

Hydrodynamics of a Tidal Inlet in Fourleague Bay/Atchafalaya Bay, Louisiana

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ABSTRACT

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Field measurements of hourly water level, flow velocity, suspended sediment, and water salinity were performed simultaneously during two spring tides (in a low and a high river flow season) with two stations (a bay and a gulf station) at each end of the Oyster Bayou, a tidal inlet connecting Fourleague Bay/Atchafalaya Bay and the Gulf of Mexico in south Louisiana. The objective of this study is to examine the patterns of sediment transport through Oyster Bayou from the Bay to the Gulf and vice versa. During spring tides in a low river flow season (Fall 1992), averaged flow velocity, water discharge, sediment concentration, and sediment flux transported from the Gulf to the Bay were higher at the gulf station than at the bay station. This indicates that the tidal flow regime contributes to sediment sources derived largely from marine processes. During spring tides in a high river flow season (Spring 1993), these physical quantities transported from the Bay to the Gulf were higher at the bay station than at the gulf station. This indicates that the flow regime contributes to the sediment sources derived from both riverine and marine processes. During Fall 1992, data showed that stratification of the water column occurred during flood flow and destratification occurred during ebb flow. This implies that reduced water column stratification on ebb is due to turbulent mixing induced by bottom shear stress. During Spring 1993, stratification occurred throughout the study period because of the river discharge. Our field observations show that the Bay undergoes a transformation from a near-riverine estuary in the Spring to a near-marine lagoon in the Fall.

ADDITIONAL INDEX WORDS: *Hydrodynamics processes, tidal inlet, suspended sediment, shear stress, stratification, Fourleague Bay/Atchafalaya Bay, Louisiana.*

INTRODUCTION

The coastal plains of south Louisiana have been formed by riverine sediments mainly from the Mississippi River since Cretaceous time (COLEMAN, 1981). The sediments have built a sequence of deltaic lobes and have prograded the Louisiana coast seaward into the Gulf of Mexico. These coastal basins are river-lake-estuary-bay systems (ROBERTS *et al.*, 1980) connected by river distributaries, shallow lakes, estuaries and embayments (WANG, 1984).

Many man-made canals were made to join inner bays to the Gulf of Mexico to facilitate various activities in coastal shipping, estuarine fisheries, and offshore exploration. It has been suggested that deep navigation channels have caused saltwater intrusion into the marshlands of Louisiana (GAGLIANO *et al.*, 1981). WANG (1988) developed two-dimensional numerical model to study the dynamics of saltwater intrusion in three coastal

channels in south Louisiana. Her results showed that the extent of saltwater intrusion was dependent on the freshwater inflow from river discharge and channel dimension.

SHETYE and GOUVEIA (1992) studied the role of channel dimensions on flow dominance in shallow estuaries. They found that tidal asymmetry of flood-dominance often occurred when flood duration was shorter and its peak discharge was larger than the corresponding values during ebb in estuaries without mudflats. In south Louisiana, where extensive tidal flats adjacent to coastal channels exist, they produce flow asymmetry with ebb-dominance of a relatively short duration but strong ebb currents (WANG *et al.*, 1994).

An important issue as to whether salt marshes export materials to or import from coastal waters through tidal channels, consequently to serve as material sources and sinks, has been debated over the last two decades (NIXON, 1980). Salt marsh survival depends on the ability to maintain their elevations by the sedimentation processes of vertical accretion to negate the combined effects of

