

Historic Patterns of Sedimentation in Grand Lake, Louisiana

LAMAR HALE¹, MICHAEL GENE WALDON², C. FREDERICK BRYAN³,
PAUL A. RICHARDS⁴

¹*Louisiana Cooperative Fish & Wildlife Research Unit,
124 Forestry, Wildlife, and Fisheries, Louisiana State University,
Baton Rouge, LA 70803; email: lhale@mail.cadgis.lsu.edu*

²*WPI, 2000 Kraft Drive, Blacksburg, VA 24060;
TEL: 540-557-6080; FAX: 540-557-6085
email: waldon@members.asce.org*

³*Louisiana Cooperative Fish & Wildlife Research Unit,
124 Forestry, Wildlife, and Fisheries, Louisiana State University,
Baton Rouge, LA 70803; email: cbryan@lsuvm.sncc.lsu.edu*

⁴*Department of Civil Engineering, Center for Louisiana Inland Water Studies,
University of Southwestern Louisiana, P.O. Box 42291,
Lafayette, LA 70504-2291; email: par6763@usl.edu*

ABSTRACT: When Europeans first explored Louisiana, Grand Lake, formerly called Lake Chitimaches, was a major feature of what is now the Atchafalaya Basin. The natural process of lake sedimentation and succession of Grand Lake has been accelerated through natural and man-induced hydrologic modifications of the Atchafalaya River and Basin. Today, only small remnants of this former lake ecosystem remain. Grand Lake has succeeded into a deep river channel and floodplain swamp ecosystem.

Historic information on the bathymetry of Grand Lake was analyzed along eight surveyed transect lines, termed rangelines. In 1917, during the earliest rangeline surveys, Grand Lake covered an area of 352 km² (136 mi²). The rangeline profiles were surveyed at irregular time intervals over this century, and provide a dynamic picture of how sediments have filled and are filling Grand Lake. In 1917, average elevation above mean sea level (AMSL) of the most upstream and most downstream rangelines was -1.07 and -3.19 m (-3.5 and -10.5 ft), respectively. By 1978 the upstream rangeline had elevated to an average of 0.93 m (3.1 ft) AMSL; and downstream, in the 1980 survey, the rangeline had elevated to an average of -0.34 m (-1.1 ft). The rangeline survey data also document development of a deep channel through the lake.

In a first attempt to describe mechanisms and trends underlying the observed dynamics of bottom surface elevation, we developed a simple annual accretion model. This model assumes that annual accretion is proportional to annual volumetric water discharge, and that as average water depth increases accretion rate increases asymptotically toward a maximum. As bottom elevation rises, the model assumes that an equilibrium elevation is approached. At this equilibrium elevation, rangeline accretion is hypothesized to stop. Following calibration, the model was in close agreement with the observed rangeline elevation values.

The sedimentation of Grand Lake has significant implications not only for the Atchafalaya Basin ecosystem, but also for the Gulf of Mexico littoral ecosystem which it feeds. As Grand Lake filled, a significant mechanism of benthic storage and removal of sediments in the Atchafalaya River Basin disappeared. Temporal patterns of sediment delivery to the Gulf have changed and the fraction of sediment load discharging to the Gulf has increased. These changes can affect not only the growing Atchafalaya Bay deltaic ecosystem, but also human needs for navigation and flood control. The rapid and unusually well documented succession of Grand Lake provides a model of coastal sedimentation patterns which may provide insight into more general mechanisms of sedimentation in shallow inland and coastal waters.

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Introduction

Today, the Atchafalaya River originates near the confluence of Old River and the Red River. Locations along the channel are typically identified as river miles downstream from this confluence which is five river miles north of Simmesport, Louisiana. The present 2190 km² (846 mi²) Atchafalaya Basin Floodway that lies between the East and West Floodway Protection Levees has been termed "America's Greatest River Swamp" (United States Fish and Wildlife Service 1978). The Atchafalaya Basin extends inland 201 km (125 mi) and is roughly 24 km (15 mi) wide. The Atchafalaya River is effectively dammed across its entire lower end by natural levees of long abandoned Mississippi River courses (Russell 1967). Long term patterns of sediment deposition in the Atchafalaya Basin are driven by subsidence and the development of distributary channels (Tye and Coleman 1989a; Tye and Coleman 1989b). Grand Lake, the large lake which formed at the lower end of the Basin, primarily discharges through two outlets, the Lower Atchafalaya River at Morgan City, and the Wax Lake Outlet artificial channel, completed in 1942. In recent decades sedimentation has filled most of the area of Grand Lake (Fig. 1).

