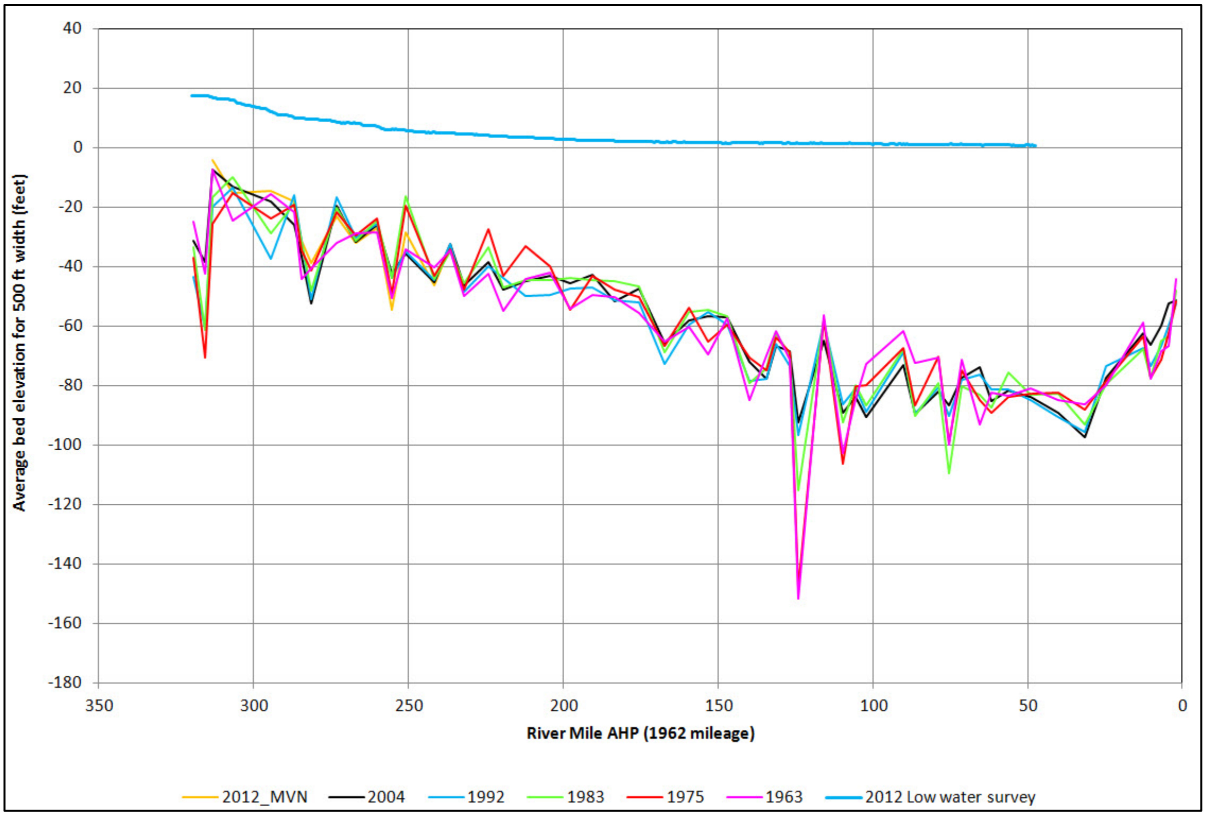
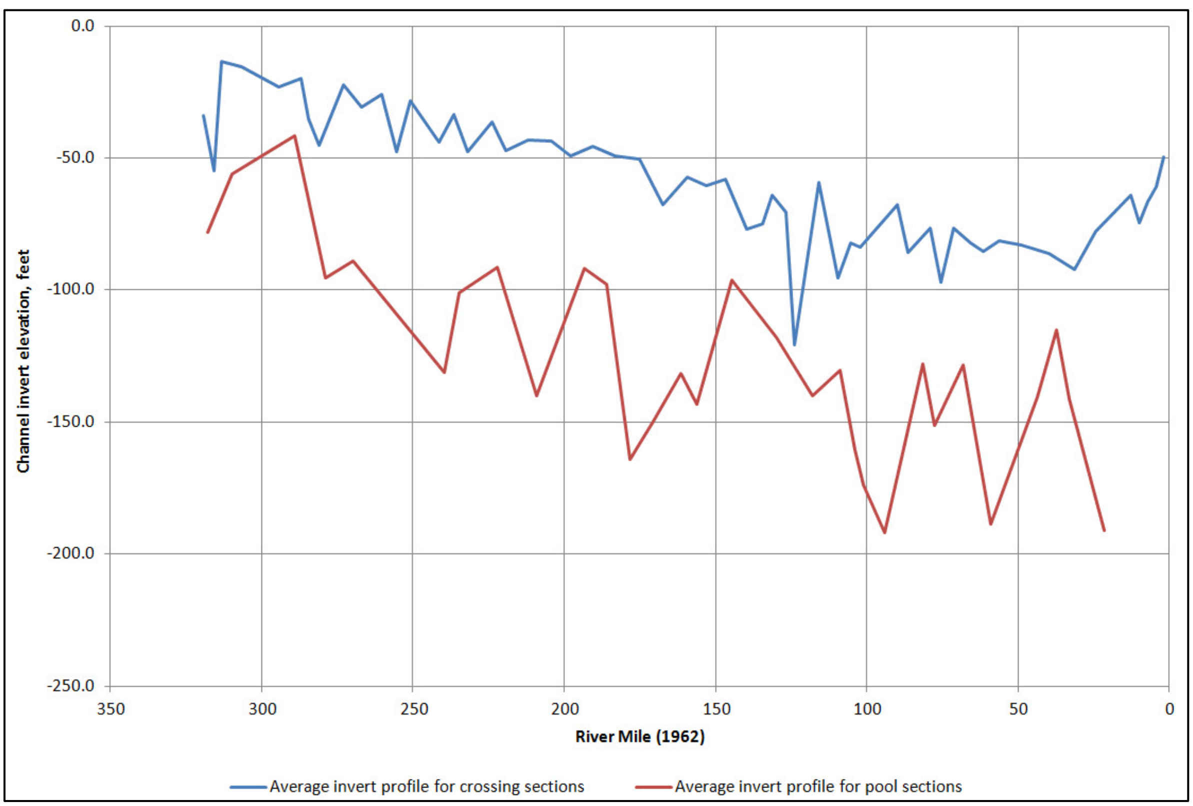
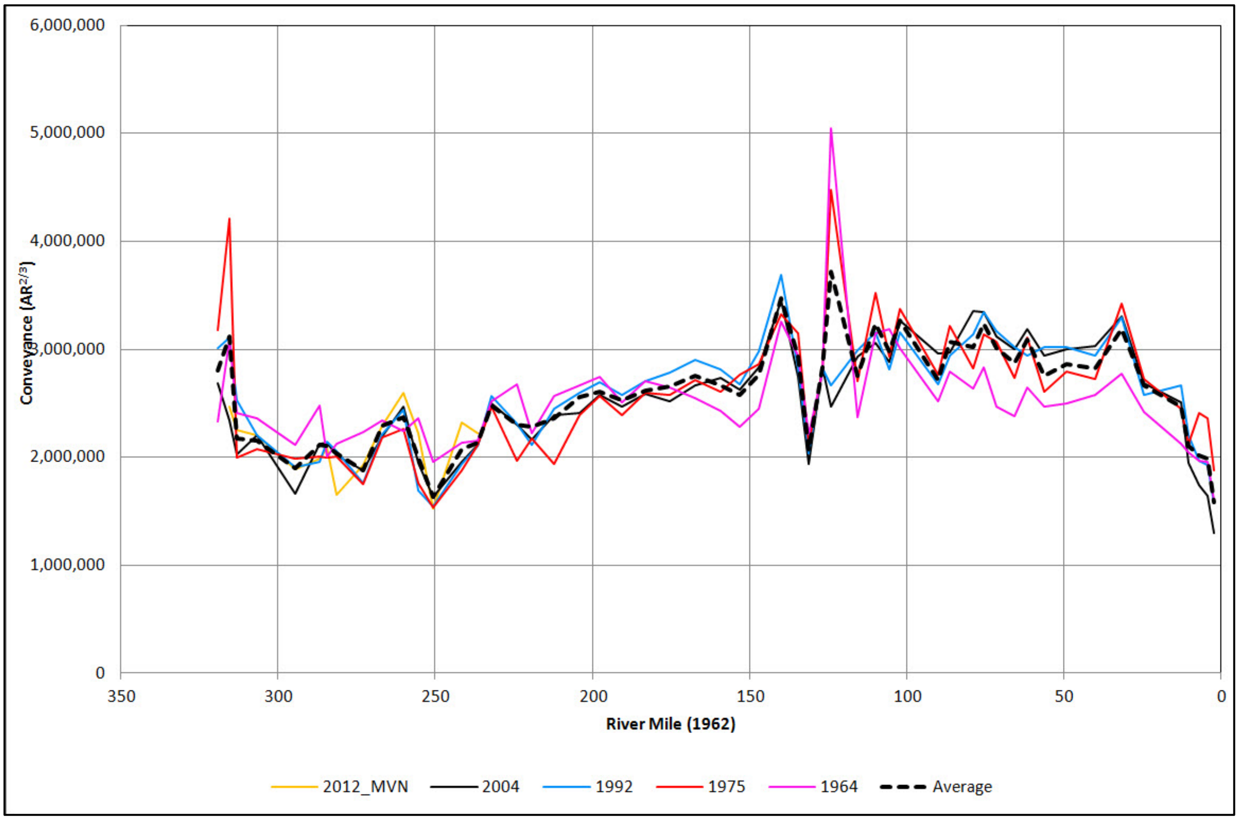


Figure 39. Mississippi River profiles of average channel invert for crossing and pool sections.



The conveyance at top bank elevation for the crossing sections was computed for all surveys. Conveyance was computed as $AR^{2/3}$, where A is the cross-sectional area, and R is the hydraulic radius. The conveyance gives an indication of the hydraulic efficiency of the channel. Figure 40 presents the conveyance for the crossing sections along the study. The plot indicates that the highest hydraulic conveyance of the channel is located from approximately RM 140 to 35 AHP.

Figure 40. Mississippi River profiles of hydraulic conveyance for crossing sections.



4.1.2 Volumetric analysis

The cross section data analysis provides information on the channel geometry at a given location. Natural variability in the river system, such as the passage of dunes during floods, can result in significant fluctuation in the channel bed at a given location. The degree of fluctuation in the channel bed also varies longitudinally along the channel. Volume computations for the channel over a reach will capture average changes that are more representative of reach conditions than single cross sections.

Volume below top bank elevation for the polygons described in Section 3.2 was computed for each hydrographic survey. The exception is the 1983–

1985 survey, which did not have sufficient spatial coverage to the top bank of the channel. The difference between successive surveys indicates the volume of erosion or deposition for the time period. The volumes were divided by the lengths of the polygons in river miles and by the time period between surveys in years to provide average annual values by mile. Table 14 presents the tabulated results.

Graphs of the average annual erosion/deposition volumes per river mile for each survey period are presented in Figures 41–44. The graph for the period 1963–1975 shown in Figure 41 indicates a general trend of channel erosion from approximately RM 210 AHP to the downstream end of the study reach. Upstream of RM 210 AHP there is a trend of deposition, with the exception of the polygon from RM 320 to 316.4 AHP. This polygon is located upstream of the entrance channel for the low sill structure at ORCC, and the volume change indicates significant erosion that occurred after the structure began operation. The results for the survey period 1975–1992 shown in Figure 42 indicate no discernible overall pattern of erosion or deposition for the study reach. However, the observed changes for the polygons from ORCC to Bayou Sara (RM 320–256 AHP) are opposite of those observed from 1963 to 1975, which may indicate adjustment of the river back toward an equilibrium condition. The trend from Bayou Sara to near Bonnet Carré floodway (RM 126 AHP) is primarily deposition while the trend from Bonnet Carré downstream is primarily erosion. The results for the survey period 1992–2004 shown in Figure 43 indicate a predominance of deposition for the entire study reach. The largest magnitude of deposition occurs for the polygons from RM 320 to 306 AHP in the vicinity of ORCC. The deposition is believed to be a result of the initiation of hydropower operation at ORCC. The results for the survey period 2004–2012 shown in Figure 44 are limited due to the incomplete coverage of the 2012 survey. However, the available data indicate a continuation of the deposition downstream of ORCC and suggest that the deposition zone may be shifting farther downstream.

The computed erosion and deposition volumes were also evaluated as an average annual bed displacement for each polygon. The average annual bed displacement was computed by dividing the volume change between surveys by the surface area for each polygon and the years between surveys. This method results in a uniform annual bed displacement over the entire polygon area. Although the bed displacement will likely never be uniform over the entire river channel, it is indicative of the general trends of erosion

Table 14. Average annual volume of erosion/deposition per river mile.

Polygon Range by RM	Average Annual Volume of Erosion/Deposition per River Mile (cubic yard/mile/year (cy/mile/yr))			
	1963–1975	1975–1992	1992–2004	2004–2012
320–316.4	–437,000	101,000	228,000	
316.4–306.3	161,000	–74,000	279,000	–70,000
306.3–296	7,000	–28,000	–15,000	404,000
296–286	250,000	–36,000	38,000	127,000
286–275	39,000	–62,000	43,000	76,000
275–266	82,000	16,000	–8,000	–19,000
266–256	–10,000	–21,000	35,000	–96,000
256–245	112,000	132,000	–118,000	159,000
245–235	46,000	114,000	–23,000	42,000
235–223	71,000	–42,000	60,000	
223–212	34,000	30,000	51,000	
212–202	–19,000	22,000	62,000	
202–190	–76,000	68,000	115,000	
190–180	–32,000	–26,000	123,000	
180–169	–87,000	48,000	141,000	
169–159	–181,000	8,000	112,000	
159–148	–147,000	74,000	85,000	
148–138	–114,000	4,000	108,000	
138–129	–13,000	–5,000	53,000	
129–123	–10,000	103,000	24,000	
123–113	–71,000	–72,000	20,000	
113–102	–103,000	0	5,000	
102–92	–67,000	–18,000	–20,000	
92–83	–219,000	–31,000	–46,000	
83–76	–149,000	–35,000	–13,000	
76–66	–177,000	–42,000	77,000	
66–57	–143,000	34,000	37,000	
57–44	–112,000	–66,000	25,000	
44–35	–51,000	–62,000	13,000	
35–29	–142,000	–60,000	65,000	
29–18	–198,000	26,000	100,000	
18–12	–280,000	–31,000	80,000	
12–4	–127,000	42,000	170,000	

Figure 41. Mississippi River average annual erosion/deposition volume per RM, 1963–1975.

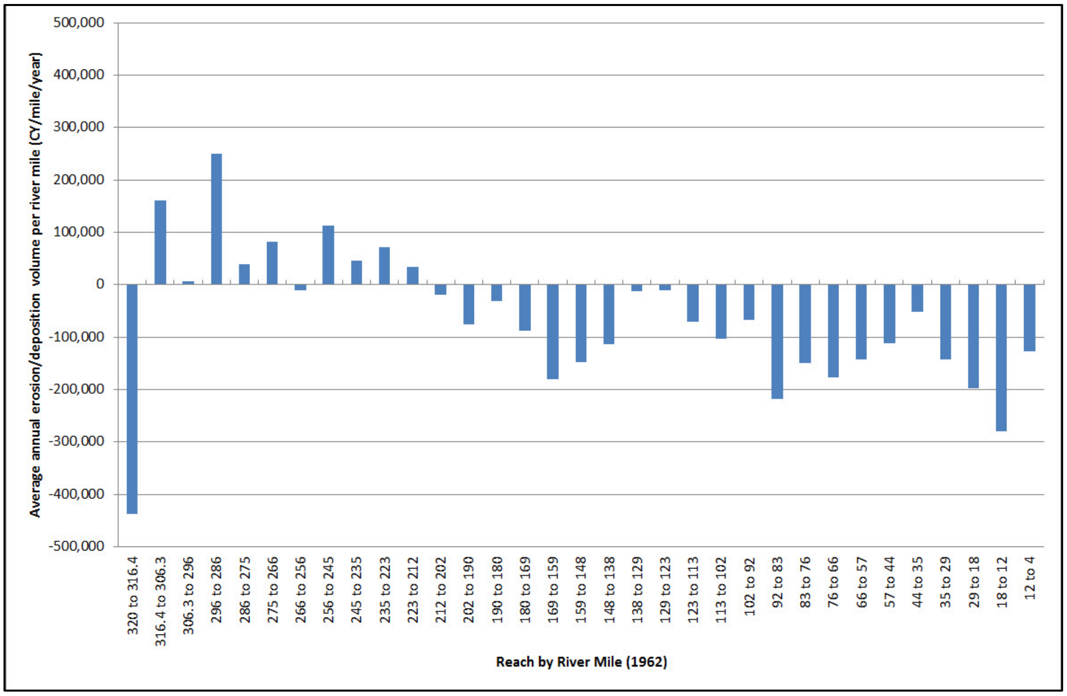


Figure 42. Mississippi River average annual erosion/deposition volume per RM, 1975–1992.

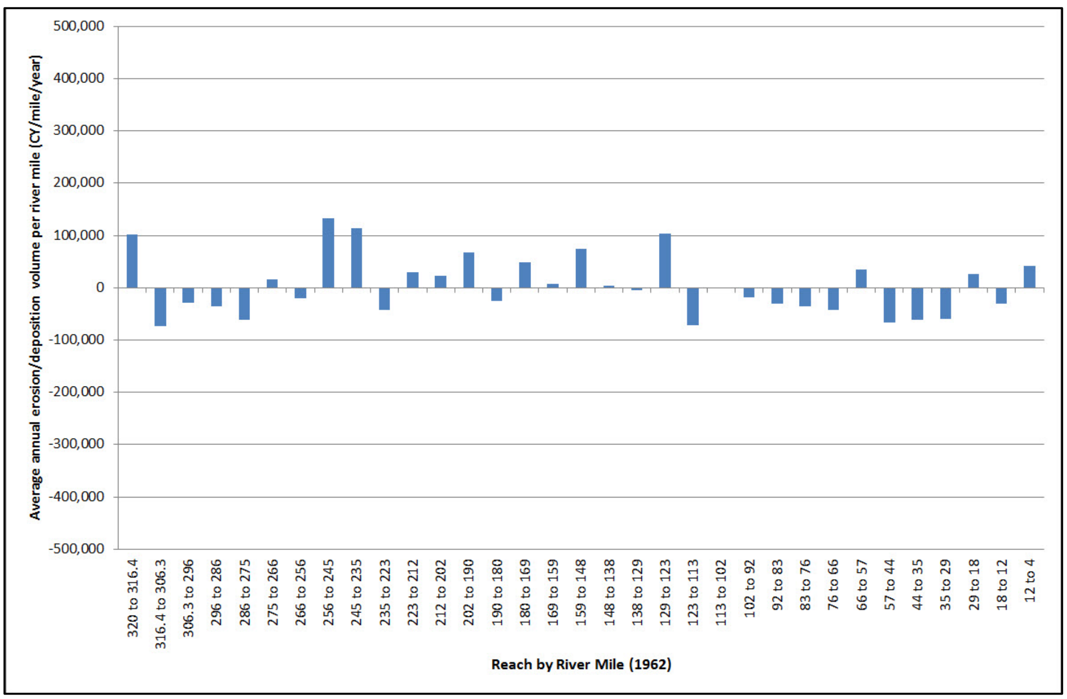


Figure 43. Mississippi River average annual erosion/deposition volume per RM, 1992–2004.

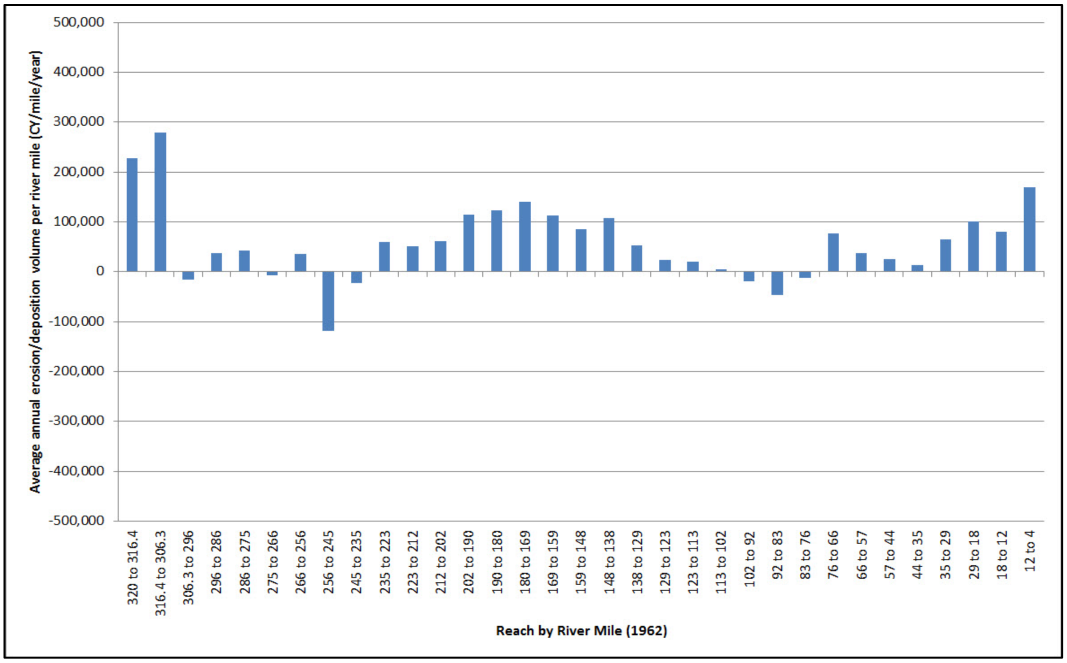
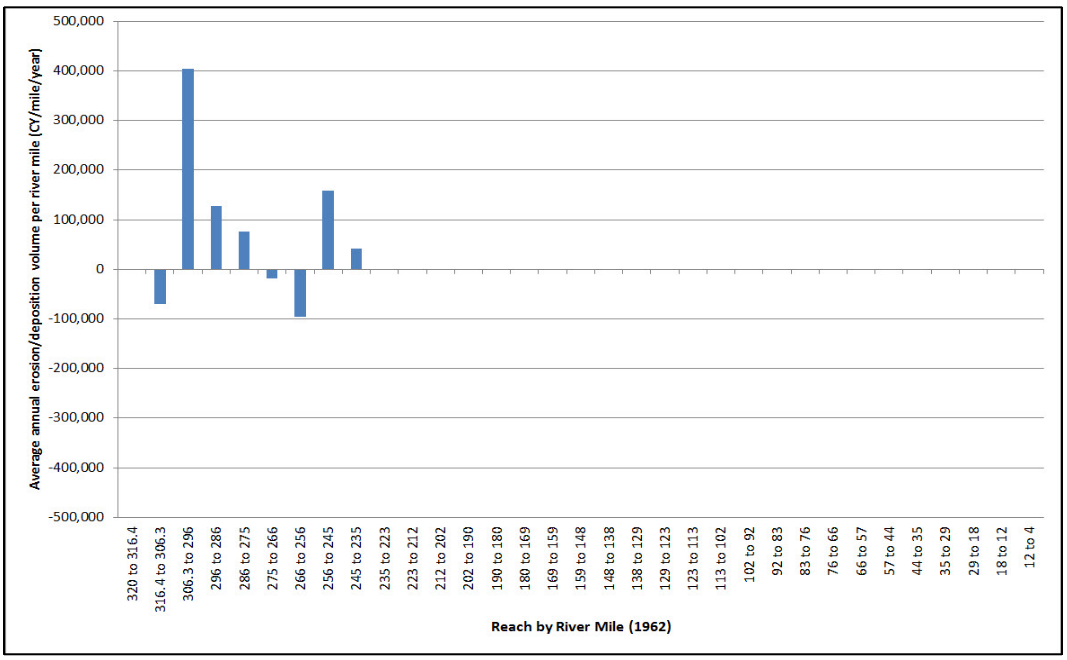


Figure 44. Mississippi River average annual erosion/deposition volume per RM, 2004–2012.



and deposition over the time period and gives some sense of the relative magnitudes of erosion and deposition. The computed average annual bed displacement for all polygons is listed in Table 15 and Figures 45–48. The trends are basically identical to those observed in the erosion/deposition volume data. The average annual bed displacements range from a maximum erosion of –0.82 ft/yr to a maximum deposition of 0.55 ft/yr.

Table 15. Computed average annual bed displacement by polygon reach.

Polygon range by RM	Computed Average Annual Bed Displacement by Polygon (ft/yr)			
	1963–1975	1975–1992	1992–2004	2004–2012
320–316.4	–0.82	0.20	0.44	
316.4–306.3	0.31	–0.15	0.55	–0.14
306.3–296	0.01	–0.03	–0.02	0.52
296–286	0.40	–0.06	0.07	0.22
286–275	0.08	–0.12	0.09	0.15
275–266	0.16	0.03	–0.02	–0.04
266–256	–0.02	–0.04	0.06	–0.16
256–245	0.18	0.22	–0.20	0.26
245–235	0.09	0.22	–0.04	0.08
235–223	0.13	–0.08	0.11	
223–212	0.06	0.06	0.10	
212–202	–0.03	0.04	0.11	
202–190	–0.15	0.14	0.23	
190–180	–0.06	–0.05	0.24	
180–169	–0.17	0.10	0.28	
169–159	–0.41	0.02	0.27	
159–148	–0.28	0.15	0.17	
148–138	–0.23	0.01	0.22	
138–129	–0.03	–0.01	0.11	
129–123	–0.02	0.23	0.05	
123–113	–0.15	–0.15	0.04	
113–102	–0.24	0.00	0.01	
102–92	–0.18	–0.05	–0.05	
92–83	–0.49	–0.07	–0.10	
83–76	–0.32	–0.08	–0.03	
76–66	–0.35	–0.08	0.15	
66–57	–0.29	0.07	0.08	
57–44	–0.21	–0.13	0.05	
44–35	–0.10	–0.12	0.03	
35–29	–0.26	–0.11	0.12	
29–18	–0.35	0.05	0.18	
18–12	–0.51	–0.06	0.14	
12–4	–0.21	0.07	0.28	

Figure 45. Computed average annual Mississippi River bed displacement between 1963 and 1975 surveys.

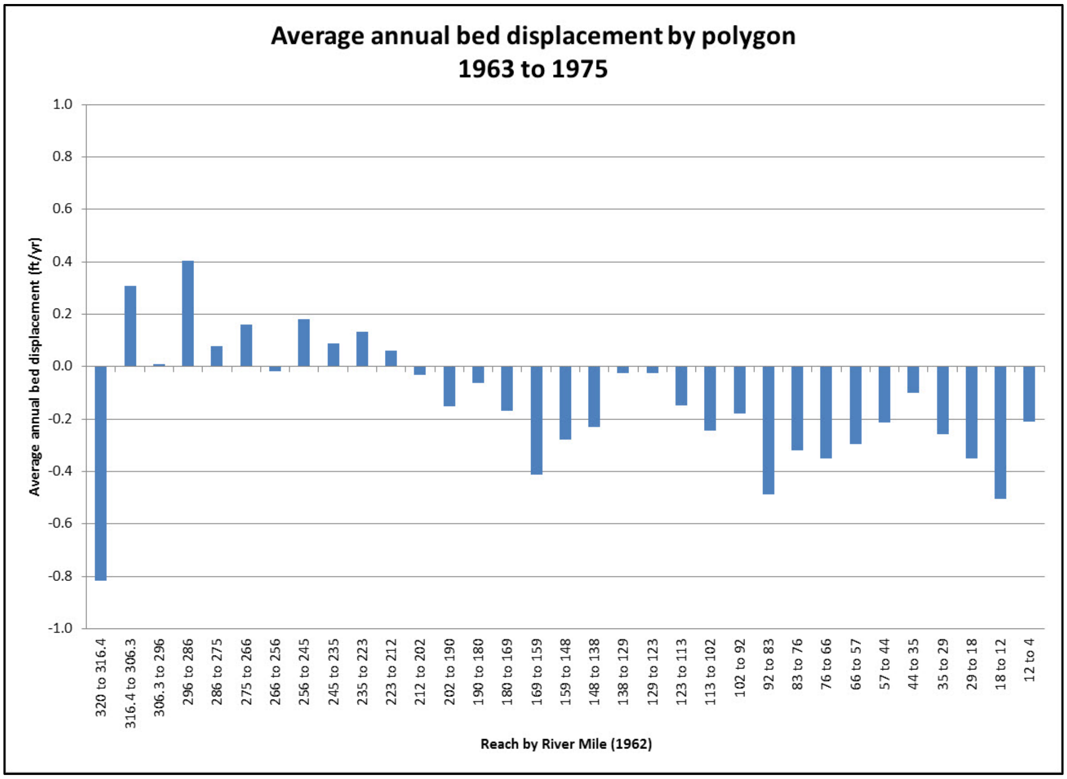


Figure 46. Computed average annual Mississippi River bed displacement between 1975 and 1992 surveys.

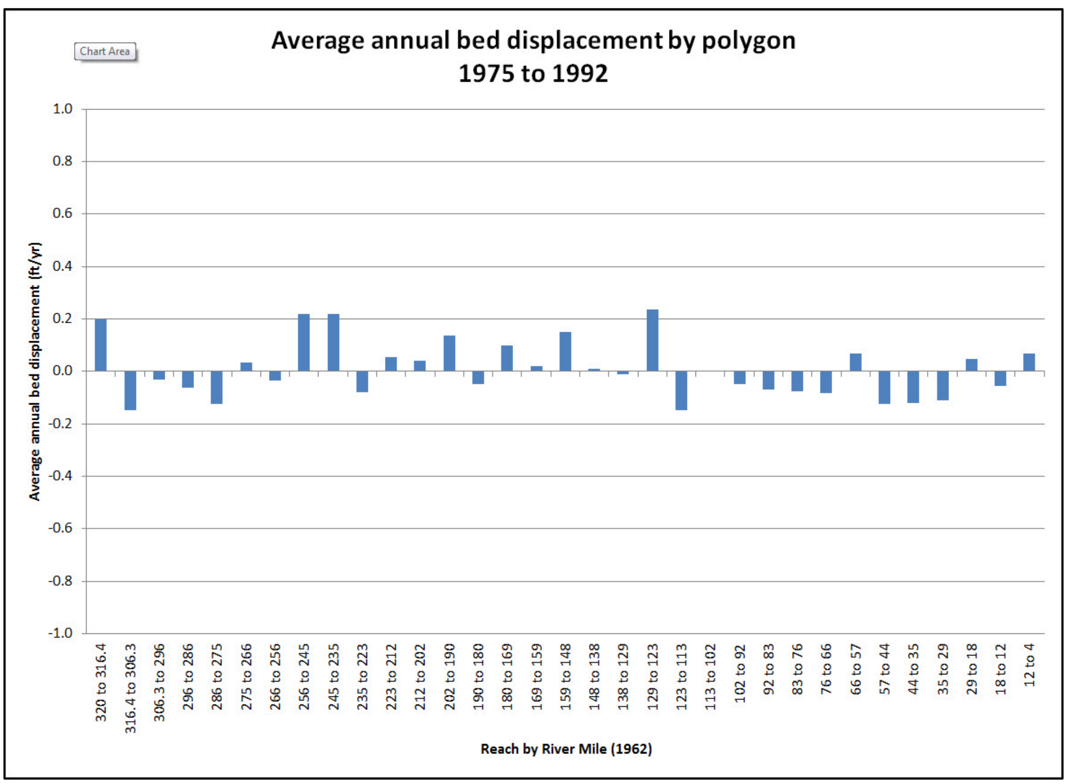


Figure 47. Computed average annual Mississippi River bed displacement between 1992 and 2004 surveys.

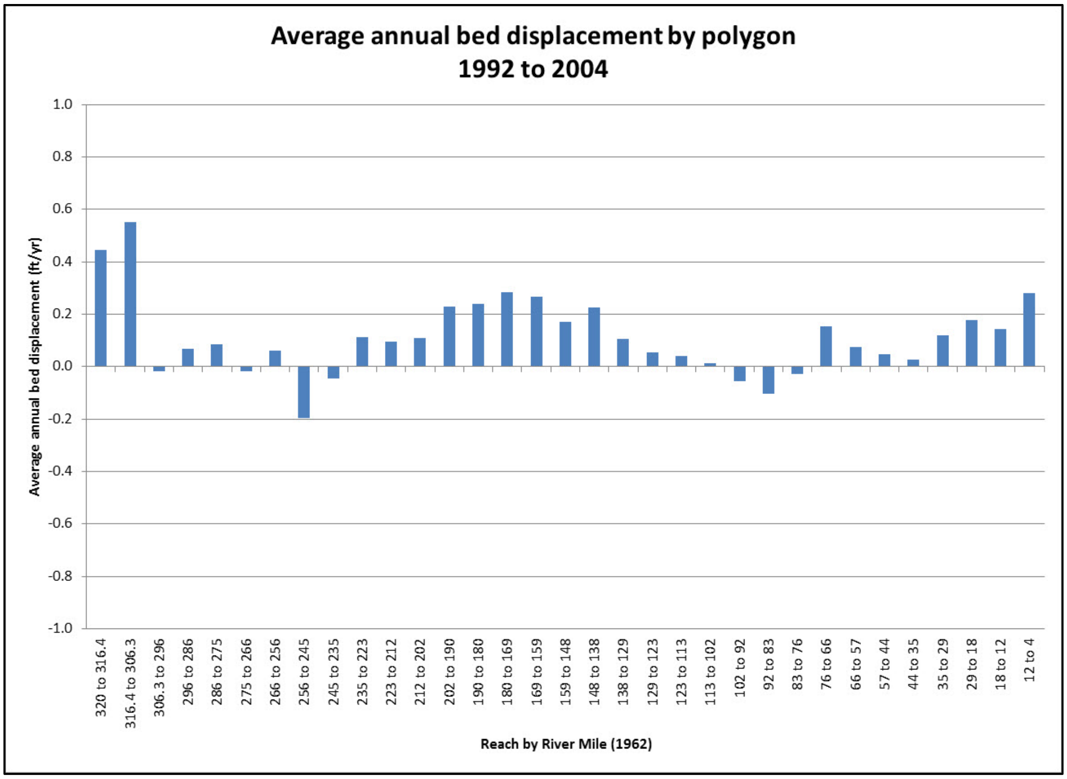
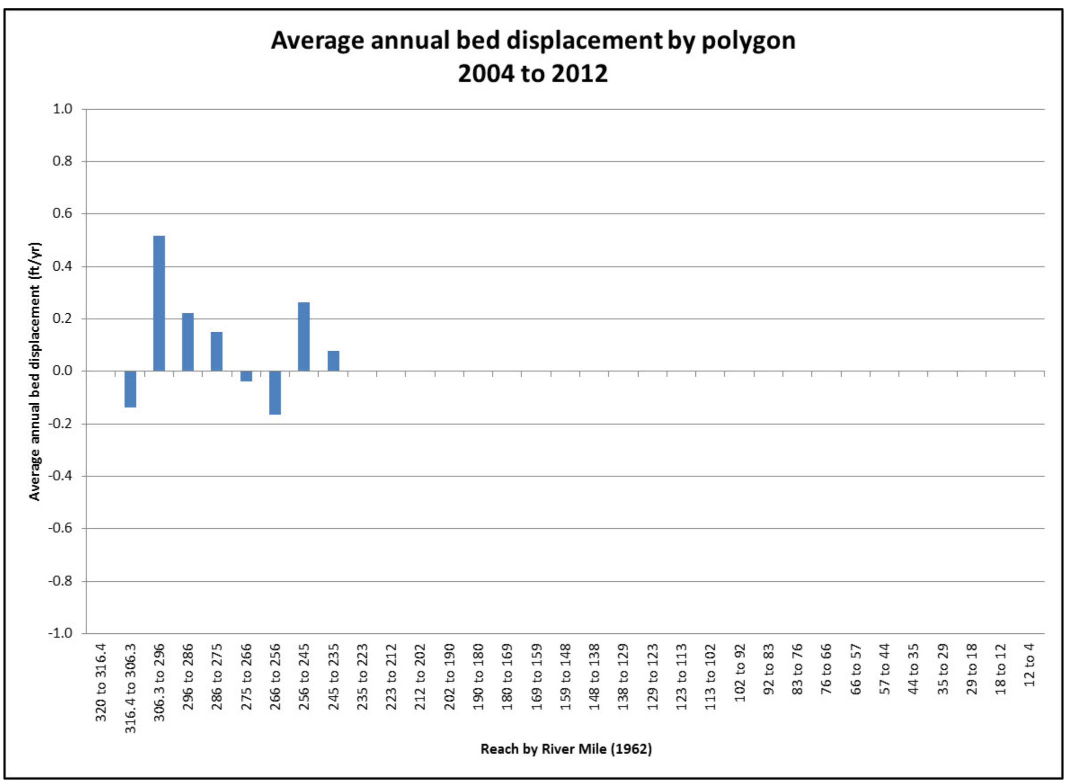


Figure 48. Computed average annual Mississippi River bed displacement between 2004 and 2012 surveys.



The results of the volumetric analysis were also used to inform the sediment budget analysis. The volume changes for the polygons located between the computation points for the sediment budget were summed to determine the erosion/deposition volume for the budget reaches. These values were used to interpret the computed budget changes for the reaches and are discussed in Section 4.4.

4.1.3 Geometry analysis for Old River Control Complex (ORCC)

The geometry analysis for the ORCC vicinity involved more closely spaced cross sections and shorter polygon lengths than were utilized in the reach-wide analysis. This was done so that the channel geometry changes in response to the various river-engineering activities at ORCC could be identified. The analysis methodology for the ORCC investigation was the same as for the reach-wide analysis.

Comparative cross sections plots for the ORCC section locations previously presented in Figure 9 are displayed in Appendix C. These plots include data from various ERDC multi-beam surveys collected in 2006, 2008, and 2010 for limited areas in the ORCC vicinity. These surveys generally did not have sufficient spatial coverage for use in the volumetric analysis but did provide additional information for the cross section assessment.

Figure 49 shows the comparative cross sections for the ORCC section at RM 317.6 AHP. The sections indicate that the channel depths have decreased since the 1992 survey. With the exception of point bar erosion between the 1963 and 1975 surveys, the cross sections are fairly consistent in dimension.

The comparative sections at RM315.0 AHP shown in Figure 50 illustrate the channel dimension changes that occurred subsequent to the opening of the low sill structure and the hydropower plant. This section is located immediately upstream of the low sill structure entrance channel. The channel geometry change from 1963 to 1975 is characterized by a shift in the channel thalweg from the left descending bank to the right descending bank and an increase in depth between 20 and 25 ft. This response corresponds to the opening of the low sill structure which began operation in 1963. Also noted is a reduction in top width of approximately 15% that occurred as the channel area occupied along the left descending bank in 1963 filled with sediment. The channel position remained consistent and depths decreased approximately 10 ft through the 1992 survey period.

Figure 49. Comparative cross sections at ORCC section RM 317.6 AHP.

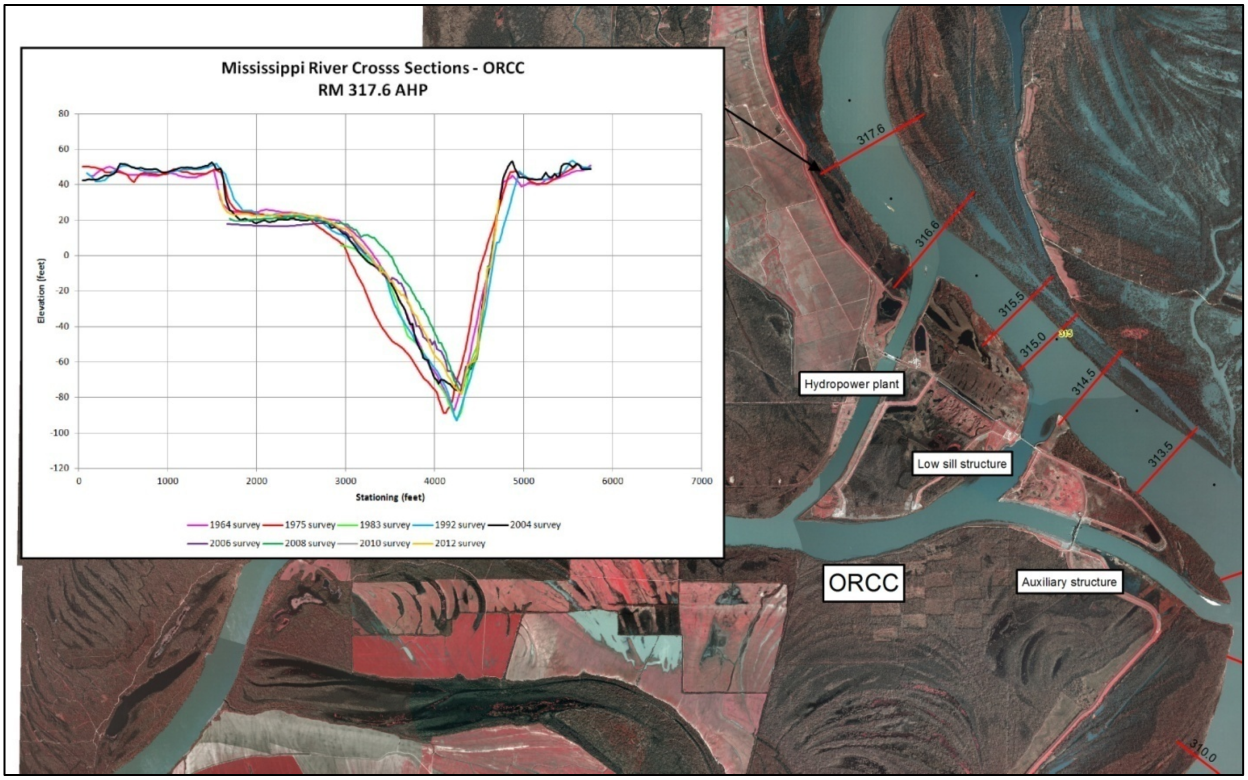
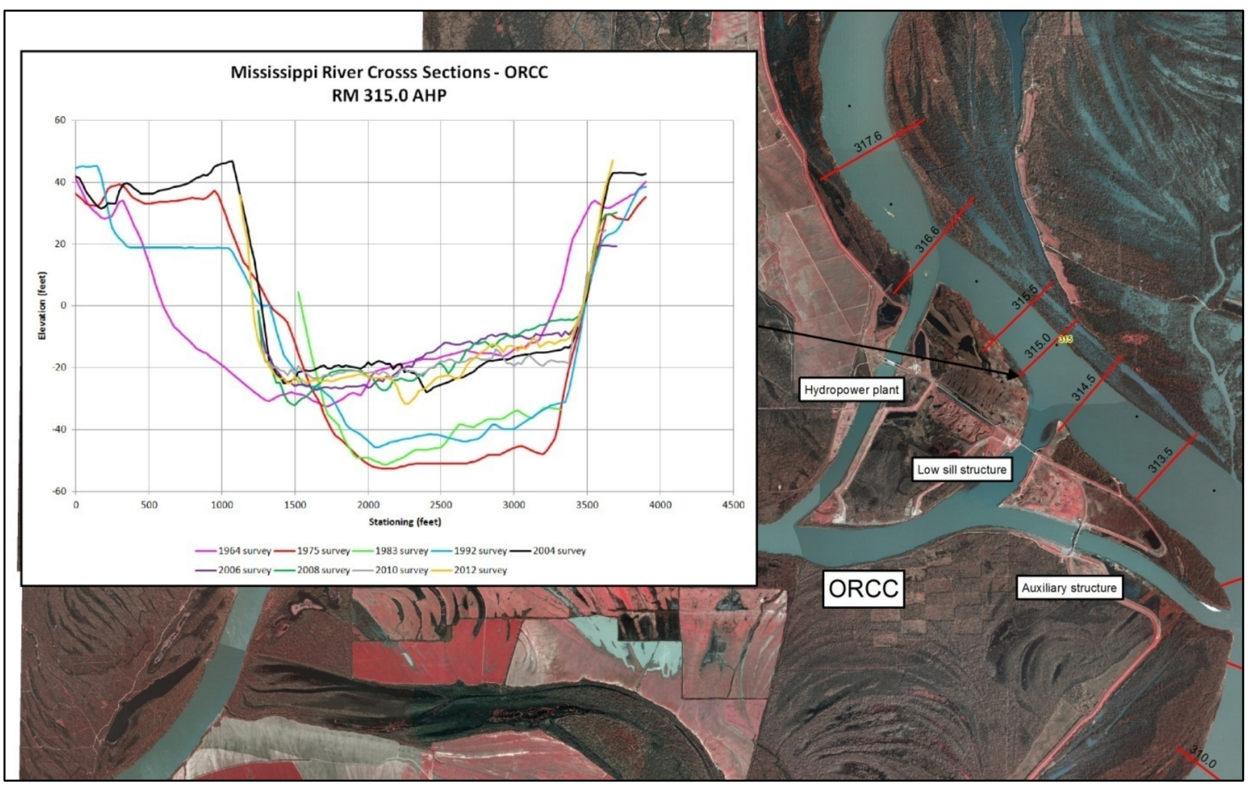


Figure 50. Comparative cross sections at ORCC section RM 315.0 AHP.



Subsequent to the 1992 survey, the channel thalweg shifted back toward the left descending bank, and depths decreased by approximately 20 ft. This distinct change in channel dimension corresponds with the beginning of operation of the hydropower plant at ORCC in 1991. Since the 2004 survey period, channel depths have varied by 5 to 10 ft, but channel dimensions have been consistent. Channel width at the time of the 2012 survey remained approximately 15% less than the width at the time of the 1963 survey.

Figure 51 shows the comparative cross sections for RM 312.1 AHP located immediately upstream of the auxiliary structure entrance channel. The cross sections indicate channel depths decreased approximately 20–22 ft from 1963 to 2004. The location of the channel thalweg has varied from the left side of the channel in 1963 to the right side of the channel in 1992. It is not clear whether this shift corresponds to the opening of the auxiliary structure in 1986, given the 1975 survey indicates the shift had begun prior to that time. Subsequent to the 2004 survey, the channel dimension has been relatively consistent, and depths have fluctuated within 10 ft. The sections also indicate the presence of deposition in the form of a middle bar that has been present since the 2006 survey. Erosion of the right descending bank between 1963 and 1992 is evident, but the bank has been stable since that time. Although a shift in the channel occurred, top bank widths are relatively the same.

The channel dimension of the river reach between the auxiliary structure entrance and Old River Lock over the survey periods is generally consistent with some minor lateral shift in the channel. The cross sections for RM 308.0 AHP shown in Figure 52 exemplify the general stability of the channel in this reach. Observed lateral shift in the channel in this reach is associated by deposition on the point bar along the right descending bank.

The Hog Point dikes and trench-fill revetment located in the vicinity of RM 300 AHP are the most extensive river-training structures deployed within the study reach, with possibly the exception of the Redeye crossing dikes located near RM 224 AHP. The dikes and revetment were constructed from the early to mid-1990s to realign the channel through a large island at Smithland that separated two channels of the river. The river channel is very wide at this location, and maintaining a dependable navigation channel was problematic. The river channel in this vicinity has undergone

Figure 51. Comparative cross sections at ORCC section RM 315.0 AHP.

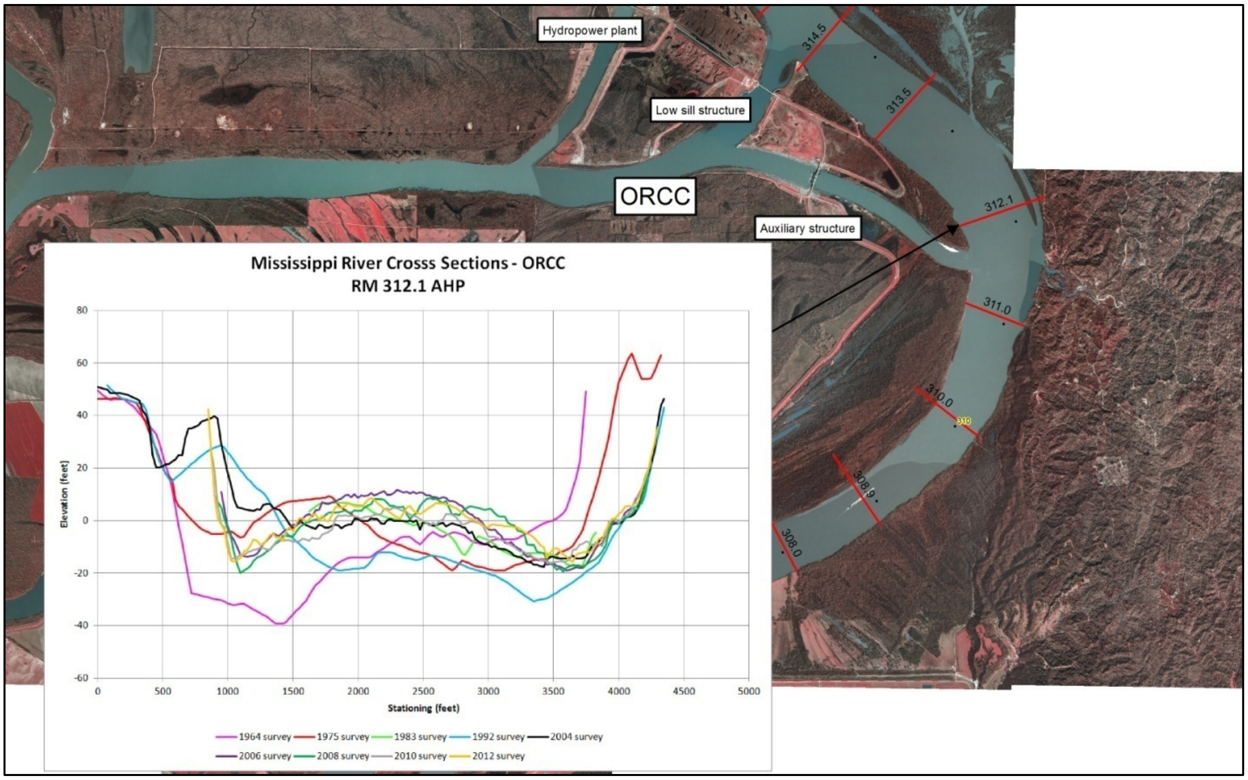
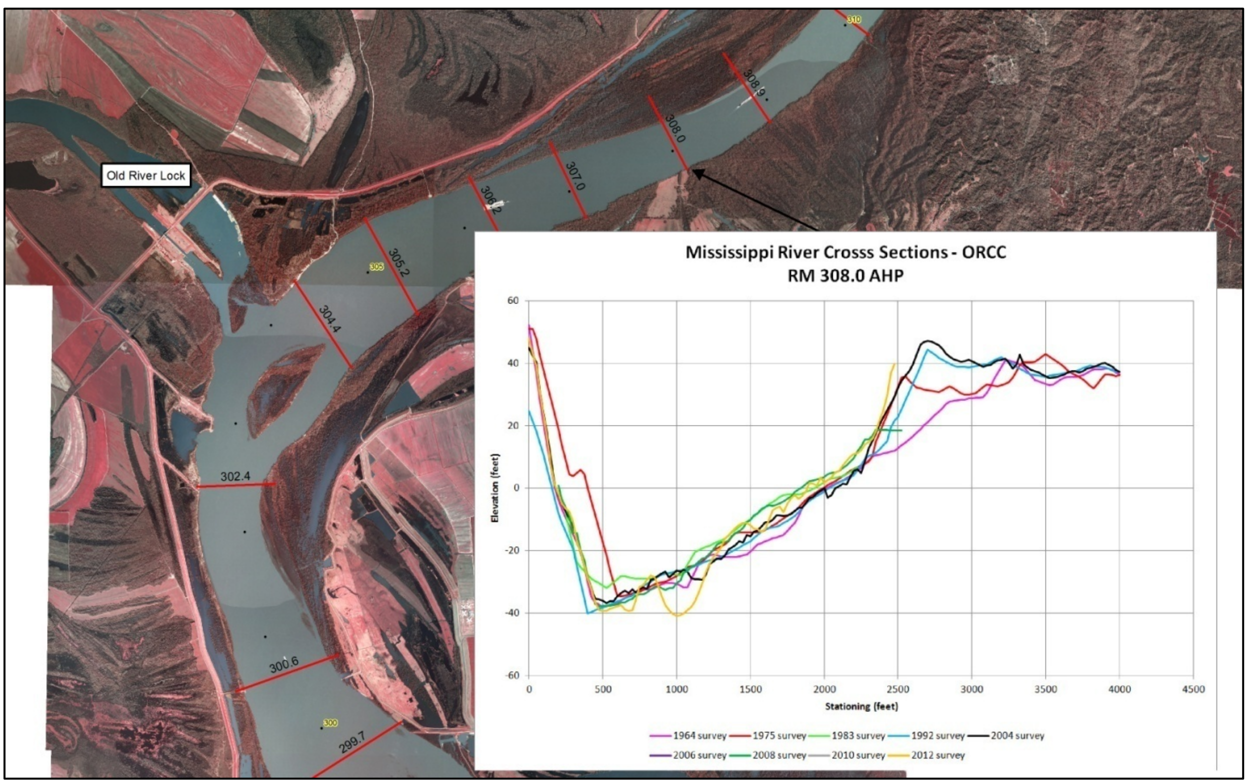


Figure 52. Comparative cross sections at ORCC section RM 308.0 AHP.



significant changes in geometry due to the river-engineering efforts as illustrated in Figure 53 for the cross sections at RM 299.7 AHP. The cross sections indicate that the split channel was the most prominent at the time of the 1992 survey. The sections for the 2004 and 2012 surveys show how the realigned channel has developed. Dredging records indicate that very little maintenance dredging has been required at this site since approximately 1997; therefore, the river-engineering efforts appear to be successful.

From the Hog Point dikes location to the downstream end of the ORCC detailed study reach at RM 287.0 AHP, the river channel has either remained relatively consistent or experienced some degree of lateral shift. Figure 54 shows the comparative cross sections for the section at RM 294.0 AHP where a channel shift from the left to the right descending bank occurred. The shift was evident in the 1975 survey and continued until 2004. A downstream extension of the Hog Point revetment along the right descending bank in the mid-1990s has effectively halted the lateral shift. It is also interesting to note that the dimension and shape of the current channel shown in the 2012 survey is very similar to the channel shape in 1963 but with less top bank width. The comparative cross sections at RM 288.0 AHP shown in Figure 55 indicate a channel that has been fairly consistent in dimension yet with some variation in depth and shape.

Figure 53. Comparative cross sections at ORCC section RM 299.7 AHP, site of Hog Point dikes and realignment.

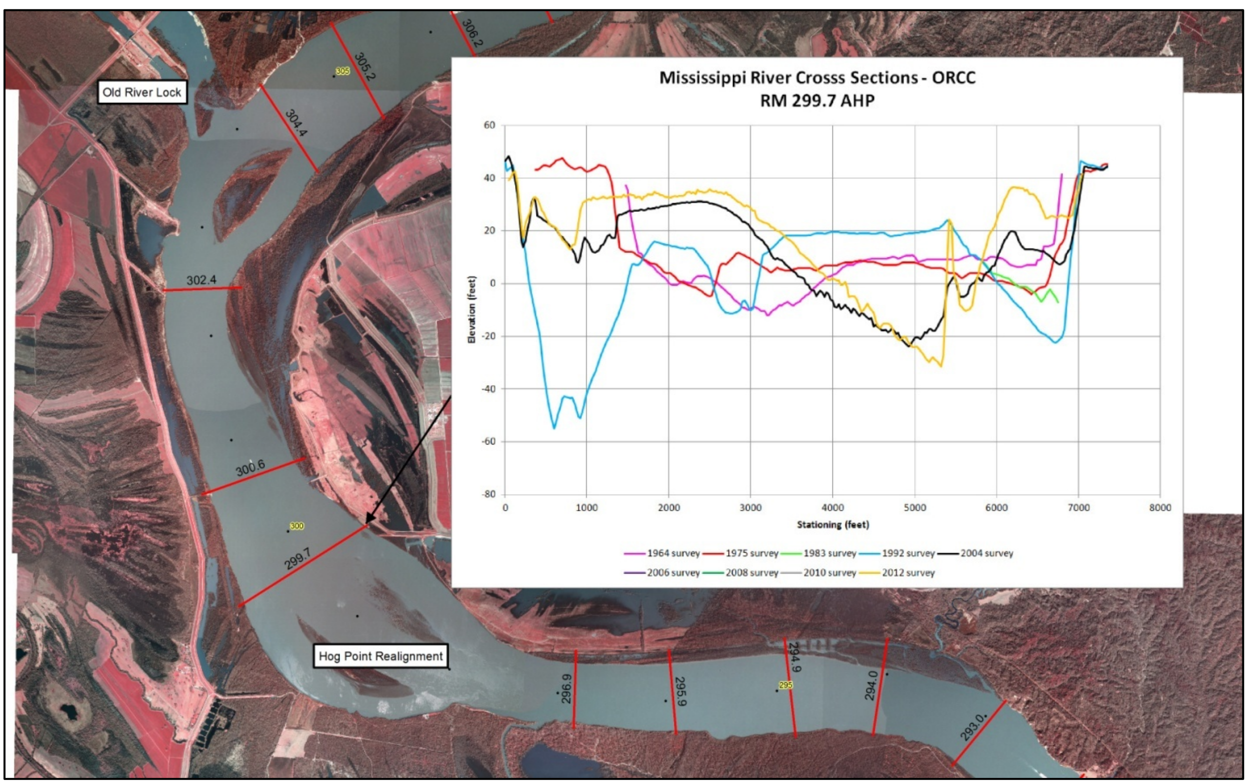


Figure 54. Comparative cross sections at ORCC section RM 294.0 AHP.

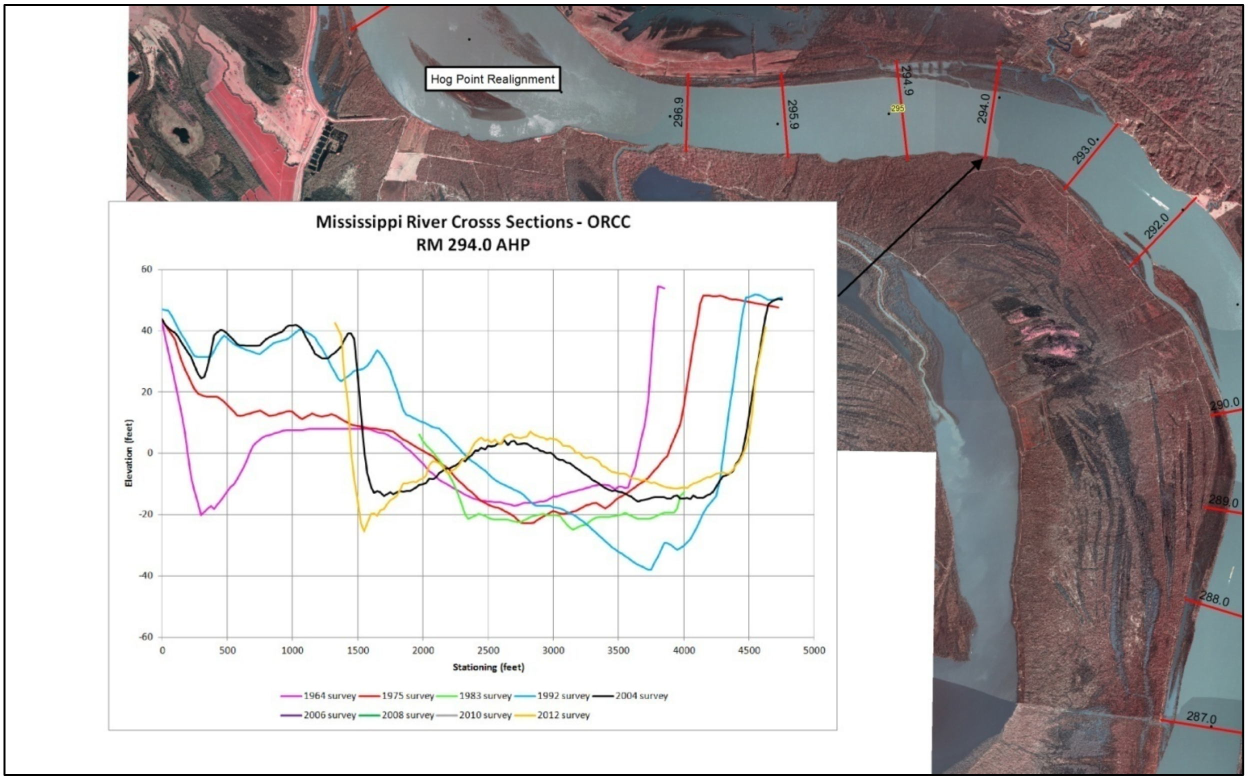
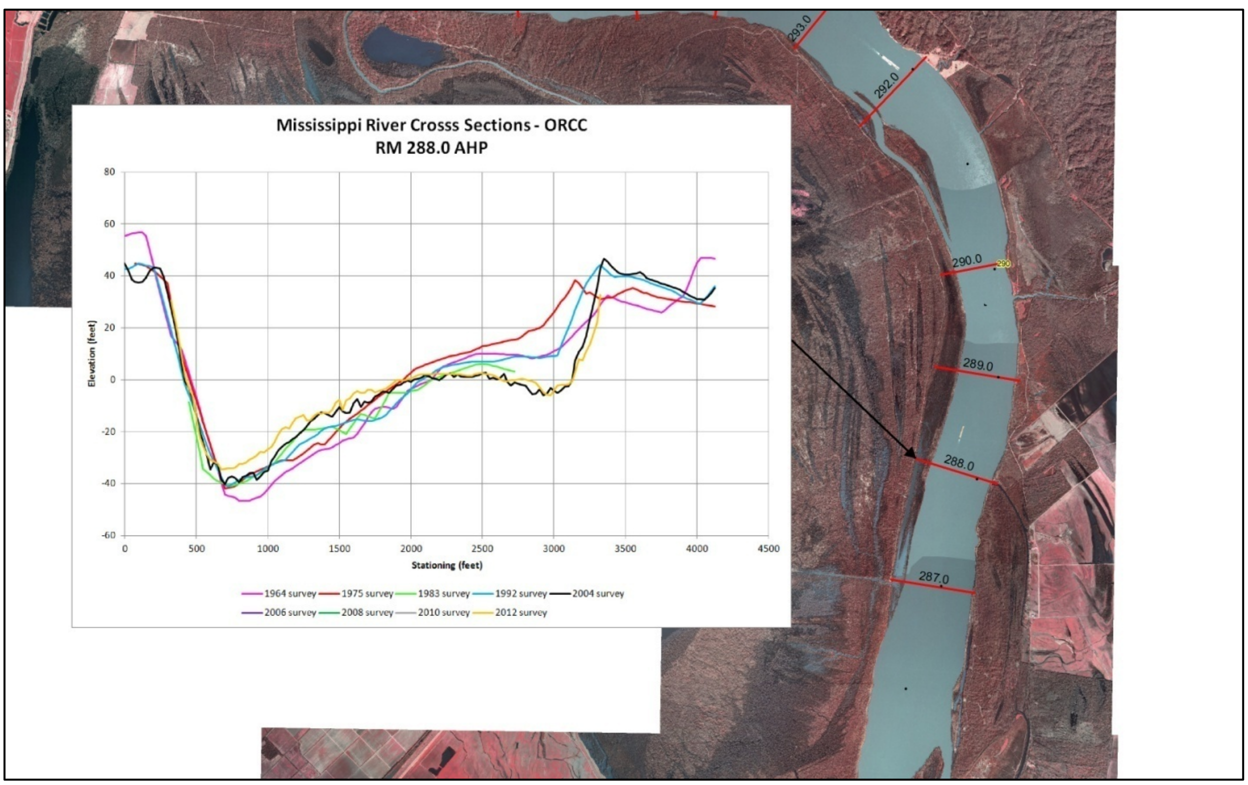


Figure 55. Comparative cross sections at ORCC section RM 288.0 AHP.



The percent change in cross-sectional area below top bank elevation for successive surveys was computed for the ORCC sections and is listed in Table 16. The percent change for the period 1963–1975 indicates erosion (positive change value) for the reach upstream of the low sill structure at RM 315.0 AHP that has previously been noted in this report. The remainder of the ORCC reach is predominantly depositional (negative change value) with the exception of a couple of sections in the vicinity of Old River Lock near RM 302.0 AHP. In addition to the effects of the opening of the low sill structure, the 1973 flood is thought to be a major contributor to channel geometry adjustments during this time period. An overall trend in erosion is noted for the majority of the ORCC reach for the time period 1975–1992. The largest degree of deposition indicated by the percent area change values is seen for the time period 1992–2004. The area change for the sections RM 316.6 to 308.9 AHP indicates a consistent deposition trend for the reach immediately downstream of the ORCC hydropower plant. This deposition is thought to be associated with ORCC hydropower operation and the resulting change in sediment passage through the ORCC to the Atchafalaya River basin. Downstream of RM 308.9 AHP, the deposition trend is generally not as pronounced. For the time period 2004–2012, a general trend of deposition is observed for the ORCC reach but at a lower rate than observed for the period 1992–2004.

Polygons of the river channel constructed between each ORCC section were used to determine the average annual erosion/deposition volume per river mile between successive surveys. The average annual volumetric changes were converted to average annual bed displacement by dividing the volume change by the surface area of each polygon. The average annual erosion/deposition volume per river mile for the ORCC polygons is listed in Table 17 and shown in maps in Appendix D. The computed average annual bed displacement for each survey period is presented in Figures 56–59. The general trends for each survey period are very similar to those indicated with the cross section data. For the period 1963–1975 shown in Figure 56, average annual bed displacement indicated erosion upstream of the low sill structure and deposition downstream of the structure. This trend reverses for the 1975–1992 time period (Figure 57), showing deposition upstream of the low sill structure and erosion downstream. The average annual bed displacement for 1992–2004 shown in Figure 58 indicates consistent deposition from the hydropower plant to just upstream of Tarbert Landing. A general deposition trend for the entire ORCC reach is observed from 2004 to 2012 (Figure 59), although the magnitude is less than observed from 1992 to 2004.

Table 16. Percent change in cross-sectional area for ORCC sections.

RM of ORCC Section	Percent Change in Cross-Sectional Area below Top Bank Elevation			
	1963–1975	1975–1992	1992–2004	2004–2012
317.6	12.2%	–4.0%	–3.4%	–6.6%
316.6	3.9%	7.7%	–11.9%	–3.2%
315.5	18.5%	–16.5%	–19.6%	–2.3%
315.0	8.5%	0.3%	–26.3%	–3.1%
314.5	–16.7%	12.7%	–16.0%	–6.6%
313.5	–3.9%	13.1%	–11.4%	–4.0%
312.1	–10.7%	16.3%	–16.1%	–6.3%
311.0	–14.0%	21.0%	–14.0%	–5.3%
310.0	–10.0%	3.7%	–13.0%	–2.0%
308.9	–15.5%	–0.2%	–10.6%	–0.4%
308.0	–13.5%	9.2%	–5.7%	–6.2%
307.0	–5.8%	3.2%	–0.9%	–3.3%
306.2	–7.2%	3.4%	0.5%	–5.0%
305.2	–18.0%	10.9%	–0.3%	–4.0%
304.4	–16.9%	5.0%	–1.0%	–0.3%
302.4	17.3%	1.0%	–11.5%	–4.8%
300.6	8.4%	–2.5%	–3.1%	–10.2%
299.7	3.6%	33.3%	–18.1%	–19.0%
296.9	–10.8%	10.7%	–3.7%	3.0%
295.9	–12.8%	5.8%	3.0%	–4.4%
294.9	0.8%	4.5%	10.0%	–3.6%
294.0	–1.8%	–3.0%	–1.4%	–8.3%
293.0	–6.7%	10.9%	–8.8%	–6.9%
292.0	–14.0%	16.9%	–0.2%	–8.2%
290.0	–4.4%	6.8%	–8.7%	–7.5%
289.0	–8.7%	4.2%	–6.4%	–0.9%
288.0	–10.4%	5.6%	2.7%	–7.7%
287.0	–10.6%	–0.9%	4.2%	–7.2%

Legend for percent change in cross-sectional area. Positive change indicates erosion; negative change indicates deposition.

Purple	Greater than 15%
Blue	10% to 15%
Green	5% to 10%
White	5% to –5%
Yellow	–5% to –10%
Orange	–10% to –15%
Red	Greater than –15%

Table 17. Average annual erosion/deposition volume per mile by ORCC polygon reach.

ORCC Polygon by RM	Average Annual Erosion/Deposition Volume per River Mile (cy/mile/yr)			
	1963–1975	1975–1992	1992–2004	2004–2012
317.6–316.6	–264,000	72,000	229,000	20,000
316.6–315.5	–293,000	208,000	366,000	105,000
315.5–315.0	–378,000	211,000	489,000	53,000
315.0–314.5	148,000	67,000	556,000	–225,000
314.5–313.5	379,000	–221,000	387,000	–46,000
313.5–312.1	236,000	–210,000	333,000	–172,000
312.1–311.0	382,000	–205,000	415,000	66,000
311.0–310.0	447,000	–195,000	325,000	171,000
310.0–308.9	133,000	3,000	243,000	74,000
308.9–308.0	198,000	–104,000	218,000	–17,000
308.0–307.0	173,000	–56,000	68,000	49,000
307.0–306.2	212,000	–4,000	–45,000	147,000
306.2–305.2	321,000	30,000	–25,000	157,000
305.2–304.4	556,000	7,000	–25,000	285,000
304.4–302.4	–9,000	21,000	353,000	149,000
302.4–300.6	–266,000	–42,000	123,000	247,000
300.6–299.7	–48,000	–94,000	38,000	349,000
299.7–296.9	8,000	–59,000	–302,000	202,000
296.9–295.9	345,000	–91,000	–38,000	–190,000
295.9–294.9	131,000	9,000	–160,000	73,000
294.9–294.0	41,000	122,000	–63,000	82,000
294.0–293.0	187,000	44,000	211,000	543,000
293.0–292.0	231,000	–95,000	29,000	108,000
292.0–290.0	138,000	–139,000	151,000	–112,000
290.0–289.0	177,000	–129,000	228,000	20,000
289.0–288.0	219,000	–69,000	40,000	21,000
288.0–287.0	343,000	–130,000	–30,000	321,000

Figure 56. Average annual bed displacement for ORCC polygons, 1963–1975.

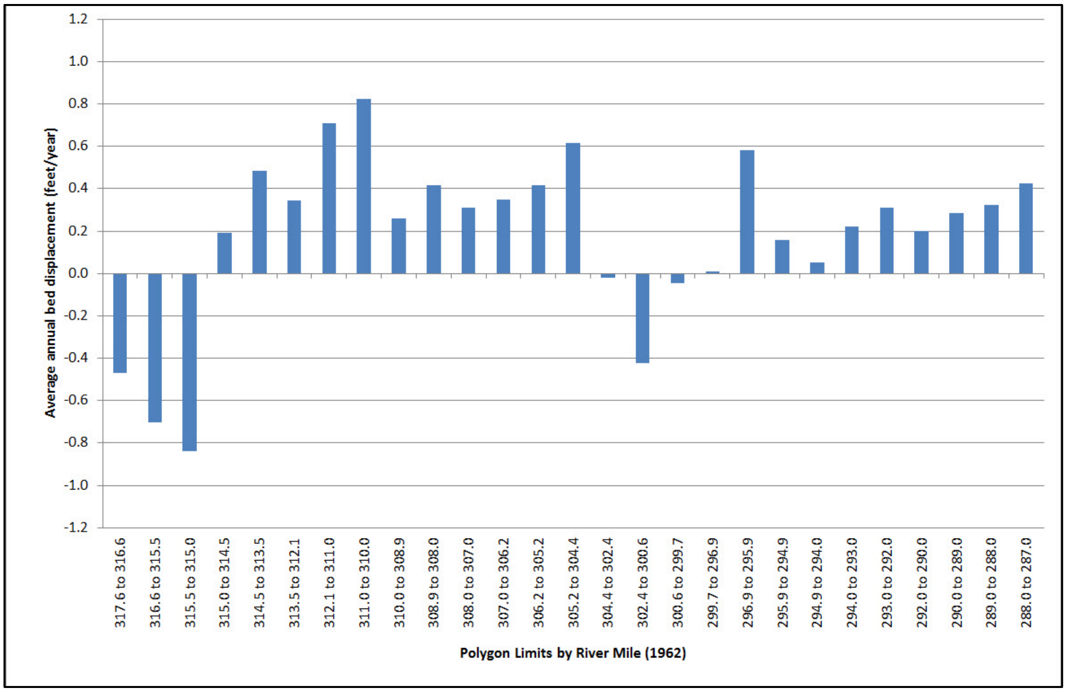


Figure 57. Average annual bed displacement for ORCC polygons, 1975–1992.

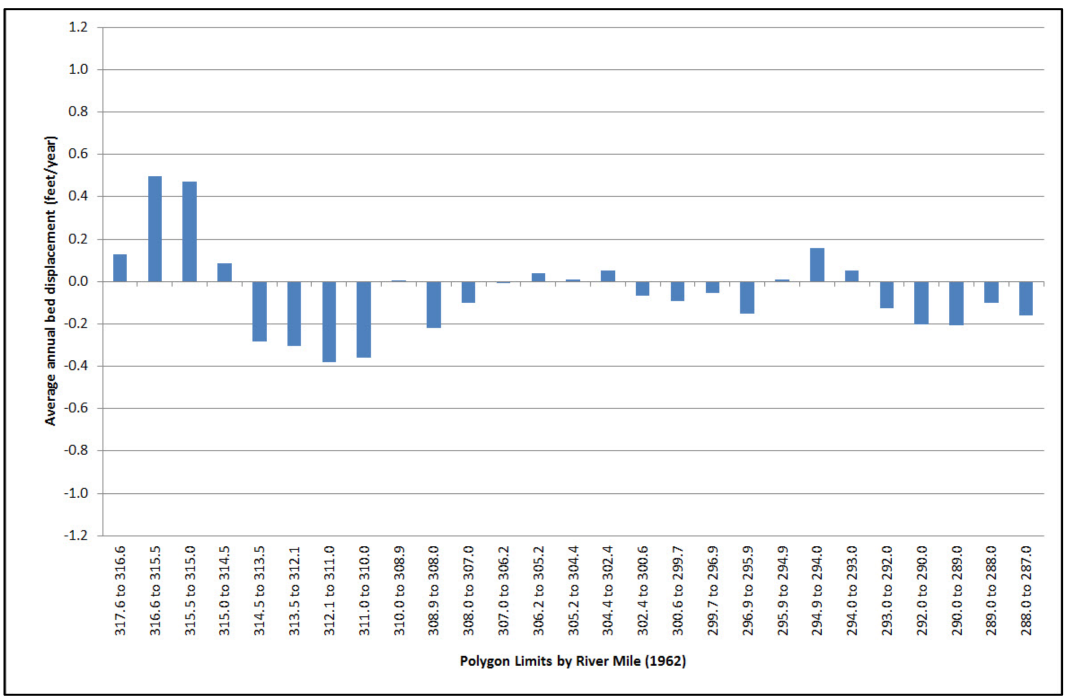


Figure 58. Average annual bed displacement for ORCC polygons, 1992–2004.

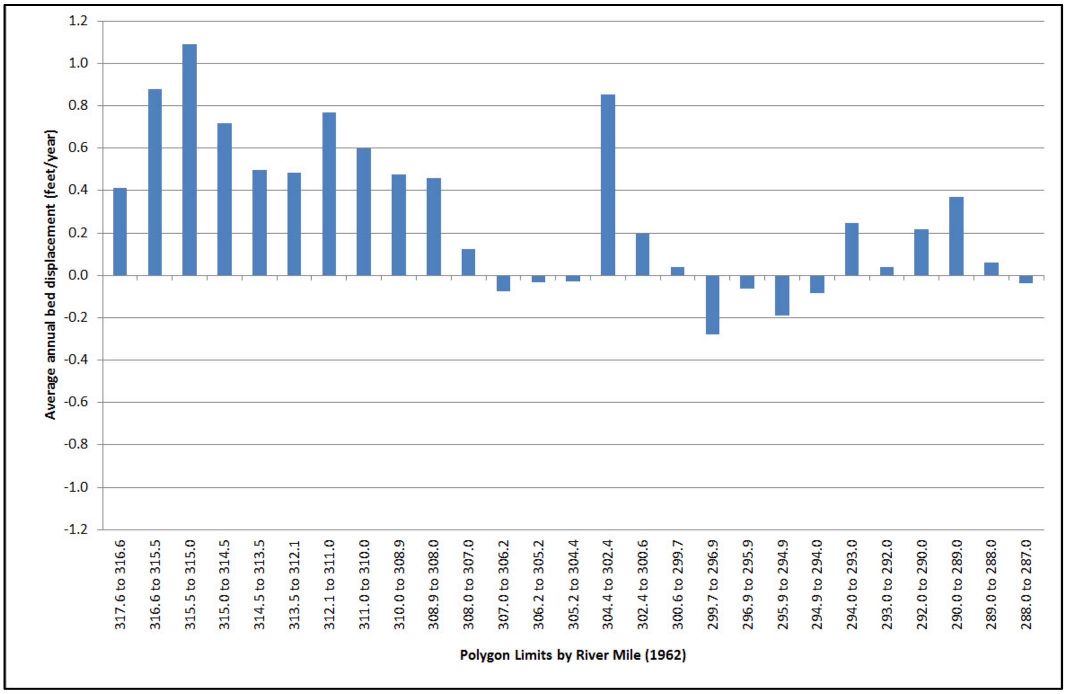
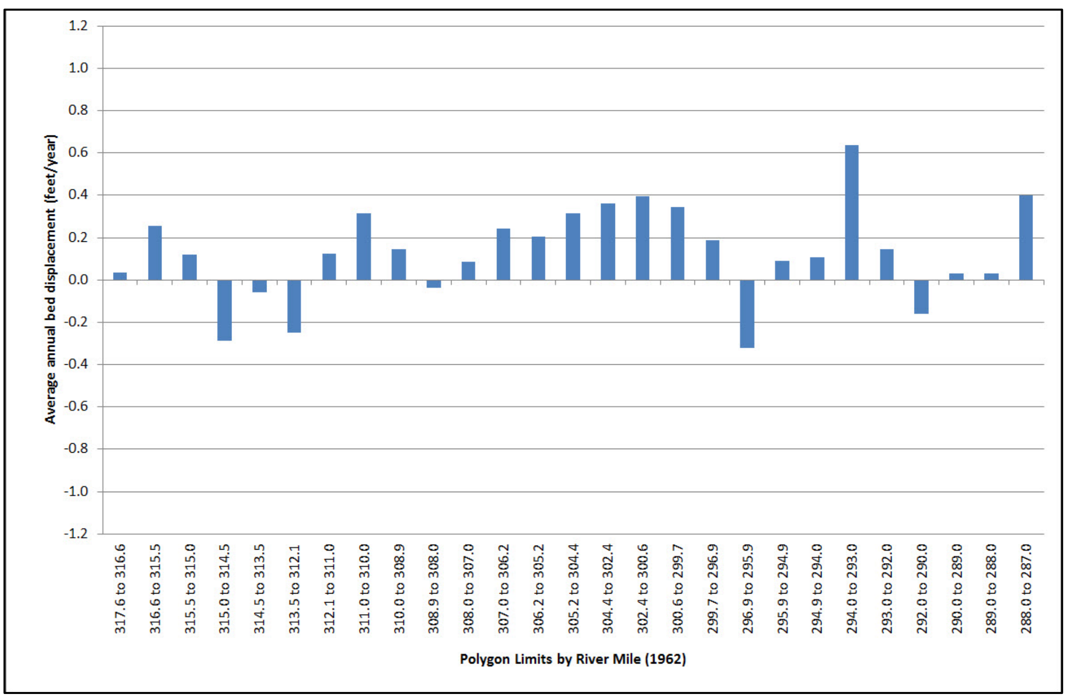


Figure 59. Average annual bed displacement for ORCC polygons, 2004–2012.



The geometry data analysis for the ORCC reach indicates that the river channel in the reach has been influenced by the structural evolution of the ORCC. The addition of the low sill structure in 1963 resulted in a definitive shift in the channel thalweg towards the structure as well as erosion of the channel bed upstream of the structure. The addition of the hydropower plant in 1991 resulted in significant deposition for the immediate reach downstream of the structure. Each of these structures, along with the auxiliary structure added in 1986, has altered the total sediment diversion percentage of the ORCC. The various combinations of operation involving these structures that can occur at ORCC can result in complex and variable sediment diversion scenarios. Thus, interpretation of observed geometric changes in the vicinity can be difficult and uncertain. However, analysis of the observed geometric changes does suggest that the response of the river channel to ORCC operation may be more of a local response rather than a system-wide adjustment. The magnitude of observed changes is greatest in the immediate vicinity of the ORCC and decreases downstream from the complex. No discernible channel adjustment trends attributable to the ORCC can be confidently identified near the downstream end of the ORCC study reach. It must be noted, however, that a system-wide response by the river to the effects of the ORCC may occur at very slow rates and over decadal temporal scales.

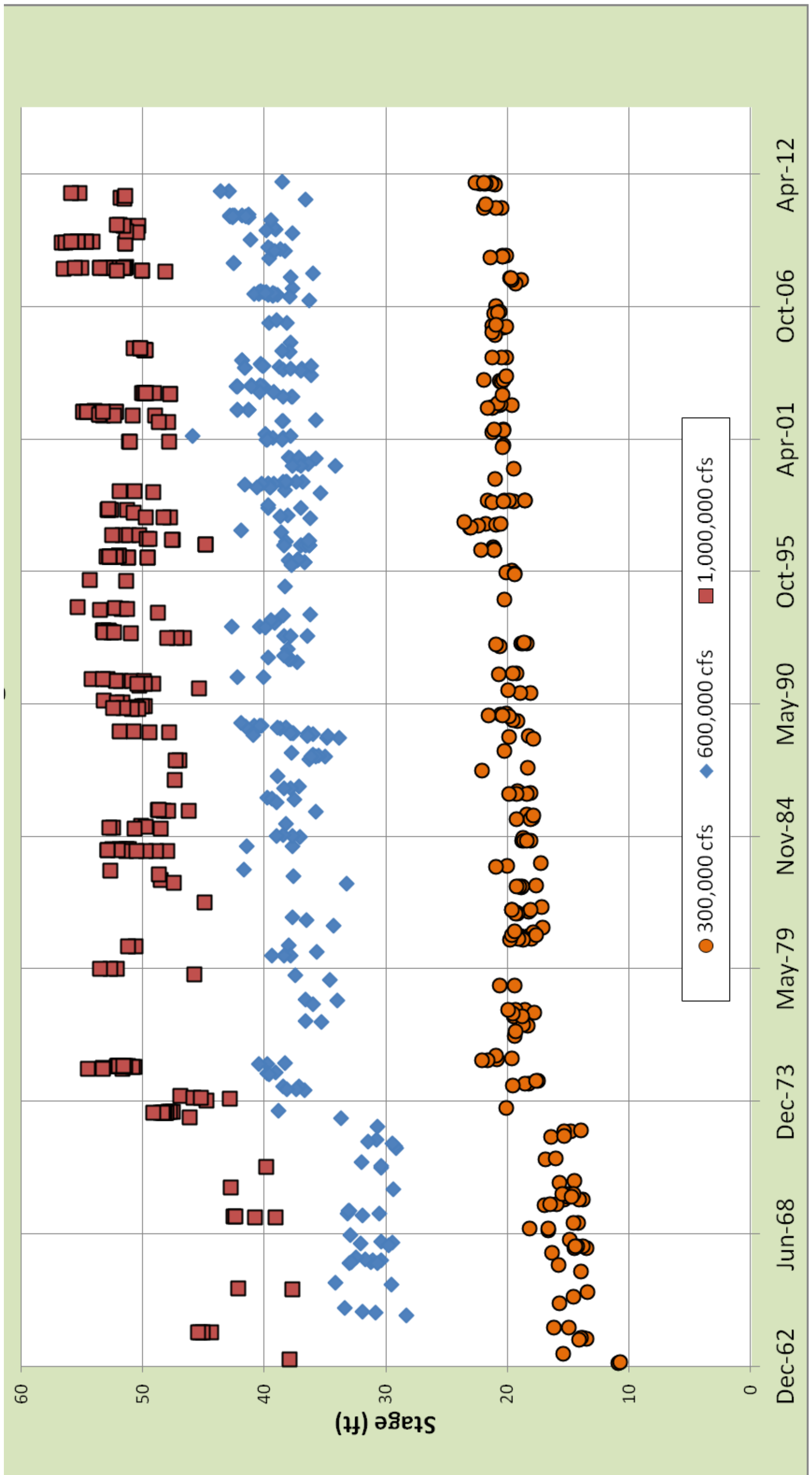
4.2 Gage and Discharge Analysis Results

Specific gage records were developed at the following stations: Red River Landing, Bayou Sara, Baton Rouge, Donaldsonville, Algiers Lock, and West Pointe a LaHache. A discussion of each of these follows.

4.2.1 Red River Landing specific gage record

The specific gage record for the Red River Landing gage for the period 1963–2011 is shown in Figure 60. This figure shows that there is a shift in the stage trends before and after approximately 1975. This increase in stages is observed at almost all of the stations on the Lower Mississippi River. For this reason, specific gage records were developed for the 1963–1974 and 1975–2012 time periods. Figure 61 shows the specific gage record at Red River Landing for the 1963–1974 time period. As shown in Figure 61, all three regression lines are statistically significant, indicating an aggradational trend during this time period. However, closer examination of the data reveals that almost all of the stage increase occurs in 1973 and 1974 and therefore is considered to be the result of the 1973 flood. For several decades

Figure 60. Red River Landing specific gage record, 1963–2011.



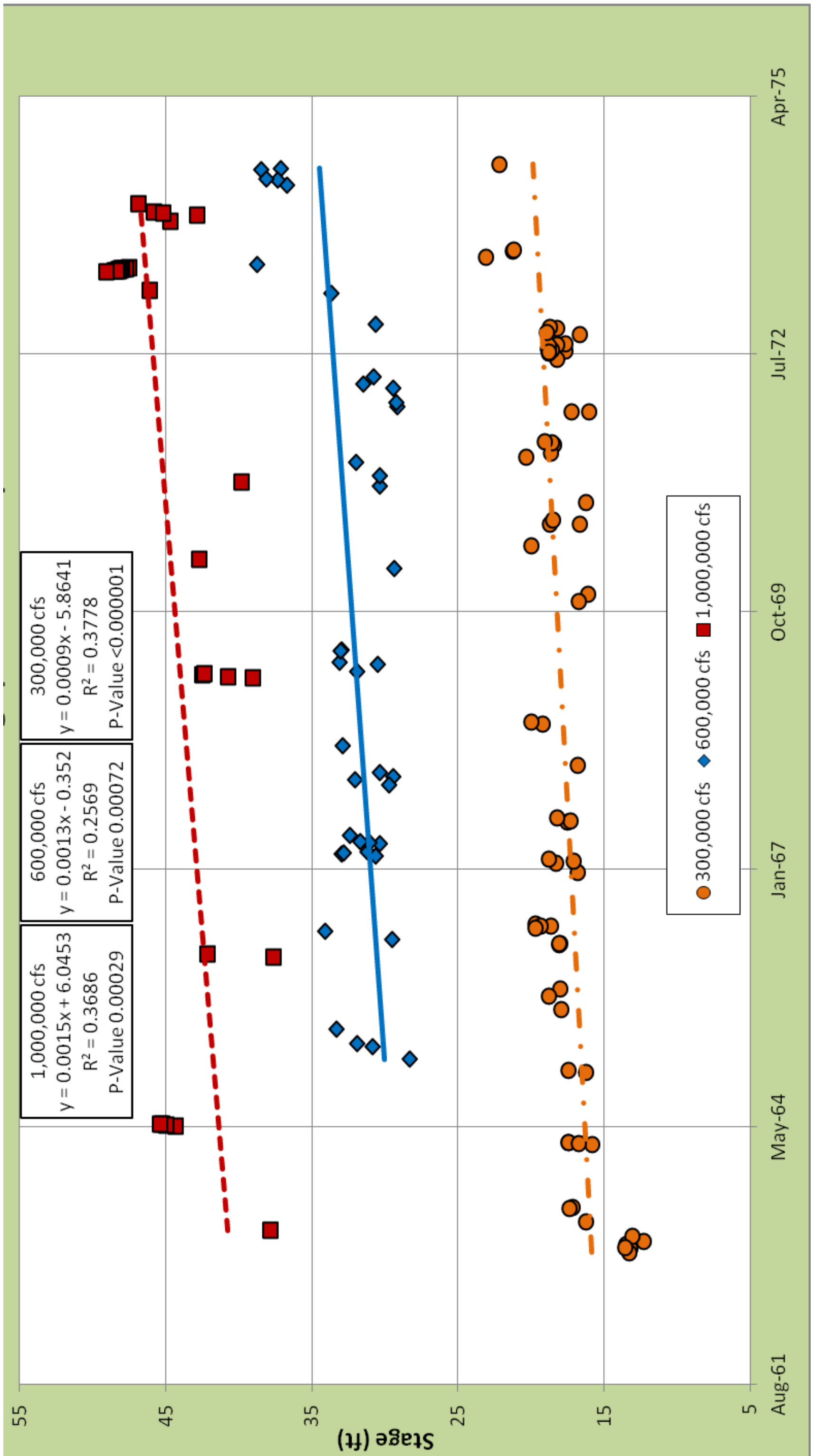


Figure 61. Red River Landing specific gage record, 1963–1974.

prior to 1973, the river was dominated by moderate flows. To examine the pre-1973 regime more closely, the specific gage record at Red River Landing was extended back to 1943. Figure 62 shows the long-term trends of the specific gage record at Red River Landing from 1943 to 2011. Examination of Figure 62 shows that stages prior to 1973 were relatively stable and consistently lower than the post-1973 stage. A more detailed examination of the pre-1973 trends (Figure 63) shows that with the exception of a very slight increasing trend at the low flows, the stage trends were relatively stable for the approximately 30 yr period prior to 1973.

The specific gage record for the 1975–2011 time period (Figure 64) shows that the aggradational trends have continued during this time period, albeit at a much slower pace. It is also important to note that during this 36 yr time period, there are cyclic periods of increasing and decreasing trends. To illustrate these varying trends, the specific gage record was developed for the following shorter term periods: 1975–1992 (Figure 65), 1993–2003 (Figure 66), and 1993–2011 (Figure 67). As shown in Figure 65, there are apparent downward trends at the high and low flows, but the trends are statistically inconclusive for the period 1975–1992. For the short period from 1993–2003, there is a statistically significant decreasing trend at 300,000 cfs, but a statistically significant increasing trend at the mid-range flow of 600,000 cfs. No trend was observed at 1 million cfs. However, when the period is extended from 1993 to 2011, both the 600,000 cfs and the 1 million cfs flows have statistically significant increasing trends. No trend was observed at the low flow.

4.2.2 Bayou Sara specific gage record

The specific gage record for the Bayou Sara gage for the period 1963–1974 is shown in Figure 68. This figure shows that all three regression lines are statistically significant, indicating an aggradational trend during this time period. The specific gage record for the 1975–2011 time period (Figure 69) indicates very slight increasing trends at the three discharges. However, only the trend for the 600,000 cfs flow is statistically significant, and the R^2 values for all three flows are extremely small (all less than 0.02). Therefore, the overall assessment suggests that the stage trends have been relatively stable during this time period. The specific gage records for the 1975–1992, 1993–2003, and 1993–2011 periods are shown in Figures 70, 71, and 72, respectively. For the 1975–1992 period (Figure 70), a statistically significant decreasing trend was observed at the 300,000 cfs flow. However, the trends at 600,000 cfs and 1 million cfs were insignificant and inconclusive.

Figure 62. Red River Landing specific gage record, 1943–2011.

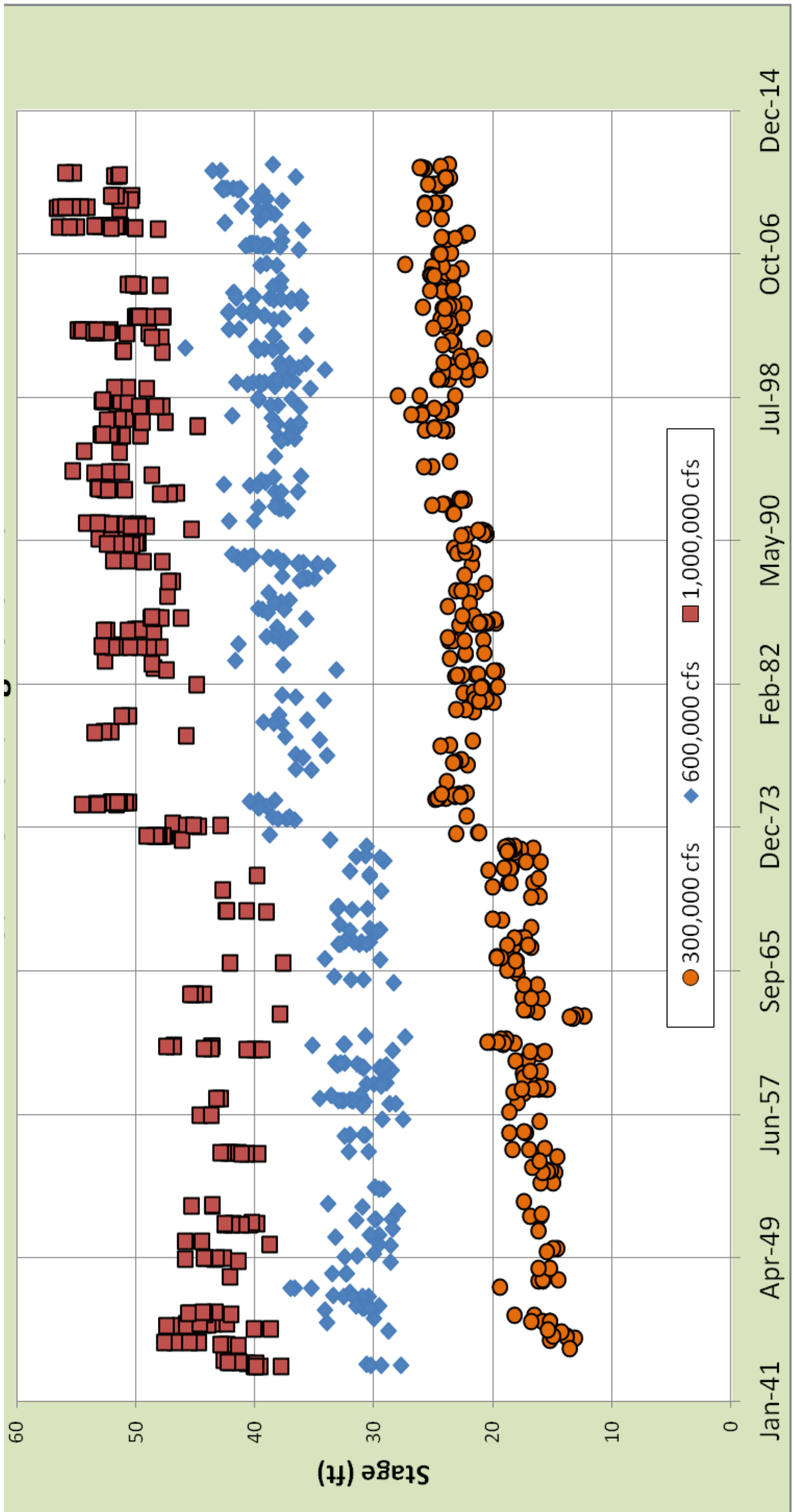


Figure 63. Red River Landing specific gage record, 1943–1972.

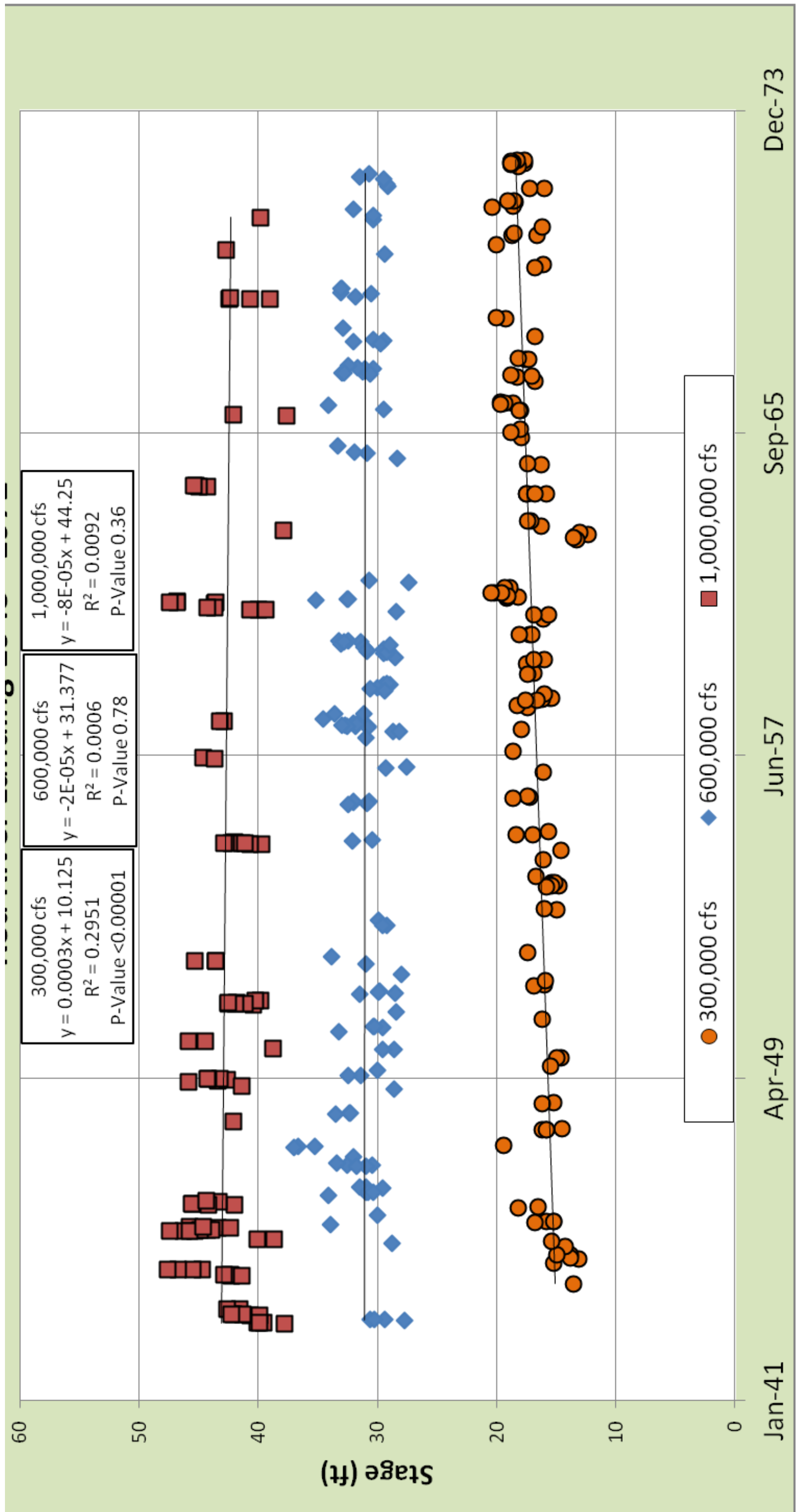


Figure 64. Red River Landing specific gage record, 1975–2011.

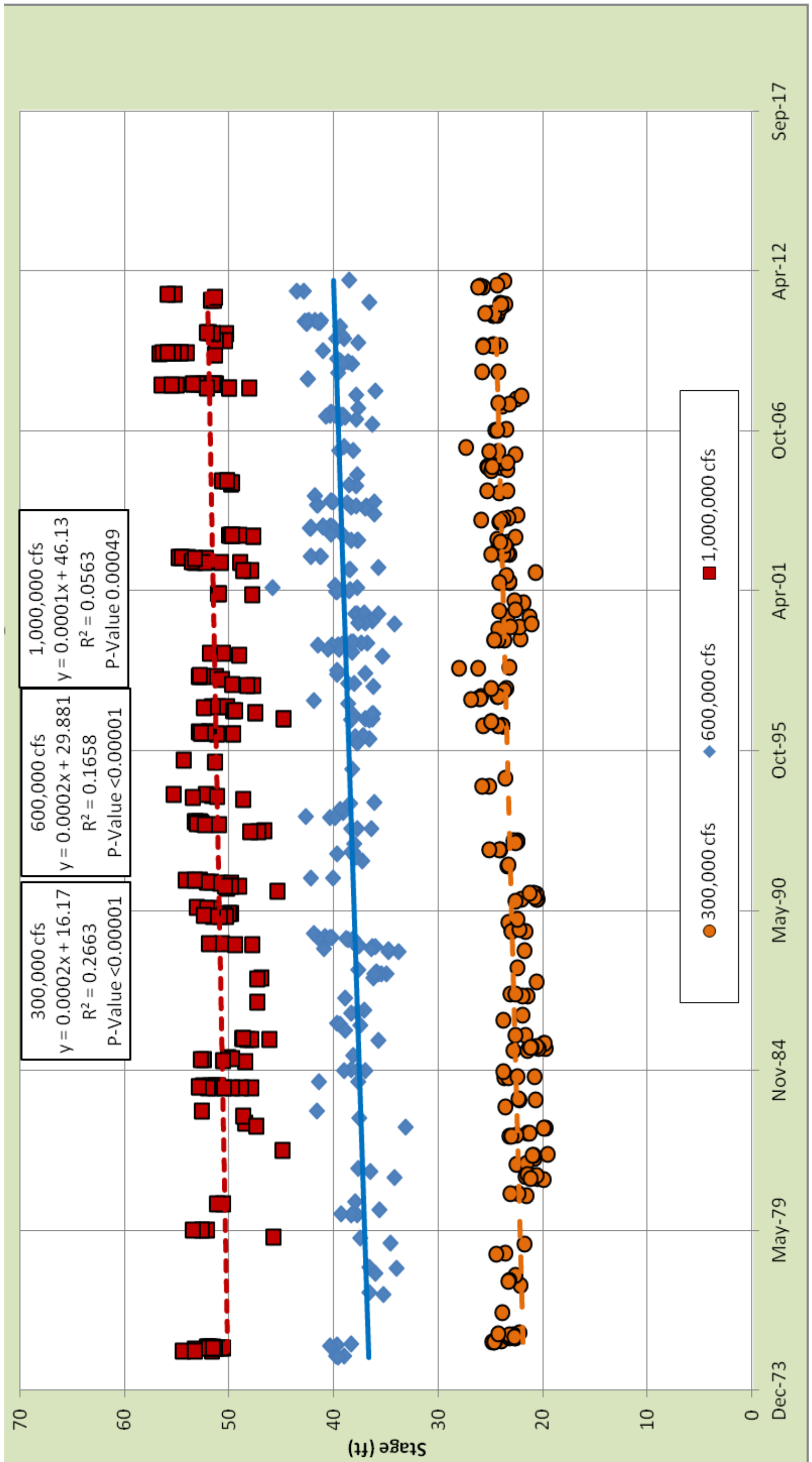


Figure 65. Red River Landing specific gage record, 1975–1992.