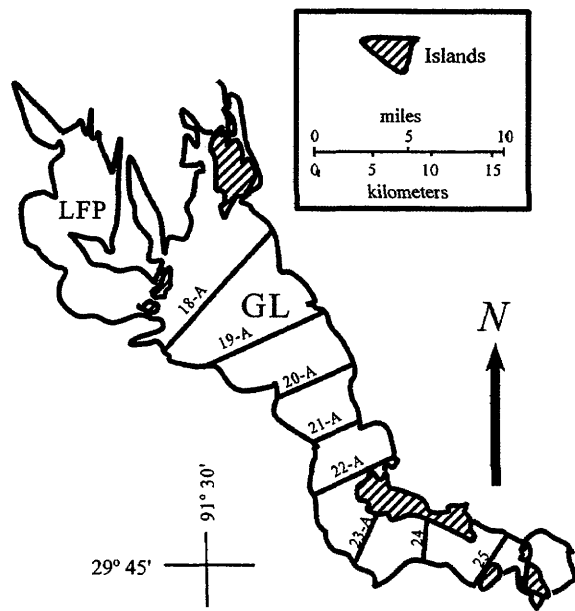


Fig. 1. Grand Lake (GL) and Lake Fausse Point (LFP) shorelines as mapped in 1917. Locations of the 8 Rangelines examined in this study are shown (18-A, 19-A, 20-A, 21-A, 22-A, 23-A, 24, and 25).

Unlike the Mississippi, the Atchafalaya River empties into the Gulf of Mexico through passes into a relatively shallow bay. Thus, in contrast to the Mississippi delta, the Atchafalaya River Delta is actively growing (Adams and Baumann 1980; van Heerden et al. 1983). This accreting delta will provide benefits to Louisiana's fisheries and protection of existing lands and property from erosion and storms. Although this growing delta causes some manageable problems for navigation and potentially impacts local flooding, its benefits vastly outweigh these costs which ultimately may be unavoidable.

The Flood Control Act of 1928 authorized the "Mississippi River and Tributaries Flood Control Plan" and developed the plan to utilize the Atchafalaya Basin as a floodway to reduce flood stages in the Lower Mississippi River. Today, the Atchafalaya Basin serves multiple uses. The principal role, and arguably the most valuable role, of the Atchafalaya Basin Floodway system is to convey one half of the 85,000 m³ s⁻¹ (3,000,000 cubic feet per second, cfs) design flood of the "Mississippi River and Tributaries Flood Control Plan." During such conditions the Atchafalaya Basin conveys half of the total Mississippi River Basin flood discharge to the Gulf. To insure use as a floodway, the federal government has purchased flowage easements on property within the Atchafalaya Basin and regulates development which might interfere with floodway operation. Other important uses of the Atchafalaya Basin include fishery production, sport and non-sport wildlife production, tourism, recreation, agriculture, and silviculture.

At the beginning of the nineteenth century the relationship of the Red River and the Atchafalaya River to the Mississippi River was different from the present configuration (Fisk 1952; Hebert 1967; Reuss 1991; Hale 1996; Reuss 1998). At that time, the Red River was a tributary to the Mississippi River in a large meander loop, and the Atchafalaya River was a very minor Mississippi River distributary originating just downstream of the confluence of the Red and Mississippi Rivers. The head of the Atchafalaya River at this time was blocked by a massive log jam; so massive that cattle were driven across it and live willow trees were

observed growing from it (Hebert 1967; Reuss 1998). The relationship of these rivers was changed dramatically in 1831 when Captain Henry Shreve was authorized to create an 800 ft cut-off through the neck of the Mississippi River's meander loop (later known as Shreve's Cut), which isolated the mouth of the Red River and head of the Atchafalaya River from the main flow of the Mississippi. The upper portion of the severed "Shreve" meander loop soon filled with sediment. The lower portion of the meander loop formed what is now termed Old River, whereupon, the Atchafalaya River began to capture flow from the Mississippi River main channel. The Red River evolved from a tributary of the Mississippi to a headwater of the Atchafalaya River. Demolition of the raft of trees on the Atchafalaya River allowed improved navigation and further changed the regional hydrologic relationships. Between 1900 and 1950, the annual discharge of the Atchafalaya River grew from 12% to 30% of the combined Mississippi River and Red River discharges.

The U.S. Congress, acting to avoid the economic and environmental disaster associated with complete capture of the flow by the Atchafalaya, authorized planning and construction by the U.S. Army Corps of Engineers to ensure that the discharge in these channels remain at the 1950 ratio (Hebert 1967; McPhee 1989; Reuss 1998). It was projected at that time that a 70/30 flow ratio could be maintained in a stable channel configuration, but that if left uncontrolled, the main river flow would naturally reroute to the Atchafalaya by about 1975. The Old River Control Structure (ORCS), completed by the Corps in 1963, controls diversion from the Mississippi River into the Atchafalaya Basin through two dam-like structures. Following flood damage to the ORCS in 1973, the U.S. Congress authorized construction of an auxiliary structure to assist in flow control. Recently, the Sidney A. Murray Jr. Hydroelectric Station generating facility has been constructed and incorporated into the overall control facilities.

Suspended sediment concentrations and loads in the Mississippi River have decreased for several decades (Keown et al. 1986; Dardeau and Causey 1990; Mossa 1990; Mossa 1993). Red River

suspended sediment concentration has declined recently, likely caused by the completion of Red River lock and dam projects. This recent decline in Red River suspended sediment concentration is particularly alarming in terms of coastal accretion because historically the Red River contributed loading to the Atchafalaya in a proportion larger than its contribution to volumetric water discharge (Mossa 1990; Mossa 1993). Operation since 1990 of the newly constructed Murray Hydroelectric Power Plant (design capacity 4500 m³ yr⁻¹ or 160,000 cfs), and the Auxiliary Control Structure, completed in 1987, also certainly have affected bedload (and to some degree suspended sediment) distributions from the Mississippi River to the Atchafalaya River.

During the early 1930's the route of the Atchafalaya River through the Atchafalaya Basin was altered. Originally, the major flow of the Atchafalaya River turned sharply eastward near Butte La Rose and followed a course which was in-part outside the current East Atchafalaya Basin Protection Levee. Before the 1930's the Atchafalaya River channel did not pass through Grand Lake. Flow through Grand Lake was limited to discharge through a web of small distributaries and overland flows during flood events. In the early 1930's the main Atchafalaya River channel was rerouted to flow through Grand Lake. Although this new channel may have improved channel capacity and created an efficient hydraulic connection to the newly constructed Wax Lake Outlet, it also promoted succession of Grand Lake through the increased deposition of sediments.

In the nineteenth century Grand Lake, also called Lake Chitimaches, was a dominant feature of the Atchafalaya Basin covering approximately 15% of the present day Atchafalaya Basin. Today, only small shallow remnants of the lake exist within the protection levees of the Atchafalaya Floodway. This rapid reduction of lake volume is similar to that documented in some man-made reservoirs which have filled in less than 25 yr (Chanson and James 1998). Protected from sediment load of the Atchafalaya, an arm of the former lake has been preserved as Lake Fausse Point (Tye and Coleman 1989a), located to the west of the West Atchafalaya

Basin Protection Levee. The rapid disappearance of Grand Lake has heightened concern about succession and loss of other features within the Atchafalaya Basin. While sedimentation and delta growth are most often considered desirable processes in the Atchafalaya Bay, sedimentation and associated succession are most commonly considered undesirable within the Atchafalaya Basin. This paper focuses on changes in Grand Lake, documented in records of the eight rangelines (upstream to downstream 18-A, 19-A, 20-A, 21-A, 22-A, 23A, 24, and 25) which cross this lake.

Methods and Materials

In order to identify changes in the capacity of the Atchafalaya Basin to convey flood discharges, the U.S. Army Corps of Engineers has surveyed elevations along transects, termed rangelines, at irregular intervals beginning in 1916. Data from these surveys were obtained from the New Orleans District Office of the Corps of Engineers as large format graphs of elevation plotted against distance along the rangeline. Rangeline data for the entire Atchafalaya Basin for all years were digitized and registered into a three-dimensional georeferenced Intergraph Microstation GIS database. In this 3-d database, the rangelines can be analyzed from many different aspects.

Average elevation was measured using the Microstation polygon area function. A horizontal base line of arbitrary elevation was constructed directly below each rangeline. Vertical lines were then erected from this baseline connecting to the rangeline under consideration at its endpoints or the inner levee toe, and at the main river channel banks. The area of the resulting polygon (or polygons if a section of the main channel crossed the rangeline) was then divided by the total length of the baseline under the polygon to determine the average elevation of the rangelines above the baseline elevation excluding the levees and main Atchafalaya River Channel. These elevations were imported into a spreadsheet for further analysis.

Results

Data from 79 rangeline surveys of Grand Lake in 23 different years over the period from 1916 to

1988 were available for this study (Table 1). Because of budget and logistical considerations, all eight rangelines were surveyed in only one (1974) of these 23 years. River miles listed with rangeline numbers in Tables 1 and 2 provide an approximation of location within the Atchafalaya Basin. As a reference, the Corps of Engineers Butte La Rose gage (03120) is located at river mile 64.8, the Six Mile Lake gage (03645) is located at river mile 105.2, and the gage at Morgan City (03780) is located at river mile 117.7.

Over the entire period of observation the bottom surface elevation sloped toward the Gulf. In the earliest observations in 1917, the minimum elevation was -3.19 m at rangeline 25 near river mile 110. By 1980 this downstream elevation had risen to -0.34 m, an average rate of accretion of 4.5 cm yr⁻¹. From 1917 to 1941 accretion rate at this rangeline was 4.2 cm yr⁻¹, and from 1941 to 1980 accretion rate was 4.7 cm yr⁻¹, an increase of 12%. At the upstream rangeline, 18-A, at river mile 85, elevation rose from -1.07 in 1917, to 0.09 in 1940, to 0.93 m in 1978. This corresponds to an accretion rate of 3.3 cm yr⁻¹ over 1917 to 1978, a rate of 5.0 from 1917 to 1940 and a rate of 2.2 cm yr⁻¹ from 1940 to 1978. Thus, at the upstream rangeline accretion rate dropped 56 percent in the later period.

Overall average accretion rate for all rangelines over the entire period of study was 3.6 cm yr⁻¹. This is an unusually high rate of accretion. Referring to canals and wetlands, Dortch (1996) states that "accretion rates are typically on the order of 0.1 to 1.0 cm yr⁻¹. Extensive reservoir sedimentation survey statistics compiled by Dendy (1969) show that typical accretion rates are more than an order of magnitude below the values determined here. The high rate of accretion observed in Grand Lake may be attributed to the high suspended sediment concentration of the Atchafalaya River, the very large flow passing through the lake, and the initial lake depth.