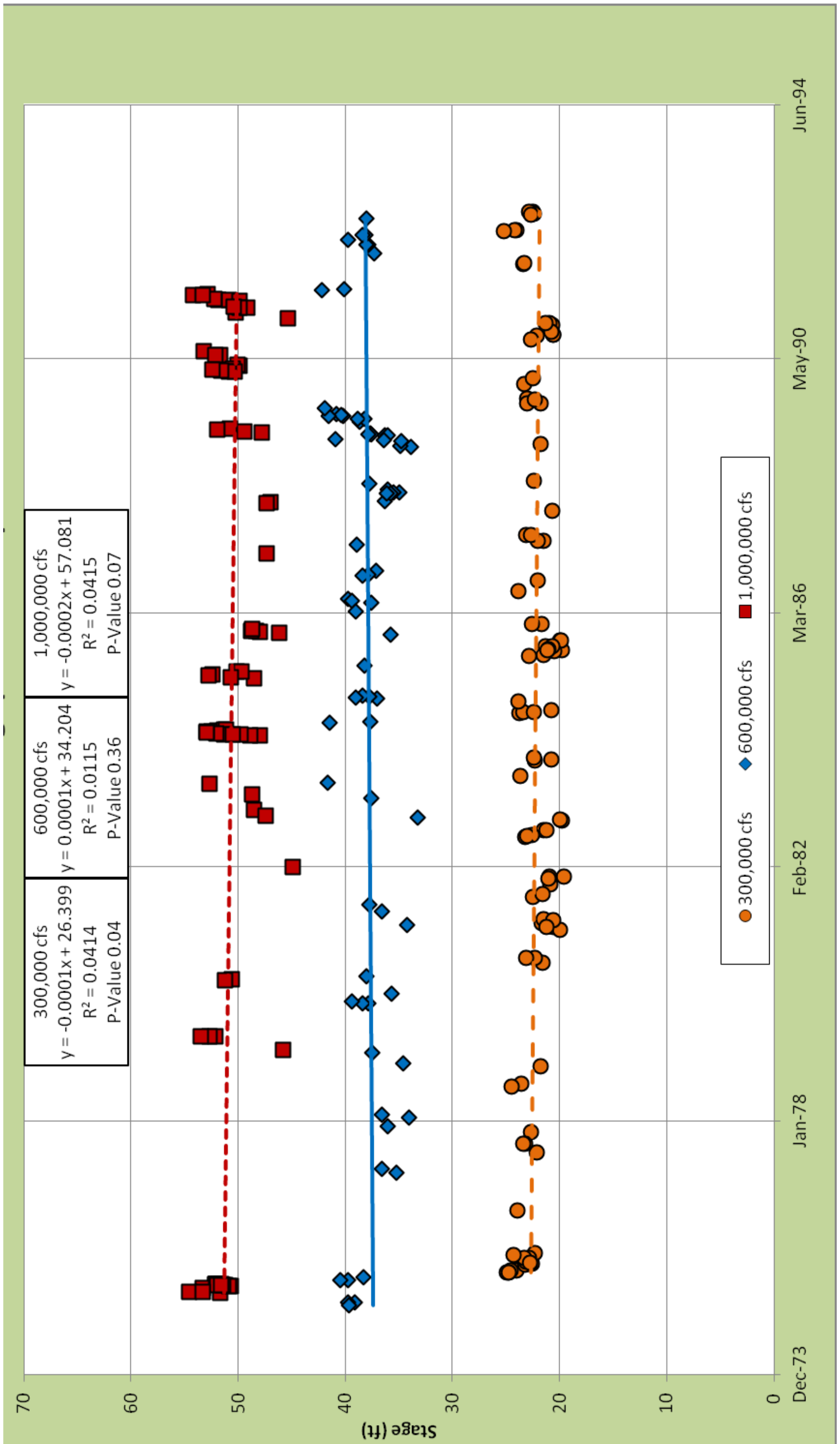


Figure 66. Red River Landing specific gage record, 1993–2003.

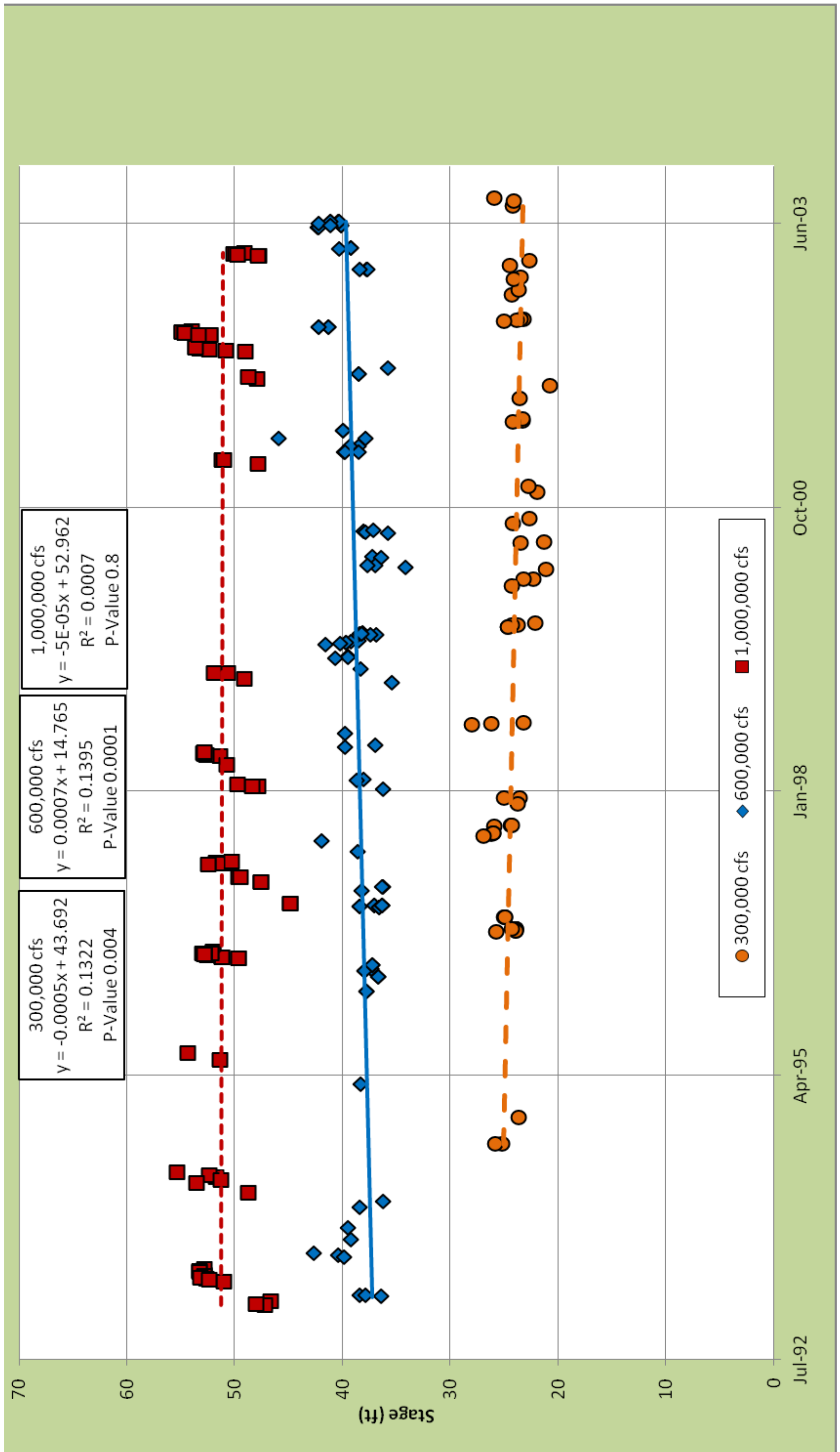


Figure 67. Red River Landing specific gage record, 1993–2011.

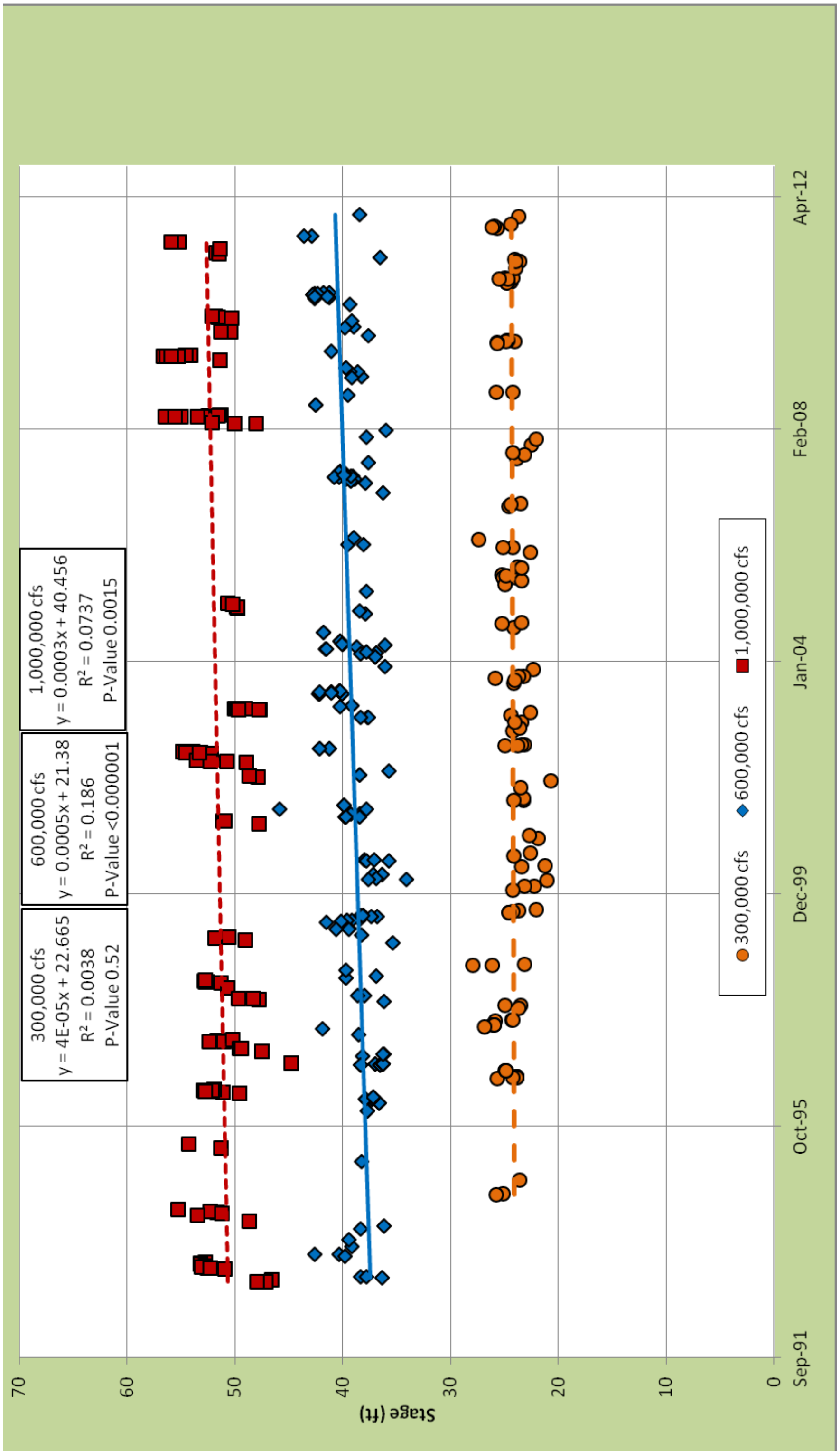


Figure 68. Bayou Sara specific gage record, 1963–1974.

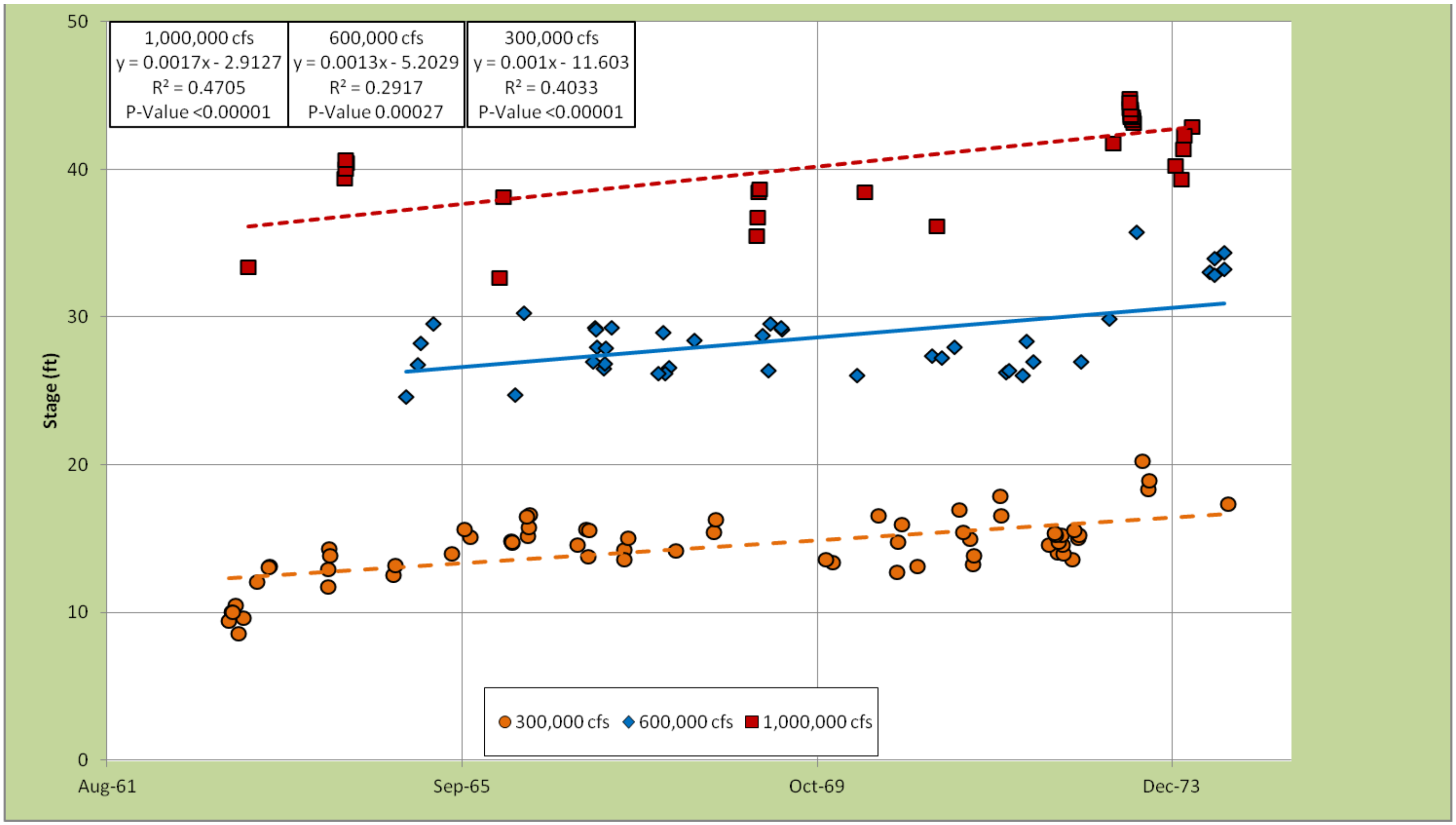


Figure 69. Bayou Sara specific gage record, 1975–2011.

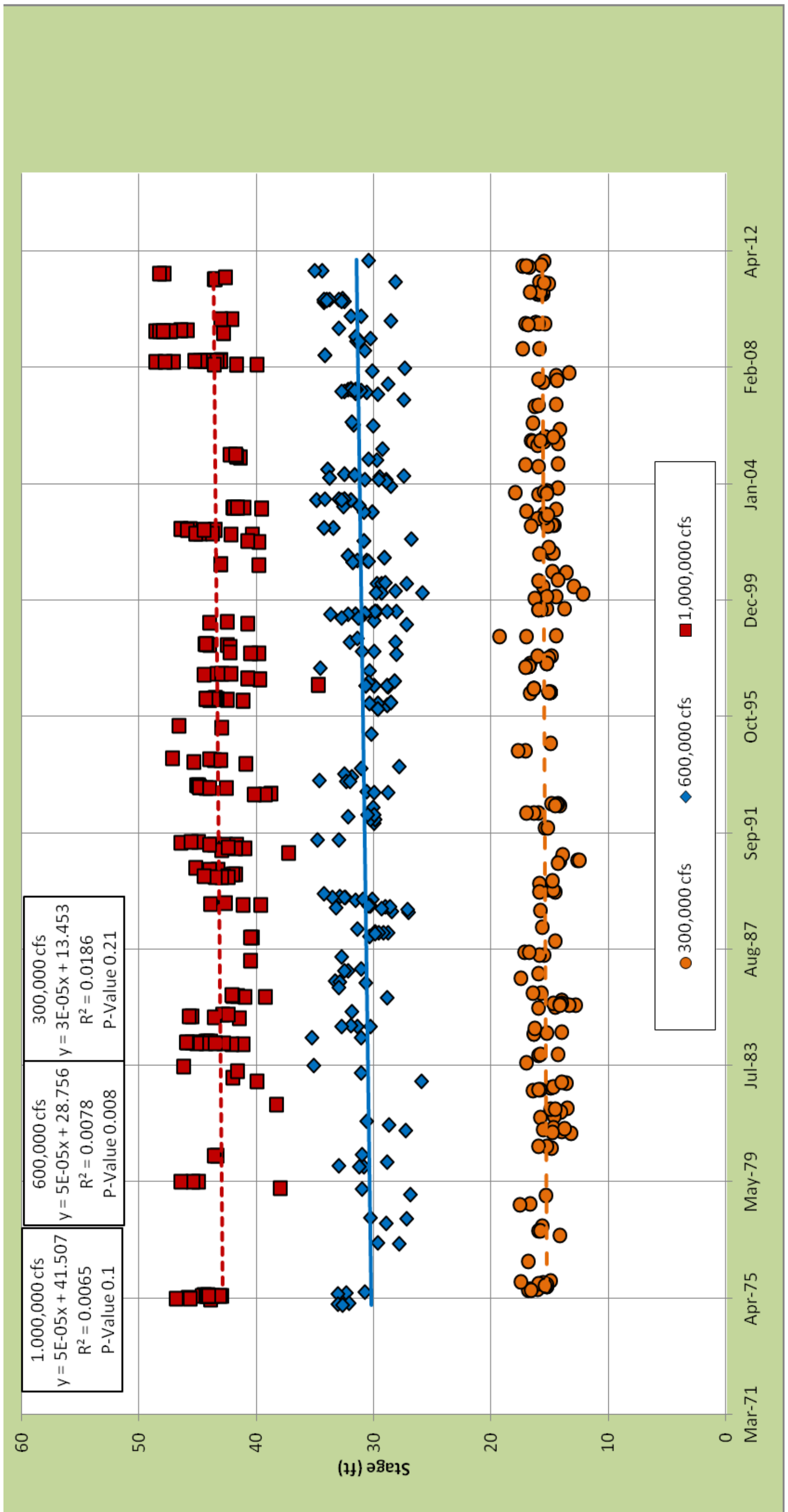


Figure 70. Bayou Sara specific gage record, 1975–1992.

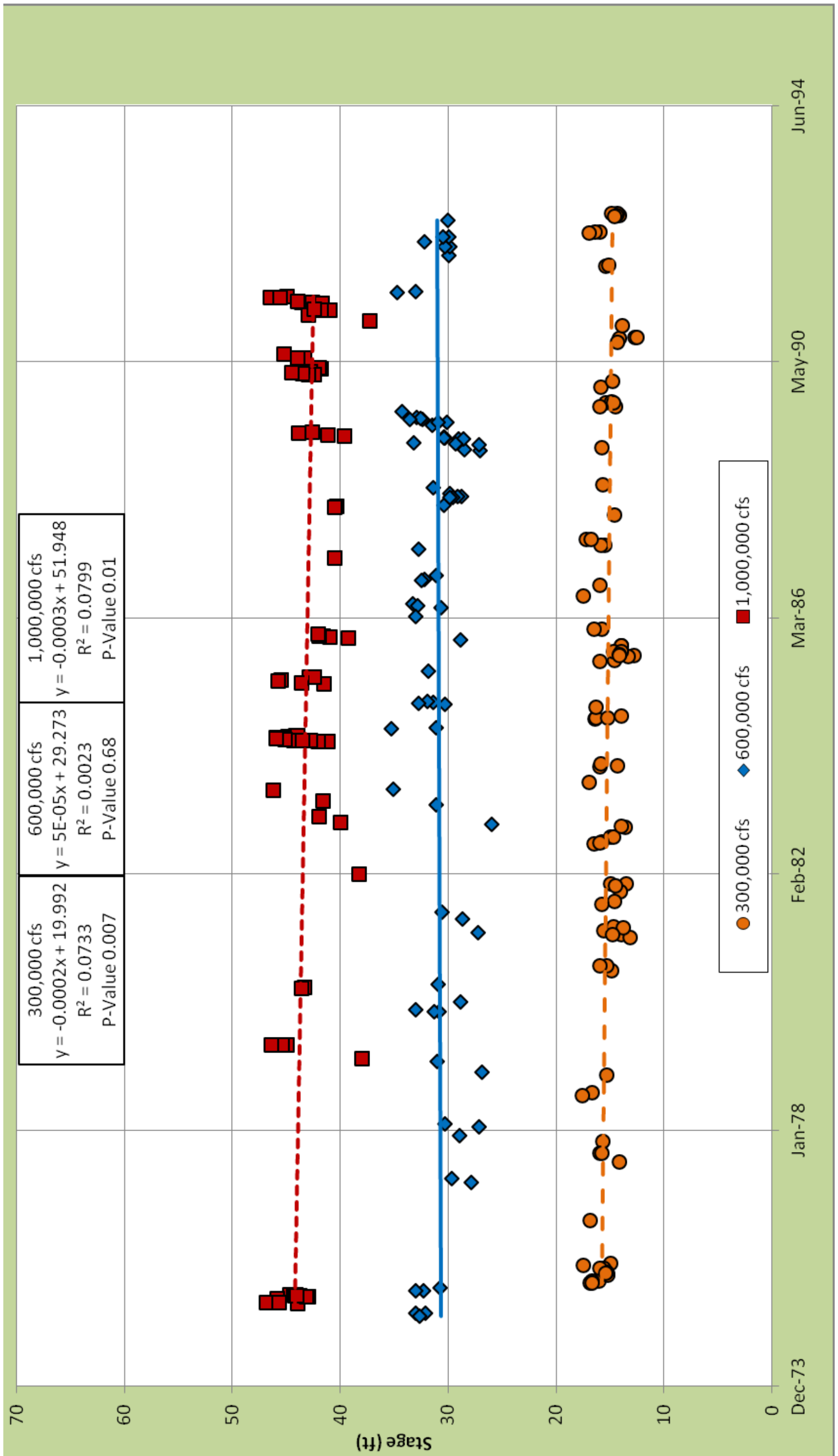
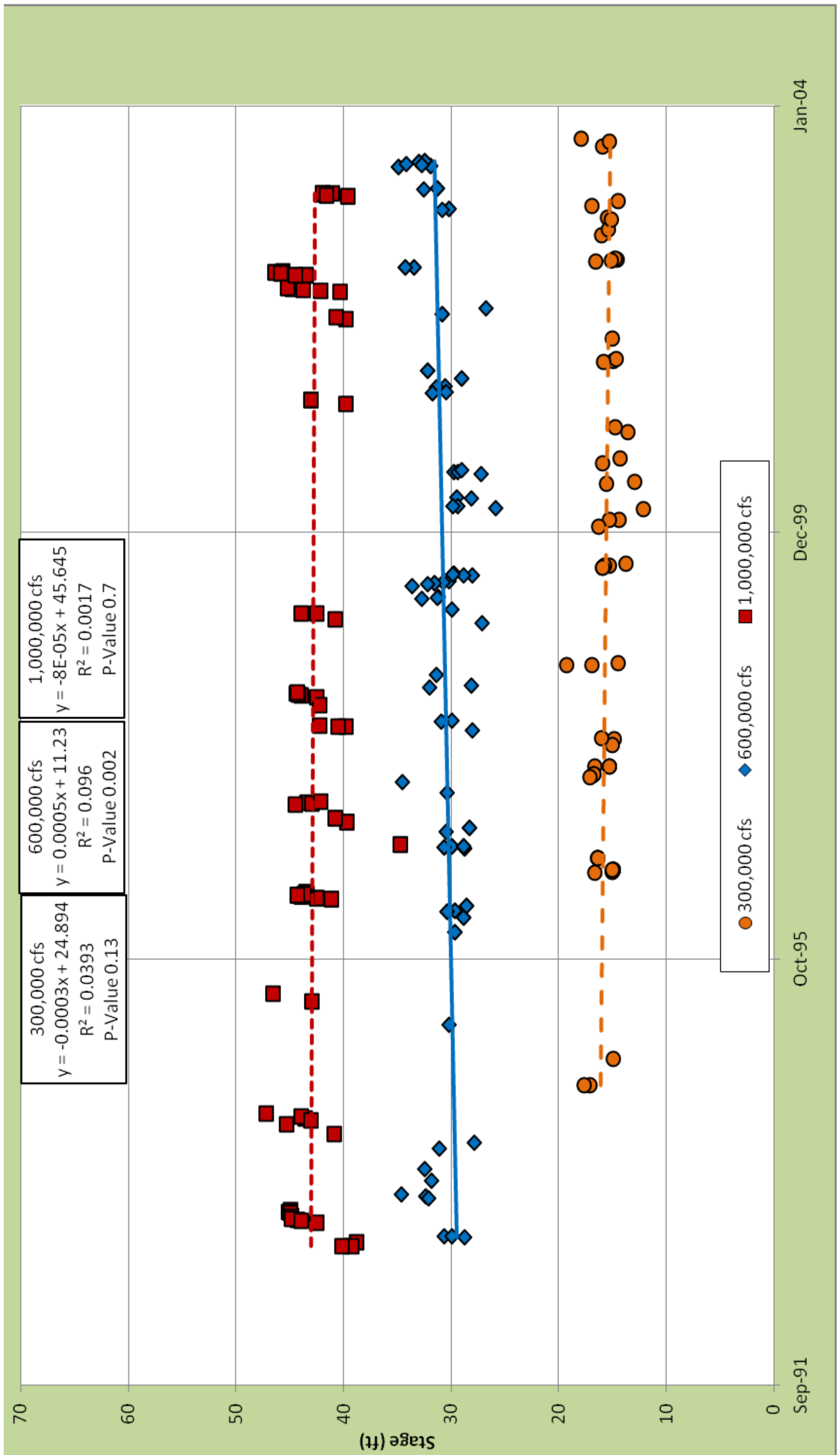


Figure 71. Bayou Sara specific gage record, 1993–2003.



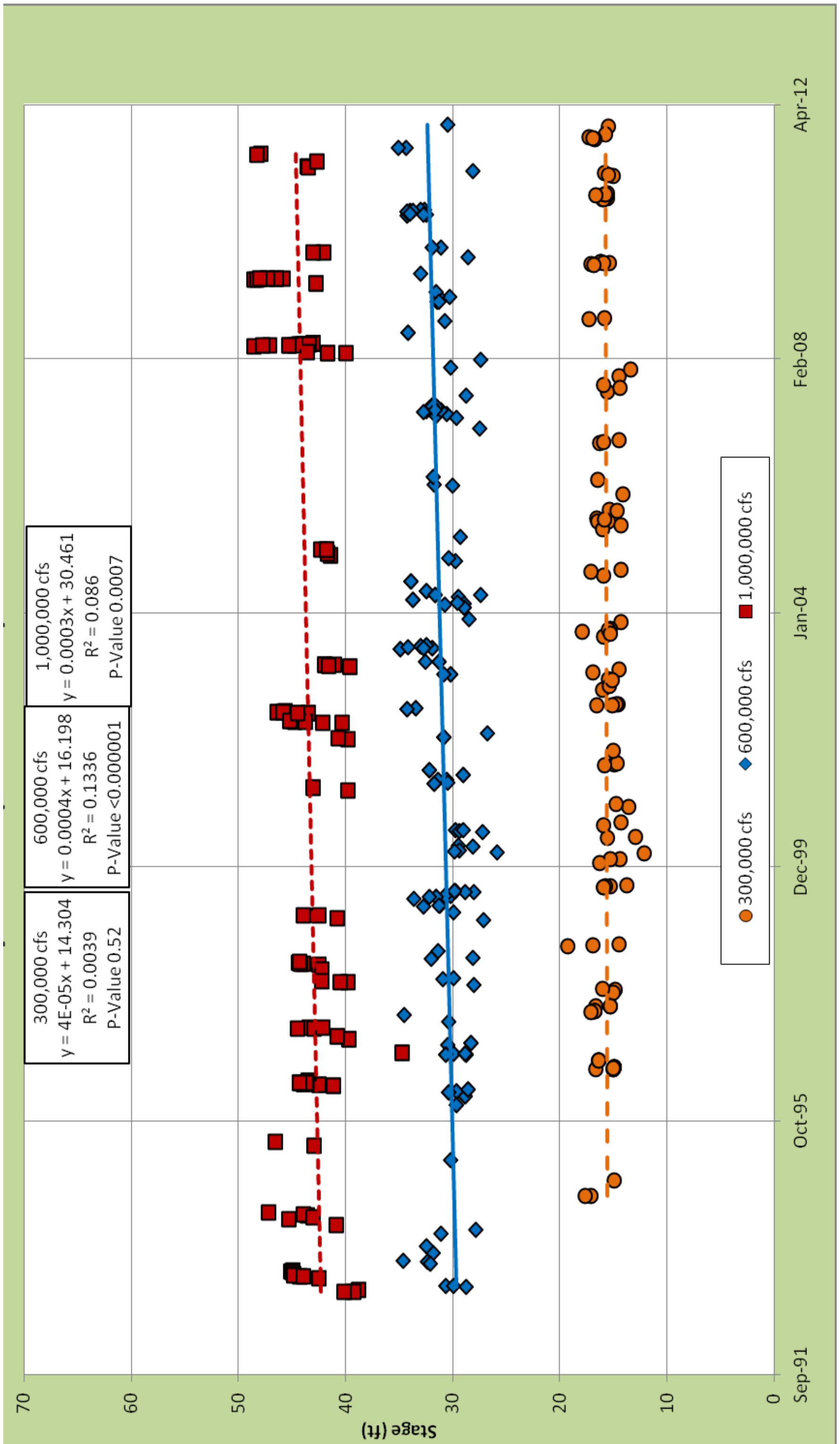


Figure 72. Bayou Sara specific gage record, 1993–2011.

For the 1993–2003 period (Figure 71), there was a statistically significant increasing trend at the 600,000 cfs flow. However, no trends were observed at the 300,000 cfs and 1 million cfs flows. A slight increasing stage trend was identified for the 600,000 cfs and 1 million cfs flows for the 1993–2011 period, but the 300,000 cfs flow exhibited no trend (Figure 72).

4.2.3 Baton Rouge specific gage record

The specific gage record for the Baton Rouge gage for the period 1963–1974 is shown in Figure 73. This figure shows that all three regression lines are statistically significant, indicating an aggradational trend during this time period, again, primarily driven by the 1973 flood. The specific gage record for the 1975–2011 time period is shown in Figure 74 and indicates very slight increasing trends at the three discharges. However, only the trend for the 600,000 cfs flow is statistically significant, and the R^2 values for all three flows are extremely small (all less than 0.05). Therefore, the overall assessment suggests that the stage trends have been relatively stable during this time period. The specific gage records for the 1975–1992, 1993–2003, and 1993–2011 periods are shown in Figures 75, 76, and 77, respectively. For the 1975–1992 period (Figure 75), a statistically significant decreasing trend was observed at the 300,000 cfs flow. However, the trends at 600,000 cfs and 1 million cfs were insignificant and inconclusive, respectively. For the 1993–2003 period (Figure 76), there was a statistically significant increasing trend at the 600,000 cfs flow. However, no trends were observed at the 300,000 cfs and 1 million cfs flows. A slight increasing stage trend was identified for the 600,000 cfs and 1 million cfs flows for the 1993–2011 period, but the trend for the 300,000 cfs flow was inconclusive (Figure 77).

4.2.4 Donaldsonville specific gage record

The specific gage record for the Donaldsonville gage for the period 1963–1974 is shown in Figure 78. Similar to the previous stations, there is a statistically significant aggradational trend during this period that is dominated by the 1973 flood. Figure 79 shows the specific gage record for the 1975–2011 time period and indicates a statistically significant degradational trend. A closer examination of the specific gage records indicates that most of the lowering may have occurred in the earlier part of the time period. As shown in Figure 80, the specific gage record indicates a statistically significant degradational trend at all flows for the time period 1975–1992. The specific gage records for the 1993–2003 and 1993–2011 time periods are shown in Figures 81 and 82, respectively. For both time periods,

Figure 73. Baton Rouge specific gage record, 1963–1974.

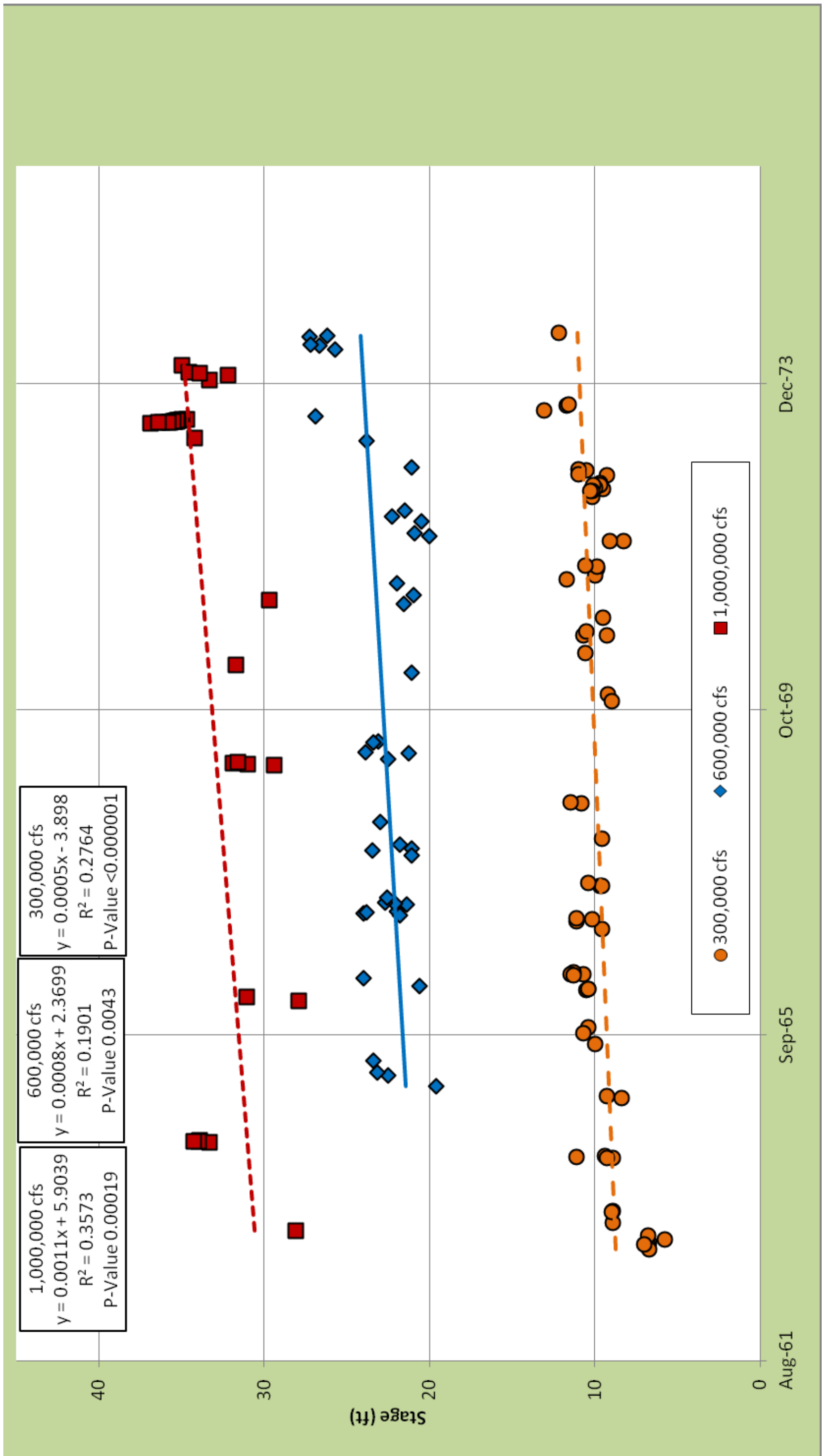


Figure 74. Baton Rouge specific gage record, 1975–2011.

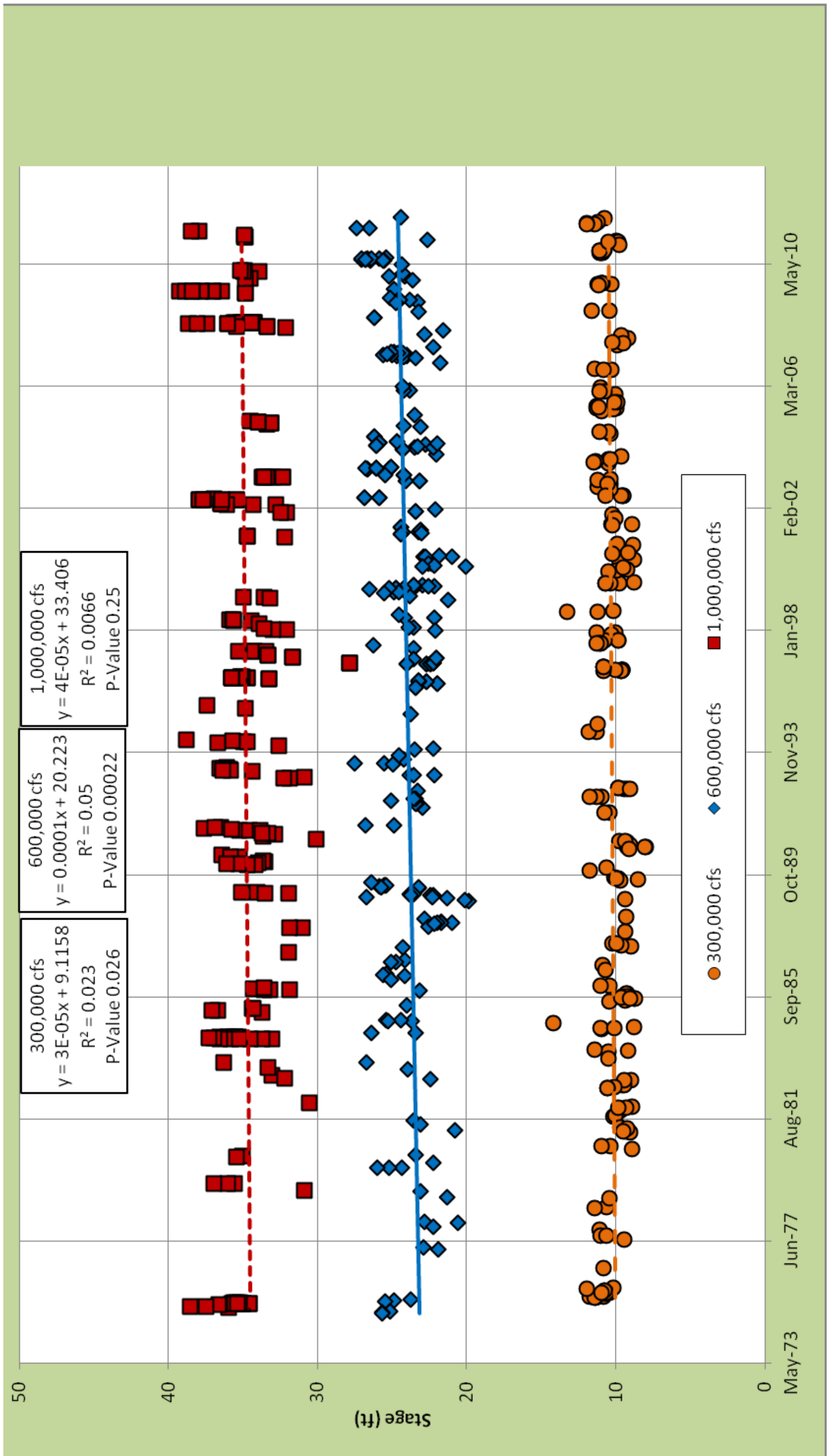


Figure 75. Baton Rouge specific gage record, 1975–1992.

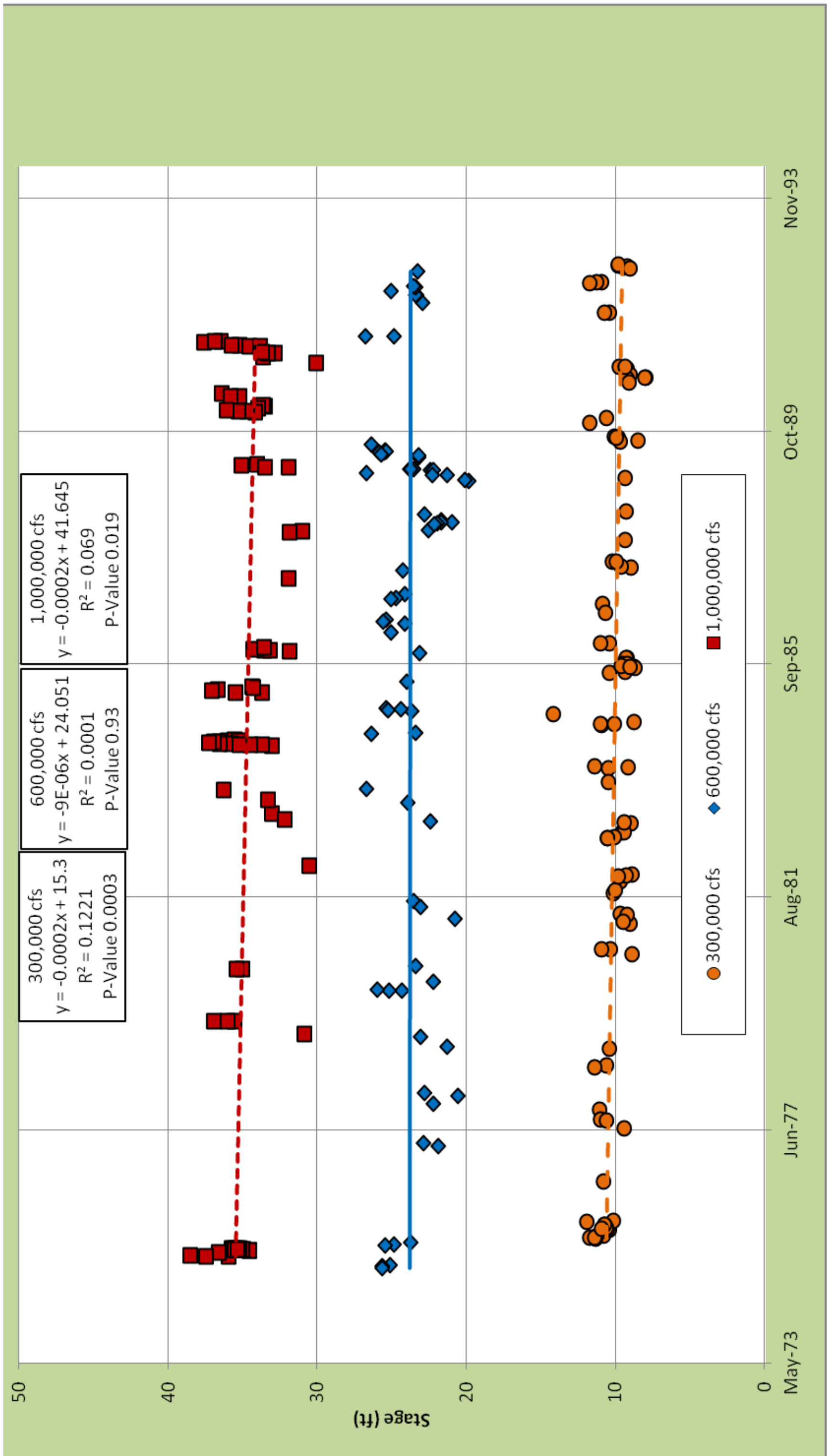


Figure 76. Baton Rouge specific gage record, 1993–2003.

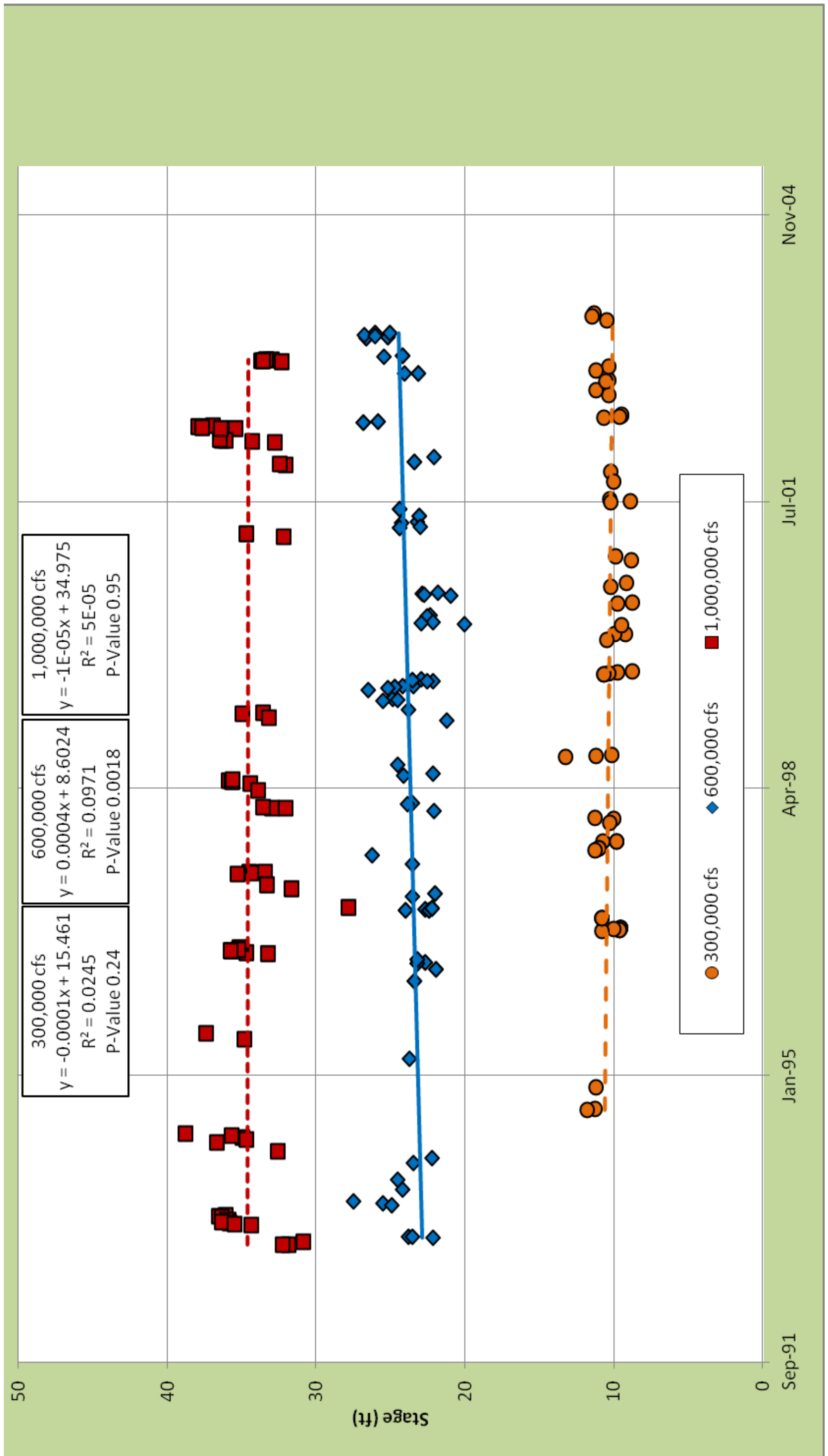


Figure 77. Baton Rouge specific gage record, 1993–2011.

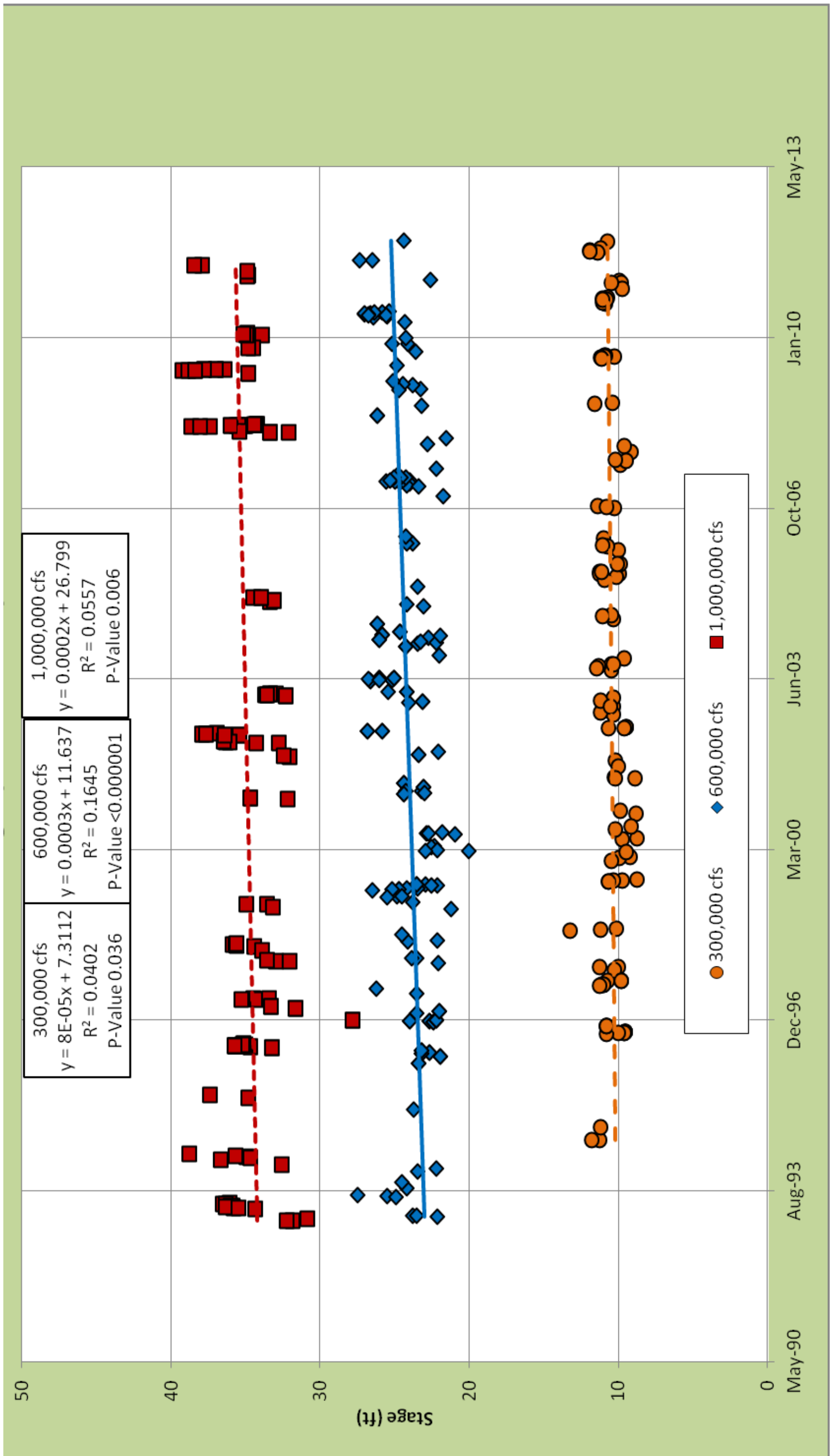


Figure 78. Donaldsonville specific gage record, 1963–1974.

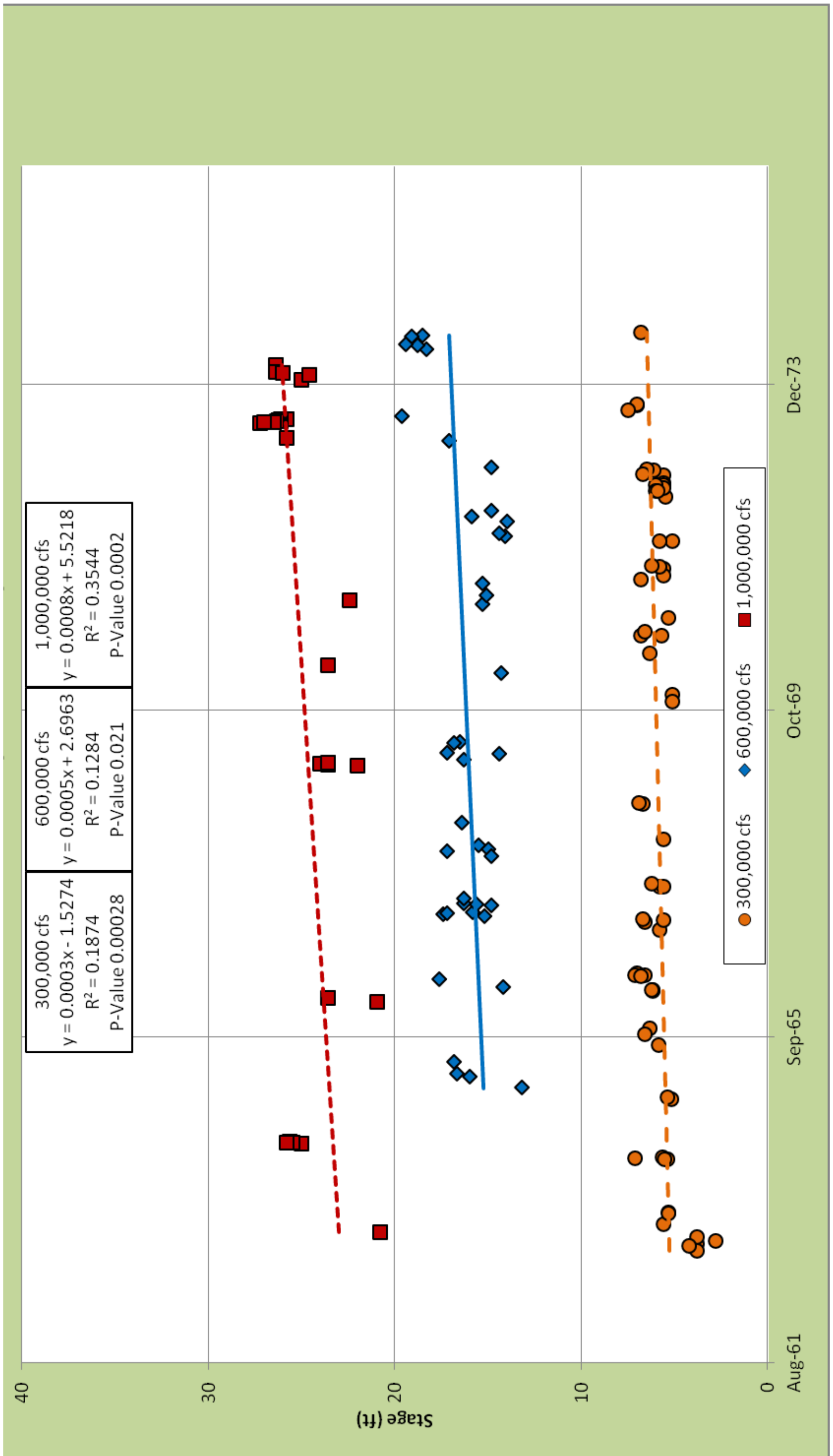
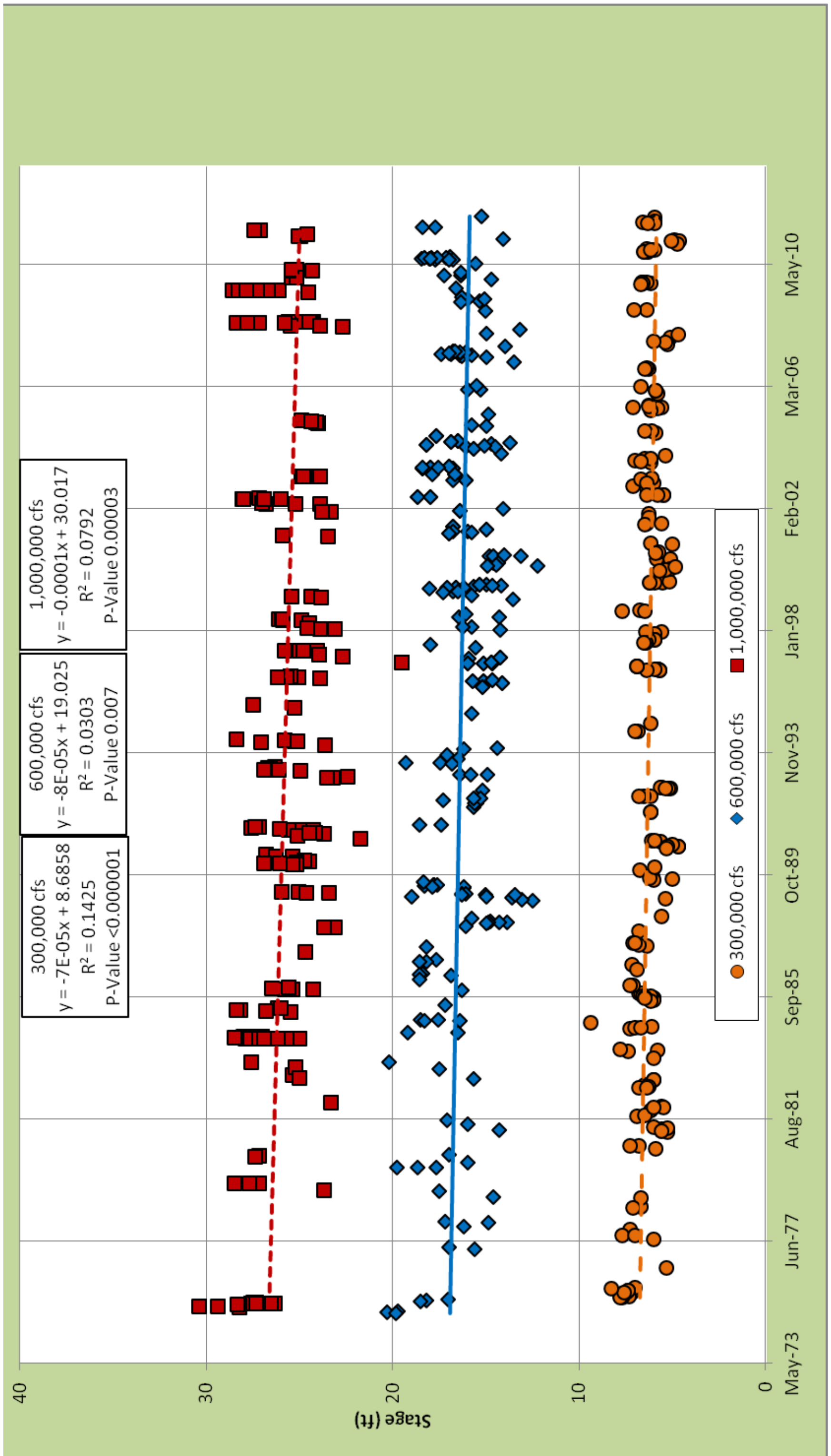


Figure 79. Donaldsonville specific gage record, 1975–2011.



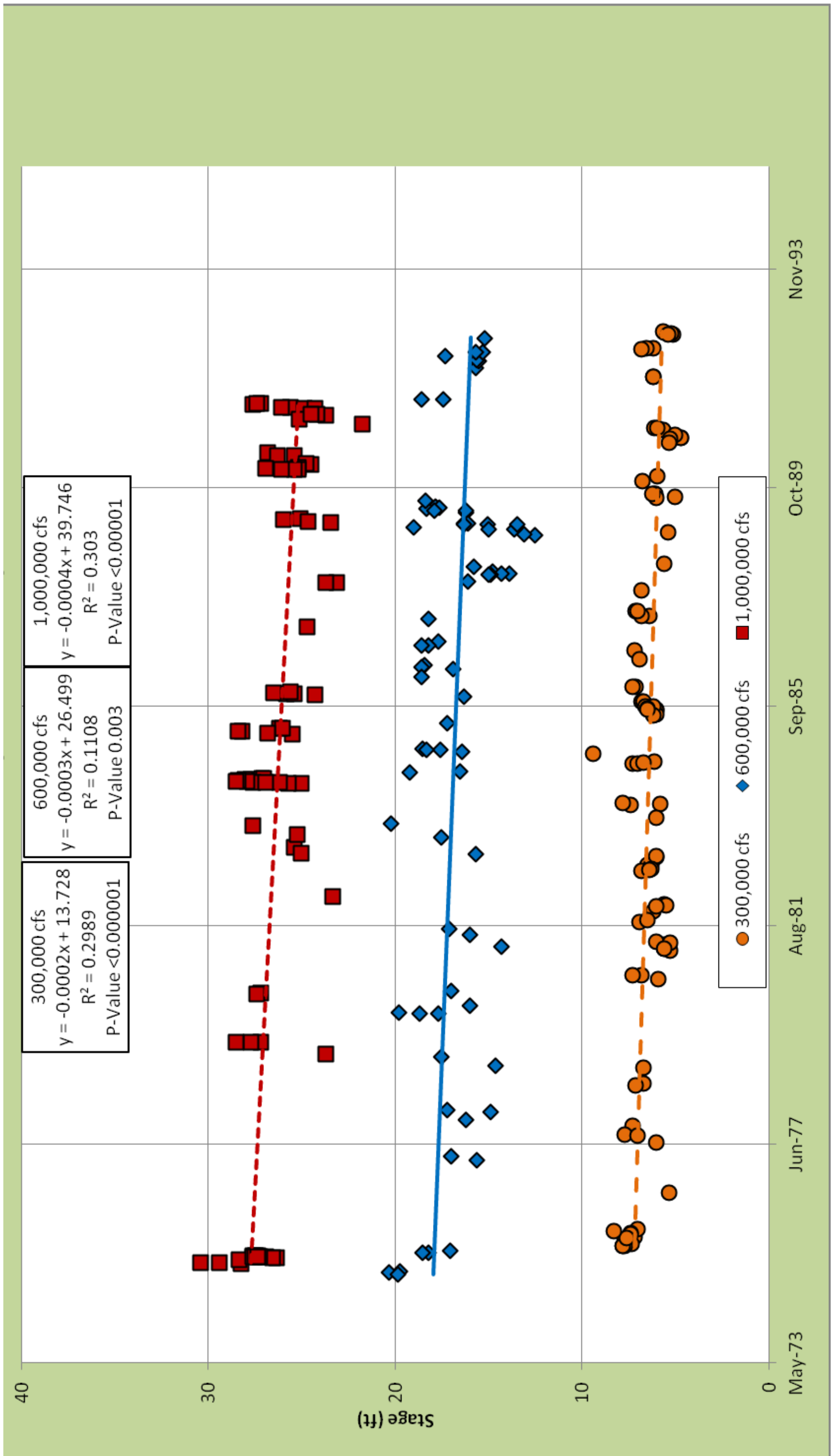


Figure 80. Donaldsonville specific gage record, 1975–1992.

Figure 81. Donaldsonville specific gage record, 1993–2003.

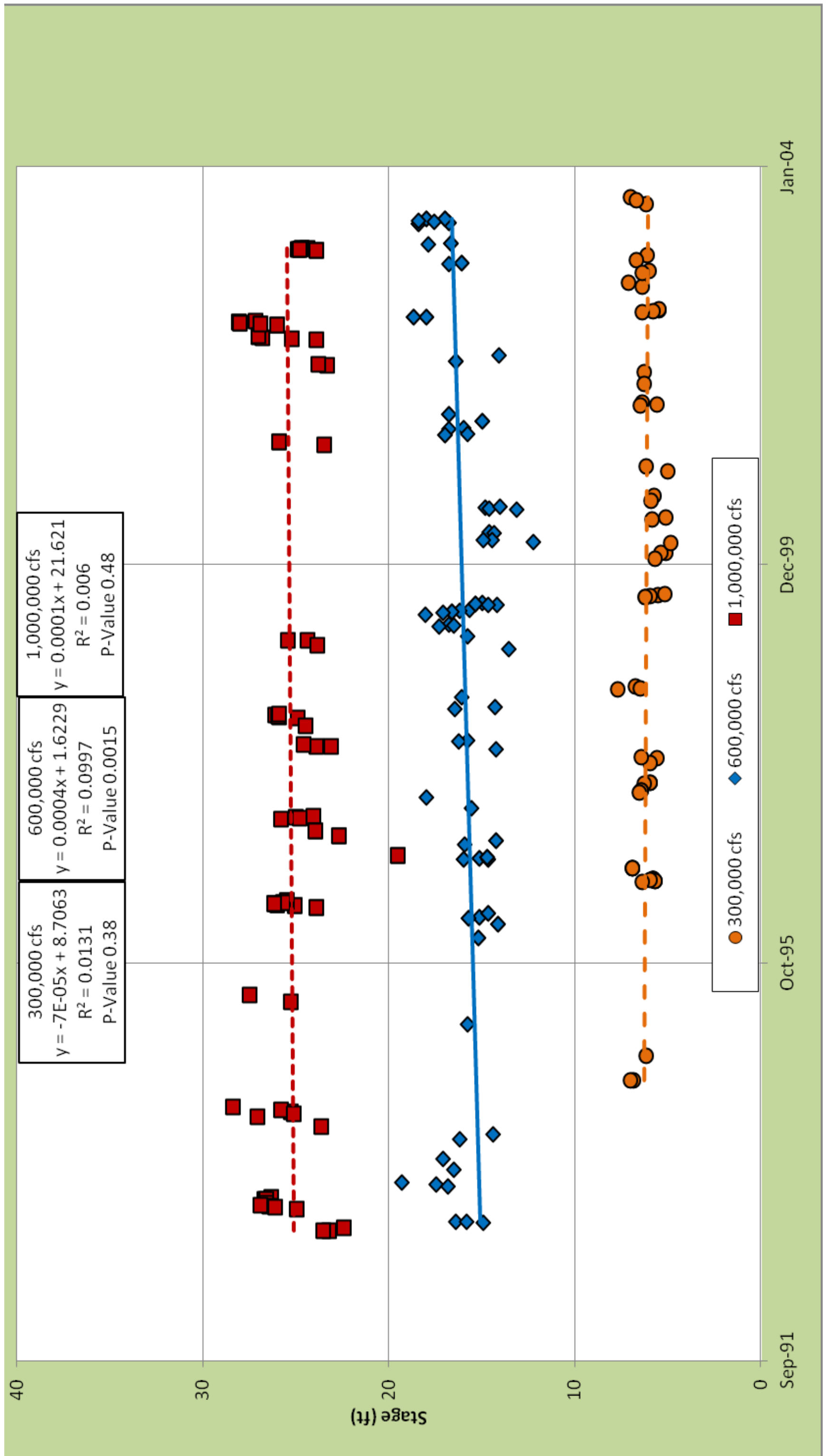
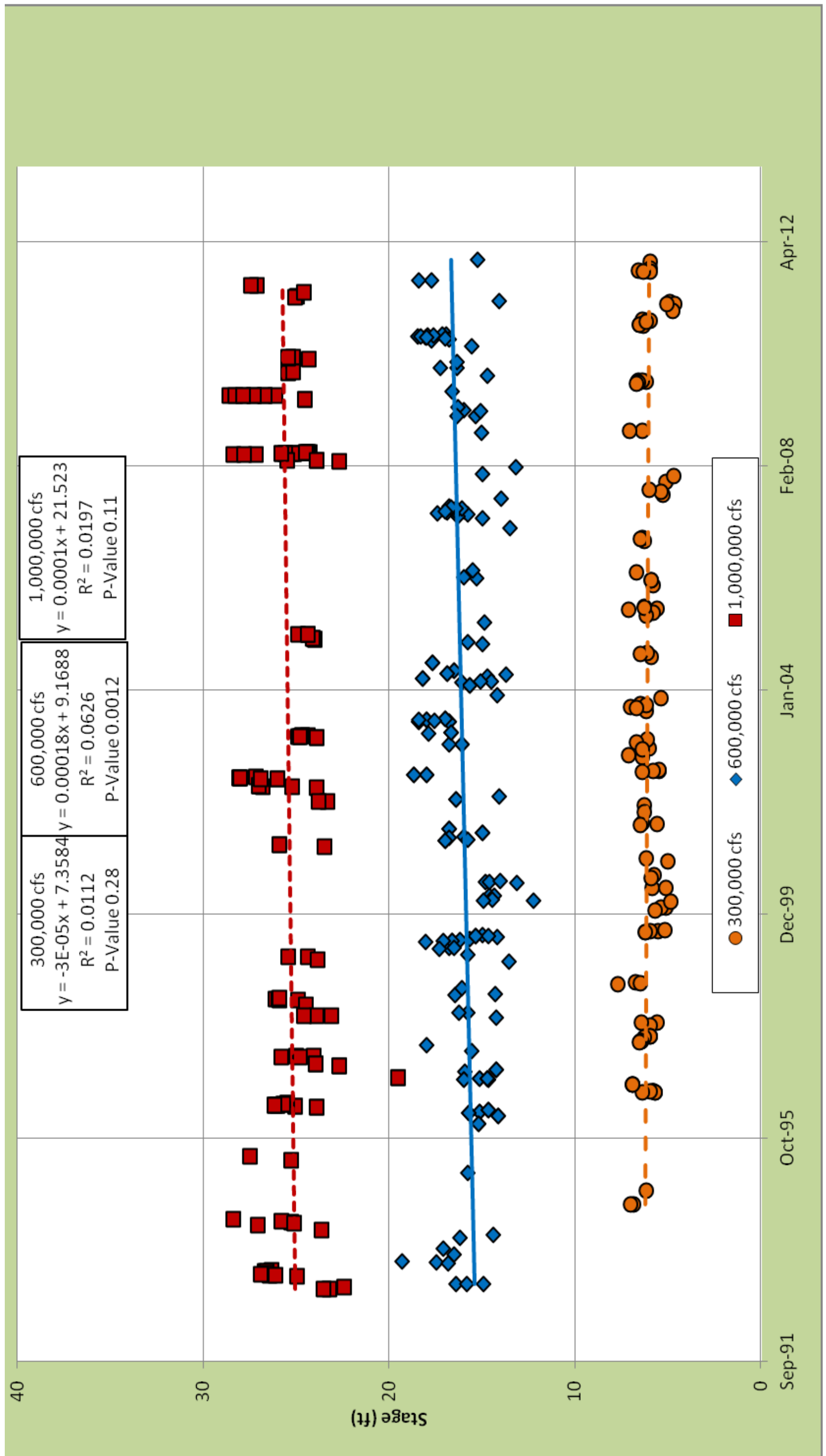


Figure 82. Donaldsonville specific gage record, 1993–2011.



there are no statistically significant stage trends at the 300,000 cfs and 1 million cfs flows. While the stage trends at 600,000 cfs are statistically significant, the R^2 values are low (less than 0.1) and the regression slopes are very small. Therefore, the overall assessment for the post-1993 time periods is that the stage trends are relatively stable. It should also be noted that the Donaldsonville record reflects lagged flows from Tarbert Landing, and because of the distance between these gages, there is more uncertainty in the results than for the stations farther upstream.

4.2.5 Algiers Lock specific gage record

The specific gage record developed at the Algiers Lock gage is shown in Figure 83. This specific gage record was developed by combining the discharge data that were obtained as part of the USGS sediment measurements at Belle Chasse with the daily stage record at Algiers Lock. The data spans the time period from 1978 to 2012. However, there is an approximate 10 yr gap in the discharge data between June 1997 and May 1997 when no discharge data were available. As shown in Figure 83, all three flows indicate apparent degradational trends. However, only the trend for the 1 million cfs flow is statistically significant. The 300,000 cfs trend is inconclusive, and the 600,000 cfs trend is insignificant. Another complicating issue is the 10 yr data gap, which adds another layer of uncertainty to the interpretation of the stage trends. Because of this uncertainty and the relatively weak statistical results, the results at this gage are considered inconclusive.

4.2.6 West Pointe a La Hache specific gage record

The specific gage record developed at the West Pointe a La Hache gage is shown in Figure 84. This specific gage record was developed by combining the discharge data that were obtained as part of the USGS sediment measurements at Belle Chasse with the daily stage record at West Pointe a La Hache. As with the Algiers Lock record, there is an approximate 10 yr gap in the discharge data between June 1997 and May 1997 when no discharge data were available. As shown in Figure 84, there were no statistically significant trends at any of the flows. Once again, the 10 yr gap in the data makes it difficult to draw any definite conclusions with respect to long term trends.

Figure 83. Algiers Lock specific gage record, 1978–2012.

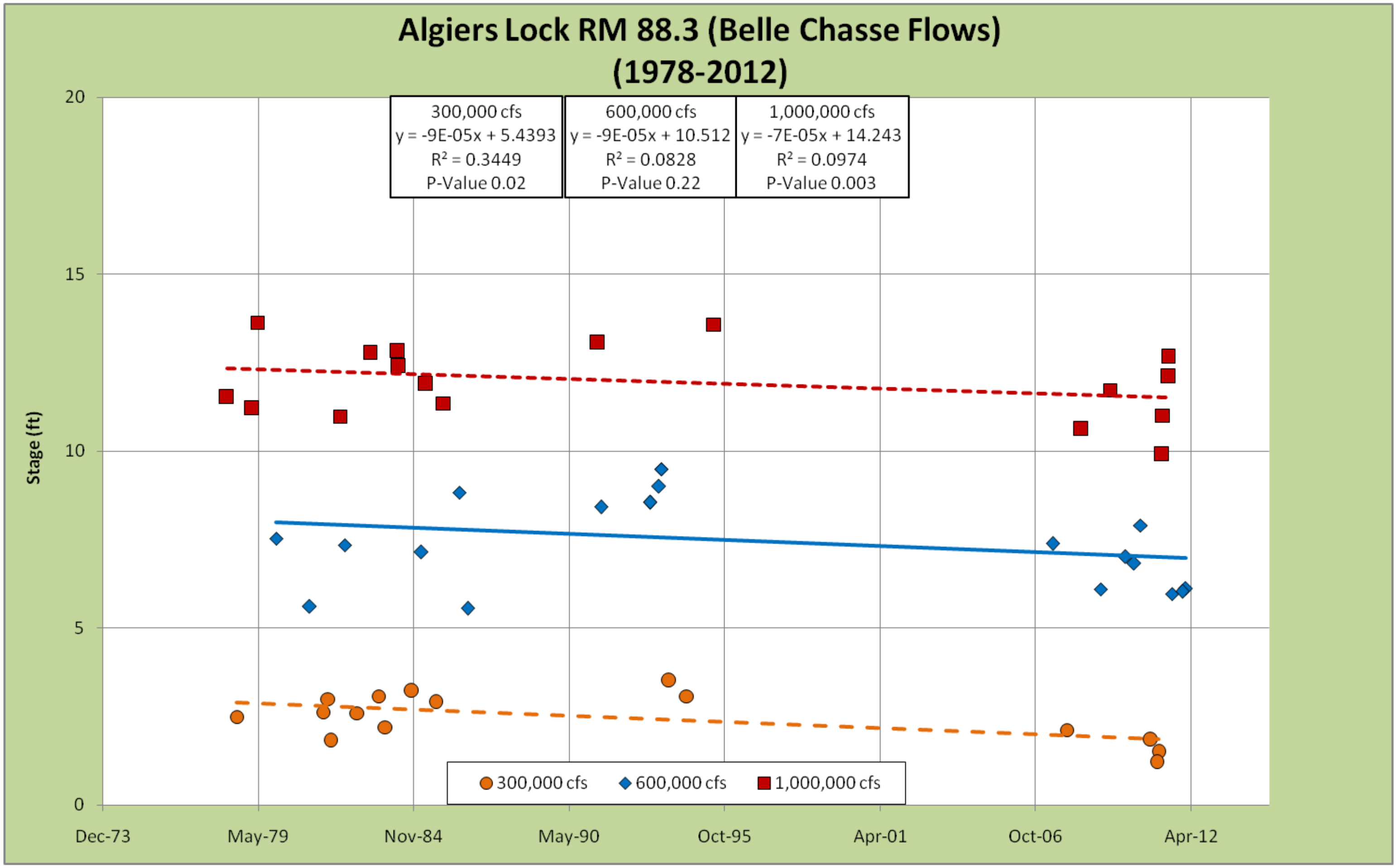
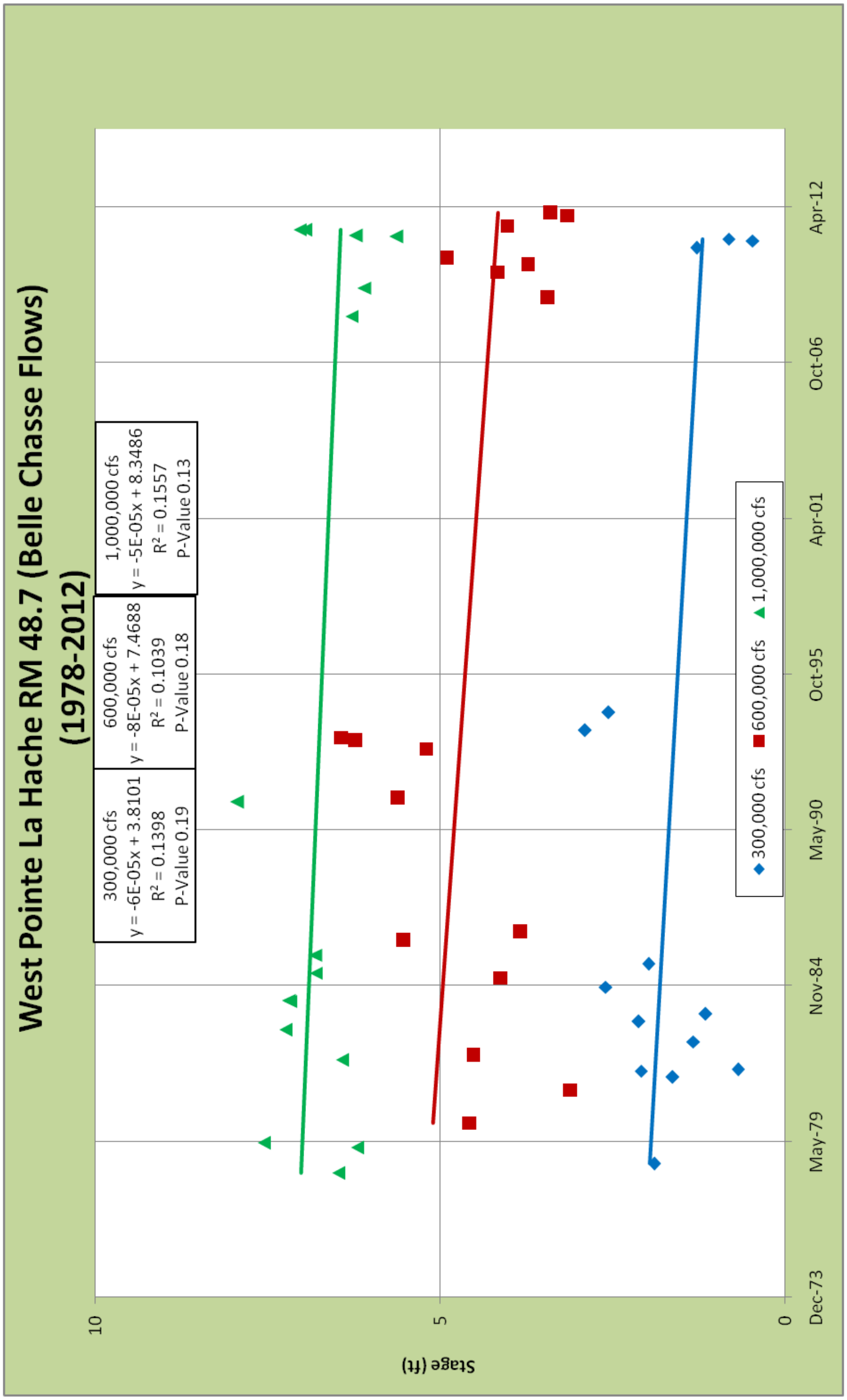


Figure 84. West Pointe a La Hache specific gage record, 1978–2012.



4.3 Dredge Records Analysis Results

The Mississippi River crossings that generally require some degree of dredging to maintain the deep-draft and shallow-draft navigation channel are listed in Table 18. Crossings that require dredging within the deep draft navigation channel are generally located in an 84-mile reach between Baton Rouge and Belmont, with the exception of Fairview located downstream of Bonnet Carré floodway near Kenner. No deep-draft channel crossings downstream of New Orleans have ever required maintenance dredging. Crossings within the shallow-draft navigation channel are Smithland, Bayou Sara, and Wilkerson Point. The Smithland reach is in the vicinity of the Hog Point dikes and channel realignment. The annual maintenance dredge reports obtained for this study cover the period of fiscal years 1970–2011. For the period 1970–1979, the annual reports list the yearly dredge volumes collectively for all crossings. Beginning in 1980, the reports list the dredge volumes individually for each crossing for most years. Figure 85 shows the annual dredge volumes for all river crossing locations collectively. The average annual dredge volume for the period 1970–2011 is approximately 13.3 million cubic yards (MCY). The average annual dredge volumes for the time periods prior to and subsequent to the deepening of the navigation project in 1987 from –40 to –45 feet elevation are 8.3 MCY and 17.2 MCY, respectively. As expected, the annual dredge needs increase with the deeper navigation project. To determine if the increased dredge volumes may be related to the hydrology of the period, the yearly maximum discharges at Tarbert Landing were superimposed on the chart. The annual dredging volumes appear to be reasonably correlated with the peak discharges for the entire time period with the exception of the late 1970s period. Given that the magnitude and frequency of yearly peak discharges are generally consistent before and after project modification, the increase in post-navigation project modification dredge volumes is most likely simply a result of the deeper draft requirement.

Table 18. Mississippi River channel crossing locations.

Crossing	RM	Crossing	RM
Smithland*	297–305 (in 3 reaches)	Bayou Goula	194–199
Bayou Sara*	263–268	Alhambra	188–193
Wilkerson Point*	234–237	Philadelphia Point	181–185
Baton Rouge Front	229–234	Smoke Bend	172–179
Redeye	221–226	Rich Bend	155–160
Sardine Point	216–221	Belmont	150–155
Medora	208–214	Fairview	111–117
Granada	202–207	*located in shallow draft channel	

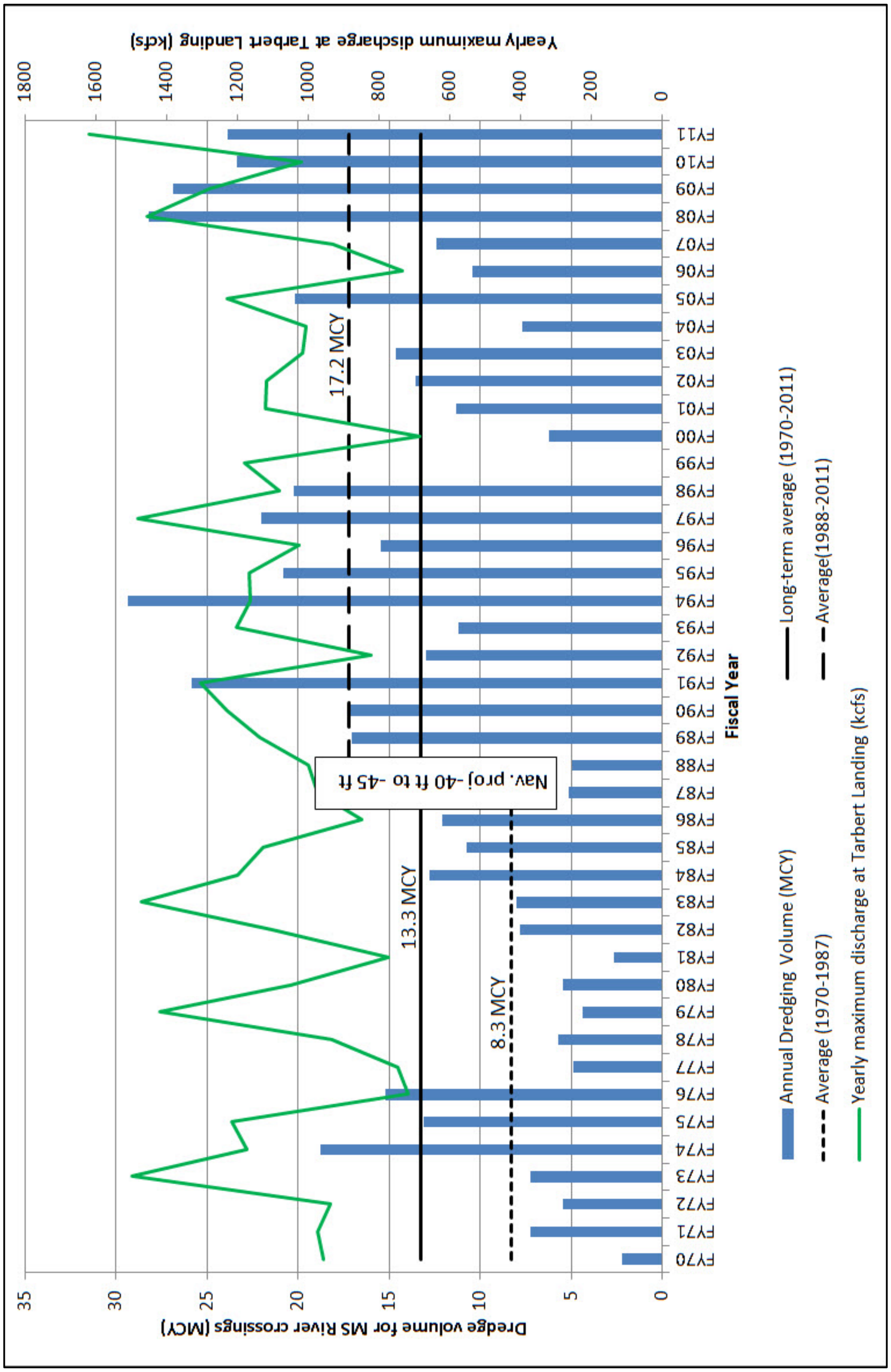


Figure 85. Annual dredge quantities for Mississippi River crossings.

For the time period 1980–2011, the percentage of years that annual maintenance dredging was required at each crossing location is shown in Figure 86. Figure 87 illustrates the frequency and magnitude of dredge volumes for the individual crossing locations. The deep–draft crossings at Redeye, Medora, Granada, Bayou Goula, Alhambra, and Belmont required annual maintenance dredging for over 80% of the years from 1970 to 2011. The rest of the deep draft crossings required dredging between 30% and 70% of the years, except for the crossings at Rich Bend and Fairview. For the crossings located in the shallow-draft navigation channel, percentages range from near 60% for Wilkerson Point to approximately 6% for Bayou Sara. Figure 87 indicates that the crossing at Redeye requires the greatest quantity of dredging. Dikes were constructed at Redeye crossing in the mid-1990s to alleviate dredge needs, but the site continues to be the most problematic in terms of required maintenance. Alhambra, Belmont, and Medora require the next-most dredging after Redeye. The dikes and channel realignment at Smithland appear to be functioning effectively as no dredging has been required since construction of the features in the mid-1990s. Dikes were also constructed at Medora crossing in 2000 and appear to be reasonably effective in reducing required maintenance dredging. More recently, dikes were constructed in 2006 at Springfield Bend near RM 241.5 AHP, but these dikes were constructed to correct an alignment problem more than a shoaling problem. Figure 88 shows the magnitude and frequency of maintenance dredging requirements for four of the more troublesome crossings: Redeye, Medora, Alhambra, and Belmont.

In general, the dredge record analysis shows that the river crossing areas are very active in terms of sediment deposition and that many crossings in the upper half of the deep draft channel between Baton Rouge and Bonnet Carré require regular maintenance dredging to ensure navigable depths. The geometry data analysis indicates that crossings in the lower half of the deep-draft channel downstream of Bonnet Carré are also subject to active sedimentation processes, yet depths are sufficient such that maintenance dredging is not required. Increases in required maintenance dredging at the crossings appear to reasonably correspond to increases in river discharge. The regular dredging that occurs at the crossing locations in the reach from Baton Rouge to Bonnet Carré results in long-term, consistent elevations at these crossings.

Figure 86. Percentage of years between 1980 and 2011 requiring maintenance dredging at Mississippi River crossings.

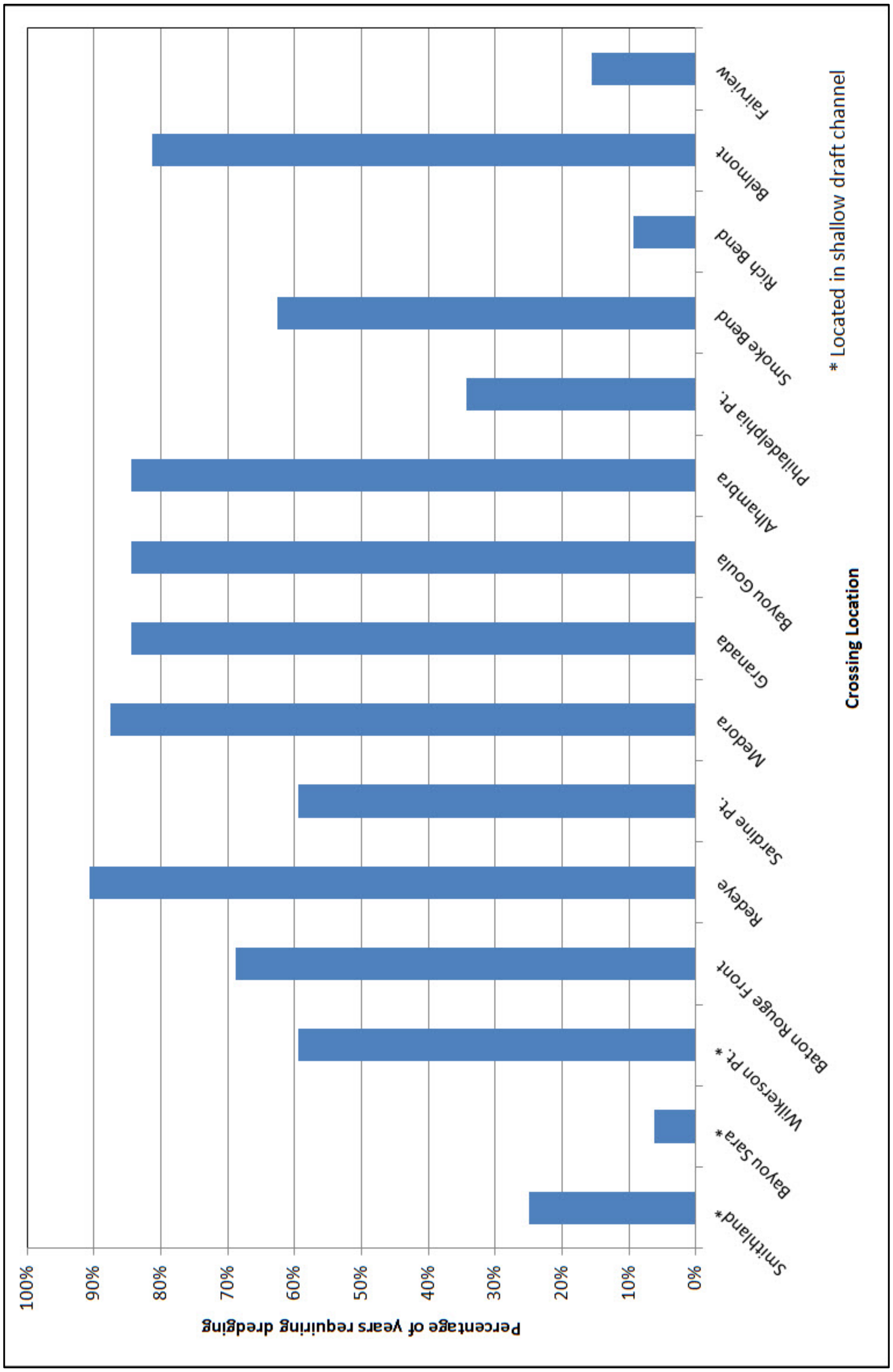


Figure 87. Magnitude and frequency of maintenance dredging at Mississippi River crossings, 1980–2011.

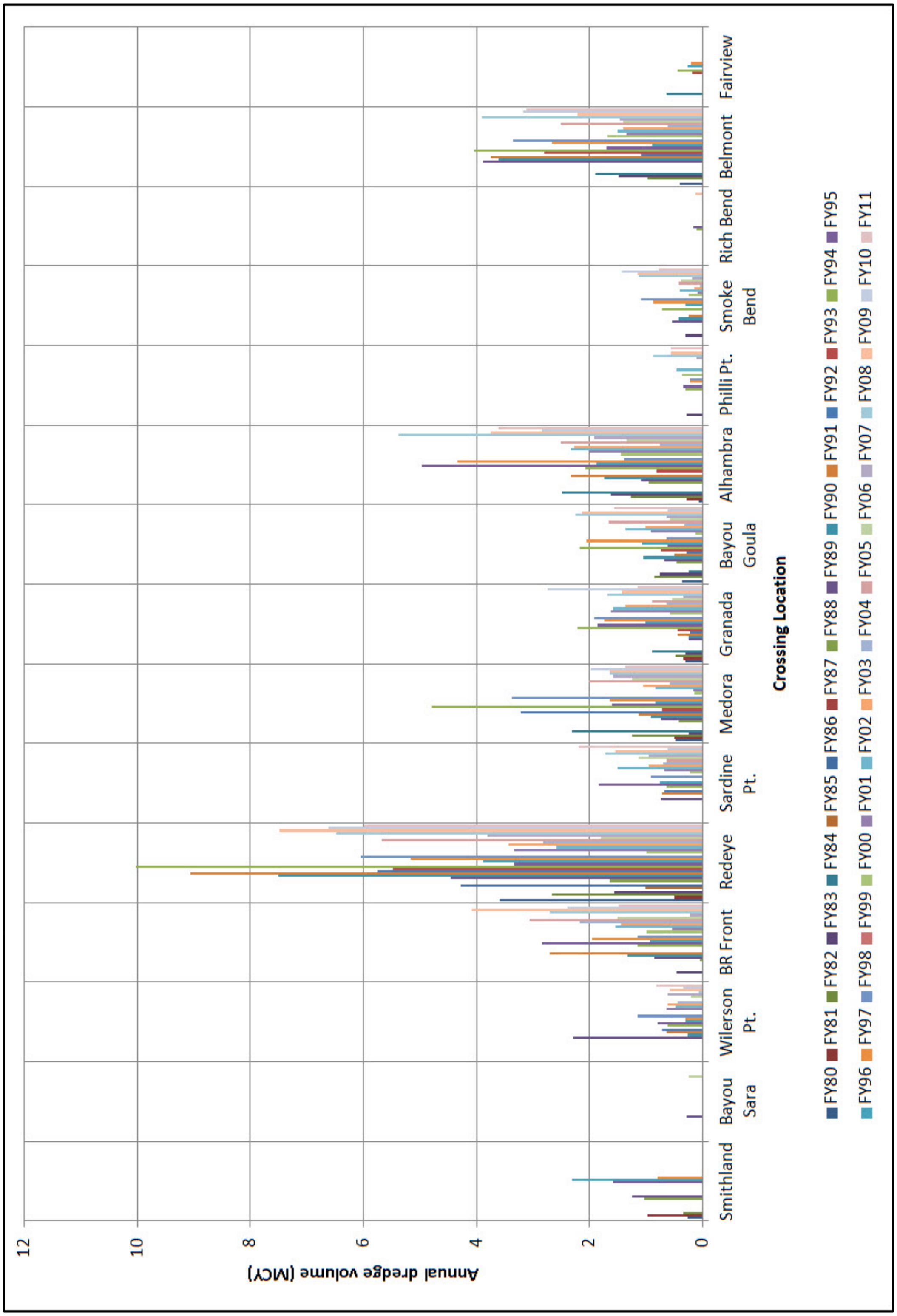
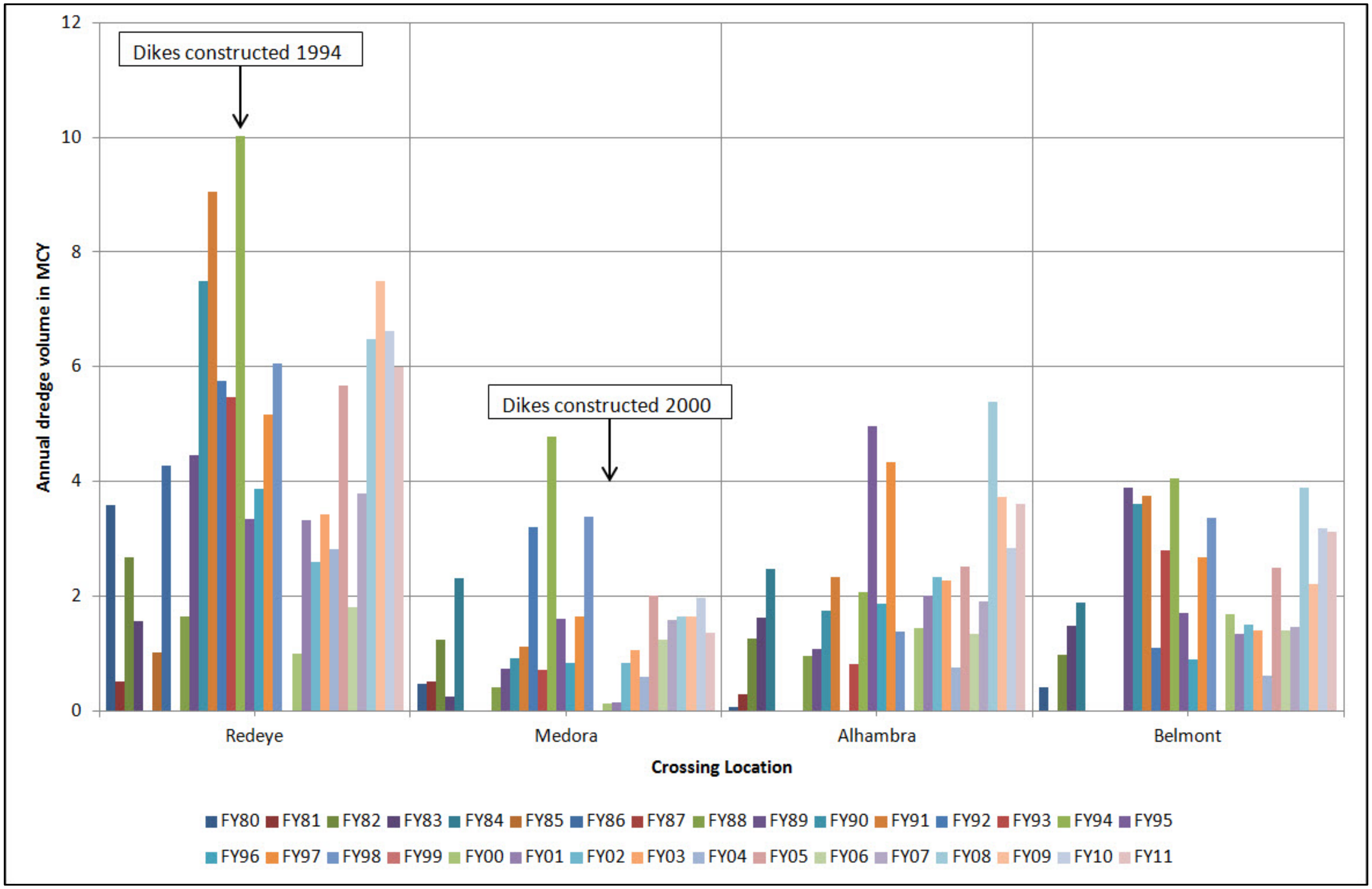


Figure 88. Magnitude and frequency of Mississippi River maintenance dredging at Redeye, Medora, Alhambra, and Belmont crossings, 1980–2011.



4.4 Sediment Data Analysis Results

This section discusses the spatial and temporal trends in sediment data within the study area. The first section describes the changes in sediment (fines and sands) concentrations since the 1950s; the second section discusses the probabilistic sediment budget; and the last section describes the changes in bed material composition.

4.4.1 Temporal changes in measured suspended sediment concentrations

As discussed in Section 3.5.3, one of the first steps in the development of the PSB was to develop the regression equations describing the sediment-discharge relationships at the study gages. However, there are numerous studies that document the long-term reductions in the sediment loads on the Mississippi River over the past 50–150 yr (Mead and Moody 2010; Horowitz 2010; Keown et al. 1981; Kesel 1988; Robbins 1977). Therefore, it was first necessary to ensure that there were no increasing or decreasing trends in the sediment concentration during the time period that the regressions were developed. Since Tarbert Landing had the longest record of measured suspended data, an analysis of these data was conducted to examine temporal trends spanning several decades.

Tarbert Landing data were collected using four different methods at different time intervals during the study period. The 8-sample technique was used from 1986 to 1989 to collect suspended sediments at 70% of the total water column whereas the 12-, 20-, and 40-sample techniques sampled 90% of the water column. Therefore, suspended sand concentration data were examined for potential effects from the four collection methods, particularly regarding the depth at which samples were collected, as this could bias the percentage of sand present in the sample. Sample number differed among the collection methods, and the homogeneity of variance assumption was violated (Brown and Forsythe's F=7.92; df=3,698; p<.0001); therefore, Welch's analysis of variance (ANOVA) was used to test for differences among sampling techniques, which were statistically significant (F=43.43; df=3,127; p<.0001). The 8-sample technique was significantly lower than all other techniques (p<.0001) indicating that collecting suspended sand from only 70% of the water column underestimates the actual concentration of sand present. In subsequent analyses, these data were excluded, and data collected with the remaining three techniques were combined. A similar analysis conducted for the fine concentrations data did not reveal any significant differences related to the sampling technique.

Polynomial analysis of covariance (ANCOVA) comparing mean fines concentration with discharge as the covariate revealed significant differences among decades with a discernible negative (decreasing) trend from the 1950s to 1980s. However, no significant trends were observed from the 1990s to present. Therefore, in order to avoid developing a regression curve over a period of decreasing concentrations, the study period for the fine sediment analysis was limited to the period from 1990 to 2012 when fine concentrations were unchanging. Polynomial ANCOVA for sand concentration data for the period 1959–2011, excluding 1986–1989, data revealed no monotonically decreasing trend over time. Because there was no discernible trend in the data, it was deemed acceptable to combine the sand data over the historical period of record.

4.4.2 Probabilistic sediment budget for sand loads

This section discusses the PSB for the sand loads between Tarbert Landing and Belle Chasse for the period 1973–2012. The methodology for the development of the PSB was discussed in Section 3.5. Figures 89, 90, 91, and 92 show the percentile plots for annual sand loads at Tarbert, St. Francisville, Baton Rouge, and Belle Chasse. The relationship among the four stations is illustrated graphically in the box plots shown in Figure 93. The bottom and top of the box represent the 25th and 75th percentile, respectively, and the band near the middle of the box represents the 50th (median) percentile. The ends of the whiskers represent the minimum and 95th percentile. Any data not included within the whiskers are shown as outliers. As shown in Figure 93, the whiskers and outliers extend over an extremely wide range of values. These extremes are not likely possibilities, and in order to more clearly illustrate the relationship among the stations, the box plots are shown in Figure 94 with the extremes outliers removed. The box plots provide an overall view of the sand-load characteristics at the four stations. As shown in Figure 94, there is an overall decrease in the sand loads between Tarbert Landing and Belle Chasse.

The sediment budget percentile curves for the Tarbert Landing to St. Francisville, St. Francisville to Baton Rouge, and Baton Rouge to Belle Chasse reaches are shown in Figures 95, 96, and 97, respectively. The methodology used for the development of these curves was discussed in Section 3.5.4. As shown in all three curves, there are extreme values associated with the lower and upper percentile ranges. These extremes are not likely possibilities, and a more likely range of practical outcomes occurs along the flatter portion of the curves for some distance on either side of the 50% value. As discussed in Section 3.5.4, the range selected for this study was based on the 35th and 65th percentile curves for the individual stations. As shown in Figures 95, 96, and 97, this resulted in a range between approximately the 30th and 70th percentile on the annual sand-load-change percentile plots. A brief discussion of the sand-load changes in each reach follows.

Figure 89. Percentage of annual Mississippi River sand loads at Tarbert Landing.

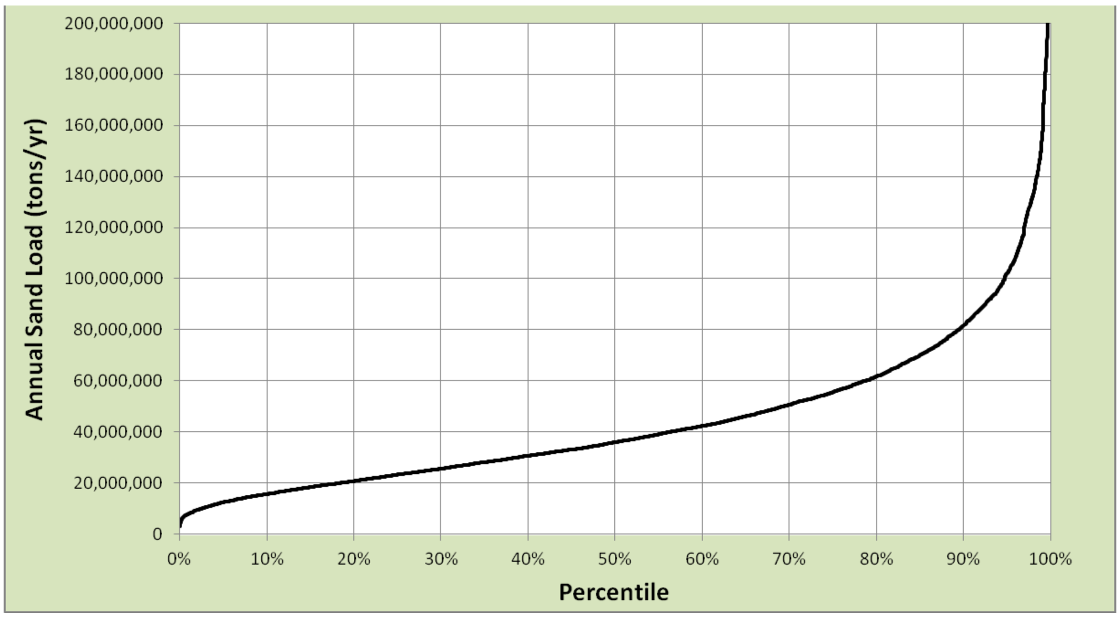


Figure 90. Percentage of annual Mississippi River sand loads at St Francisville.