To provide comparative water surface elevations, stage data from three Atchafalaya River Stage gages were analyzed (Fig. 2). Lines of water surface elevation, termed flowlines, at three different discharge values were derived from published stage and discharge data for the 1974 calendar year.

Table 1. Average Grand Lake rangeline elevation in meters above mean sea level (AMSL). Main channel and main channel natural or artificial levees are excluded.

Year	18-A	19-A	20-A	21-A	22-A	23-A	24	25
1916				-1.65	-1.86			
1917	-1.07	-1.35	-1.44			-2.14	-2.42	-3.19
1934	-0.52	-0.91	-1.41	-1.93	-1.68			
1940	0.09	-0.28	-0.77					
1941				-1.34	-1.31	-1.62	-2.09	-2.18
1950		0.47	0.13	-0.64	-0.90			
1951	0.72	0.39		-0.50	-0.91	-1.71	-1.58	-2.62
1953			0.35					
1956							-1.14	
1959				-0.18		-1.19	-0.74	
1963	0.71	0.76			-0.13			-1.24
1964				0.07		-0.70	-0.48	
1967				-0.16		-1.02	-0.51	-0.78
1968	0.78	0.77	0.33		0.00			
1972				0.04		-0.54		
1974	0.98	0.76	0.58	0.34	0.51	-0.27	-0.22	-0.05
1975				0.39	0.56			
1976			0.47			0.01	0.16	-0.14
1978	0.93							
1980				0.07	0.22		0.03	-0.34
1987				1.18	0.40			
1988			-0.17			0.10	0.00	

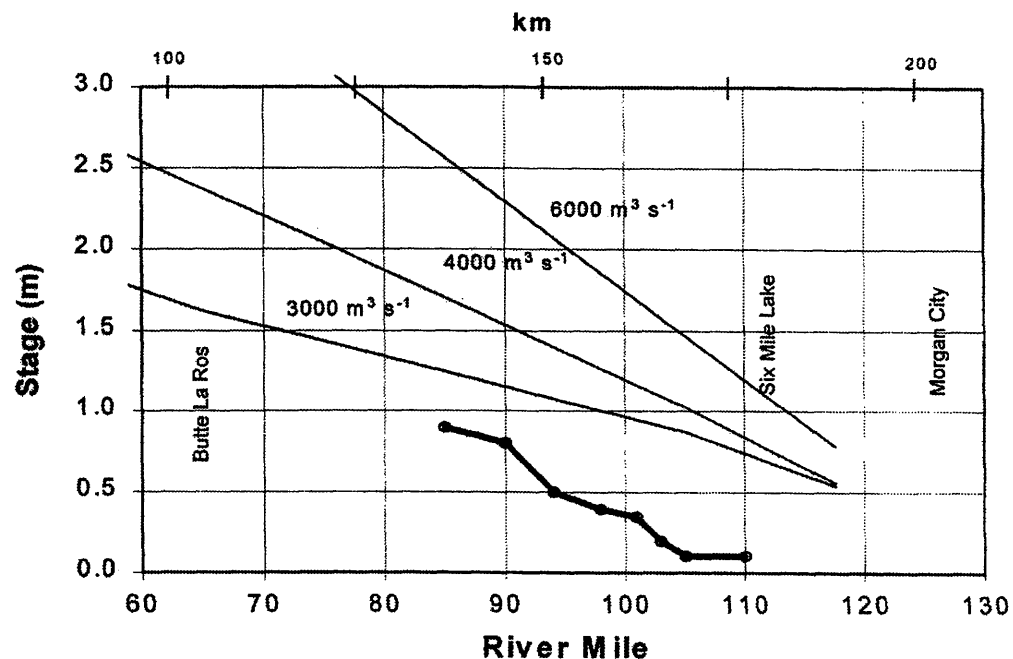


Fig. 2. Model equilibrium elevations (heavy line), and flowlines of water surface elevation at 3000, 4000, and 6000 m^3s^{-1} discharge derived from 1974 USACE stage data.

Elevations at Butte La Rose, Six Mile Lake, and Morgan City were determined for three Atchafalaya River discharges measured at Simmesport. Flowlines for 3000, 4000, and 6000 m³ s⁻¹ (106, 141, 212 thousand cfs) were determined. These discharges represent approximately the 25, 40, and 60 % flow duration (i.e. percent of days that the flow is not exceeded) since the Old River Control Structure began operation (Wells and Demas, 1977).

Model Development

Observations listed in Table 1 are difficult to analyze because of the large number of missing values for any specific year. Additionally, variability in individual observations obscures more general trends. In order to overcome these difficulties, a simple empirical model of annual accretion was developed and compared to the values in Table 1. Sedimentation and accretion models are most commonly based on an assumed particle settling velocity determined through calibration or using Stoke's Law (Cerco and Cole 1995; Dortch 1996). Application of these models requires at a minimum, a knowledge of water velocities and depths; these were unavailable for Grand Lake. In consideration of this limitation, the model developed here is empirical and is based on observed trends and asymptotic reasoning. Annual change in average elevation was modeled as:

$$r_t = E_t - E_{t-1} = \frac{E_0 - E_{t-1}}{K + E_0 - E_{t-1}} = r_{\max} \quad (1)$$

$$r_{\max} = r_0 Q_t^a \quad (2)$$

where r_t is the annual accretion rate over year t (m yr⁻¹),

E_t is average rangeline elevation AMSL (m) at the end of year t ,

E_0 is the equilibrium (maximum) accretion elevation (m),

r_{\max} is the maximum accretion rate (m yr⁻¹),

Q_t is river annual calendar-year average volumetric discharge (m³s⁻¹),

K is the distance (m) below E_0 at which accretion rate is reduced to half r_{\max} , and r_0 and a are constants.

For Grand Lake these parameters were estimated through a visual calibration to the observed values. An optimal value of the exponent "a" was found to be near unity, and a value of 1 was accepted as the calibrated value. The parameter r_0 was determined to be 1.803 s m⁻² yr⁻¹ through calibration. For these parameter selections, the average value of r_{\max} over the period from 1934 to 1990 is 9.95 cm yr⁻¹. The parameter K was found, through calibration, to be 0.4 m at all rangelines. The maximum accretion elevation, E_0 , was found to depend on the rangeline location, and generally decreased from upstream to downstream locations. For the rangelines 18-A, 19-A, 20-A, 21-A, 22-A, 23-A, 24, and 25, the value of E_0 was estimated to be 0.9, 0.8, 0.5, 0.4, 0.35, 0.2, 0.1, and 0.1 m, respectively (Table 2; Fig. 2).

Because the spatial pattern of flows through the Atchafalaya Basin was radically changed in the 1930's, the calibrated model was initiated in 1934 (Table 2). Initial values were input for 1934, and subsequent years were then calculated on an Excel spreadsheet using the parameters cited above (Table 2). Calculated values were in close agreement (Fig. 3) with the observations listed in Table 1.

One goal of this study is to provide a more generalized method for projecting accretion which may be particularly useful in planning river diversions for habitat restoration. It is therefore further conjectured that r_{\max} can be related to annual average suspended sediment concentration, c_a and water application rate (discharge per unit area inundated), q_t , by:

$$r_{\max} = r^* q_t \frac{c_a}{\lambda} \quad (3)$$

where

r^* is a dimensionless constant which may be expressed as a percentage,

γ is surficial sediment bulk density, the dry weight of bottom sediments per unit accreted volume (kg l⁻¹),

and

$$q_t = \frac{Q}{A} \quad (4)$$

Table 2. Model calculated average Grand Lake rangeline elevation in m above mean sea level (AMSL). Model parameters are displayed near the top of the table.

	Rangeline/River Mile							
Rangeline	18-A	19-A	20-A	21-A	22-A	23-A	24	25
River Mile	85	90	94	98	101	103	105	110
E_0 (m)	0.9	0.8	0.5	0.4	0.35	0.2	0.1	0.1
K (m)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
r_0 (cm cms ⁻¹ yr ⁻¹)	1.803	1.803	1.803	1.803	1.803	1.803	1.803	1.803
a	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
YEAR								
1916	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1917	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1934	-0.30	-0.70	-1.15	-1.80	-1.90	-3.00	-2.60	-3.10
1940	0.00	-0.38	-0.82	-1.45	-1.55	-2.63	-2.24	-2.73
1941	0.04	-0.33	-0.78	-1.40	-1.50	-2.58	-2.19	-2.68
1950	0.59	0.29	-0.13	-0.68	-0.77	-1.79	-1.43	-1.89
1951	0.64	0.36	-0.05	-0.58	-0.68	-1.68	-1.32	-1.78
1953	0.71	0.45	0.05	-0.46	-0.55	-1.54	-1.19	-1.64
1956	0.77	0.53	0.15	-0.34	-0.42	-1.39	-1.05	-1.49
1959	0.83	0.65	0.29	-0.13	-0.22	-1.13	-0.81	-1.23
1963	0.87	0.73	0.40	0.07	-0.01	-0.84	-0.56	-0.94
1964	0.88	0.74	0.41	0.09	0.01	-0.81	-0.52	-0.91
1967	0.89	0.77	0.45	0.19	0.12	-0.63	-0.38	-0.73
1968	0.89	0.78	0.46	0.23	0.16	-0.56	-0.32	-0.66
1972	0.90	0.79	0.49	0.34	0.28	-0.28	-0.11	-0.38
1974	0.90	0.80	0.50	0.38	0.32	-0.10	0.00	-0.20
1975	0.90	0.80	0.50	0.38	0.33	-0.03	0.03	-0.13
1976	0.90	0.80	0.50	0.39	0.34	0.00	0.04	-0.10
1977	0.90	0.80	0.50	0.39	0.34	0.03	0.05	-0.07
1978	0.90	0.80	0.50	0.39	0.34	0.06	0.06	-0.04
1980	0.90	0.80	0.50	0.40	0.35	0.12	0.08	0.02
1987	0.90	0.80	0.50	0.40	0.35	0.19	0.10	0.09
1988	0.90	0.80	0.50	0.40	0.35	0.19	0.10	0.09

The value of q_1 is commensurable with precipitation rate and other area-specific intensive parameters, and may be most conveniently reported as $m\ yr^{-1}$.