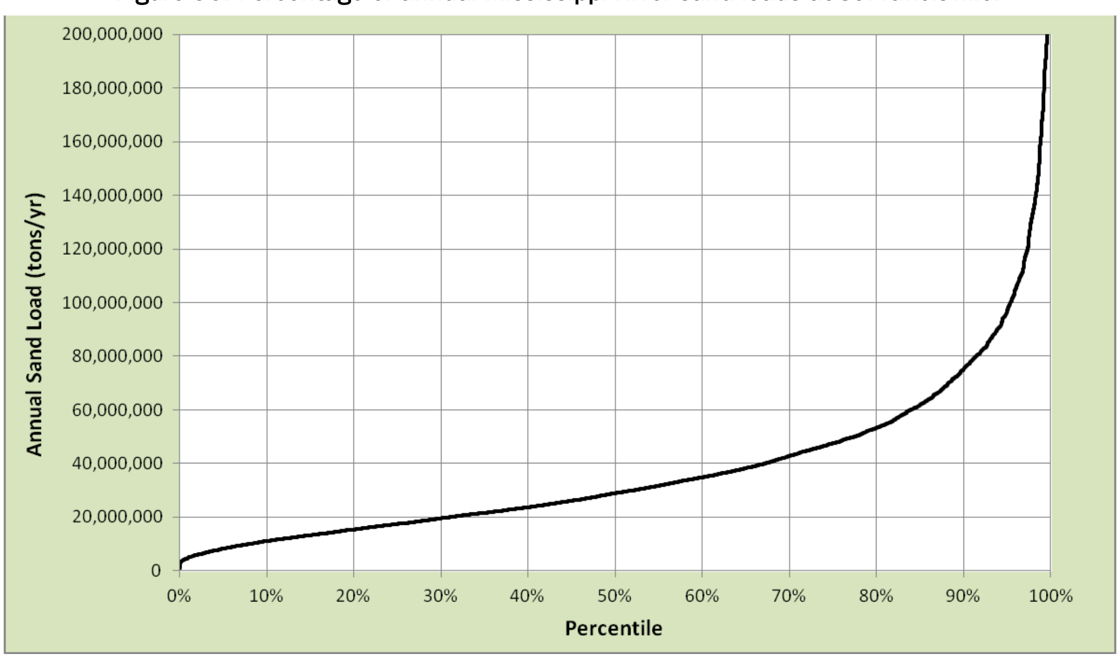


Figure 91. Percentage of annual Mississippi River sand loads at Baton Rouge.

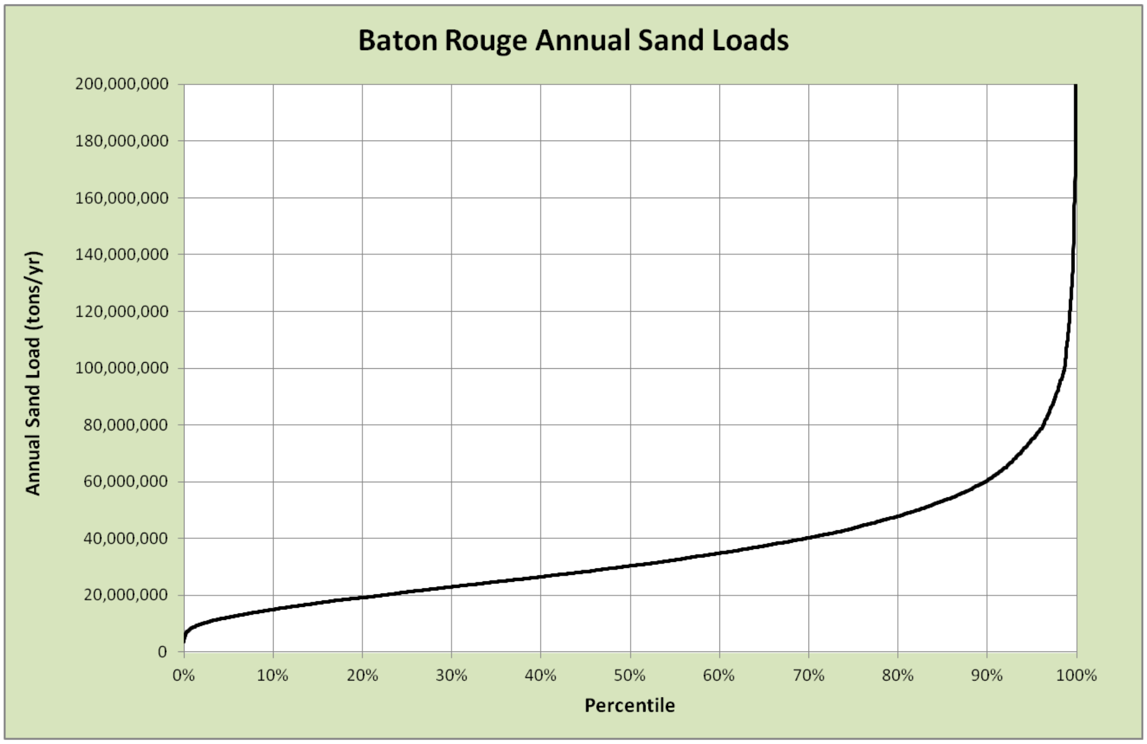


Figure 92. Percentage of annual Mississippi River sand loads at Belle Chasse.

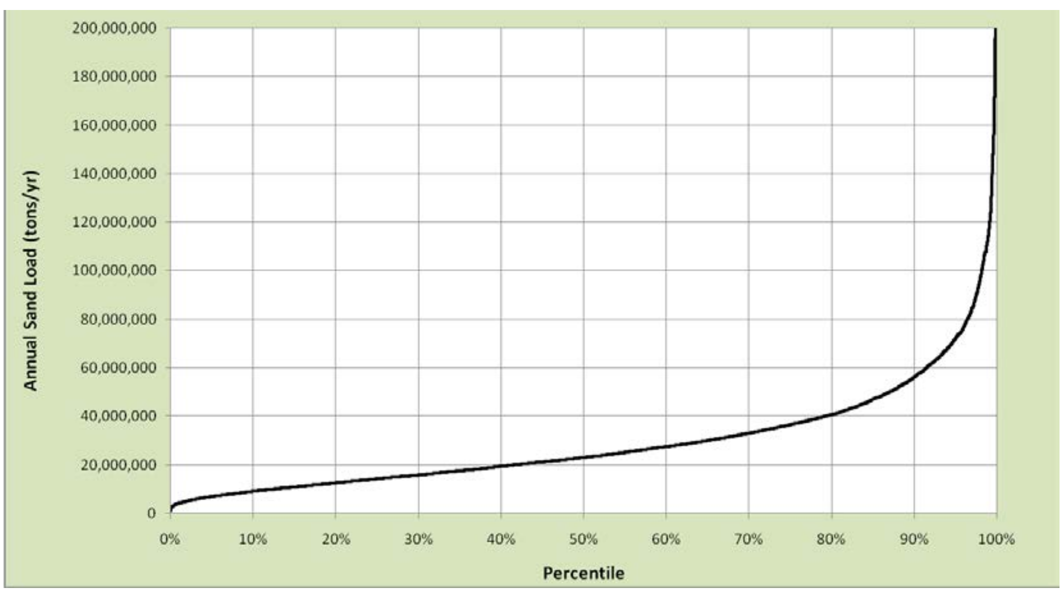


Figure 93. Annual Mississippi River sand load at Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse.

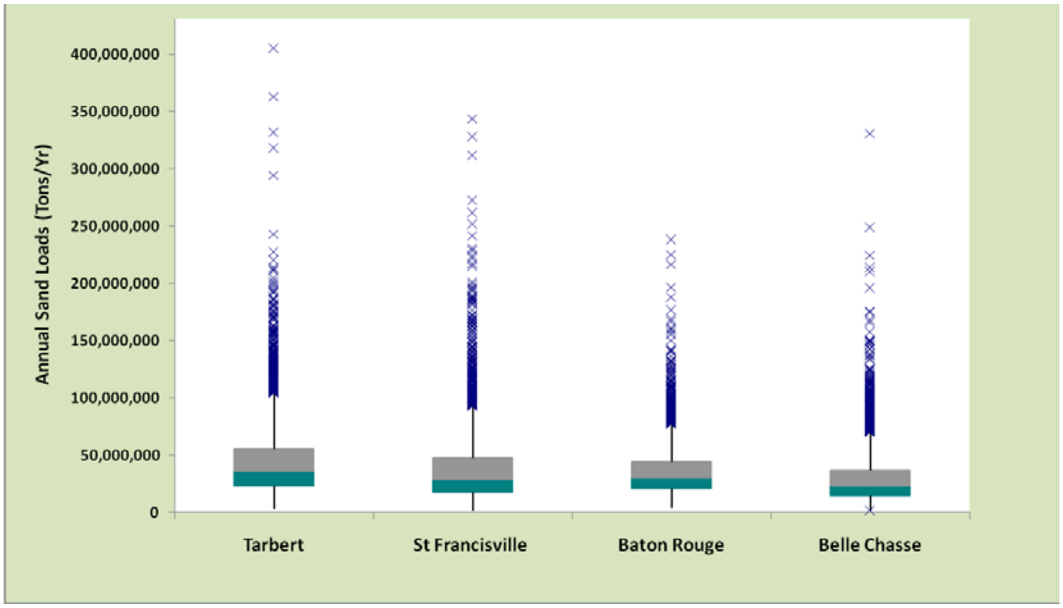


Figure 94. Annual Mississippi River sand load for Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse with outliers removed.

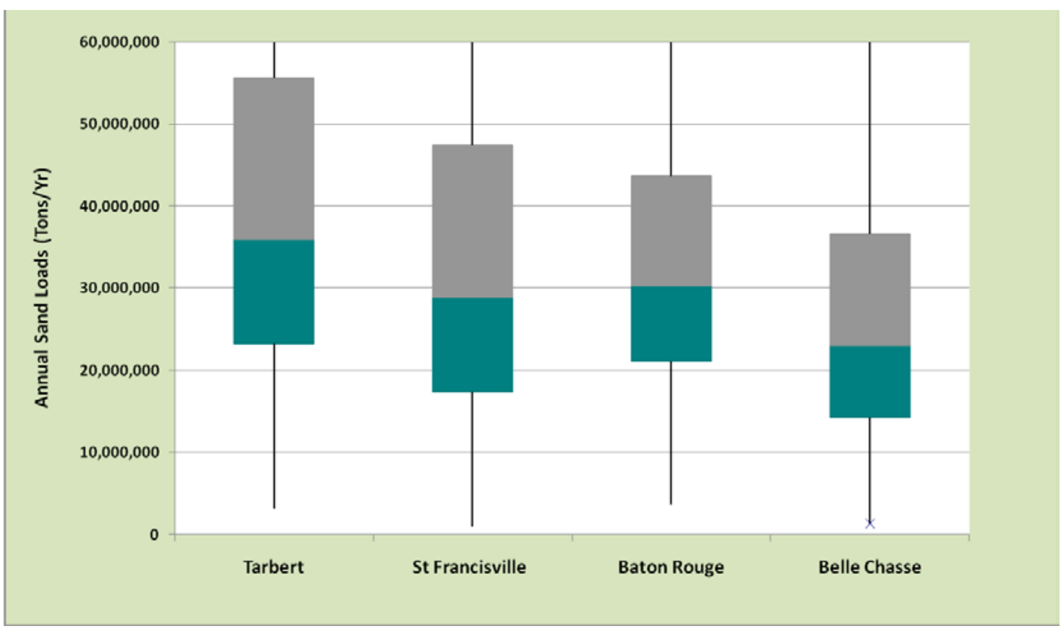


Figure 95. Percentile ranks of annual Mississippi River sand loads in tons/yr for the Tarbert Landing to St. Francisville reach, 1973–2012.

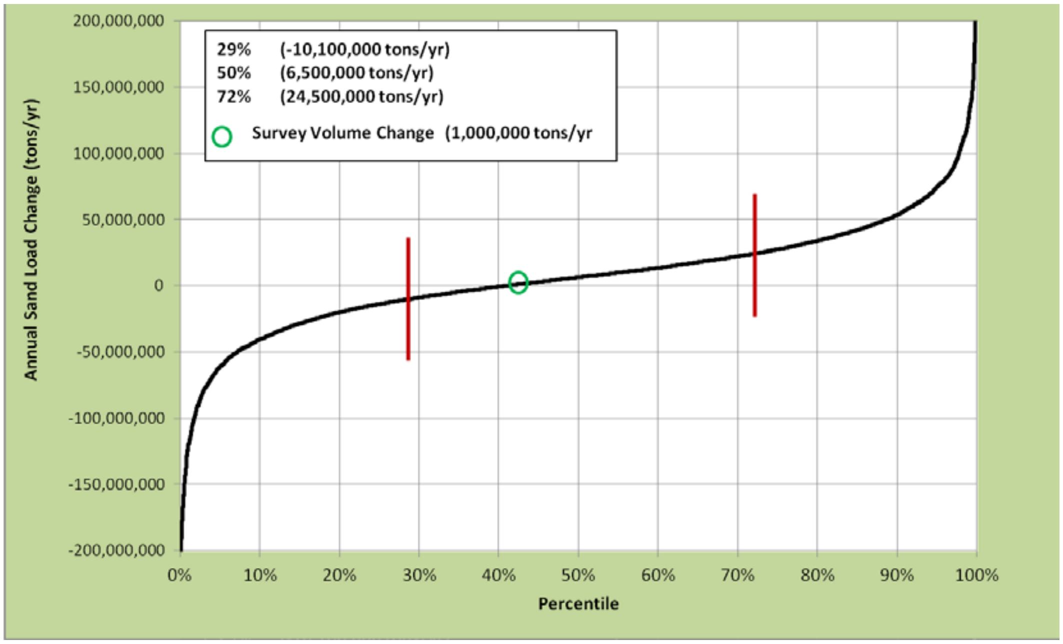


Figure 96. Percentile ranks of annual Mississippi River sand loads in tons/yr for the St. Francisville to Baton Rouge reach, 1973–2012.

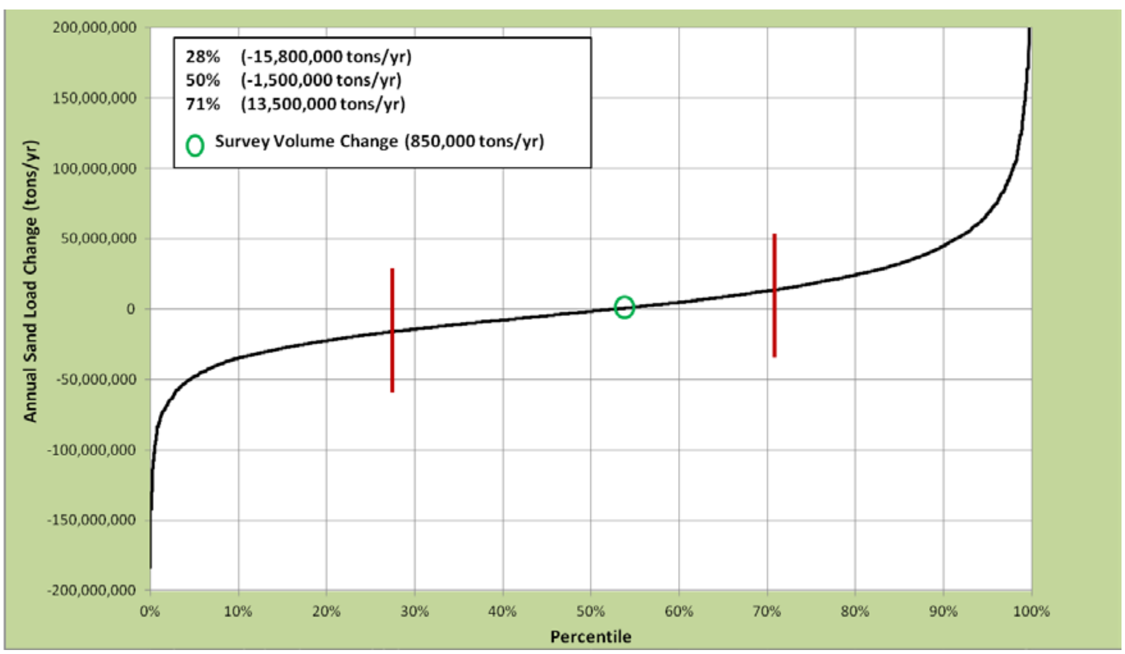
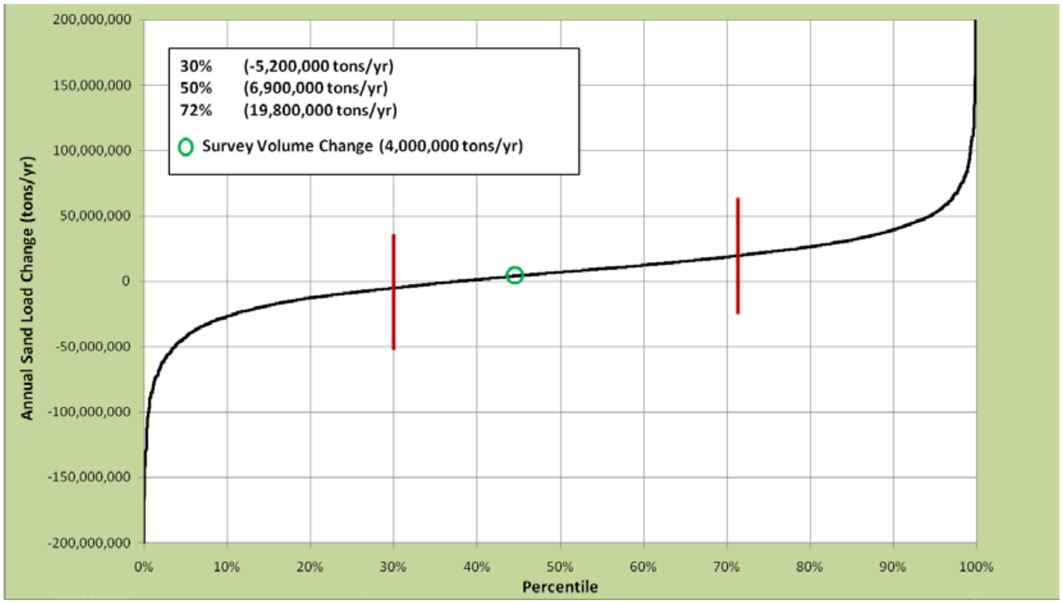


Figure 97. Percentile ranks of annual Mississippi River sand loads in tons/yr for the Baton Rouge to Belle Chasse reach, 1973–2012.



Tarbert Landing to St. Francisville. The percentile curve for the change in annual sand load for the Tarbert Landing to St. Francisville reach is shown in Figure 95. The median (50%) value for this reach is about 6.5 million tons/yr of sand deposition. According to the curve, approximately 60% of the 10,000 scenarios were aggradational while only 40% were degradational. The range of practical outcomes extends from about 10.1 million tons/yr of degradation to 24.5 million tons/yr of aggradation. Although this range includes both degradational and aggradational trends, it is skewed more towards aggradation. Therefore, based on the PSB, it appears that this reach could be expected to experience periods of both aggradation and degradation; however, the overall long-term tendency would be towards aggradation. This trend agrees well with the annual volumetric change (3.26 million tons/yr) obtained from comparison of the decadal surveys (Figure 95).

St. Francisville to Baton Rouge. The percentile curve for the change in annual sand load for the St. Francisville to Baton Rouge reach is shown in Figure 96. The median value for annual sand load change is about –1.5 million tons/year. While the PSB results suggest a slight degradation, examination of the curve indicates that the scenarios are fairly evenly distributed between degradation (52%) and aggradation (48%). The range of probable outcomes extends from approximately –15.8 million tons/year to 13.5 million tons/year, which is also fairly evenly balanced between degradation and aggradation. Therefore, the PSB suggests that while there might be a slight tendency for degradation, it appears that this reach may be approaching dynamic equilibrium. This seems to agree with the annual volumetric change for this reach which was only 813,000 tons/yr (Figure 96).

Baton Rouge to Belle Chasse. The percentile curve for the change in annual sand load for the Baton Rouge to Belle Chasse reach is shown in Figure 97. The median value of the annual sand load change in this reach is approximately 6.9 million tons/years of aggradation. The curve also indicates that approximately 62% of the scenarios were aggradational while only 38% were degradational. The practical outcome range extends from –5.2 million tons/year to 19.8 million tons/year. Therefore, the PSB indicates that this reach could be expected to experience periods of both aggradation and degradation; however, the overall long-term tendency would be towards aggradation. The annual volumetric change for this reach obtained from comparison of the decadal surveys was 10.046 million tons/yr, which supports the tendency for aggradation (Figure 97).

4.4.3 Probabilistic sediment budget for fine loads

This section discusses the PSB for the fine loads between Tarbert Landing and Belle Chasse for the period 1990–2012. As discussed in Section 3.5, the fine sediment analysis covered a shorter time period than for the sands due to the decreasing fine concentrations prior to the 1990s. Figures 98, 99, 100, and 101 show the percentile plots for annual fine loads at Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse. The relationship among the four stations is illustrated graphically in the box plots shown in Figure 102. To more clearly illustrate the relationship among the stations, the box plots are shown in Figure 103 with the extremes outliers removed. The box plots provide an overall view of the fine load characteristics at the four stations. As shown in Figure 103, there is an overall decrease in the fine loads between Tarbert Landing and Baton Rouge and an increase between Baton Rouge and Belle Chasse.

The fine sediment budget percentile curves for the Tarbert Landing to St. Francisville, St. Francisville to Baton Rouge, and Baton Rouge to Belle Chasse reaches are shown in Figures 104, 105, and 106, respectively. The methodology used for the development of these curves was discussed in Section 3.5.4. As shown in all three curves, there are extreme values associated with the lower and upper percentile ranges. These extremes are not likely possibilities, and a more likely range of practical outcomes occurs

Figure 98. Percentage of annual Mississippi River fine loads at Tarbert Landing, 1990–2012.

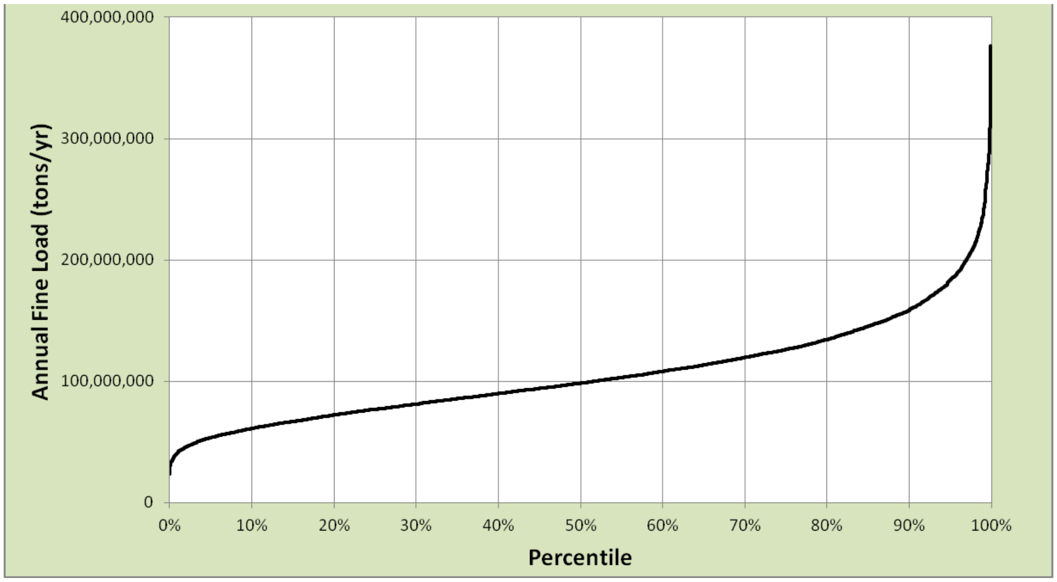


Figure 99. Percentage of annual Mississippi River fine loads at St. Francisville, 1990–2012.

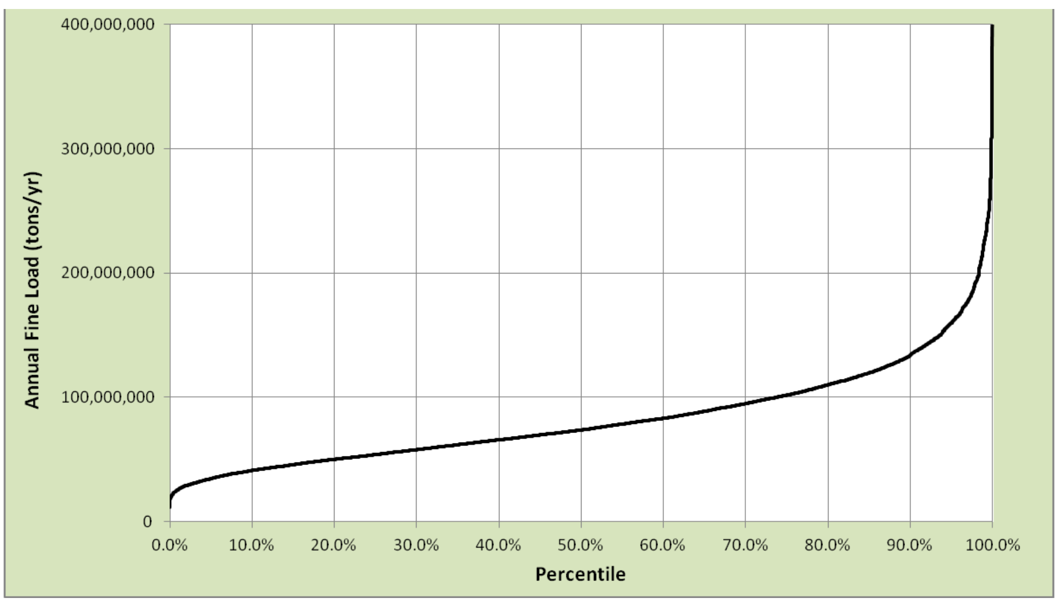


Figure 100. Percentage of annual Mississippi River fine loads at Baton Rouge, 1990–2012.

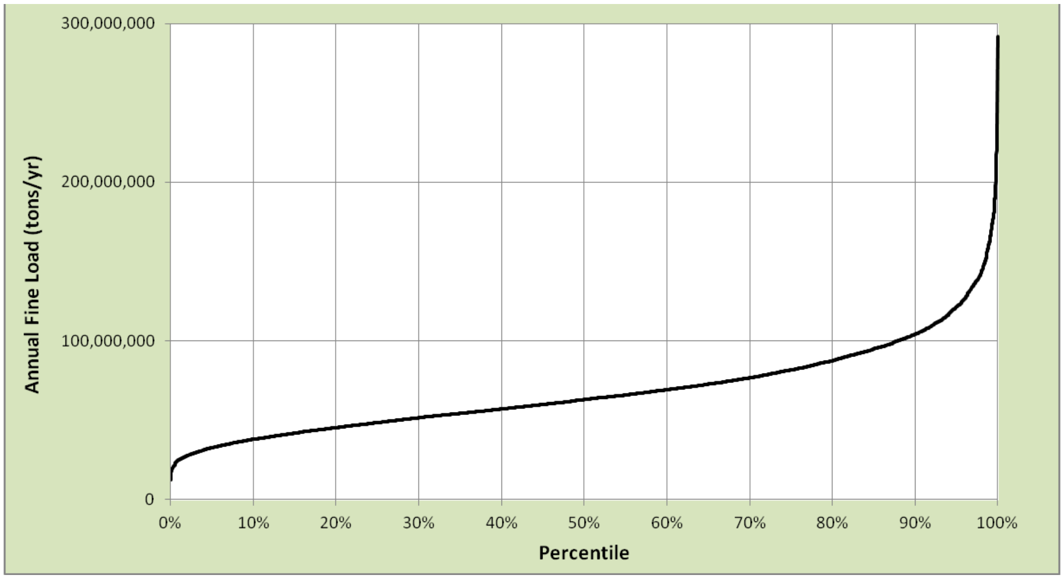


Figure 101. Percentage of annual Mississippi River fine loads at Belle Chasse, 1990–2012.

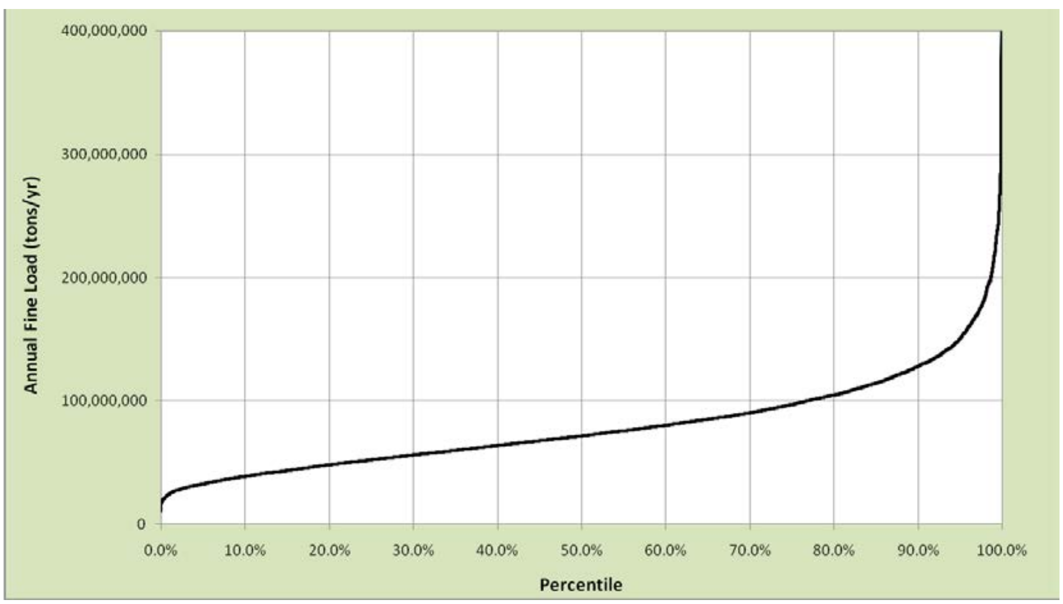


Figure 102. Annual Mississippi River fine loads at Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse, 1990–2012.

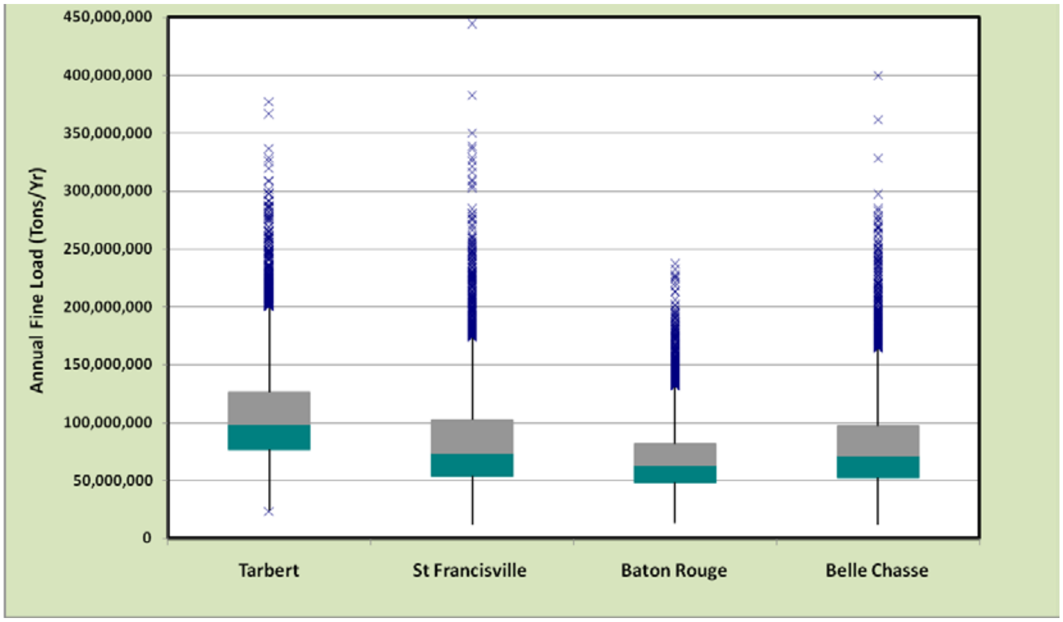


Figure 103. Annual Mississippi River fine loads at Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse, 1990–2012, with outliers removed.

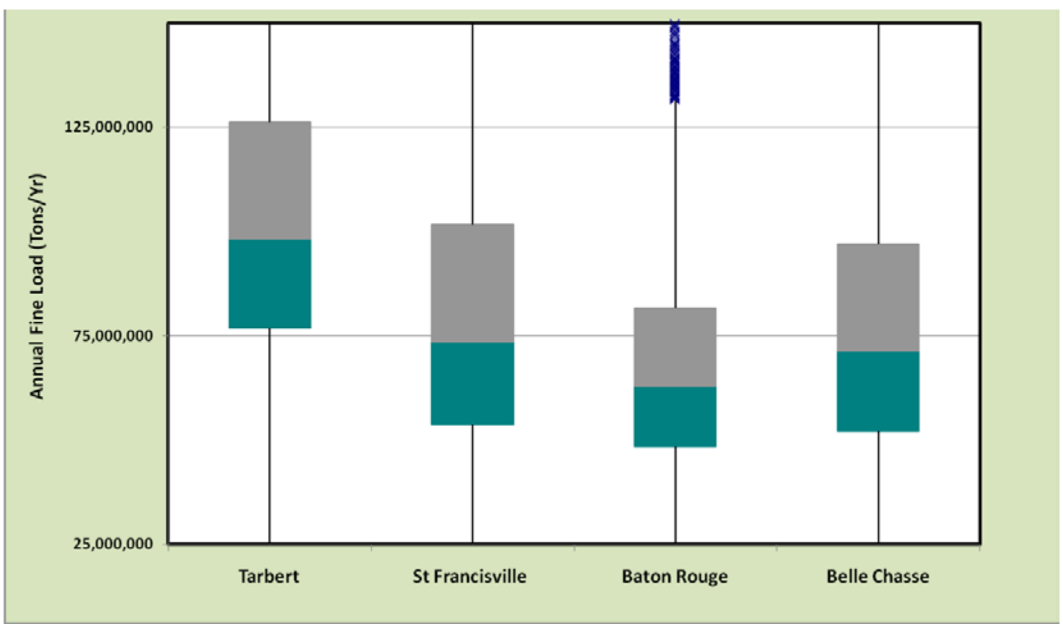


Figure 104. Annual Mississippi river fine loads in tons/yr for the Tarbert Landing to St. Francisville reach, 1990–2012.

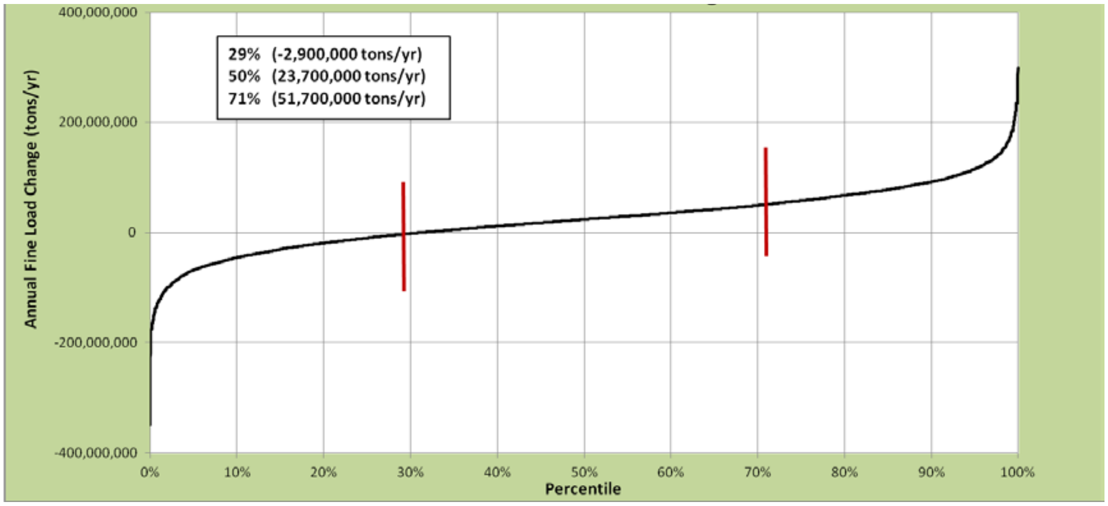


Figure 105. Annual Mississippi River fine loads in tons/yr for the St. Francisville to Baton Rouge reach, 1990–2012.

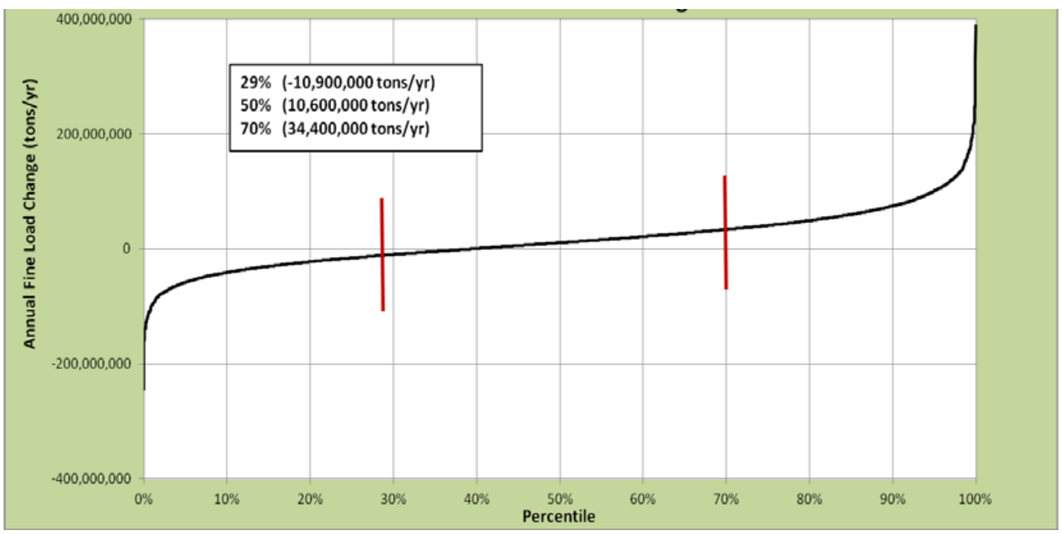
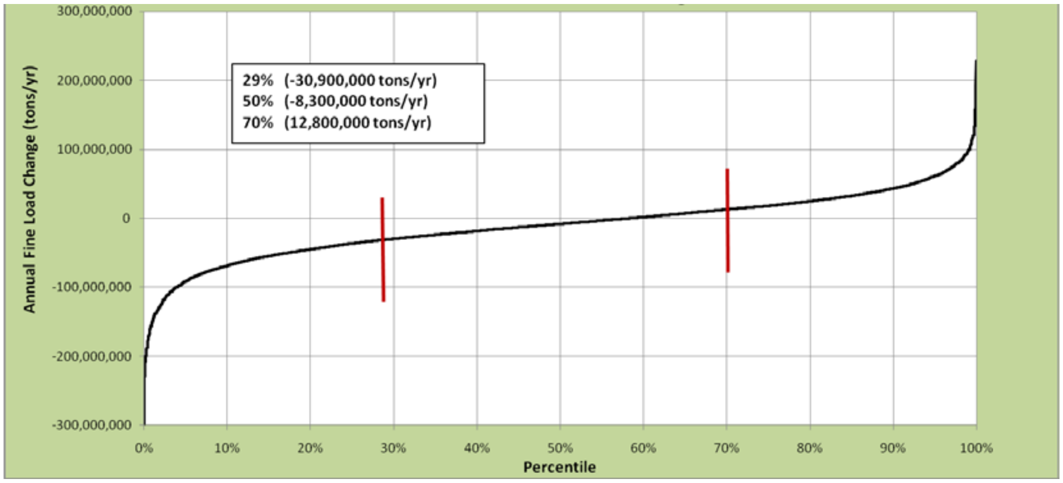


Figure 106. Annual Mississippi River fine loads in tons/yr for the Baton Rouge to Belle Chasse reach, 1990–2012.



along the flatter portion of the curves for some distance on either side of the 50% value. Using the same rationale as for the sand loads, the range selected for this study was based on the 35th and 65th percentile curves for the individual stations. As shown in Figures 104, 105, and 106, this resulted in a range between approximately the 30th and 70th percentile on the annual fine load change percentile plots. It is important to note that there is more uncertainty in the fine sediment-discharge regressions than for the sand data. In general, the sand-discharge regressions had R^2 values between approximately 0.5 and 0.8 (Figure 18), while the R^2 values for the fine-discharge regressions were much smaller, ranging from approximately 0.19 to 0.45 (Figure 19). A brief discussion of the fine load changes in each reach follows.

Tarbert Landing to St. Francisville. The percentile curve for the change in annual fine loads for the Tarbert Landing to St. Francisville reach is shown in Figure 104. The median (50%) value for this reach is approximately 23.7 million tons/yr of fine sediment deposition. According to the curve, approximately 68% of the 10,000 scenarios were depositional. The range of practical outcomes extends from approximately –2.9 million tons/yr to 24.5 million tons/yr. Although there are some scenarios indicating an erosional regime, this reach is heavily skewed towards deposition.

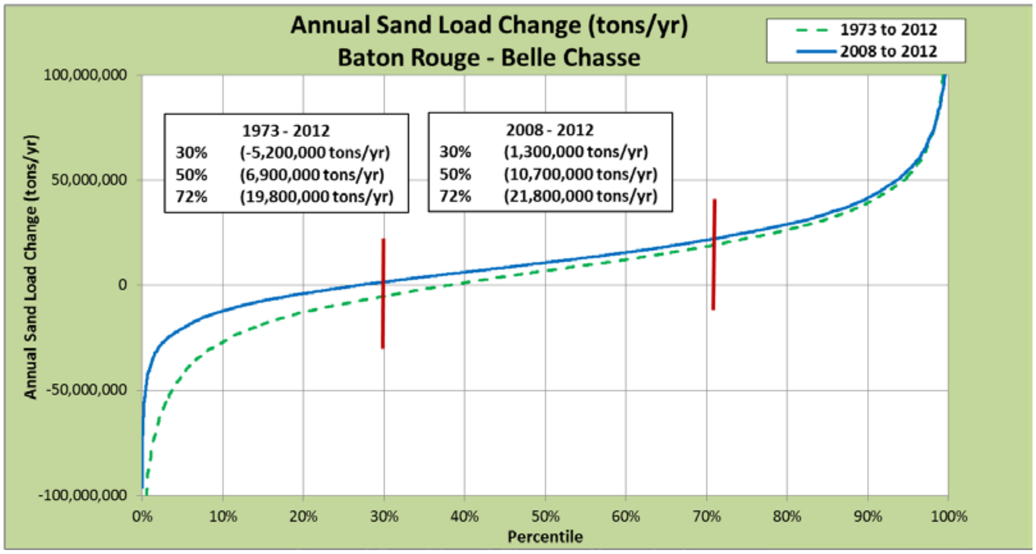
St. Francisville to Baton Rouge. The percentile curve for the change in annual fine load for the St. Francisville to Baton Rouge reach is shown in Figure 105. The median (50%) value for this reach is approximately 10.6 million tons/yr of fine sediment deposition. According to the curve, approximately 60% of the 10,000 scenarios were depositional. The range of practical outcomes extends from approximately –10.9 million tons/yr to 34.4 million tons/yr. Although there are some scenarios indicating an erosional regime, this reach is skewed towards deposition, albeit not as severely as the upstream reach from Tarbert Landing to St. Francisville.

<u>Baton Rouge to Belle Chasse</u>. The percentile curve for the change in annual fine load for the Baton Rouge to Belle Chasse reach is shown in Figure 106. The median (50%) value for this reach indicates the erosion of approximately 8.3 million tons of fines annually. According to the curve, approximately 58% of the 10,000 scenarios were erosional. The range of practical outcomes extends from approximately –30.9 million tons/yr to 12.8 million tons/yr. Although there are some scenarios indicating a depositional regime, this reach is skewed towards erosion.

<u>Effects of Flow Period and Sediment Regime on the PSB</u>. In the previous discussion, the PSB was developed for a specific time period, 1973–2012 for sands and 1990–2012 for the fines. However, the PSB can also provide insight into the behavior of the channel system resulting from short-term droughts or flood periods, or long-term changes due to flow diversions or climate change. This section provides examples to illustrate the impacts of alternate flow conditions on the sediment regime.

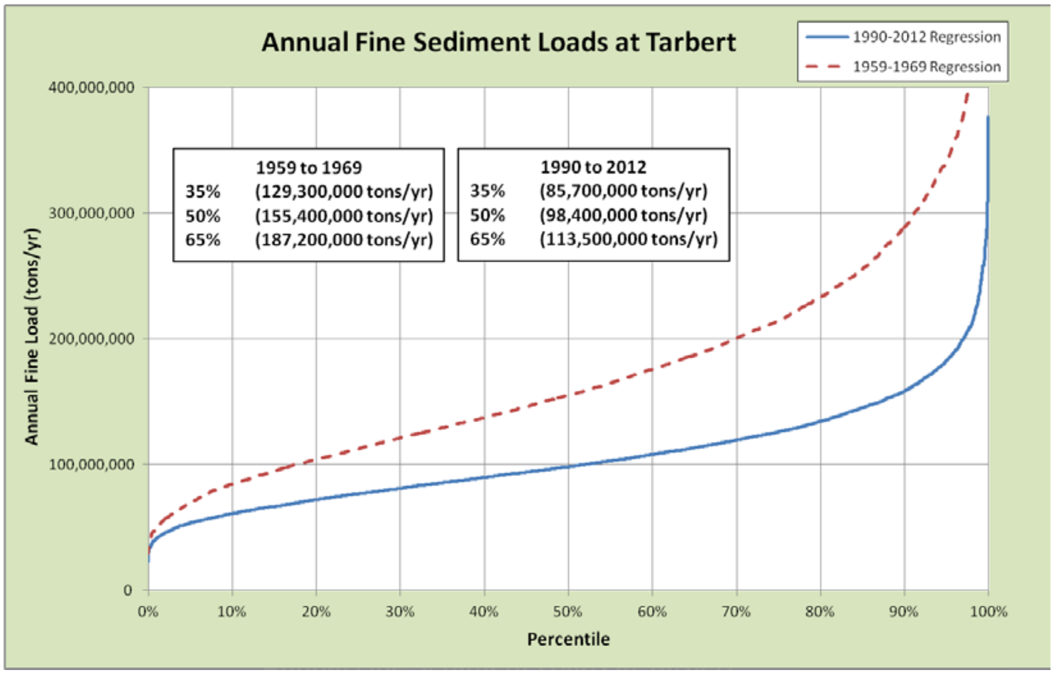
In order to test the effects of the flow regime, the PSB was conducted for a short, high-flow period from 2008 to 2012 and compared with the results for the 1973–2012 time period. This test was conducted for the Baton Rouge to Belle Chasse reach using the sand data. This required the development of new sand concentration-discharge regressions curves and flow-duration data for both stations for the time period 2008–2012. Using these data, the PSB was re-calculated. Figure 107 presents the percentile curve for the changes in annual sand loads for the Baton Rouge to Belle Chasse reach. As shown in Figure 106, the 2008–2012 period shifted the curve up, indicating a much greater tendency for aggradation. In fact, the practical outcome range (30%–72%) is now completely aggradational, extending from 1.3 million tons/yr to 21.8 million tons/yr, as compared to –5.2 million tons/yr to 19.8 million tons/yr for the 1973–2012 period. This example clearly illustrates the importance of the time period considered when conducting a sediment budget.

Figure 107. Annual Mississippi River sand loads in tons/yr for the Baton Rouge to Belle Chasse reach, 1973–2012 and 2008–2012.



As shown above, the effects of the flow period selected can be significant. Likewise, changes in the sediment regime must also be considered. As discussed in Section 4.4.1, there were no significant changes in the sand concentration data from the 1950s to present. However, there has been a significant decrease in the fine sediment concentrations during this period. To illustrate the effects of these declining fine concentrations on the annual loads, the 1959–1969 flow period was compared to the 1990–2012 period using the Tarbert Landing data. Lack of data at the other stations for the 1959–1969 period prevented the development of a PSB between these stations; however, the effects on the annual loads at Tarbert Landing are presented. To illustrate the effects of the sediment regime, the PSB was developed using the 1990–2012 flow duration with both the 1959–1969 and the 1990–2012 fine sediment concentration–discharge regressions. Figure 108 presents a comparison of the fine loads for these two time periods. As shown in Figure 108, the annual fine loads at Tarbert Landing were much greater in the 1959–1969 period than in the 1990–2012 period. The median (50%) value decreased approximately 37% from about 155.4 million tons/yr to 98.4 million tons/yr. Similar decreases were observed at the 35% and 65% levels.

Figure 108. Annual Mississippi River fine loads at Tarbert Landing, 1959–1969 and 1990–2012.



4.4.4 Effective discharge analysis

Effective discharge analysis was conducted at Tarbert Landing for various time periods to assess temporal trends in the effective discharge results. The time periods analyzed include the following: (1) 1955–1972, (2) 1973–1992, (3) 1992–2012, and (4) 1973–2012. The sand regressions were combined with the flow-duration data to produce effective discharge curves for each time period shown in Figures 109–112. The post-1973 curves exhibit the typical bell-shaped curve with a fairly well-defined peak representing the effective discharge. The pre-1973 curve shown in Figure 109 also exhibits a bell curve but with a much broader peak, making the precise identification of the effective discharge more problematic. Table 19 presents the effective discharge results for each time period. As shown in Table 19, the effective discharges for the post-1973 time periods are in the range of approximately 800,000 cfs while the pre-1973 effective discharge is closer to 700,000 cfs.

Although the effective discharge analysis provides an estimate of the single flow that is responsible for transporting the most sediment, Figures 109–112 show that there is a wide range of flows that contributes significantly to the overall sediment transport at each location. Biedenharn and Thorne (1994) conducted a cumulative analysis of sediment transport to define an *effective range* of flows. Using this same approach, the cumulative percentage of sand transport for each time period was calculated and is shown in Figures 109–112. Although the curves vary somewhat for each time period, they exhibit a similar form, and the zone representing the steepest segment of the cumulative curves where the maximum sediment transport occurs for each increment of discharge can generally be identified. In general, it appears that this zone occurs between approximately the 15% and 85% values on the cumulative percent curve. Thus, the flows in this range are responsible for transporting aproximately 70% of the total sediment. Table 19 presents the discharges corresponding to the 15% and 85% values along with the total sand moved in this range during each time period. As shown in Table 19, the effective range of flows in the post-1973 time period is fairly consistent, ranging from close to 500,000 cfs to slightly over 1 million cfs. The total sand moved by these flows in the post-1973 time period varied slightly but was generally in the range of approxiamtely 25 million tons/yr. The effective range of flows in the pre-1972 time period was much smaller, ranging from approximately 400,000 cfs–900,000 cfs with a total sand transport of only approximately 16.5 million tons/yr. Thus, the Mississippi River morphology in the pre-1973 time period would have been responding to a smaller channel forming discharge regime than in the post-1973 time period.

Figure 109. Mississippi River effective discharge and cumulative percentage sand load curves for Tarbert Landing, 1955–1972.

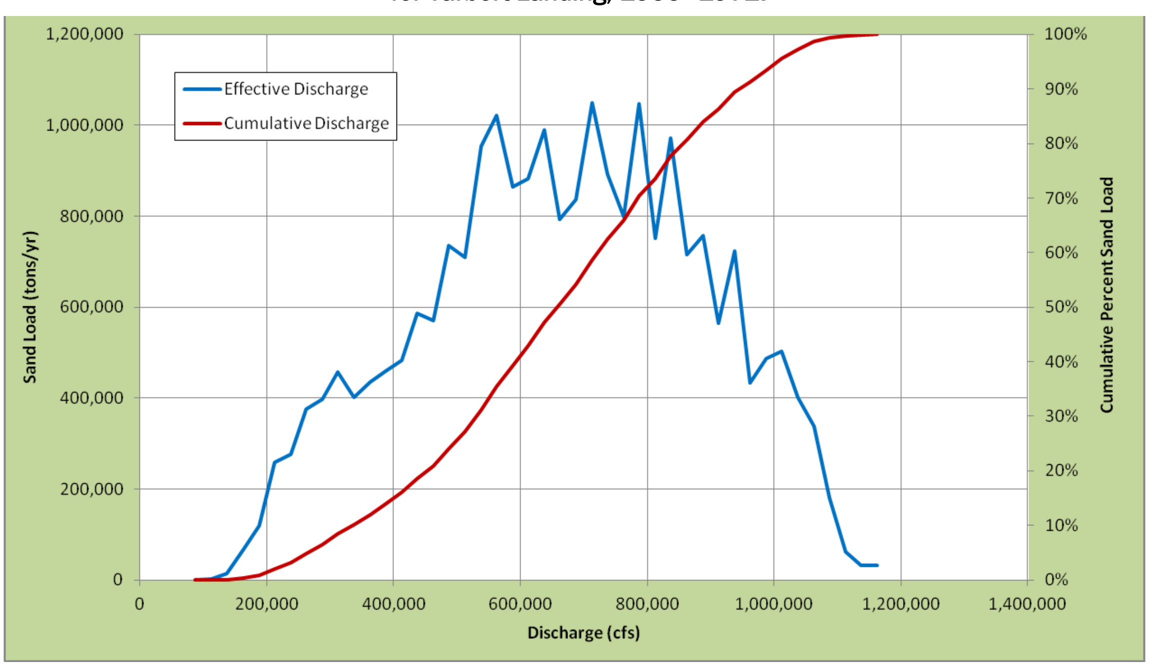


Figure 110. Mississippi River effective discharge and cumulative percentage sand load curves for Tarbert Landing, 1973–1992.

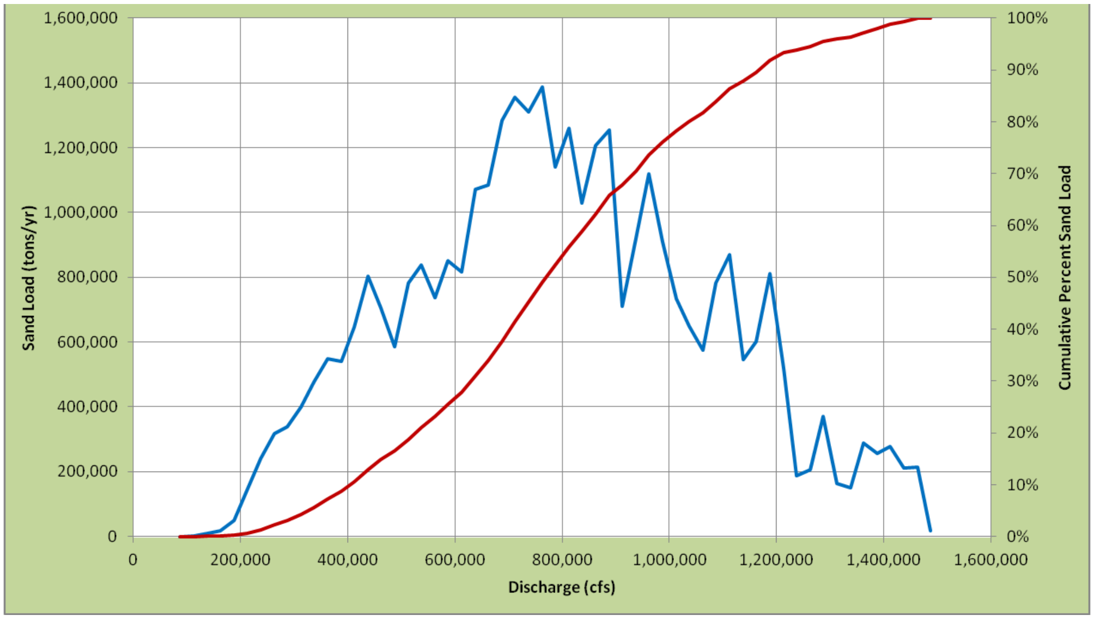


Figure 111. Mississippi River effective discharge and cumulative percentage sand load curves for Tarbert Landing, 1992–2012.

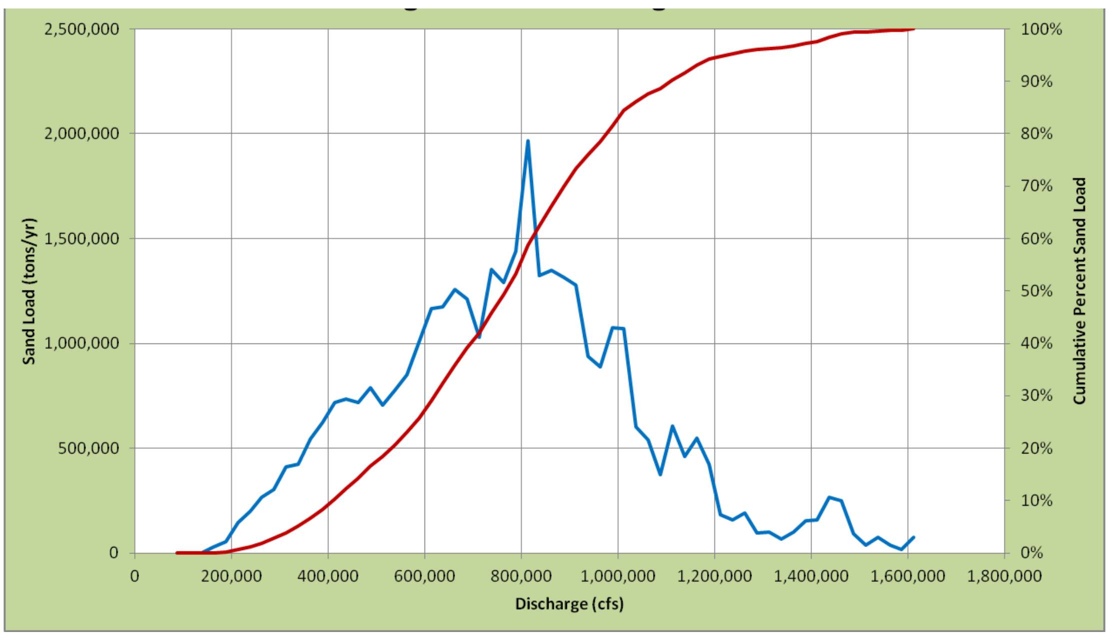


Figure 112. Mississippi River effective discharge and cumulative percentage sand load curves for Tarbert Landing, 1973–2012.

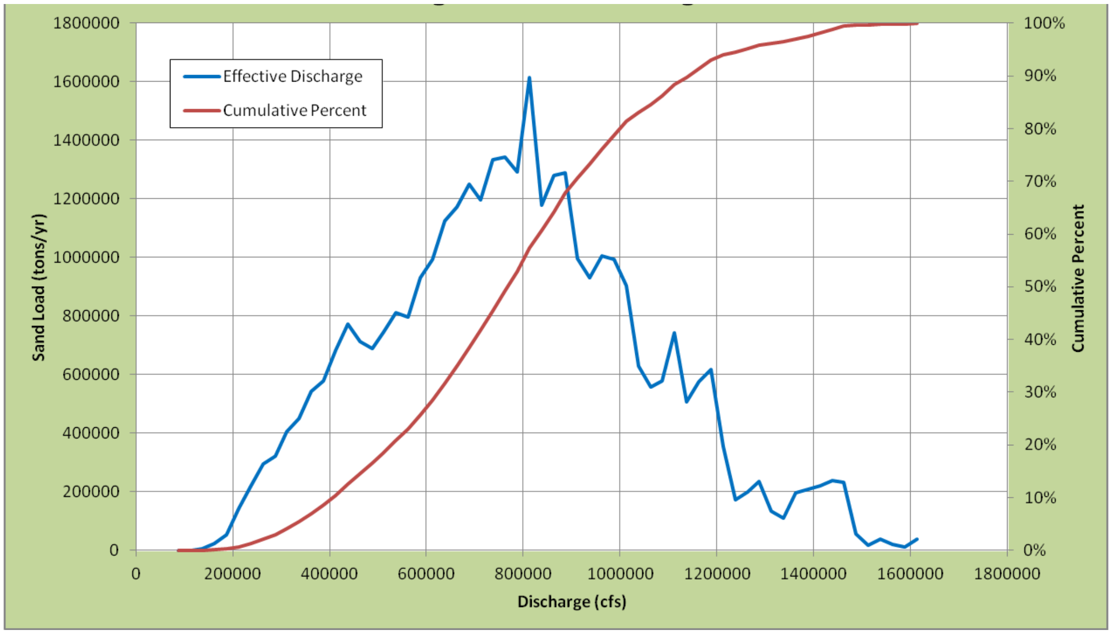


Table 19. Effective discharge and cumulative percentage sand load at Tarbert Landing for four time periods.

Time Period	Effective Discharge (cfs)	Cumulative Percentage Sand Load		Sand Load (tons/yr)
		15	85	
1955–1972	712,000	400,000	900,000	16,500,000
1973–1992	762,000	470,000	1,100,000	24,700,000
1992–2012	812,000	470,000	1,020,000	25,300,000
1973–2012	812,000	500,000	1,080,000	25,000,000

4.4.5 Bed material analysis

The primary focus of this section is to present a comparison of Mississippi River bed sediment gradations based on three separate sampling investigations. The first of these investigations is the systematic sampling of bed sediments in 1932 from the Mississippi River channel thalweg along a 1,070-mile reach between Cairo, Illinois, and Head of Passes. A total of 572 samples were collected (WES 1935). In 1989, the Corps of Engineers contracted with Colorado State University (CSU) to undertake a sampling program to duplicate the 1932 sampling program (Nordin and Queen 1992). Two purposes of the study were to determine if the size distributions of the thalweg bed sediments had changed since 1932 and to provide a baseline of information against which future changes could be monitored.

Nordin and Queen (1992) report the final conclusions from the 1989 sampling as follows:

> The 1989 samples contained less coarse sand and gravel, and less very fine sand than the 1932 samples; generally, they were more uniform in distribution than the 1932 samples.
>
> Between Cairo, Illinois, and RM 300 near the Old River Control Structure, the bed sediments were generally finer in 1989 than in 1932. Downstream of the Old River Control Structure, the median and mean diameters were about the same for both sets of samples, but the 1989 samples contained less very fine sand (0.062 mm – 0.125 mm) and more fine sand (0.125 mm–0.25 mm) than in 1932.
>
> The mean diameters of the sample fractions between 0.062 and 1.0 mm were generally slightly smaller in 1989 upstream of about RM 300 and generally slightly larger in 1989 downstream of RM 300 compared to 1932.
>
> Of the three types of samplers tested in 1989 (USGS 4-inch pipe dredge, US BM-54, and 8-inch pipe dredge), there were no systematic differences in particle size distribution of samples collected with the different samplers.

The Nordin and Queen (1992) results represent the first systematic long-term comparison of bed material along the entire Lower Mississippi River. However, it must be remembered that the study results are based on only two *snapshots in time* of the bed material, and therefore, any definitive conclusions from these data must be viewed with caution.

ERDC acquired the third set of bed samples in December 2012. Samples were acquired in much greater density than in the 1932 or 1989 investigations and were concentrated within approximately 5-mile reaches near Vicksburg, Natchez, Tarbert Landing, and Baton Rouge as shown in Figures 113, 114, 115, and 116. Samples were taken at various locations across the channel and not all were along the thalweg. Table 20 lists the average, minimum, and maximum D50 values for the 1932, 1989, and 2012 time periods. These data reflect the approximate 5-mile reach associated with the 2012 sampling. Figure 117 shows a plot of the D50 for the three time periods. Table 20 indicates that the average D50 value had been relatively

Figure 113. Location of Mississippi River samples taken in 2012 near Vicksburg, Mississippi.

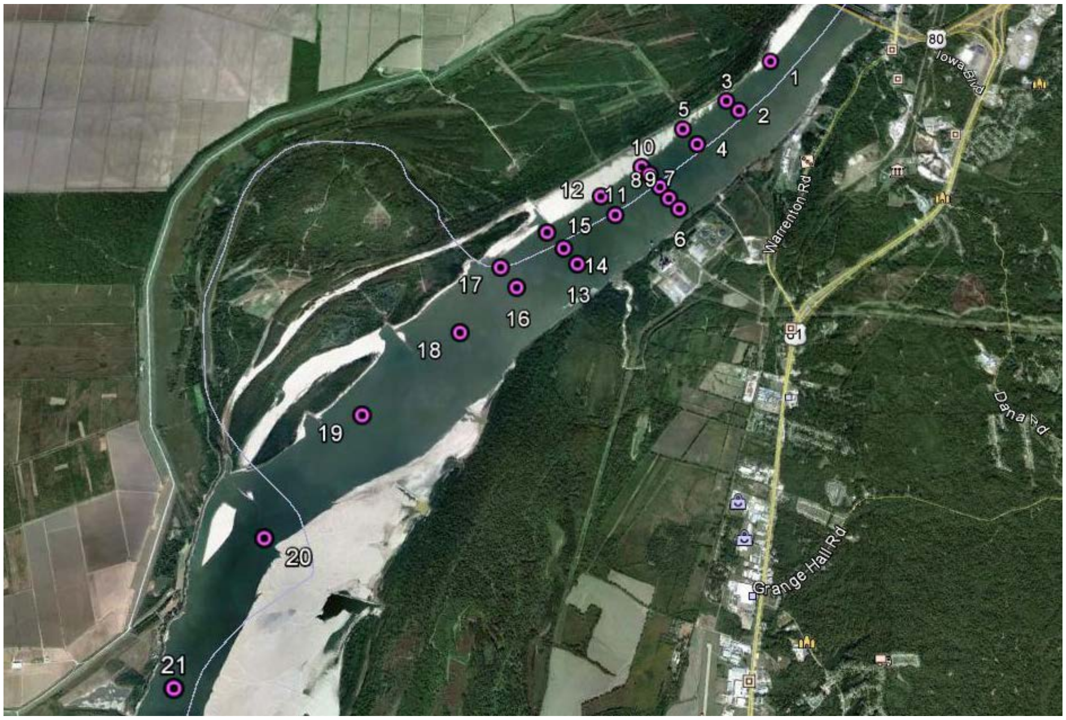


Figure 114. Location of Mississippi River samples taken in 2012 near Natchez, Mississippi.

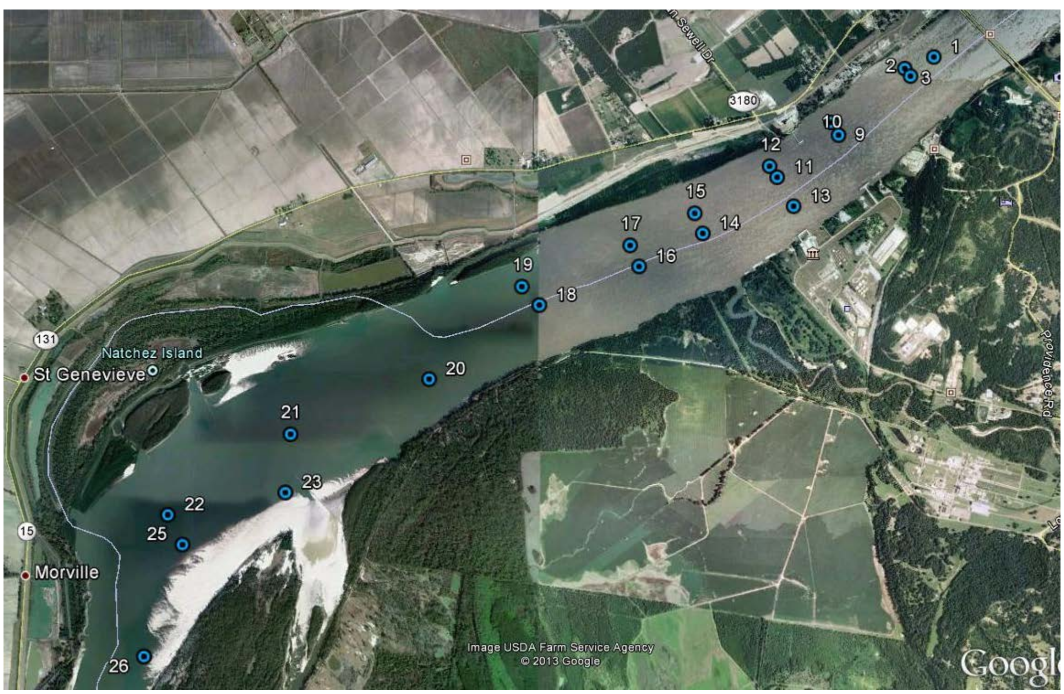


Figure 115. Location of Mississippi River samples taken in 2012 near Tarbert Landing, Louisiana.

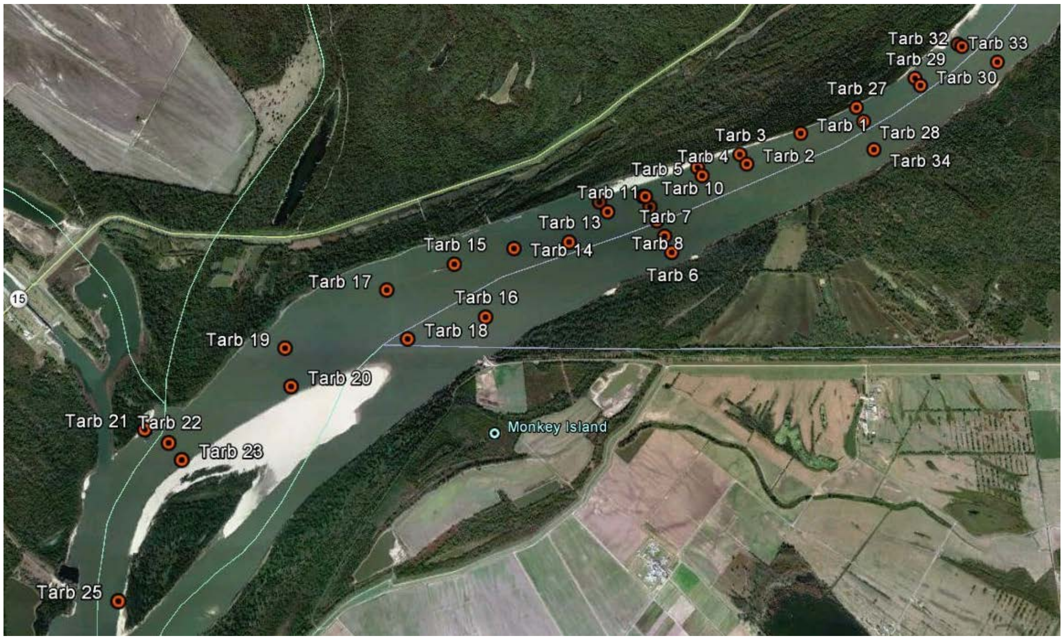


Figure 116. Location of Mississippi River samples taken in 2012 near Baton Rouge, Louisiana.

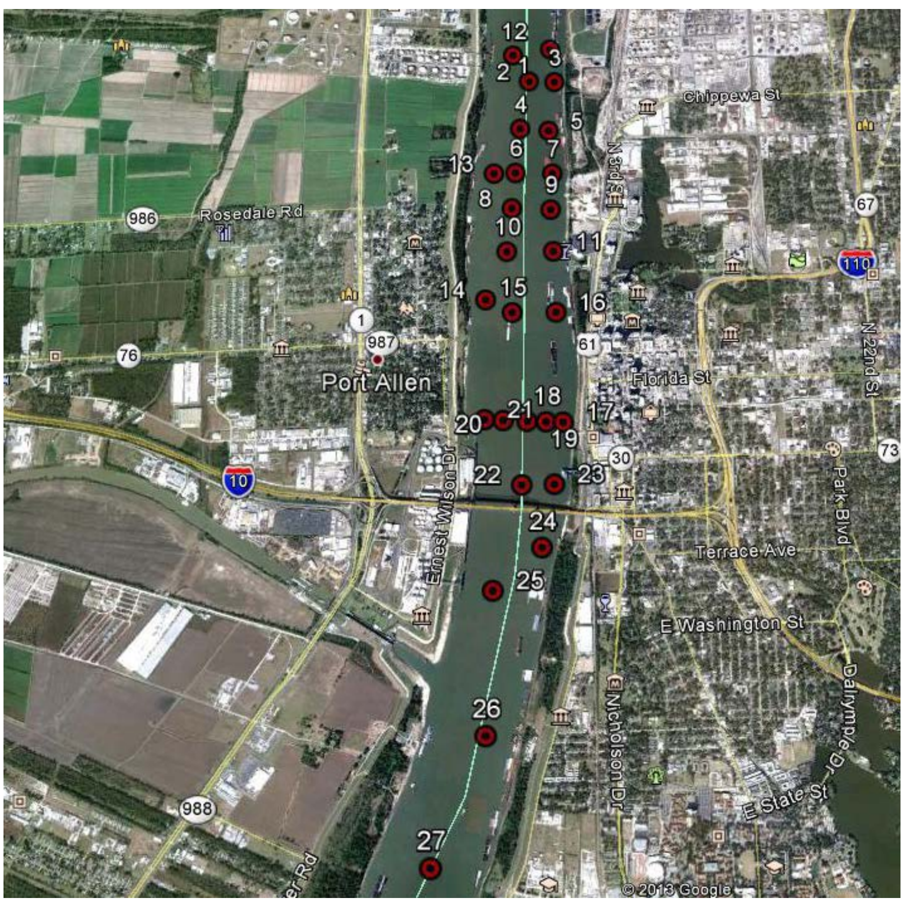
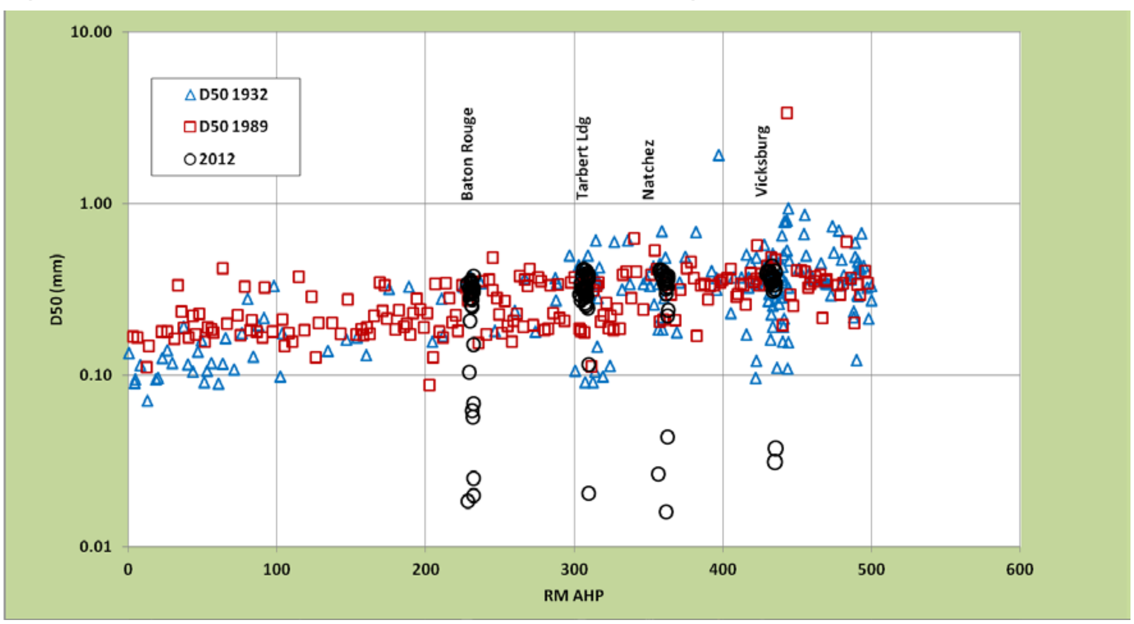


Table 20. Average, maximum, and minimum D50 values for three sampling periods.

	Bed Material D50 (millimeters (mm)) for 3 Sampling Years		
	1932	1989	2012
Vicksburg			
Average	0.330	0.464	0.34
Maximum	0.508	0.485	0.429
Minimum	0.162	0.433	0.031
Natchez			
Average	0.355	0.251	0.317
Maximum	0.695	0.339	0.414
Minimum	0.184	0.205	0.016
Tarbert Landing			
Average	0.346	0.252	0.311
Maximum	0.502	0.369	0.415
Minimum	0.091	0.178	0.021
Baton Rouge			
Average	0.347	0.274*	0.235
Maximum	0.373	NA*	0.380
Minimum	0.32	NA*	0.019

*Only one cross section was available in 1989 within the 5-mile reach.

Figure 117. D50 values for the 1932, 1989, and 2012 samplings from Mississippi River RM 0–RM 500.



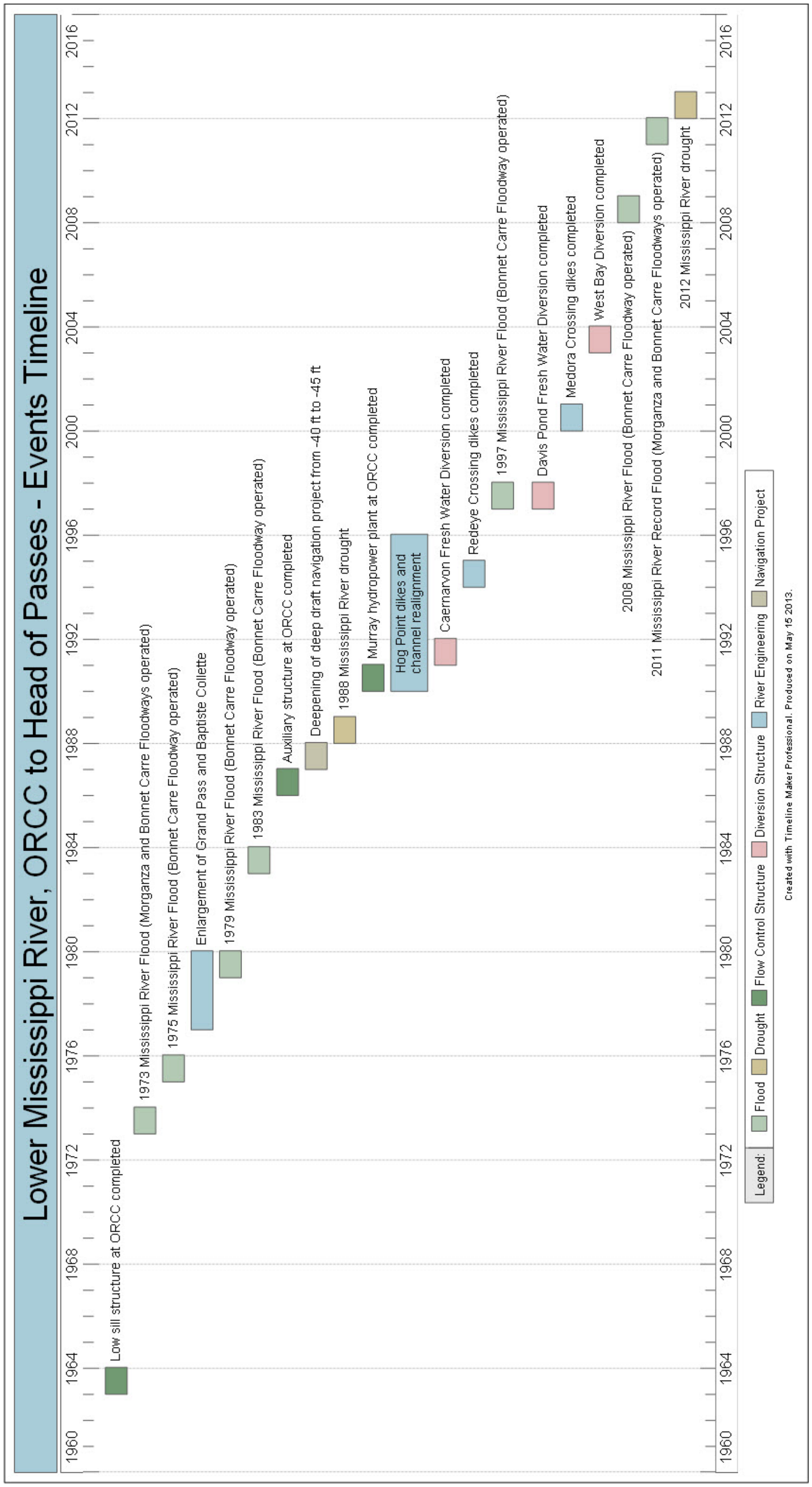
stable at these three points in time, with the average 2012 value generally falling between the 1932 and 1989 values. Table 20 also indicates that the minimum D50 values for the 2012 sampling were generally much finer than the 1932 and 1989 values. Figure 117 presents the same. This is probably explained by the difference in sampling locations of the 2012 samples as compared to the 1932 and 1989 samples. The 2012 sampling had a much wider spatial variability covering most of the channel width, while the 1932 and 1989 samples were restricted to the thalweg. Because of this difference in sampling locations, and the fact that there are only three time periods (1932, 1989, and 2012), it is difficult to draw any definitive conclusions with respect to bed-material trends.

4.5 Events Timeline Results

A timeline bar chart of the major events that have occurred during the study time period that are considered influential in terms of morphology in the lower reach of the Mississippi River is shown in Figure 118. Since 1960 there have been seven major floods on the lower Mississippi River that have required the operation of the Bonnet Carré floodway (1973, 1975, 1979, 1983, 1997, 2008, and 2011). Of these flood events, the 1973 and 2011 floods also required the operation of the Morganza floodway. The 2011 flood was the flood of record on the lower Mississippi River, setting record stages at Vicksburg, Natchez, and Red River Landing. Although of less magnitude than the 2011 flood, the flood of 1973 appears to have been a more significant event in terms of impact to river morphology. The 1973 flood terminated a relatively flood-free period of more than 2 decades. Specific gage records indicate a definitive rise in stage at the time of the 1973 flood whereas response to the 2011 flood was not as noticeable. A potential reason for this is the river may have adjusted to a lower regime of discharge during the flood-free decades. The 1973 flood resulted in significant reworking of the channel through erosion, as evidenced by the general erosional patterns observed between the 1963 and 1975 hydrographic surveys in the geometric data analysis.

In terms of anthropogenic events, the construction and evolution of the ORCC has been the major activity on the lower river during the study period. The low sill structure of ORCC began operation in 1963; the auxiliary structure was added in 1986; and the hydropower plant came on line in 1990. With the addition of each structure, the location of the water diversion point for the ORCC was altered. In addition, the sediment diversion characteristics of the ORCC were also altered as the various combinations of structure operation have evolved.

Figure 118. Timeline of major events on the lower Mississippi River, 1960–2013.



There are numerous revetments along the river banks within the study reach, but there are relatively few dike fields compared to river reaches between Cairo, Illinois, and ORCC. The primary dike fields are located at Hog Point/Smithland, Redeye, and Medora crossings and Springfield Bend. The Hog Point dikes are associated with a river channel realignment that was constructed in the early 1990s. The dikes at Redeye and Medora crossings were constructed in the early 1990s and 2000s, respectively, with the purpose of maintenance dredging reduction. The Springfield Bend dikes were constructed for bank protection and channel realignment.

5 Discussion

5.1 Geometry Data

Evaluation of the cross section data obtained from decadal hydrographic surveys indicates that the lower Mississippi River channel can vary considerably in channel dimension from survey to survey. Channel depths were observed to fluctuate as much as 10 ft between successive surveys, yet there was often no discernible long-term trend in geometry change. In general, the cross sections at the crossing locations indicate more change due to erosion and deposition than cross sections at the pool locations. It is generally understood that the channel crossings in a sand bed river are important in defining the vertical stability of the river. Channel invert profiles of cross sections at the crossing and pool locations indicate that the crossing profile ranges from 20 to 50 ft higher than the pool profile. In addition, the channel invert profiles generally indicate that reach-scale slope of the river has been very consistent for the study time period. In general, the river pattern has been very stable over the study time period, with significant lateral shifts of 200 to 300 ft observed at only a few bends in the reach between ORCC and Baton Rouge.

Volumetric data analyses for polygons along the study reach indicate a general erosional trend in the river reach from Baton Rouge to Head of Passes for the time period 1963–1975. This erosional trend was somewhat surprising, and may possibly be related to effects of the major flood in 1973 after a 2–decade, non-flood period. General deposition was noted for this time period from ORCC downstream to approximately Baton Rouge, where the trend transitioned to erosion. No identifiable pattern of erosion or deposition was noted for the 1975–1992 time period. A shift towards a reach-wide general trend of deposition was observed for the time period 1992–2004 for the entire study reach as well as 2004–2012 for the reach between ORCC and Baton Rouge. The highest rates of deposition for the 1992–2004 time period were observed at ORCC, between Baton Rouge and Bonnet Carré floodway and from Belle Chasse to Head of Passes. It should be noted that the percent change in channel volume below top bank elevation for successive survey periods is only 5% or less for the majority of the analysis polygons with the exception of those in the immediate vicinity of ORCC and below Venice, Louisiana.

Analysis of the channel geometry in the immediate vicinity of ORCC reveals that the river channel has readily adjusted as the complex has evolved with the addition of the various structures. The 1963 and 1975 hydrographic surveys indicate that significant erosion occurred upstream of the ORCC low sill structure, which began operation in 1963. This erosion is most likely a result of drawdown caused by the structure. Additionally, the drawdown effect was potentially increased during the 1973 flood when discharge through the structure was increased to reduce the head on the structure due to structural damage during the flood. The most significant changes observed in the vicinity of ORCC were between the 1990 survey and 2004 survey, when deposition of 20 to 25 ft occurred in the reach immediately downstream of the hydropower structure. The sediment diversion characteristic of the hydropower structure along with the change in the point of discharge withdrawal resulted in less sediment being diverted from the Mississippi River, thus causing deposition in the river channel. From all indications, the observed deposition appears to be local to the ORCC; however, additional years of survey data may indicate the changes are more systematic than local.

5.2 Specific Gage

A summary of the overall trends for each station during five different time periods is shown in Table 21. The trends identified in Table 21 reflect an overall assessment for all three flow regimes based on the statistical analyses tempered with engineering judgment. All gages for which data were available indicated an aggradational trend during the 1963–1974 time period. These aggradational trends were almost entirely the result of the 1973 flood. For the 1975–2011 period, the individual gage trends varied. The Red River Landing gage exhibited a general aggradational trend over this entire time period. The overall assessment at the Bayou Sara and Baton Rouge gages suggests that the stage trends have been relatively stable during this time period. At Donaldsonville, a degradational trend for the 1975–2011 period was observed. The specific gage record at Algiers lock indicated an apparent downward trend. However, overall, these trends are considered inconclusive due to a 10 yr gap in the data. At West Pointe a La Hache, no significant stage trends were observed. The longer period from 1975 to 2011 was broken into smaller periods in an attempt to capture any shorter term trends. Table 21 indicates that the time period selected can impact the observed trends.

Table 21. Specific gage trends for all stations for specific time periods.

Station	Trends for Specific Time Periods			
	1963–1974	1975–1992	1993–2011	1975–2011
Red River Landing	A	I(D)	A	A
Bayou Sara	A	I(D)	A	EQ
Baton Rouge	A	I(D)	A	EQ
Donaldsonville	A	D	EQ	D
Algiers Lock	NA	EQ	NA	I(D)
West Pointe a LaHache	NA	EQ	NA	EQ

A=Increasing stage trend
D=Decreasing state trend
EQ=Dynamic equilibrium (no stage trend)
I(D)=Inconclusive (degradational)
I(A)=Inconclusive (aggradational)
NA=Not applicable

In evaluating the specific gage trends, it is worth noting that with the exception of the dramatic increase in stages associated with the 1973 flood, most all other trends in the post-1973 period are very subtle, and it is difficult to determine if a real trend exists or not, particularly over relatively short time periods. Even when statistically significant trends were identified, the R^2 values were extremely small, indicating that there was little relationship between stage and time. Additionally, the regression slopes were also very small. For instance, the regression slope for 1 million cfs at Red River Landing for the 1975–2011 period was only approximately 0.05 ft/yr, which equates to approximately a 1.8 ft rise during this 36 yr period.

5.3 Sediment Budget

This section provides a discussion of the results of the analysis of the sediment data.

5.3.1 PSB for sands

The PSB results for the Tarbert Landing-to-St. Francisville reach for the period 1973–2011 indicate a range of practical outcomes that extends from approximately 10.1 million tons/yr of degradation to 24.5 million tons/yr of aggradation, with a median (50%) value of approximately 6.5 million tons/yr of sand deposition. Therefore, the Tarbert Landing-to-St. Francisville reach could be expected to experience periods of both aggradation and degradation; however, the overall long-term tendency would be towards aggradation. For the St. Francisville to Baton Rouge reach, the PSB indicates the median value for annual sand load change is approximately –1.5 million tons/yr, and the range of practical outcomes extends from approximately –15.8 million tons/yr to 13.5 million tons/yr, which is fairly evenly balanced between degradation and aggradation. This suggests that while this reach may have a slight tendency for degradation, it appears that it may be approaching dynamic equilibrium. The PSB results for the Baton Rouge to Belle Chasse reach for the period 1973–2011 indicate a range of practical outcomes that extends from approximately 5.2 million tons/yr of degradation to 19.8 million tons/yr of aggradation, with a median (50%) value of approximately 6.9 million tons/yr of sand deposition. Therefore, the PSB indicates that this reach could be expected to experience periods of both aggradation and degradation; however, the overall long-term tendency would be towards aggradation.

The results of the PSB indicate an extremely wide range of practical results, owing to the uncertainty in the data. Because of this, it is difficult to use the measured sediment data by itself as a morphological predictor. A more appropriate use of these data is to supplement the geometric and specific gage analyses. It is also important to note that since the data are limited to four stations within the study reach, the sediment budget results are most applicable at the broader scale analysis. At the smaller, sub-reach scale, their utility is limited.

5.3.2 PSB for fines

The PSB results for the fine loads raises questions about the fate of fine sediments between Tarbert Landing and Belle Chasse. According to the PSB, there is a tendency for the deposition of fine sediment between Tarbert Landing and Baton Rouge. However, it must be noted that the PSB also indicated a wide range of practical outcomes ranging from approximately 59 million tons/yr of deposition to 13.8 million tons/yr of erosion. Within this reach, there are a number of low over bank areas, particularly just upstream of St. Francisville that are potential deposition areas for fine sediments. Sediment deposition of fine sediments in these overbank areas has been documented by a number of researchers (Kesel et al. 1974). However, a quantitative determination of the volume of fine sediment deposited in these areas has not been established; it is likely that fine sediments are being stored in this reach. Quantifying this deposition using the measured fine sediment data is difficult due to the uncertainty in the data.

With respect to the Baton Rouge to Belle Chasse reach, the PSB indicates that there is a tendency for erosion of fine sediments. More importantly, the PSB produced a wide range of practical outcomes, ranging from 30.9 million tons/yr of erosion to 12.8 million tons/yr of deposition. Therefore, it is difficult to establish with any certainty whether fine sediments are being eroded or deposited within this reach using the measured fine sediment data.

6 Integration

Channel stability was assessed using channel geometry changes from the decadal surveys, specific gage records, and the PSB. For this assessment, the river between Old River and the Head of Passes was divided into the following nine geomorphic reaches:

- Old River to Tarbert Landing
- Tarbert Landing to Bayou Sara
- Bayou Sara to Baton Rouge
- Baton Rouge to Donaldsonville
- Donaldsonville to Bonne Carré
- Bonne Carré to New Orleans
- New Orleans to Belle Chasse
- Belle Chasse to Empire
- Empire to RM 4

Temporally, the analysis was divided into the following four general time periods:

- 1960s–1970s, extending from approximately 1961–1963 to 1973–1975
- 1970s–1990s, extending from approximately 1973–1975 to 1991–1992
- 1990s–2000s, extending from approximately 1991–1992 to 2003–2004 downstream of Baton Rouge and to 2012 upstream of Baton Rouge
- 1970s–2000s, extending from approximately 1973–1975 to 2003–2004 downstream of Baton Rouge and to 2012 upstream of Baton Rouge.

For each time period, the channel geometry, specific gage data, and PSB were integrated to obtain a composite stability assessment for each reach. Stability was divided into the following five broad categories:

- Aggradation
- Trending Aggradation
- Dynamic Equilibrium
- Trending Degradation
- Degradation

The interpretation of the results necessarily involved some engineering judgment when distinguishing among the different categories. In an effort to provide some consistency in the approach, general criteria were developed to aid in the interpretation of trends. Table 22 lists these trends. The confidence placed in each metric (channel geometry, specific gage, and PSB), and consequently the weight given to it in the final integration of results, varied according to the reach and time period considered. Tables 23–26 list the tabulation of results for each time period. Table 27 lists the results for all time periods. Figures 119–122 present color-coded maps of the stability assessments by reach for each time period.

Table 22. Criteria for integration of geomorphic assessment analyses.

Assessment	Criteria for Integration of Analyses		
	Channel Volume Percent Change	Specific Gage Trends	PSB
Aggradation	>1.5%	Statistically significant aggradational trends	Not applicable
Trending Aggradation	0.8% to 1.5%	Inconclusive aggradational trends	Dominant trends indicate aggradation
Dynamic Equilibrium	0.8% to −0/8%	No statistically significant trends	Results balanced between aggradation and degradation
Trending Degradation	−0.8% to −1.5%	Inconclusive degradational trends	Dominant trends indicate degradation
Degradation	<−1.5%	Statistically significant degradational trends	Not applicable

Table 23. Geomorphic reach stability (1960s–1970s).

Reach	Channel Geometry	Specific Gage	Sediment Budget	Integrated Result
Old River–Tarbert	D	A	N/A	TD
Tarbert–Bayou Sara	A	A	N/A	A
Bayou Sara–Baton Rouge	A	A	N/A	A
Baton Rouge–Donaldsonville	EQ	A	N/A	EQ
Donaldsonville–Bonnet Carré	D	A	N/A	D
Bonnet Carré–New Orleans	D	N/A	N/A	D
New Orleans–Belle Chasse	D	N/A	N/A	D
Belle Chasse–Empire	D	N/A	N/A	D
Empire–RM4	D	N/A	N/A	D

A=Aggradation

TA=Trending Aggradation

D=Degradation

TD=Trending Degradation

EQ=Dynamic Equilibrium

N/A=Not Applicable

Table 24. Geomorphic reach stability (1970s–1990s).

Reach	Channel Geometry	Specific Gage	Sediment Budget	Integrated Result
Old River–Tarbert	EQ	TD	N/A	EQ
Tarbert–Bayou Sara	D	TD	TA	TD
Bayou Sara–Baton Rouge	A	TD	EQ	EQ
Baton Rouge–Donaldsonville	EQ	TD	TA	TD
Donaldsonville–Bonnet Carré	TA	D	TA	EQ
Bonnet Carré–New Orleans	EQ	N/A	TA	EQ
New Orleans–Belle Chasse	TD	EQ	TA	TD
Belle Chasse–Empire	D	EQ	N/A	D
Empire–RM4	EQ	N/A	N/A	EQ

A=Aggradation
TA=Trending Aggradation
D=Degradation
TD=Trending Degradation
EQ=Dynamic Equilibrium
N/A=Not Applicable

Table 25. Geomorphic reach stability (1990s–2000s).

Reach	Channel Geometry	Specific Gage	Sediment Budget	Integrated Result
Old River–Tarbert	A	A	N/A	A
Tarbert–Bayou Sara	A	A	TA	A
Bayou Sara–Baton Rouge	TD	A	EQ	EQ
Baton Rouge–Donaldsonville	A	TA	TA	TA
Donaldsonville–Bonnet Carré	A	EQ	TA	TA
Bonnet Carré–New Orleans	EQ	N/A	TA	EQ
New Orleans–Belle Chasse	TD	N/A	TA	TD
Belle Chasse–Empire	TA	N/A	N/A	TA
Empire–RM4	A	N/A	N/A	A

A=Aggradation
TA=Trending Aggradation
D=Degradation
TD=Trending Degradation
EQ=Dynamic Equilibrium
N/A=Not Applicable

Table 26. Geomorphic reach stability (1970s–2000s).

Reach	Channel Geometry	Specific Gage	Sediment Budget	Integrated Result
Old River–Tarbert	A	A	N/A	A
Tarbert–Bayou Sara	A	TA	TA	A
Bayou Sara–Baton Rouge	TA	EQ	EQ	EQ
Baton Rouge–Donaldsonville	A	TD	TA	TA
Donaldsonville–Bonnet Carré	A	D	TA	TA
Bonnet Carré–New Orleans	TA	N/A	TA	TA
New Orleans–Belle Chasse	D	TD	TA	TD
Belle Chasse–Empire	EQ	EQ	N/A	EQ
Empire–RM4	A	N/A	N/A	A

A=Aggradation
TA=Trending Aggradation
D=Degradation
TD=Trending Degradation
EQ=Dynamic Equilibrium
N/A=Not Applicable

Table 27. Geomorphic reach stability for all time periods.

Analysis Type	Stability Assessment for Given Time Period			
	1960s–1970s	1970–1990s	1990s–2000s	1970s–2000s
	Old River to Tarbert Landing			
Channel Geometry	D	EQ	A	A
Specific Gage	A	TD	A	A
Sediment Budget	N/A	N/A	N/A	N/A
Integrated Result	TD	EQ	A	A
	Tarbert Landing to Bayou Sara			
Channel Geometry	A	D	A	A
Specific Gage	A	TD	A	A
Sediment Budget	N/A	TA	TA	TA
Integrated Result	A	TD	A	A
	Bayou Sara to Baton Rouge			
Channel Geometry	A	A	TD	TA
Specific Gage	A	TD	A	EQ
Sediment Budget	N/A	EQ	EQ	EQ
Integrated Result	A	EQ	EQ	EQ
	Baton Rouge to Donaldsonville			
Channel Geometry	EQ	EQ	A	A

Analysis Type	Stability Assessment for Given Time Period			
	1960s–1970s	1970–1990s	1990s–2000s	1970s–2000s
Specific Gage	A	TD	TA	TA
Sediment Budget	N/A	TA	TA	TA
Integrated Result	EQ	TD	TA	TA
	Donaldsonville to Bonnet Carré			
Channel Geometry	D	TA	A	A
Specific Gage	A	D	EQ	D
Sediment Budget	N/A	TA	TA	TA
Integrated Result	D	EQ	TA	TA
	Bonnet Carré to New Orleans			
Channel Geometry	D	EQ	EQ	TA
Specific Gage	N/A	N/A	N/A	N/A
Sediment Budget	N/A	TA	TA	TA
Integrated Result	D	EQ	EQ	TA
	New Orleans to Belle Chasse			
Channel Geometry	D	TD	TD	D
Specific Gage	N/A	EQ	N/A	TD
Sediment Budget	N/A	TA	TA	TA
Integrated Result	D	TD	TD	TD
	Belle Chasse to Empire			
Channel Geometry	D	D	TA	EQ
Specific Gage	N/A	EQ	N/A	EQ
Sediment Budget	N/A	N/A	N/A	N/A
Integrated Result	D	D	TA	EQ
	Empire to RM4			
Channel Geometry	D	EQ	A	A
Specific Gage	N/A	N/A	N/A	N/A
Sediment Budget	N/A	N/A	N/A	N/A
Integrated Result	D	EQ	A	A

A=Aggradation
TA=Trending Aggradation
D=Degradation
TD=Trending Degradation
EQ=Dynamic Equilibrium
N/A=Not Applicable

Figure 119. Color-coded map of geomorphic reach stability assessment, 1960s–1970s.

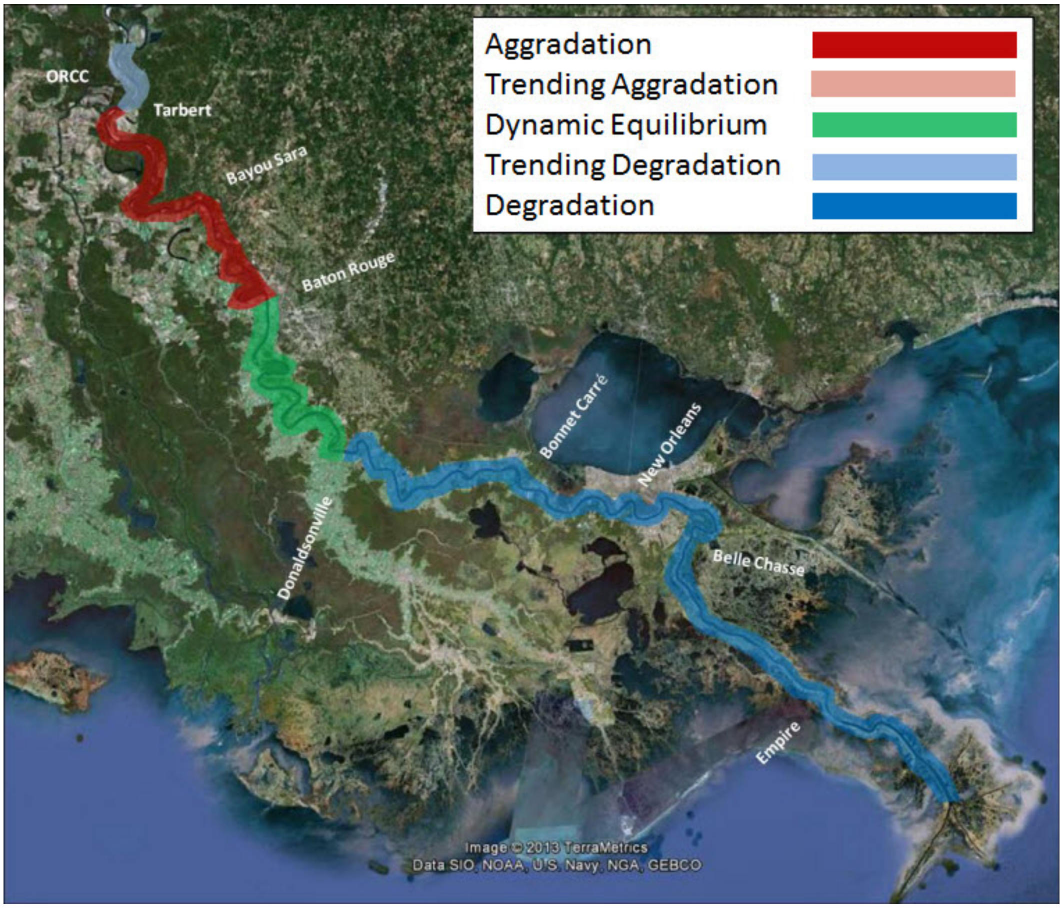


Figure 120. Color-coded map of geomorphic reach stability assessment, 1970s–1990s.