The parameter r^* can be interpreted as the fraction of the suspended sediment which is removed from the water column in the process of accretion and is related to trapping efficiency defined in other sedimentation studies (Strand and Pemberton 1982; Salas and Shin 1999). Solving Equations 2 and 3 gives:

$$r^* = r \frac{A\lambda}{c} \quad (5)$$

Using parameter values available from the literature, the value of r^* can be roughly estimated. Over the period 1964 through 1974, Atchafalaya River suspended sediment concentration averaged $460\ mg\ l^{-1}$ (Wells and Demas 1977). Although suspended sediment concentrations in the Mississippi River have declined since the middle of this century (Dardeau and Causey 1990), a constant value is used here for analysis in order to simplify computation, and because very roughly half of the suspended sediment of the Atchafalaya River is supplied by the Red River (Mossa 1990) which is not known to have declined in suspended sediment concentration prior to the relatively recent

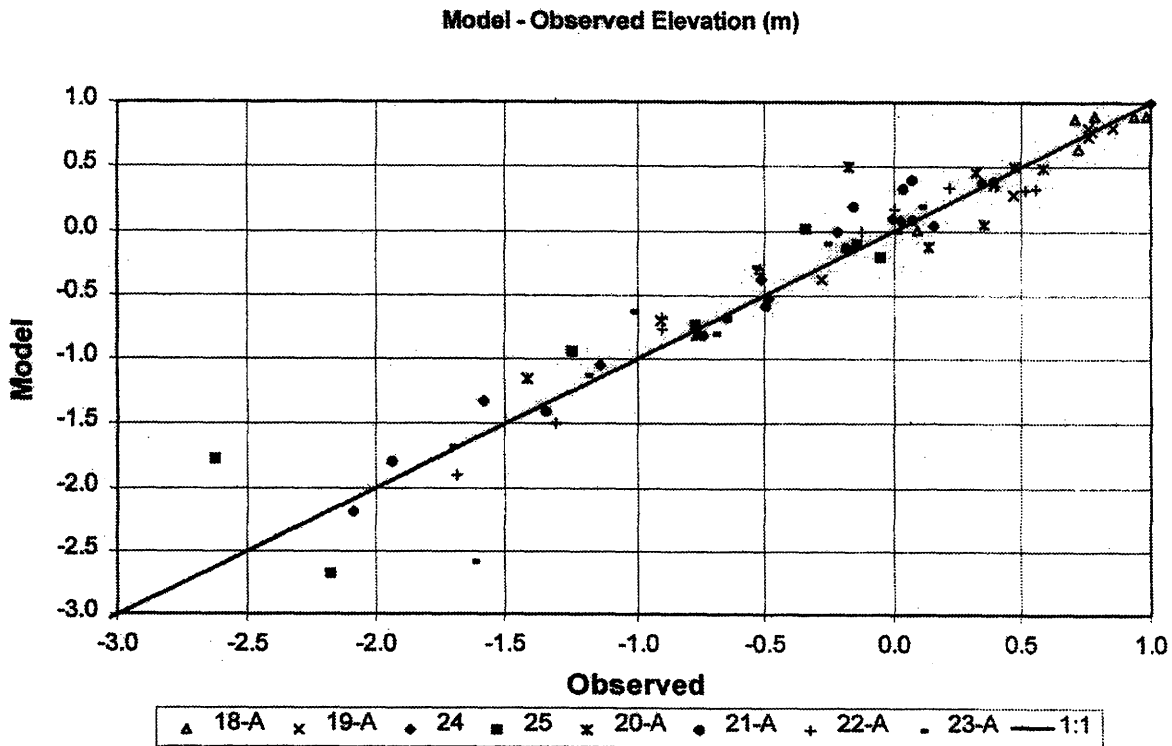


Fig. 3. Comparison of model and observed average rangeline elevations. Solid line is line of perfect fit (1:1 slope).