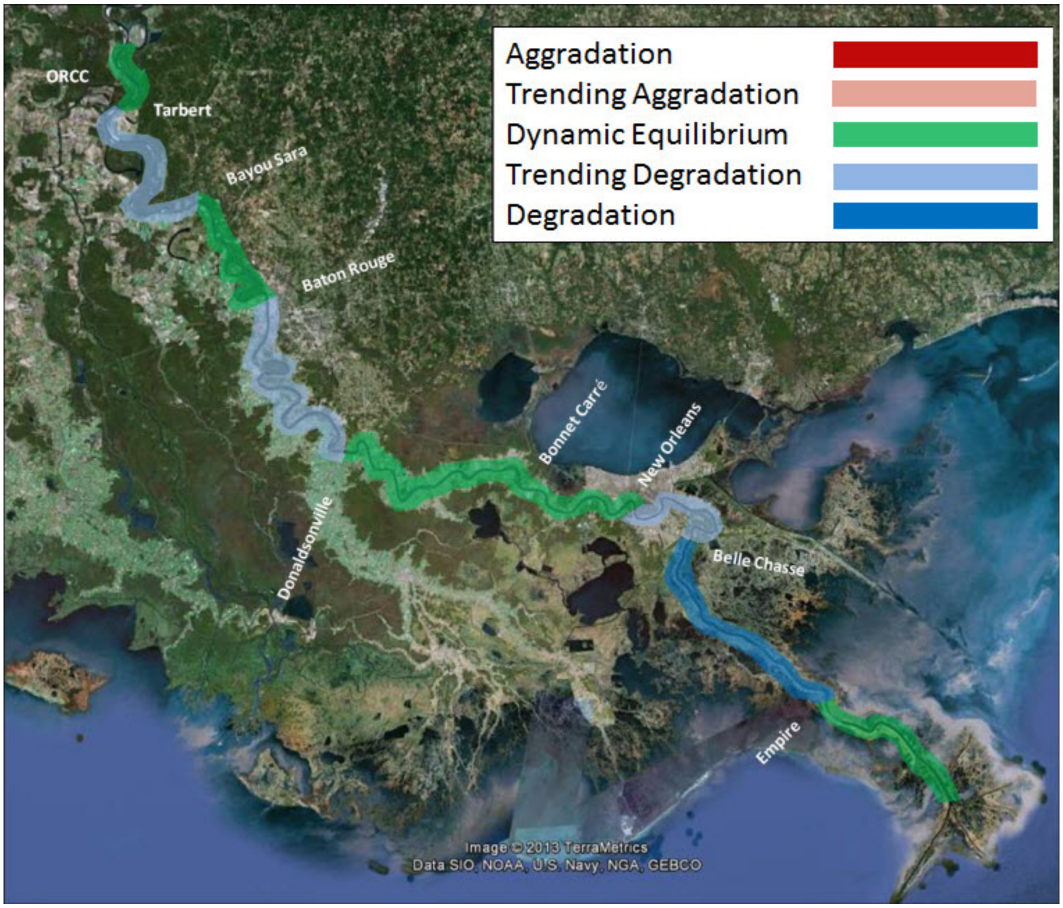


Figure 121. Color-coded map of geomorphic reach stability assessment, 1990s–2000s.

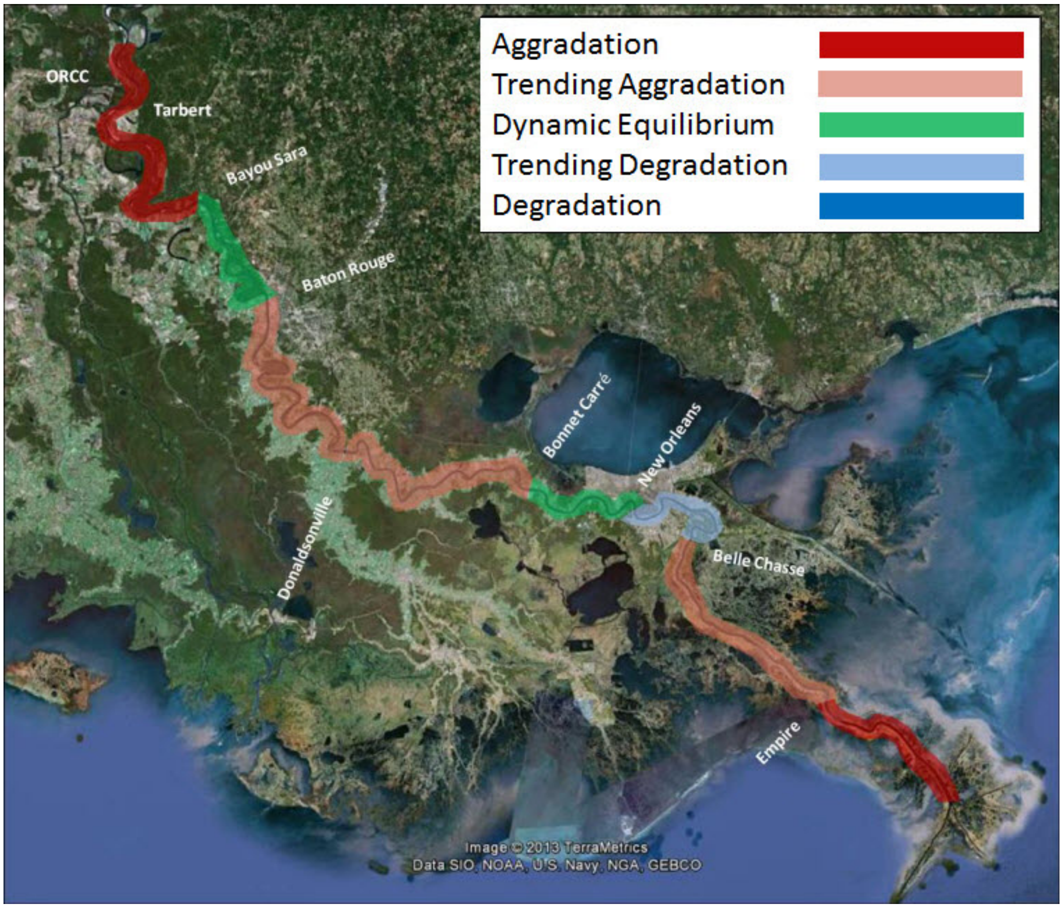
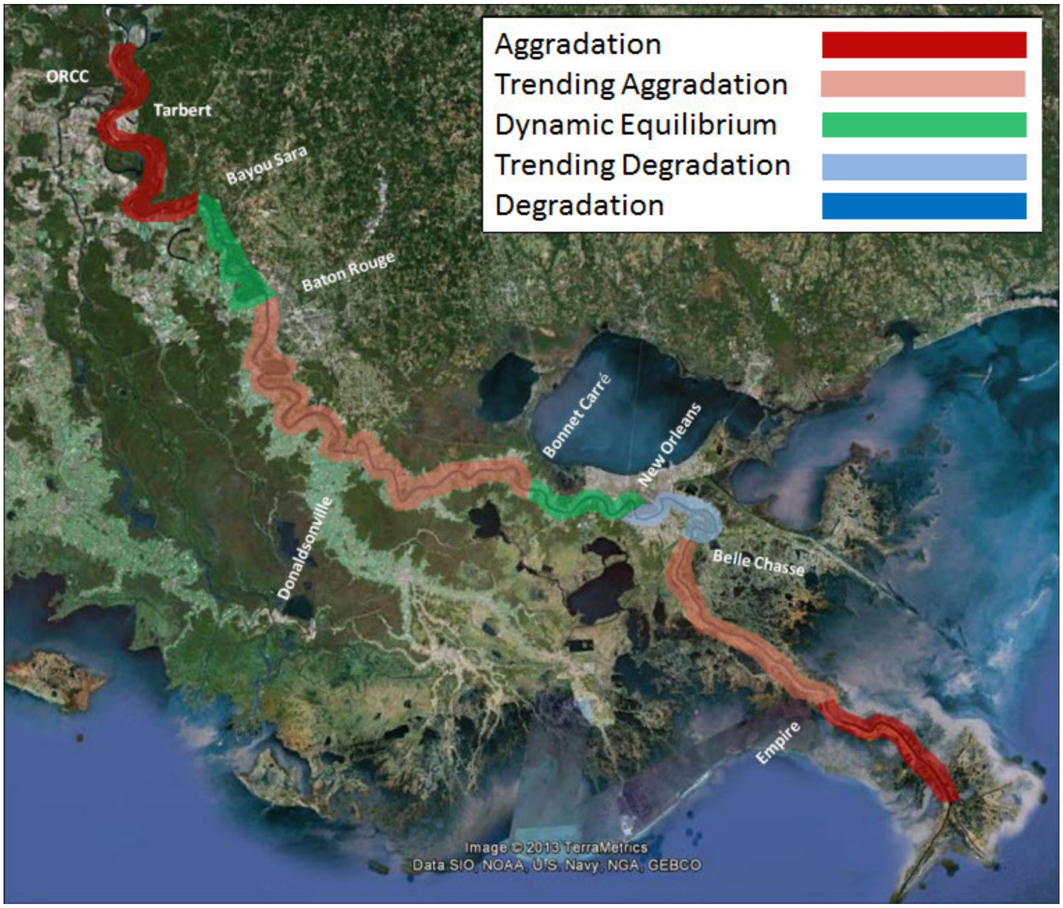


Figure 122. Color-coded map of geomorphic reach stability assessment, 1970s–2000s.



7 Conclusions

1. Analysis of geometric data indicates there is considerable variability in channel dimensions between decadal surveys.
2. Planform and profiles of the river in the study reach have been relatively stable for the study time period.
3. Channel dimension at river crossing sections were observed to be more variable than pool sections.
4. Grid files of observed change between decadal surveys were developed that can be used to investigate channel morphology at desired locations for the Mississippi Hydro and Delta Management Studies.
5. Geometric data analysis at ORCC indicates that diversion structures can have significant impact on local geometry. The evolution of the ORCC has resulted in various sediment diversion ratios due to the characteristics of the individual structures. Changes in the sediment diversion characteristics and location of structures within the ORCC have resulted in notable geometric changes in the immediate vicinity of the ORCC. However, these appear to be local changes based on available data. Long–term, system-wide impacts may occur but are not evident based on current analysis.
6. Depositional trends downstream of Venice that were identified in the West Bay study were confirmed.
7. Observed changes between surveys indicated that the percent change of channel volume below top-bank elevation is relatively small (generally less than ± 5%).
8. It is important to recognize that channel surveys represent single points in time and that channel morphology can change rapidly in the river. Therefore, observed changes between these points in time should be viewed with some caution as they may not necessarily reflect true long-term morphologic trends.
9. The specific gage analysis indicates that with the exception of the dramatic increase in stages associated with the 1973 flood, almost all other trends in the post-1973 period are very subtle. It is often difficult to determine if a real trend exists or not, particularly over relatively short time periods. Even when statistically significant trends were identified, the R^2 values were extremely small, indicating that there was little relationship between stage and time.
10. A statistical analysis of the measured suspended sediment data indicated that there had been a statistically significant decreasing trend in the fine

sediment concentration from the 1950s–1980s. However, no significant trends were observed from the 1990s to present. Statistical analysis of the sand concentration data for the period 1959–2011 revealed no monotonically decreasing trend over time.

11. Measured suspended sediment data were analyzed to assist in the assessment of historical channel morphology. Because of the uncertainty in the data, a Monte Carlo approach was developed to capture this uncertainty. A probabilistic sediment budget (PSB) was developed for the 1973–2012 time period using the data at the four main gauging stations (Tarbert Landing, St. Francisville, Baton Rouge, and Belle Chasse).
12. The PSB for the sand loads indicated a tendency for aggradation between Tarbert Landing and St. Francisville and Baton Rouge and Belle Chasse, while the St. Francisville to Baton Rouge reach was in dynamic equilibrium. The median values of the PSB agreed well with observed channel volume changes obtained from the decadal surveys. However, the PSB also indicated a wide range of possible outcomes ranging from degradation to aggradation.
13. The PSB for the fine sediment loads indicated a significant deposition of fine sediment between Tarbert Landing and Baton Rouge. Deposition of fine sediment in the floodplain areas in this reach is reasonable. However, it is difficult to quantify the amount of deposition due to the uncertainty in the suspended sediment data and the limited mapping in the overbank areas. Between Baton Rouge and Belle Chasse, the PSB indicated a wide range of results ranging from erosion to deposition; however, the dominant tendency was for the erosion of fine sediments.
14. The PSB indicates an extremely wide range of practical results, owing to the uncertainty in the data. It is also important to note that since the data are limited to four stations within the study reach, the sediment budget results are most applicable for broader scale analyses. At the smaller, sub-reach scale, its utility is limited.
15. The 1973 flood event had a dramatic impact on the morphology of the river as evidenced by the specific gage records and channel geometry comparisons. The changes in stage and channel geometry resulting from the 1973 flood were the most pronounced changes observed in the past 50 yr. It is important to note that the previous 2 decades prior to the 1973 flood were dominated by moderate flows.
16. The overall stability assessment for the 1960s–1970s time period indicates that the reach downstream of Donaldsonville was dominated by channel degradation. Upstream of Baton Rouge the reach was dominated by aggradation, except for the ORCC to Tarbert Landing reach that was

trending towards degradation due to impacts of the low sill structure. The Baton Rouge to Donaldsonville reach was a transition reach. It is important to note that trends experienced during this period were significantly influenced by the 1973 flood.

17. The overall stability assessment for the 1970s–1990s time period shows that the ORCC to Tarbert Landing, Bayou Sara to Baton Rouge, and Donaldsonville to New Orleans reaches were in dynamic equilibrium. The remaining reaches were trending toward degradation with the exception of the Empire to River Mile 4 above Head of Passes (AHP) reach, which was trending towards aggradation.
18. For the period between the 1990s and the 2000s, the channel shifted to a predominantly aggradational regime throughout the study reach. The only reaches that were not aggradational were the Bonnet Carré to New Orleans reach, which was in dynamic equilibrium, and the New Orleans to Belle Chasse reach, which was trending towards degradation.
19. Over the longer time period between the 1970s and 2012, the general trend of the entire study reach was predominantly aggradational, with the exception of the New Orleans to Belle Chasse reach which was trending toward degradation, and the Belle Chasse to Empire reach which was in dynamic equilibrium.
20. The geomorphic assessment highlighted the importance of considering spatial and temporal variability when assessing channel stability. For instance, the 1970s–1990s was a period reflecting erosion and dynamic equilibrium, while the 1990s–2000s was dominated by aggradation. Morphologic trends on the Lower Mississippi River typically occur over decadal timescales. Consequently, there is considerable uncertainty with assessments that only cover short time periods. Therefore, investigators must be cautious when assuming that short term recent trends will reflect future conditions.

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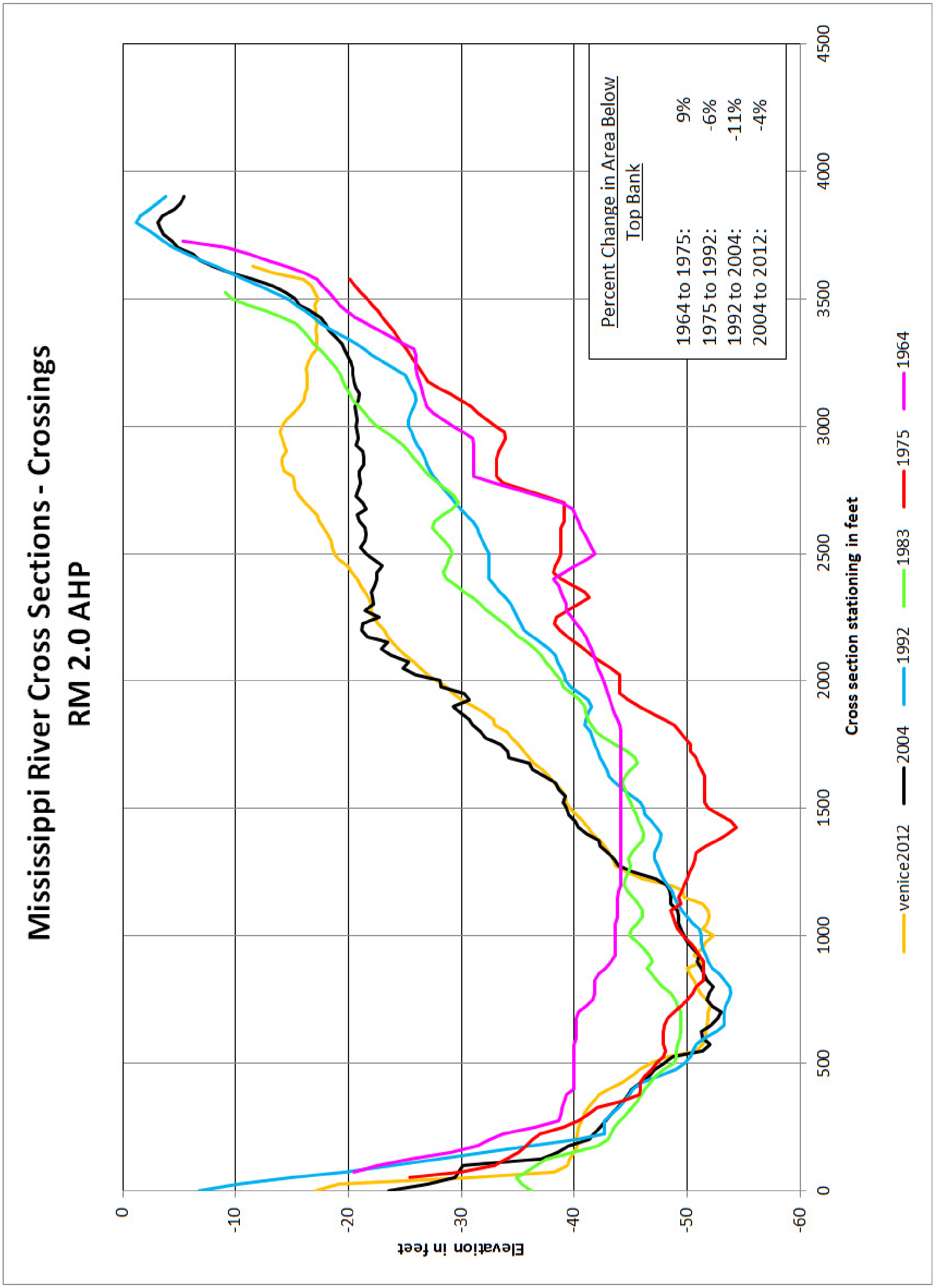
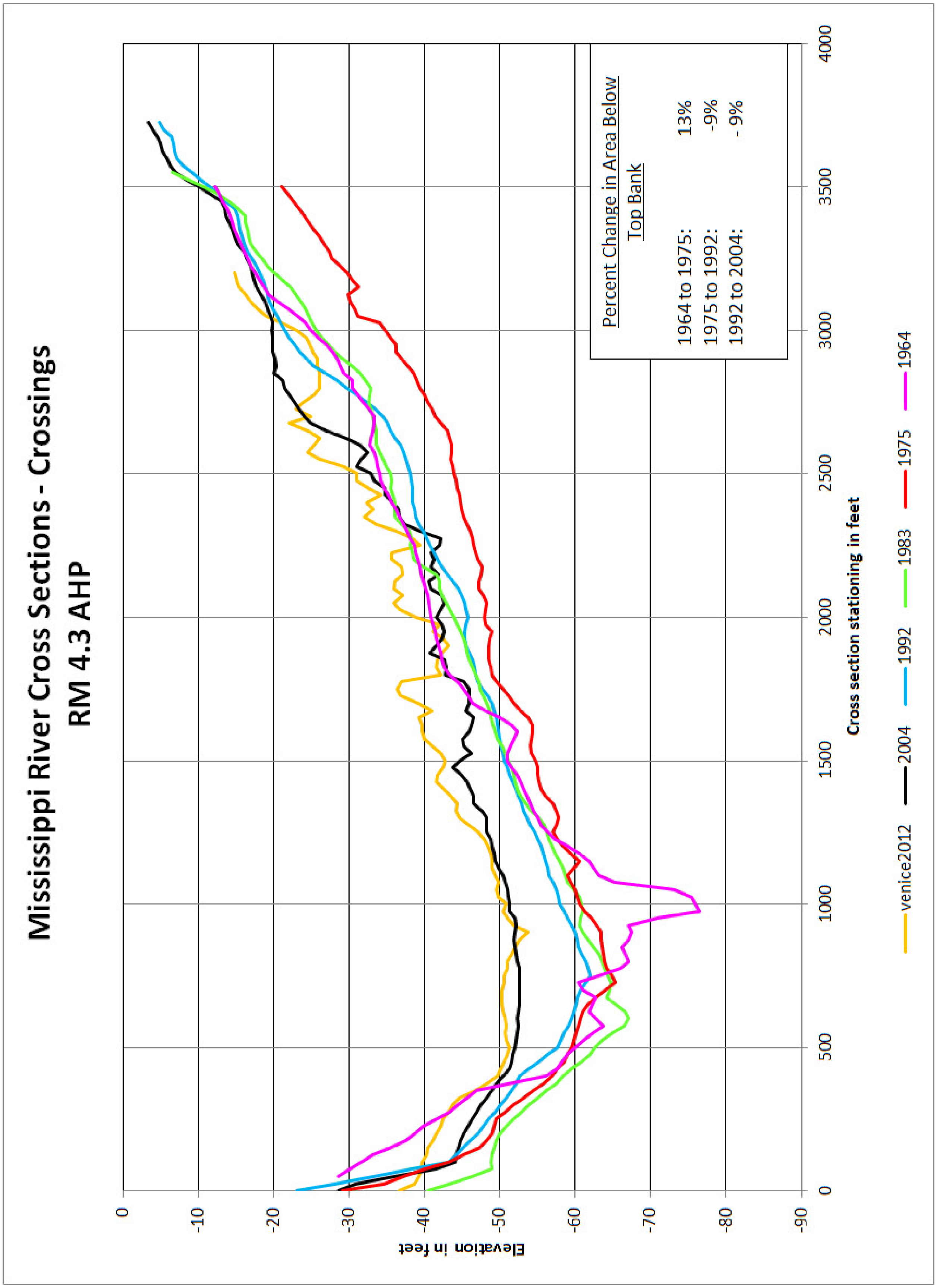
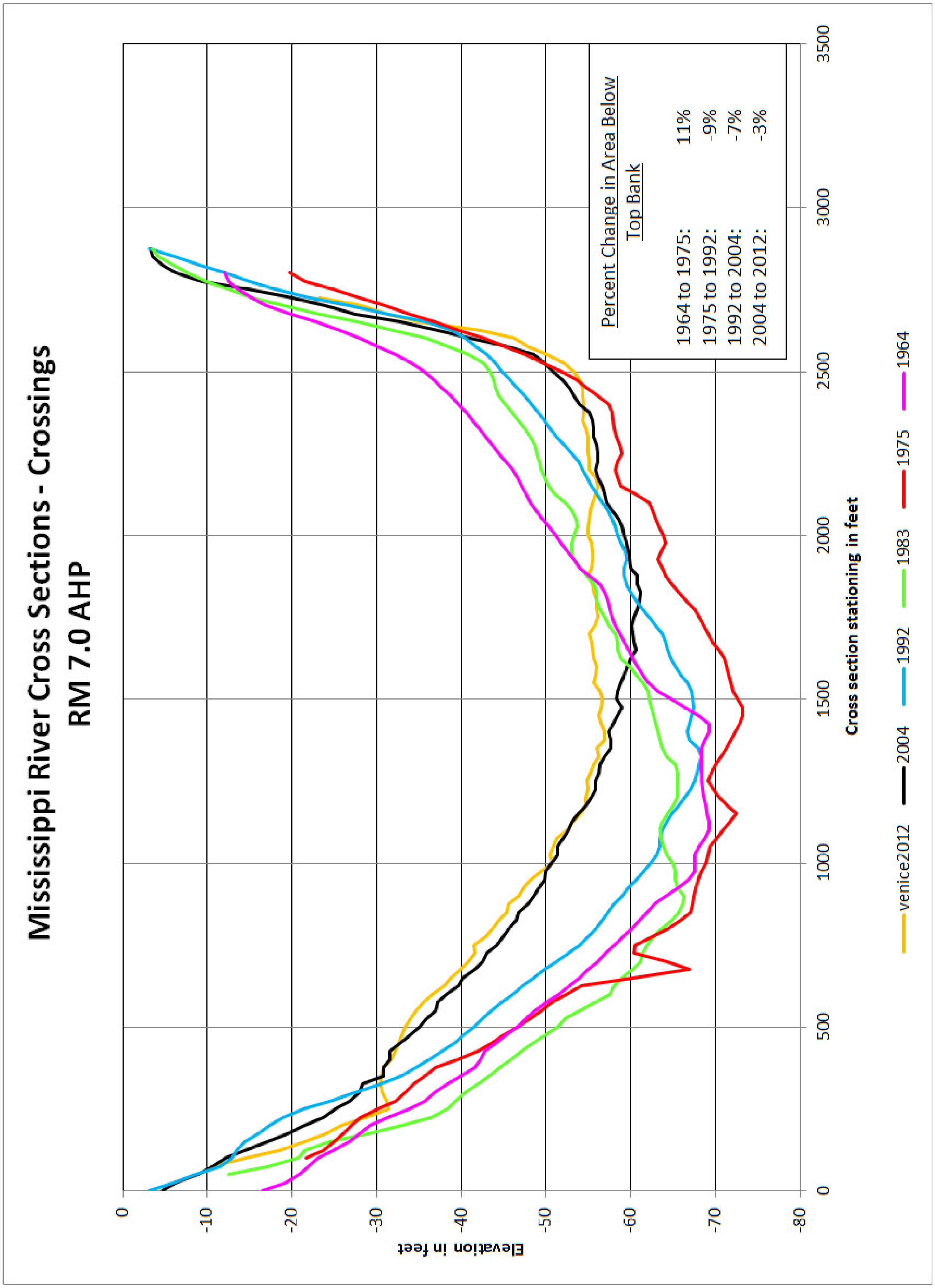
Appendix A: Geometry Data Analysis, Comparative Cross Sections

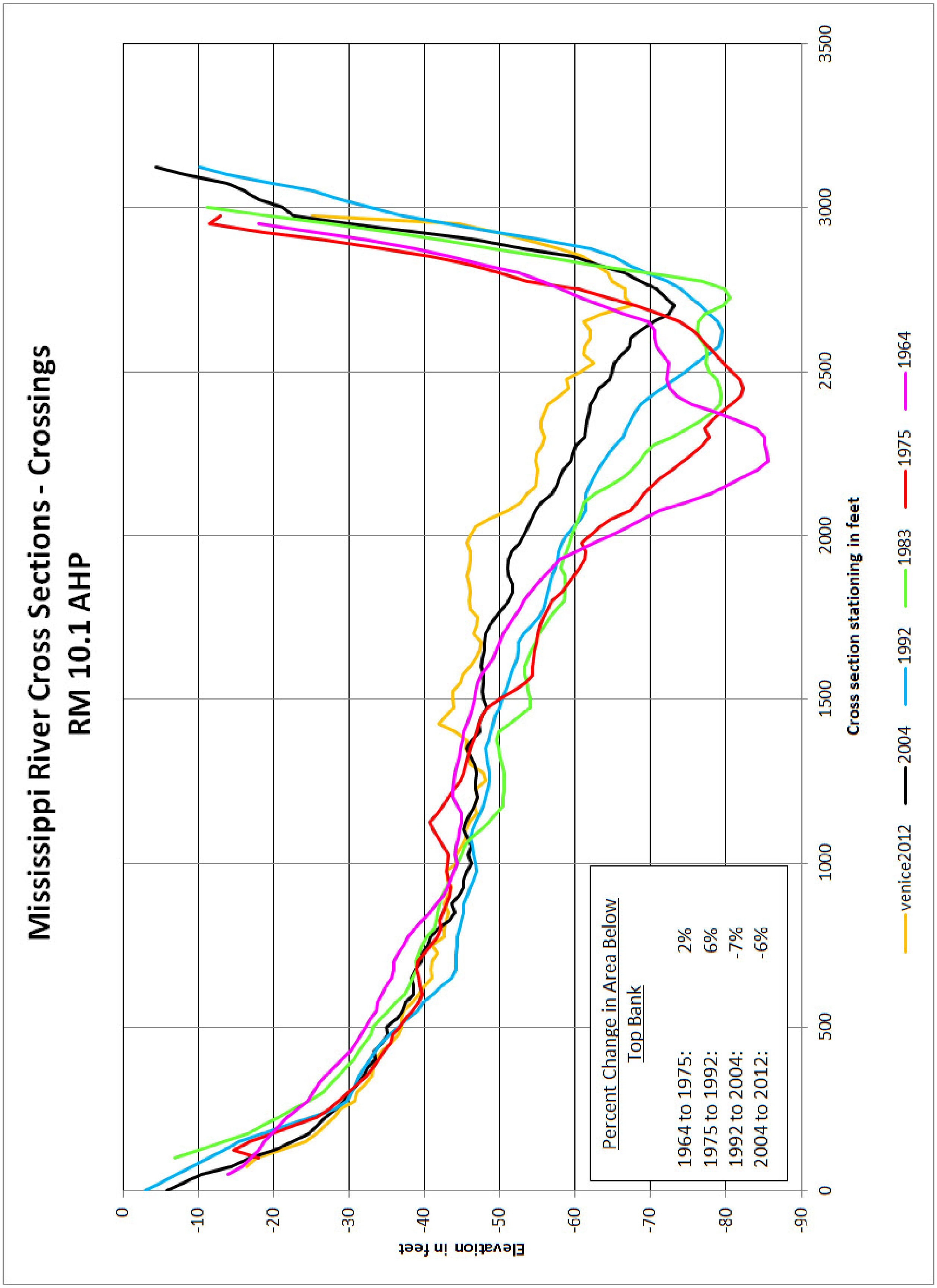
Abbreviations Used in Appendix A	
River mile	RM
Above head of passes	AHP
Cubic yards/mile/year	CY/mi/yr
Old River Control Complex	ORCC
Average	ave.

Comparative cross sections–Crossing locations

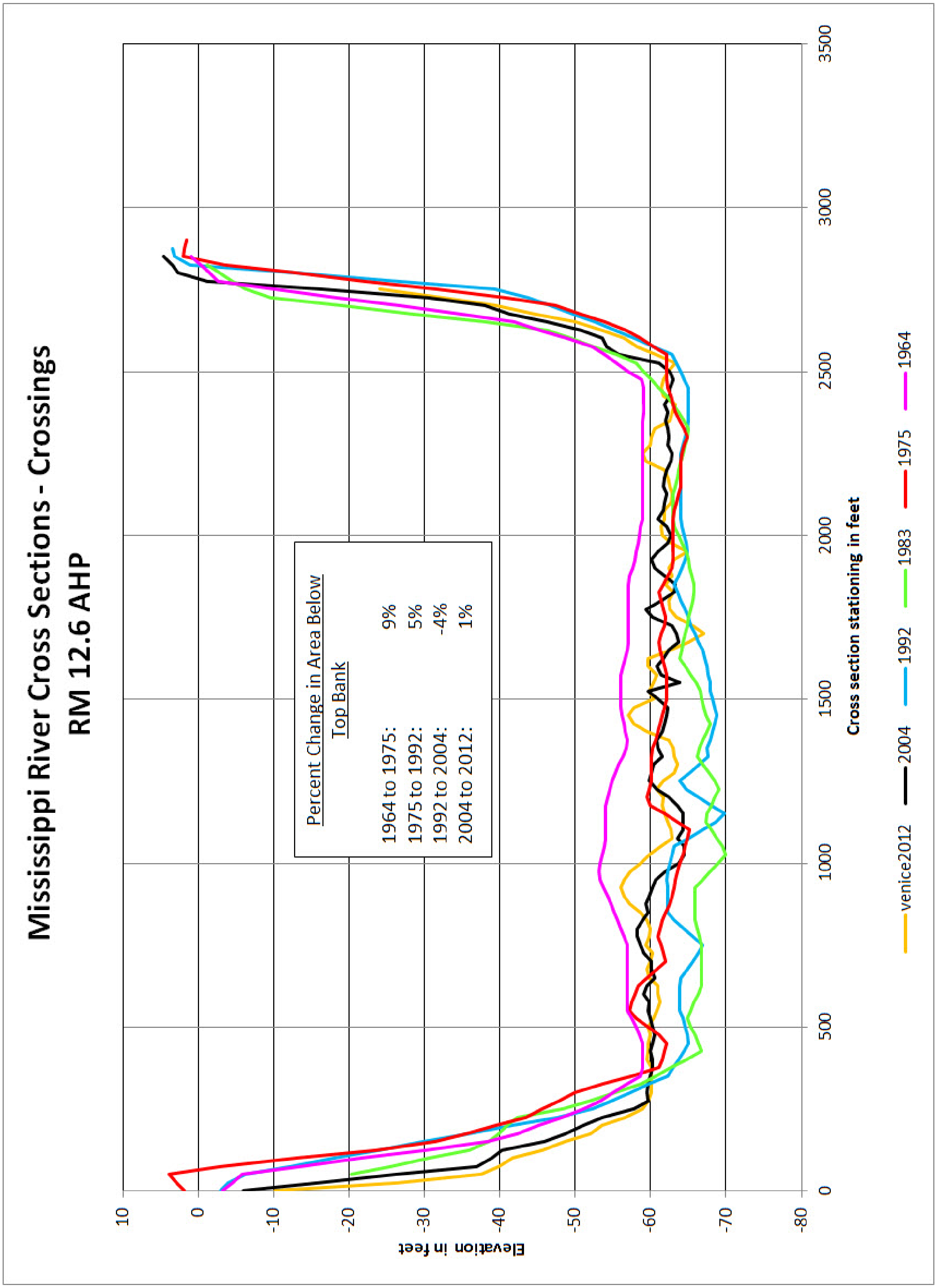

Mississippi River Cross Sections - Crossings
RM 2.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 9%
1975 to 1992: -6%
1992 to 2004: -11%
2004 to 2012: -4%
Elevation in feet
Cross section stationing in feet
0
-10
-20
-30
-40
-50
-60
0
500
1000
1500
2000
2500
3000
3500
4000
4500
venice2012
2004
1992
1983
1975
1964

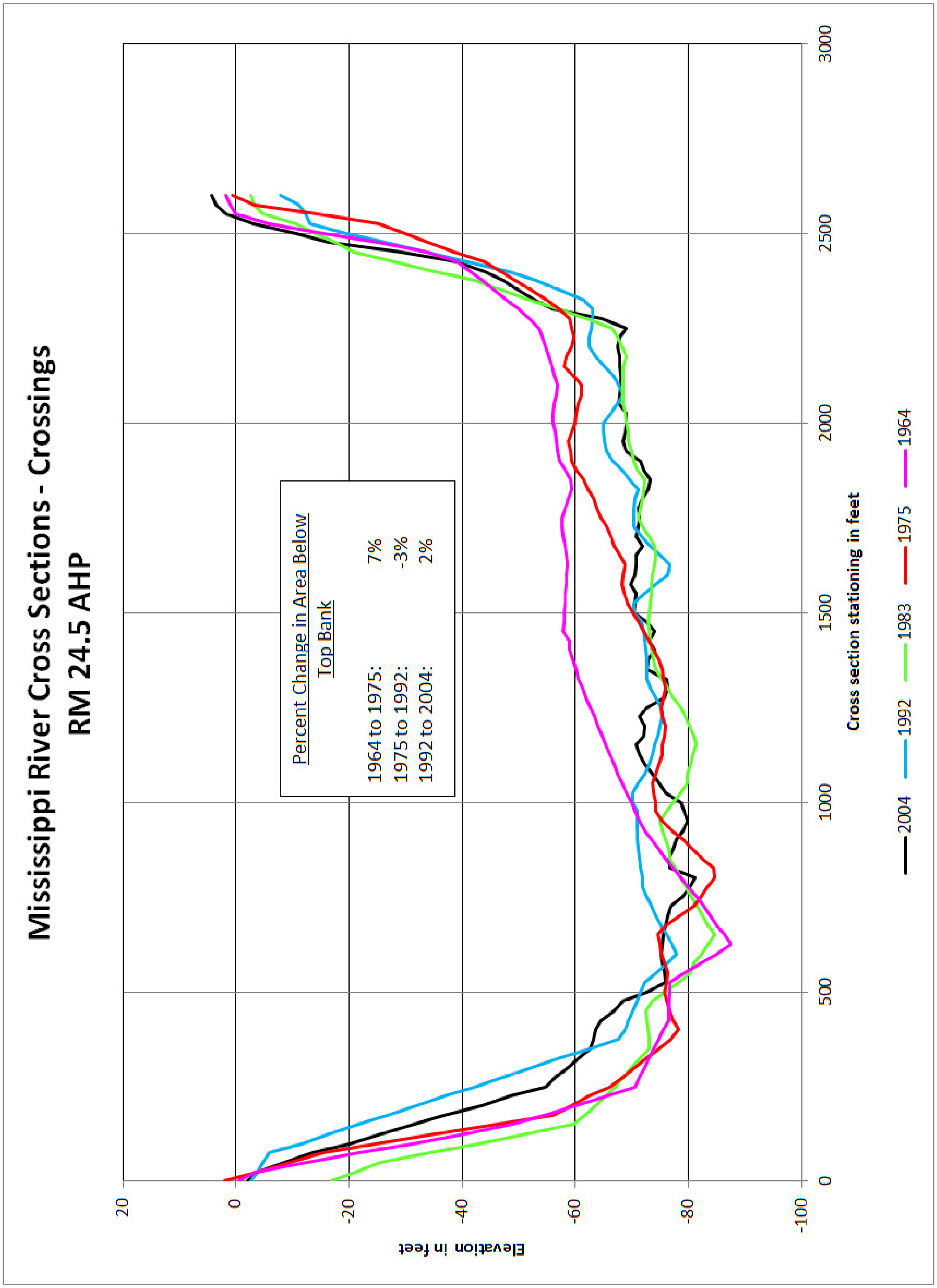

Mississippi River Cross Sections - Crossings
RM 4.3 AHP
Elevation in feet
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
500
1000
1500
2000
2500
3000
3500
4000
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 13%
1975 to 1992: -9%
1992 to 2004: - 9%
venice2012
2004
1992
1983
1975
1964

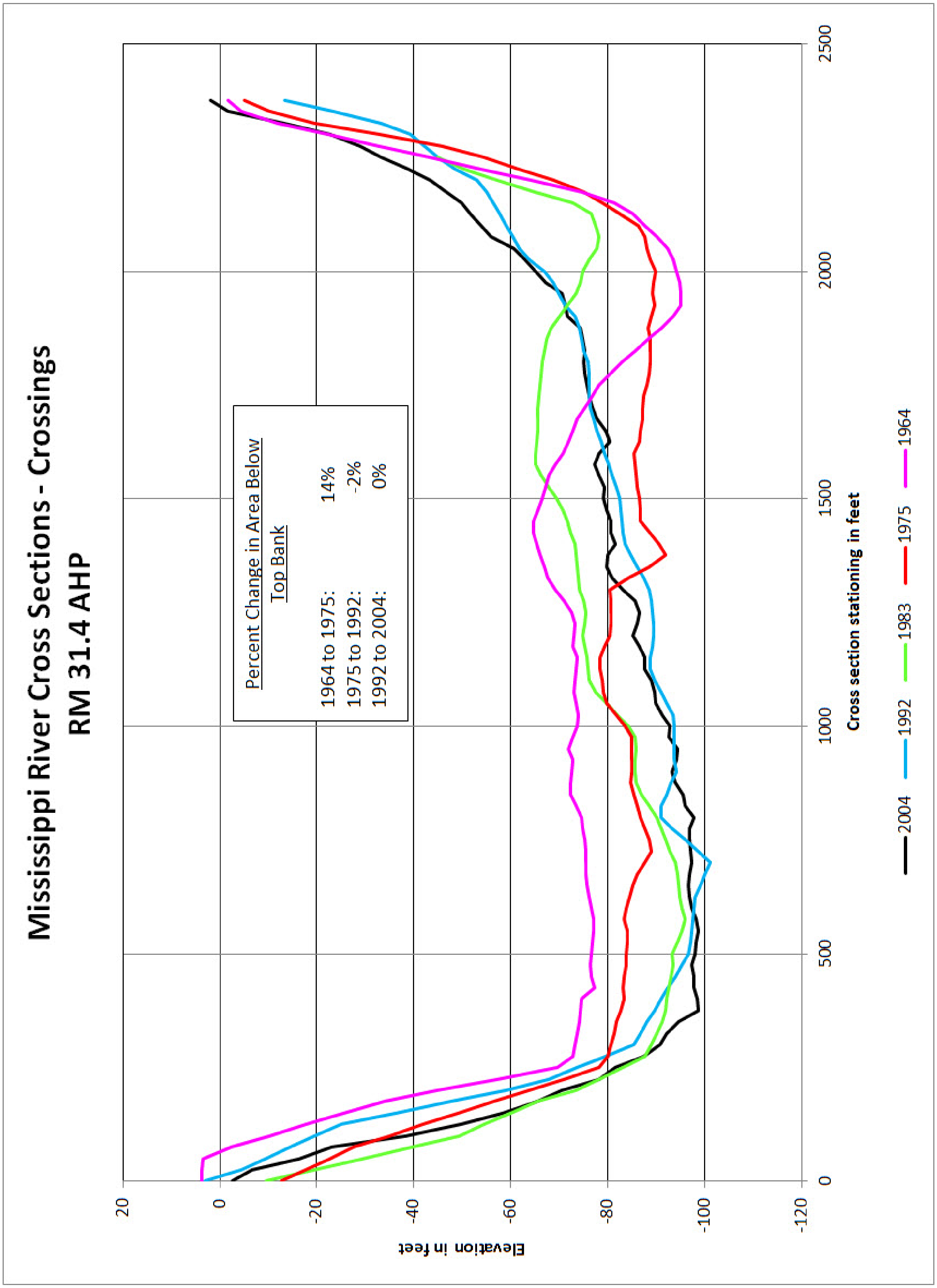

Mississippi River Cross Sections - Crossings
RM 7.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 11%
1975 to 1992: -9%
1992 to 2004: -7%
2004 to 2012: -3%
Elevation in feet
0
-10
-20
-30
-40
-50
-60
-70
-80
Cross section stationing in feet
0
500
1000
1500
2000
2500
3000
3500
venice2012
2004
1992
1983
1975
1964

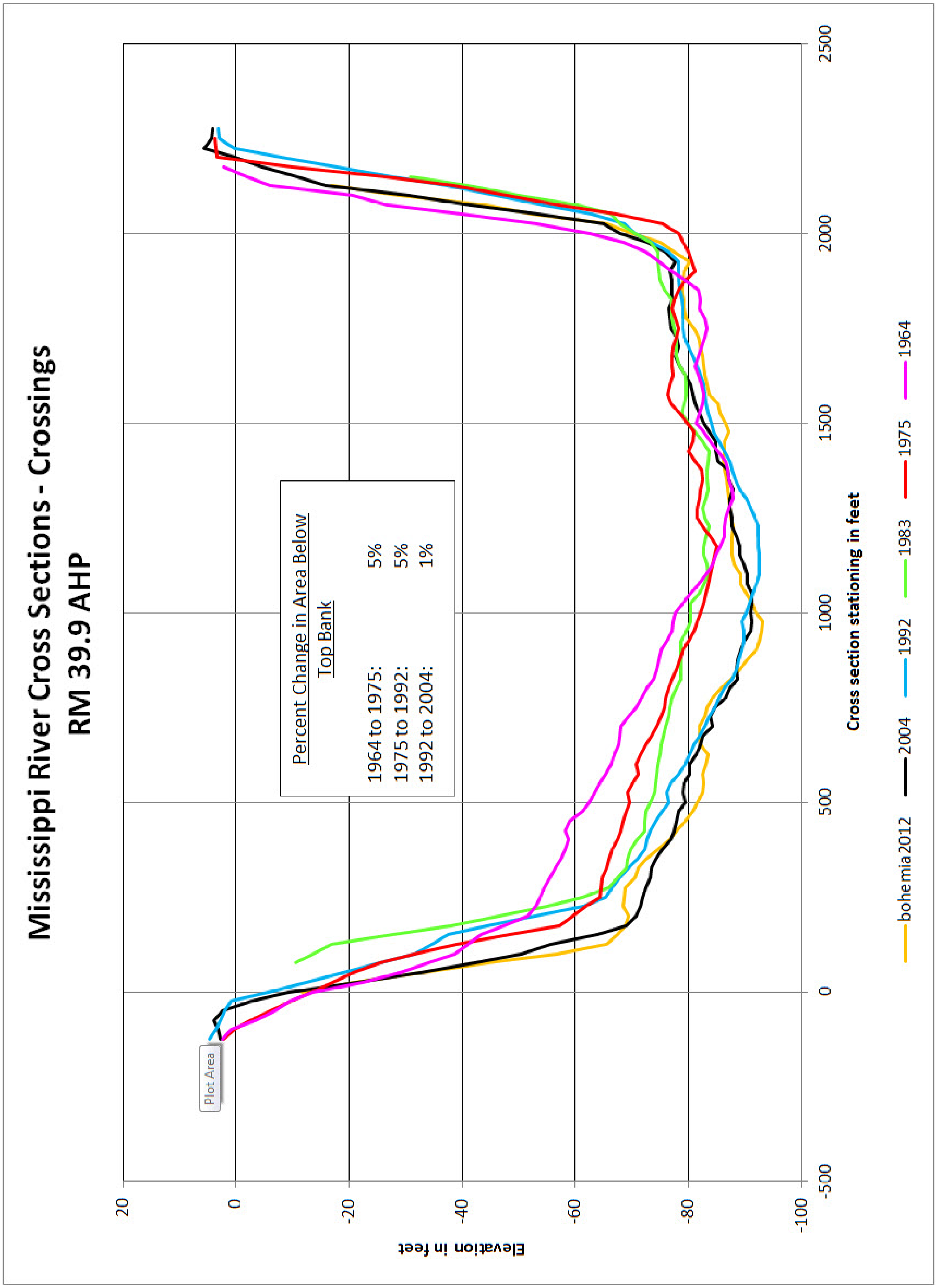


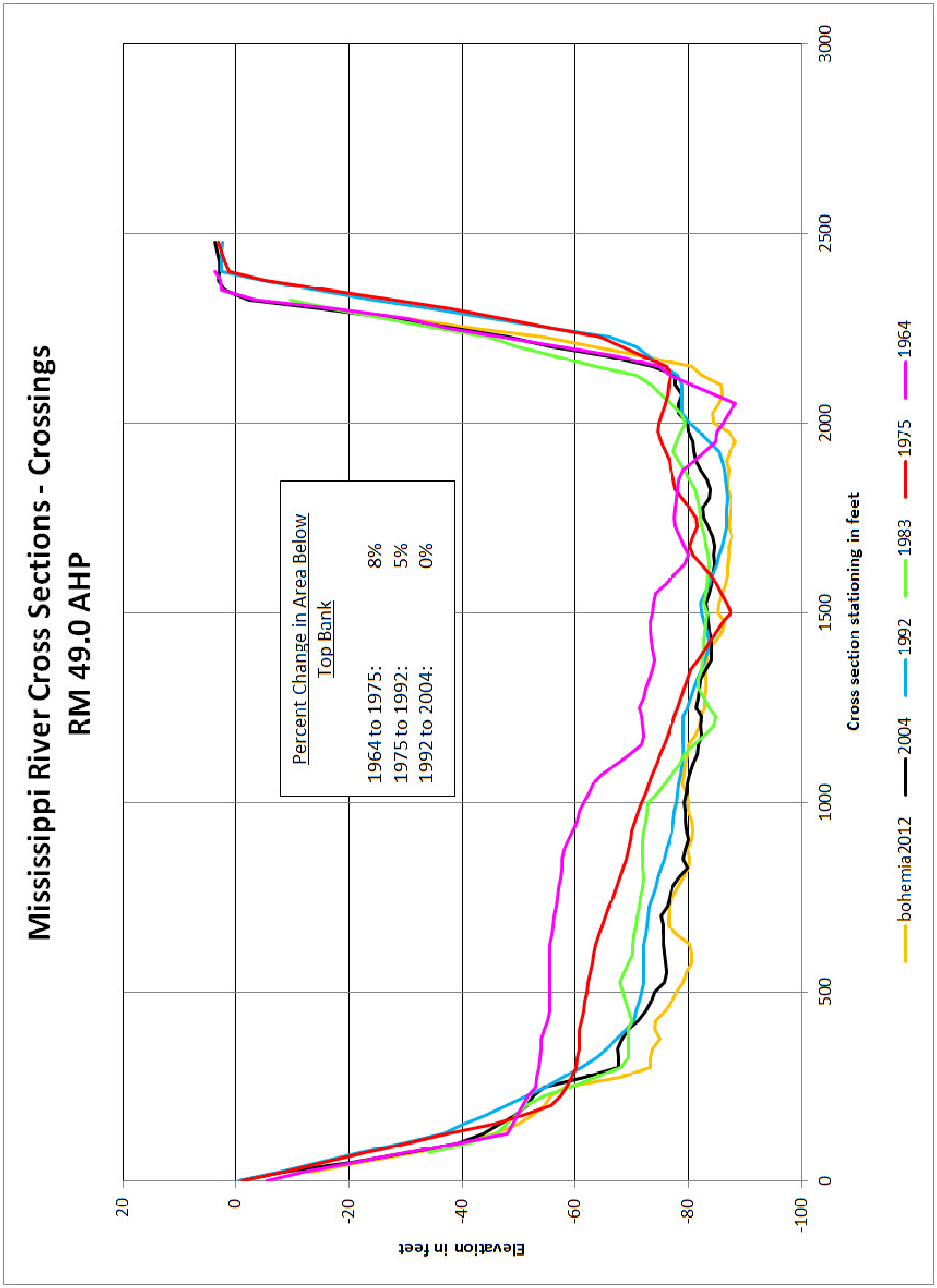
Mississippi River Cross Sections - Crossings
RM 10.1 AHP
Elevation in feet
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Cross section stationing in feet
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: 2%
1975 to 1992: 6%
1992 to 2004: -7%
2004 to 2012: -6%
venice2012
2004
1992
1983
1975
1964

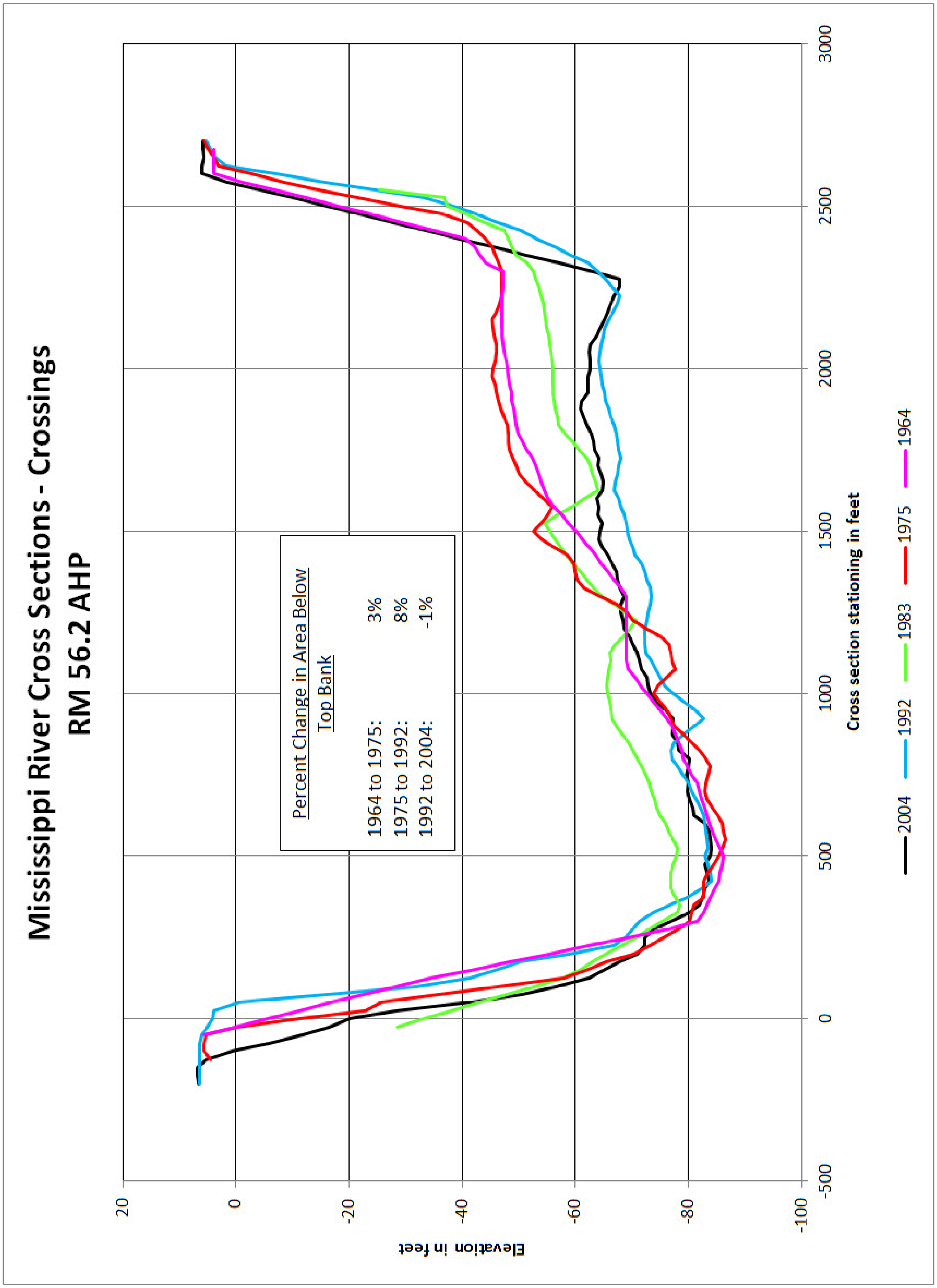

Mississippi River Cross Sections - Crossings
RM 12.6 AHP
Percent Change in Area Below
Top Bank
1964 to 1975: 9%
1975 to 1992: 5%
1992 to 2004: -4%
2004 to 2012: 1%
Elevation in feet
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
venice2012
2004
1992
1983
1975
1964

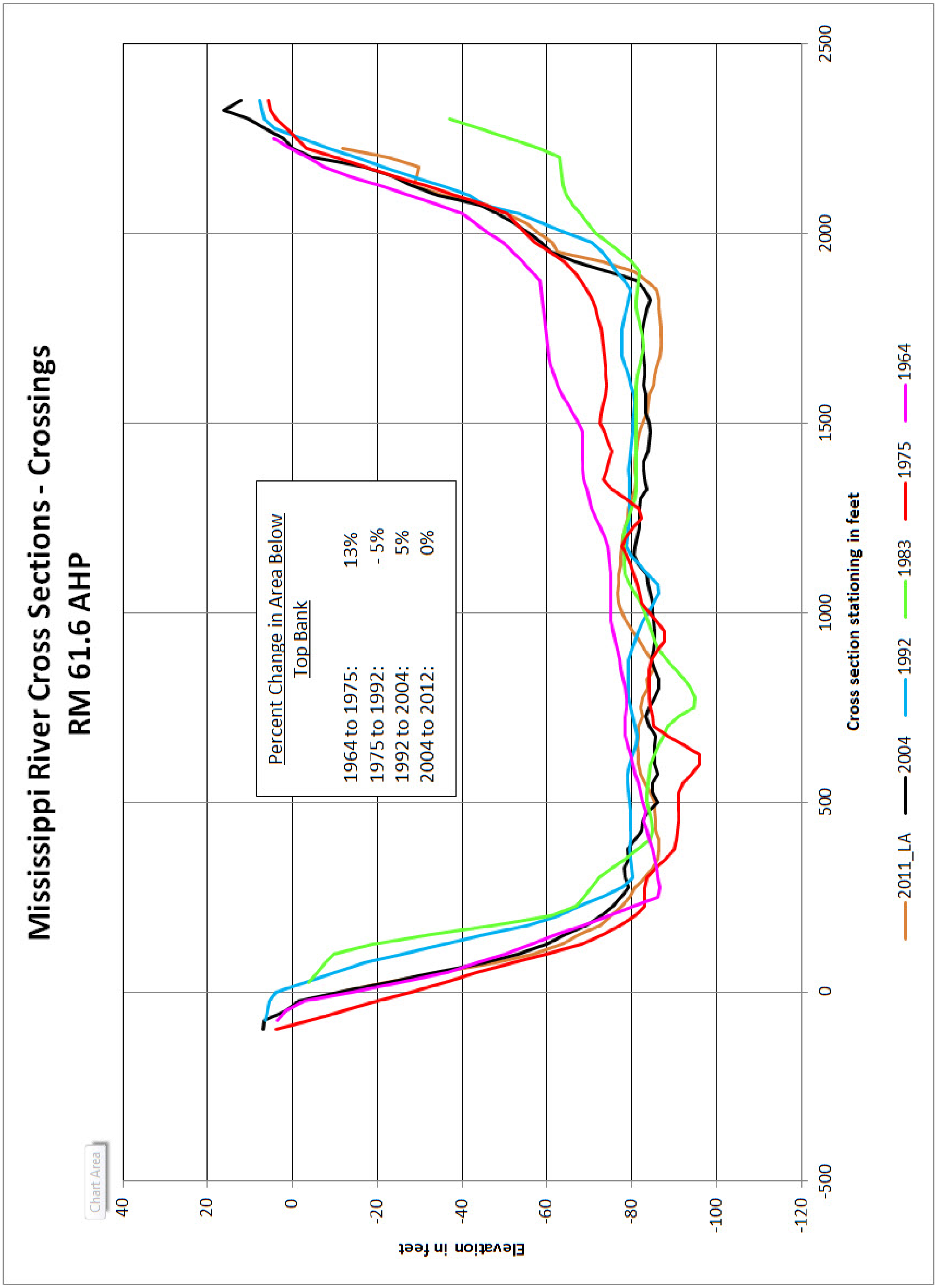

Mississippi River Cross Sections - Crossings
RM 24.5 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: -3%
1992 to 2004: 2%
Elevation in feet
20
0
-20
-40
-60
-80
-100
Cross section stationing in feet
0
500
1000
1500
2000
2500
3000
2004
1992
1983
1975
1964

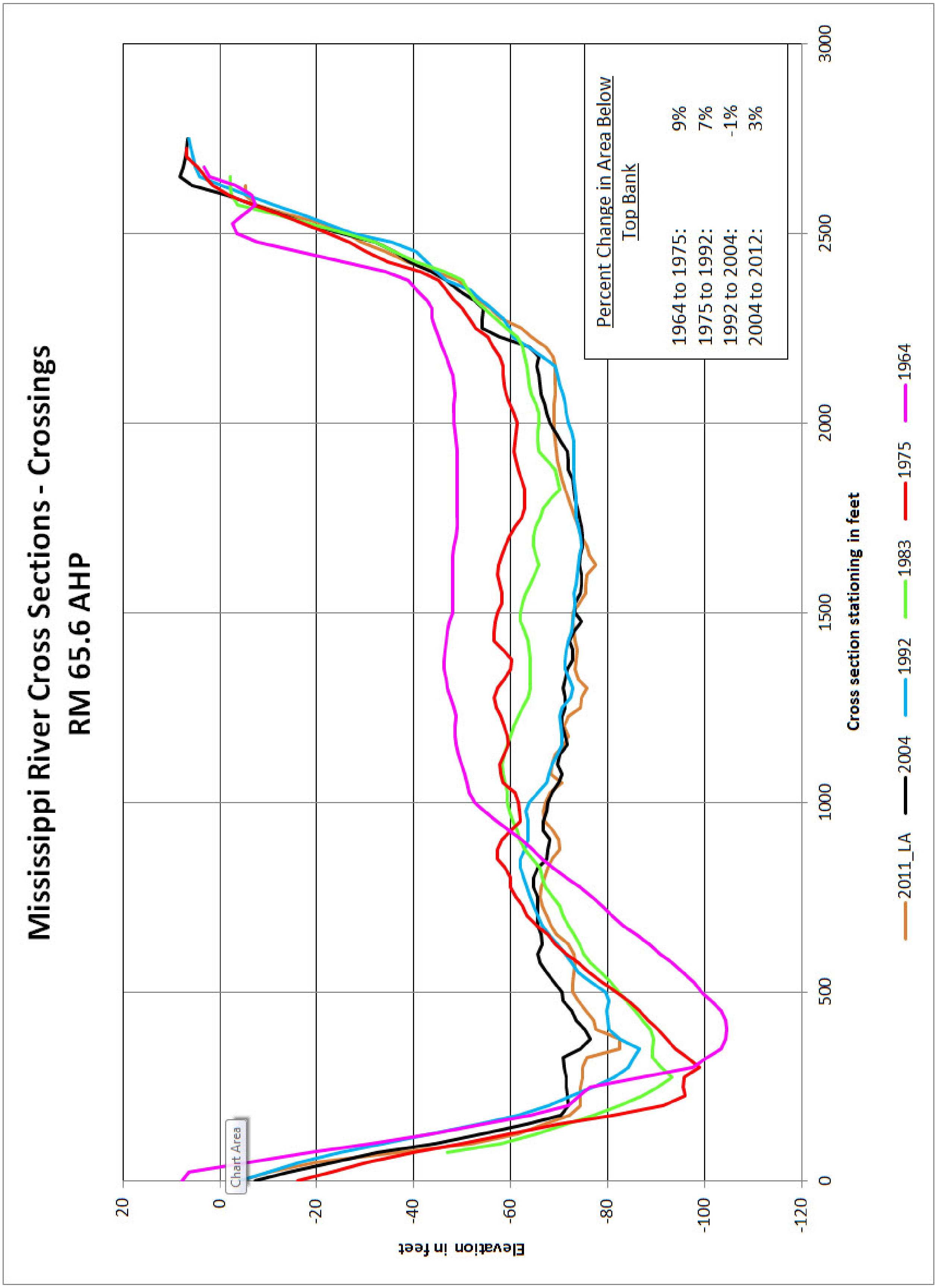

Mississippi River Cross Sections - Crossings
RM 31.4 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 14%
1975 to 1992: -2%
1992 to 2004: 0%
Elevation in feet
20
0
-20
-40
-60
-80
-100
-120
Cross section stationing in feet
0
500
1000
1500
2000
2500
2004
1992
1983
1975
1964

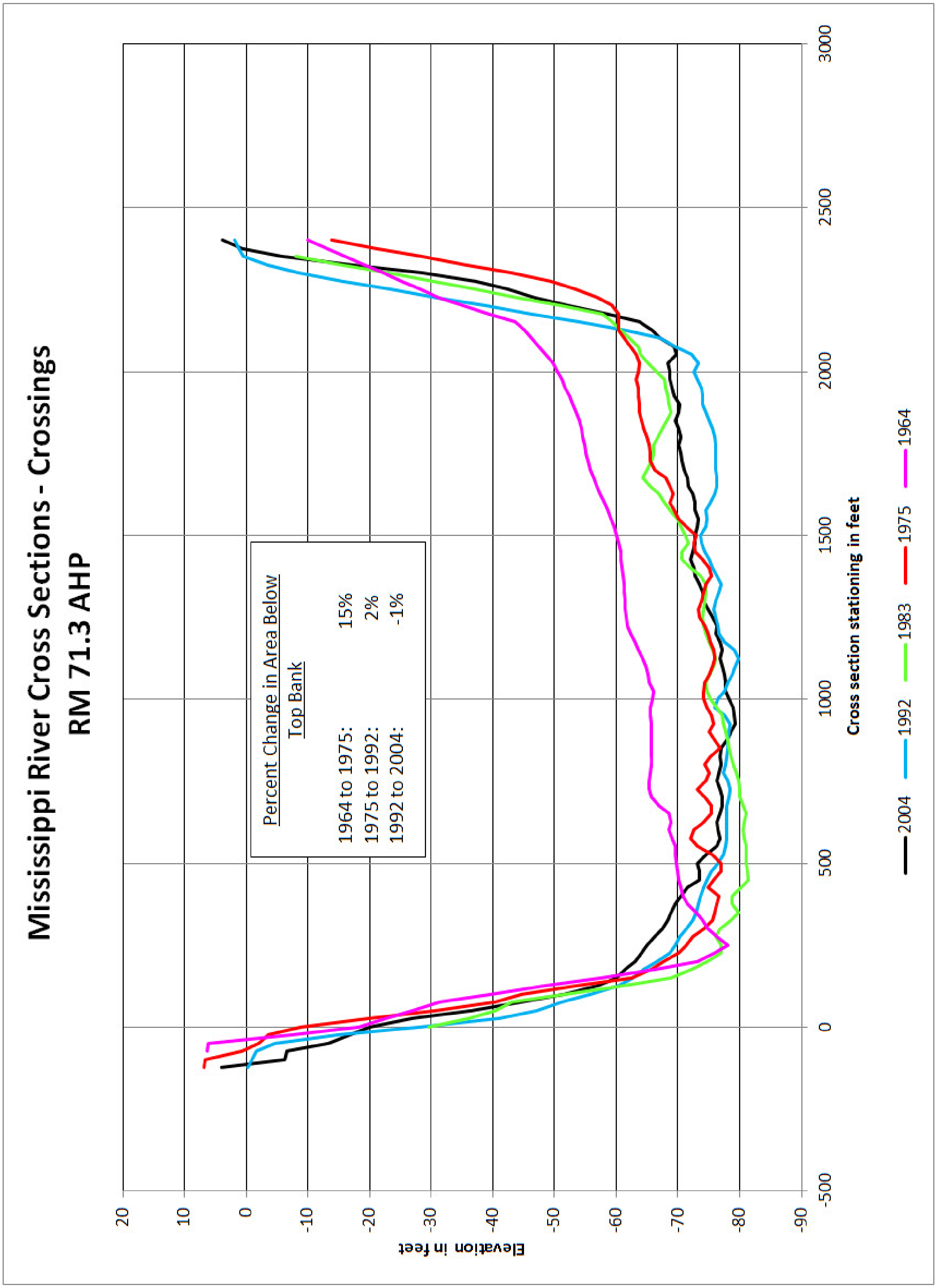

Mississippi River Cross Sections - Crossings
RM 39.9 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 5%
1975 to 1992: 5%
1992 to 2004: 1%
Plot Area
Elevation in feet
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
Cross section stationing in feet
bohemia 2012
2004
1992
1983
1975
1964

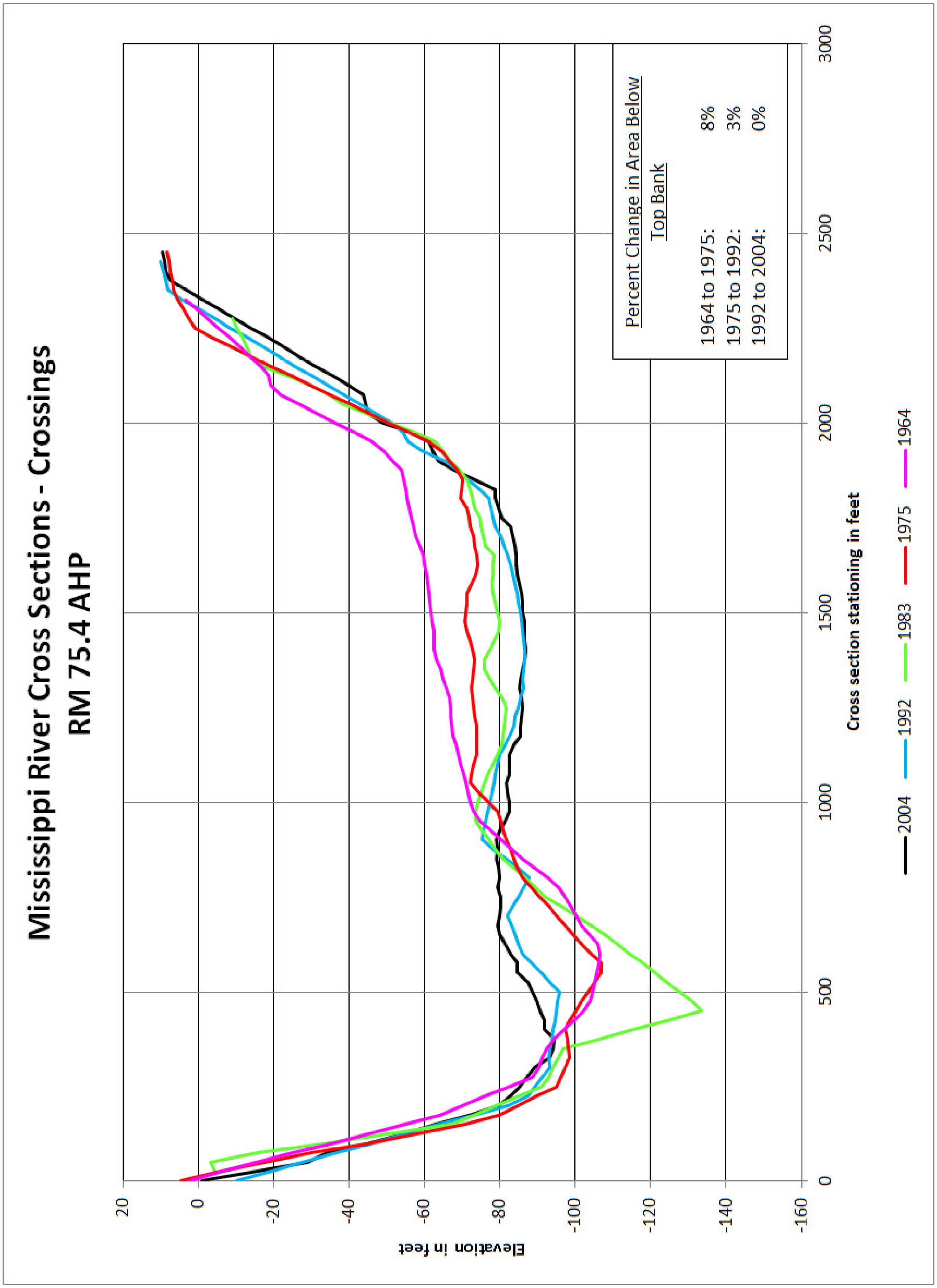

Mississippi River Cross Sections - Crossings
RM 49.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 8%
1975 to 1992: 5%
1992 to 2004: 0%
Elevation in feet
20
0
-20
-40
-60
-80
-100
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
bohemia2012
2004
1992
1983
1975
1964

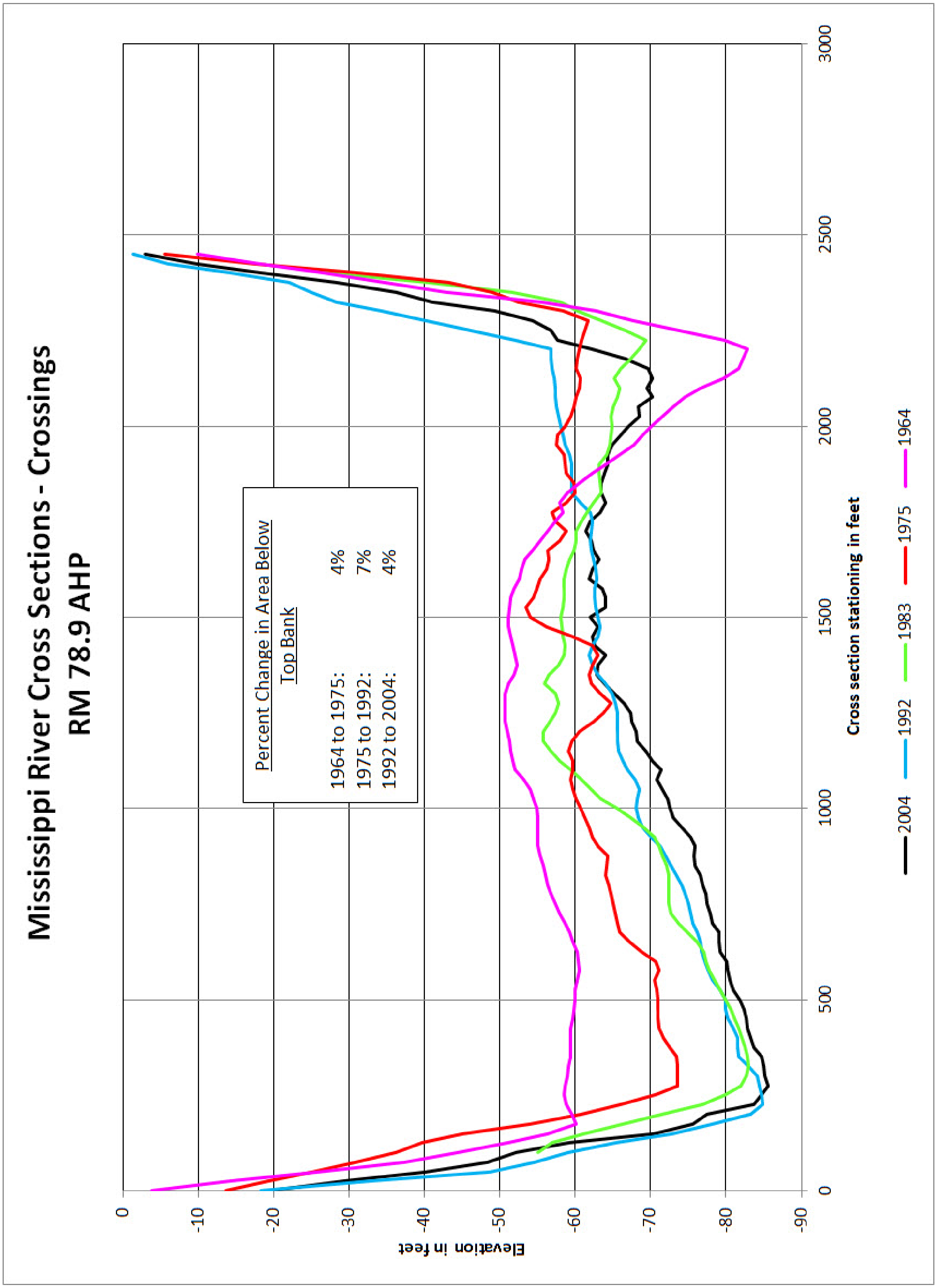

Mississippi River Cross Sections - Crossings
RM 56.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 3%
1975 to 1992: 8%
1992 to 2004: -1%
Elevation in feet
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2004
1992
1983
1975
1964

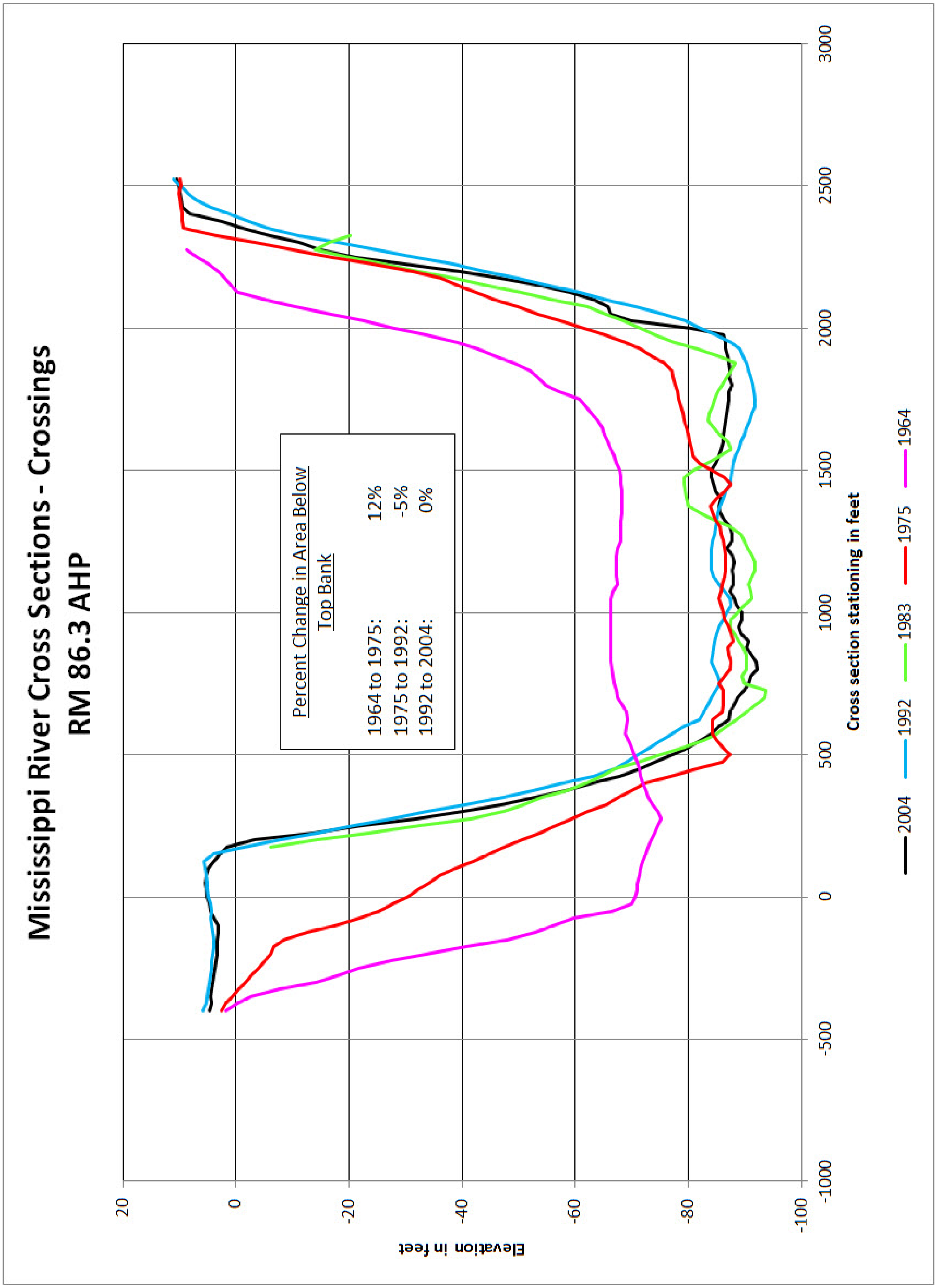

Mississippi River Cross Sections - Crossings
RM 61.6 AHP
Percent Change in Area Below
Top Bank
1964 to 1975: 13%
1975 to 1992: - 5%
1992 to 2004: 5%
2004 to 2012: 0%
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
-120
-500
0
500
1000
1500
2000
2500
Cross section stationing in feet
2011_LA
2004
1992
1983
1975
1964
Chart Area

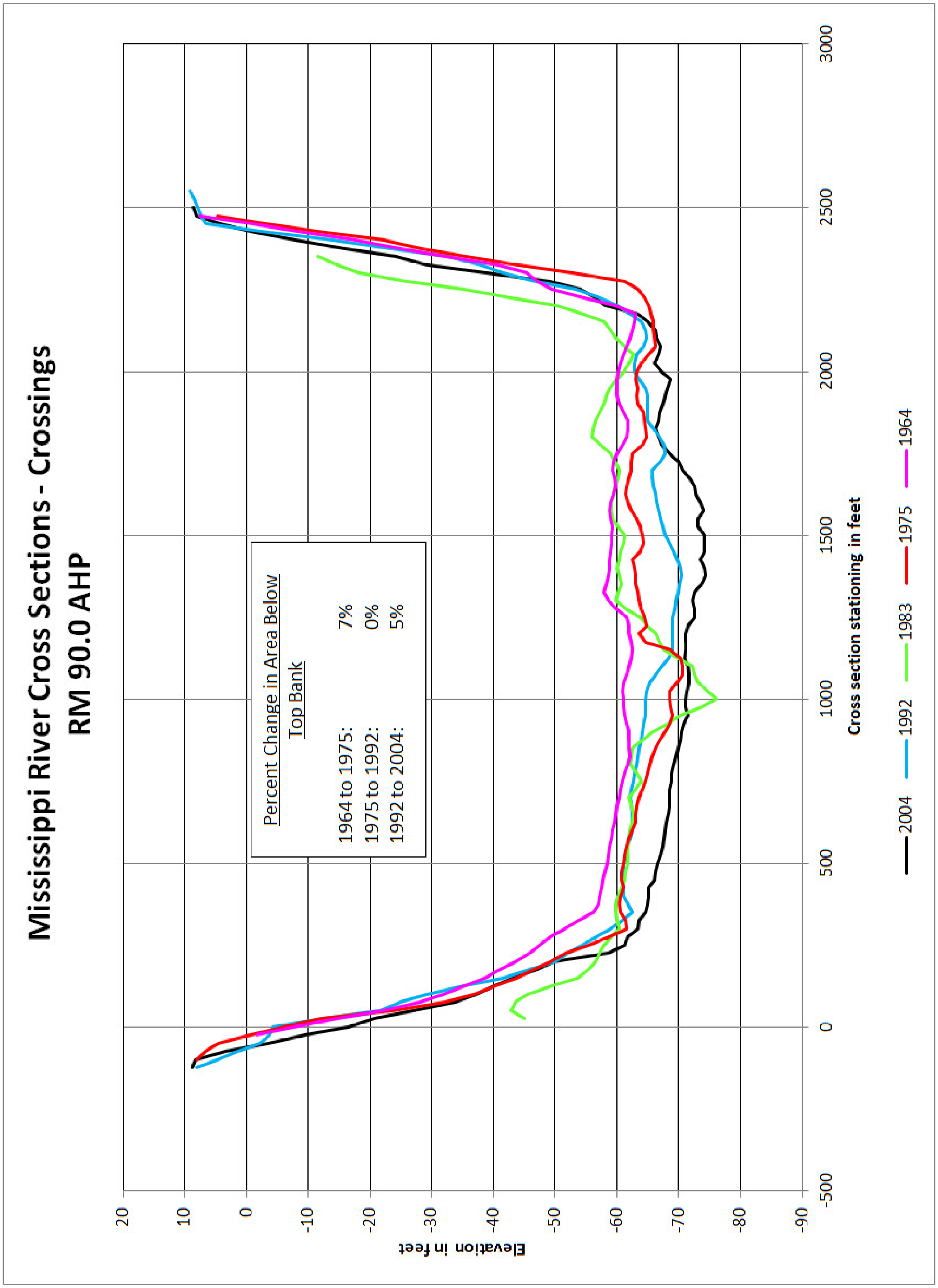

Mississippi River Cross Sections - Crossings
RM 65.6 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 9%
1975 to 1992: 7%
1992 to 2004: -1%
2004 to 2012: 3%
Elevation in feet
Cross section stationing in feet
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
3000
2011_LA
2004
1992
1983
1975
1964
Chart Area

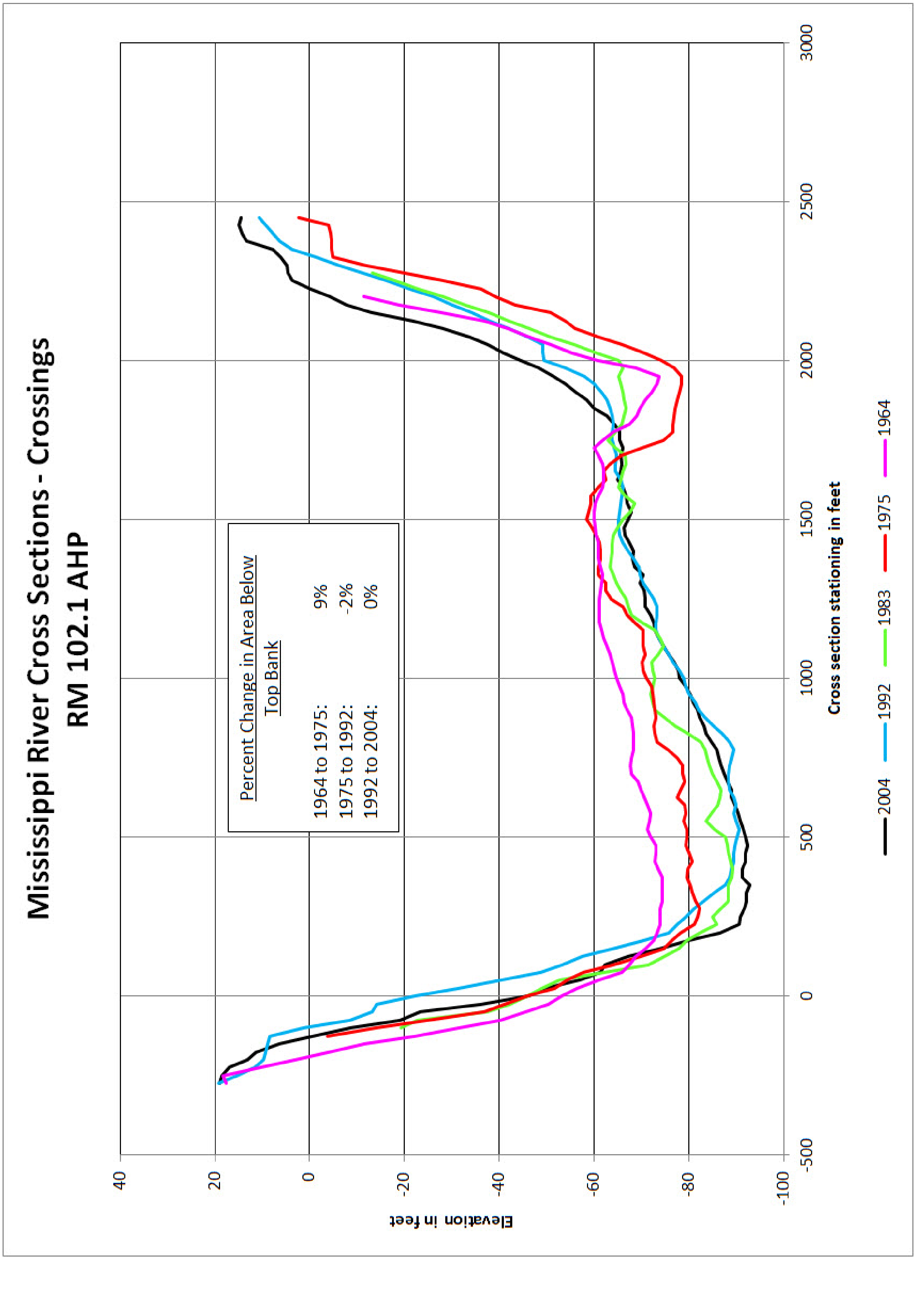

Mississippi River Cross Sections - Crossings
RM 71.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 15%
1975 to 1992: 2%
1992 to 2004: -1%
Elevation in feet
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 75.4 AHP
Elevation in feet
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 8%
1975 to 1992: 3%
1992 to 2004: 0%
2004
1992
1983
1975
1964

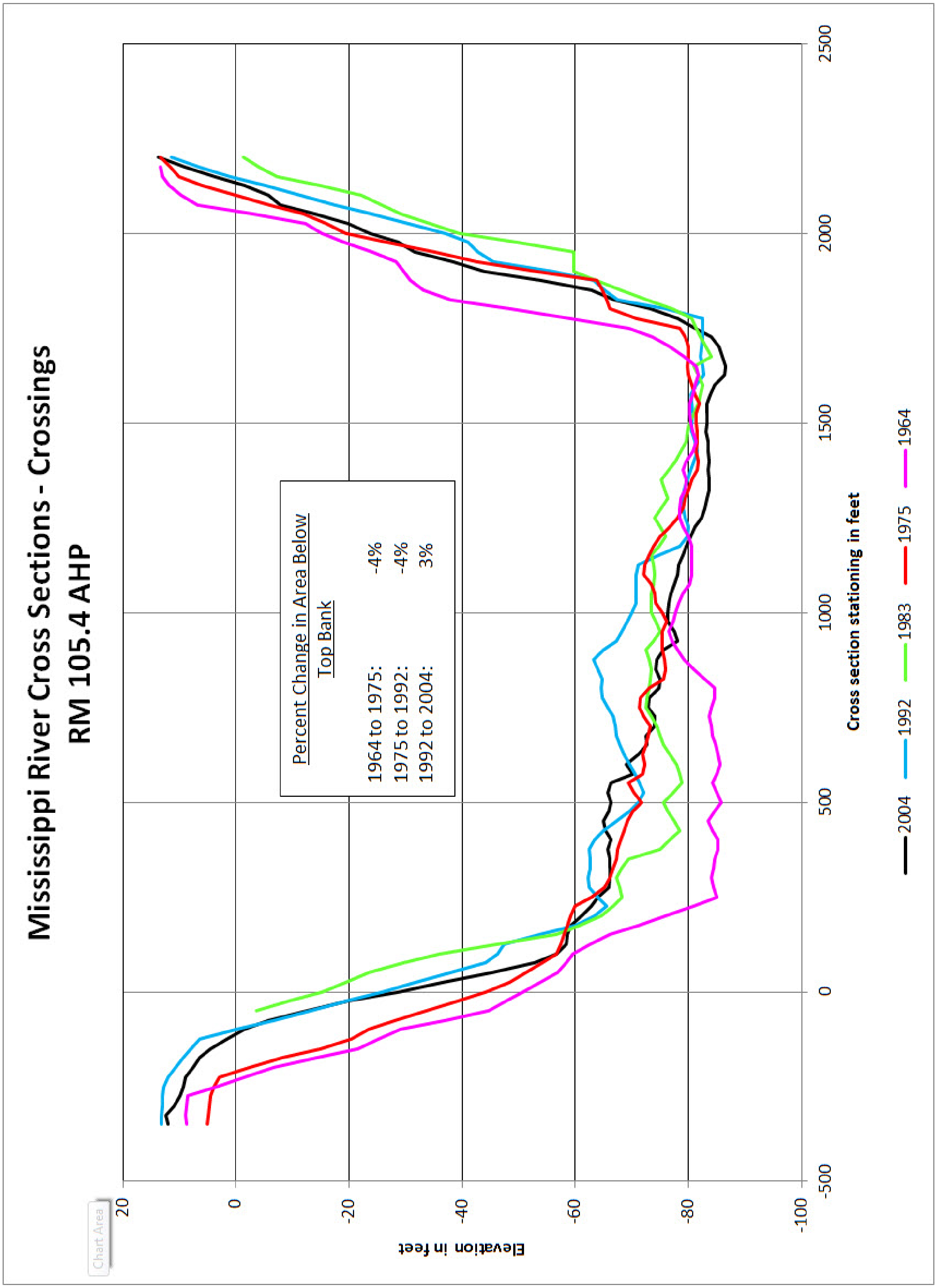

Mississippi River Cross Sections - Crossings
RM 78.9 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 4%
1975 to 1992: 7%
1992 to 2004: 4%
Elevation in feet
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2004
1992
1983
1975
1964

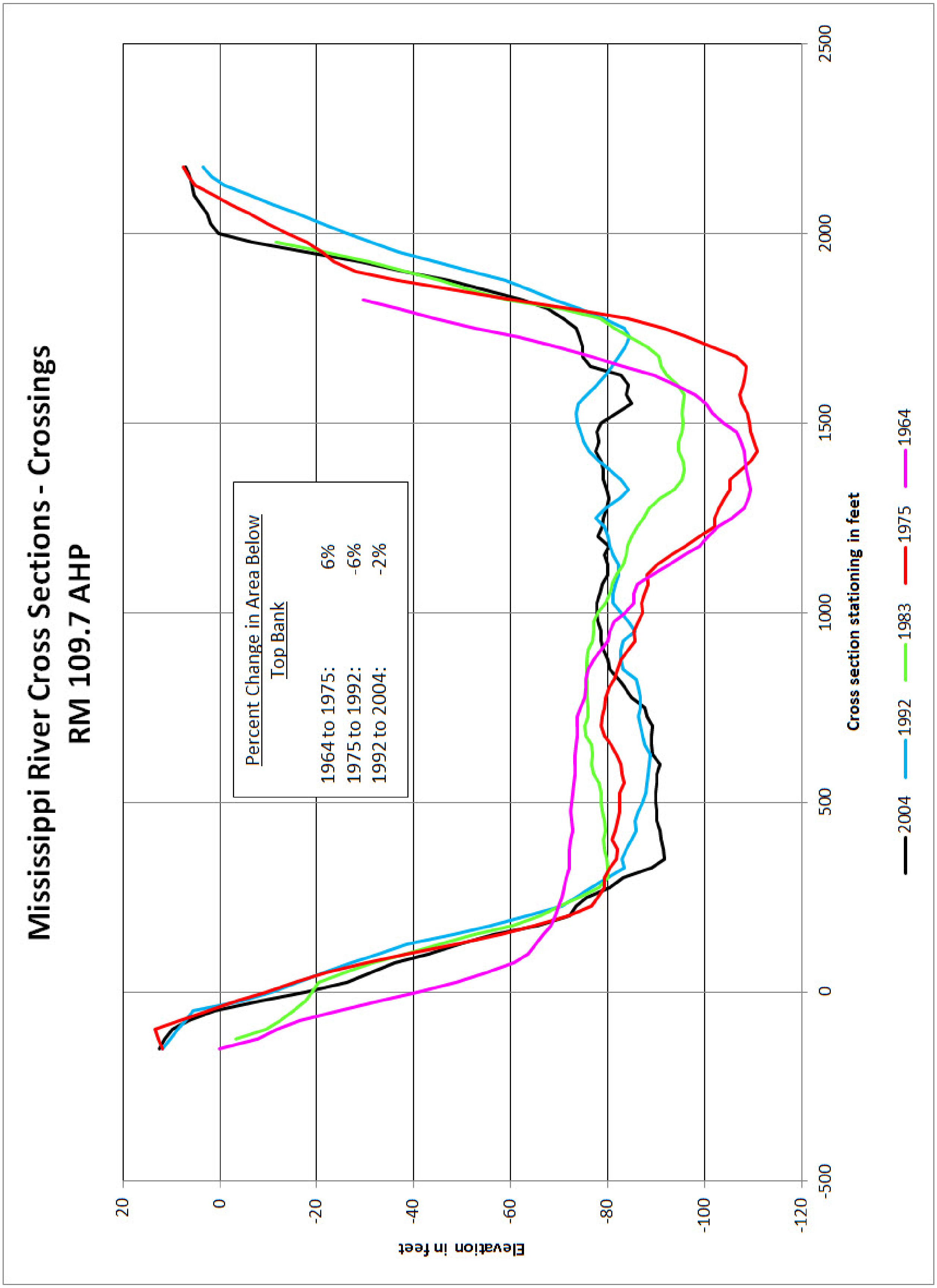

Mississippi River Cross Sections - Crossings
RM 86.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 12%
1975 to 1992: -5%
1992 to 2004: 0%
Elevation in feet
Cross section stationing in feet
20
0
-20
-40
-60
-80
-100
-1000
-500
0
500
1000
1500
2000
2500
3000
2004
1992
1983
1975
1964

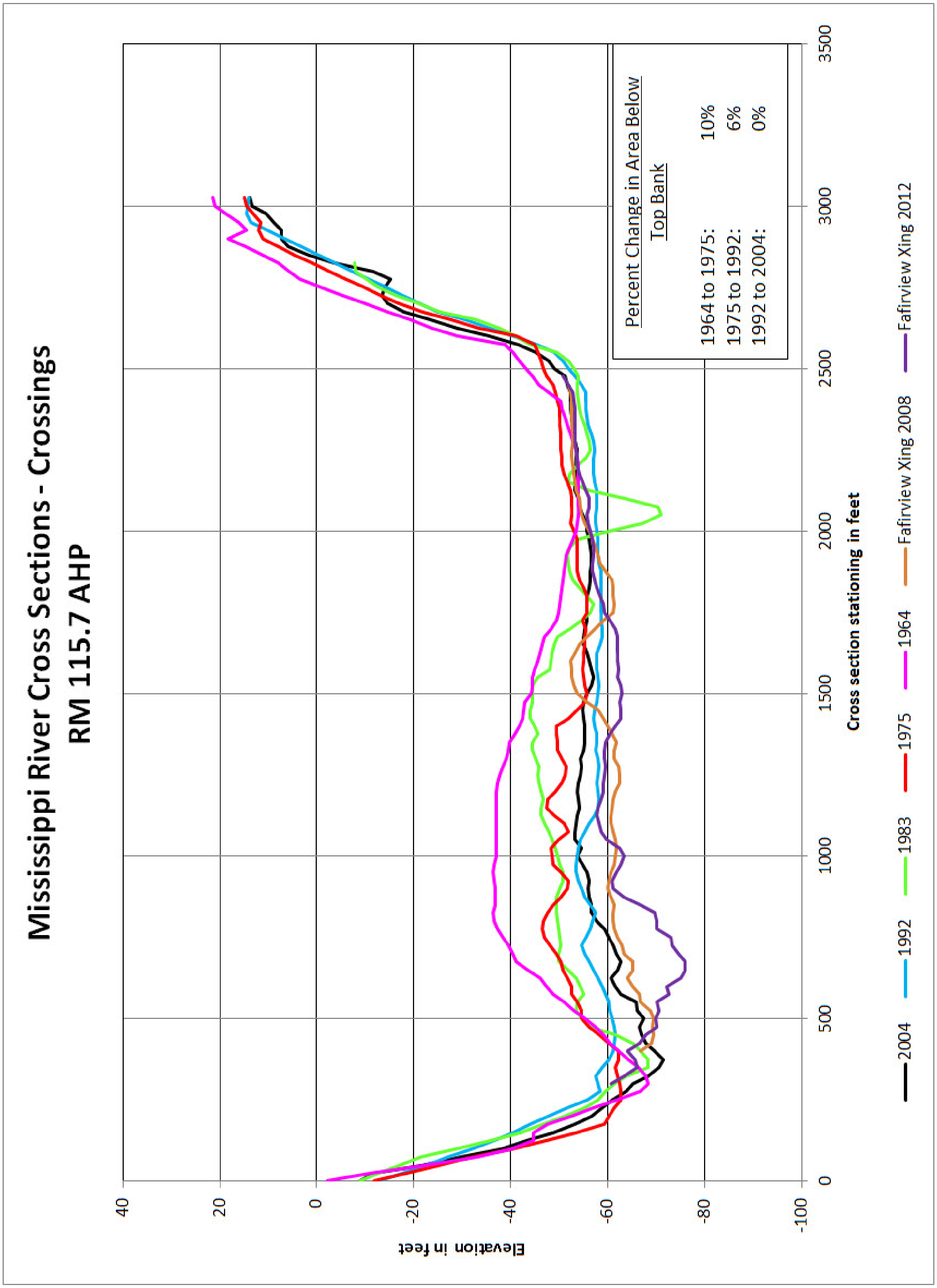

Mississippi River Cross Sections - Crossings
RM 90.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: 0%
1992 to 2004: 5%
Elevation in feet
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2004
1992
1983
1975
1964

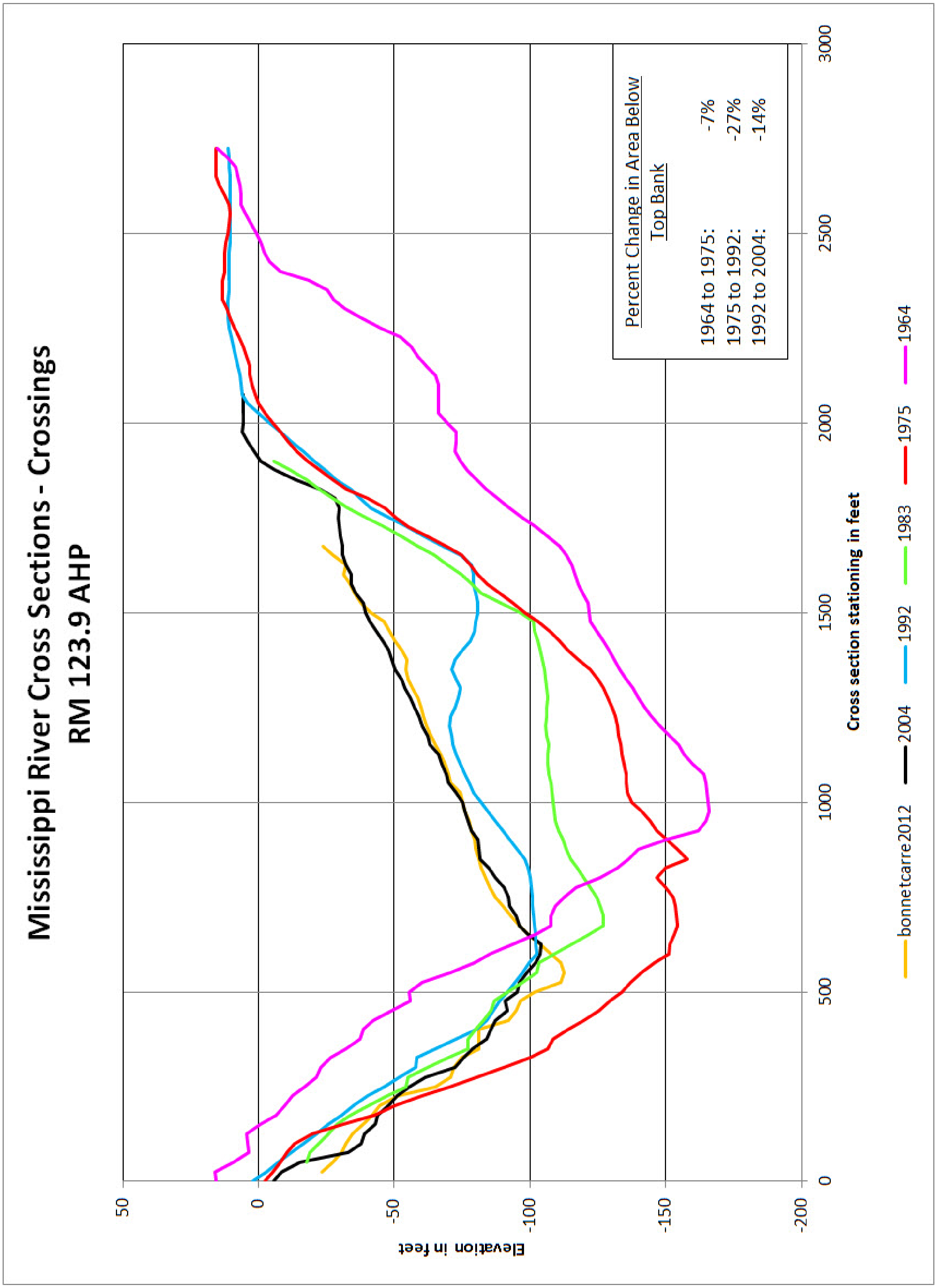


Mississippi River Cross Sections - Crossings
RM 102.1 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 9%
1975 to 1992: -2%
1992 to 2004: 0%
Elevation in feet
Cross section stationing in feet
40
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
3000
2004
1992
1983
1975
1964

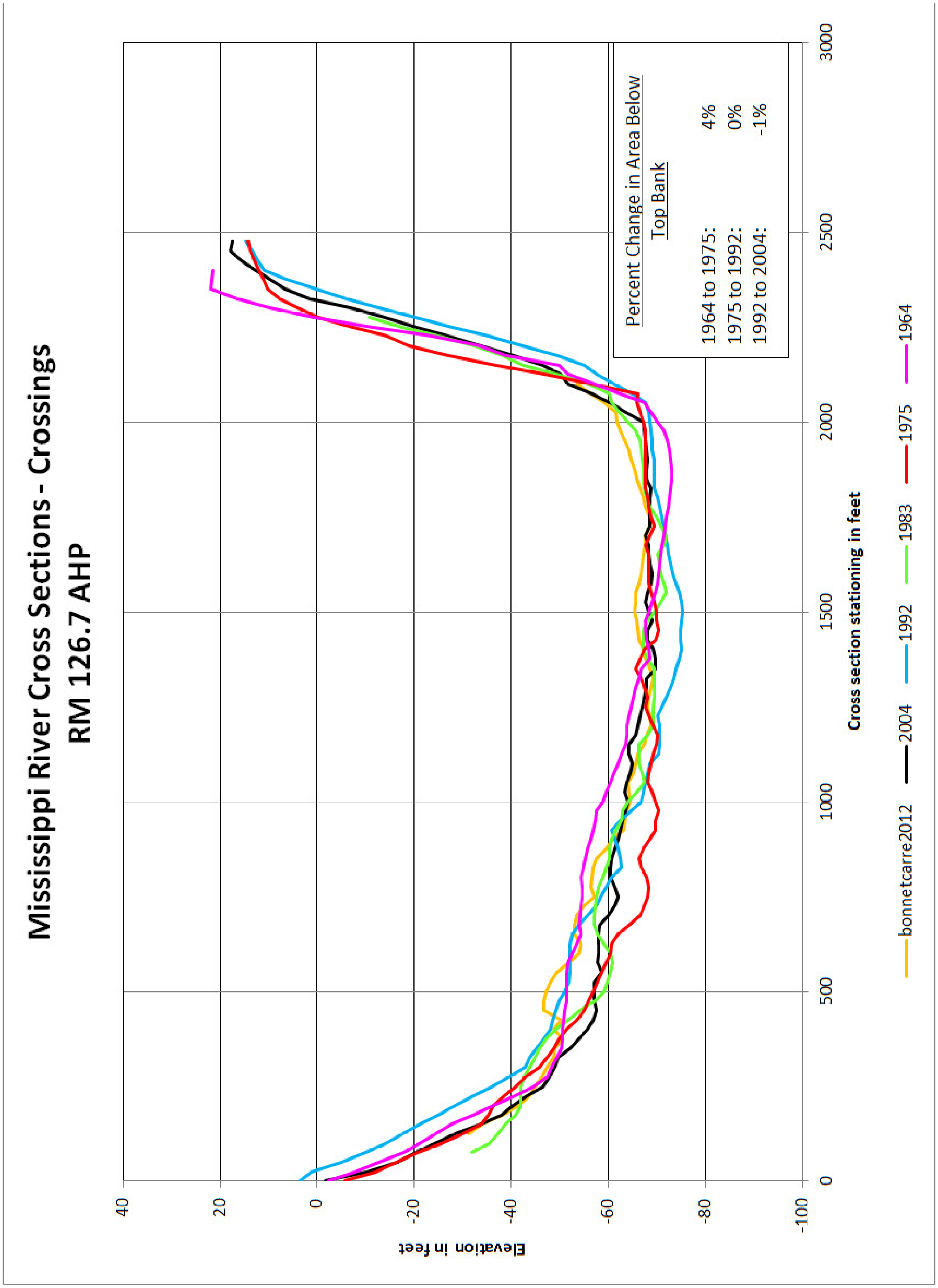

Mississippi River Cross Sections - Crossings
RM 105.4 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -4%
1975 to 1992: -4%
1992 to 2004: 3%
Elevation in feet
Cross section stationing in feet
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 109.7 AHP
Percent Change in Area Below
Top Bank
1964 to 1975: 6%
1975 to 1992: -6%
1992 to 2004: -2%
Elevation in feet
20
0
-20
-40
-60
-80
-100
-120
-500
0
500
1000
1500
2000
2500
Cross section stationing in feet
2004
1992
1983
1975
1964