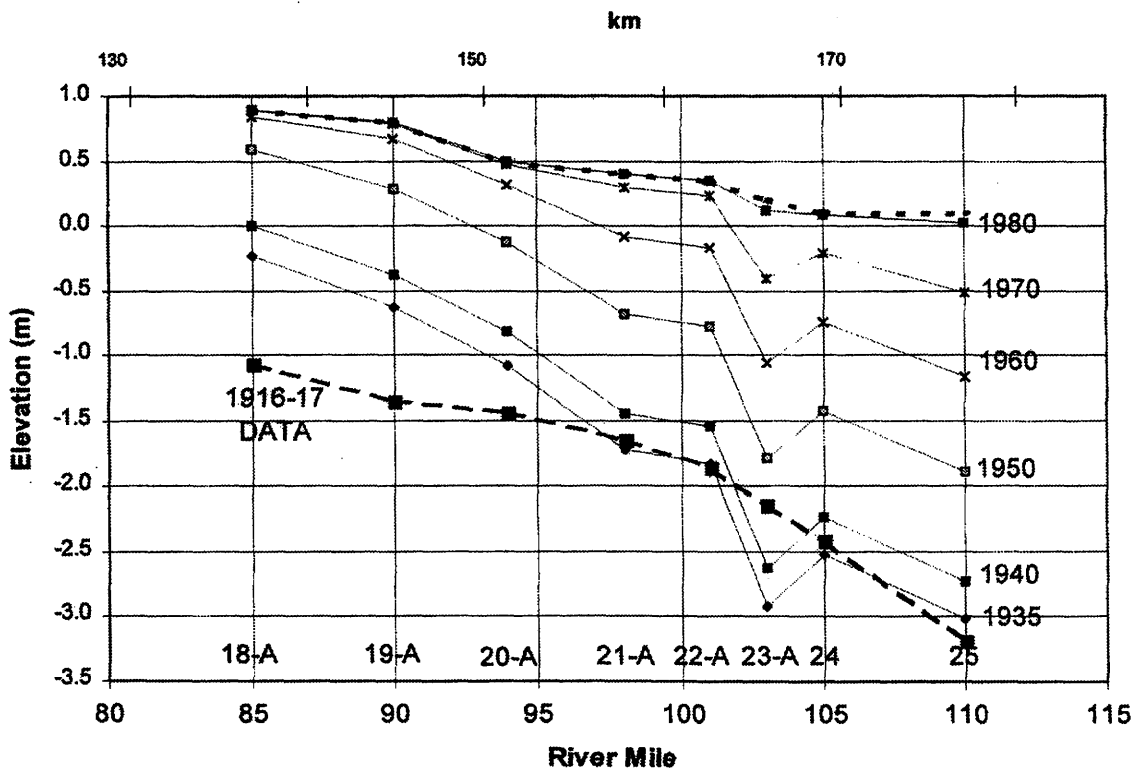


Fig. 4. Average elevation along Grand Lake rangelines. Points from 1916-1917 are observed values, solid lines are model projections, upper dashed line is equilibrium elevation.

navigation improvements. Bottom surficial sediment densities have been compiled for a large number of North American lakes by Dendy and Champion (1969). A typical value of 1.12 kg l^{-1} (70 lb ft^{-3}) is used here. Combining these values with the original area of Grand Lake provides an estimate of 49% for r^* .

This estimate may be further compared to the peak percent of load removal projected in the model. Wells and Demas (1977) report that the average suspended sediment load passing Simmesport is $86 \times 10^6 \text{ t yr}^{-1}$ ($260,000 \text{ t d}^{-1}$). The peak modeled annual accretion rate (Fig. 5) is $38 \times 10^6 \text{ m}^3$, which, using 1.12 t m^{-3} , converts to $43 \times 10^6 \text{ t yr}^{-1}$, or 50% of the average suspended sediment load. Average annual accretion projected by the model from 1965 through 1971 is $11.8 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$. This would correspond to an annual removal of $13.2 \times 10^6 \text{ t}$. Wells and Demas (1977) report that although data are limited, it is estimated that over this period approximately 75% of the suspended sediment load at Simmesport was transported through the two outlets. They also

report that net scour of the Basin was observed during the floods of 1973, 1974, and 1975.

Discussion and Conclusions

Accretion in Grand Lake peaked around 1950, and has generally diminished since that time (Fig. 5). Sedimentation and succession of Grand Lake will continue in isolated areas, but at a greatly reduced rate. In the future, sedimentation will likely focus on the remaining low-lying areas of the former lake as upper rangelines equilibrate at a mean elevation of $<1 \text{ m}$. During the disappearance of deep open water, the river channel extended itself through its growing floodplain. Development of a more efficient channel must, to some degree, reduce the sediment load flowing over the elevated floodplain, and affect final equilibrium elevations. Succession is approaching a final equilibrium condition with a typical channel, natural levee, and flood plain morphology. Today, the rate of sediment trapping in the former Grand Lake has greatly slowed or stopped, and Grand Lake is approaching an equilibrium surface elevation.