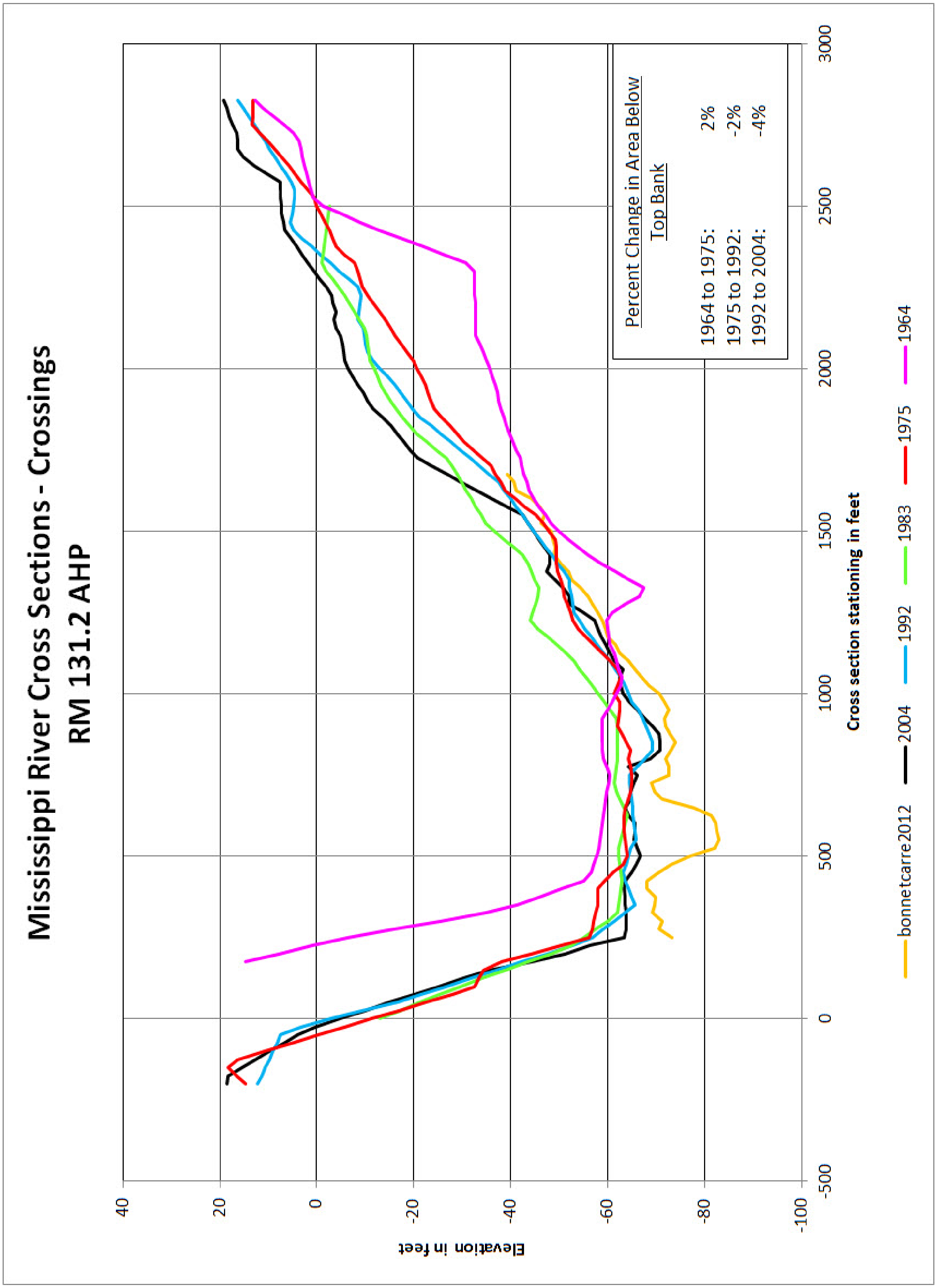

Mississippi River Cross Sections - Crossings
RM 115.7 AHP
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 10%
1975 to 1992: 6%
1992 to 2004: 0%
2004
1992
1983
1975
1964
Fafirview Xing 2008
Fafirview Xing 2012

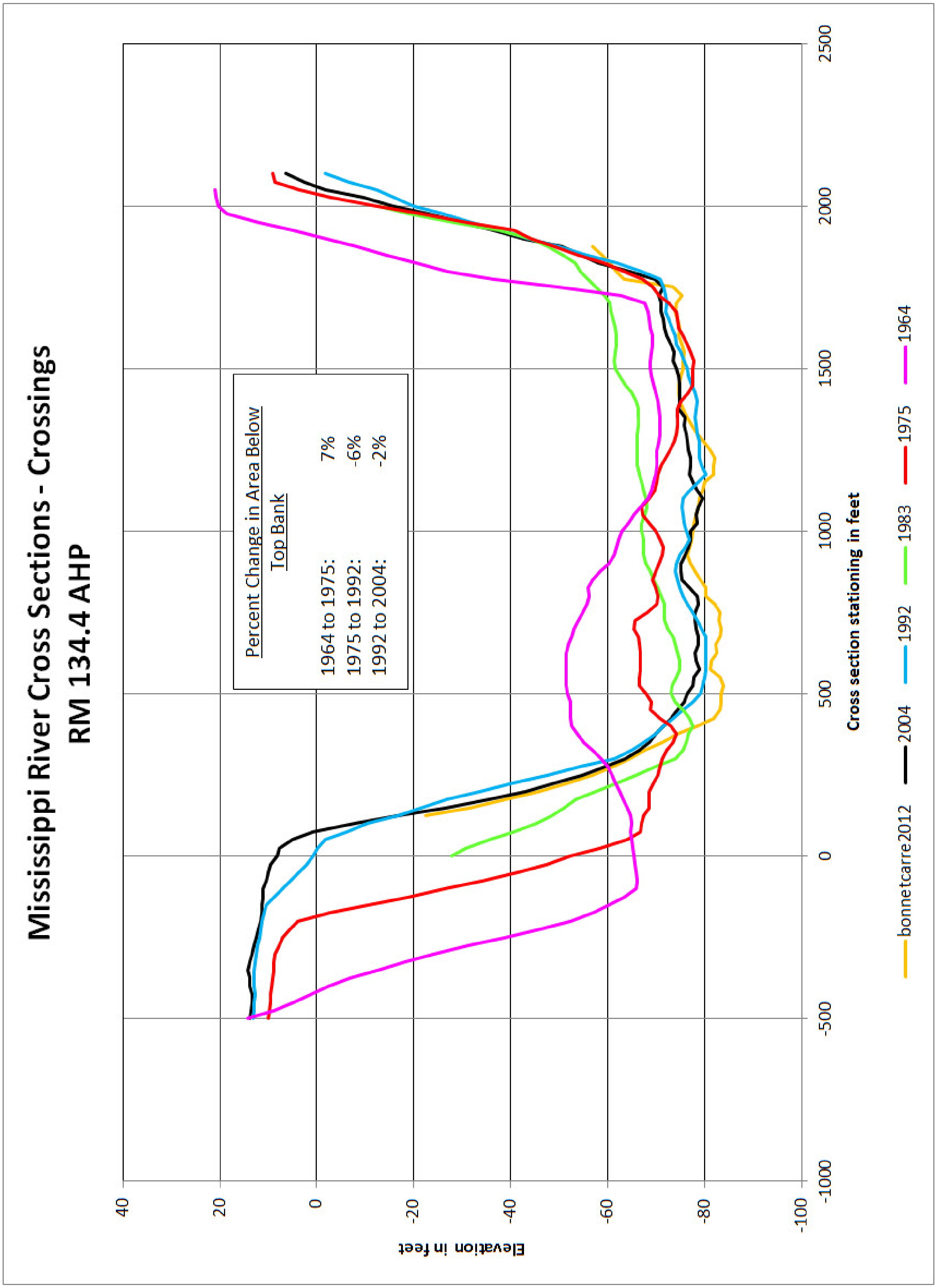


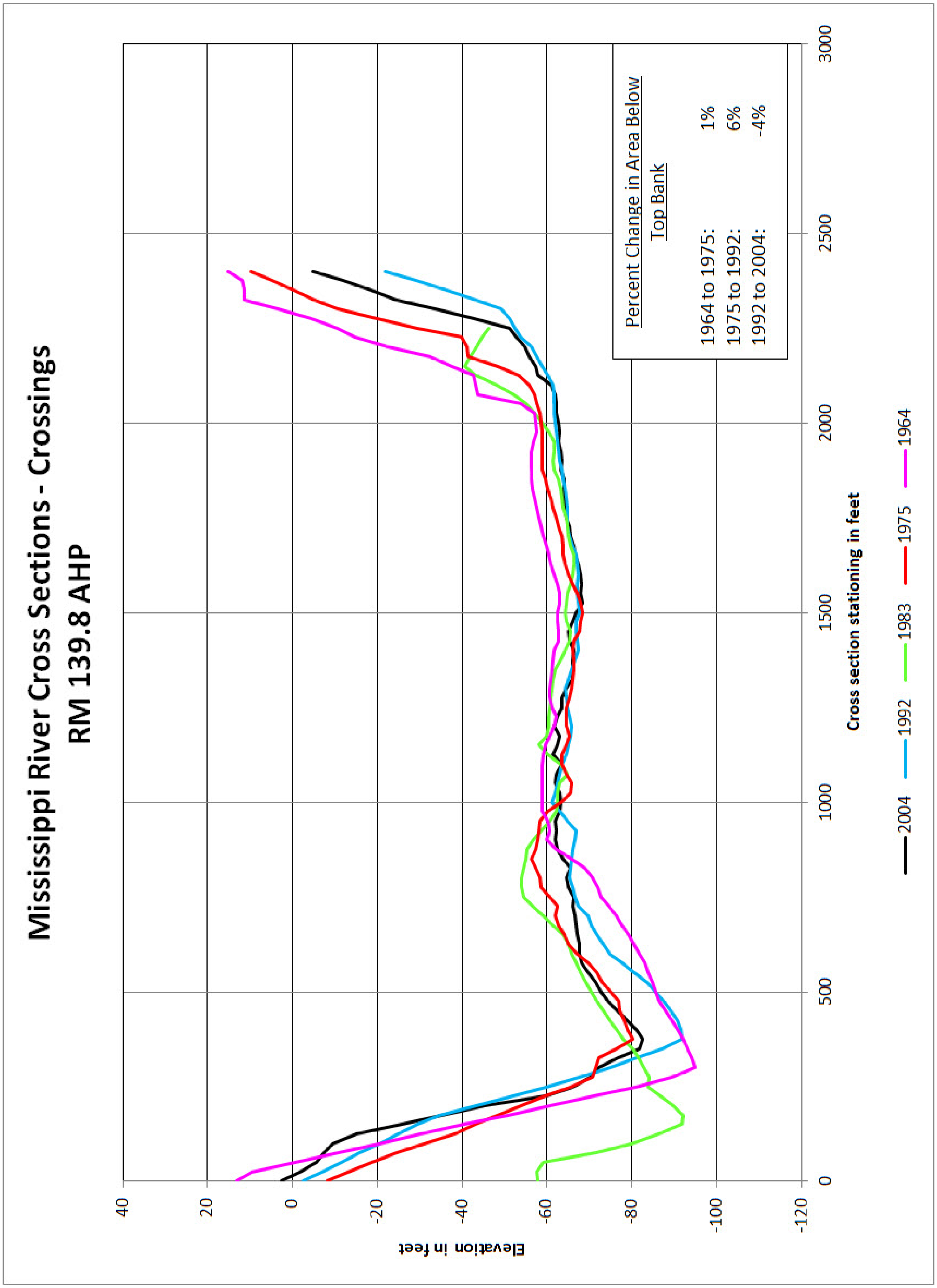
Mississippi River Cross Sections - Crossings
RM 123.9 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -7%
1975 to 1992: -27%
1992 to 2004: -14%
Elevation in feet
50
0
-50
-100
-150
-200
Cross section stationing in feet
0
500
1000
1500
2000
2500
3000
bonnetcarre2012
2004
1992
1983
1975
1964

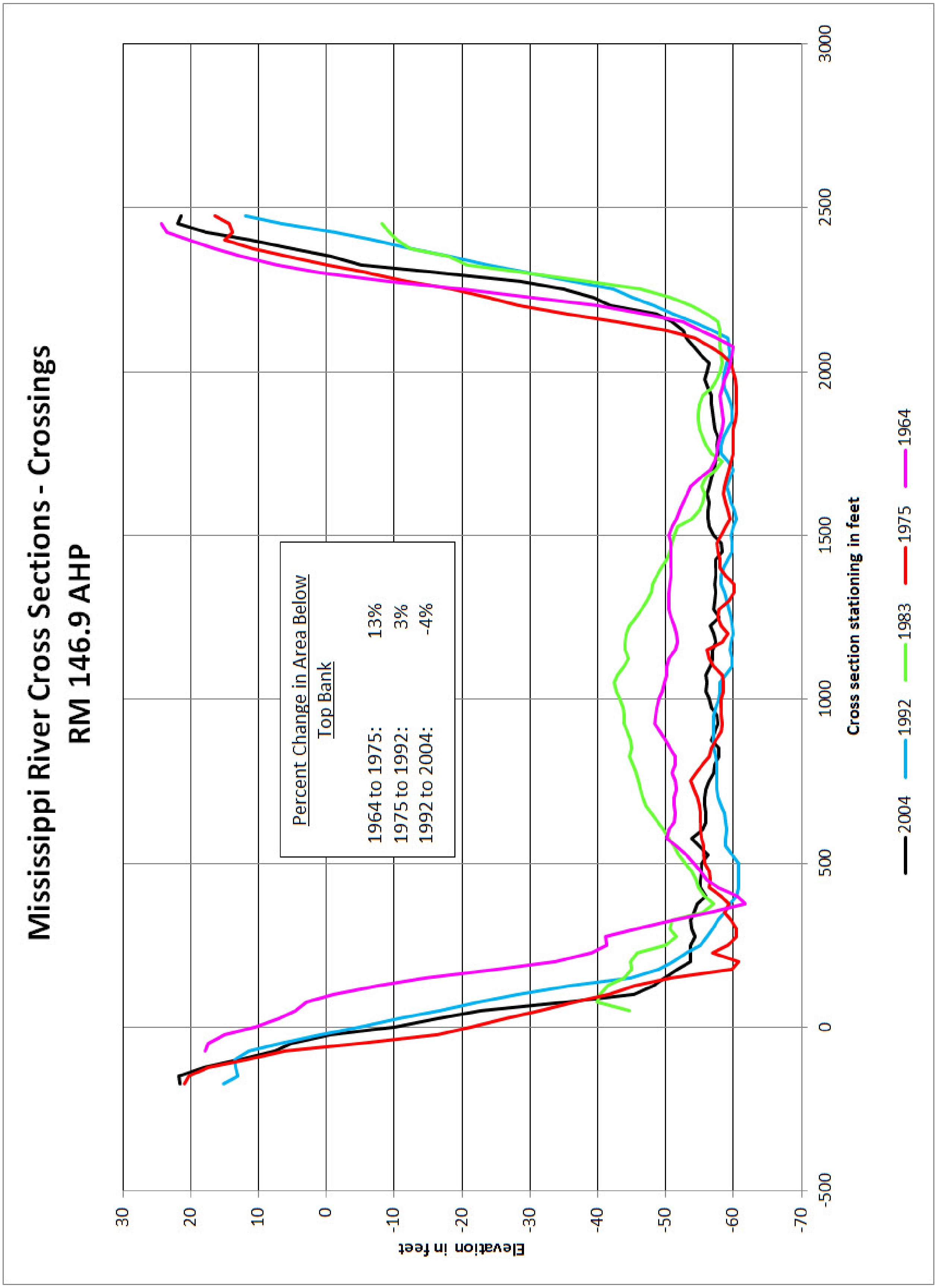


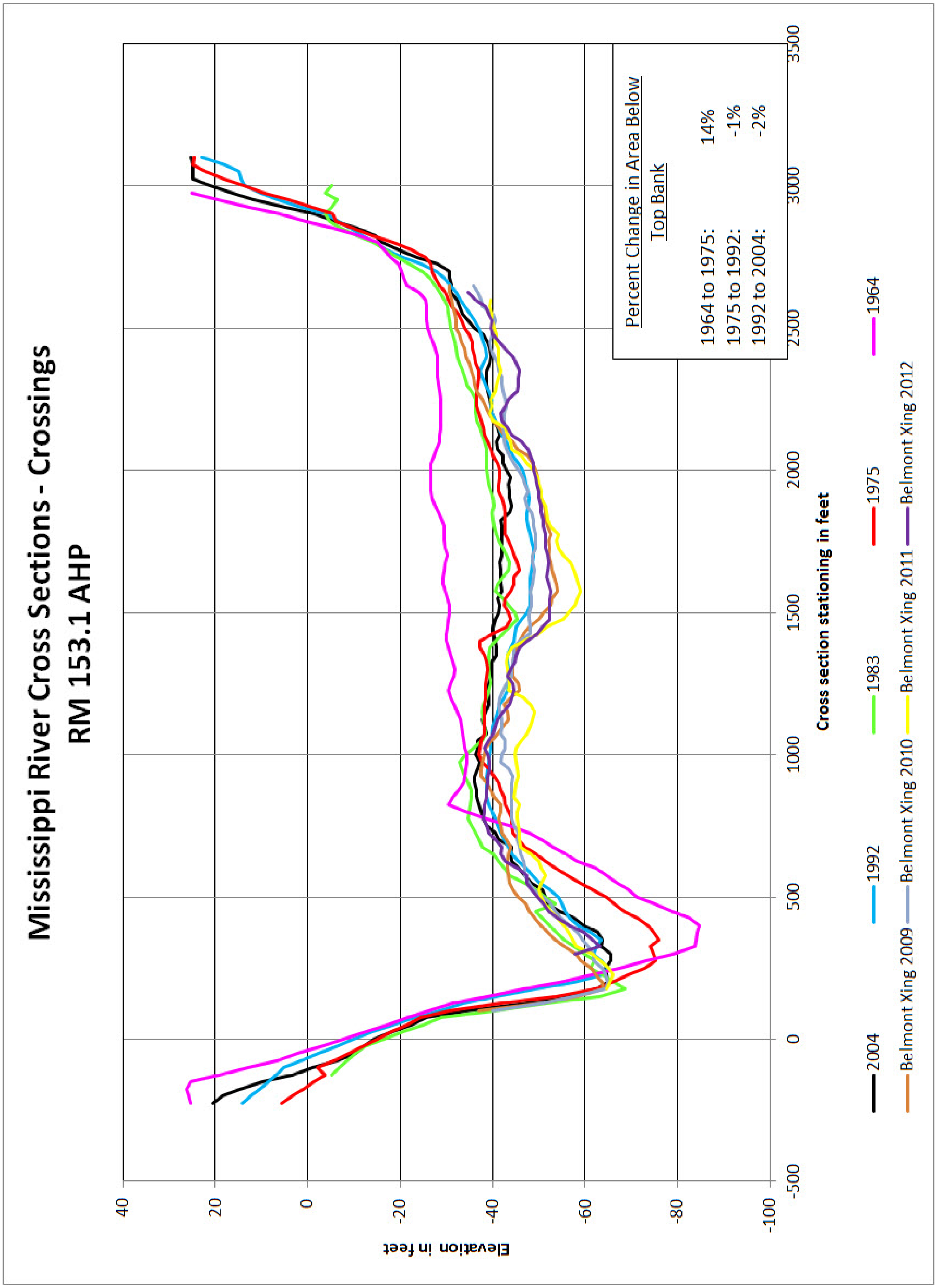
Mississippi River Cross Sections - Crossings
RM 126.7 AHP
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 4%
1975 to 1992: 0%
1992 to 2004: -1%
bonnetcarre2012
2004
1992
1983
1975
1964

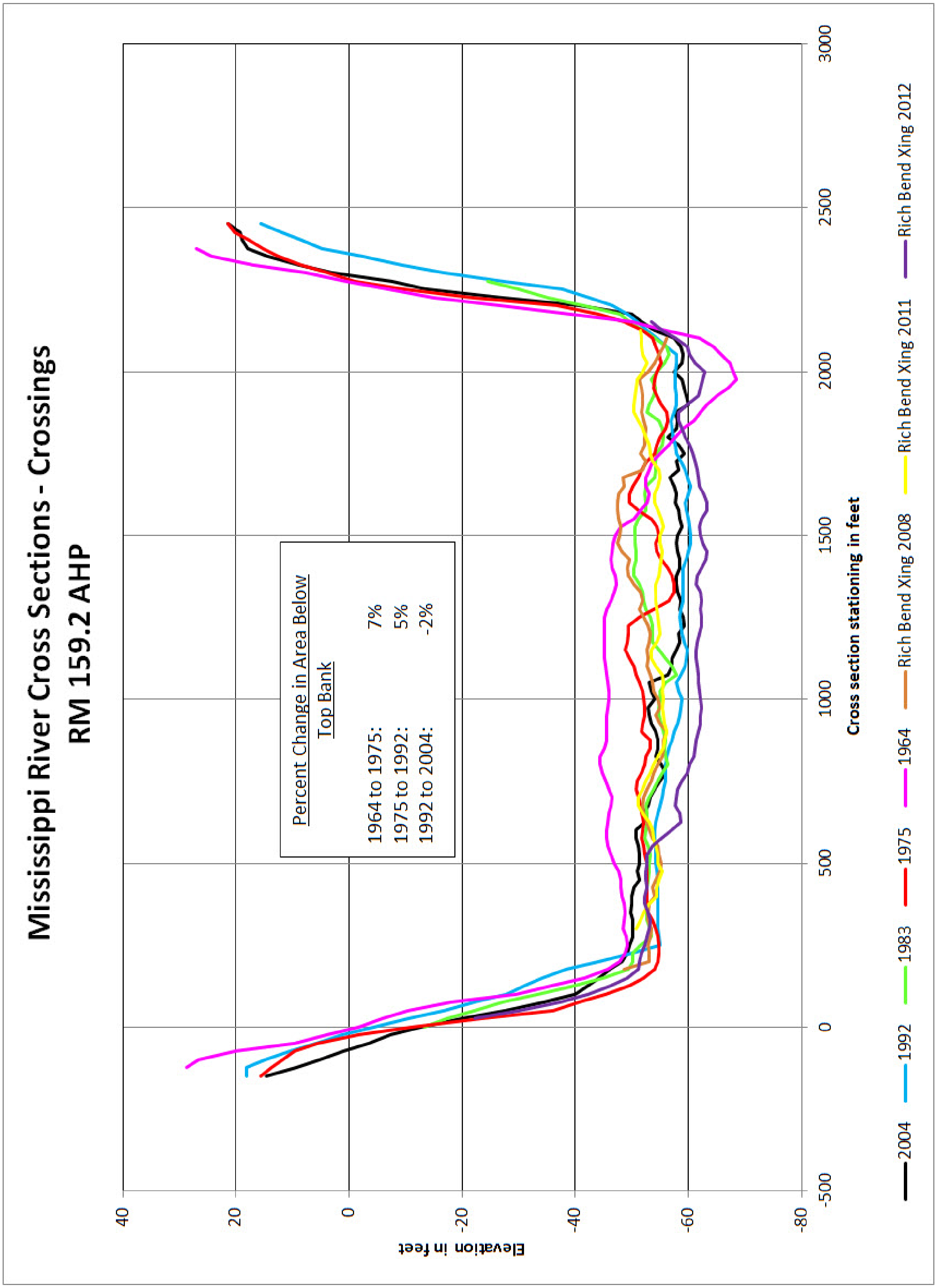

Mississippi River Cross Sections - Crossings
RM 131.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 2%
1975 to 1992: -2%
1992 to 2004: -4%
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
bonnetcarre2012
2004
1992
1983
1975
1964

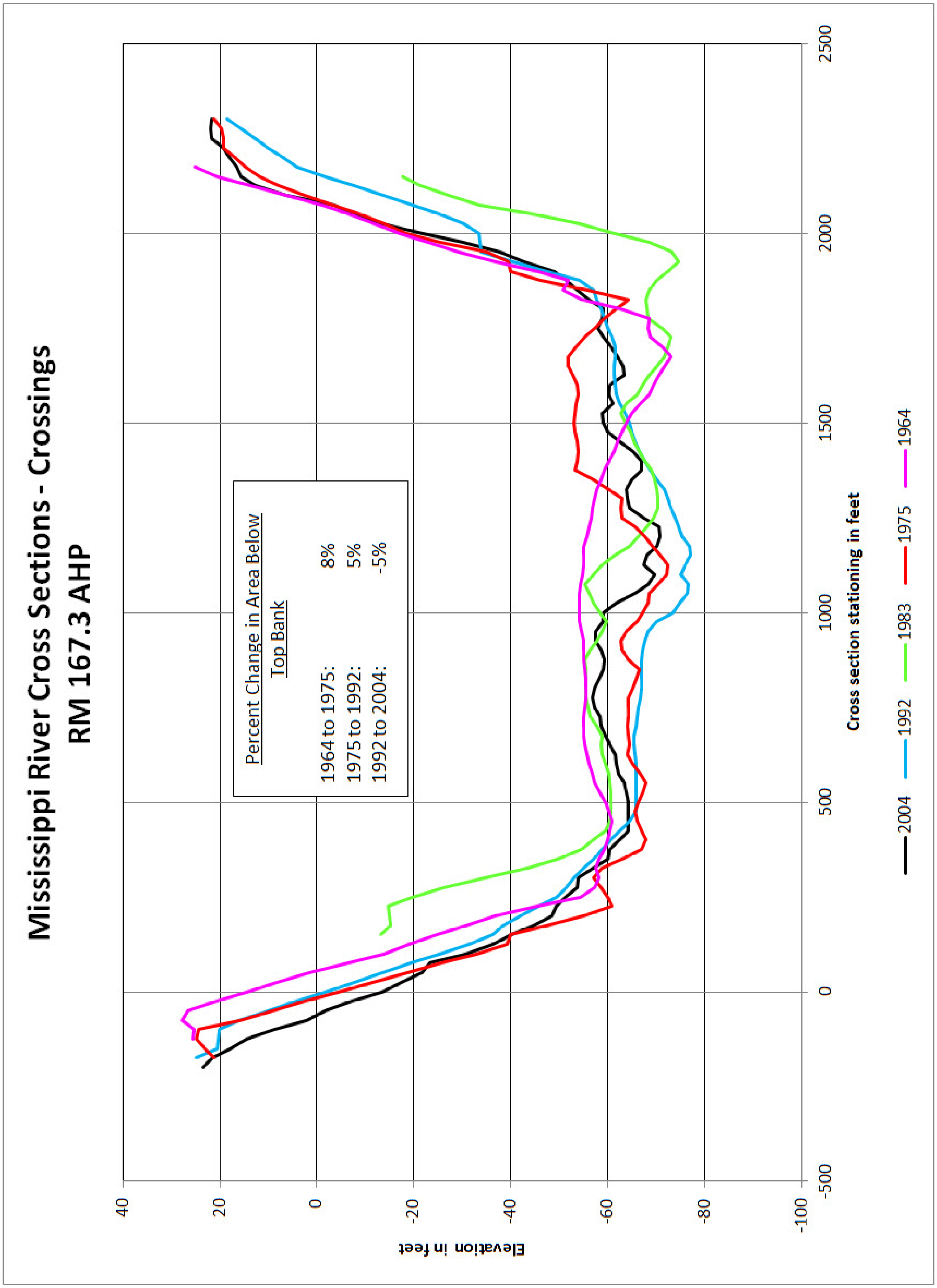

Mississippi River Cross Sections - Crossings
RM 134.4 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: -6%
1992 to 2004: -2%
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
-1000
-500
0
500
1000
1500
2000
2500
Cross section stationing in feet
bonnetcarre2012
2004
1992
1983
1975
1964

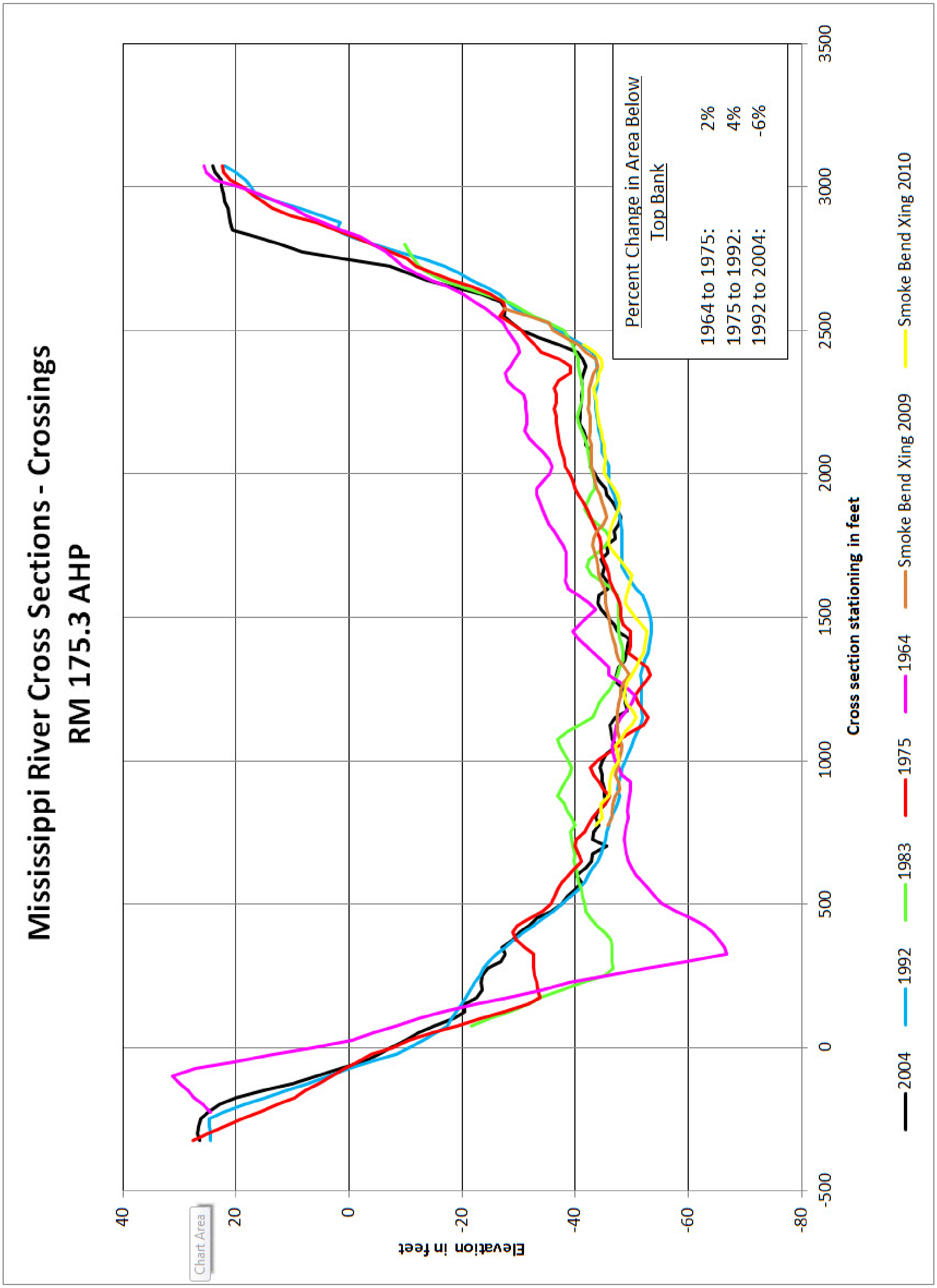

Mississippi River Cross Sections - Crossings
RM 139.8 AHP
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 1%
1975 to 1992: 6%
1992 to 2004: -4%
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 146.9 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 13%
1975 to 1992: 3%
1992 to 2004: -4%
Elevation in feet
Cross section stationing in feet
2004
1992
1983
1975
1964
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-500
0
500
1000
1500
2000
2500
3000

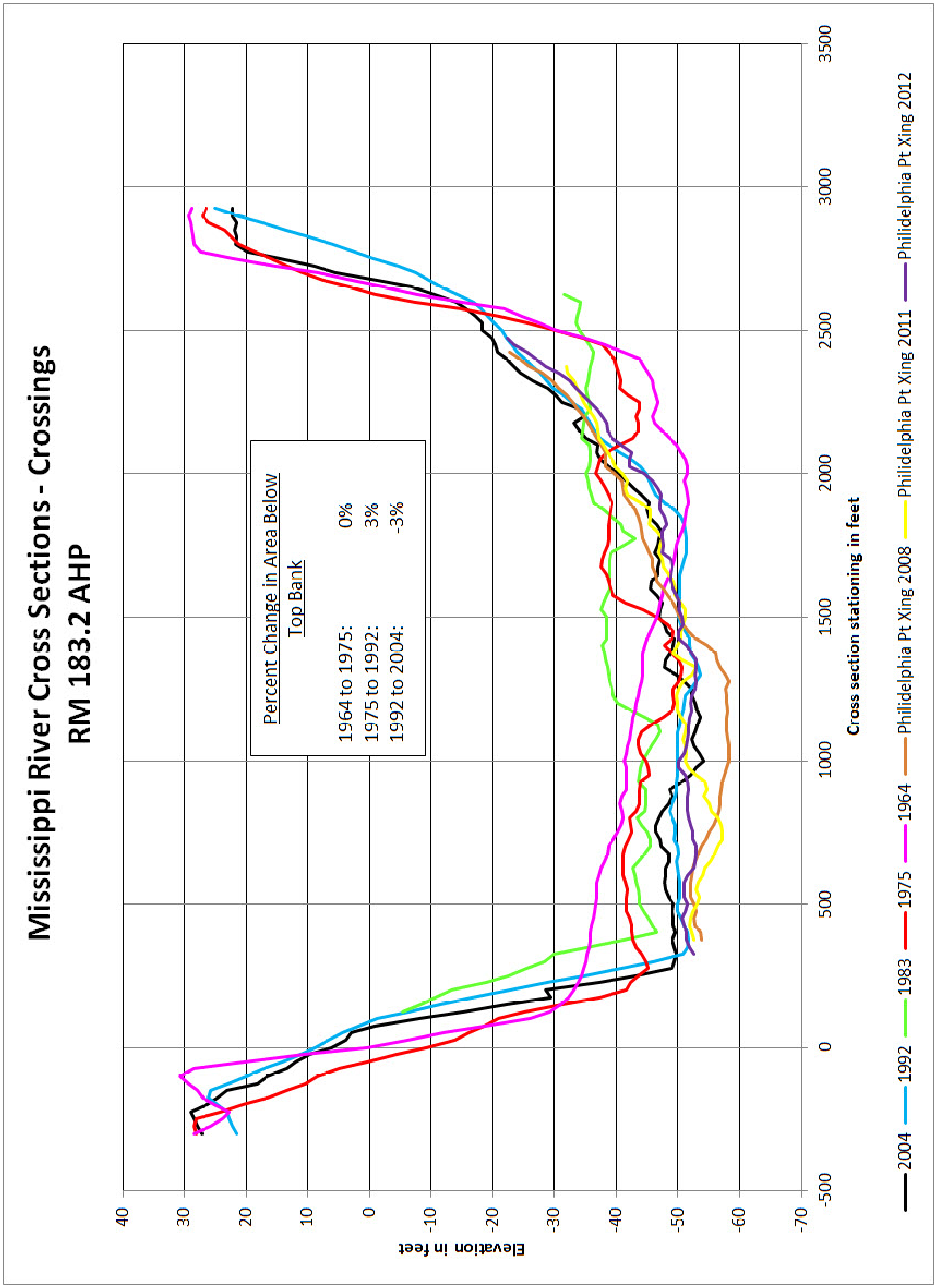

Mississippi River Cross Sections - Crossings
RM 153.1 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 14%
1975 to 1992: -1%
1992 to 2004: -2%
2004
1992
1983
1975
1964
Belmont Xing 2009
Belmont Xing 2010
Belmont Xing 2011
Belmont Xing 2012
40
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
3000
3500

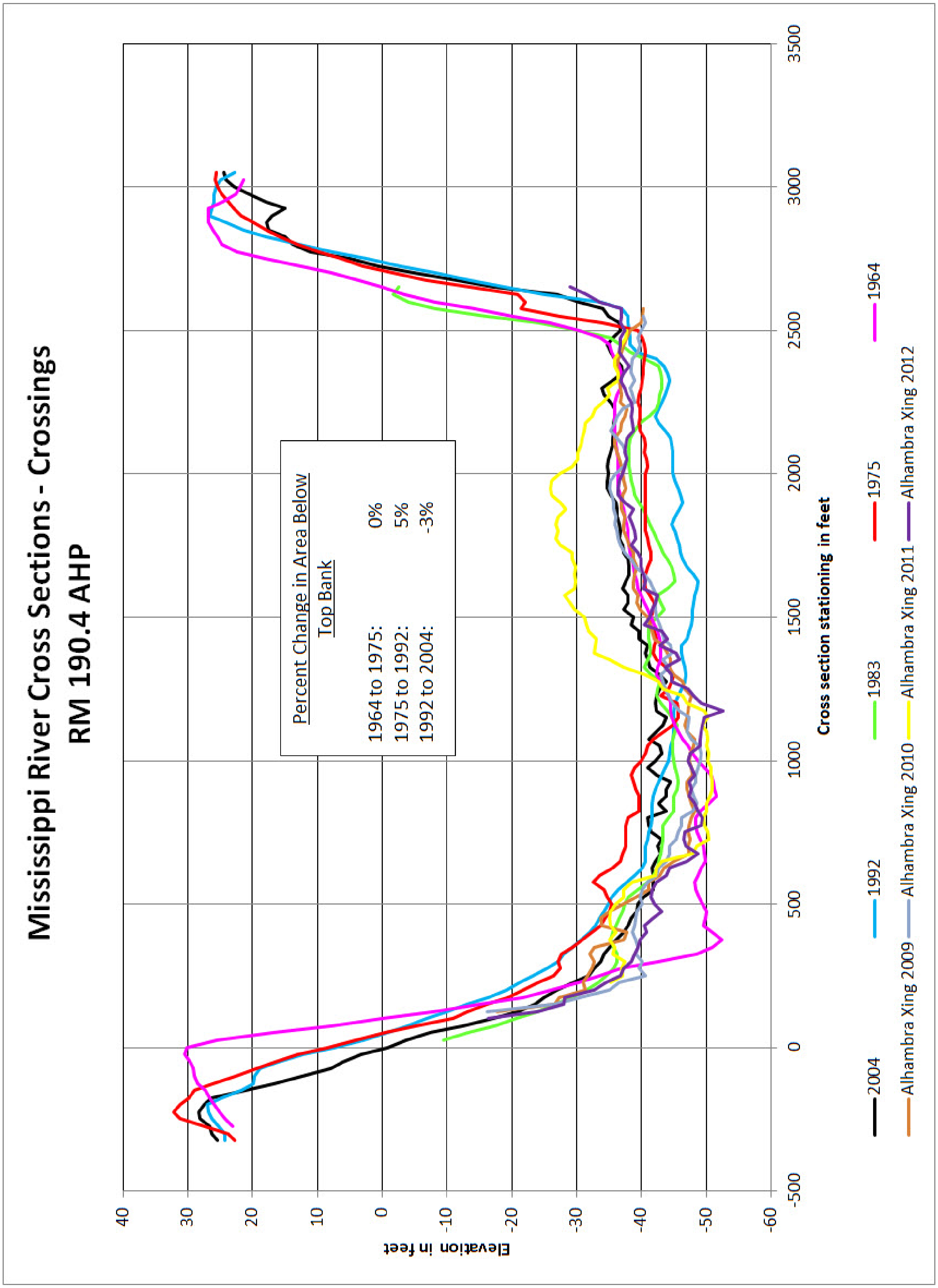

Mississippi River Cross Sections - Crossings
RM 159.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: 5%
1992 to 2004: -2%
Elevation in feet
40
20
0
-20
-40
-60
-80
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2004
1992
1983
1975
1964
Rich Bend Xing 2008
Rich Bend Xing 2011
Rich Bend Xing 2012

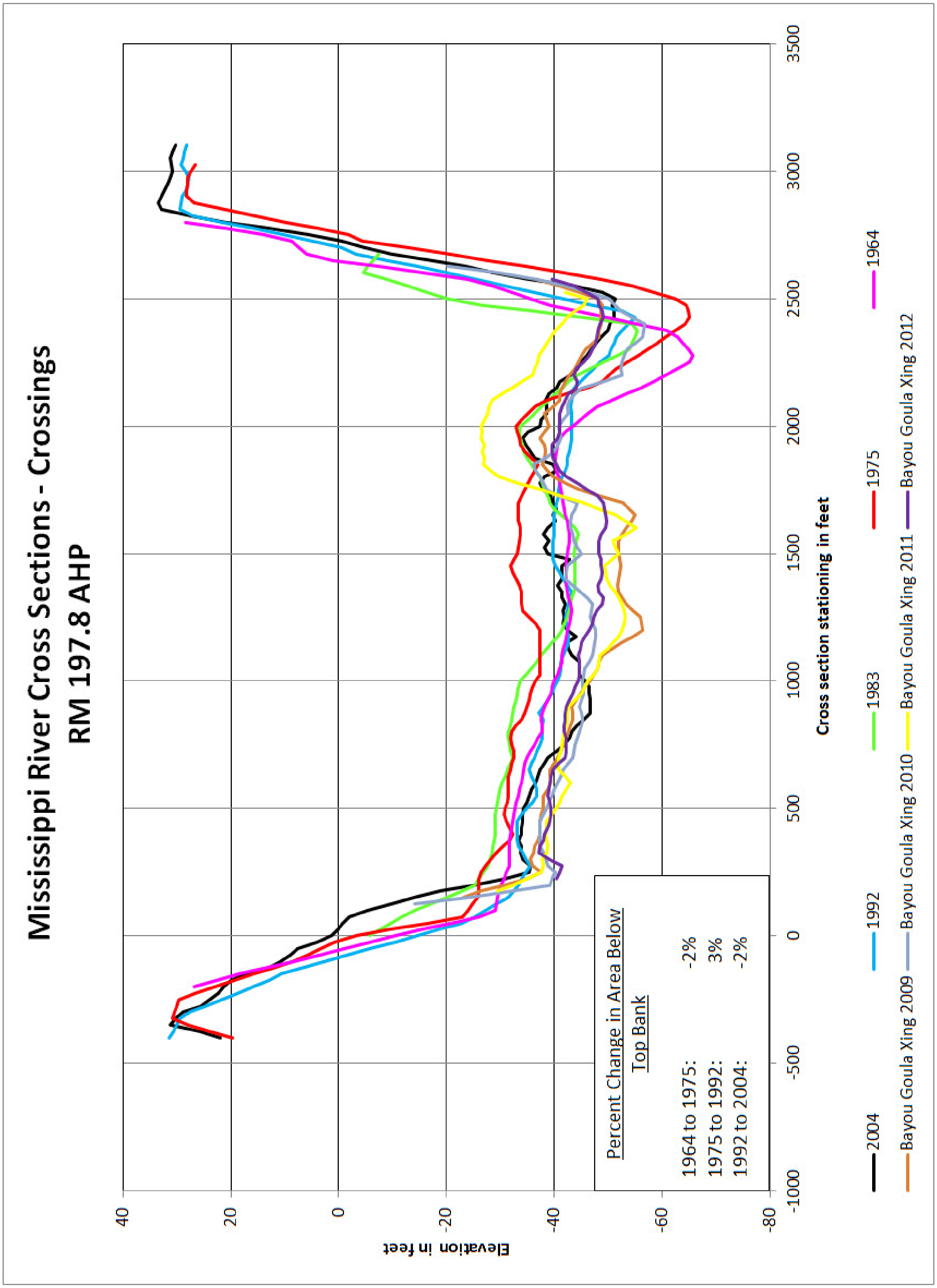

Mississippi River Cross Sections - Crossings
RM 167.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 8%
1975 to 1992: 5%
1992 to 2004: -5%
Elevation in feet
40
20
0
-20
-40
-60
-80
-100
-500
0
500
1000
1500
2000
2500
Cross section stationing in feet
2004
1992
1983
1975
1964

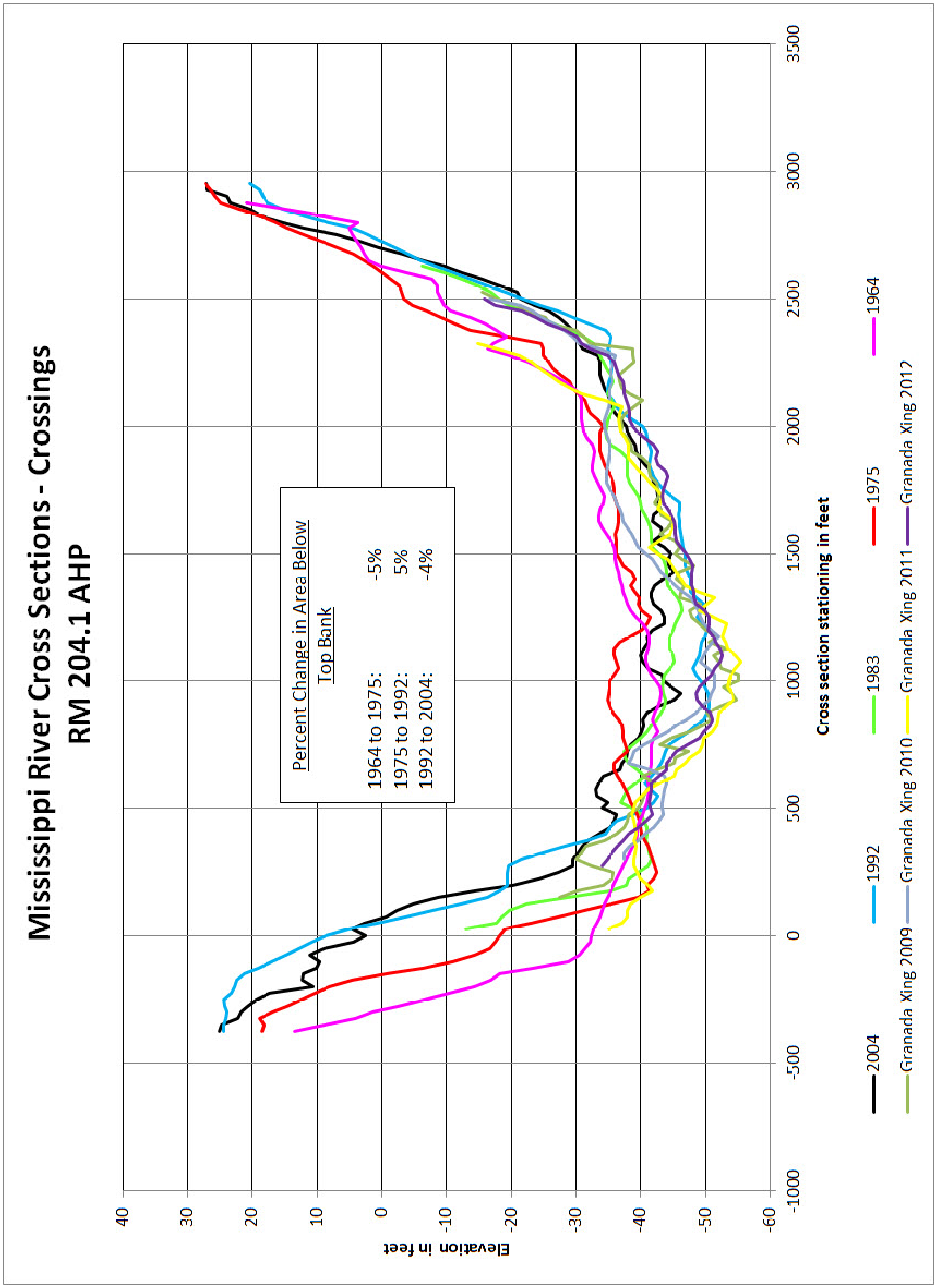


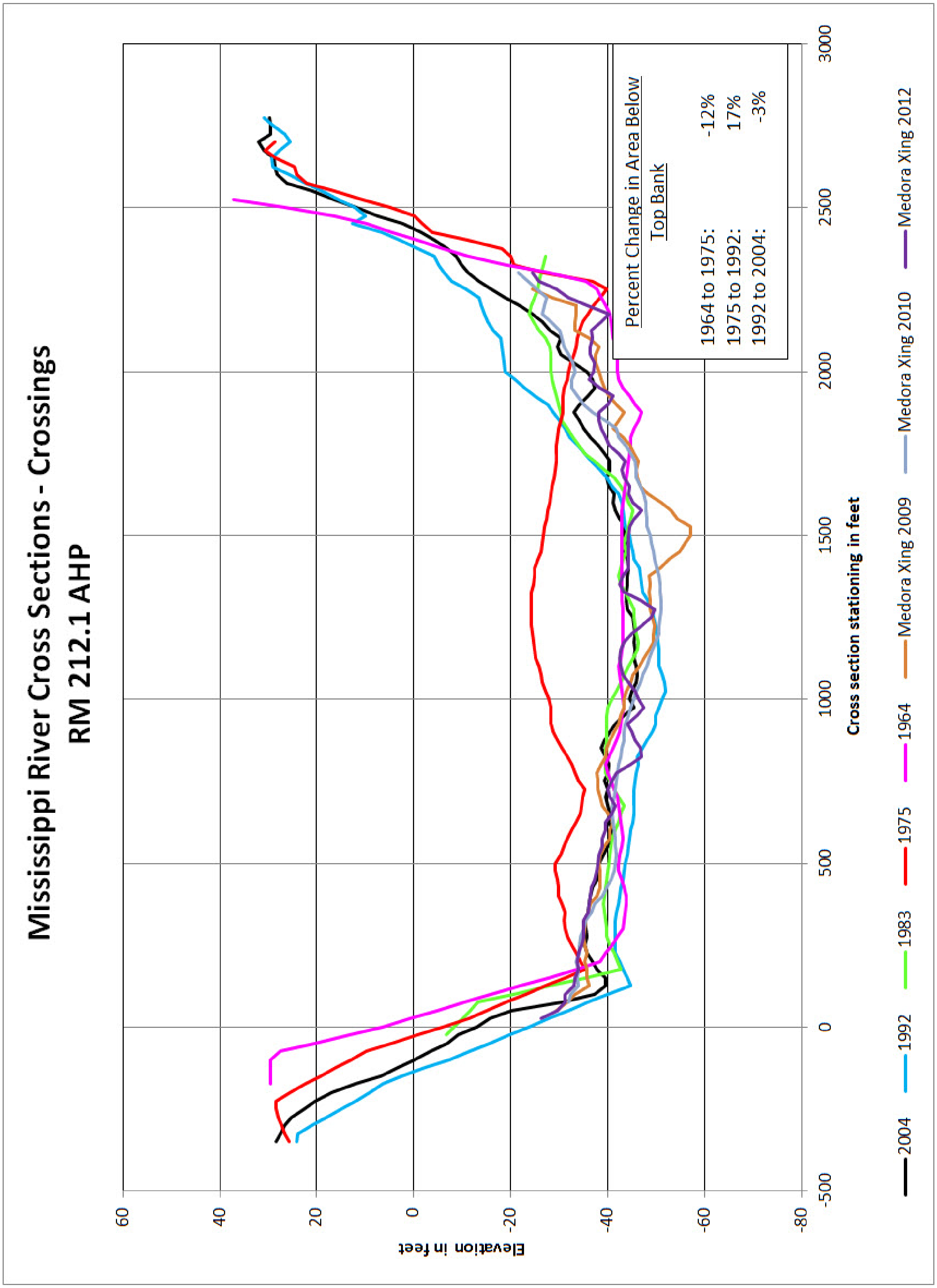
Mississippi River Cross Sections - Crossings
RM 175.3 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 2%
1975 to 1992: 4%
1992 to 2004: -6%
2004
1992
1983
1975
1964
Smoke Bend Xing 2009
Smoke Bend Xing 2010
Chart Area

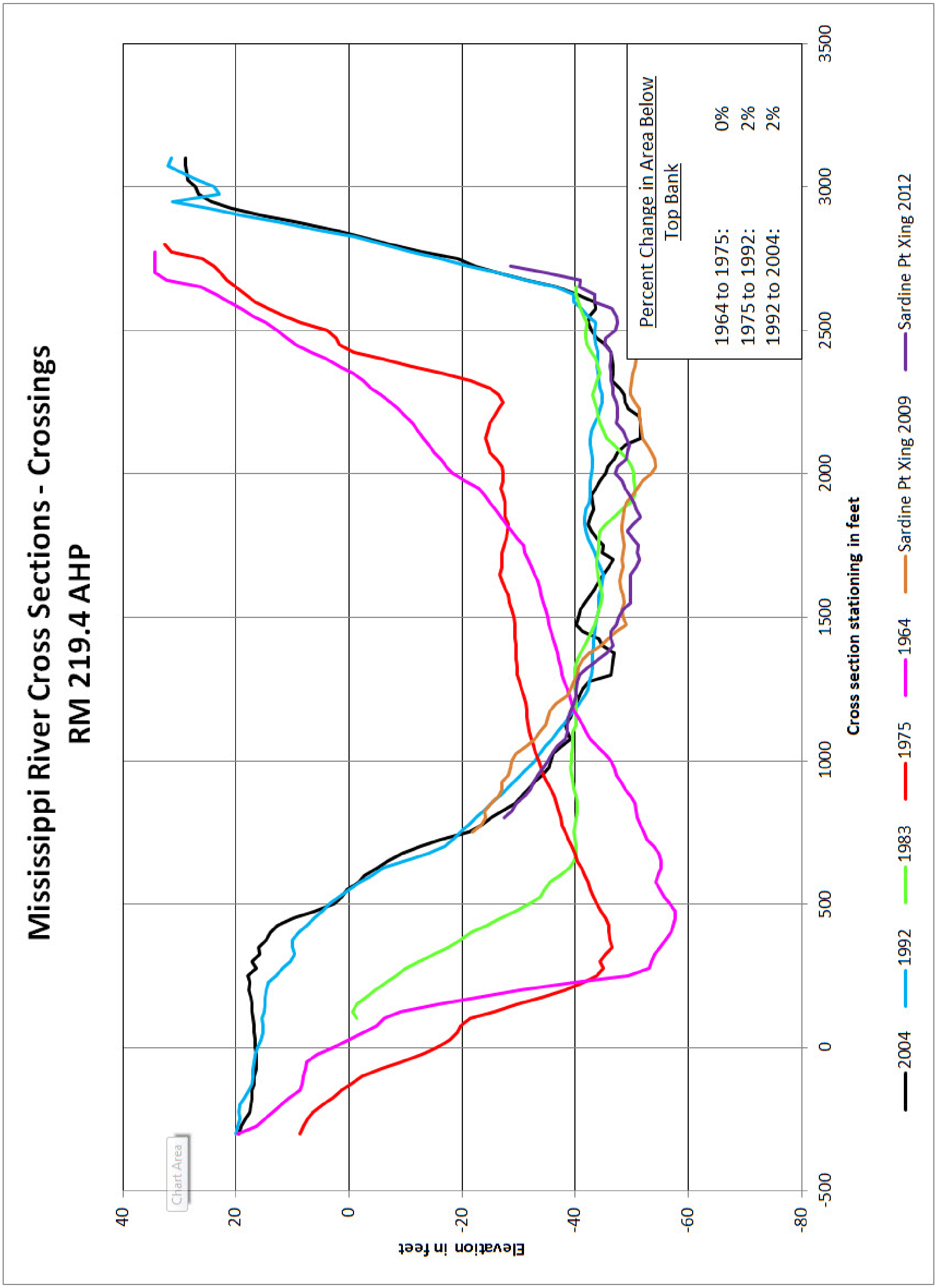

Mississippi River Cross Sections - Crossings
RM 183.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 0%
1975 to 1992: 3%
1992 to 2004: -3%
Elevation in feet
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-500
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
2004
1992
1983
1975
1964
Philidelphia Pt Xing 2008
Philidelphia Pt Xing 2011
Philidelphia Pt Xing 2012

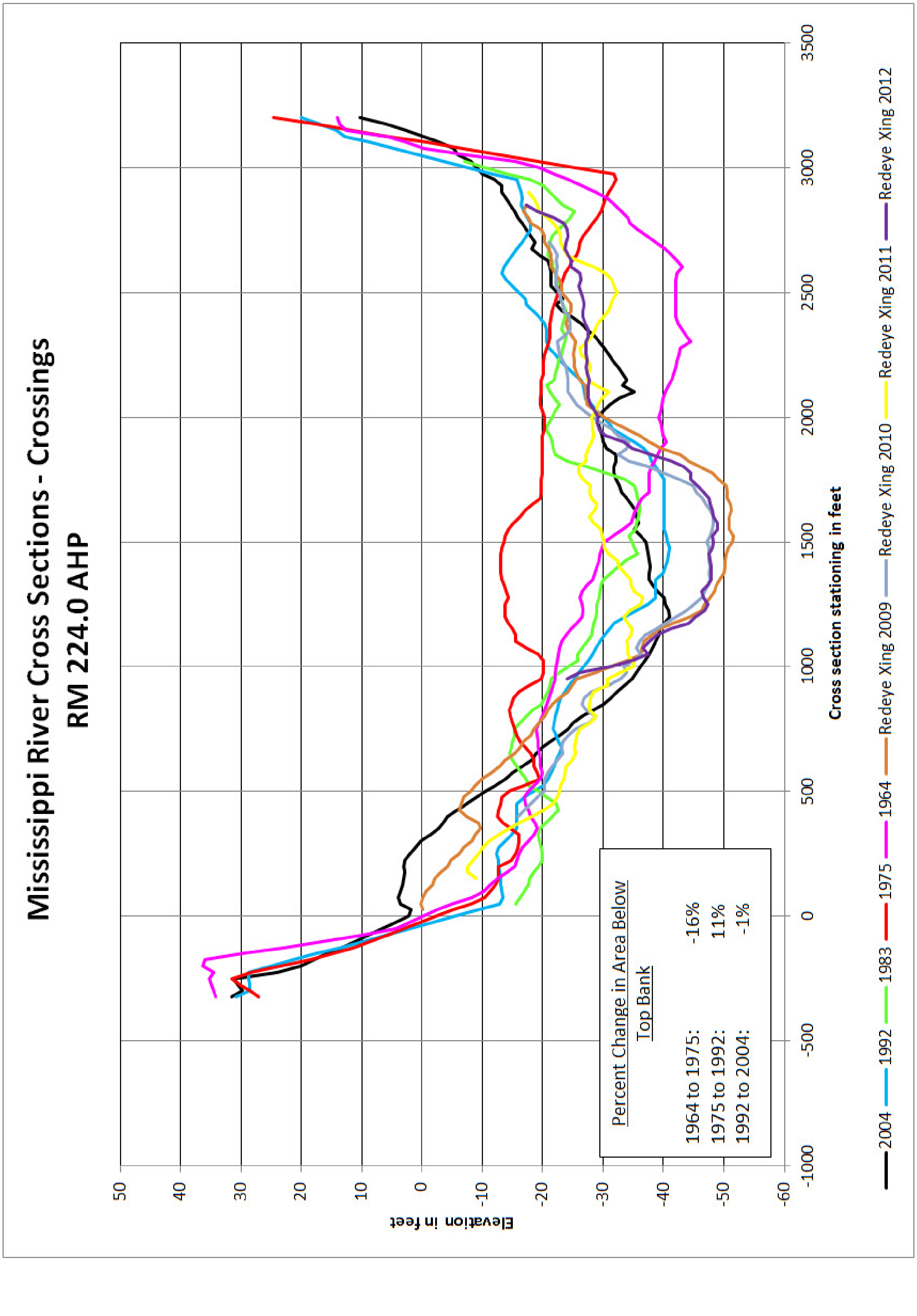

Mississippi River Cross Sections - Crossings
RM 190.4 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 0%
1975 to 1992: 5%
1992 to 2004: -3%
Elevation in feet
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-500
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
2004
1992
1983
1975
1964
Alhambra Xing 2009
Alhambra Xing 2010
Alhambra Xing 2011
Alhambra Xing 2012

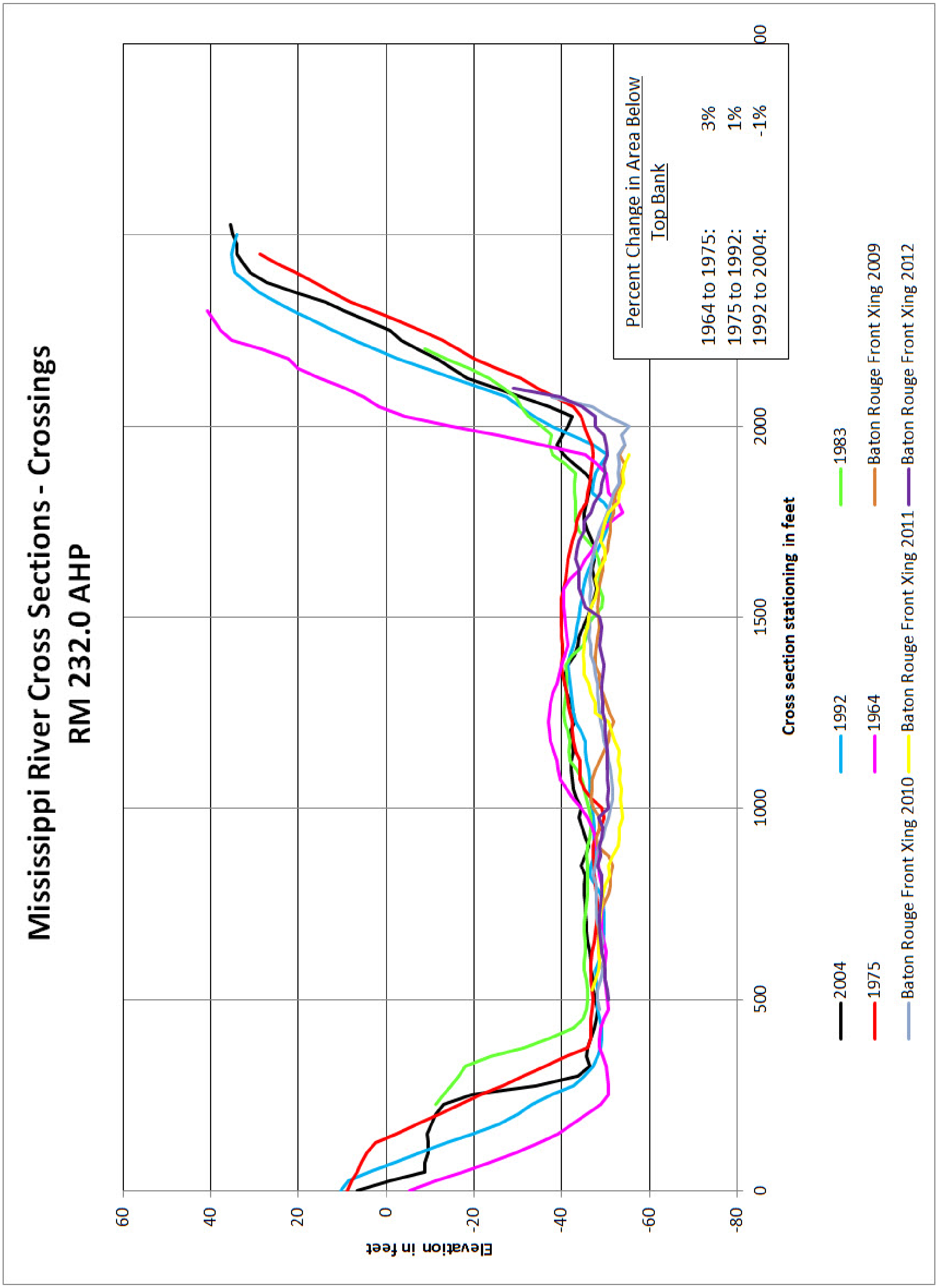

Mississippi River Cross Sections - Crossings
RM 197.8 AHP
Elevation in feet
40
20
0
-20
-40
-60
-80
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -2%
1975 to 1992: 3%
1992 to 2004: -2%
2004
1992
1983
1975
1964
Bayou Goula Xing 2009
Bayou Goula Xing 2010
Bayou Goula Xing 2011
Bayou Goula Xing 2012

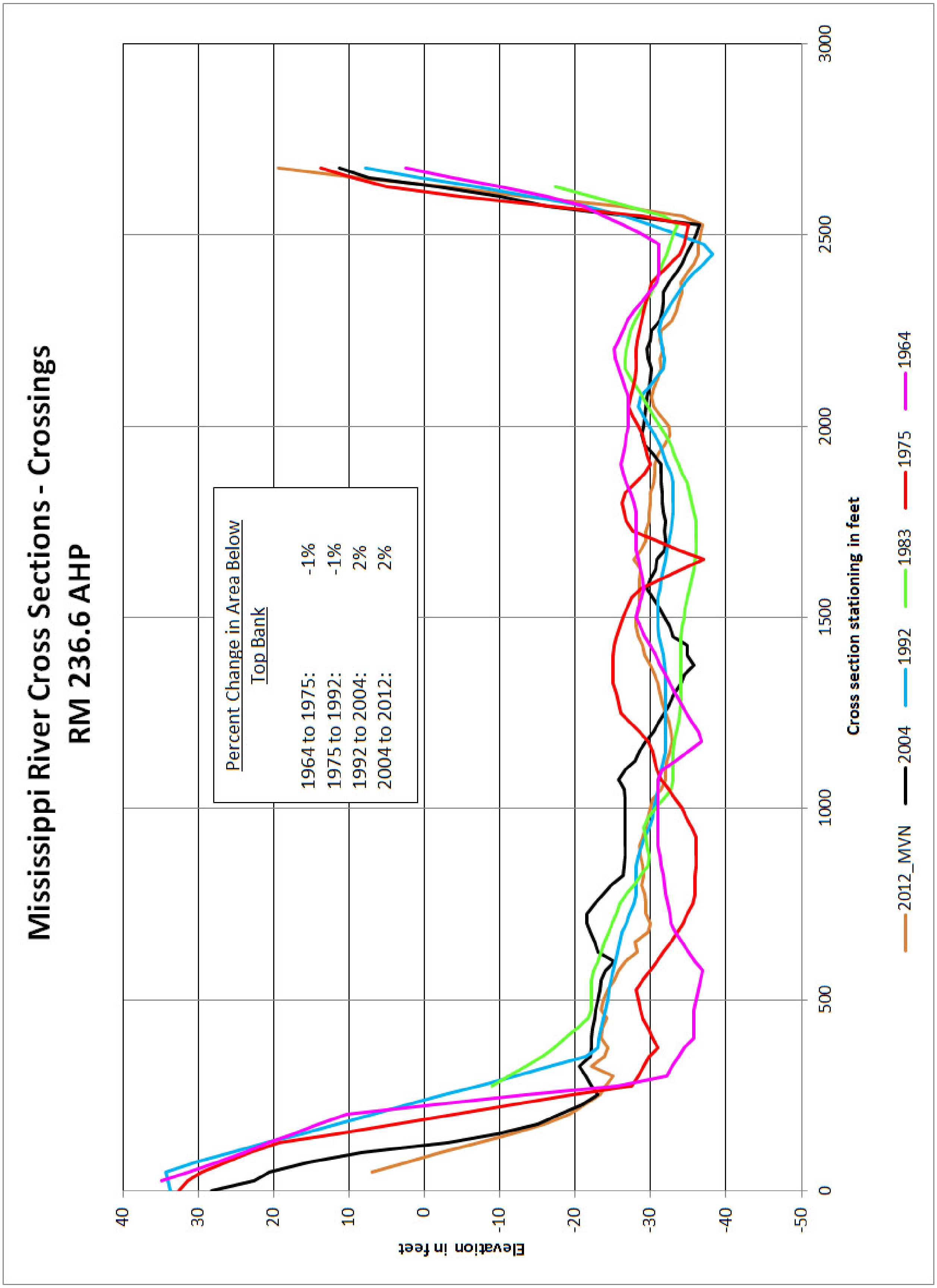

Mississippi River Cross Sections - Crossings
RM 204.1 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -5%
1975 to 1992: 5%
1992 to 2004: -4%
Elevation in feet
Cross section stationing in feet
2004
1992
1983
1975
1964
Granada Xing 2009
Granada Xing 2010
Granada Xing 2011
Granada Xing 2012

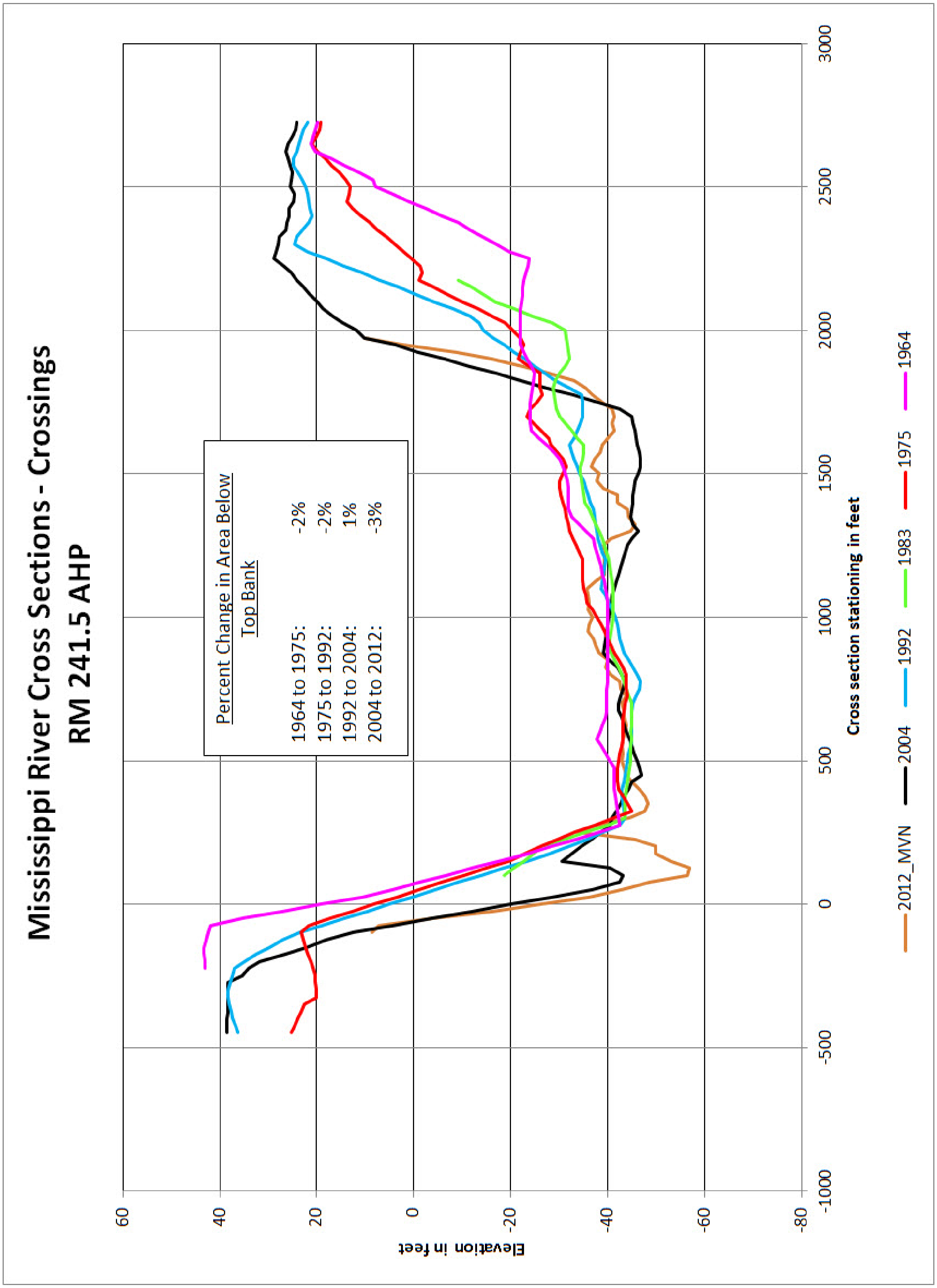

Mississippi River Cross Sections - Crossings
RM 212.1 AHP
Elevation in feet
Cross section stationing in feet
60
40
20
0
-20
-40
-60
-80
-500
0
500
1000
1500
2000
2500
3000
Percent Change in Area Below Top Bank
1964 to 1975: -12%
1975 to 1992: 17%
1992 to 2004: -3%
2004
1992
1983
1975
1964
Medora Xing 2009
Medora Xing 2010
Medora Xing 2012

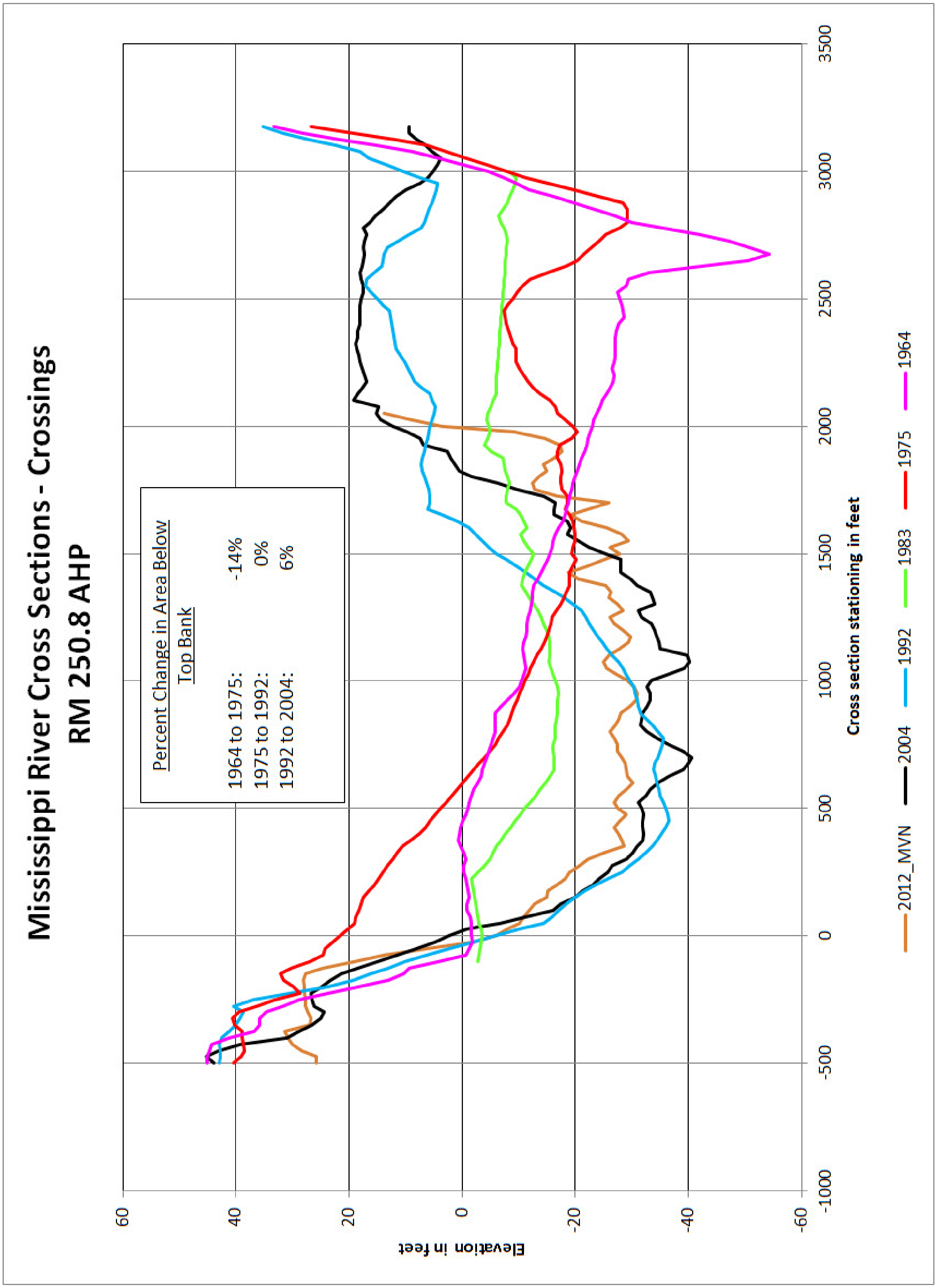

Mississippi River Cross Sections - Crossings
RM 219.4 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 0%
1975 to 1992: 2%
1992 to 2004: 2%
Elevation in feet
40
20
0
-20
-40
-60
-80
-500
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
2004
1992
1983
1975
1964
Sardine Pt Xing 2009
Sardine Pt Xing 2012
Chart Area

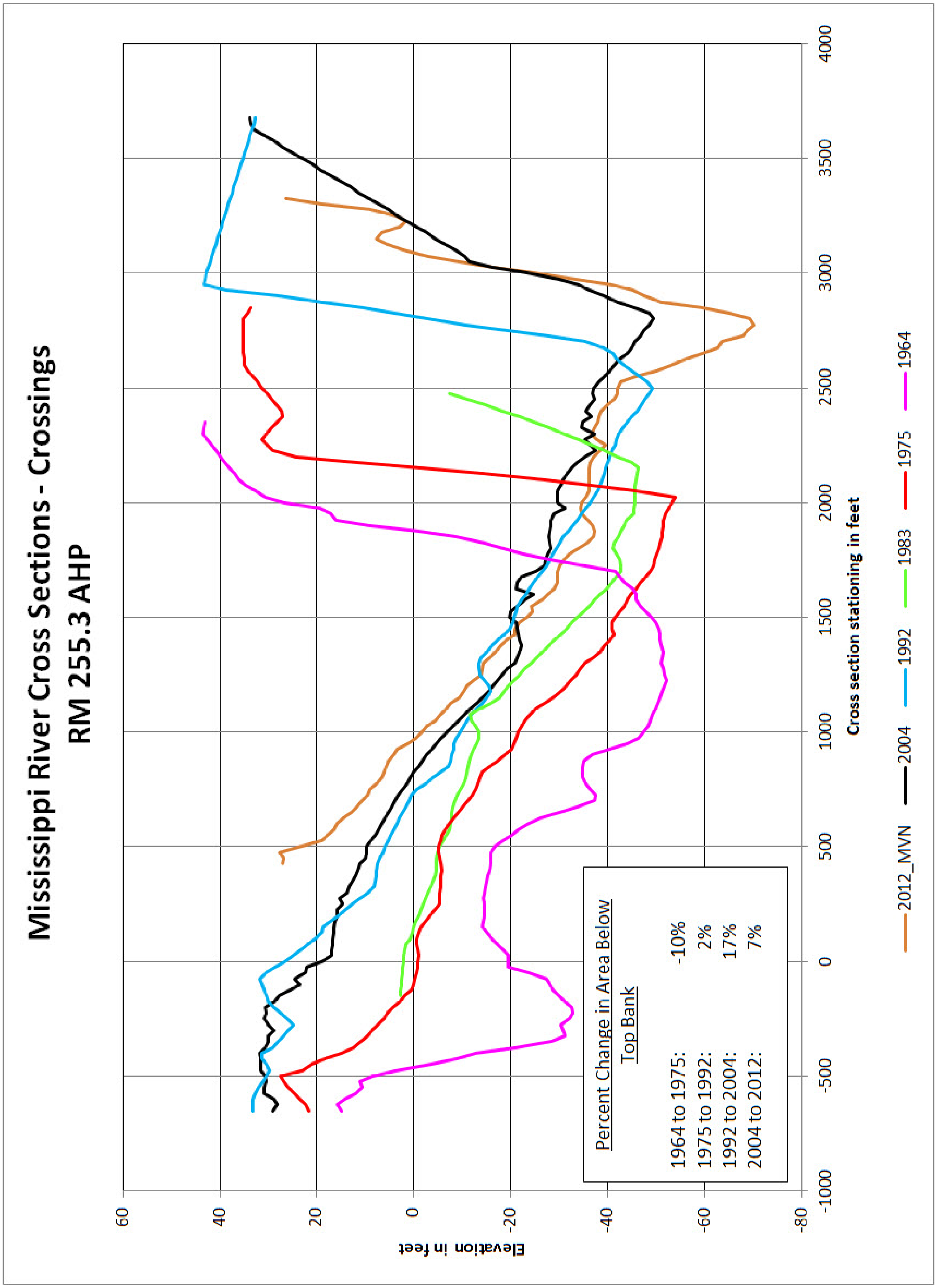

Mississippi River Cross Sections - Crossings
RM 224.0 AHP
Elevation in feet
Cross section stationing in feet
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: -16%
1975 to 1992: 11%
1992 to 2004: -1%
2004
1992
1983
1975
1964
Redeye Xing 2009
Redeye Xing 2010
Redeye Xing 2011
Redeye Xing 2012

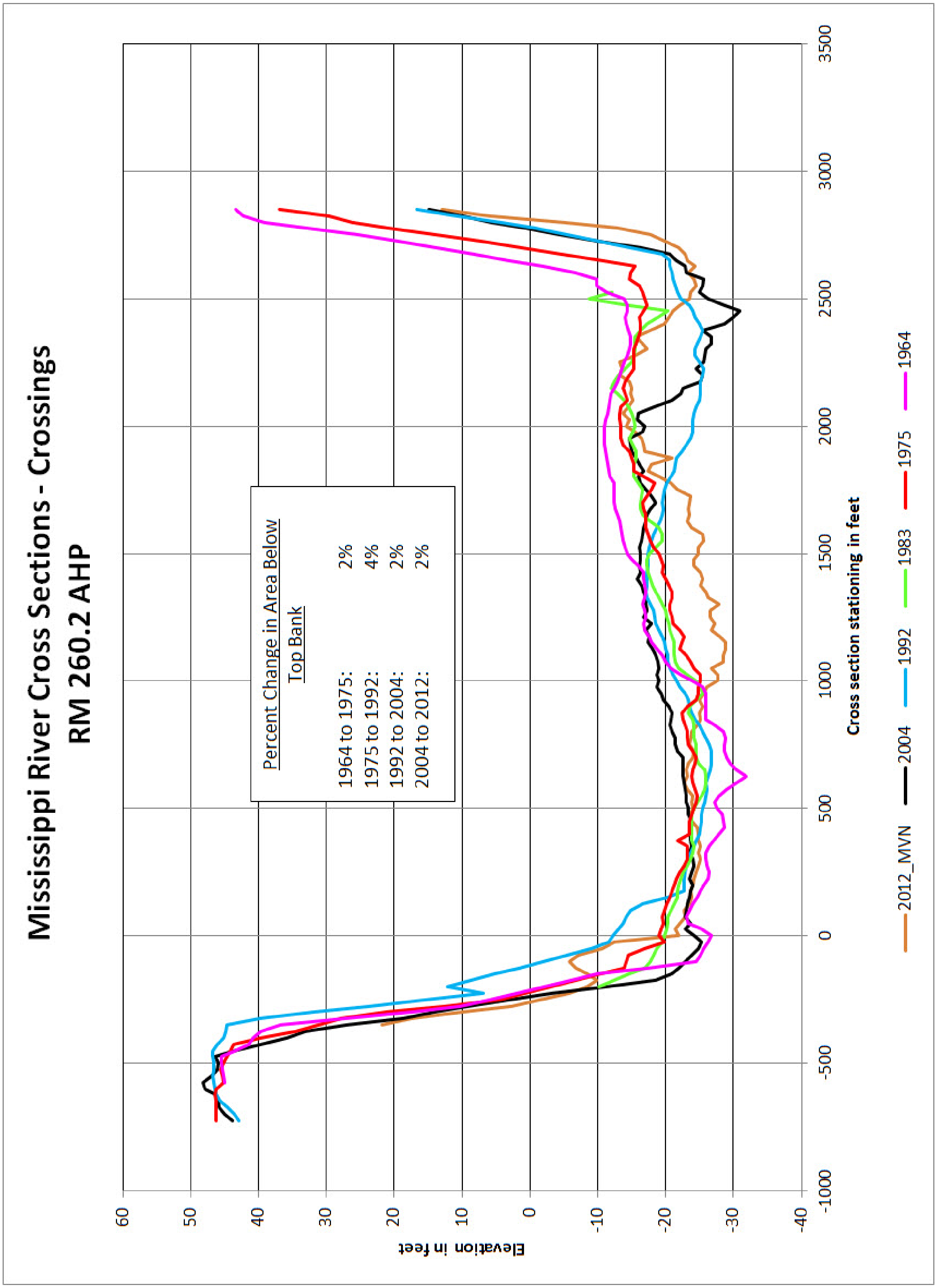

Mississippi River Cross Sections - Crossings
RM 232.0 AHP
Elevation in feet
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 3%
1975 to 1992: 1%
1992 to 2004: -1%
2004
1992
1983
1975
1964
Baton Rouge Front Xing 2009
Baton Rouge Front Xing 2010
Baton Rouge Front Xing 2011
Baton Rouge Front Xing 2012

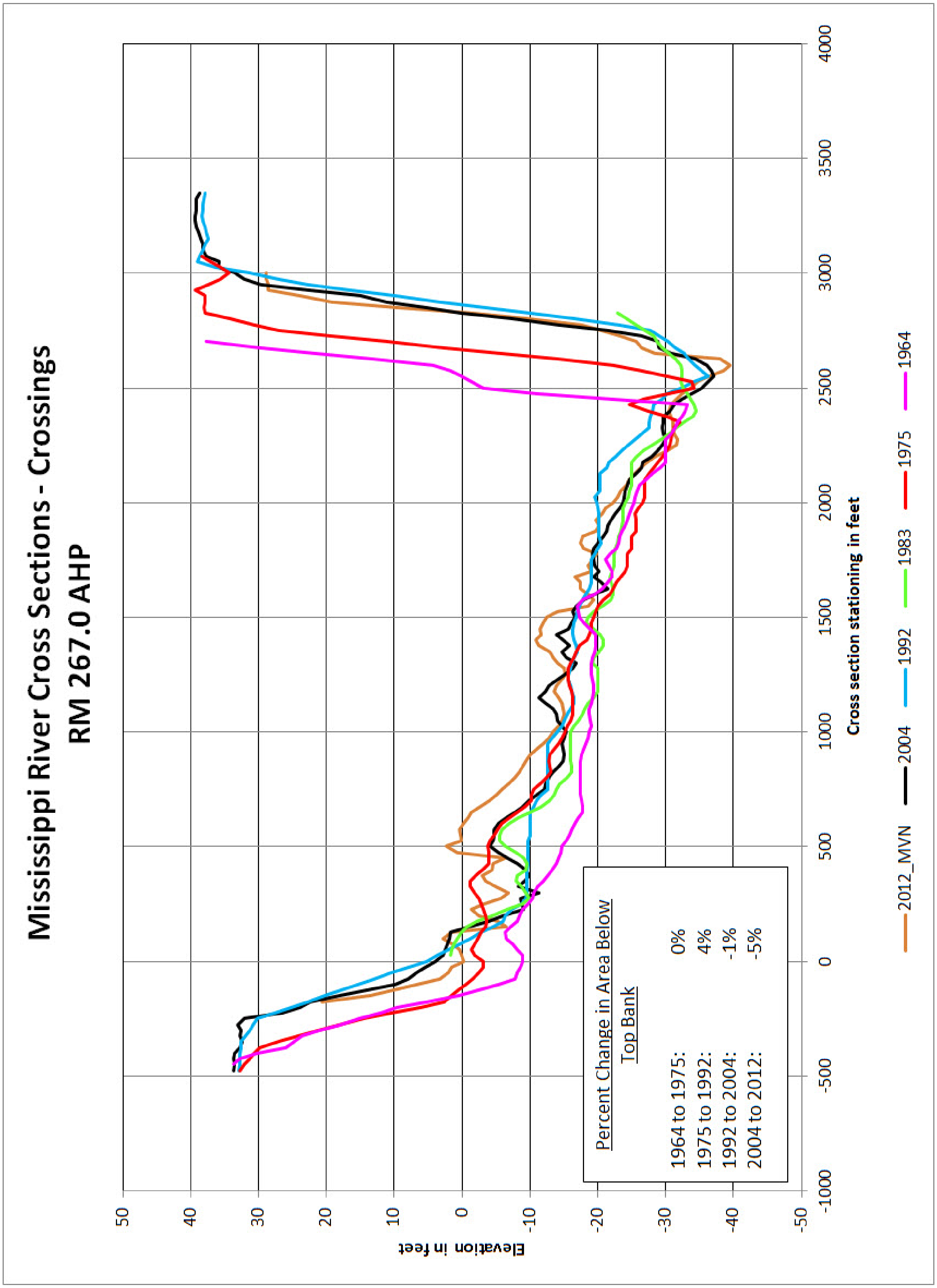

Mississippi River Cross Sections - Crossings
RM 236.6 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: -1%
1992 to 2004: 2%
2004 to 2012: 2%
Elevation in feet
40
30
20
10
0
-10
-20
-30
-40
-50
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2012_MVN
2004
1992
1983
1975
1964

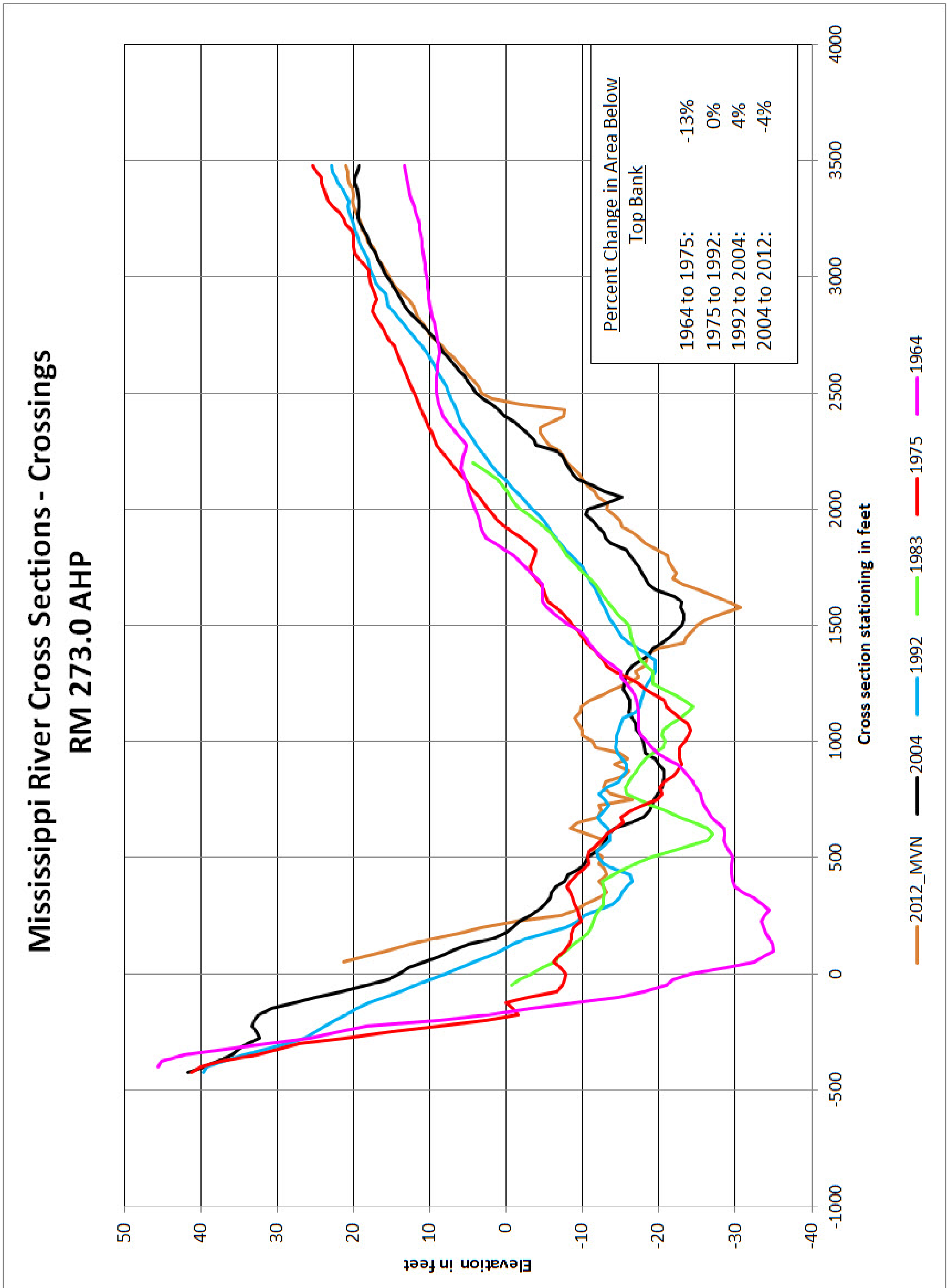

Mississippi River Cross Sections - Crossings
RM 241.5 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -2%
1975 to 1992: -2%
1992 to 2004: 1%
2004 to 2012: -3%
Elevation in feet
60
40
20
0
-20
-40
-60
-80
-1000
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
2012_MVN
2004
1992
1983
1975
1964

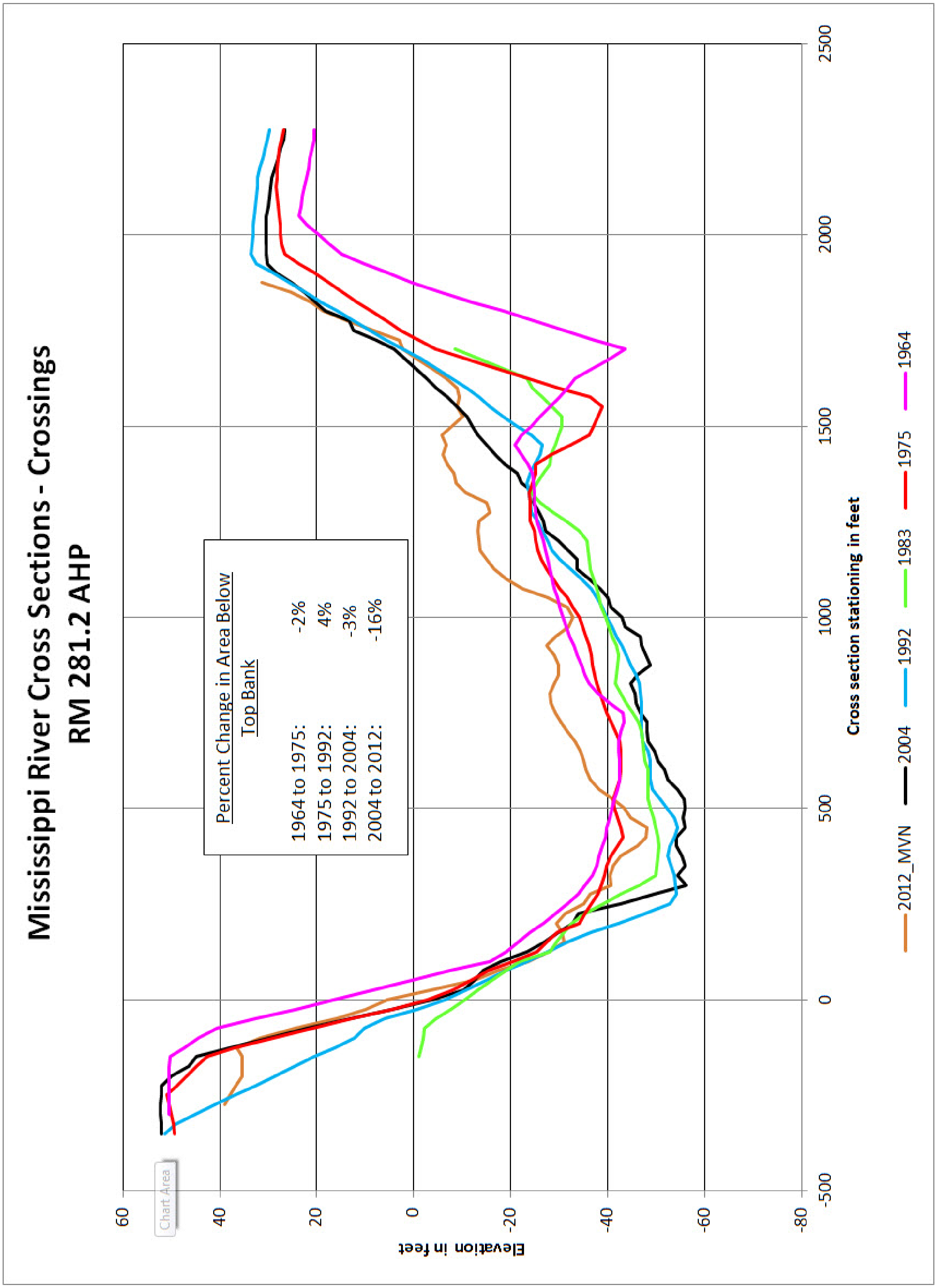

Mississippi River Cross Sections - Crossings
RM 250.8 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -14%
1975 to 1992: 0%
1992 to 2004: 6%
Elevation in feet
Cross section stationing in feet
60
40
20
0
-20
-40
-60
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
2012_MVN
2004
1992
1983
1975
1964

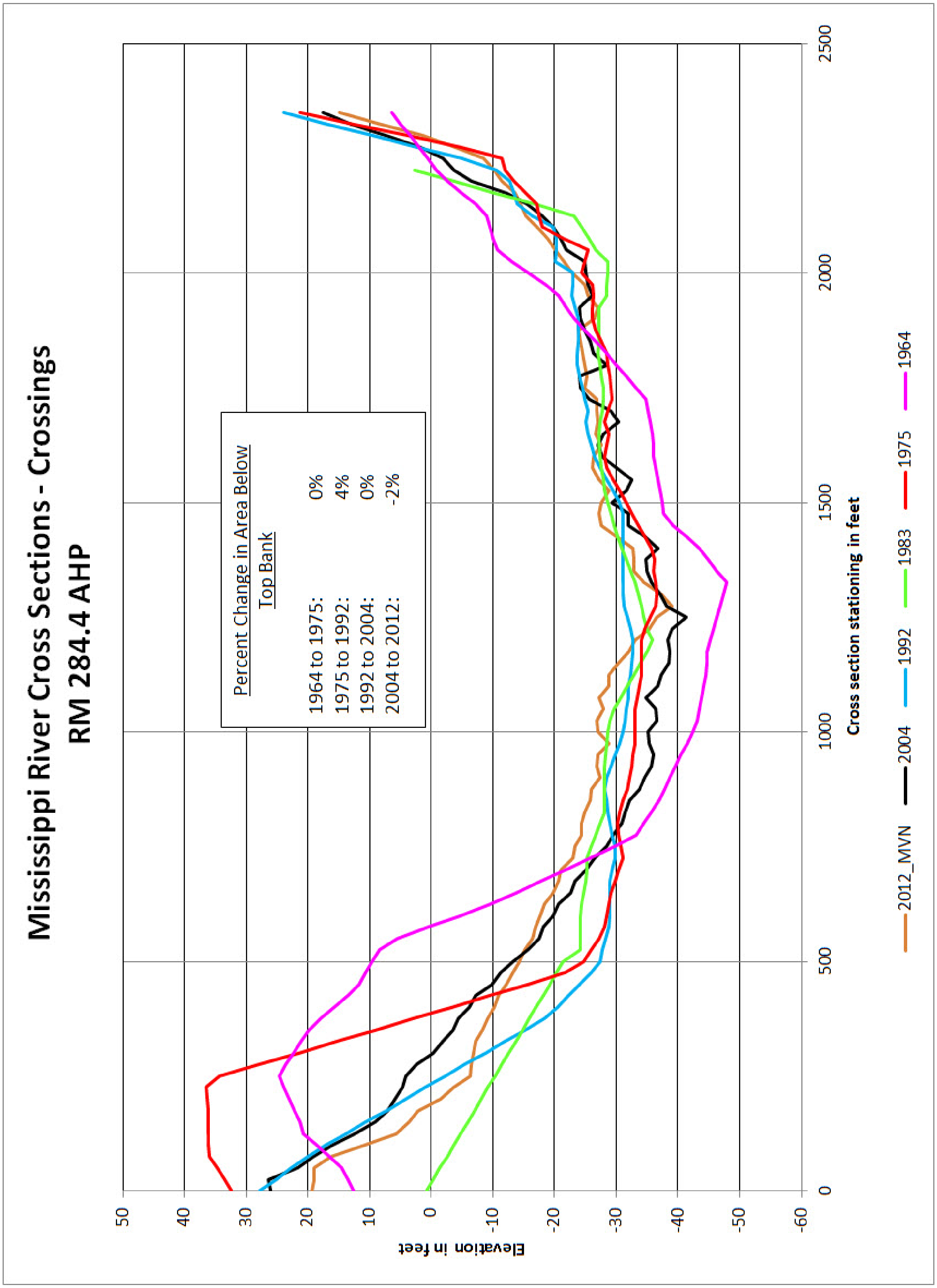

Mississippi River Cross Sections - Crossings
RM 255.3 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -10%
1975 to 1992: 2%
1992 to 2004: 17%
2004 to 2012: 7%
2012_MVN
2004
1992
1983
1975
1964
60
40
20
0
-20
-40
-60
-80
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
4000

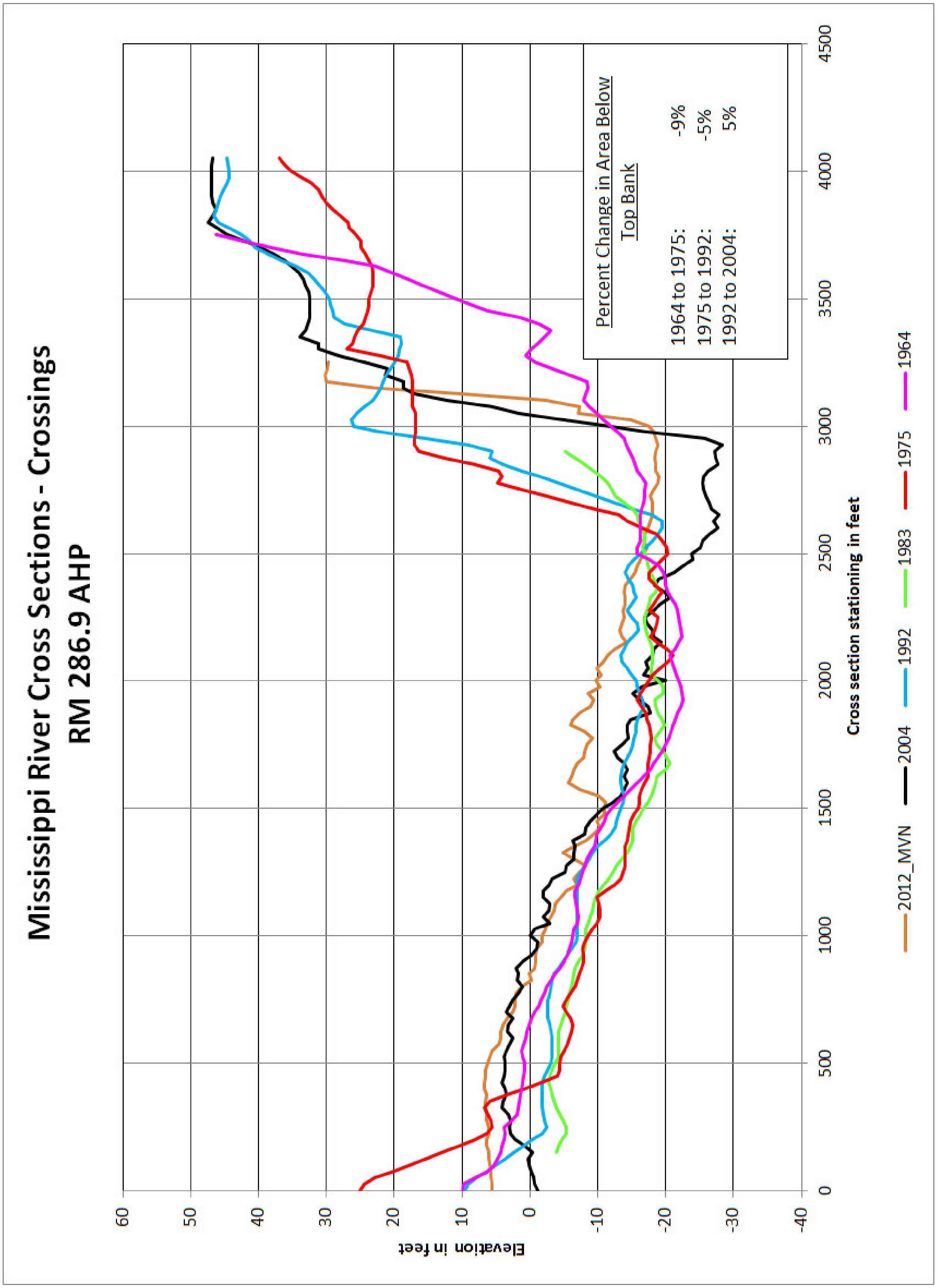

Mississippi River Cross Sections - Crossings
RM 260.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 2%
1975 to 1992: 4%
1992 to 2004: 2%
2004 to 2012: 2%
Elevation in feet
Cross section stationing in feet
60
50
40
30
20
10
0
-10
-20
-30
-40
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 267.0 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: 0%
1975 to 1992: 4%
1992 to 2004: -1%
2004 to 2012: -5%
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 273.0 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -13%
1975 to 1992: 0%
1992 to 2004: 4%
2004 to 2012: -4%
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 281.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -2%
1975 to 1992: 4%
1992 to 2004: -3%
2004 to 2012: -16%
Elevation in feet
Cross section stationing in feet
2012_MVN
2004
1992
1983
1975
1964
60
40
20
0
-20
-40
-60
-80
-500
0
500
1000
1500
2000
2500