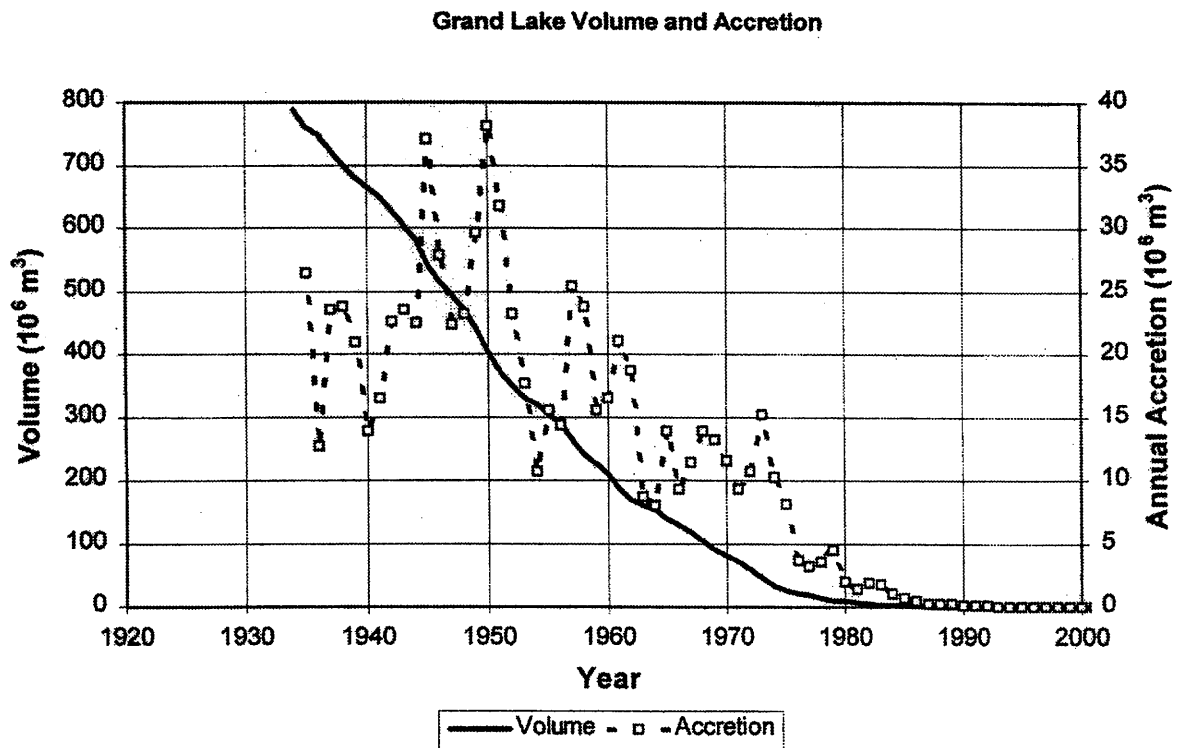


Fig. 5. Model projected Grand Lake volume (below equilibrium elevation) and annual accretion rate.

During the decades of the 1930's and 1940's a significant fraction, perhaps 20-40%, of the suspended sediment load entering the Atchafalaya Basin remained in the Basin and was unavailable for delta accretion in Atchafalaya Bay. Fisk (1952) projected that the Atchafalaya Basin would be filled with sediment by the early 1970's, and a new marine delta would then build in Atchafalaya Bay (Tye and Coleman 1989b). Since the mid 1970's, Grand Lake has been effectively filled. Today, the sediment trapping efficiency of the lake has declined to near zero, and nearly all suspended sediment entering Grand Lake is delivered to Atchafalaya Bay. Similar successional patterns have been observed in man-made reservoirs (Lajczak 1996; Kern and Westrich 1997).

Patterns of sedimentation have been identified in this study. Accretion slows and finally stops as elevation approaches an equilibrium elevation. Areas of deep water accrete sediments more rapidly than shallow water bodies. Lakes also may preferentially fill with sediments from upstream to downstream segments. Expression of these patterns to the point that they can be identified and quantified depends on local hydraulic conditions and suspended sediment availability.

Accretion occurs preferentially in deep areas. This observation is consistent with observations and models of reservoir sedimentation (Strand and Pemberton 1982). In Grand Lake, we found that accretion slows to 33% of the maximum rate at a bottom elevation 0.2 m below the equilibrium elevation. For a depth of 2 m below the equilibrium elevation, sedimentation occurred at >80% the maximum rate determined by suspended sediment load. Thus, the rate of sediment accretion is relatively uniform and higher in deeper waters.

The model developed here does not consider the longitudinal reduction of suspended sediment concentration which results from upstream accretion. Here this is appropriate because detention times are sufficiently short. In other situations it may be appropriate to consider upstream trapping and loss of suspended sediment by subdividing the study area into interconnected segments.

A better understanding is needed of the factors that determine the equilibrium surface elevation. It is likely that this elevation is related to some statistic (e.g. mean annual low water) of local water-surface elevation. Mechanisms which reduce observed accretion as the equilibrium elevation is approached include loss of sediment source, increased scour and erosion, and enhanced consolidation of higher elevation surfaces.

Preferential accretion in deep water may be one mechanism contributing to indirect land loss from excavation of canals in wetlands. In situations where suspended sediment supply is limited, sediments may preferentially settle in deep canals and therefore are unavailable to maintain surface elevations of surrounding wetlands.

The methodology reported here could provide a quantitative basis for projecting and analyzing river diversion projects which divert flow to open water. It may also provide a basis for design of accretion monitoring studies in these areas. These simple modeling techniques also may provide insight in interpretation of other wetland sedimentation studies using different data collection methodologies (Hupp and Morris 1990; Hupp et al. 1993).

Much information about sedimentation and accretion can be extracted from the Atchafalaya Basin rangeline data. Only the data concerning Grand Lake have been considered in this paper. We plan to continue examining these valuable records, and to extend the analysis to the entire Atchafalaya River Basin.

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