Mississippi River Cross Sections - Crossings
RM 284.4 AHP
Percent Change in Area Below
Top Bank
1964 to 1975: 0%
1975 to 1992: 4%
1992 to 2004: 0%
2004 to 2012: -2%
Elevation in feet
Cross section stationing in feet
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Crossings
RM 286.9 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -9%
1975 to 1992: -5%
1992 to 2004: 5%
2012_MVN
2004
1992
1983
1975
1964

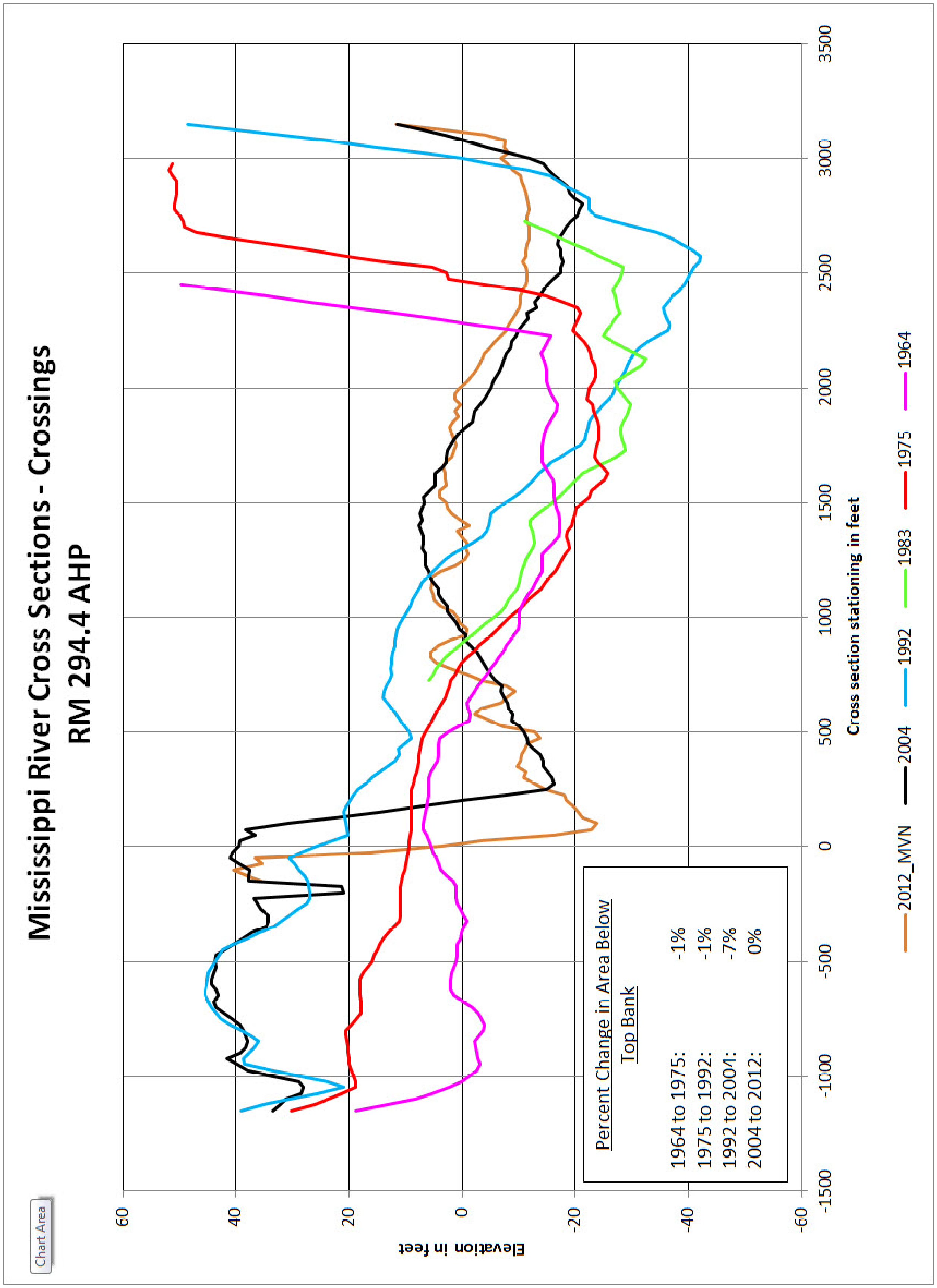
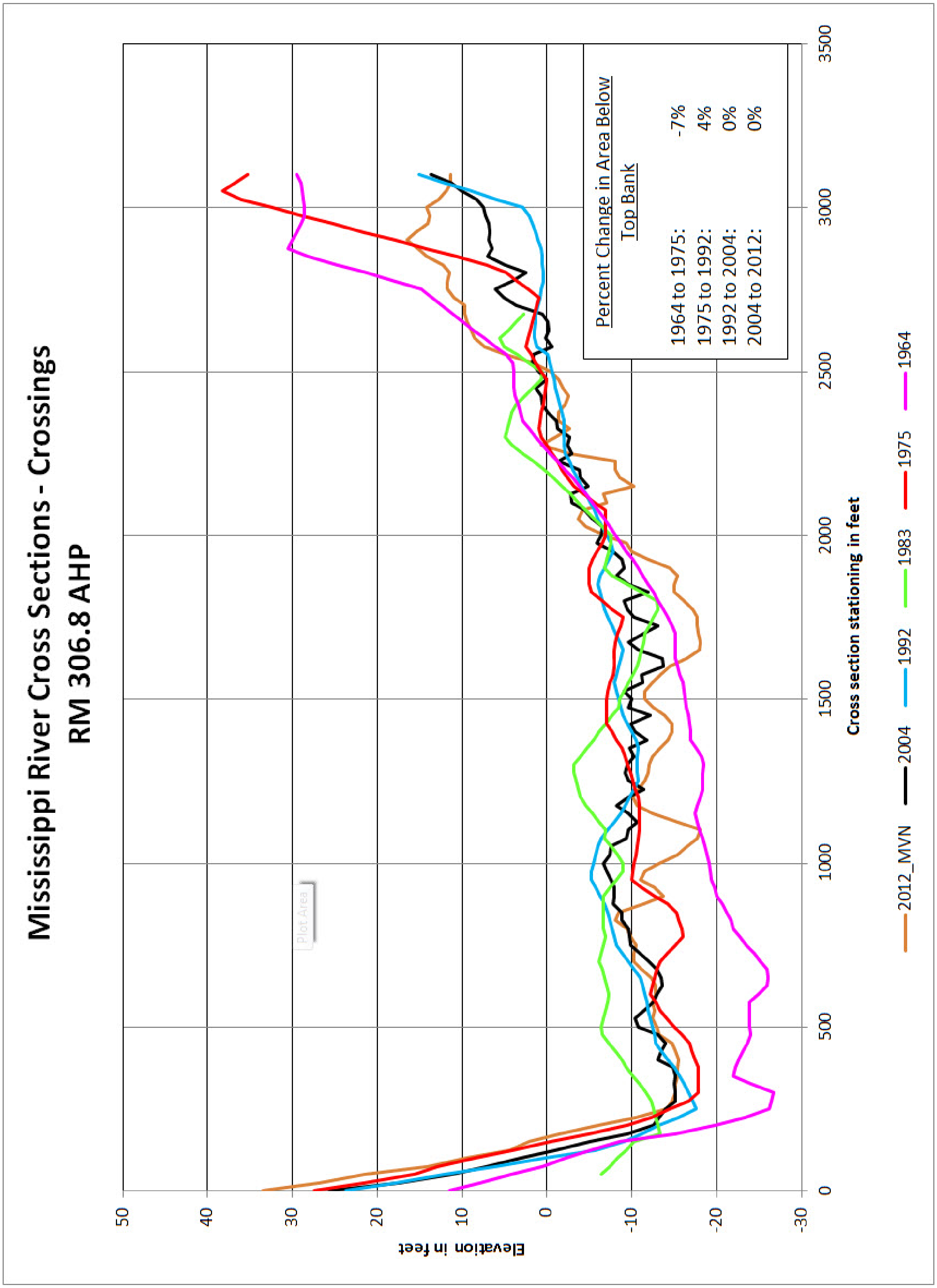
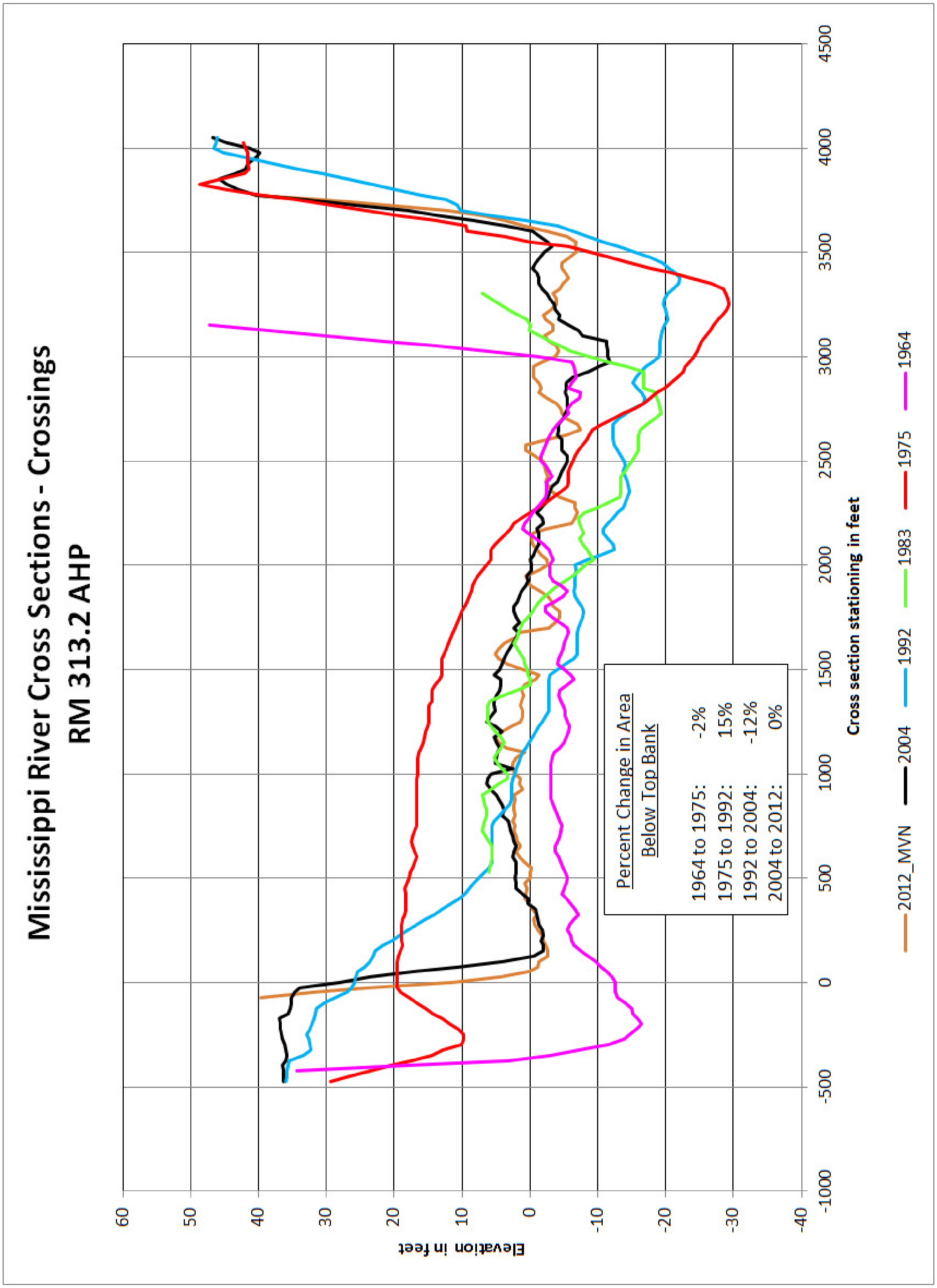
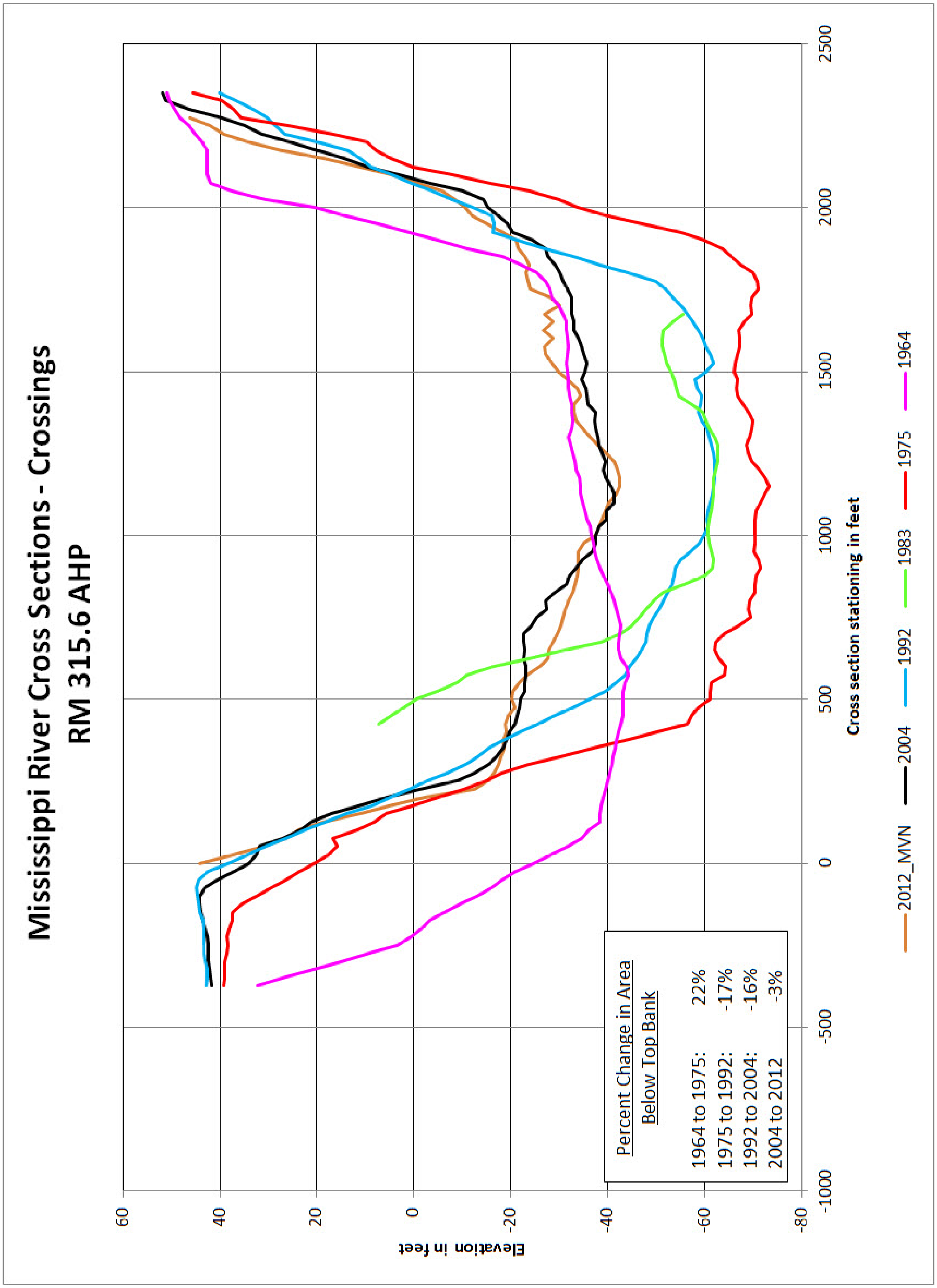
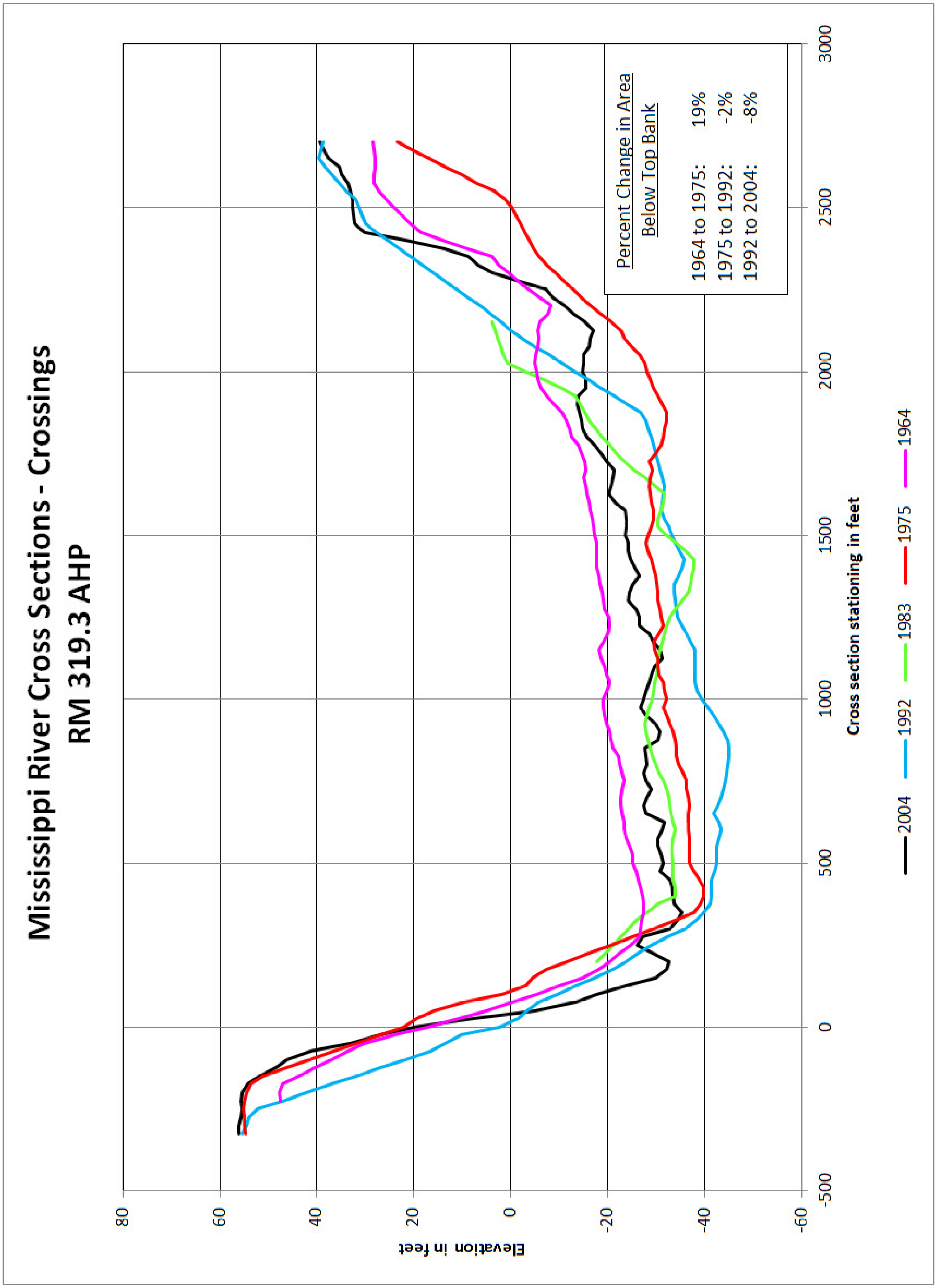


Chart Area
Mississippi River Cross Sections - Crossings
RM 294.4 AHP
Elevation in feet
60
40
20
0
-20
-40
-60
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: -1%
1992 to 2004: -7%
2004 to 2012: 0%
2012_MVN
2004
1992
1983
1975
1964

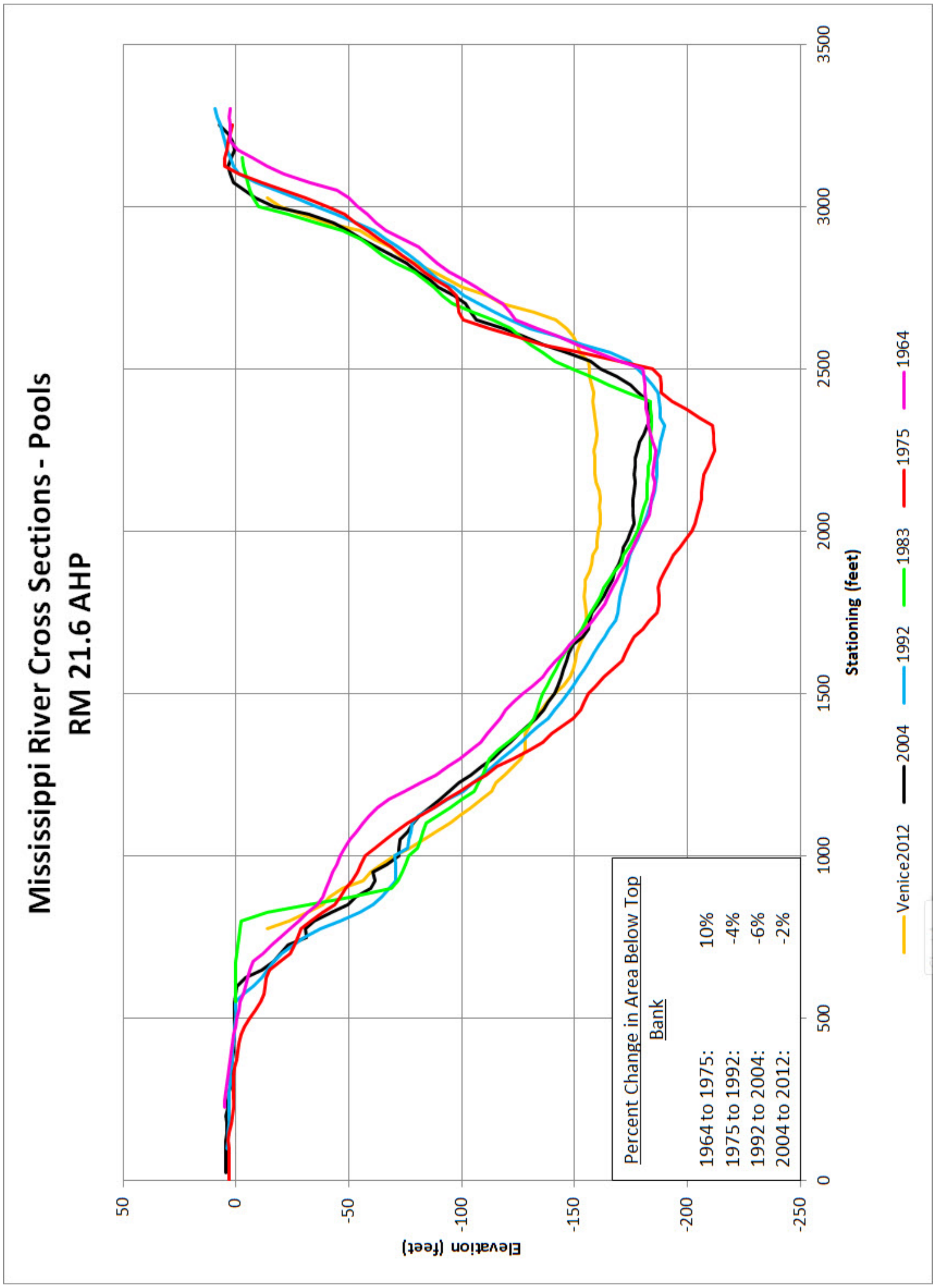

Mississippi River Cross Sections - Crossings
RM 306.8 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area Below Top Bank
1964 to 1975: -7%
1975 to 1992: 4%
1992 to 2004: 0%
2004 to 2012: 0%
2012_MVN
2004
1992
1983
1975
1964
Plot Area
50
40
30
20
10
0
-10
-20
-30
0
500
1000
1500
2000
2500
3000
3500

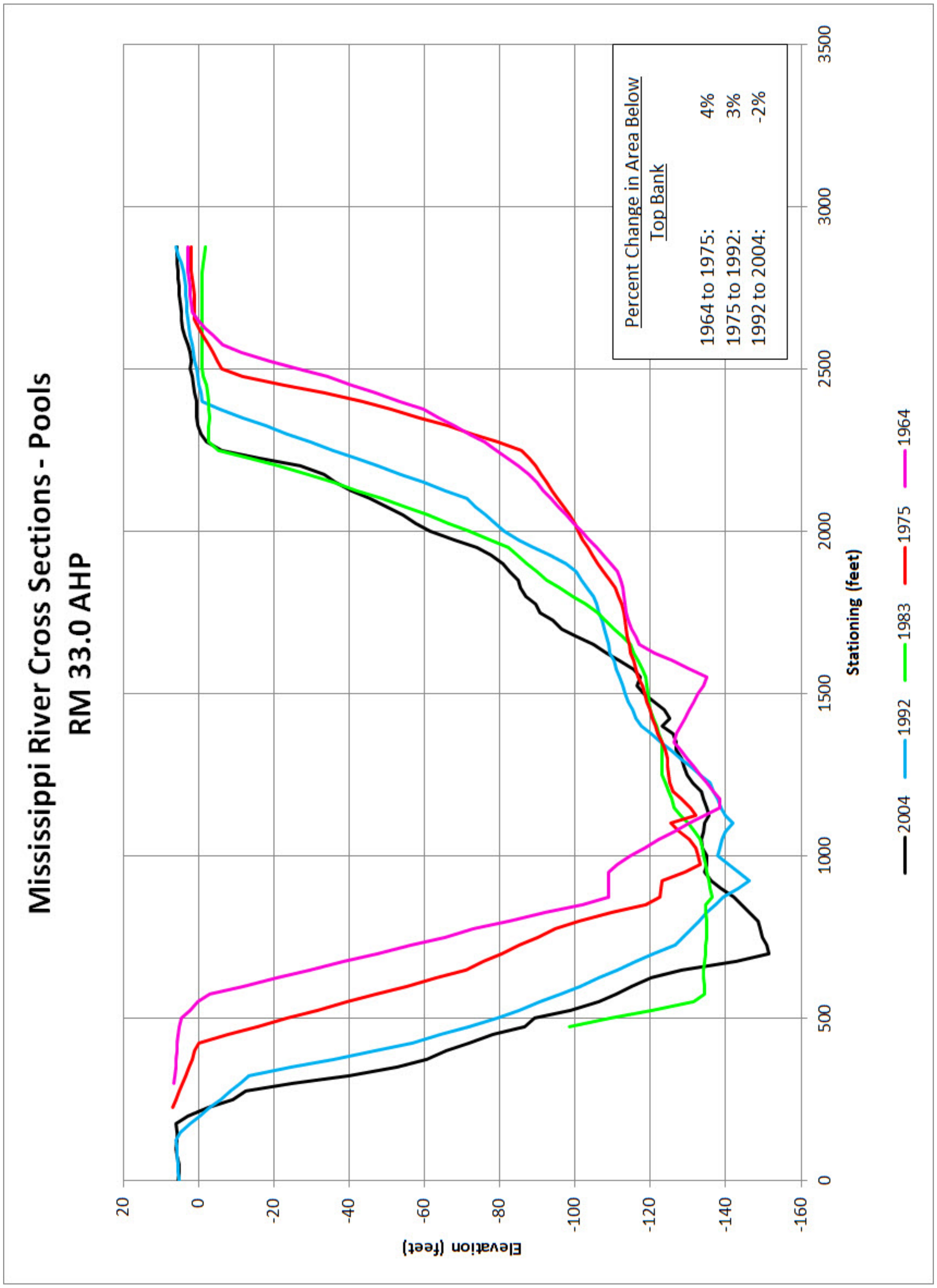

Mississippi River Cross Sections - Crossings
RM 313.2 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area
Below Top Bank
1964 to 1975: -2%
1975 to 1992: 15%
1992 to 2004: -12%
2004 to 2012: 0%
2012_MVN
2004
1992
1983
1975
1964
60
50
40
30
20
10
0
-10
-20
-30
-40
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500

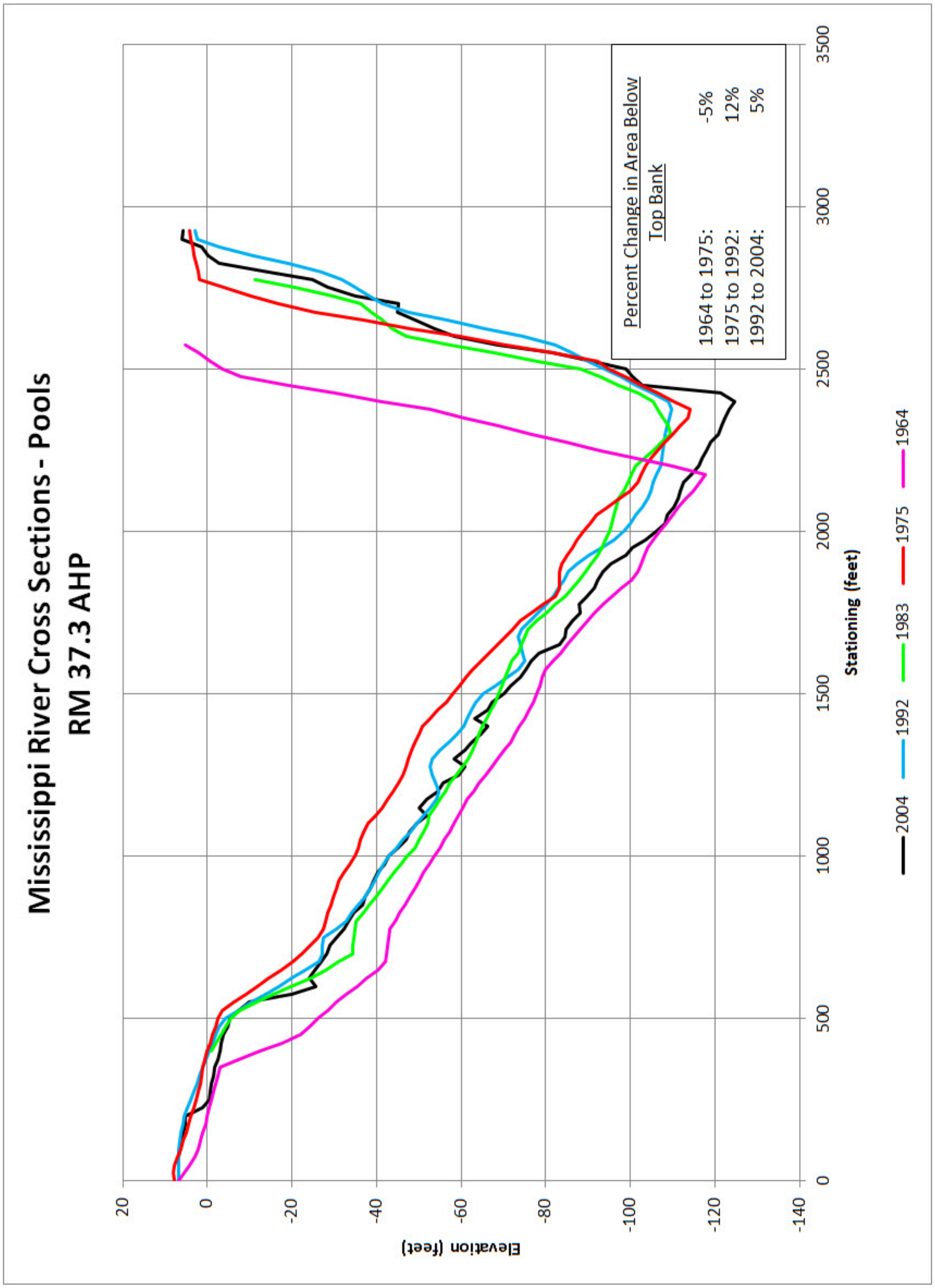

Mississippi River Cross Sections - Crossings
RM 315.6 AHP
Elevation in feet
Cross section stationing in feet
Percent Change in Area
Below Top Bank
1964 to 1975: 22%
1975 to 1992: -17%
1992 to 2004: -16%
2004 to 2012 -3%
2012_MVN
2004
1992
1983
1975
1964
60
40
20
0
-20
-40
-60
-80
-1000
-500
0
500
1000
1500
2000
2500

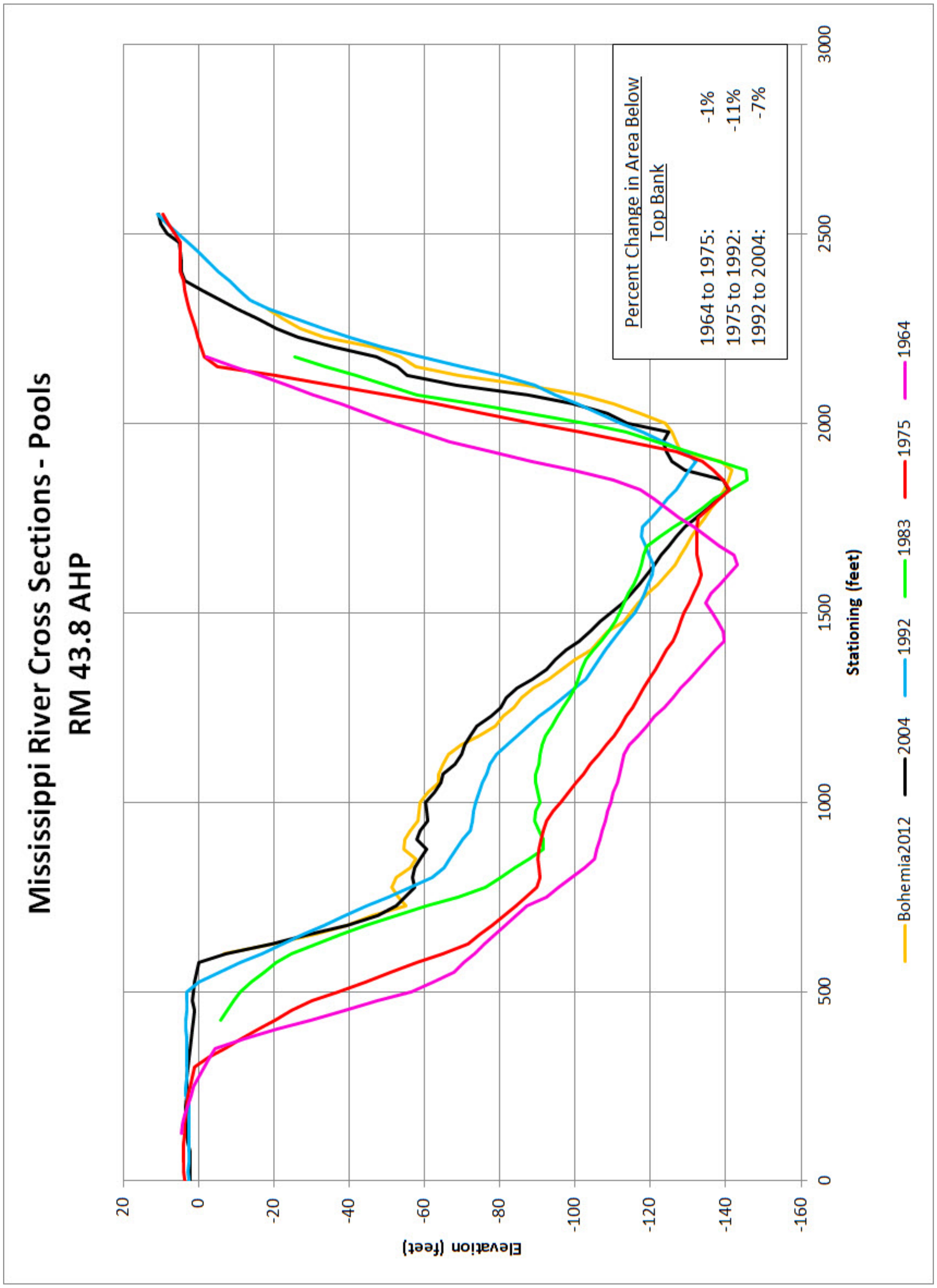

Mississippi River Cross Sections - Crossings
RM 319.3 AHP
Elevation in feet
80
60
40
20
0
-20
-40
-60
-500
0
500
1000
1500
2000
2500
3000
Cross section stationing in feet
Percent Change in Area
Below Top Bank
1964 to 1975: 19%
1975 to 1992: -2%
1992 to 2004: -8%
2004
1992
1983
1975
1964

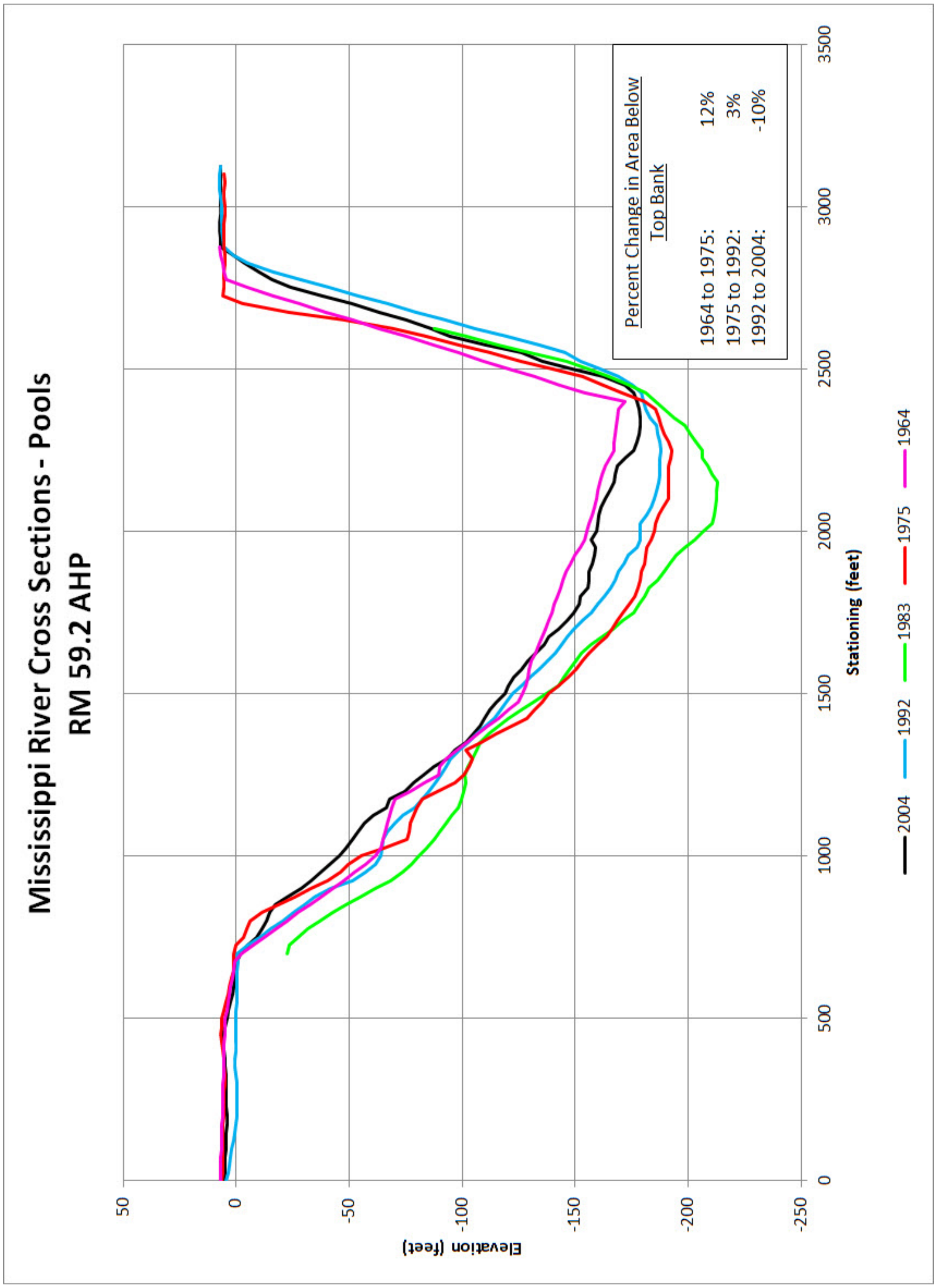
Comparative Cross Sections–Pool Locations

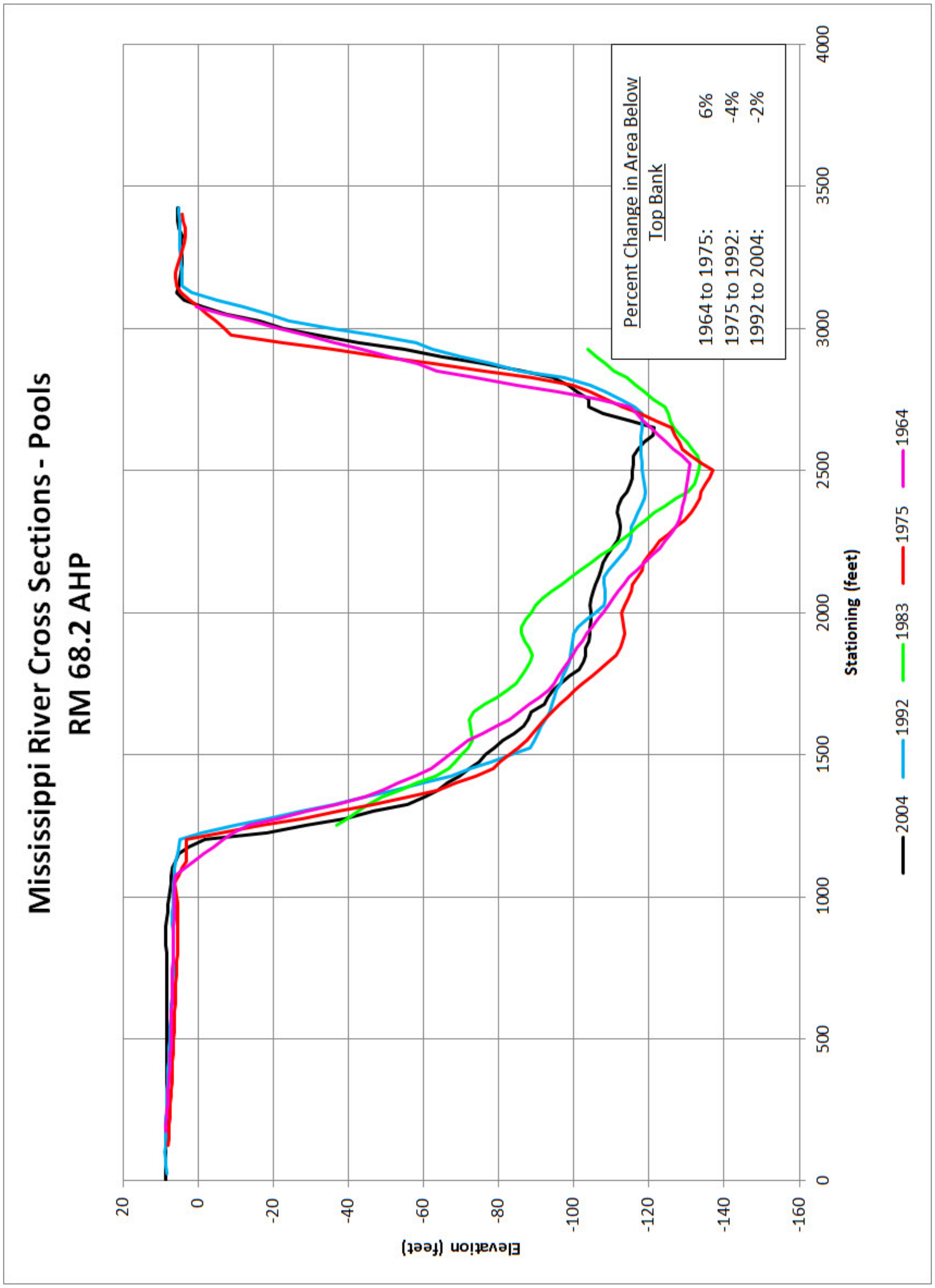


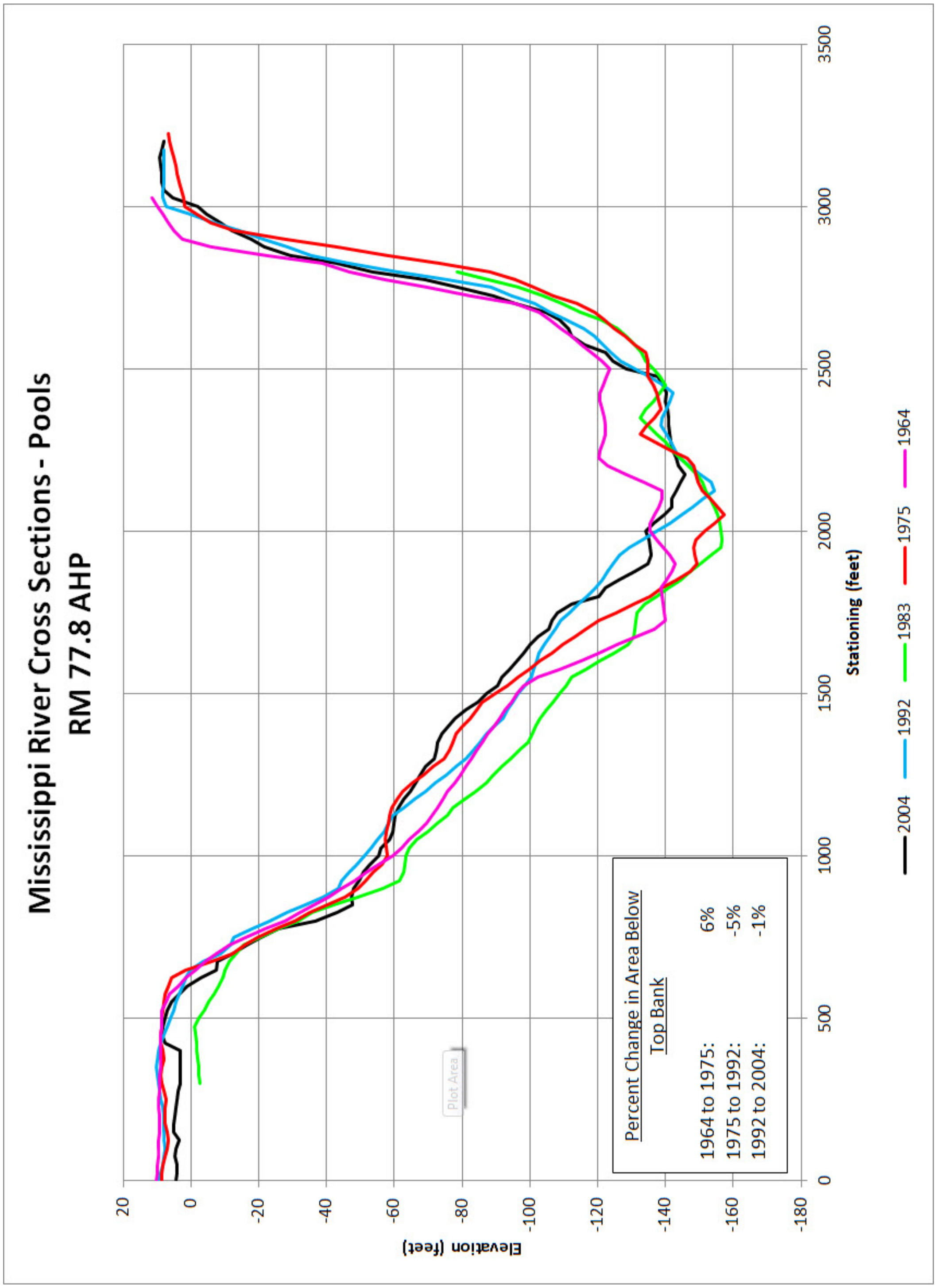

Mississippi River Cross Sections - Pools
RM 33.0 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: 4%
1975 to 1992: 3%
1992 to 2004: -2%
2004
1992
1983
1975
1964
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
3500

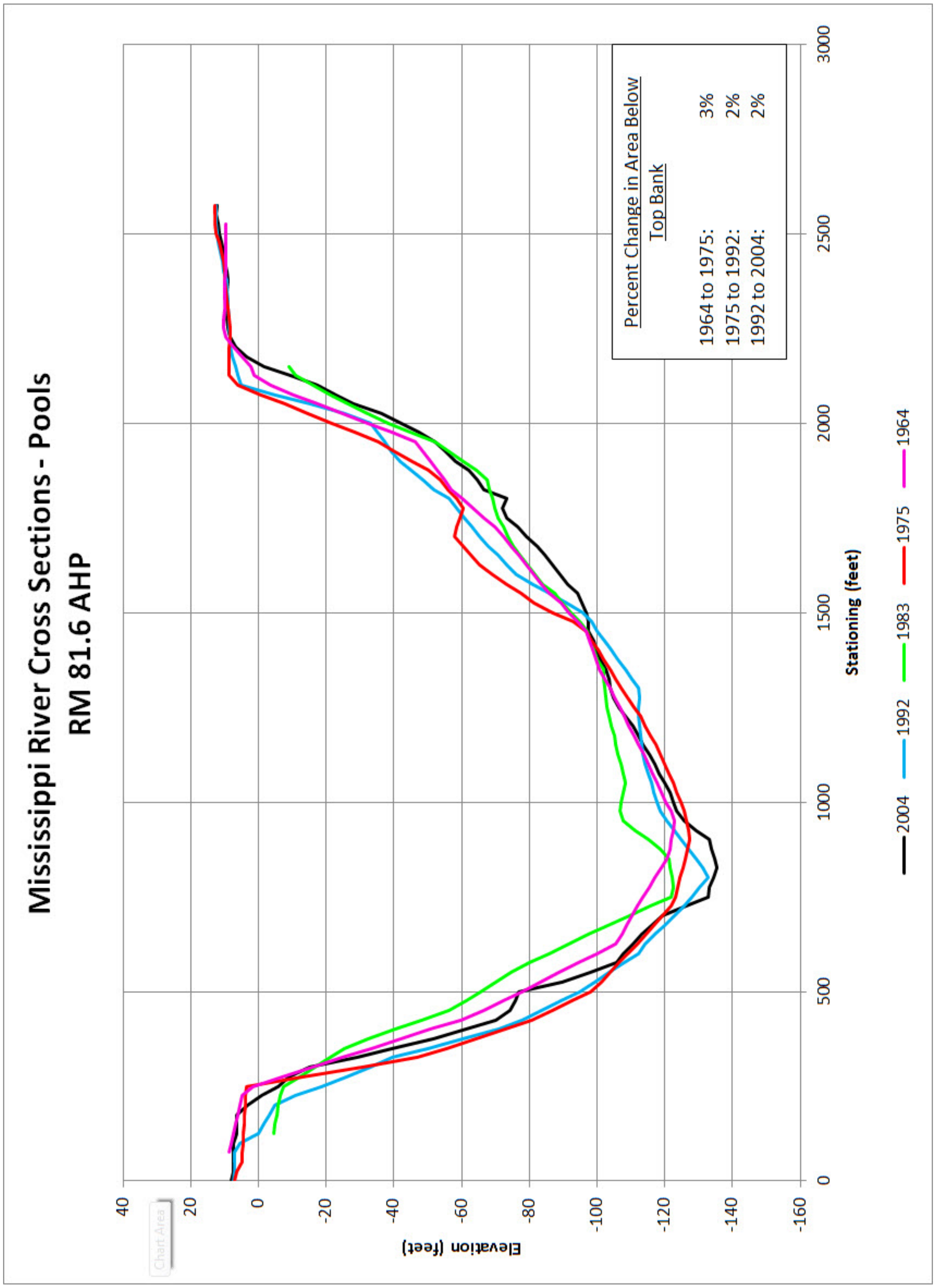

Mississippi River Cross Sections - Pools
RM 37.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -5%
1975 to 1992: 12%
1992 to 2004: 5%
Elevation (feet)
20
0
-20
-40
-60
-80
-100
-120
-140
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
2004
1992
1983
1975
1964

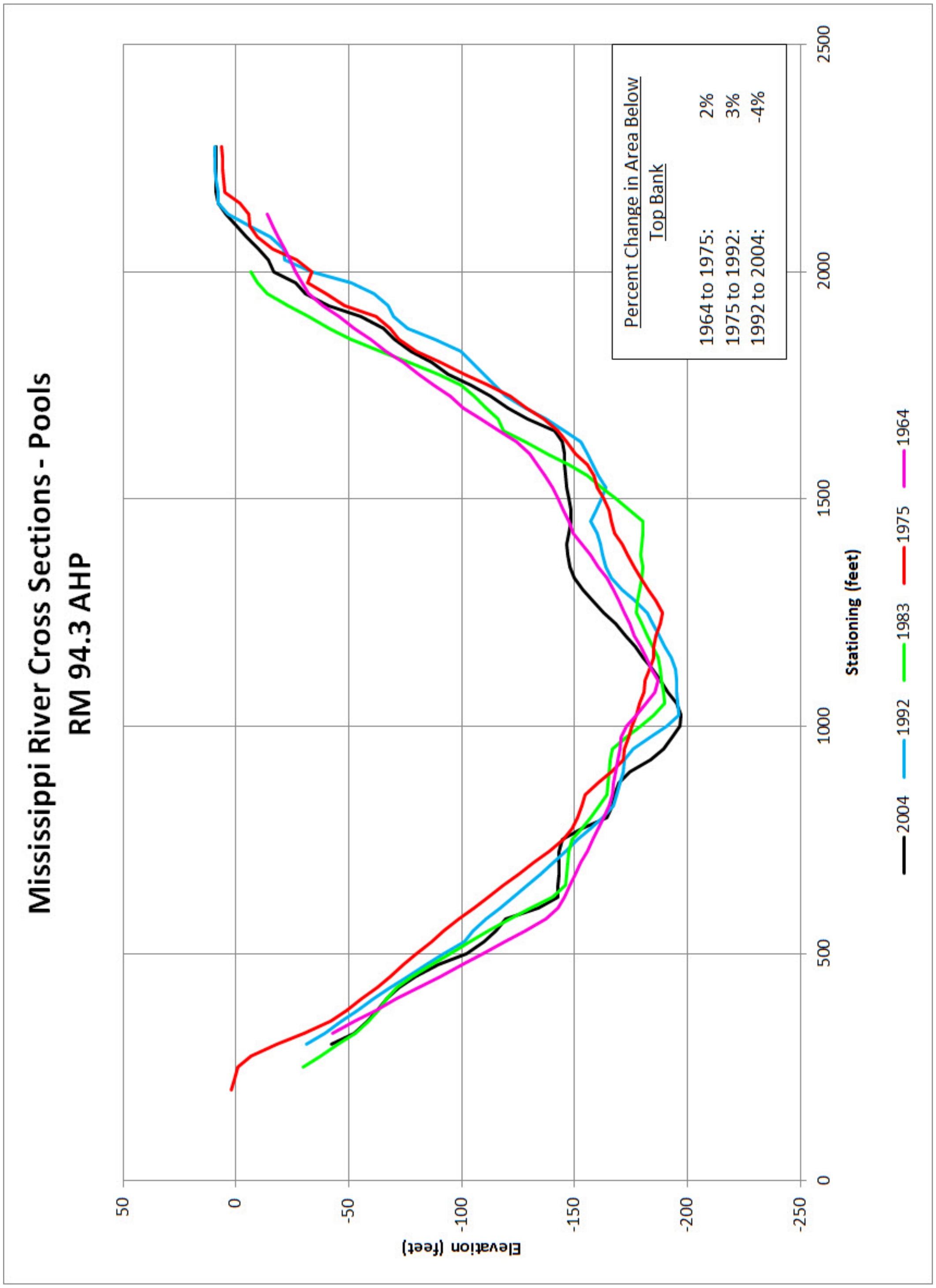

Mississippi River Cross Sections - Pools
RM 43.8 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: -11%
1992 to 2004: -7%
Bohemia2012
2004
1992
1983
1975
1964
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000

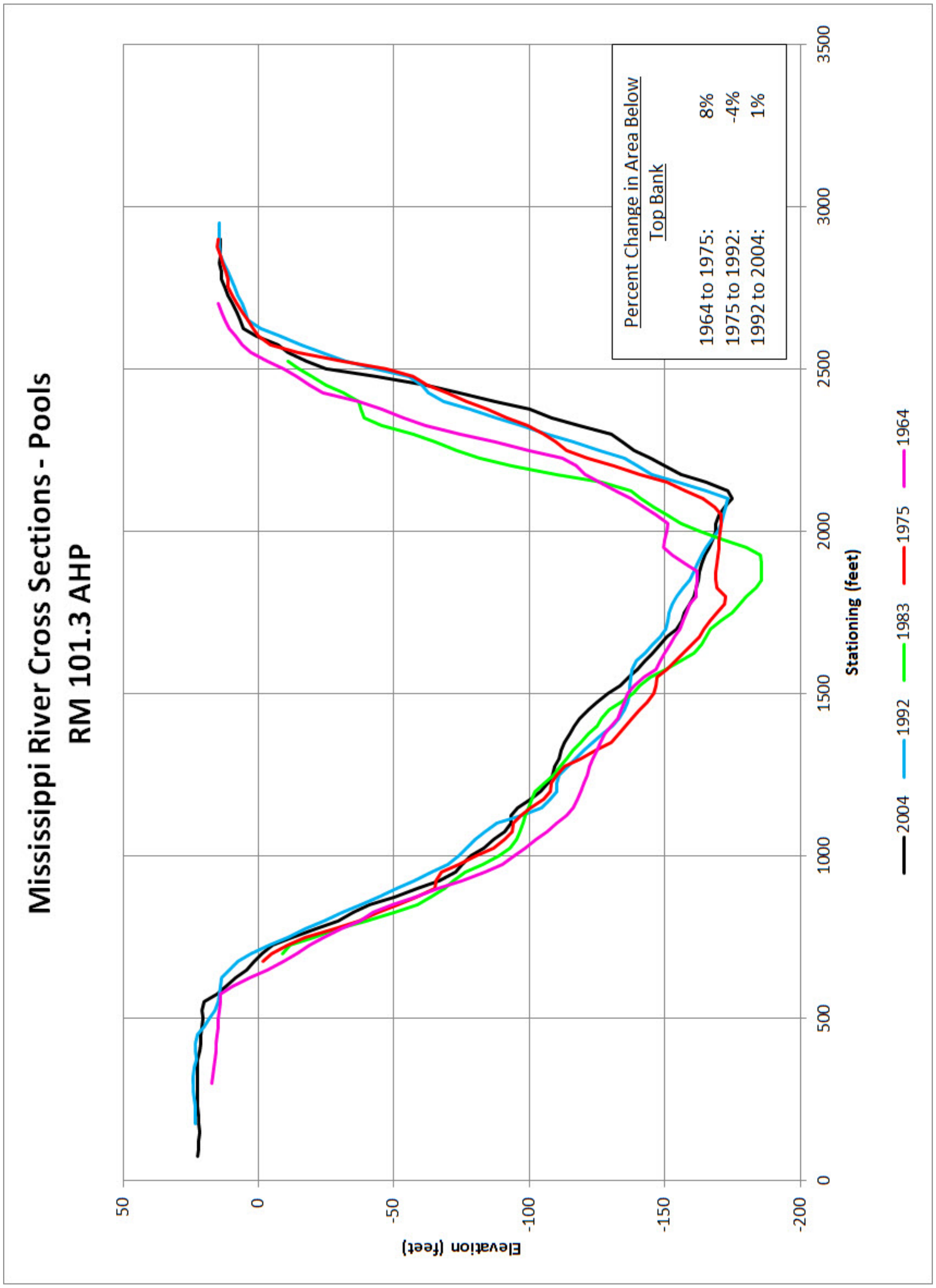

Mississippi River Cross Sections - Pools
RM 59.2 AHP
Elevation (feet)
Stationing (feet)
50
0
-50
-100
-150
-200
-250
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: 12%
1975 to 1992: 3%
1992 to 2004: -10%
2004
1992
1983
1975
1964

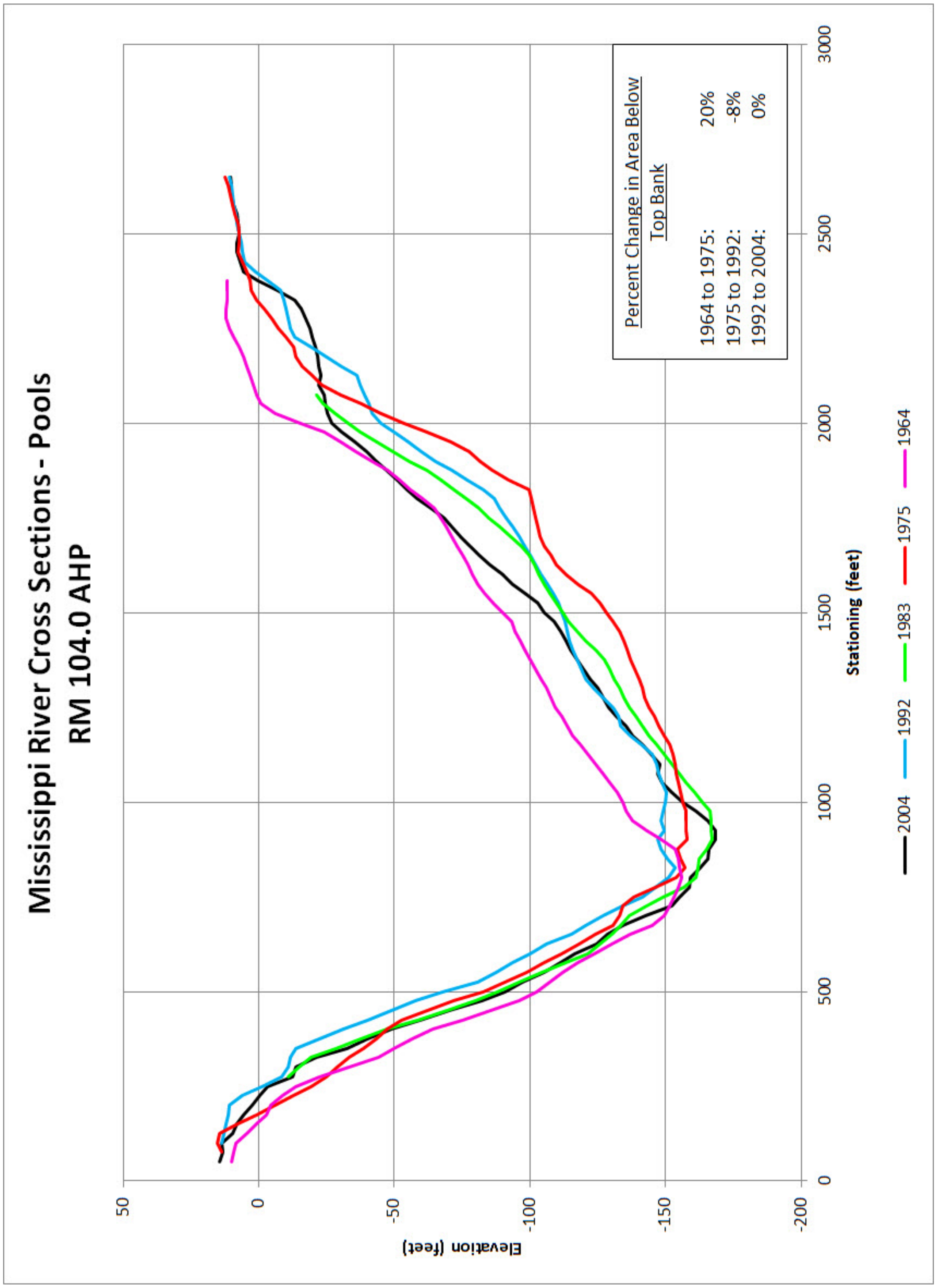

Mississippi River Cross Sections - Pools
RM 68.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 6%
1975 to 1992: -4%
1992 to 2004: -2%
Elevation (feet)
Stationing (feet)
2004
1992
1983
1975
1964
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
3500
4000

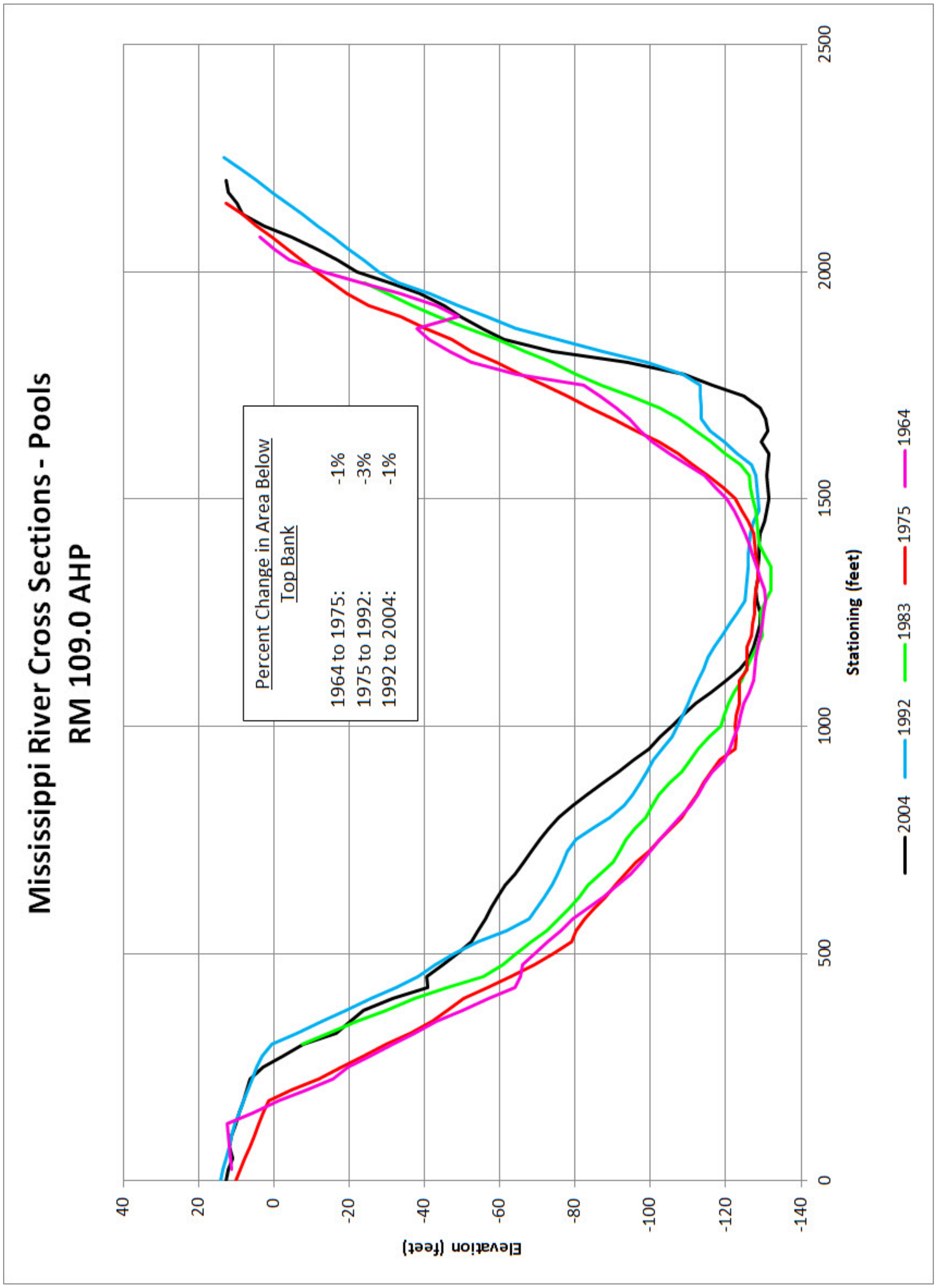

Mississippi River Cross Sections - Pools
RM 77.8 AHP
Elevation (feet)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: 6%
1975 to 1992: -5%
1992 to 2004: -1%
Plot Area
2004
1992
1983
1975
1964

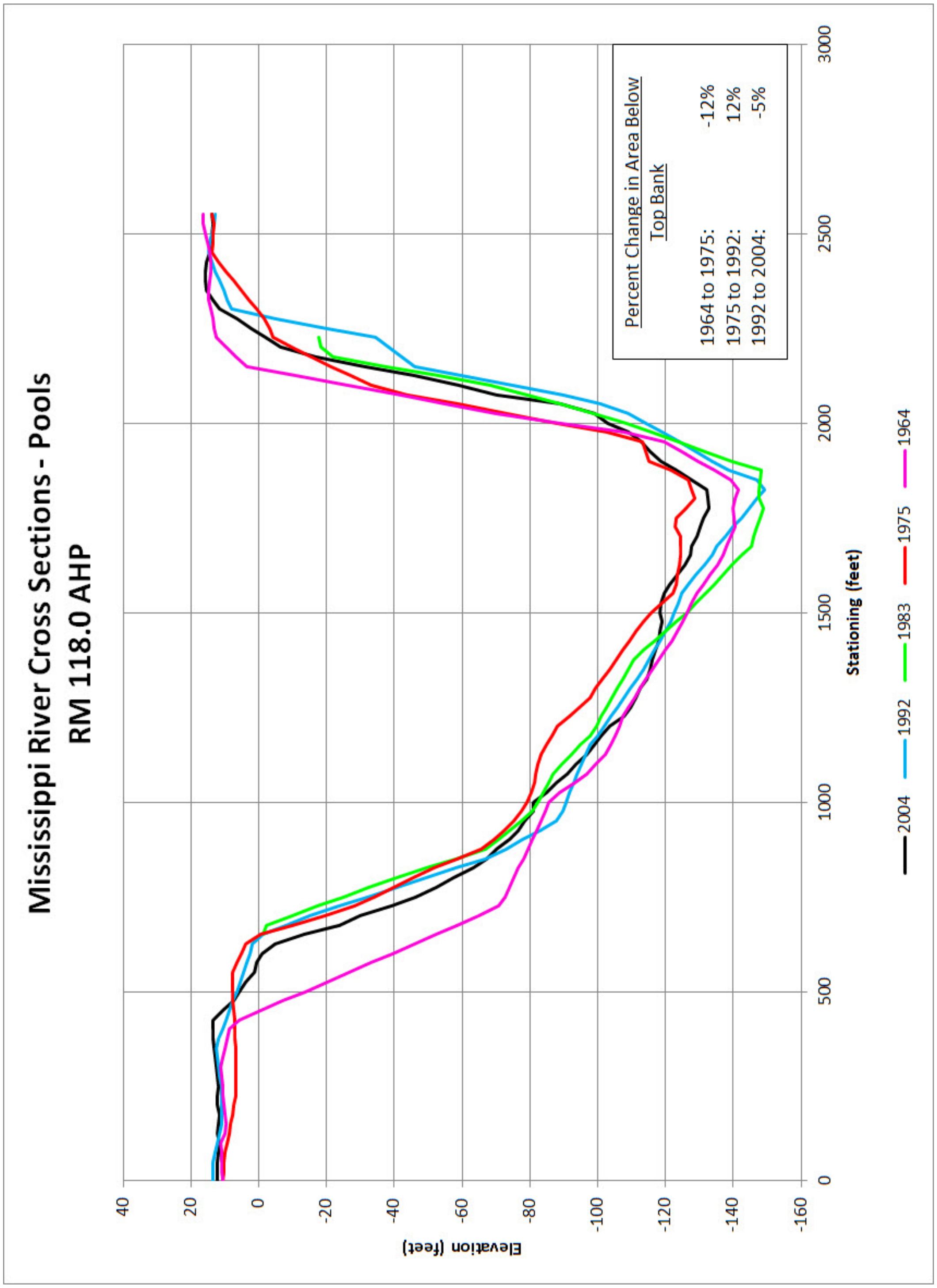

Mississippi River Cross Sections - Pools
RM 81.6 AHP
Elevation (feet)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: 3%
1975 to 1992: 2%
1992 to 2004: 2%
2004
1992
1983
1975
1964

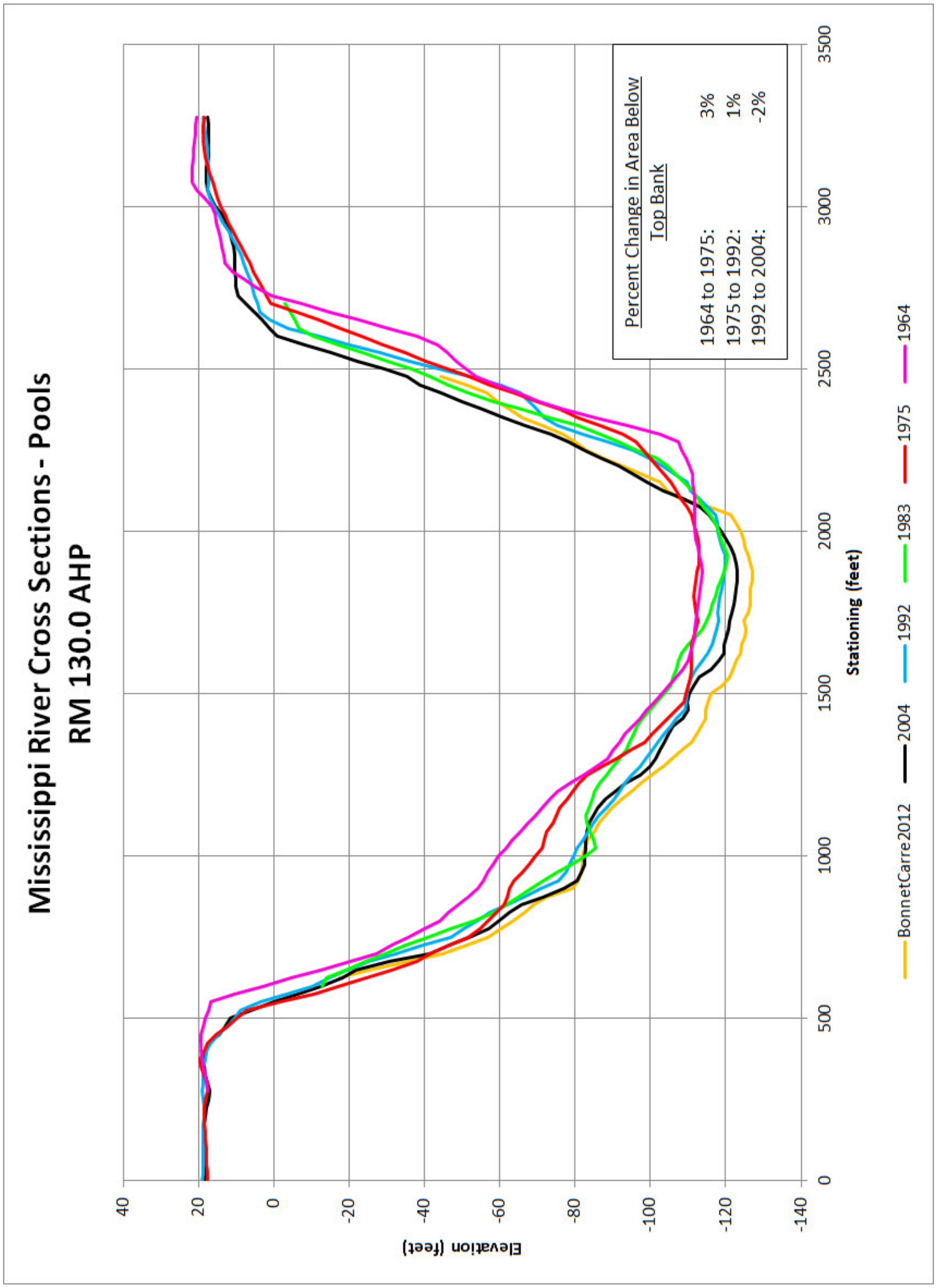

Mississippi River Cross Sections - Pools
RM 94.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 2%
1975 to 1992: 3%
1992 to 2004: -4%
Elevation (feet)
50
0
-50
-100
-150
-200
-250
Stationing (feet)
0
500
1000
1500
2000
2500
2004
1992
1983
1975
1964

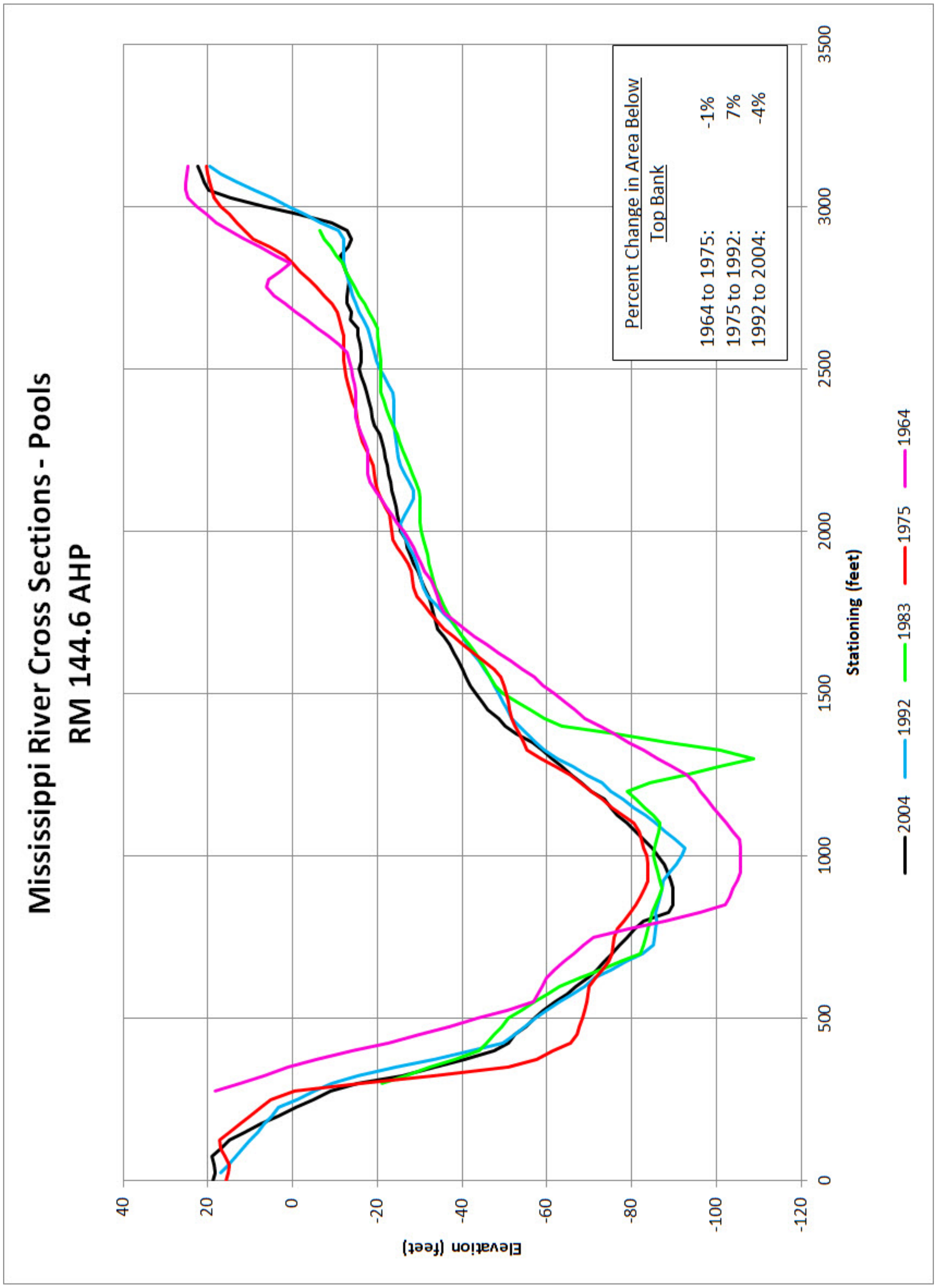

Mississippi River Cross Sections - Pools
RM 101.3 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 8%
1975 to 1992: -4%
1992 to 2004: 1%
Elevation (feet)
Stationing (feet)
50
0
-50
-100
-150
-200
0
500
1000
1500
2000
2500
3000
3500
2004
1992
1983
1975
1964

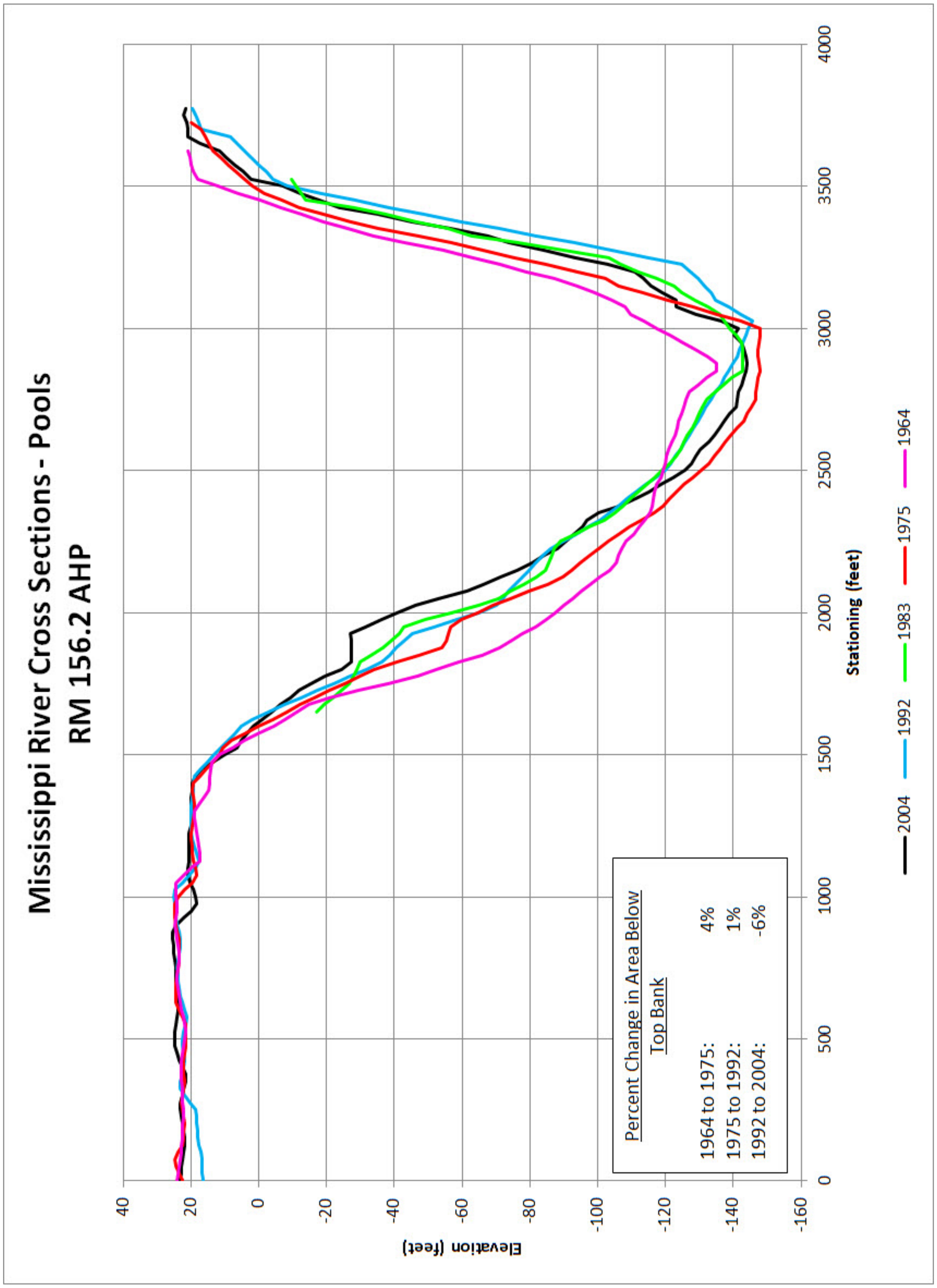

Mississippi River Cross Sections - Pools
RM 104.0 AHP
Elevation (feet)
50
0
-50
-100
-150
-200
Stationing (feet)
0
500
1000
1500
2000
2500
3000
Percent Change in Area Below Top Bank
1964 to 1975: 20%
1975 to 1992: -8%
1992 to 2004: 0%
2004
1992
1983
1975
1964

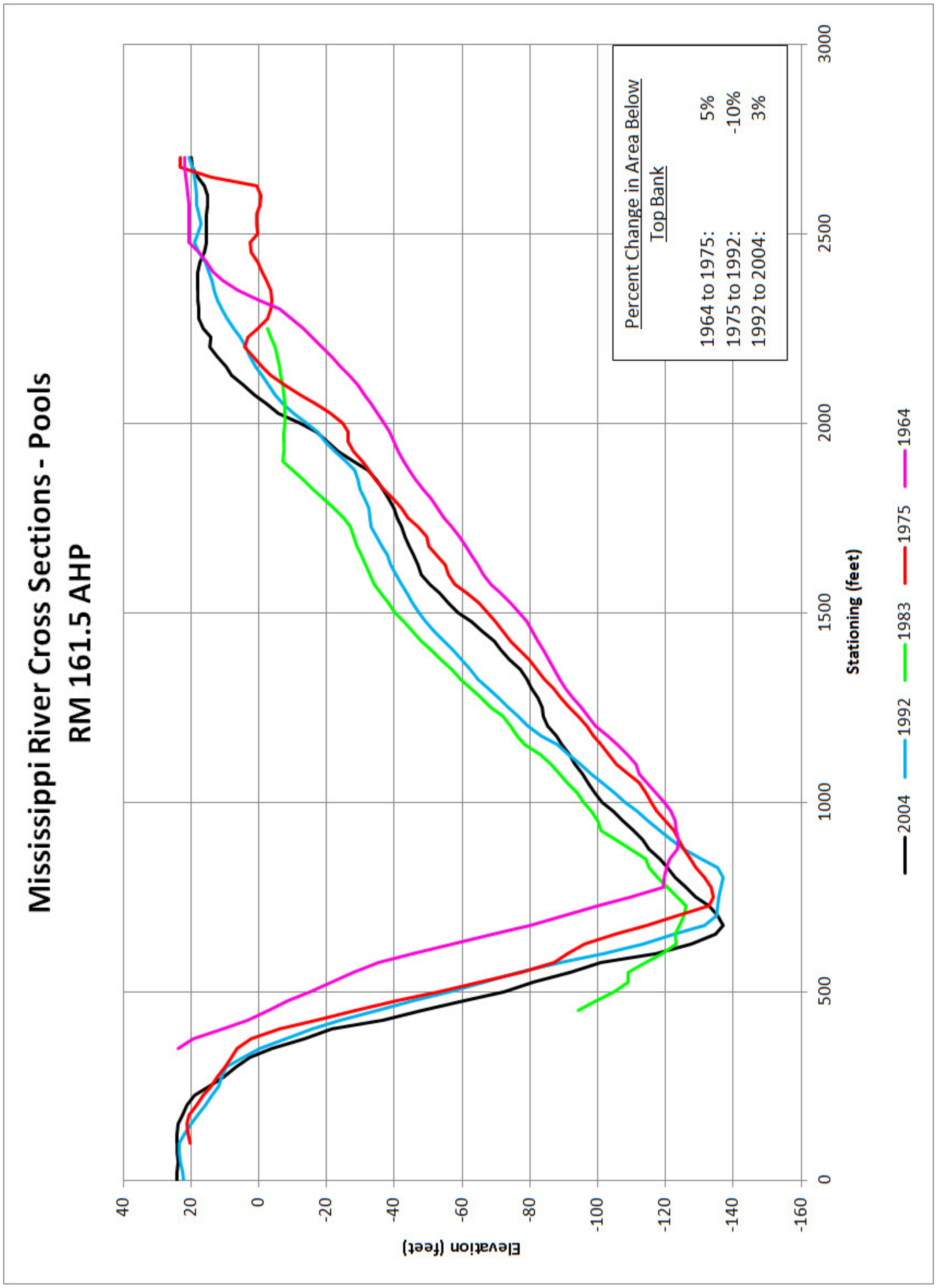

Mississippi River Cross Sections - Pools
RM 109.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: -3%
1992 to 2004: -1%
Elevation (feet)
40
20
0
-20
-40
-60
-80
-100
-120
-140
Stationing (feet)
0
500
1000
1500
2000
2500
2004
1992
1983
1975
1964

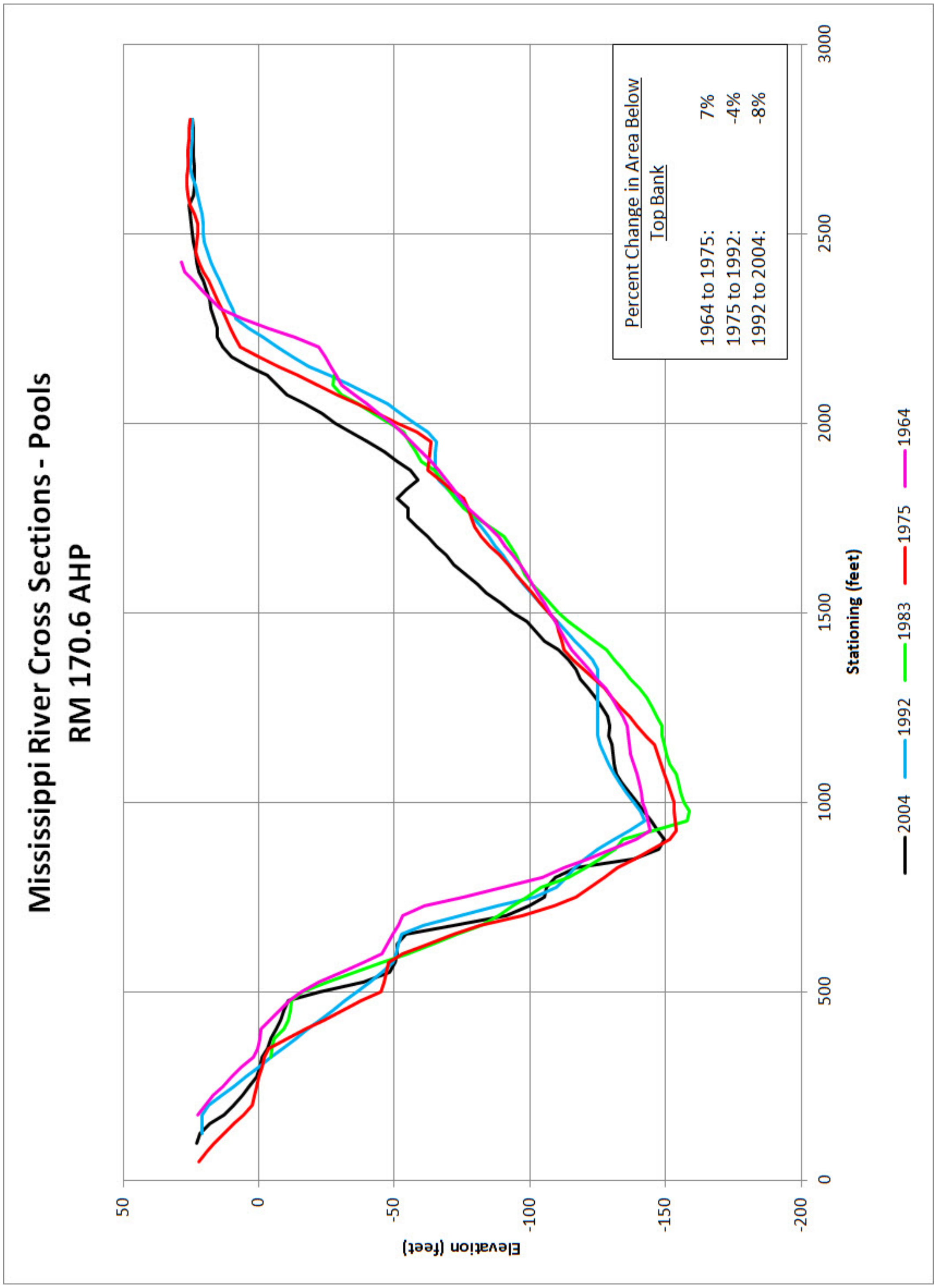

Mississippi River Cross Sections - Pools
RM 118.0 AHP
Elevation (feet)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Stationing (feet)
0
500
1000
1500
2000
2500
3000
Percent Change in Area Below Top Bank
1964 to 1975: -12%
1975 to 1992: 12%
1992 to 2004: -5%
2004
1992
1983
1975
1964

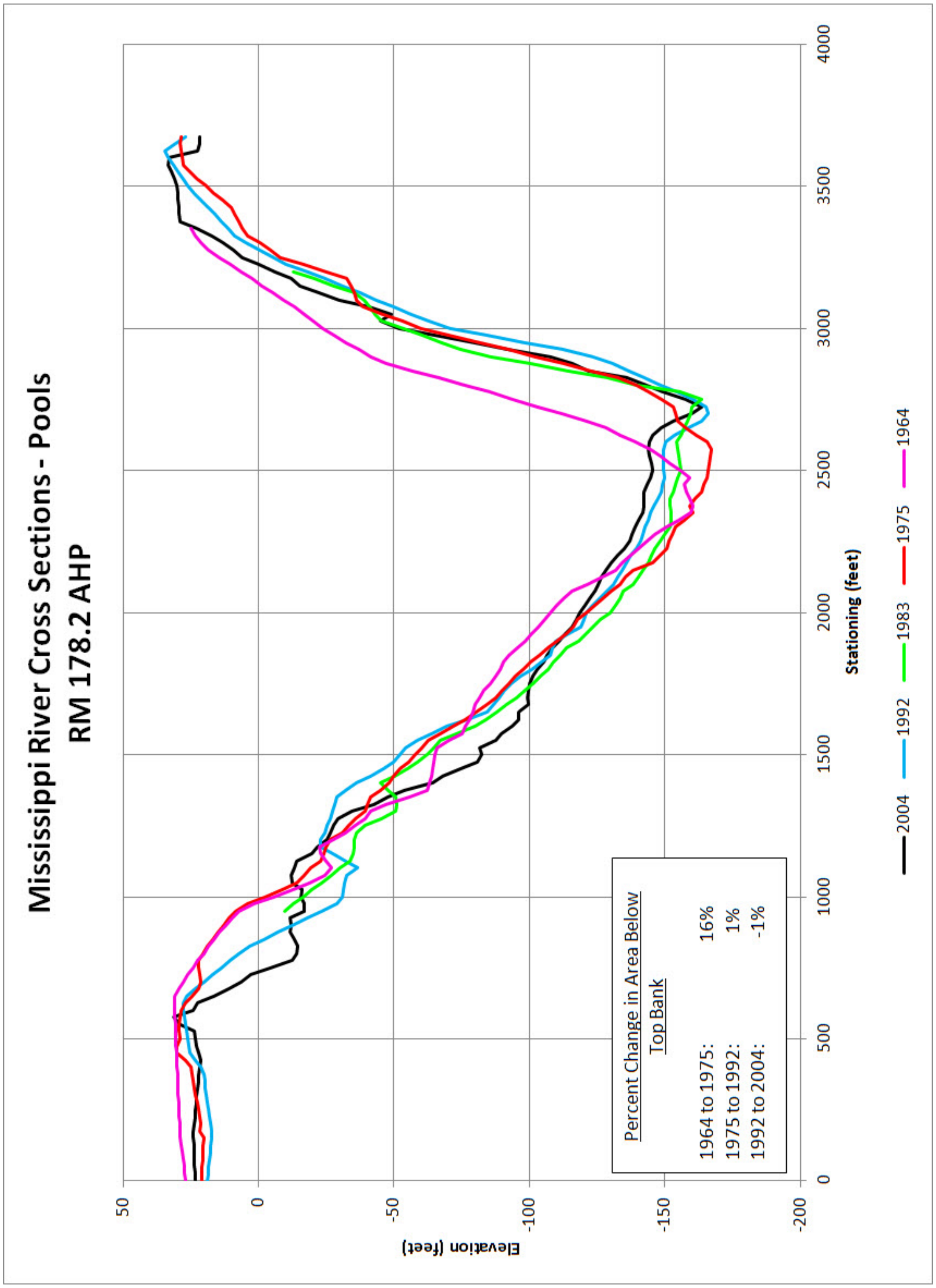

Mississippi River Cross Sections - Pools
RM 130.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 3%
1975 to 1992: 1%
1992 to 2004: -2%
Elevation (feet)
Stationing (feet)
BonnetCarre2012
2004
1992
1983
1975
1964

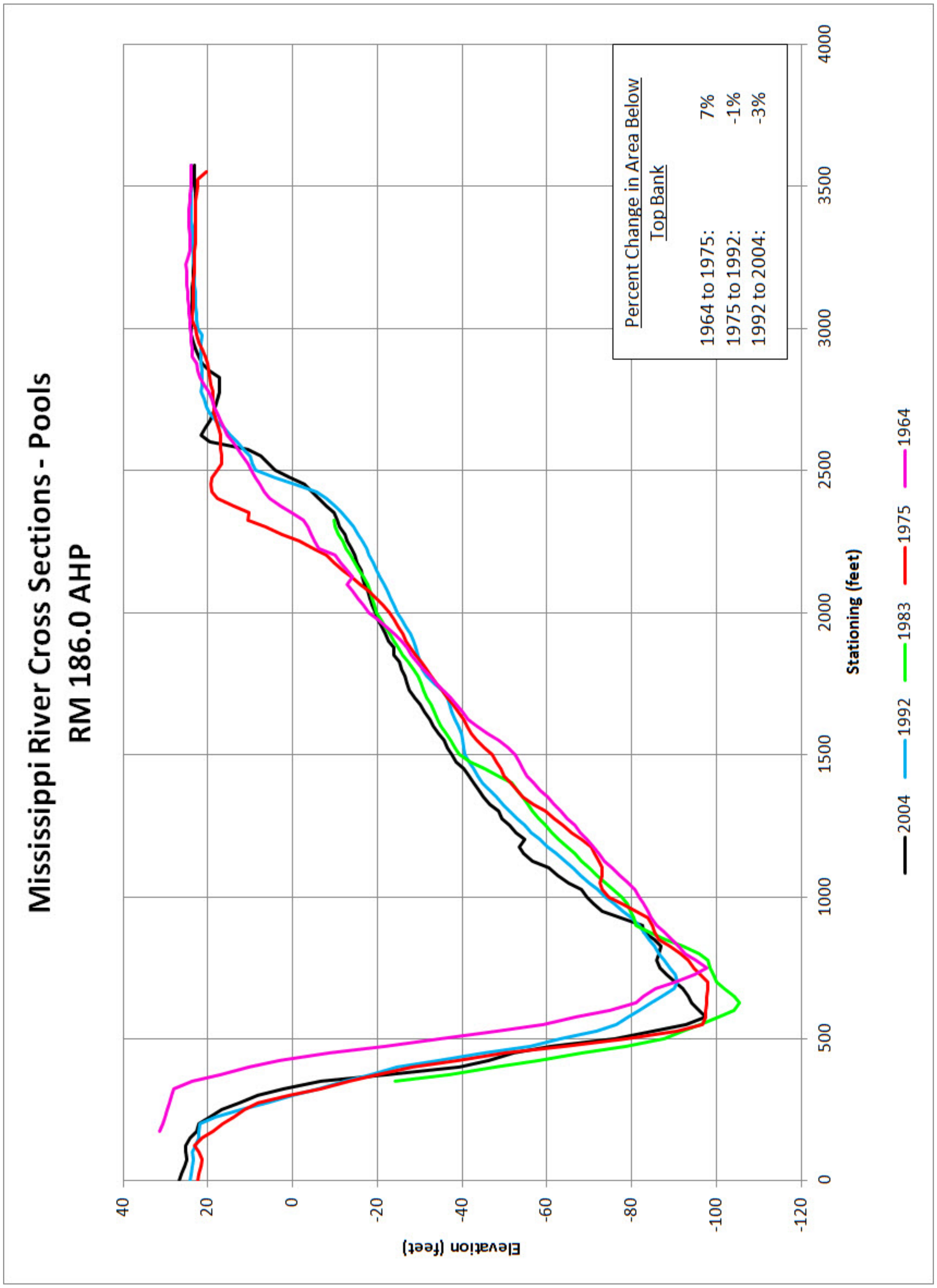

Mississippi River Cross Sections - Pools
RM 144.6 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: 7%
1992 to 2004: -4%
Elevation (feet)
Stationing (feet)
2004
1992
1983
1975
1964

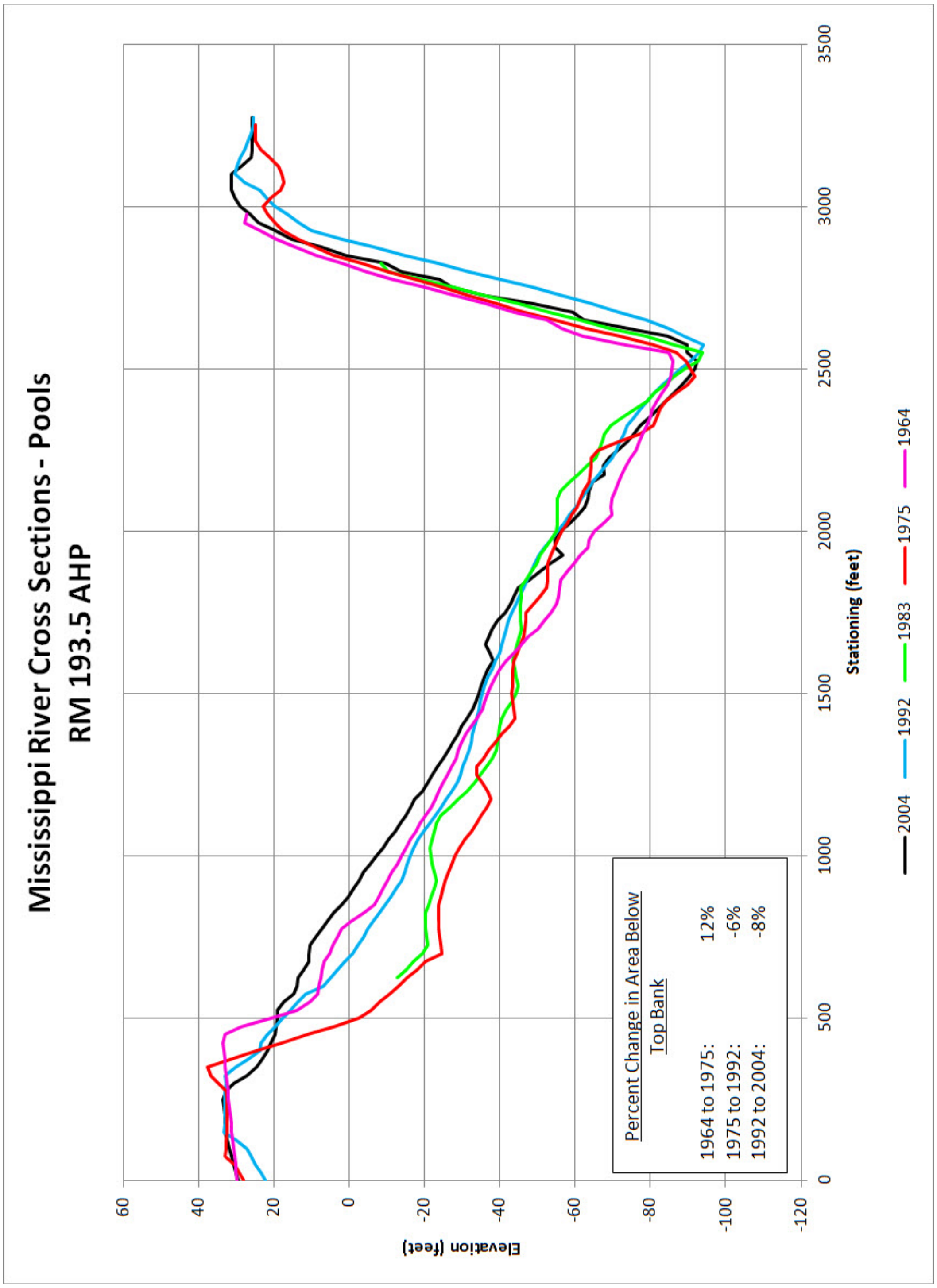

Mississippi River Cross Sections - Pools
RM 156.2 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 4%
1975 to 1992: 1%
1992 to 2004: -6%
Elevation (feet)
Stationing (feet)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
500
1000
1500
2000
2500
3000
3500
4000
2004
1992
1983
1975
1964

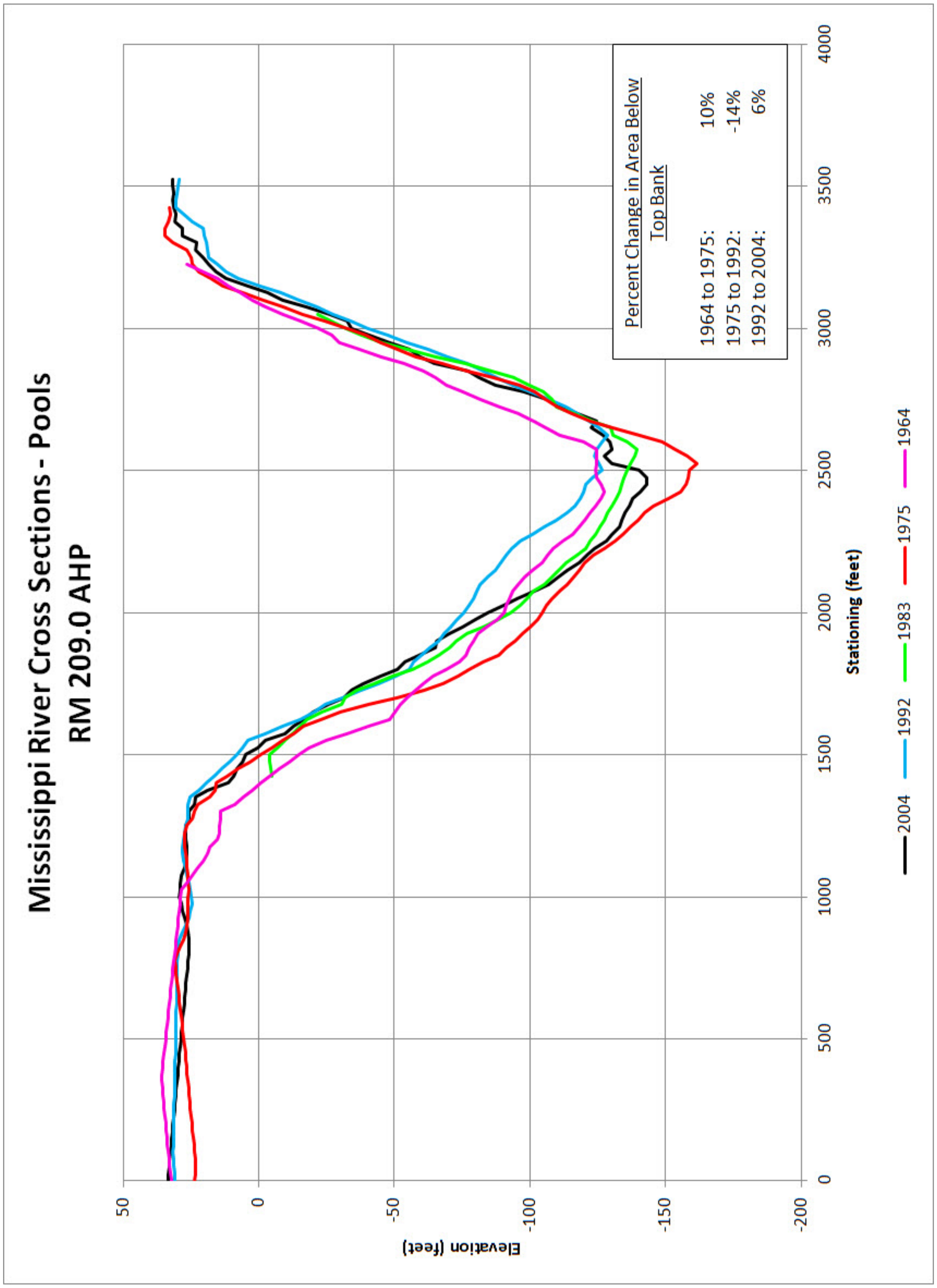

Mississippi River Cross Sections - Pools
RM 161.5 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 5%
1975 to 1992: -10%
1992 to 2004: 3%
Elevation (feet)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Stationing (feet)
0
500
1000
1500
2000
2500
3000
2004
1992
1983
1975
1964

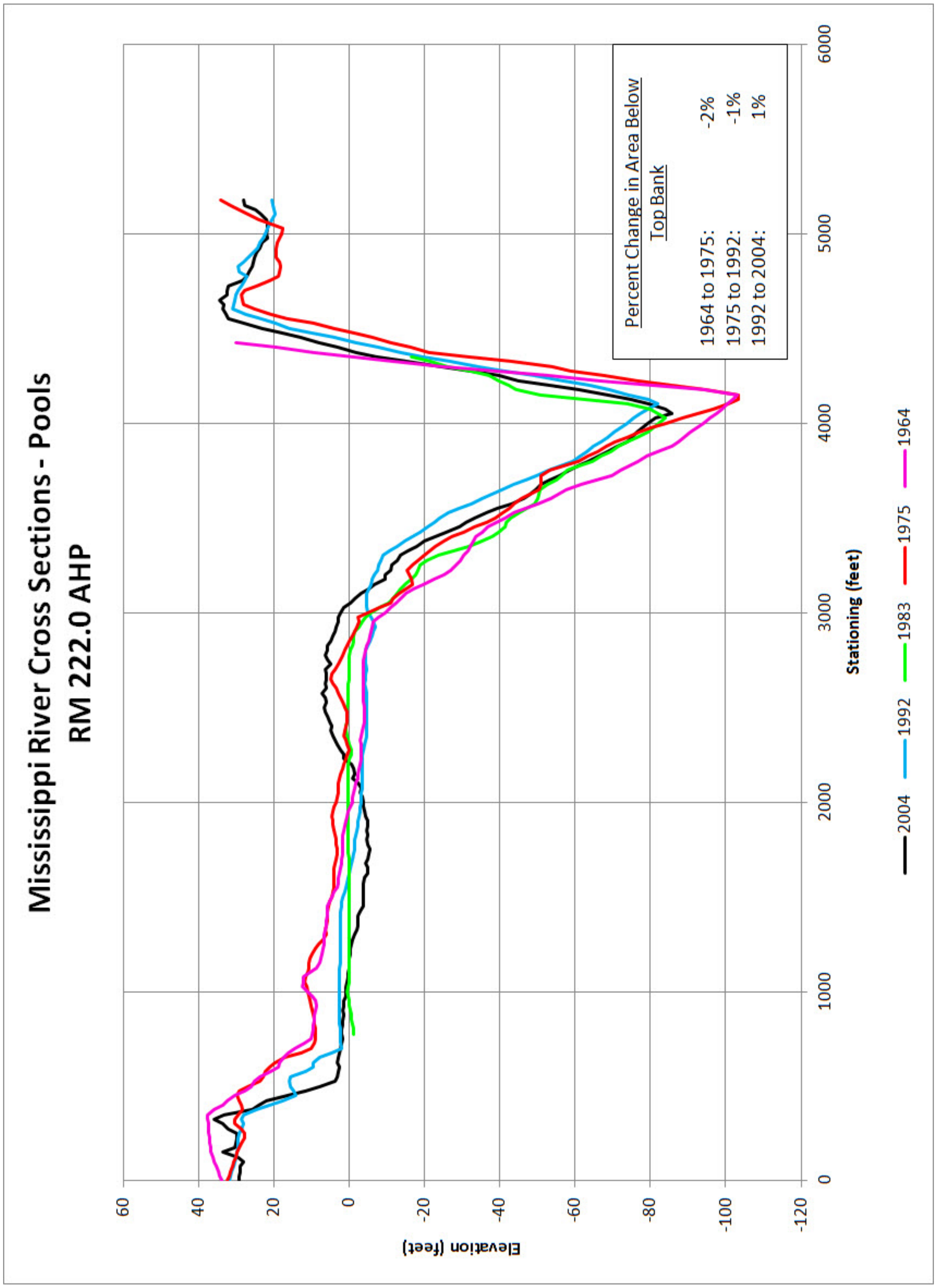

Mississippi River Cross Sections - Pools
RM 170.6 AHP
Elevation (feet)
50
0
-50
-100
-150
-200
Stationing (feet)
0
500
1000
1500
2000
2500
3000
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: -4%
1992 to 2004: -8%
2004
1992
1983
1975
1964

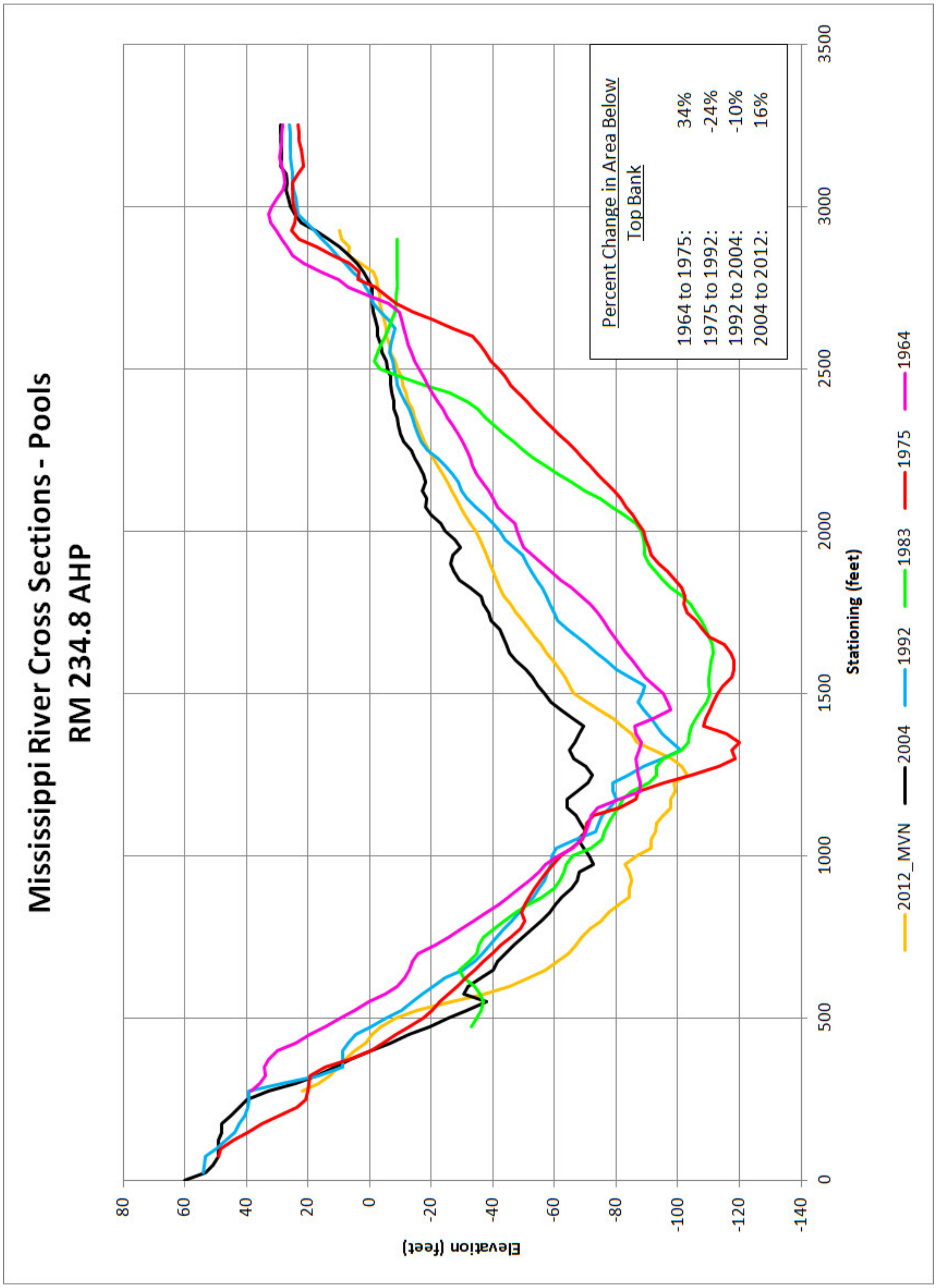

Mississippi River Cross Sections - Pools
RM 178.2 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: 16%
1975 to 1992: 1%
1992 to 2004: -1%
2004
1992
1983
1975
1964
50
0
-50
-100
-150
-200
0
500
1000
1500
2000
2500
3000
3500
4000

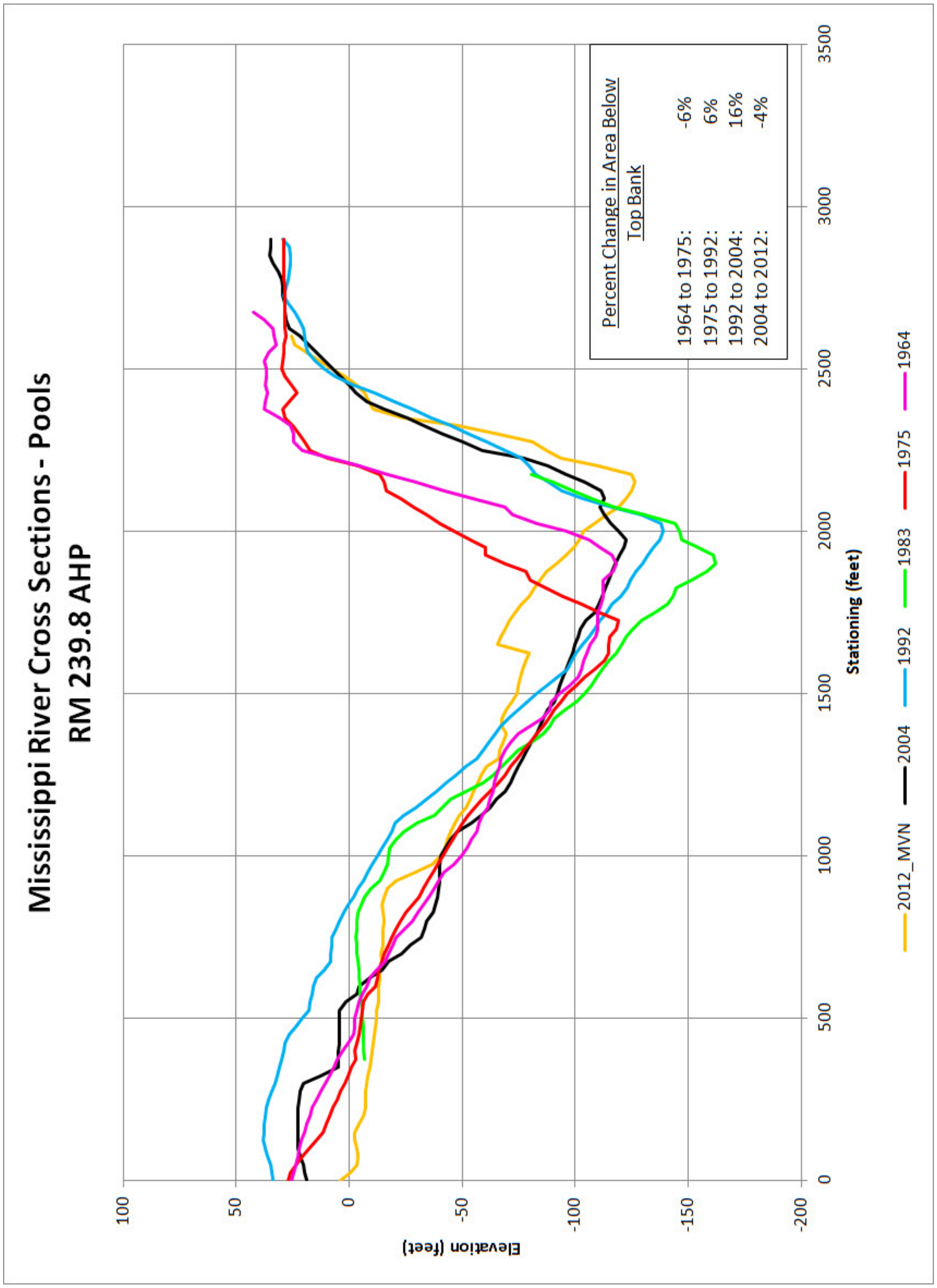

Mississippi River Cross Sections - Pools
RM 186.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 7%
1975 to 1992: -1%
1992 to 2004: -3%
Elevation (feet)
40
20
0
-20
-40
-60
-80
-100
-120
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
2004
1992
1983
1975
1964

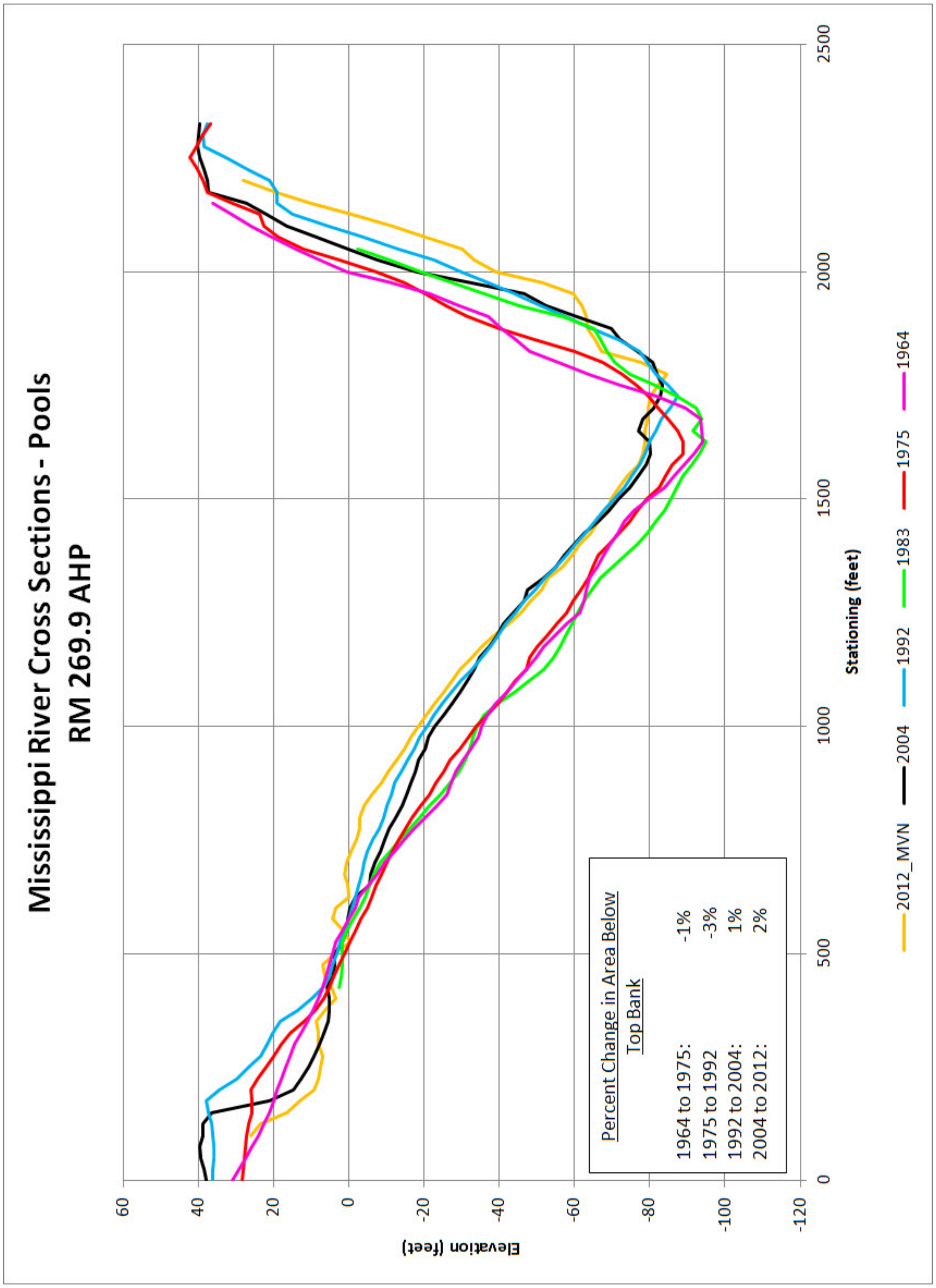

Mississippi River Cross Sections - Pools
RM 193.5 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 12%
1975 to 1992: -6%
1992 to 2004: -8%
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
-100
-120
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
2004
1992
1983
1975
1964

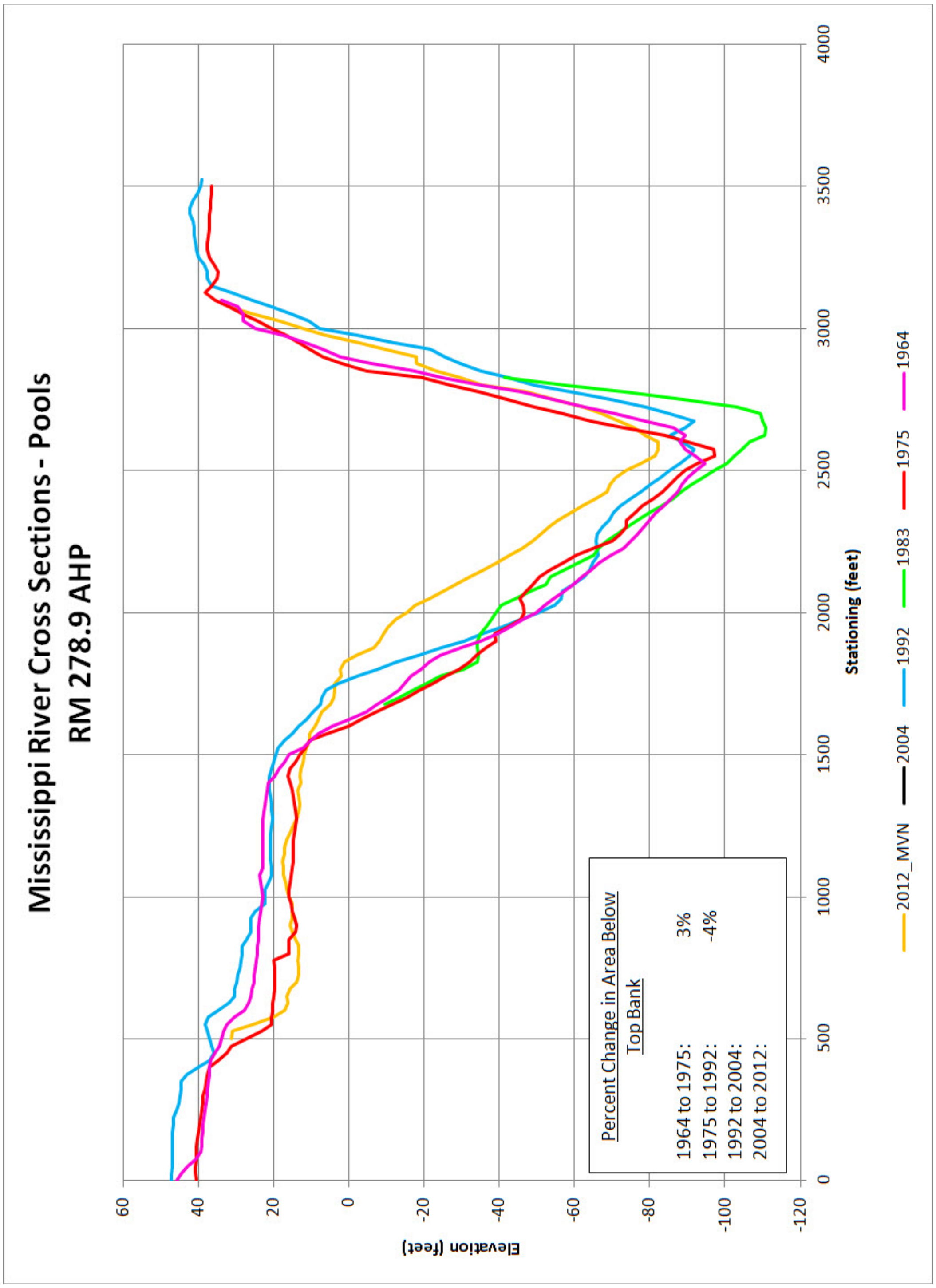

Mississippi River Cross Sections - Pools
RM 209.0 AHP
Elevation (feet)
50
0
-50
-100
-150
-200
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
Percent Change in Area Below Top Bank
1964 to 1975: 10%
1975 to 1992: -14%
1992 to 2004: 6%
2004
1992
1983
1975
1964

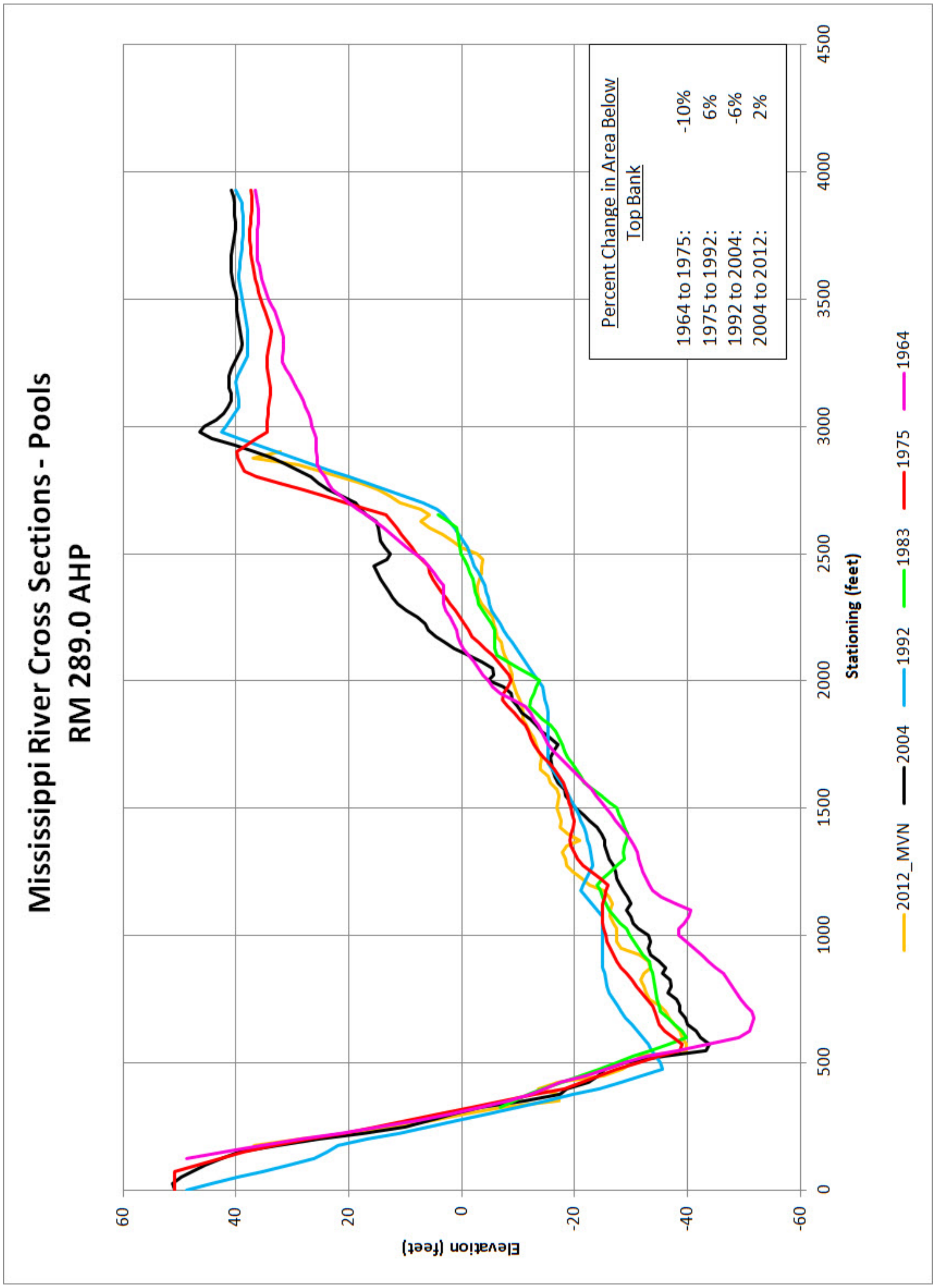

Mississippi River Cross Sections - Pools
RM 222.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -2%
1975 to 1992: -1%
1992 to 2004: 1%
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
-100
-120
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
2004
1992
1983
1975
1964

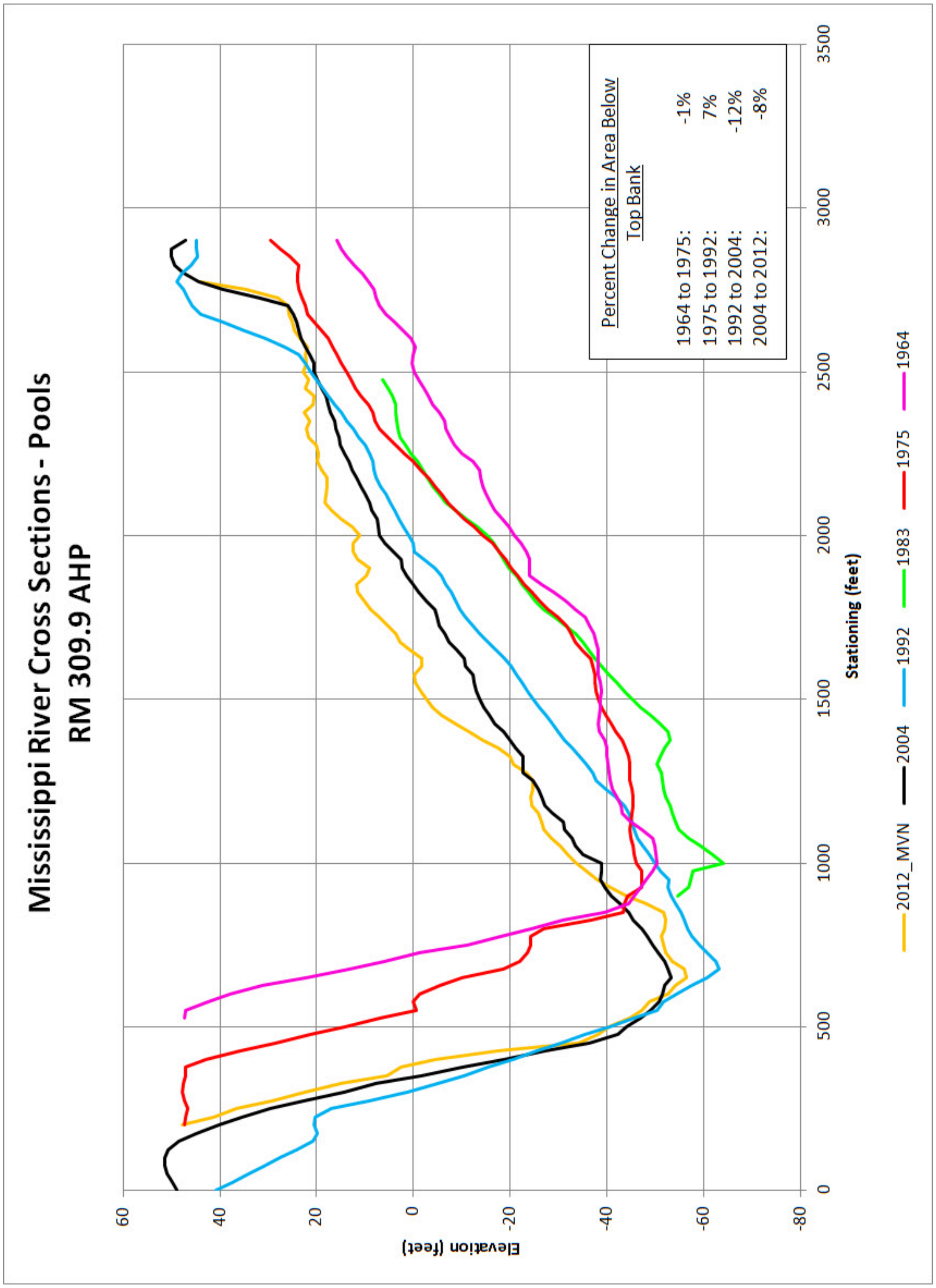

Mississippi River Cross Sections - Pools
RM 234.8 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: 34%
1975 to 1992: -24%
1992 to 2004: -10%
2004 to 2012: 16%
2012_MVN
2004
1992
1983
1975
1964
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
500
1000
1500
2000
2500
3000
3500

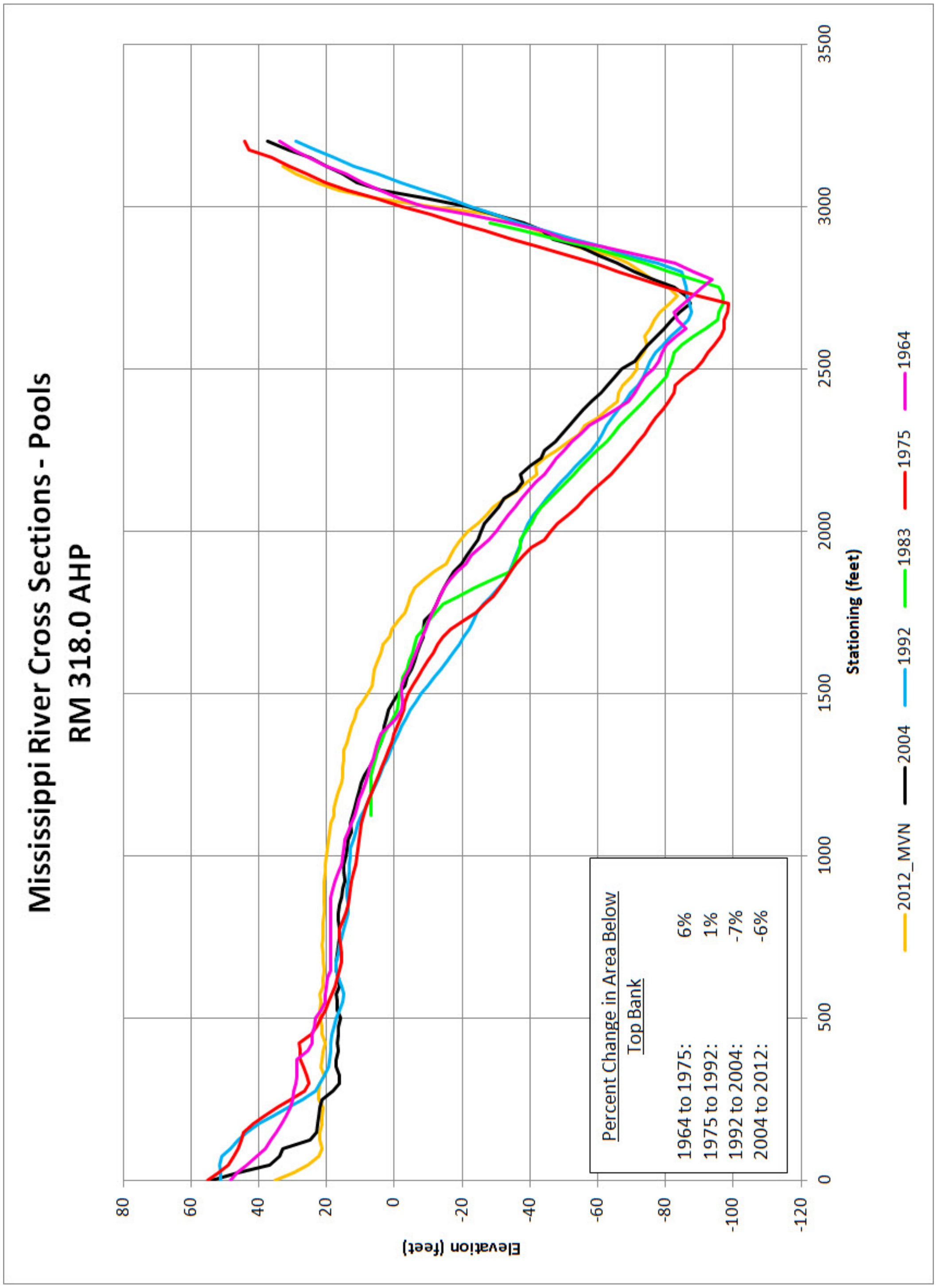

Mississippi River Cross Sections - Pools
RM 239.8 AHP
Elevation (feet)
100
50
0
-50
-100
-150
-200
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: -6%
1975 to 1992: 6%
1992 to 2004: 16%
2004 to 2012: -4%
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Pools
RM 269.9 AHP
Elevation (feet)
Stationing (feet)
60
40
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992 -3%
1992 to 2004: 1%
2004 to 2012: 2%
2012_MVN
2004
1992
1983
1975
1964


Mississippi River Cross Sections - Pools
RM 278.9 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
-100
-120
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
Percent Change in Area Below Top Bank
1964 to 1975: 3%
1975 to 1992: -4%
1992 to 2004:
2004 to 2012:
2012_MVN
2004
1992
1983
1975
1964

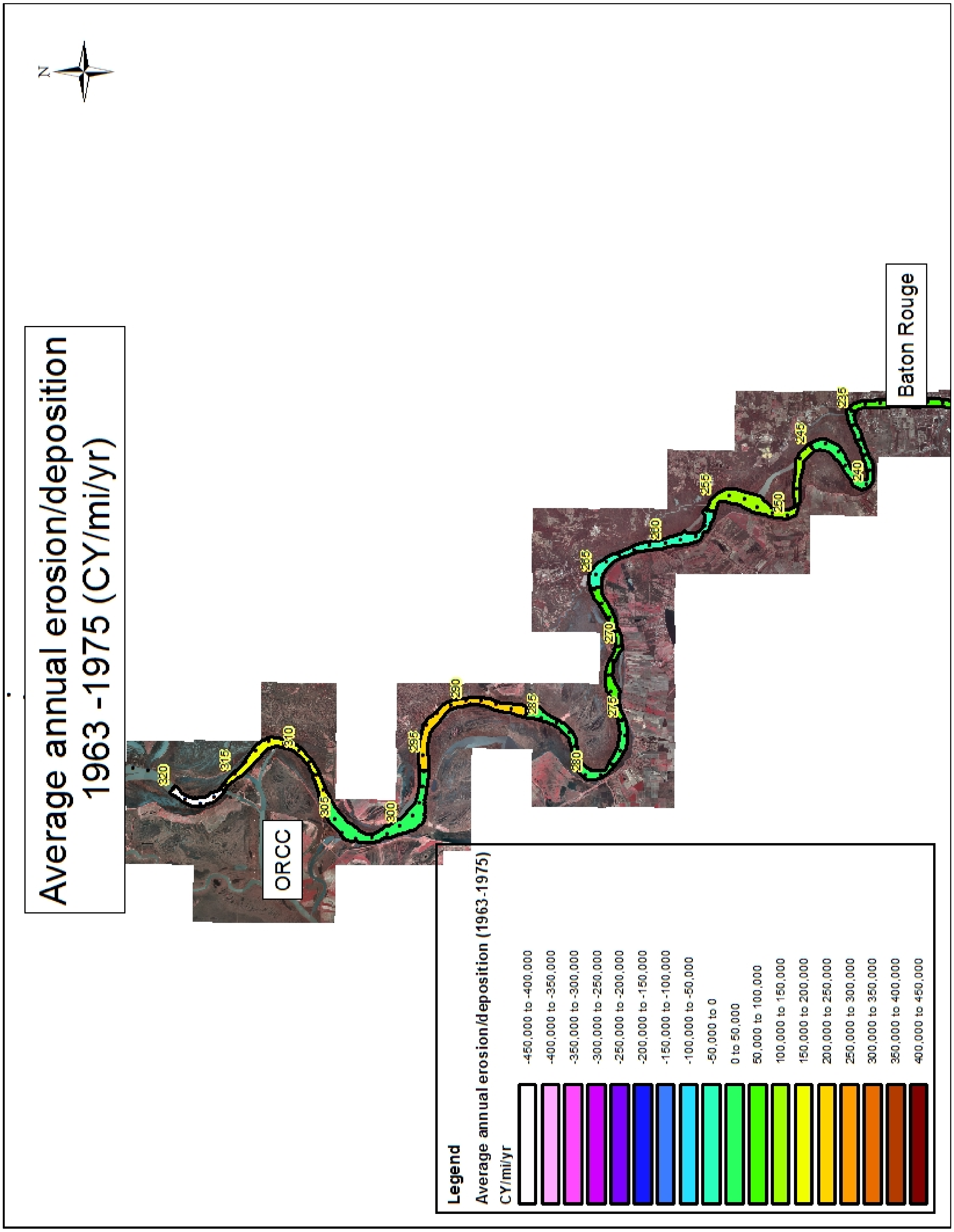

Mississippi River Cross Sections - Pools
RM 289.0 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -10%
1975 to 1992: 6%
1992 to 2004: -6%
2004 to 2012: 2%
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
2012_MVN
2004
1992
1983
1975
1964

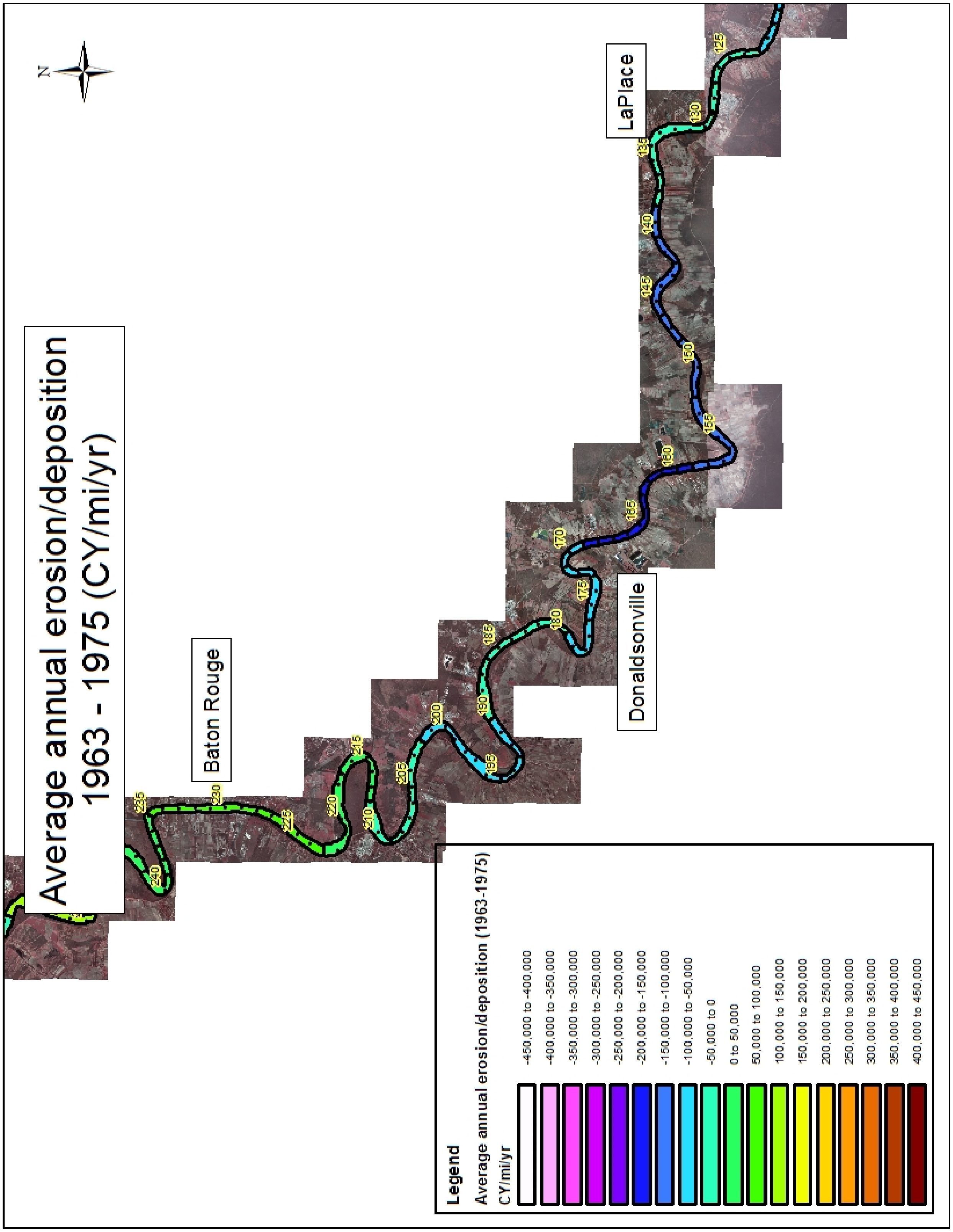

Mississippi River Cross Sections - Pools
RM 309.9 AHP
Percent Change in Area Below Top Bank
1964 to 1975: -1%
1975 to 1992: 7%
1992 to 2004: -12%
2004 to 2012: -8%
Elevation (feet)
Stationing (feet)
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
2500
3000
3500
2012_MVN
2004
1992
1983
1975
1964

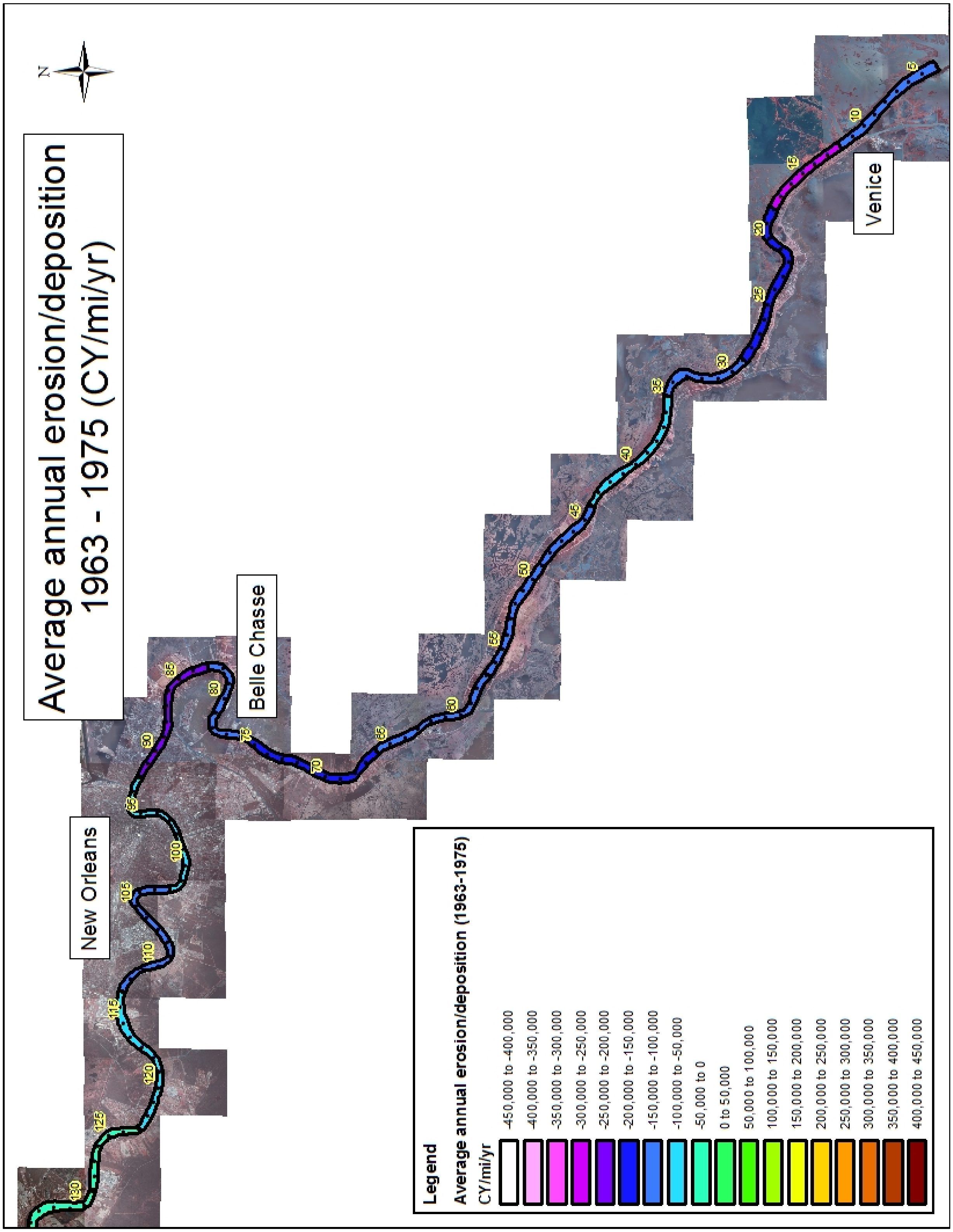

Mississippi River Cross Sections - Pools
RM 318.0 AHP
Elevation (feet)
Stationing (feet)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area Below Top Bank
1964 to 1975: 6%
1975 to 1992: 1%
1992 to 2004: -7%
2004 to 2012: -6%
2012_MVN
2004
1992
1983
1975
1964

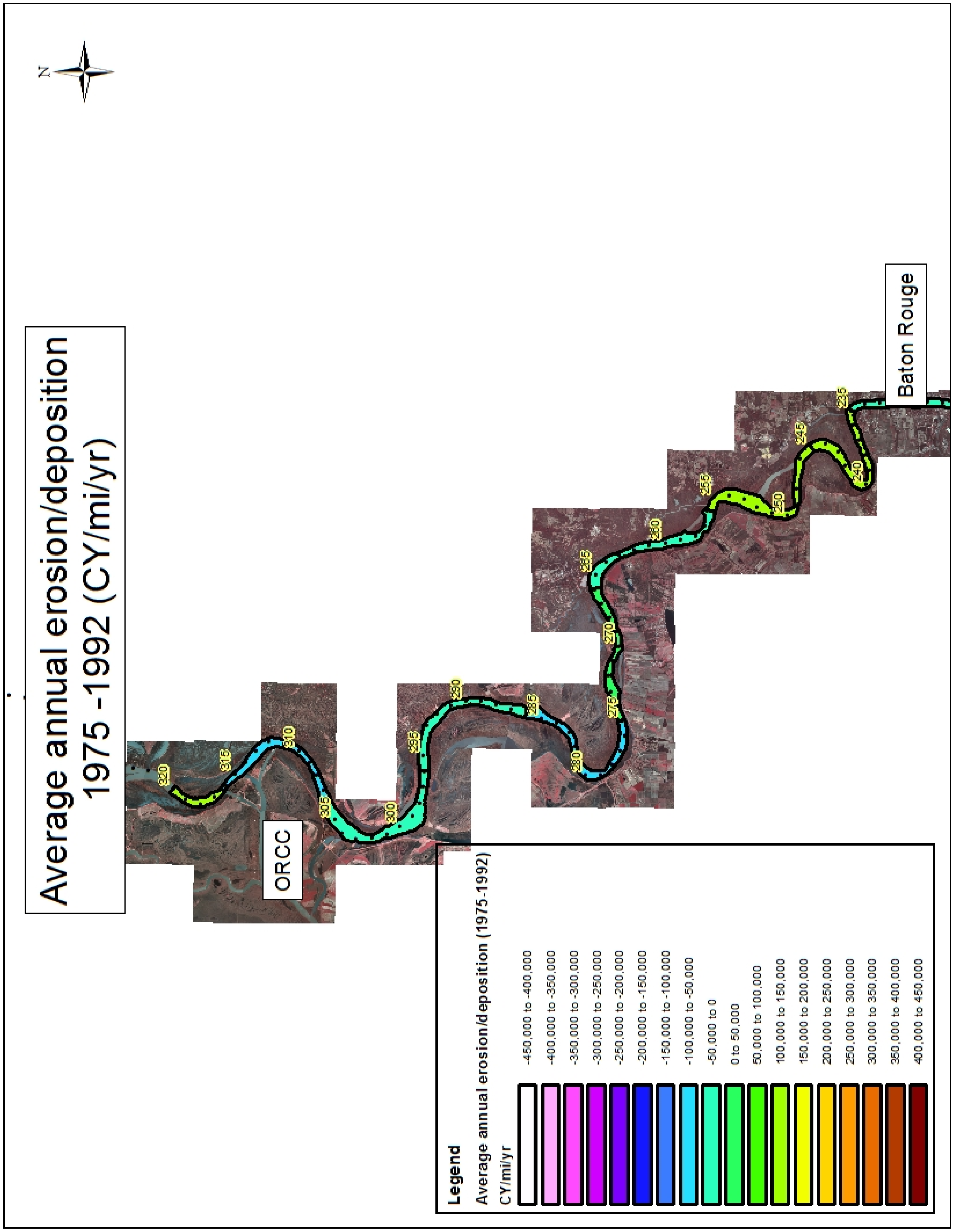
Appendix B: Geometry Data Analysis, Average Annual Erosion/Deposition Maps

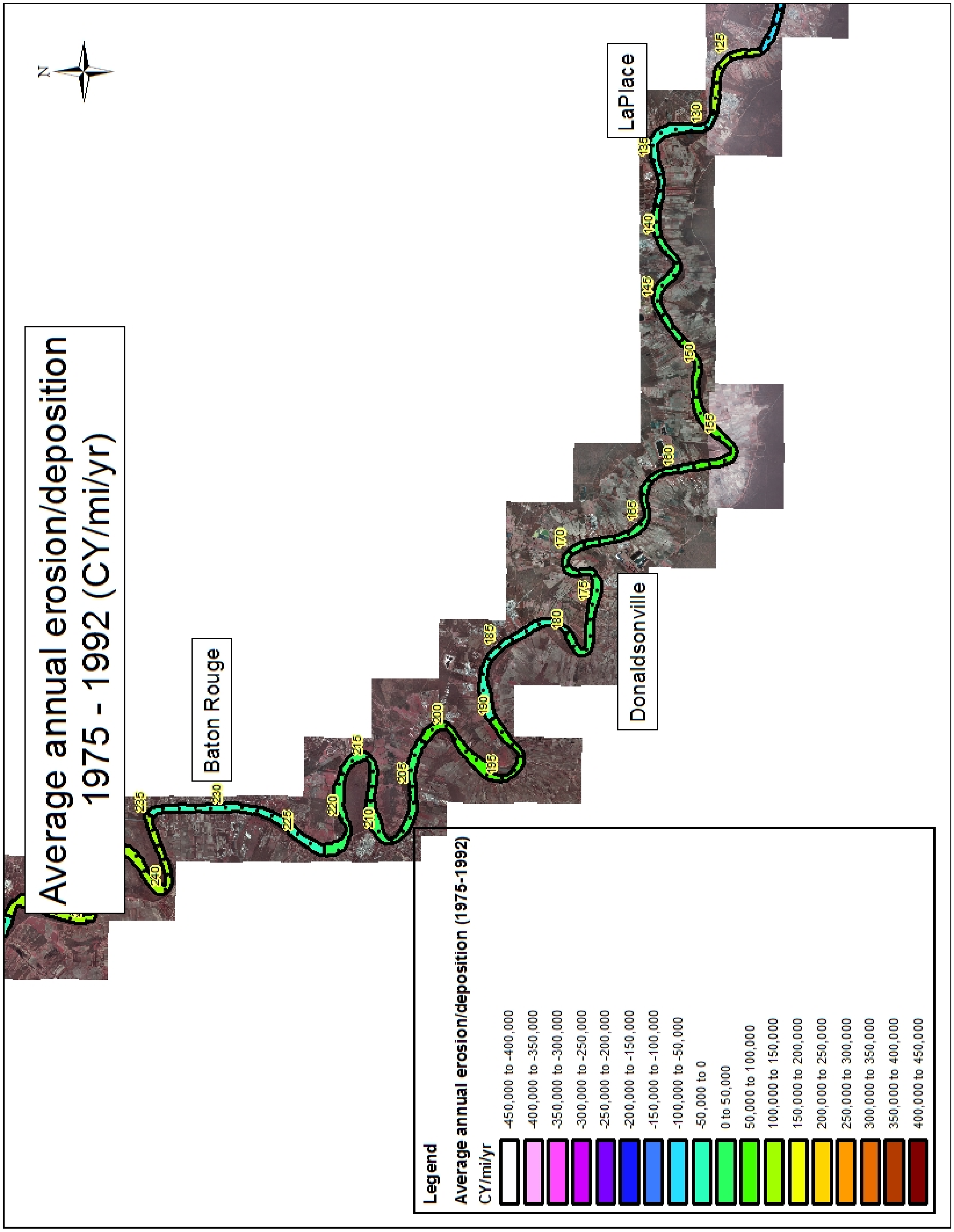
Abbreviations Used in Appendix B	
River mile	RM
Above head of passes	AHP
Cubic yards/mile/year	CY/mi/yr
Old River Control Complex	ORCC
Average	ave.

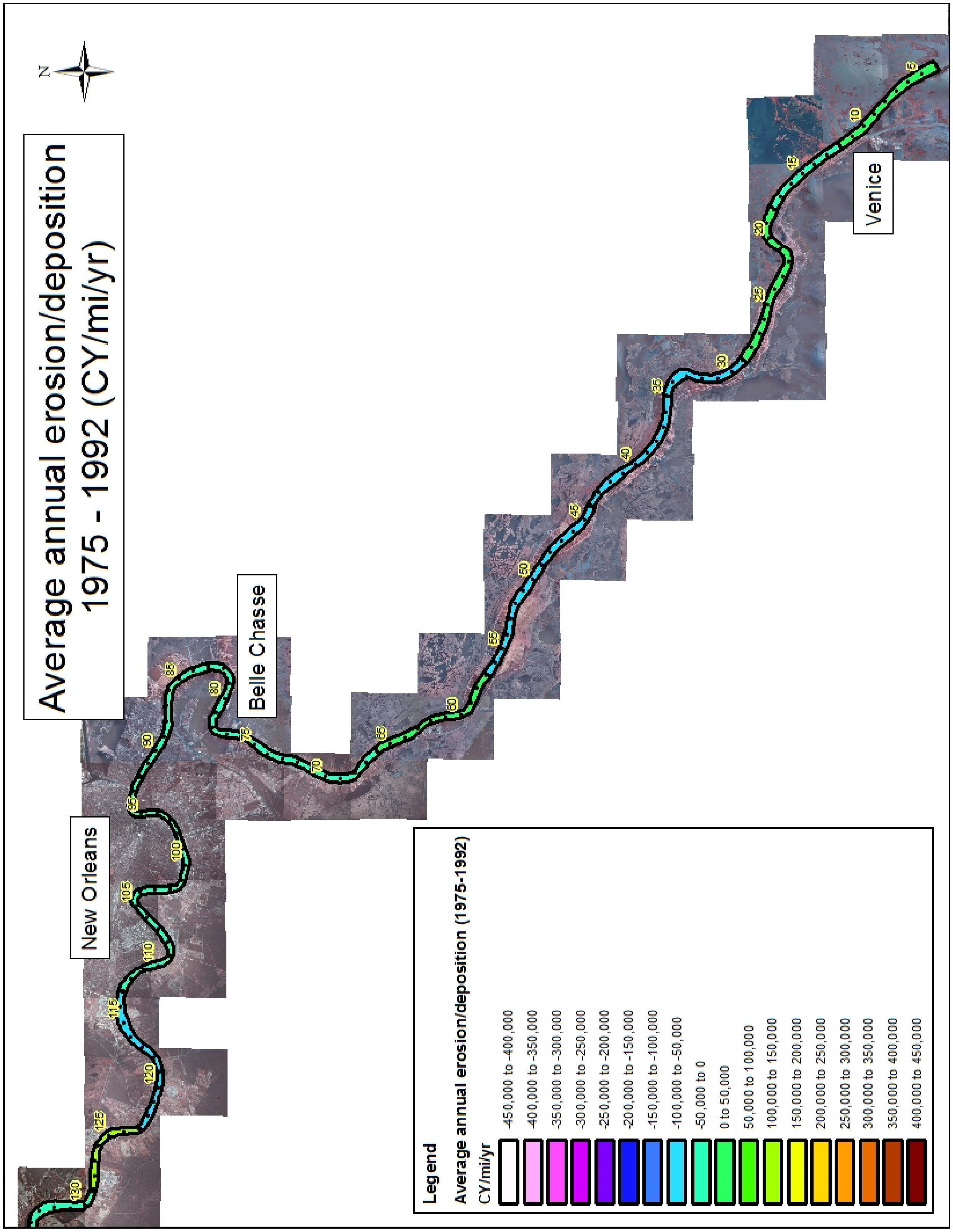

Average annual erosion/deposition
1963 -1975 (CY/mi/yr)
N
ORCC
Baton Rouge
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
Legend
Average annual erosion/deposition (1963-1975)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

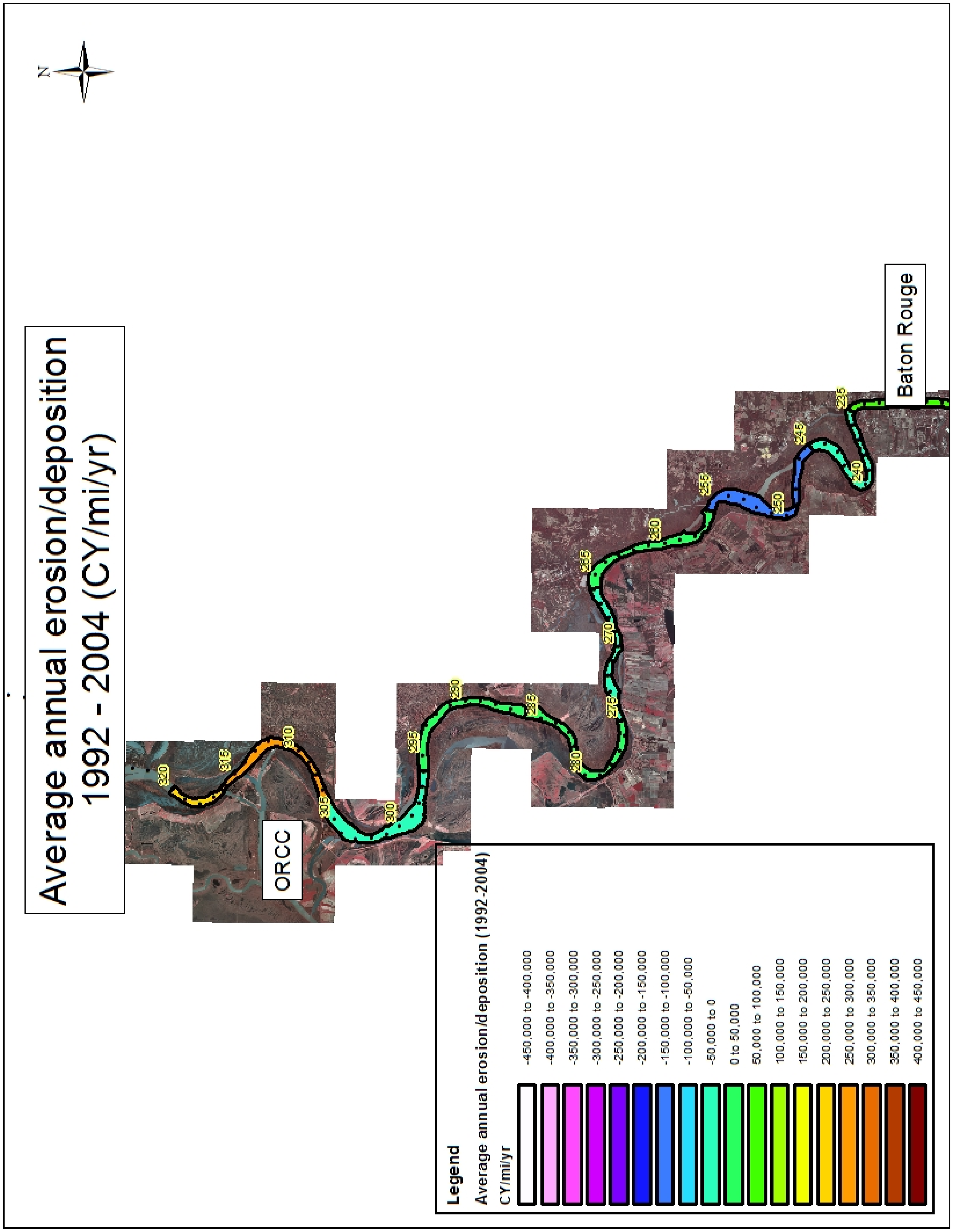

Average annual erosion/deposition
1963 - 1975 (CY/mi/yr)
Baton Rouge
Donaldsonville
LaPlace
Legend
Average annual erosion/deposition (1963-1975)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

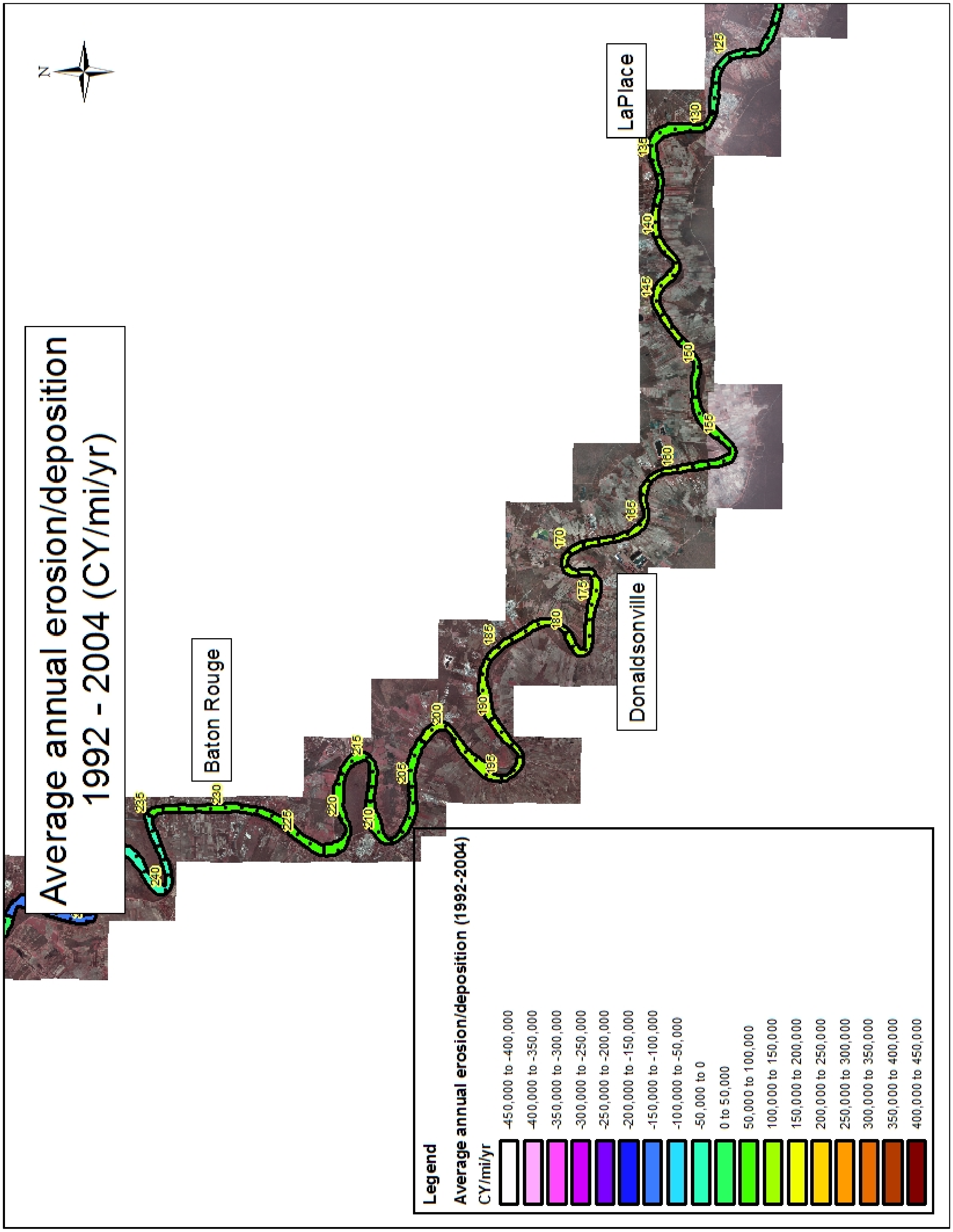

Average annual erosion/deposition
1963 - 1975 (CY/mi/yr)
N
New Orleans
Belle Chasse
Venice
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
Legend
Average annual erosion/deposition (1963-1975)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

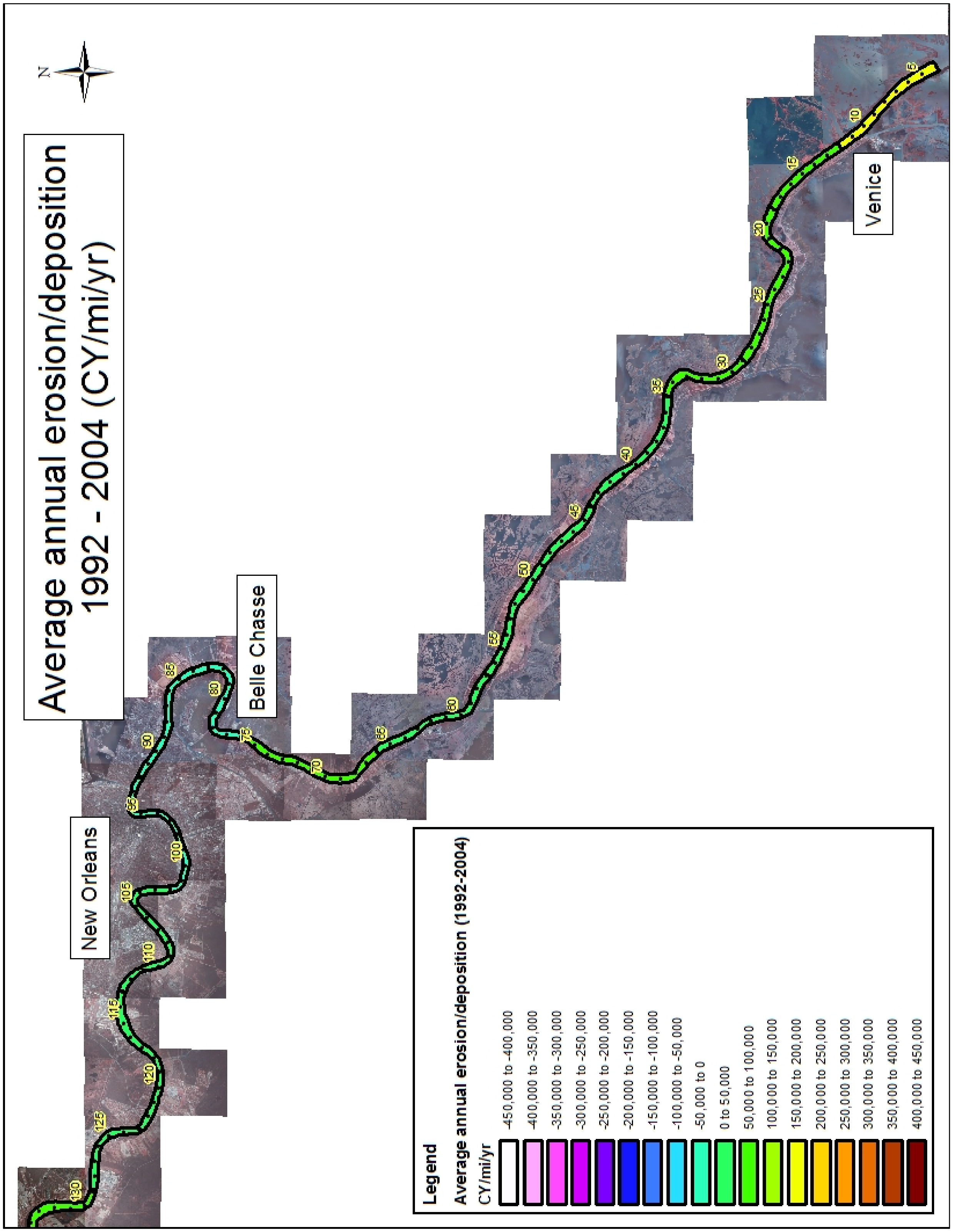

Average annual erosion/deposition
1975 -1992 (CY/mi/yr)
N
ORCC
Baton Rouge
Legend
Average annual erosion/deposition (1975-1992)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

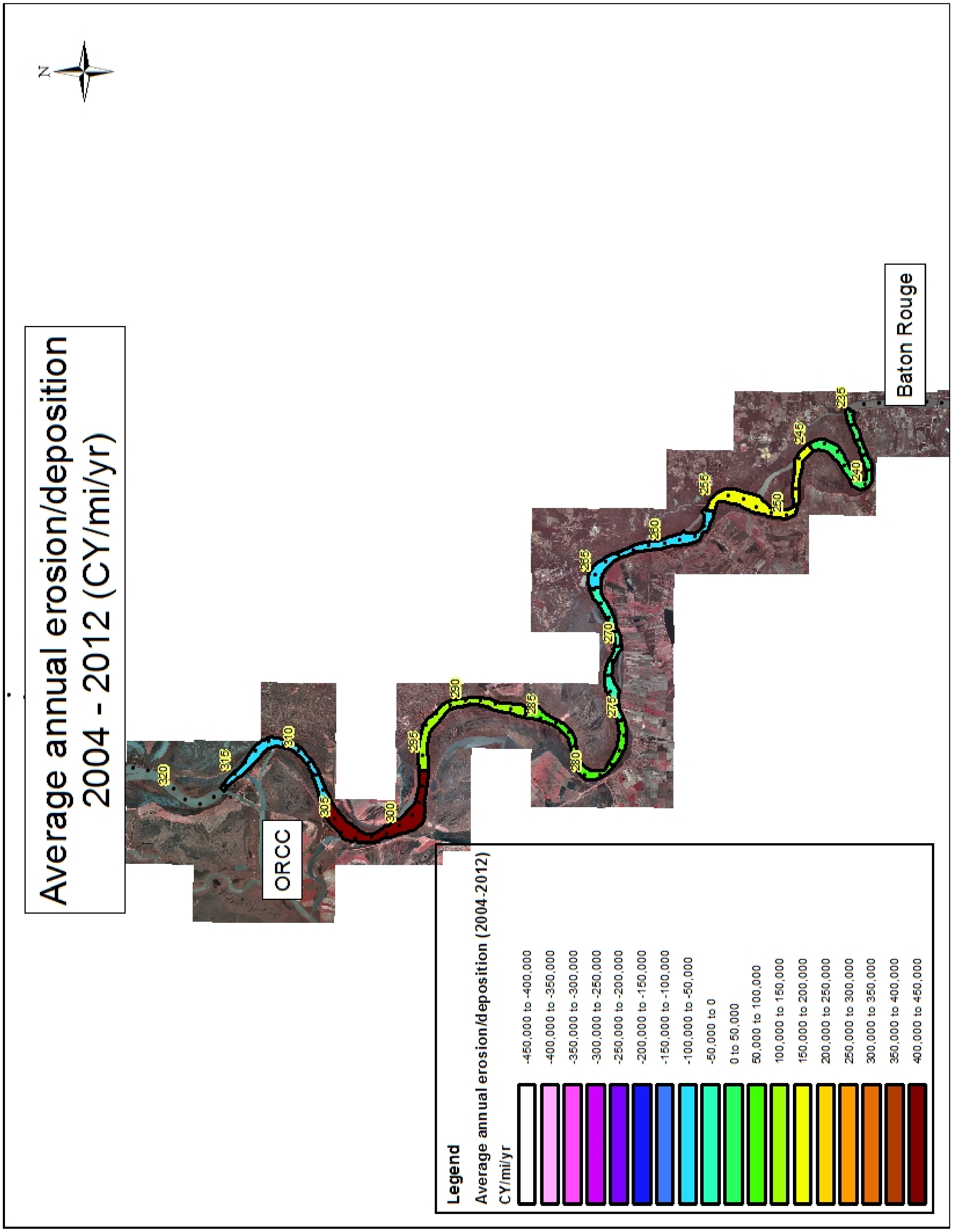

Average annual erosion/deposition
1975 - 1992 (CY/mi/yr)
Baton Rouge
Donaldsonville
LaPlace
Legend
Average annual erosion/deposition (1975-1992)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000


Average annual erosion/deposition
1975 - 1992 (CY/mi/yr)
N
New Orleans
Belle Chasse
Venice
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
Legend
Average annual erosion/deposition (1975-1992)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000


Average annual erosion/deposition
1992 - 2004 (CY/mi/yr)
ORCC
Baton Rouge
Legend
Average annual erosion/deposition (1992-2004)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

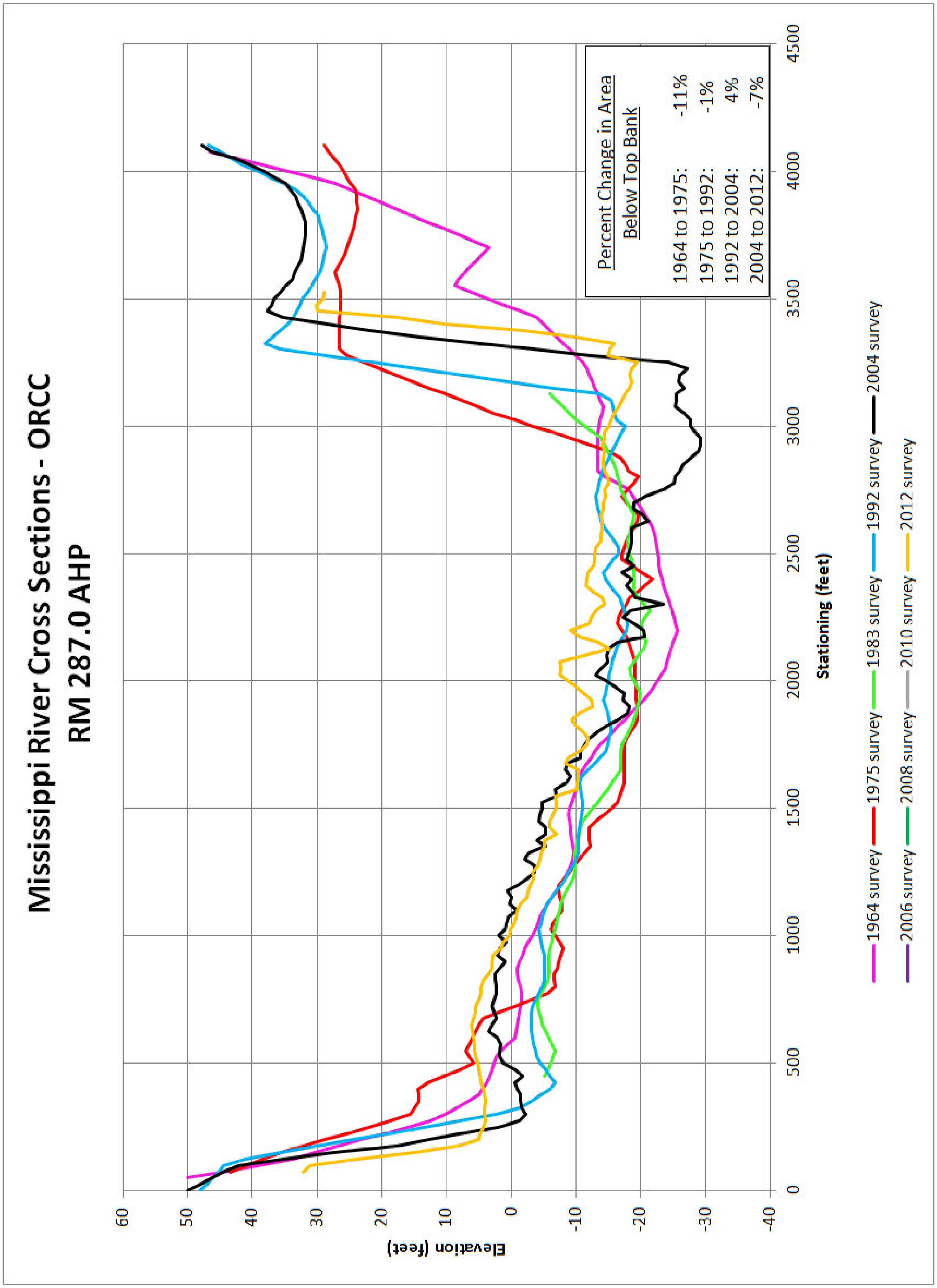

Average annual erosion/deposition
1992 - 2004 (CY/mi/yr)
Baton Rouge
Donaldsonville
LaPlace
N
Legend
Average annual erosion/deposition (1992-2004)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000


Average annual erosion/deposition
1992 - 2004 (CY/mi/yr)
N
New Orleans
Belle Chasse
Venice
Legend
Average annual erosion/deposition (1992-2004)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

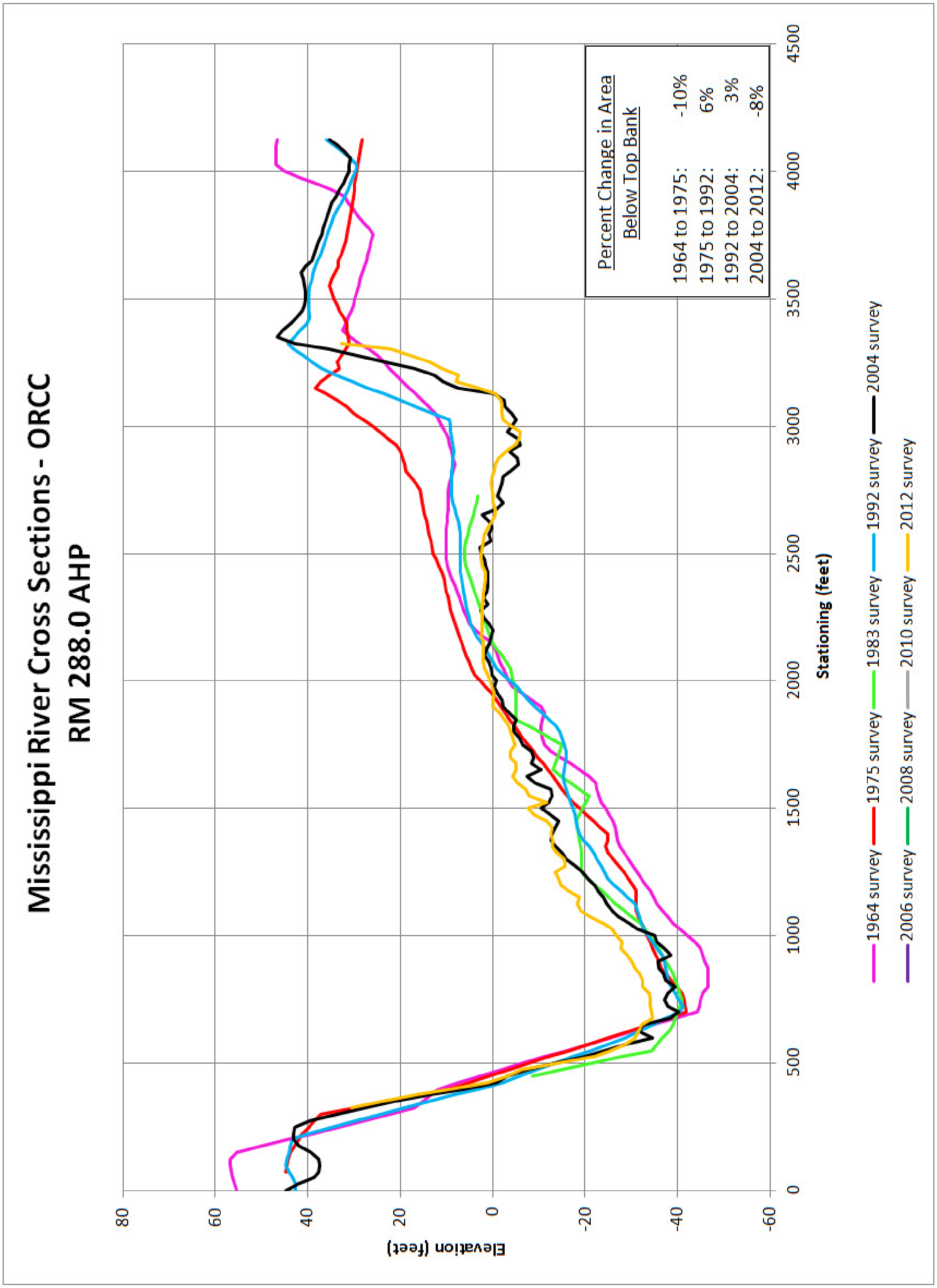

Average annual erosion/deposition
2004 - 2012 (CY/mi/yr)
N
ORCC
Baton Rouge
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
Legend
Average annual erosion/deposition (2004-2012)
CY/mi/yr
-450,000 to -400,000
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000

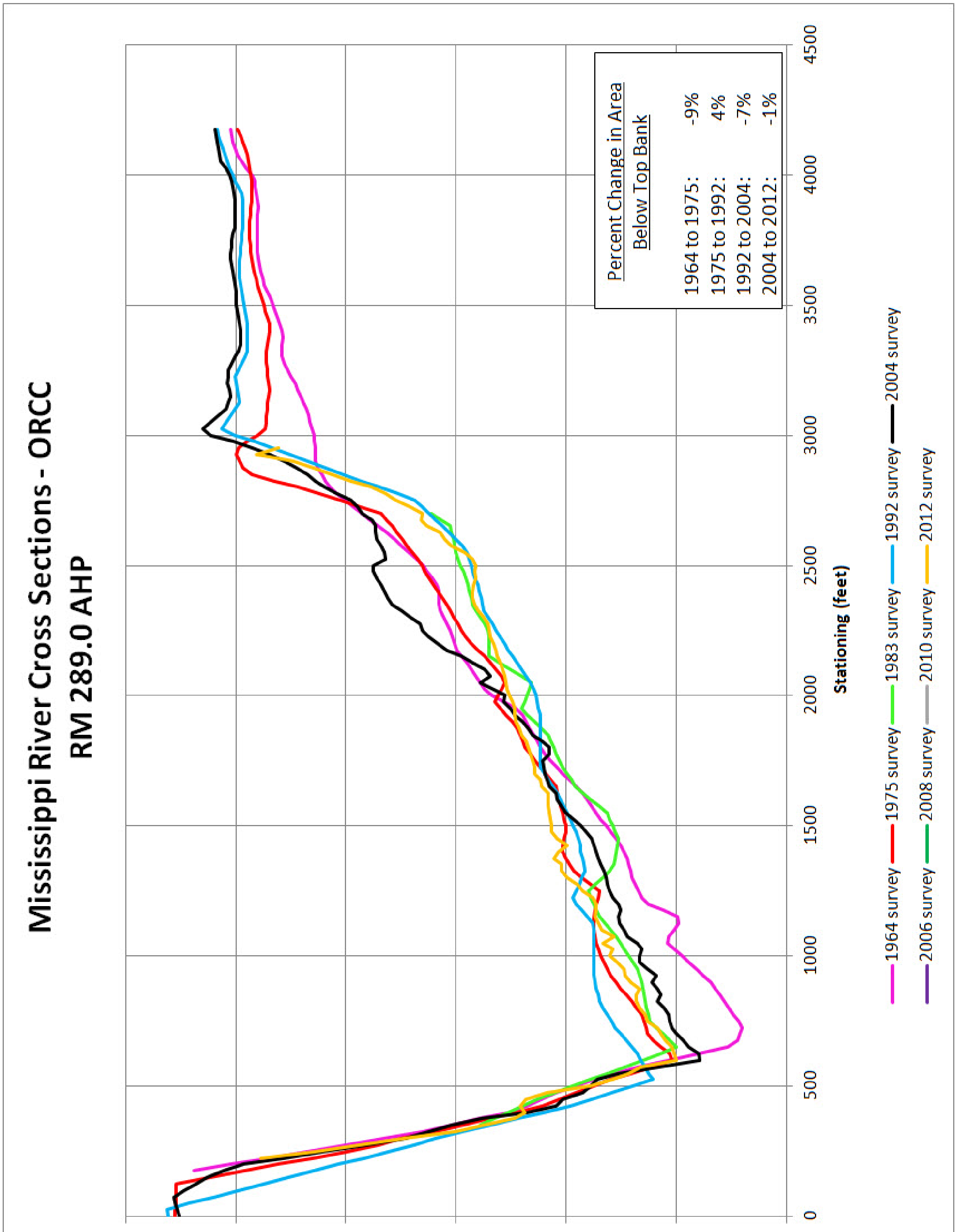
Appendix C: Geometry Data Analysis, Old River Control Complex (ORCC) Comparative Cross Sections

Abbreviations Used in Appendix C	
River mile	RM
Above head of passes	AHP
Cubic yards/mile/year	CY/mi/yr
Old River Control Complex	ORCC
Average	ave.

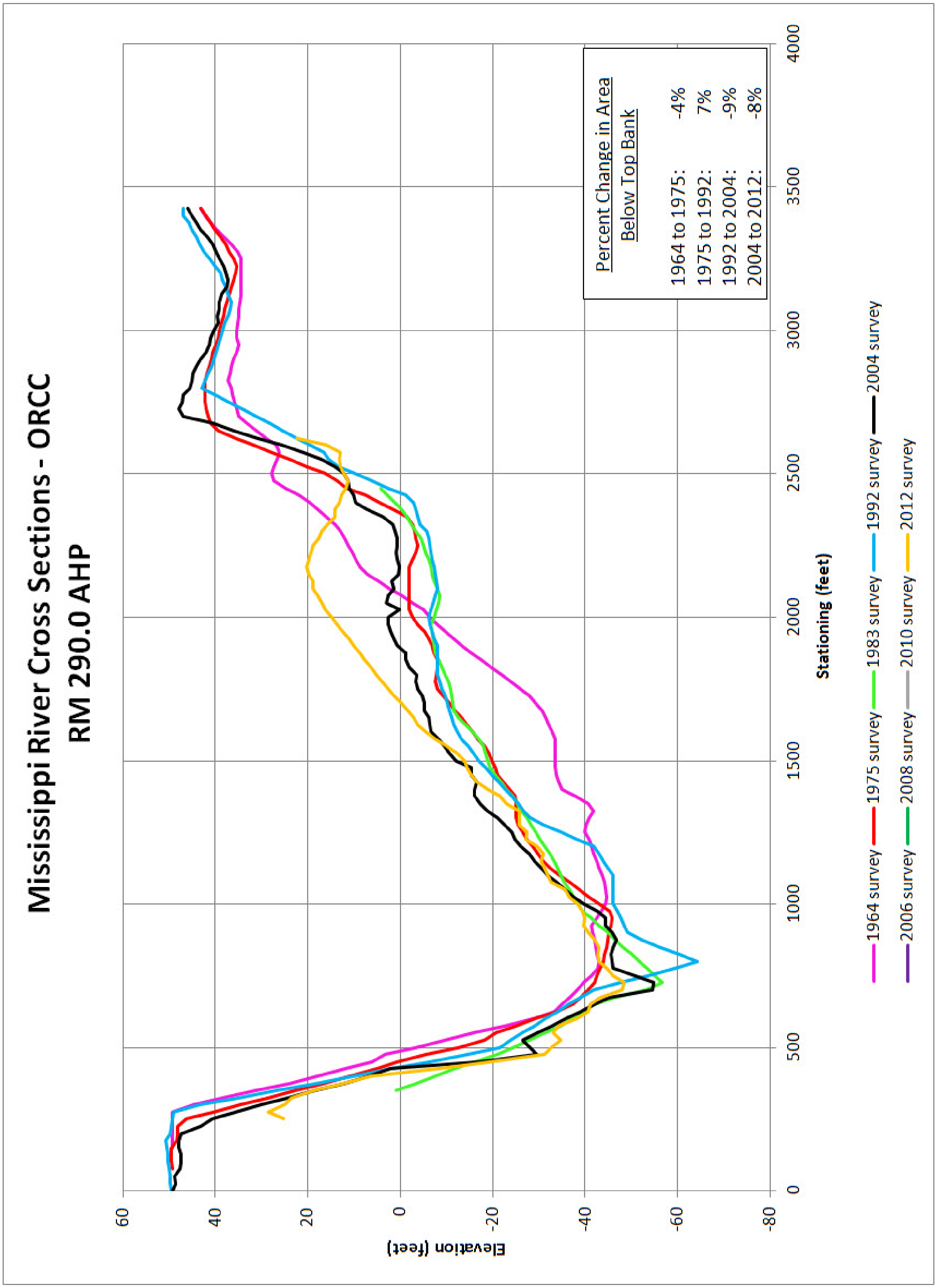


Mississippi River Cross Sections - ORCC
RM 287.0 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area
Below Top Bank
1964 to 1975: -11%
1975 to 1992: -1%
1992 to 2004: 4%
2004 to 2012: -7%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

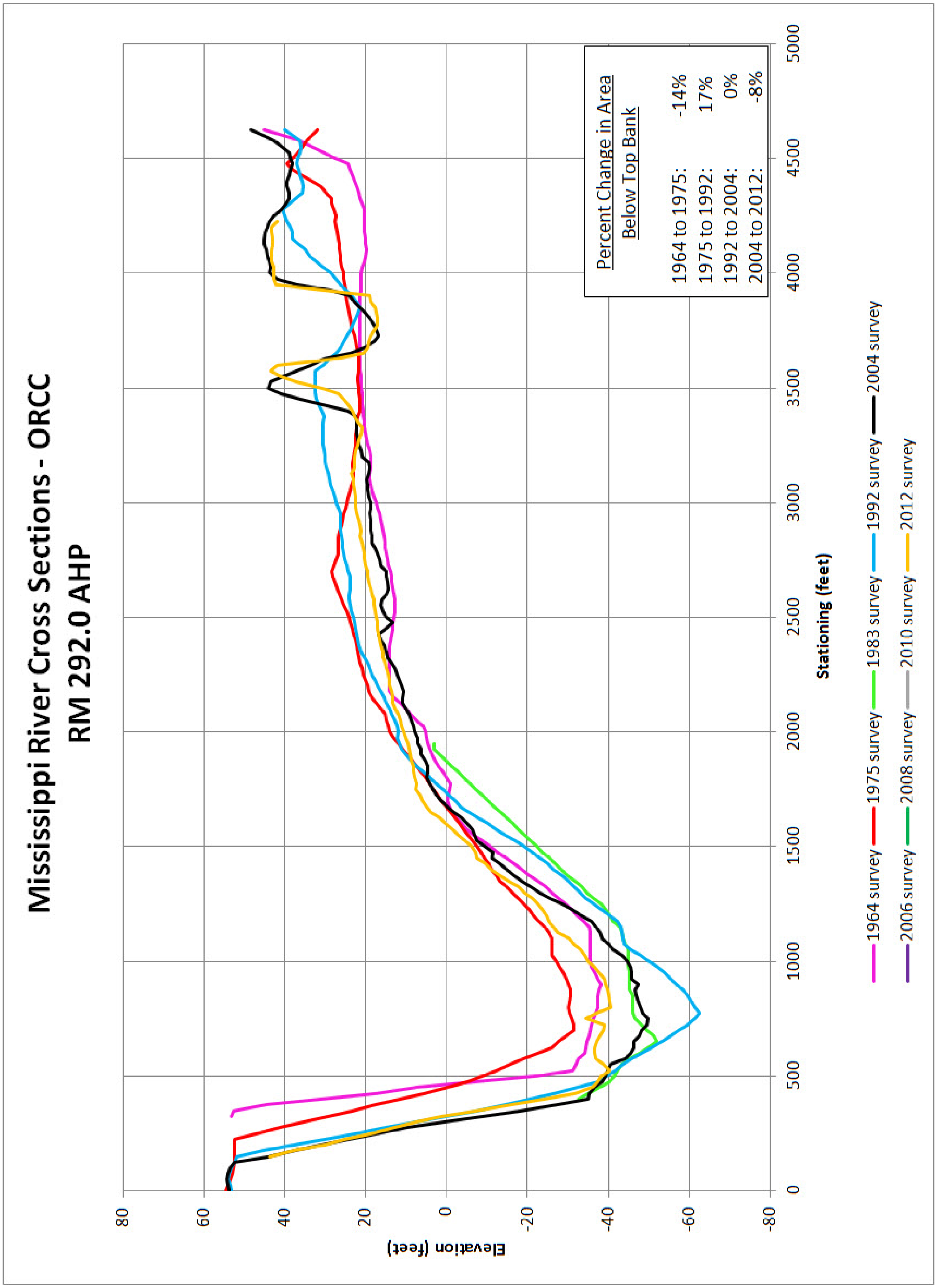

Mississippi River Cross Sections - ORCC
RM 288.0 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Percent Change in Area
Below Top Bank
1964 to 1975: -10%
1975 to 1992: 6%
1992 to 2004: 3%
2004 to 2012: -8%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

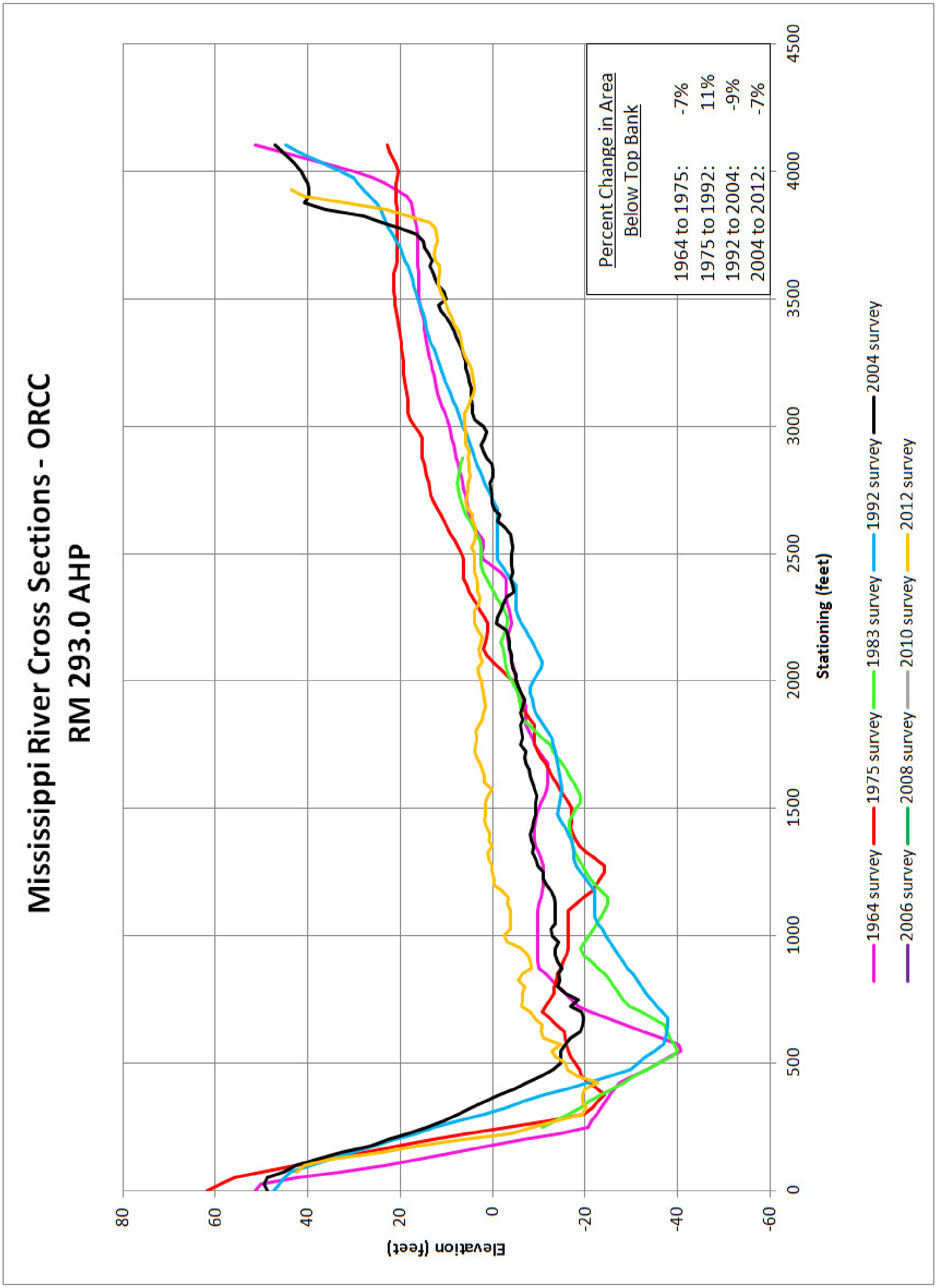


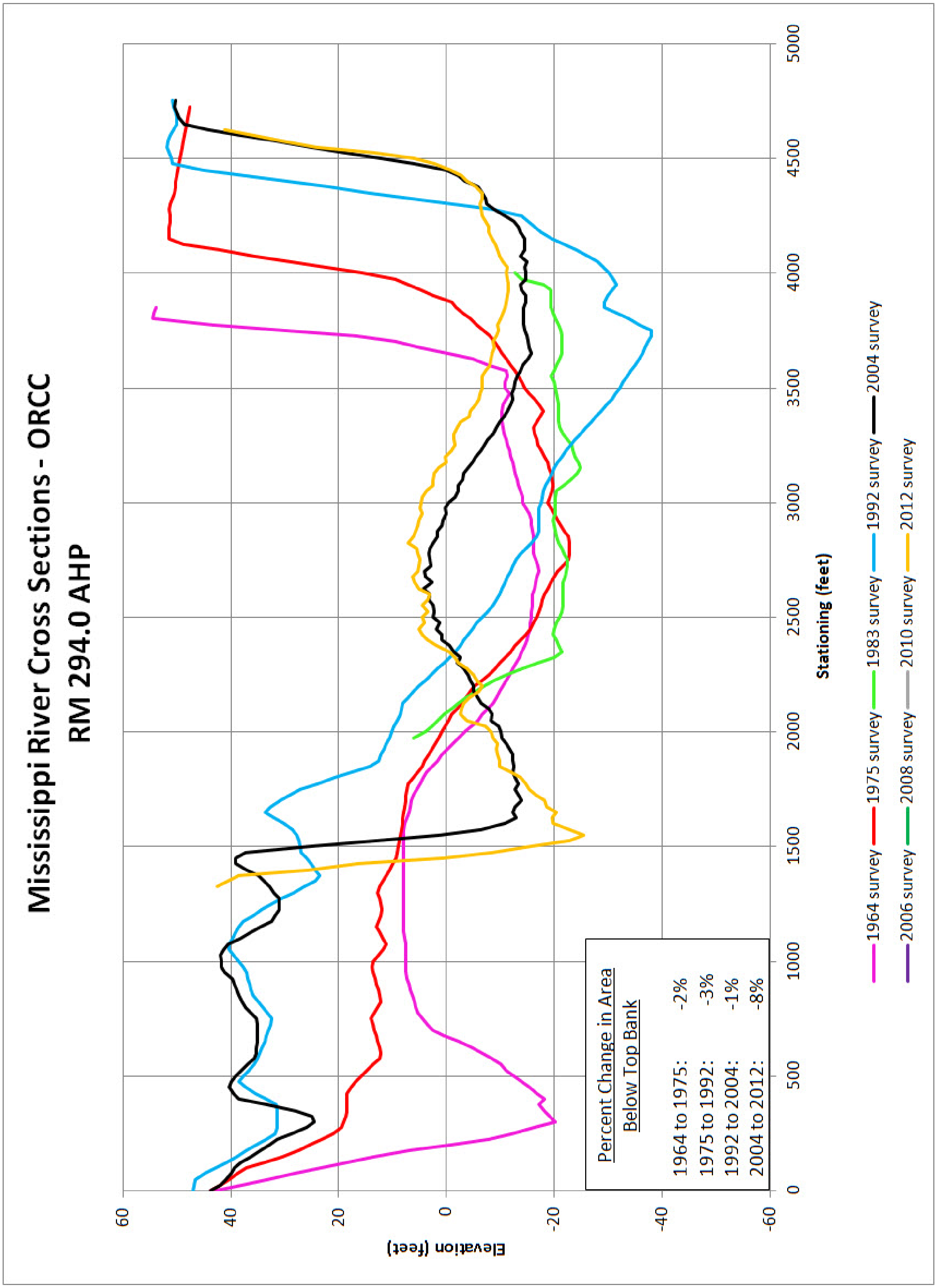
Mississippi River Cross Sections - ORCC
RM 289.0 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Percent Change in Area
Below Top Bank
1964 to 1975: -9%
1975 to 1992: 4%
1992 to 2004: -7%
2004 to 2012: -1%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

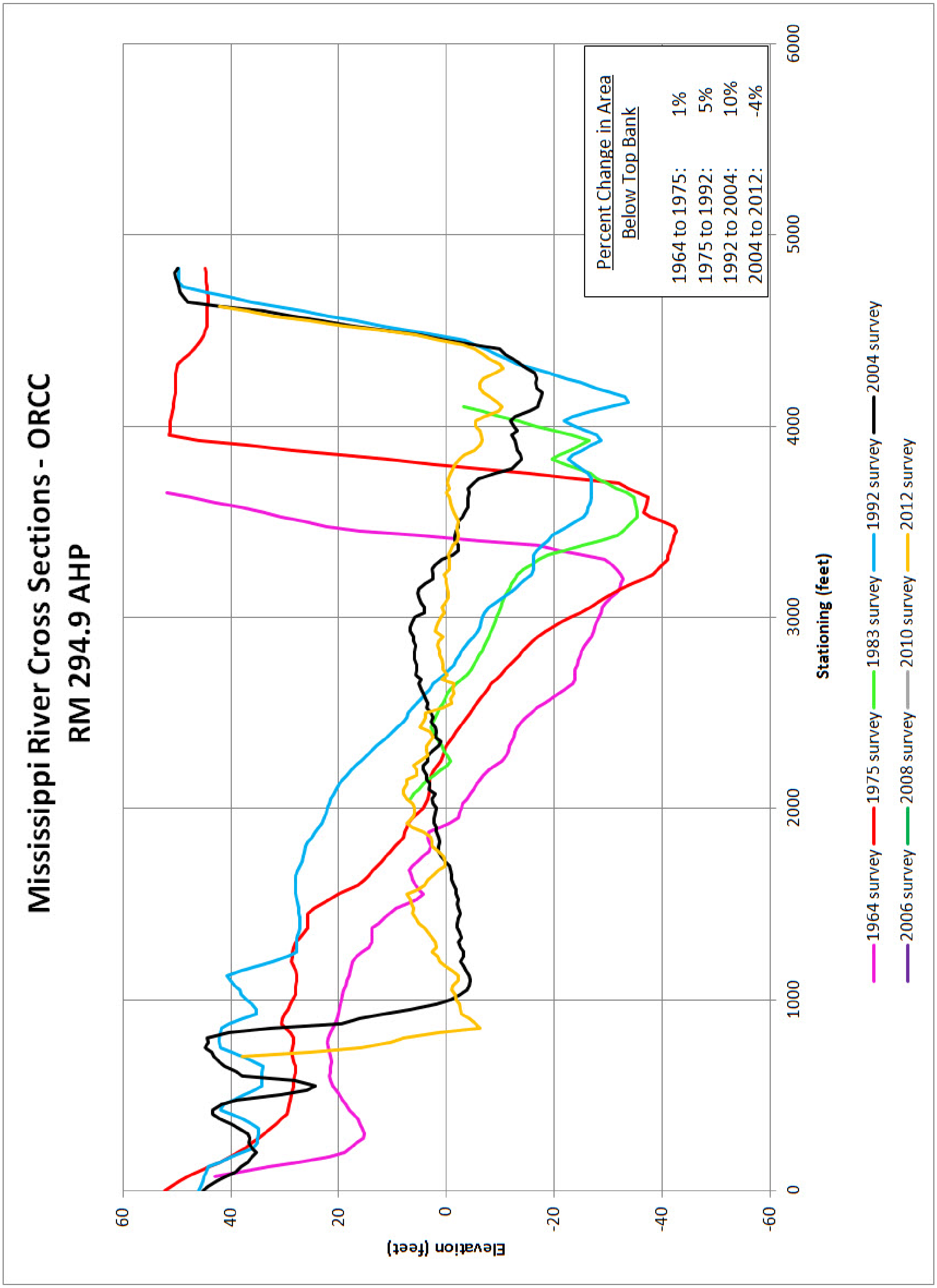


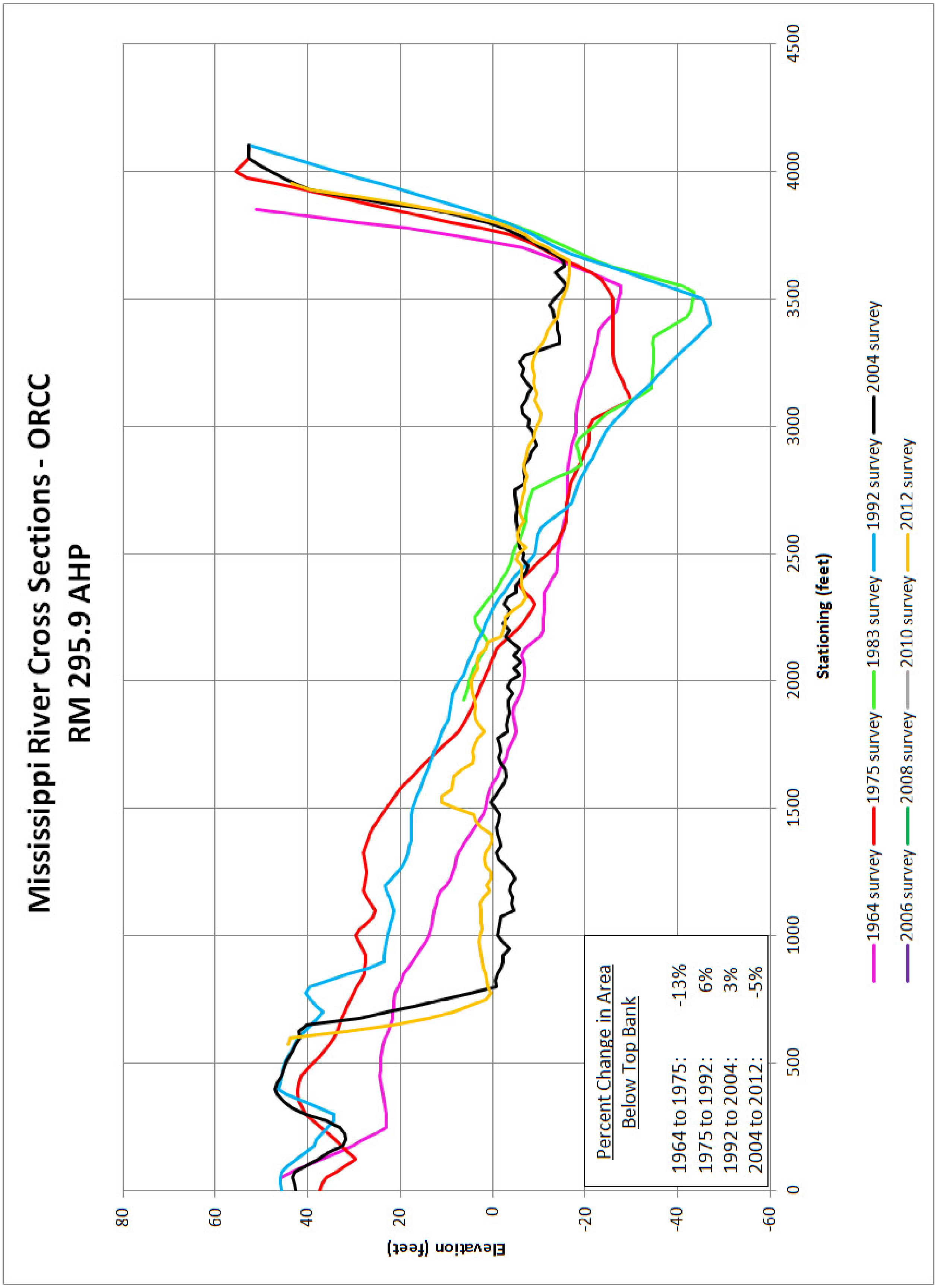
Mississippi River Cross Sections - ORCC
RM 290.0 AHP
Elevation (feet)
Stationing (feet)
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
2500
3000
3500
4000
Percent Change in Area
Below Top Bank
1964 to 1975: -4%
1975 to 1992: 7%
1992 to 2004: -9%
2004 to 2012: -8%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

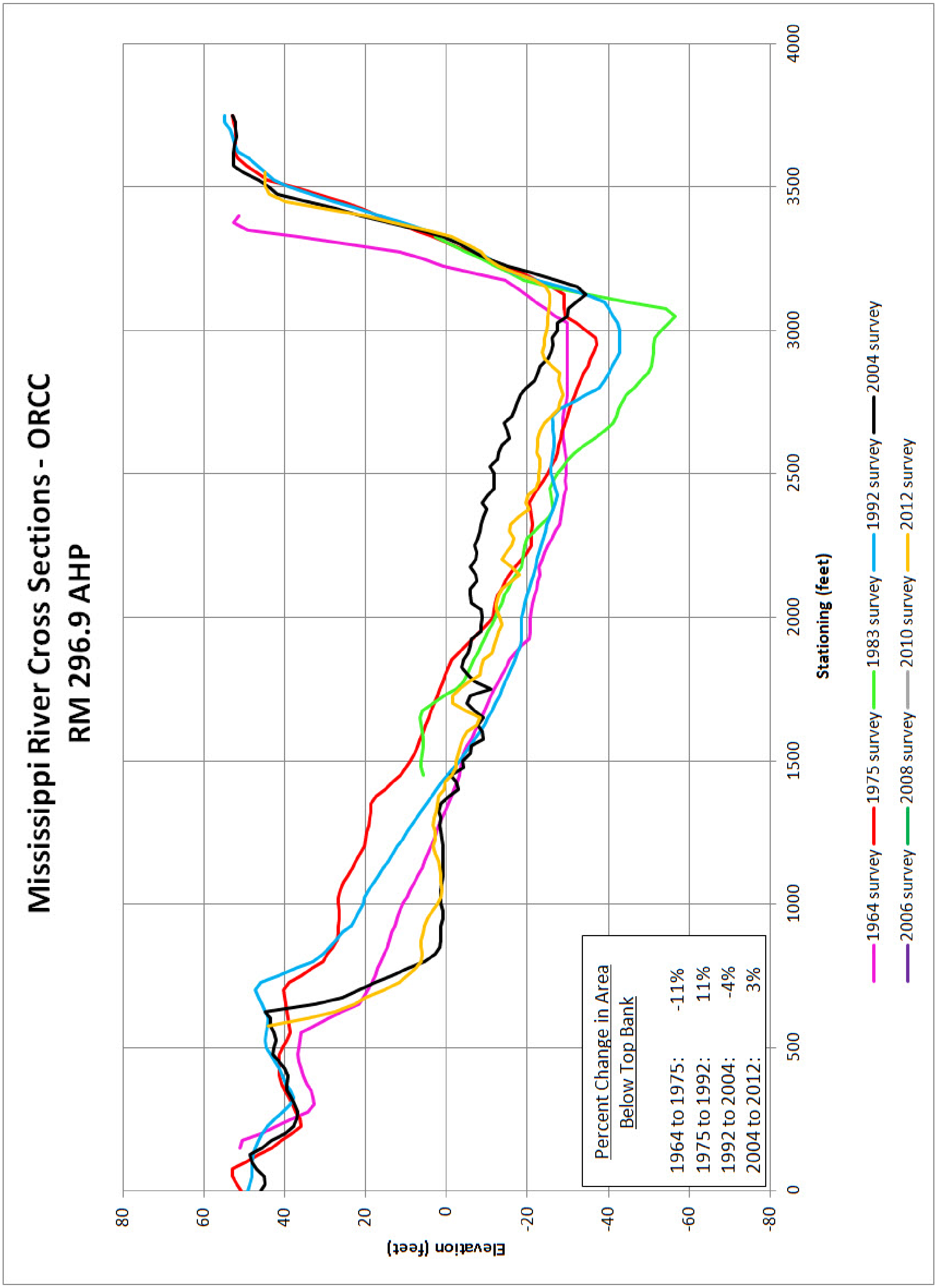

Mississippi River Cross Sections - ORCC
RM 292.0 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
-80
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Percent Change in Area
Below Top Bank
1964 to 1975: -14%
1975 to 1992: 17%
1992 to 2004: 0%
2004 to 2012: -8%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

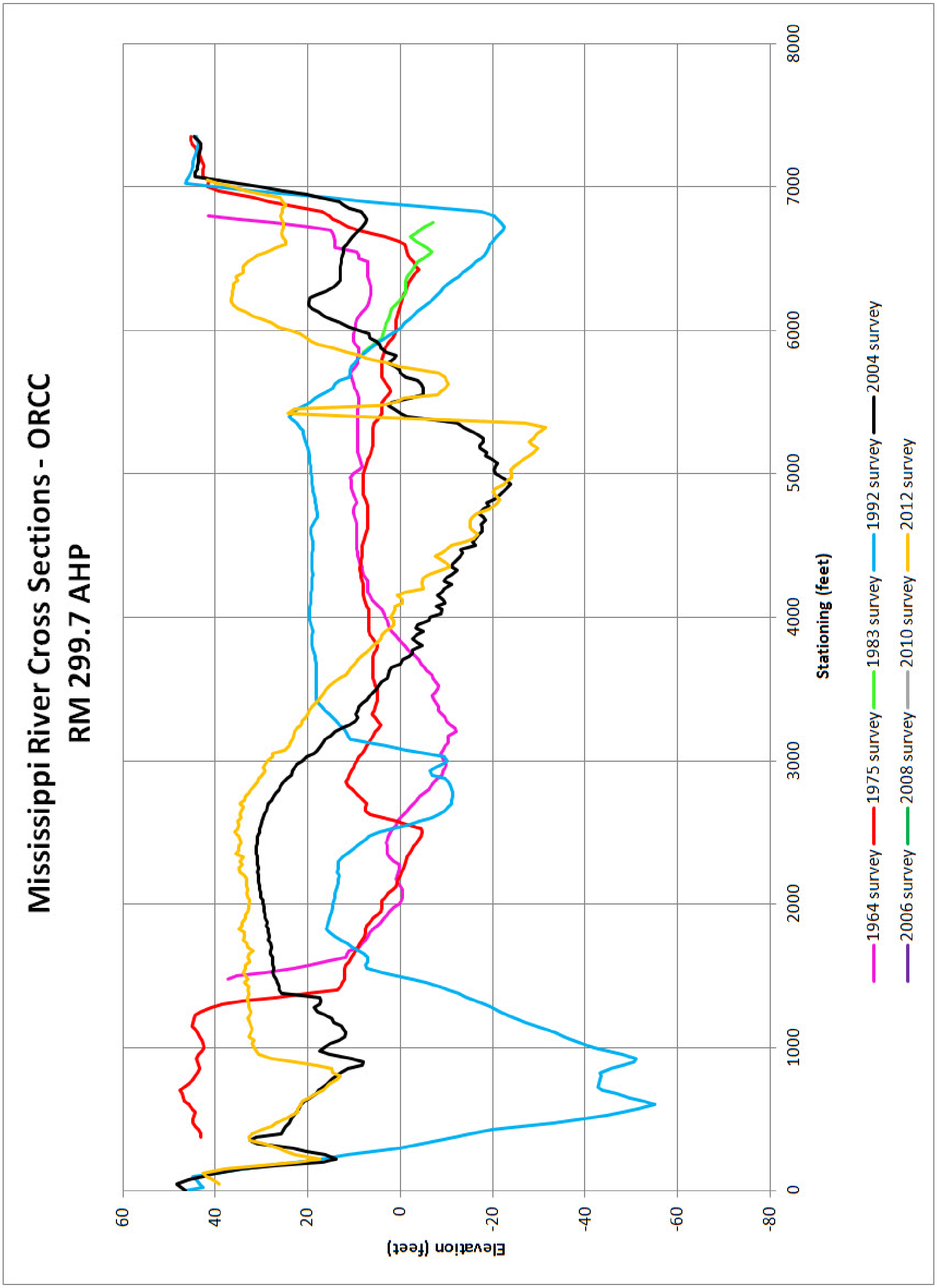

Mississippi River Cross Sections - ORCC
RM 293.0 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: -7%
1975 to 1992: 11%
1992 to 2004: -9%
2004 to 2012: -7%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

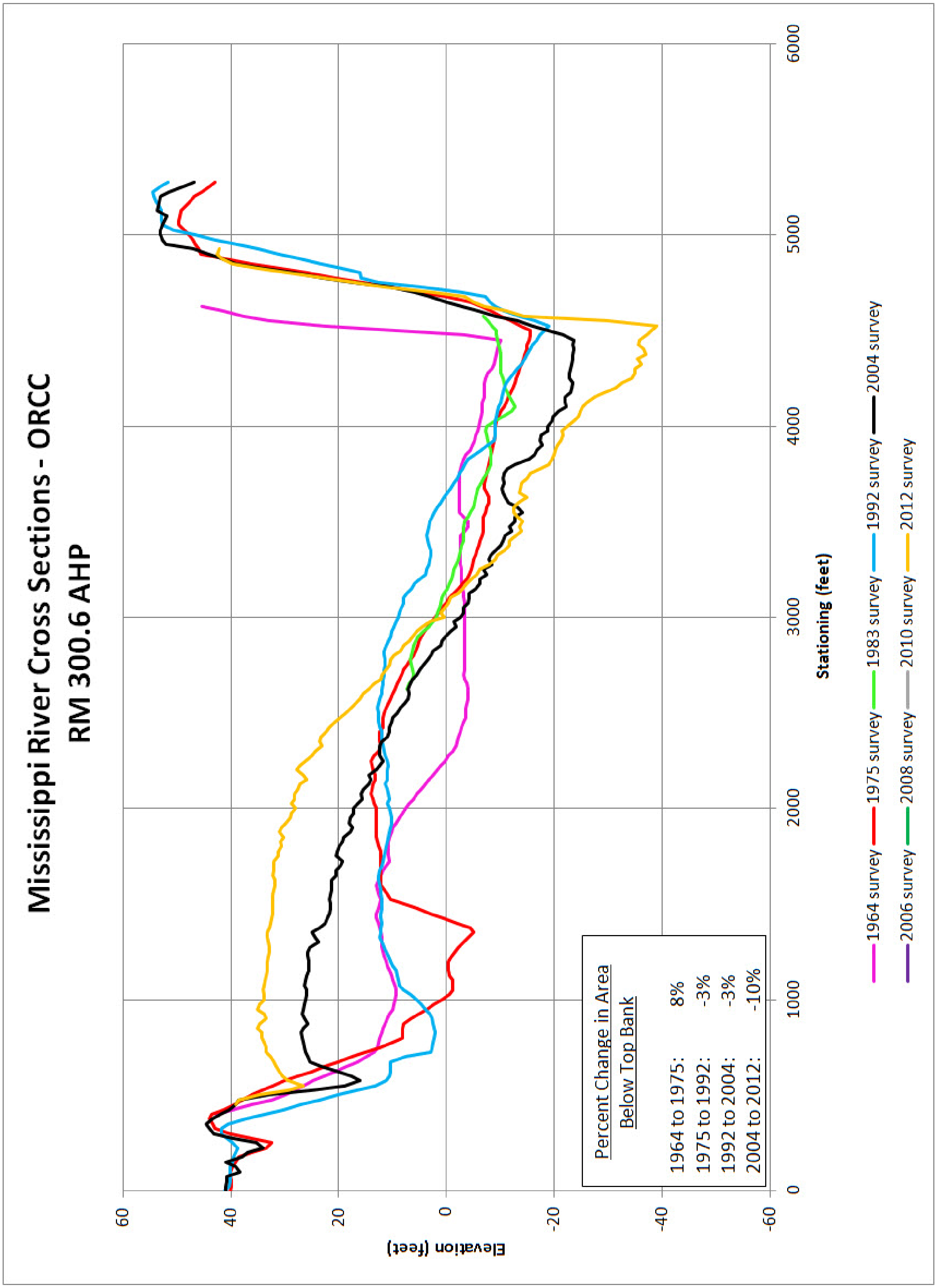

Mississippi River Cross Sections - ORCC
RM 294.0 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Percent Change in Area Below Top Bank
1964 to 1975: -2%
1975 to 1992: -3%
1992 to 2004: -1%
2004 to 2012: -8%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

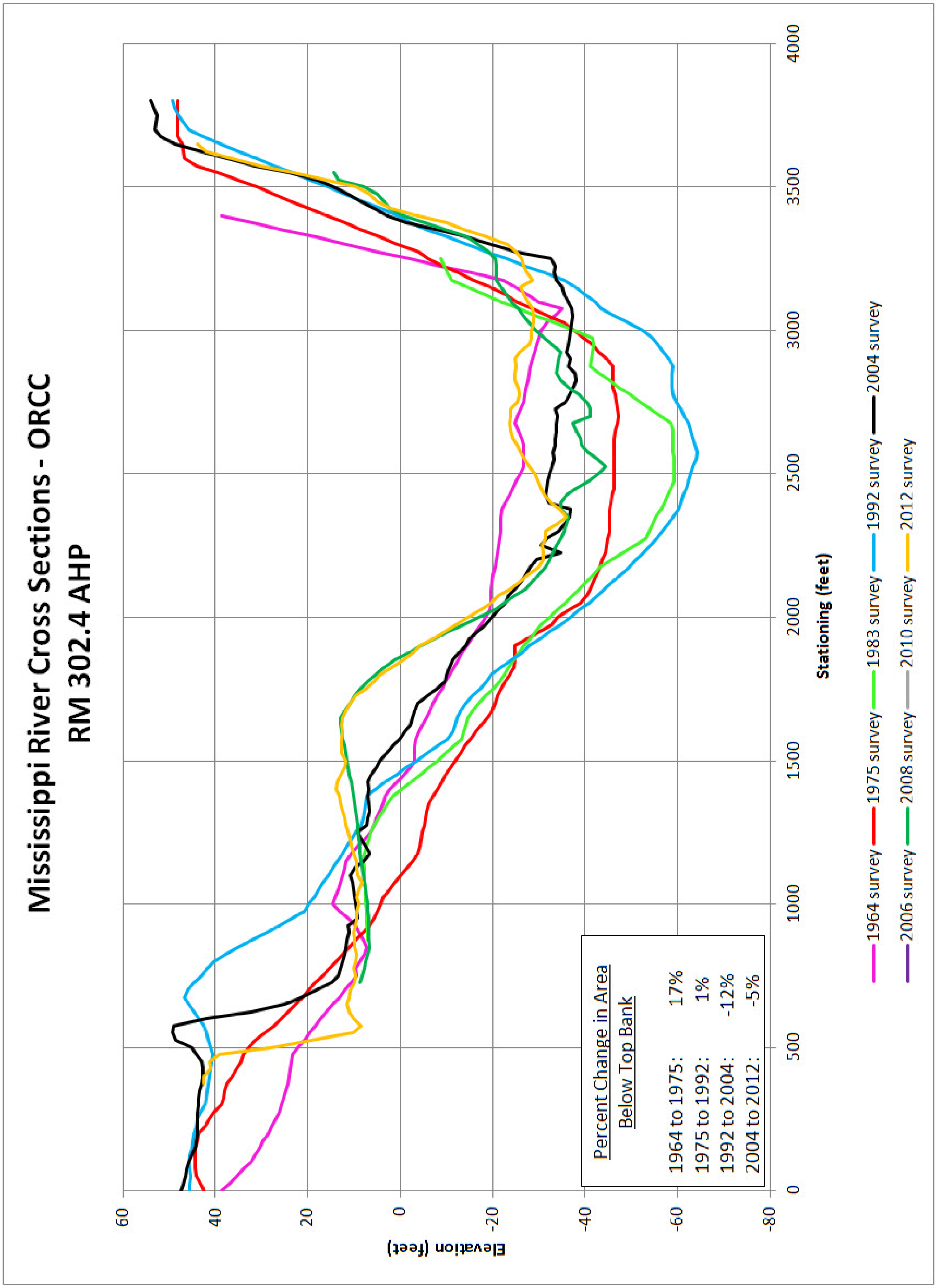

Mississippi River Cross Sections - ORCC
RM 294.9 AHP
Percent Change in Area
Below Top Bank
1964 to 1975: 1%
1975 to 1992: 5%
1992 to 2004: 10%
2004 to 2012: -4%
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey


Mississippi River Cross Sections - ORCC
RM 295.9 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area
Below Top Bank
1964 to 1975: -13%
1975 to 1992: 6%
1992 to 2004: 3%
2004 to 2012: -5%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey
80
60
40
20
0
-20
-40
-60
0
500
1000
1500
2000
2500
3000
3500
4000
4500

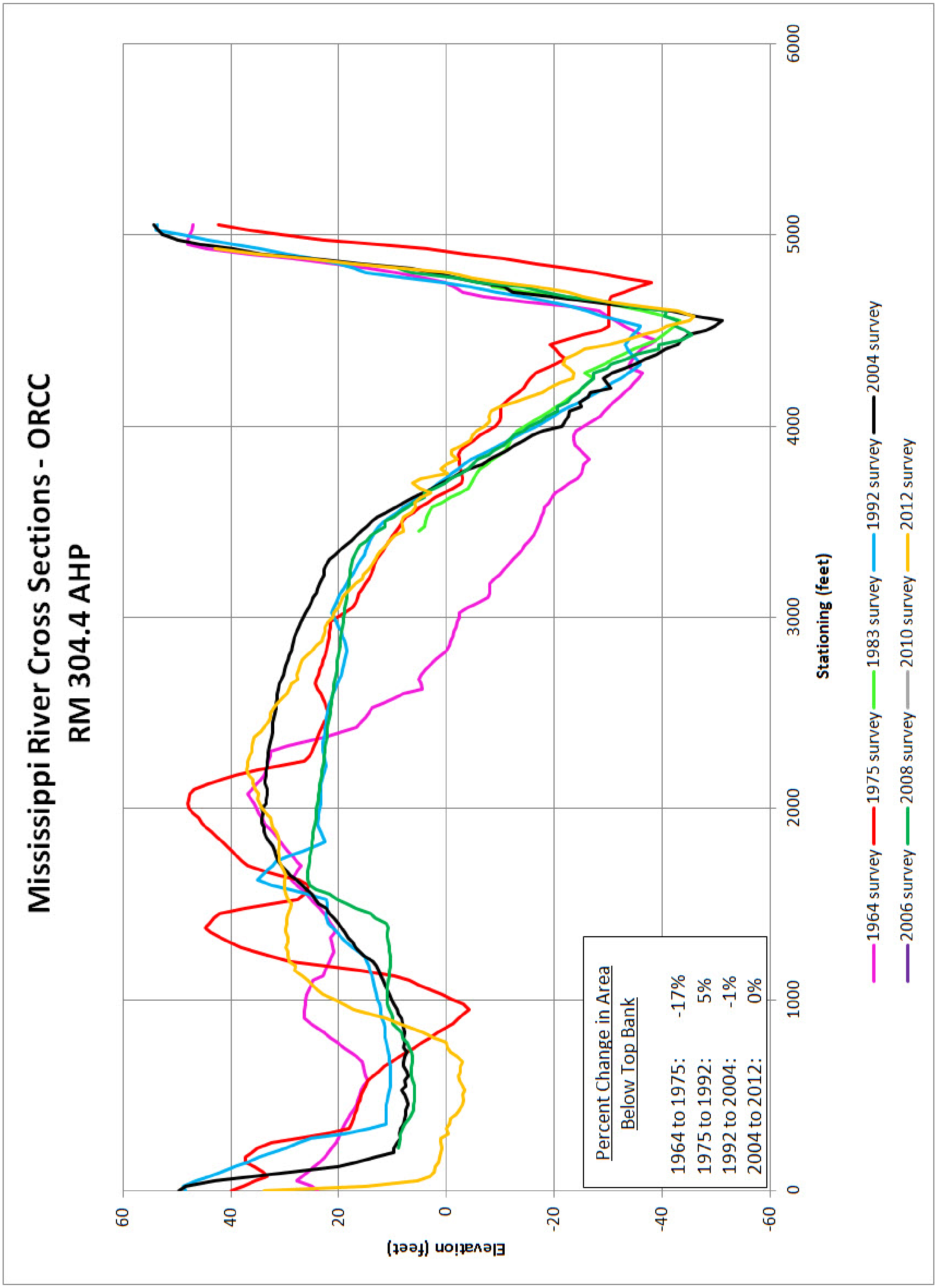

Mississippi River Cross Sections - ORCC
RM 296.9 AHP
Elevation (feet)
Stationing (feet)
80
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
2500
3000
3500
4000
Percent Change in Area Below Top Bank
1964 to 1975: -11%
1975 to 1992: 11%
1992 to 2004: -4%
2004 to 2012: 3%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

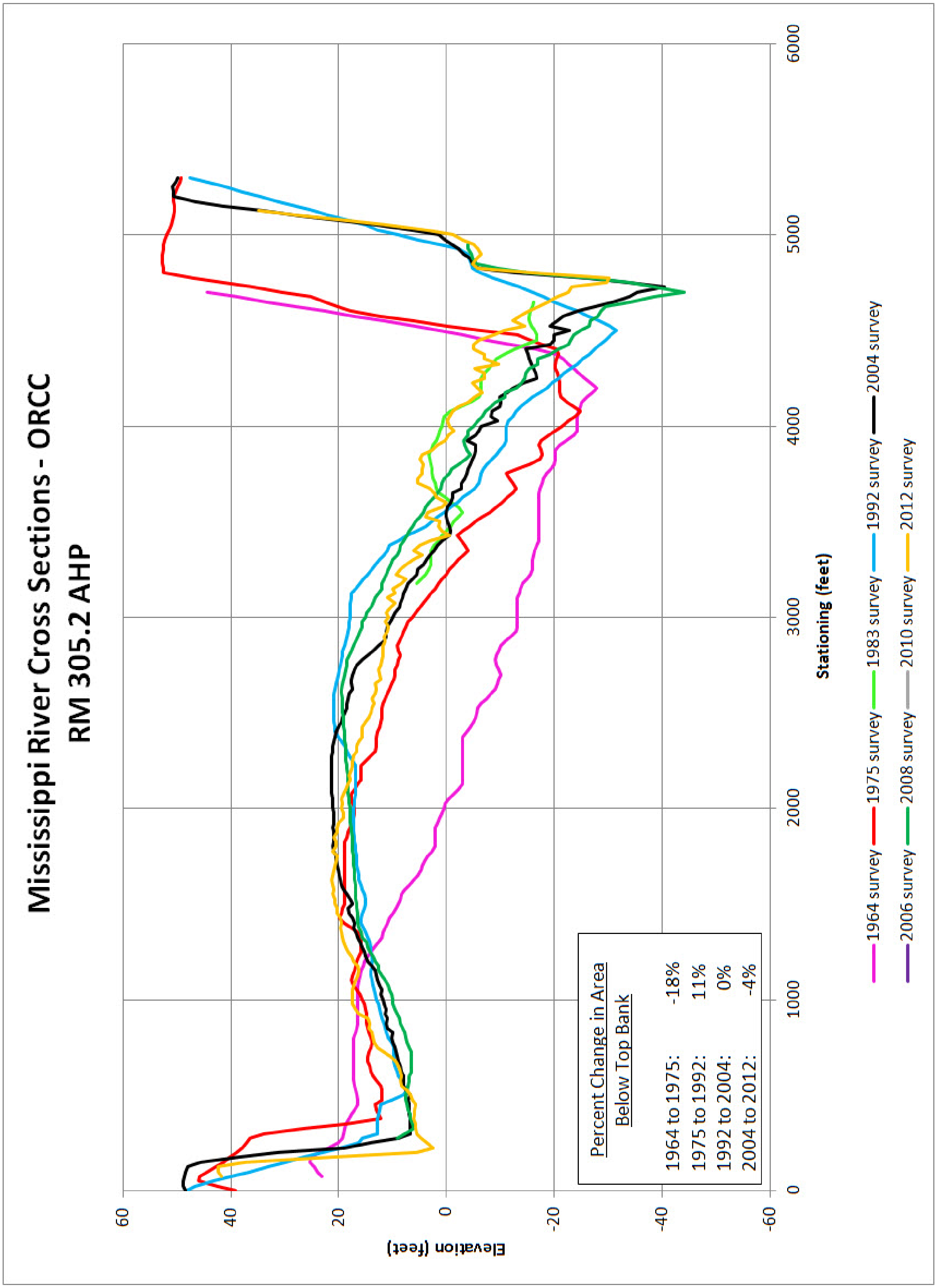

Mississippi River Cross Sections - ORCC
RM 299.7 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

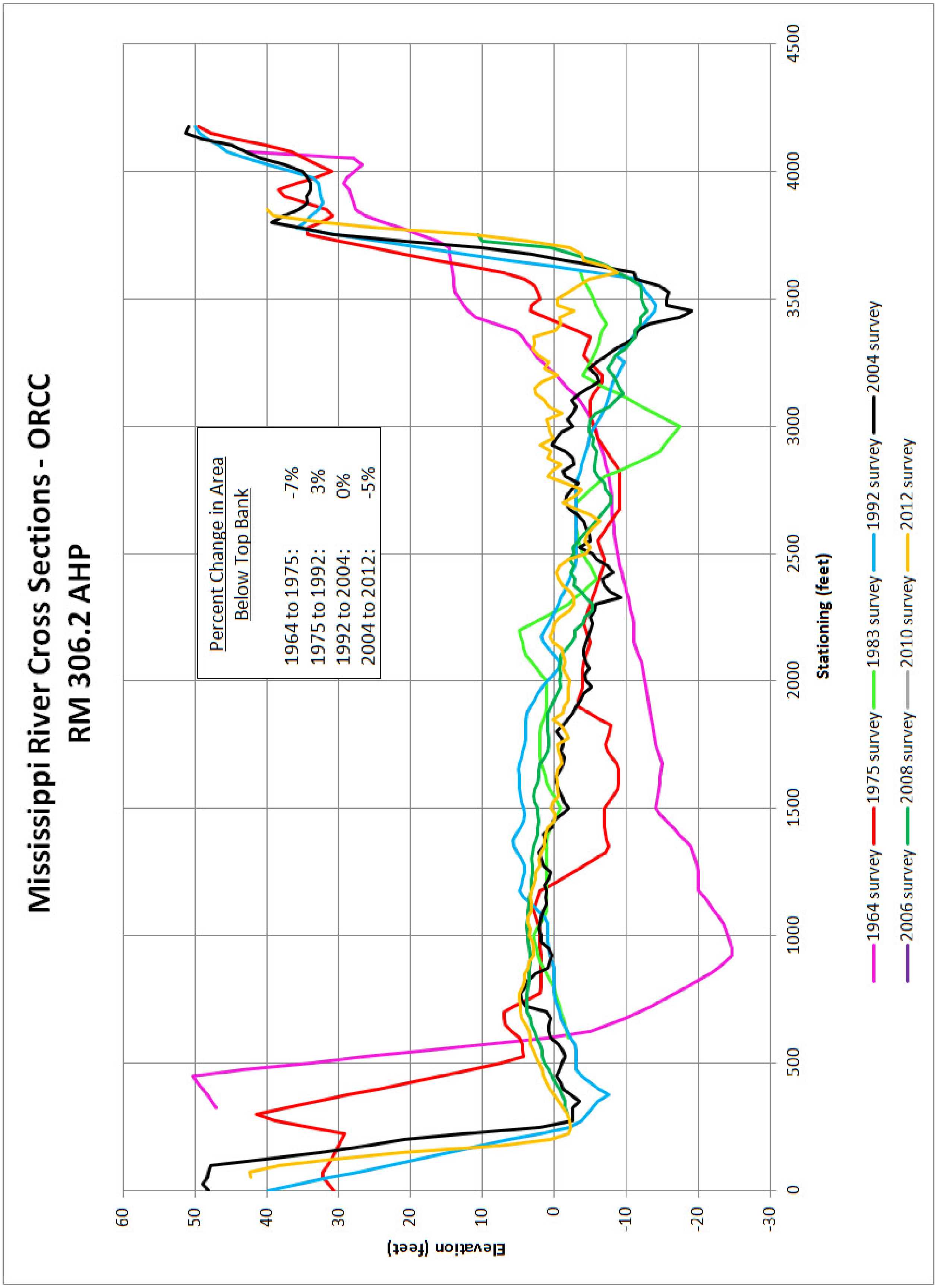

Mississippi River Cross Sections - ORCC
RM 300.6 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
Percent Change in Area
Below Top Bank
1964 to 1975: 8%
1975 to 1992: -3%
1992 to 2004: -3%
2004 to 2012: -10%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

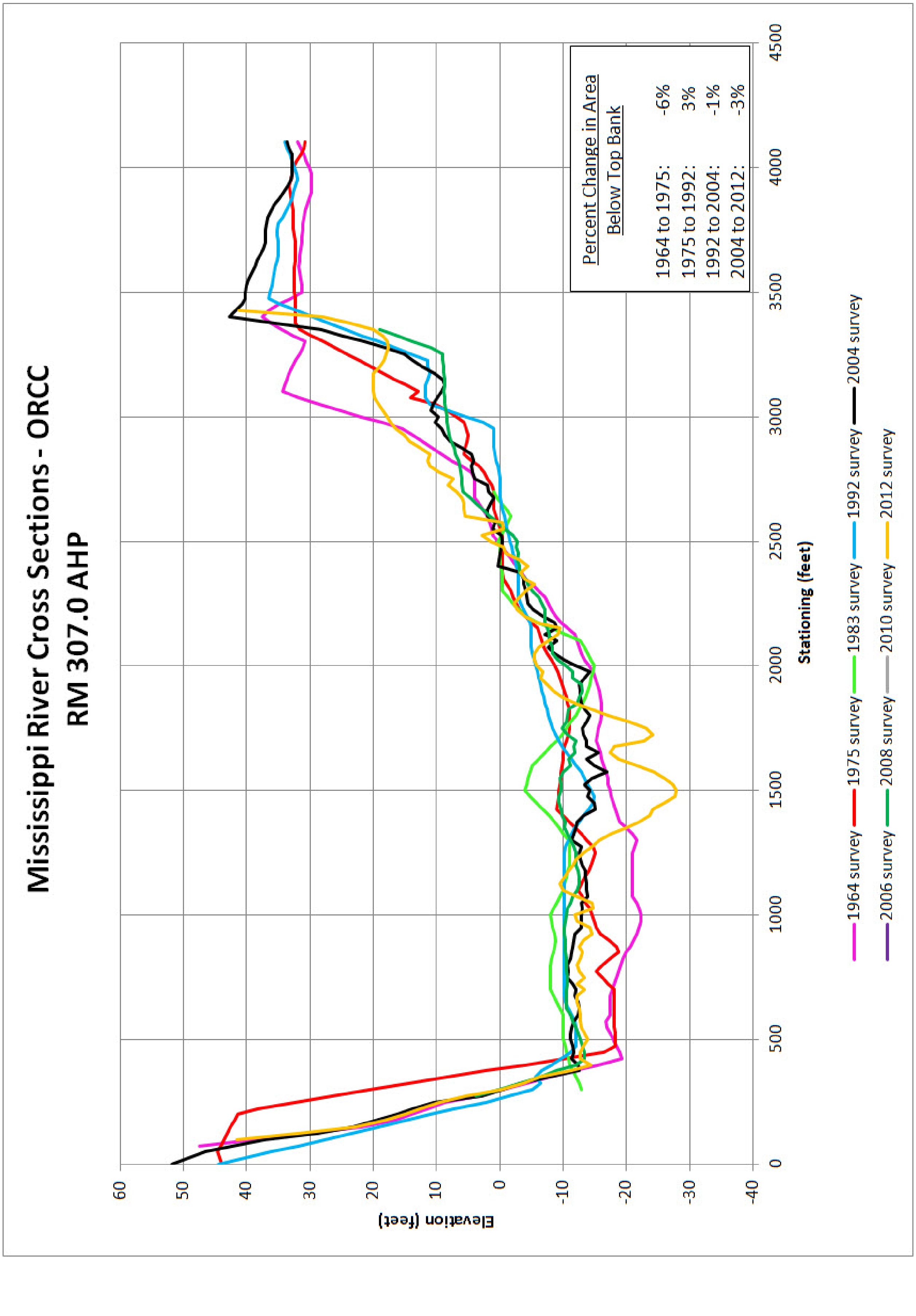


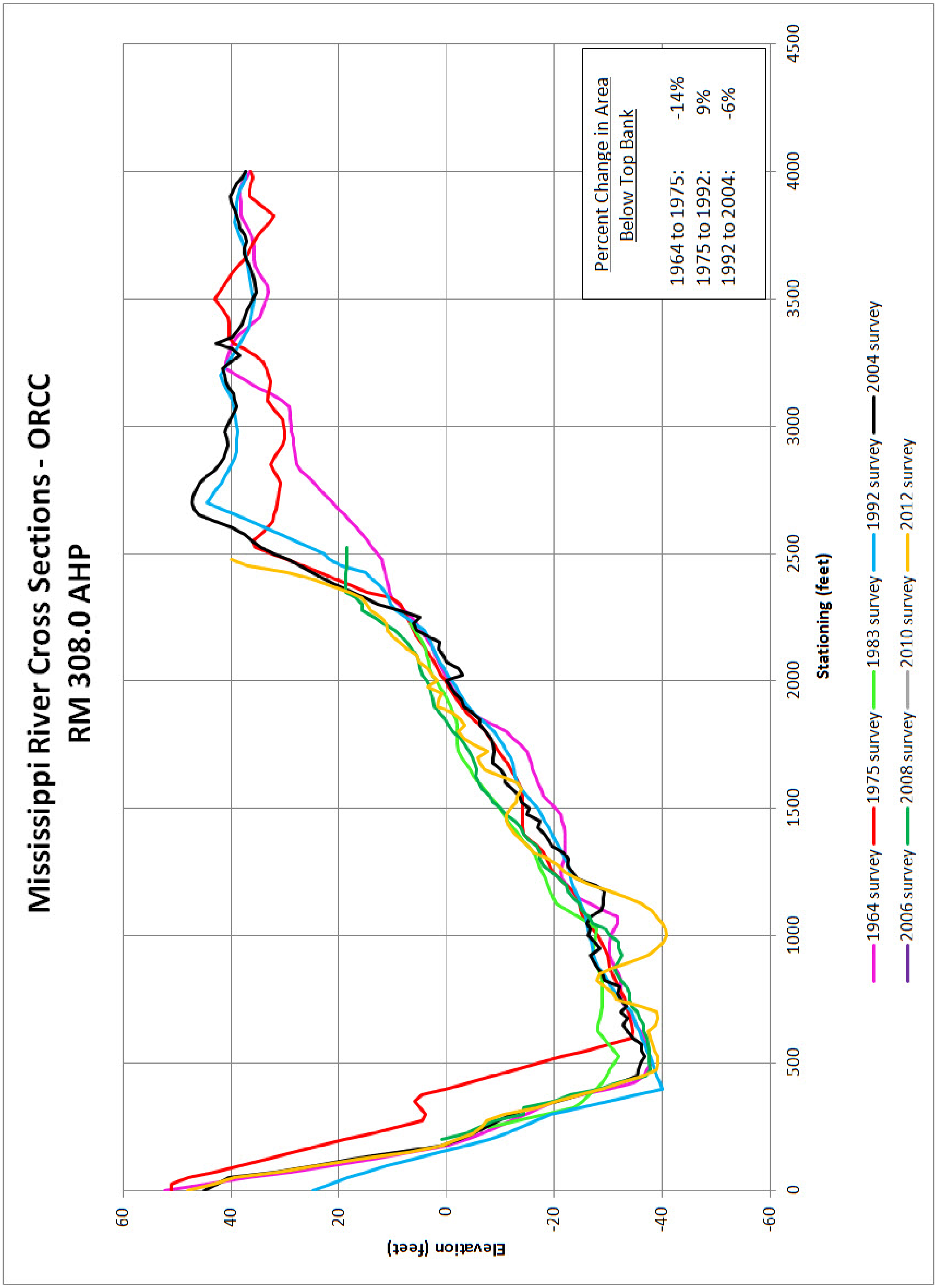
Mississippi River Cross Sections - ORCC
RM 302.4 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
Percent Change in Area
Below Top Bank
1964 to 1975: 17%
1975 to 1992: 1%
1992 to 2004: -12%
2004 to 2012: -5%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

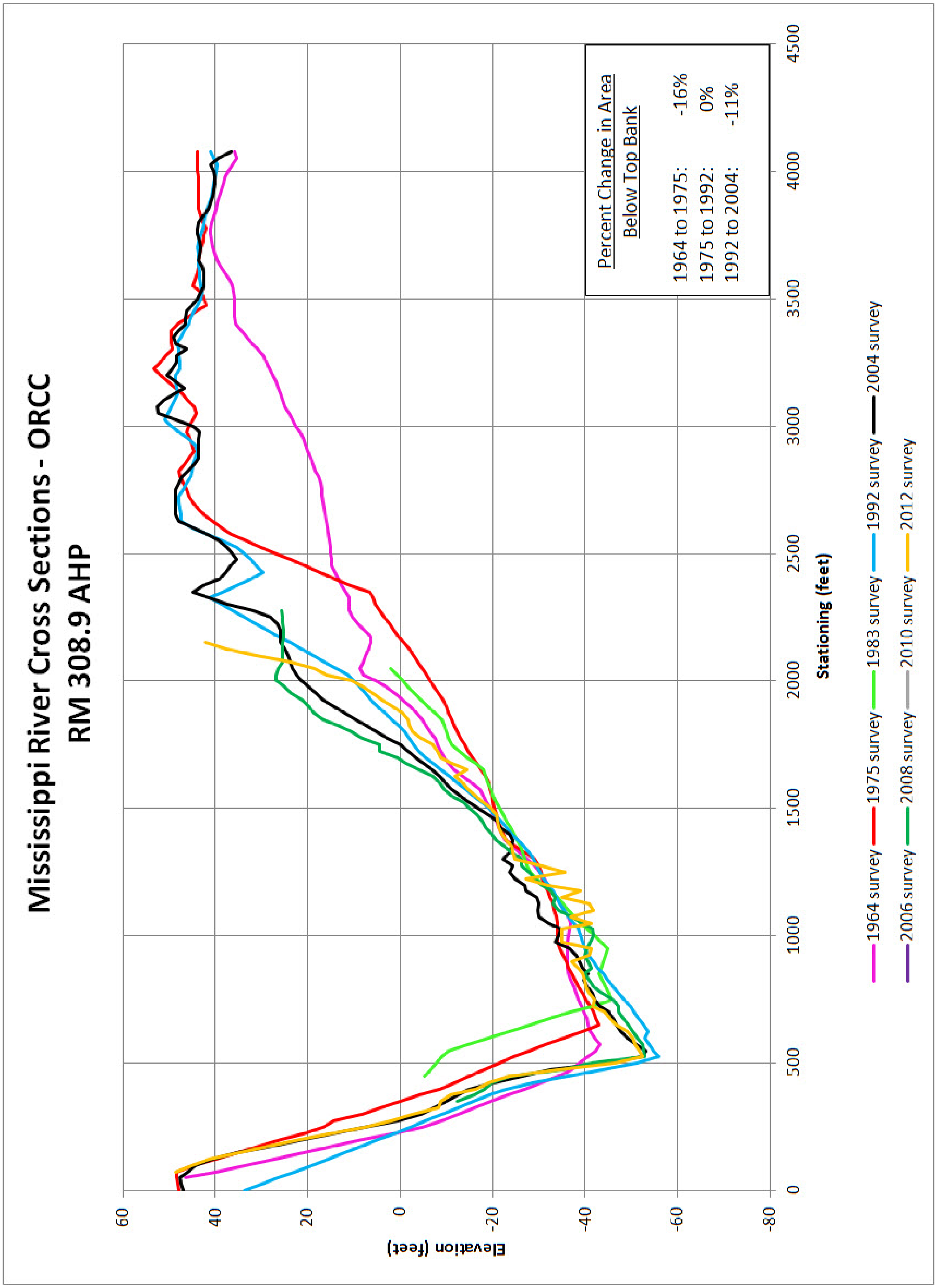

Mississippi River Cross Sections - ORCC
RM 304.4 AHP
Elevation (feet)
Stationing (feet)
60
40
20
0
-20
-40
-60
0
1000
2000
3000
4000
5000
6000
Percent Change in Area
Below Top Bank
1964 to 1975: -17%
1975 to 1992: 5%
1992 to 2004: -1%
2004 to 2012: 0%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

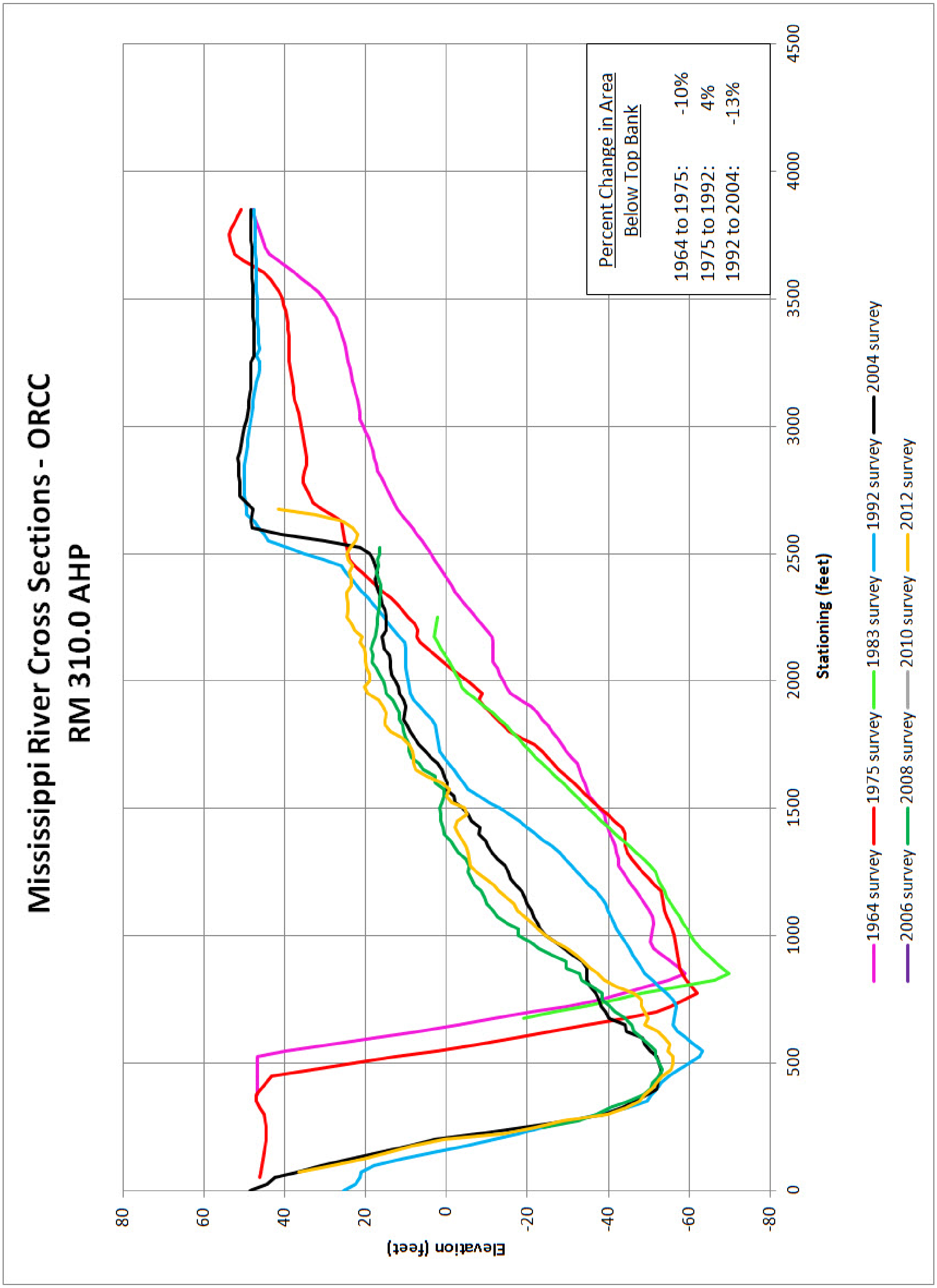

Mississippi River Cross Sections - ORCC
RM 305.2 AHP
Percent Change in Area
Below Top Bank
1964 to 1975: -18%
1975 to 1992: 11%
1992 to 2004: 0%
2004 to 2012: -4%
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

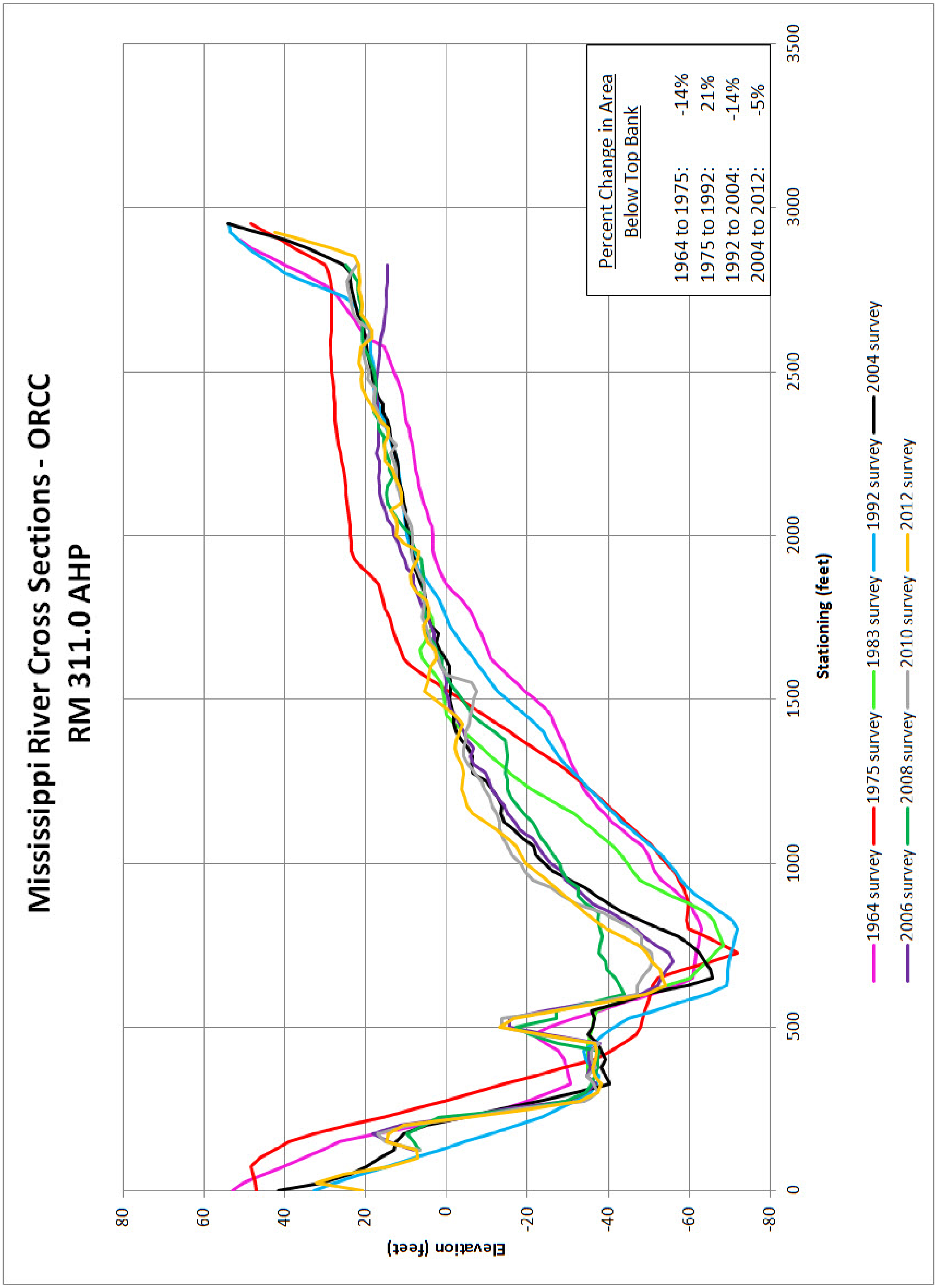

Mississippi River Cross Sections - ORCC
RM 306.2 AHP
Percent Change in Area
Below Top Bank
1964 to 1975: -7%
1975 to 1992: 3%
1992 to 2004: 0%
2004 to 2012: -5%
Elevation (feet)
Stationing (feet)
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

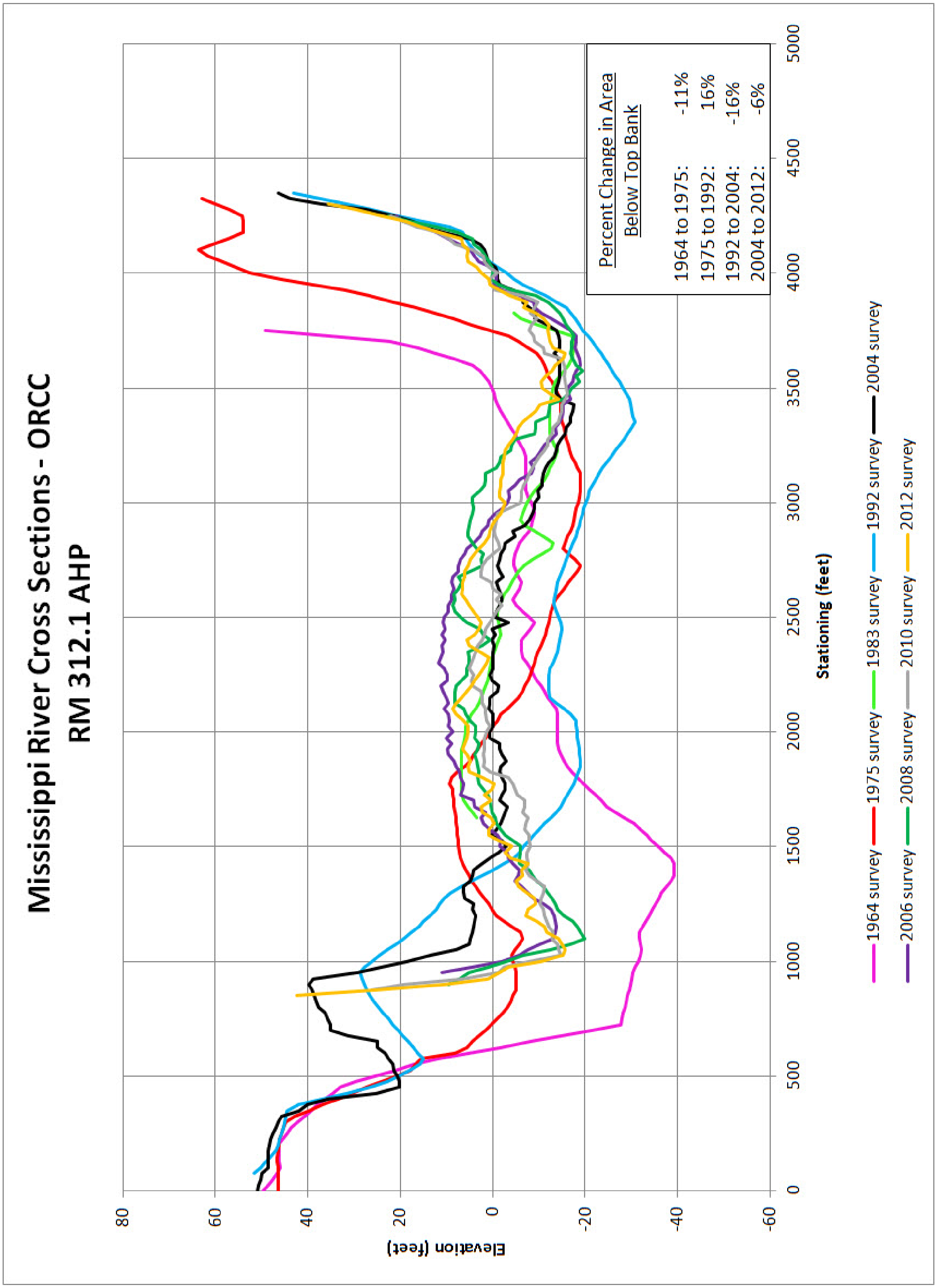

Mississippi River Cross Sections - ORCC
RM 307.0 AHP
Elevation (feet)
60
50
40
30
20
10
0
-10
-20
-30
-40
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Percent Change in Area
Below Top Bank
1964 to 1975: -6%
1975 to 1992: 3%
1992 to 2004: -1%
2004 to 2012: -3%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

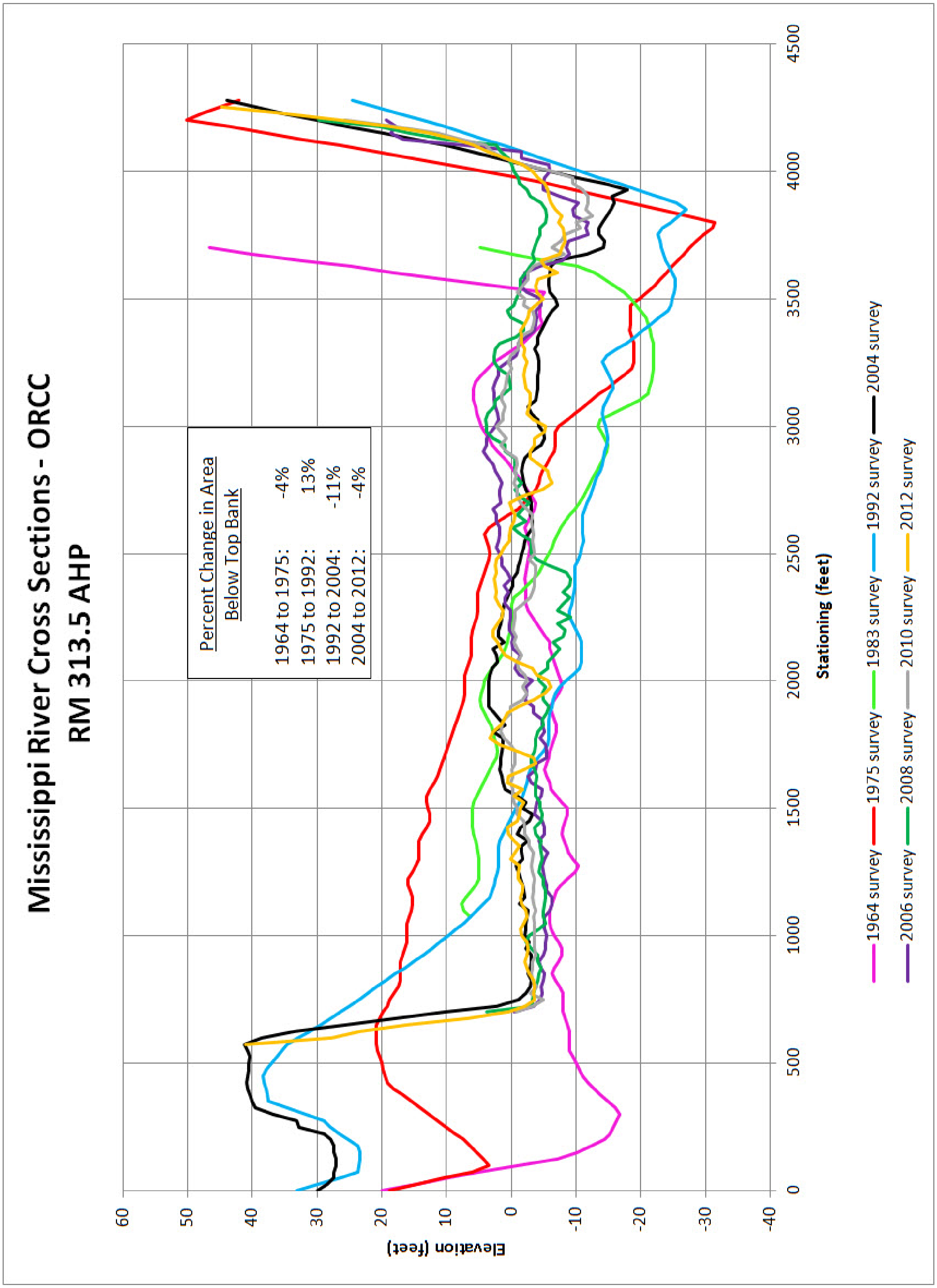

Mississippi River Cross Sections - ORCC
RM 308.0 AHP
Elevation (feet)
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Percent Change in Area Below Top Bank
1964 to 1975: -14%
1975 to 1992: 9%
1992 to 2004: -6%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

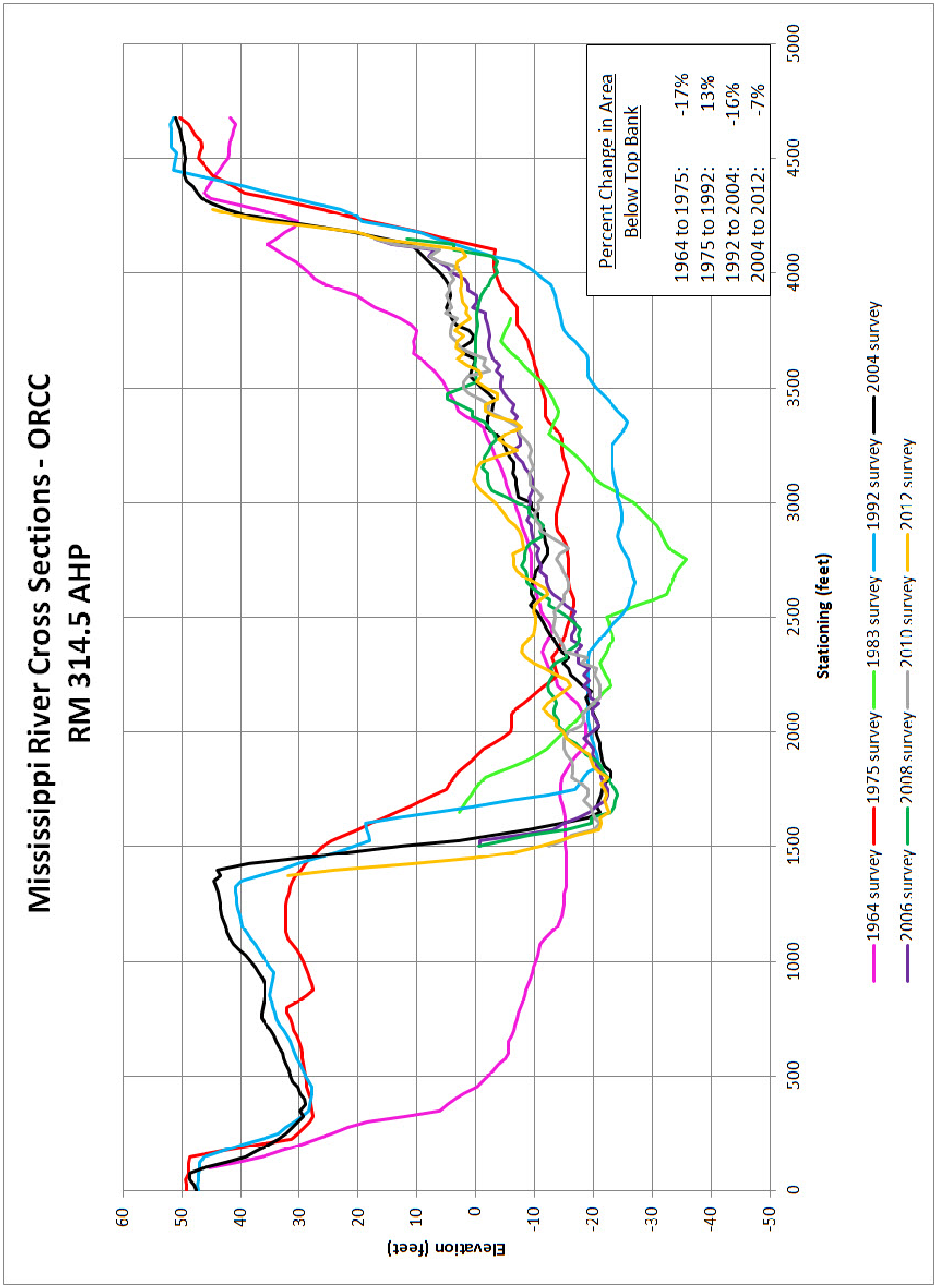

Mississippi River Cross Sections - ORCC
RM 308.9 AHP
Percent Change in Area
Below Top Bank
1964 to 1975: -16%
1975 to 1992: 0%
1992 to 2004: -11%
Elevation (feet)
60
40
20
0
-20
-40
-60
-80
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

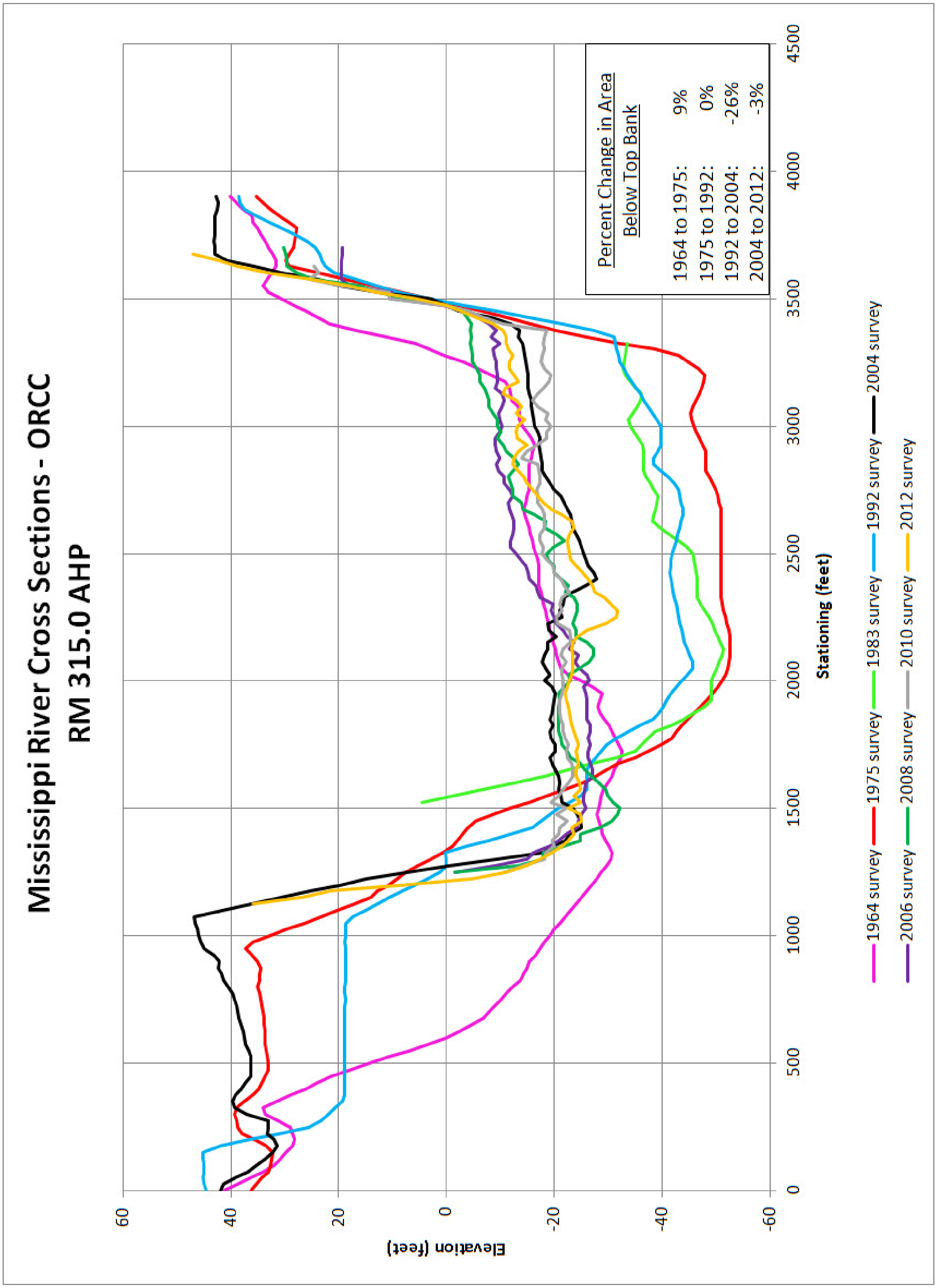

Mississippi River Cross Sections - ORCC
RM 310.0 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Stationing (feet)
Percent Change in Area
Below Top Bank
1964 to 1975: -10%
1975 to 1992: 4%
1992 to 2004: -13%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

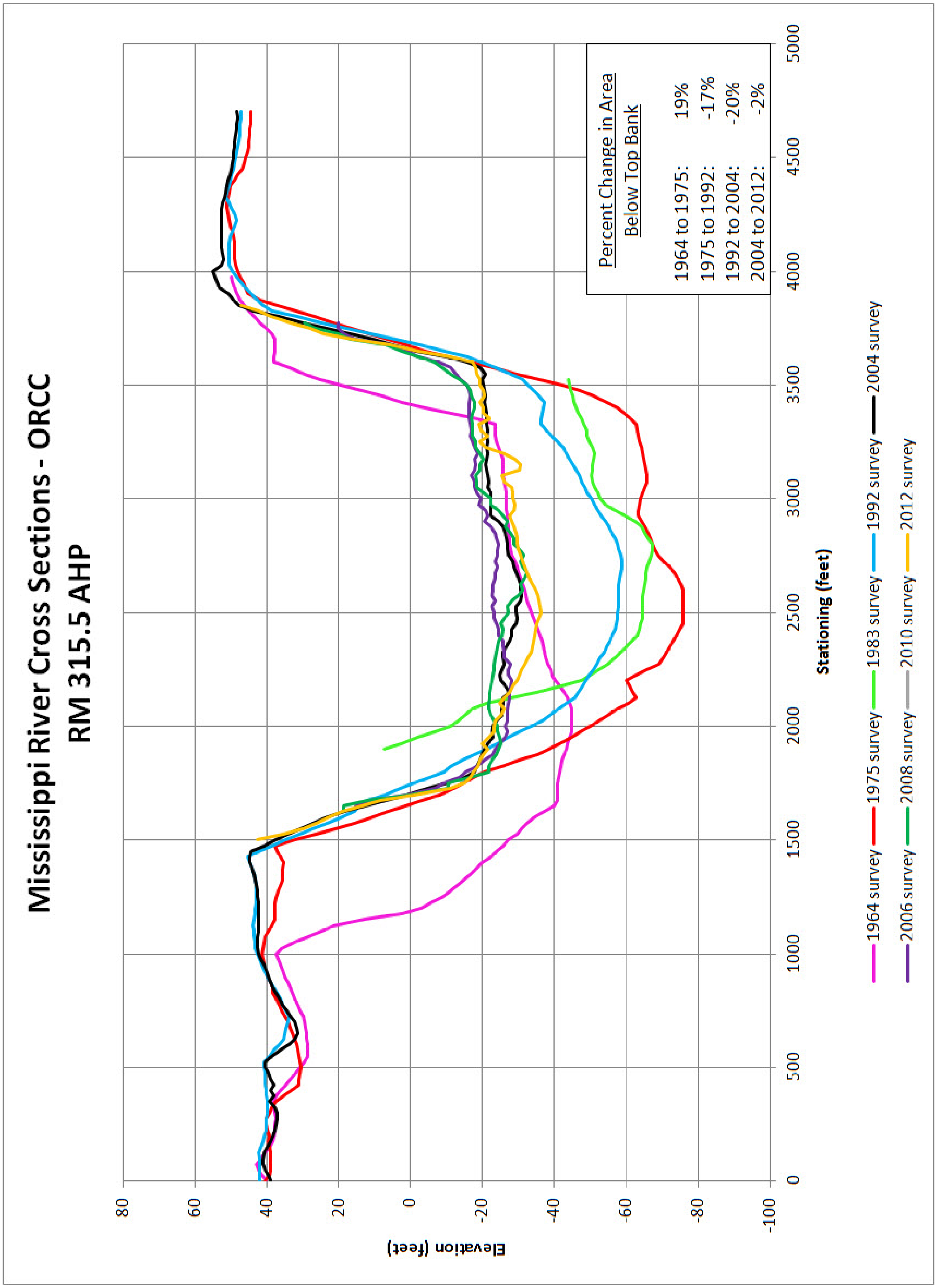

Mississippi River Cross Sections - ORCC
RM 311.0 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
-80
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
Percent Change in Area
Below Top Bank
1964 to 1975: -14%
1975 to 1992: 21%
1992 to 2004: -14%
2004 to 2012: -5%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

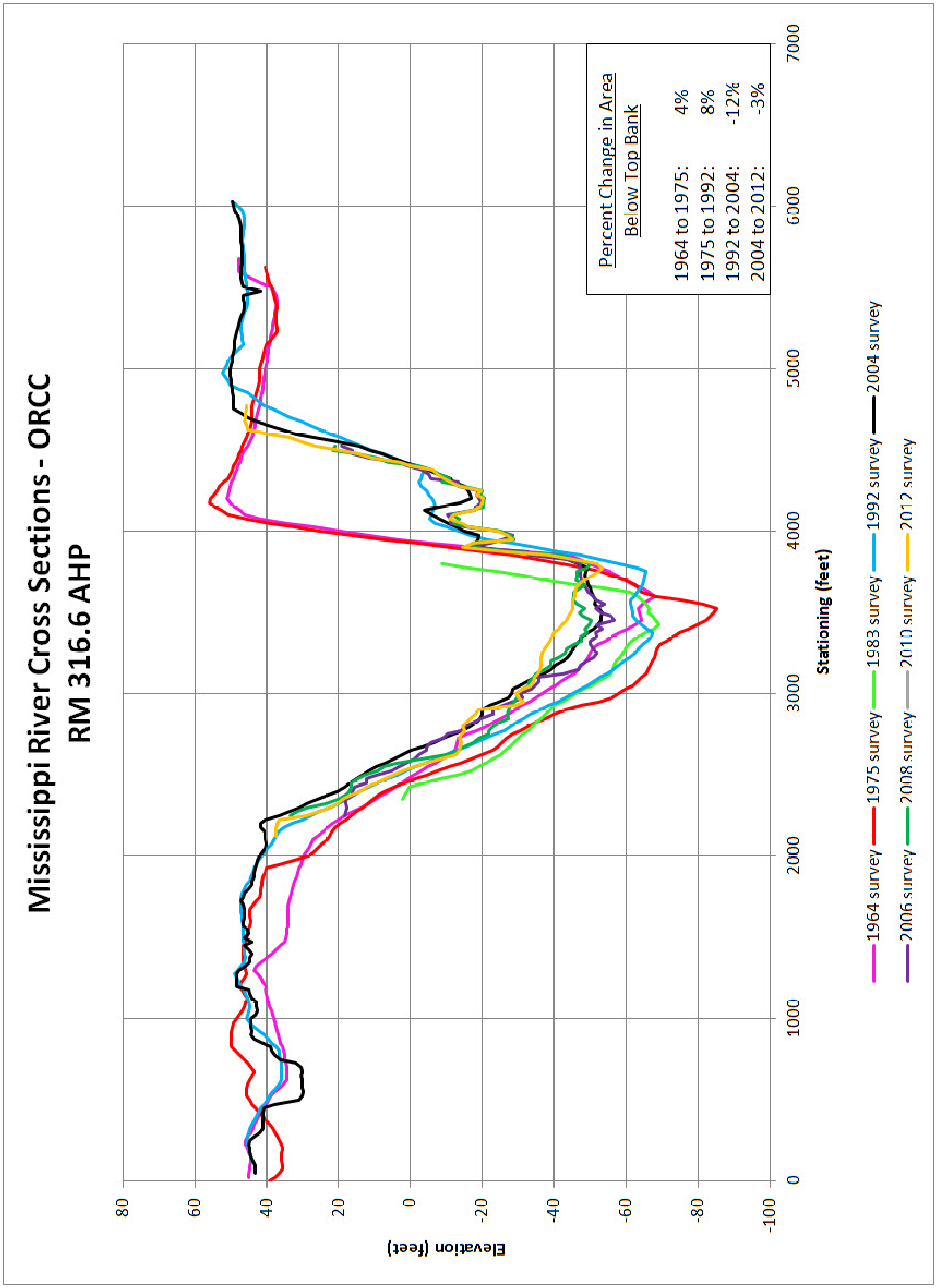

Mississippi River Cross Sections - ORCC
RM 312.1 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Percent Change in Area
Below Top Bank
1964 to 1975: -11%
1975 to 1992: 16%
1992 to 2004: -16%
2004 to 2012: -6%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

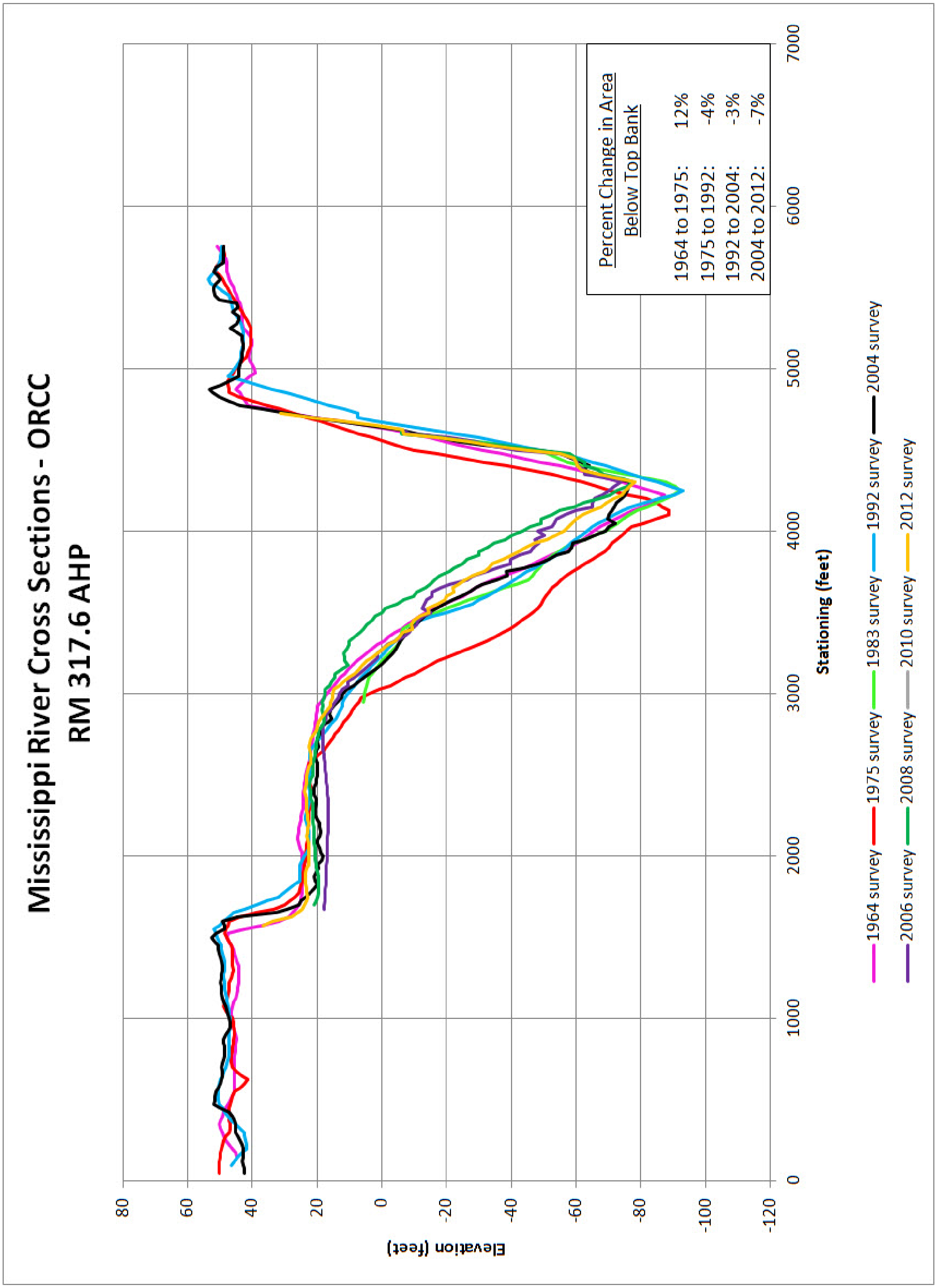

Mississippi River Cross Sections - ORCC
RM 313.5 AHP
Percent Change in Area
Below Top Bank
1964 to 1975: -4%
1975 to 1992: 13%
1992 to 2004: -11%
2004 to 2012: -4%
Elevation (feet)
60
50
40
30
20
10
0
-10
-20
-30
-40
Stationing (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey


Mississippi River Cross Sections - ORCC
RM 314.5 AHP
Elevation (feet)
Stationing (feet)
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Percent Change in Area
Below Top Bank
1964 to 1975: -17%
1975 to 1992: 13%
1992 to 2004: -16%
2004 to 2012: -7%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey


Mississippi River Cross Sections - ORCC
RM 315.0 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area Below Top Bank
1964 to 1975: 9%
1975 to 1992: 0%
1992 to 2004: -26%
2004 to 2012: -3%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

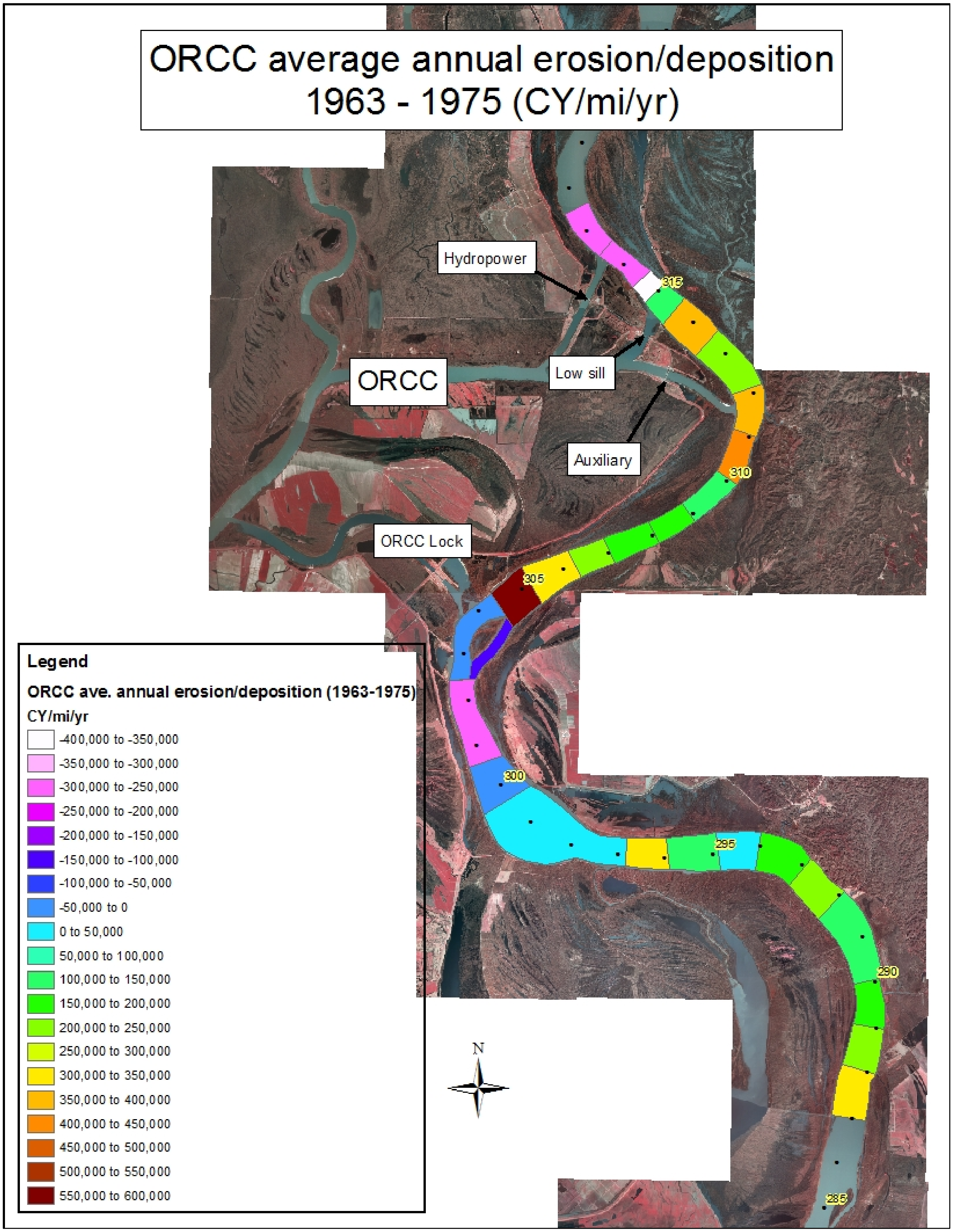

Mississippi River Cross Sections - ORCC
RM 315.5 AHP
Elevation (feet)
Stationing (feet)
Percent Change in Area
Below Top Bank
1964 to 1975: 19%
1975 to 1992: -17%
1992 to 2004: -20%
2004 to 2012: -2%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey
80
60
40
20
0
-20
-40
-60
-80
-100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Mississippi River Cross Sections - ORCC
RM 316.6 AHP
Elevation (feet)
80
60
40
20
0
-20
-40
-60
-80
-100
Stationing (feet)
0
1000
2000
3000
4000
5000
6000
7000
Percent Change in Area
Below Top Bank
1964 to 1975: 4%
1975 to 1992: 8%
1992 to 2004: -12%
2004 to 2012: -3%
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

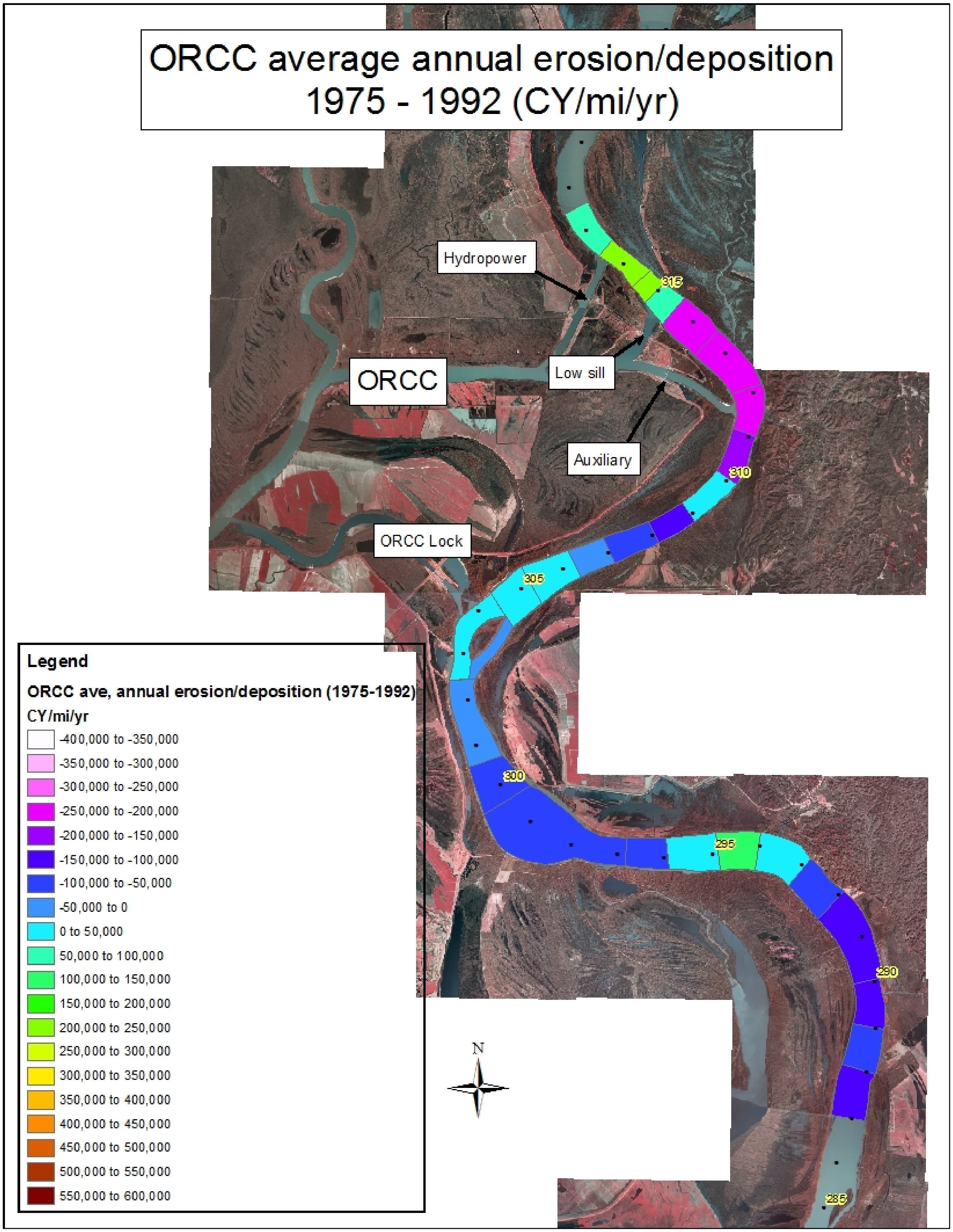

Mississippi River Cross Sections - ORCC
RM 317.6 AHP
Percent Change in Area Below Top Bank
1964 to 1975: 12%
1975 to 1992: -4%
1992 to 2004: -3%
2004 to 2012: -7%
Elevation (feet)
Stationing (feet)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
0
1000
2000
3000
4000
5000
6000
7000
1964 survey
1975 survey
1983 survey
1992 survey
2004 survey
2006 survey
2008 survey
2010 survey
2012 survey

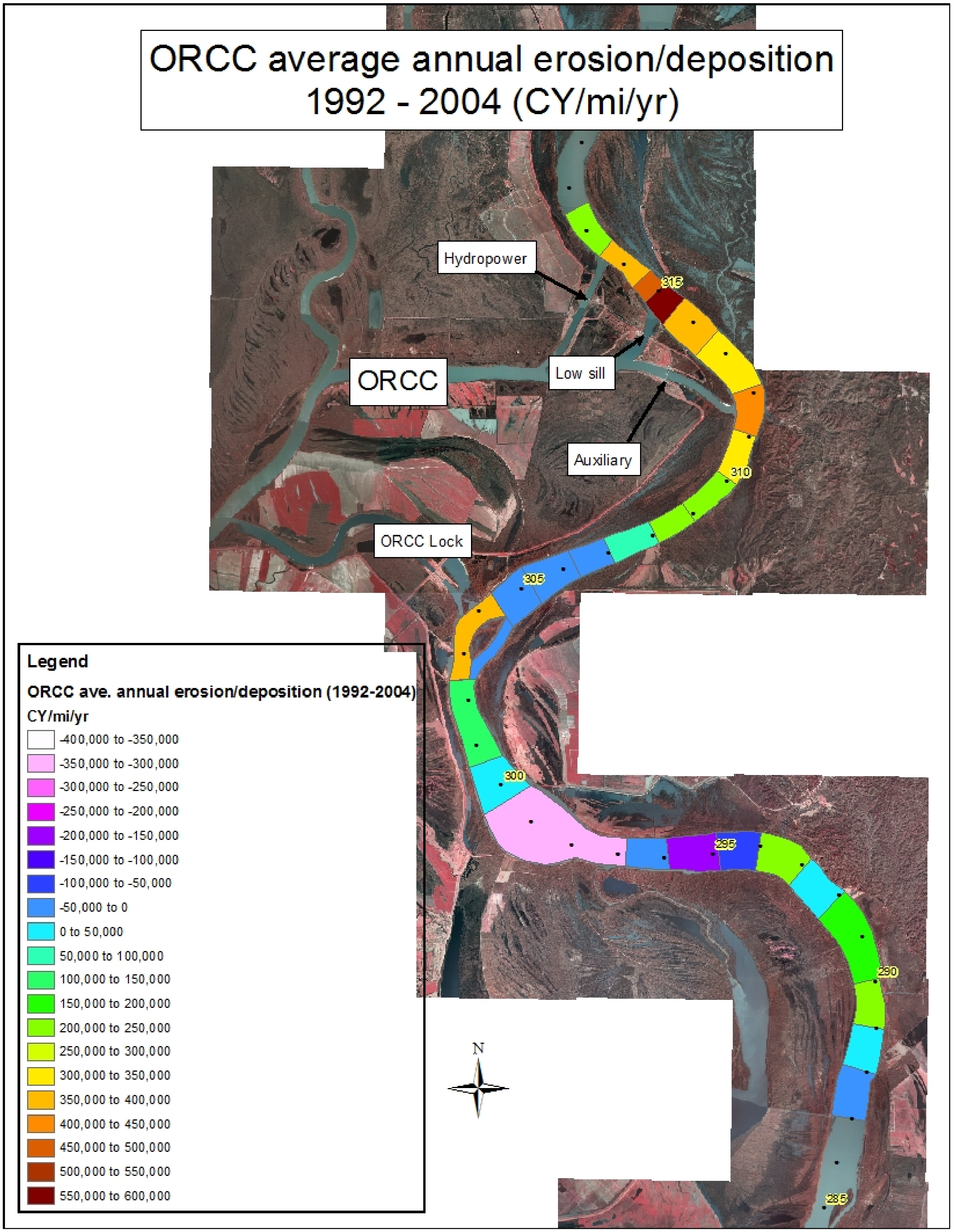
Appendix D: Geometry Data Analysis, Old River Control Complex (ORCC) Average Annual Erosion/Deposition Maps

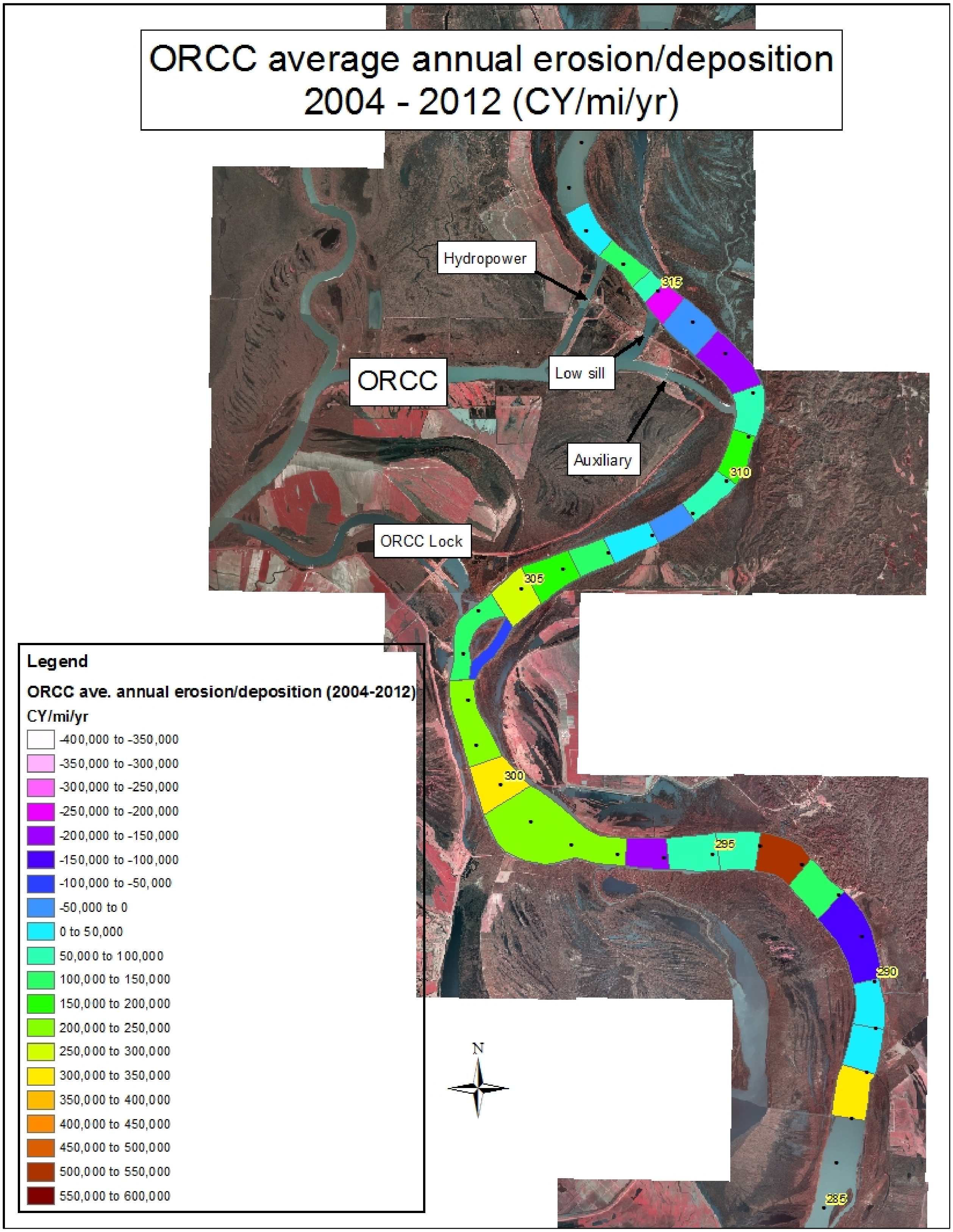
Abbreviations Used in Appendix D	
River mile	RM
Above head of passes	AHP
Cubic yards/mile/year	CY/mi/yr
Old River Control Complex	ORCC
Average	ave.



ORCC average annual erosion/deposition
1963 - 1975 (CY/mi/yr)
Hydropower
Low sill
ORCC
Auxiliary
ORCC Lock
315
310
305
300
295
290
285
N
Legend
ORCC ave. annual erosion/deposition (1963-1975)
CY/mi/yr
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000
450,000 to 500,000
500,000 to 550,000
550,000 to 600,000


ORCC average annual erosion/deposition
1975 - 1992 (CY/mi/yr)
Hydropower
Low sill
ORCC
Auxiliary
ORCC Lock
315
310
305
300
295
290
285
N
Legend
ORCC ave, annual erosion/deposition (1975-1992)
CY/mi/yr
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000
450,000 to 500,000
500,000 to 550,000
550,000 to 600,000


ORCC average annual erosion/deposition
1992 - 2004 (CY/mi/yr)
Hydropower
Low sill
ORCC
Auxiliary
ORCC Lock
315
310
305
300
295
290
285
N
Legend
ORCC ave. annual erosion/deposition (1992-2004)
CY/mi/yr
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000
450,000 to 500,000
500,000 to 550,000
550,000 to 600,000


ORCC average annual erosion/deposition
2004 - 2012 (CY/mi/yr)
Hydropower
Low sill
ORCC
Auxiliary
ORCC Lock
315
310
305
300
295
290
285
N
Legend
ORCC ave. annual erosion/deposition (2004-2012)
CY/mi/yr
-400,000 to -350,000
-350,000 to -300,000
-300,000 to -250,000
-250,000 to -200,000
-200,000 to -150,000
-150,000 to -100,000
-100,000 to -50,000
-50,000 to 0
0 to 50,000
50,000 to 100,000
100,000 to 150,000
150,000 to 200,000
200,000 to 250,000
250,000 to 300,000
300,000 to 350,000
350,000 to 400,000
400,000 to 450,000
450,000 to 500,000
500,000 to 550,000
550,000 to 600,000

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13. SUPPLEMENTARY NOTES
This report documents results of a joint research between USACE and State of Louisiana.

14. ABSTRACT
This report documents the geomorphic assessment component of the Mississippi River Hydrodynamic and Delta Management Feasibility Study. The overall objectives of the geomorphic assessment were to utilize all available data to document the historical trends in hydrology, sedimentation, and channel geometry in the lower Mississippi River and to summarize the local changes observed at locations where repetitive datasets exist and at key reaches determined during the study. The assessment focused on, but was not limited to, the river reach downstream of the Old River Control Complex and the time period from 1960 to the present (2013). The geomorphic assessment tasks included 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 defined, and the morphologic trends during different time periods were evaluated. The geomorphic assessment highlighted the importance of considering spatial and temporal variability when assessing morphological trends. Morphological trends on the Lower Mississippi River typically occur over decadal timescales. Consequently, there is considerable uncertainty with assessments that only cover short time periods. Therefore, investigators must be cautious when assuming that short term recent trends will predict future conditions.

15. SUBJECT TERMS
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Lower Mississippi delta
Mississippi River delta
Morphological trends in rivers
River channel geometry
Sediment budget
Sediment data
Specific gage records

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