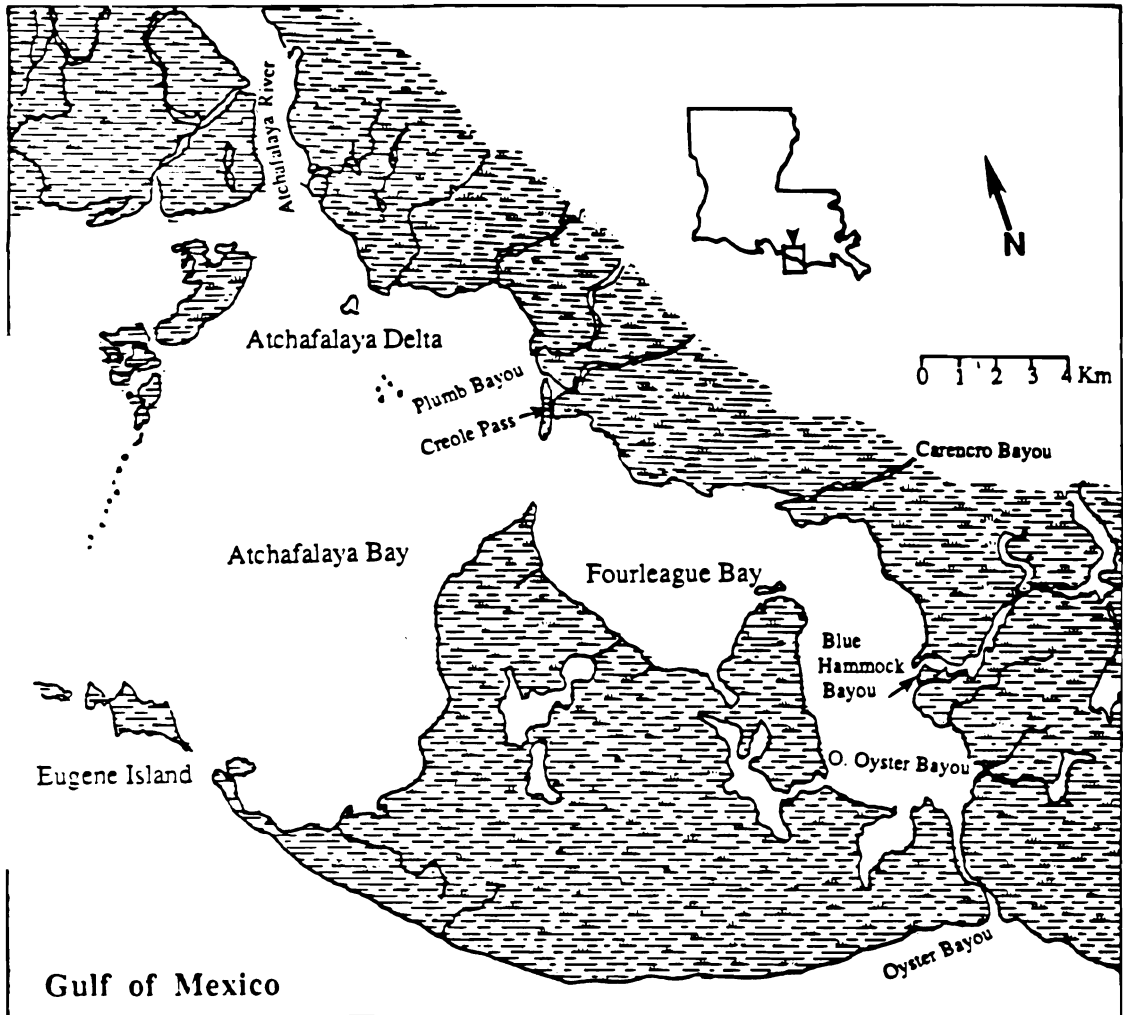


Figure 1. (a) Location map of Fourleague Bay/Atchafalaya Bay in south-central Louisiana, and (b) Map of the study area showing the location of Oyster Bayou sampling stations: Station 14 (Bay Station) and Station 16 (Gulf Station).

subsidence and eustatic sea level rise (DELAUNE *et al.*, 1990). Marsh sediments are predominantly inorganic fine silt and clay (STUMPF, 1983). In the absence of a river source, the required inorganic sediment is transported into the marsh via tidal creeks from the ocean (PILLAY *et al.*, 1992). PILLAY *et al.* (1992) studied the effect of variations in cross-sectional velocity and concentration on the rates of sediment transport in tidal creeks, in an attempt to resolve the dilemma of net sediment transport direction.

River inflows, tidal currents, and prevailing

winds, with fluctuations in the water level at the coast are the major forcing functions in estuaries (DYER, 1973). In Louisiana's microtidal coastal basins, river discharge and tidal flow both play a major role in the transport of suspended sediment (DENES and CAFFREY, 1988; WANG, 1988). Pre- and post-frontal events cause the wind direction to change from predominantly south-southeasterly to north-northwesterly in south Louisiana (MOELLER *et al.*, 1993; WANG *et al.*, 1993). GARVINE (1985) and WANG (1988) have studied the effects of wind, both remote and local forcings,

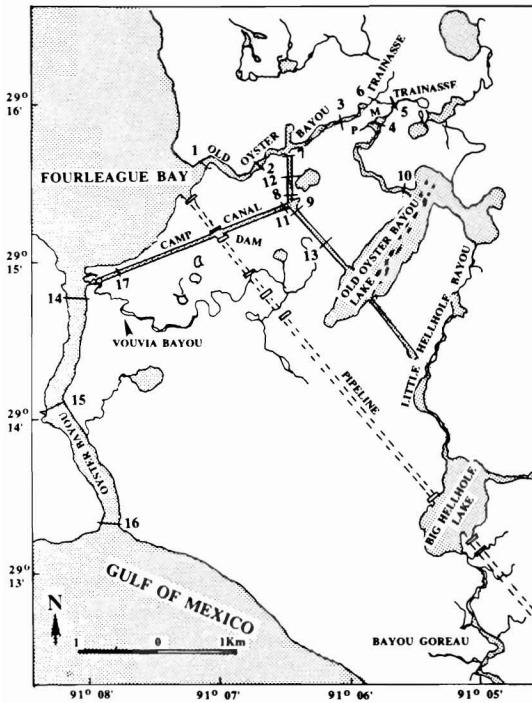


Figure 1. Continued.

on the circulation within an estuary. At the Louisiana coast, the microtidal sea level fluctuations will set up a south-north barotropic pressure gradient affecting the circulation in tidal bayou.

The purpose of this study is to examine the patterns of sediment transport between a shallow bay and the Gulf of Mexico through a tidal inlet. The data sets, obtained from two intensive sampling trips conducted during spring tides in a low river flow season (Fall 1992) and a high river flow season (Spring 1993), are used in this study. The tidal inlet dynamics, concerning its water and sediment flux, mean shear and stratification strength, are discussed in light of field observations. These field results also provide needed data for wetland sedimentation modeling.

STUDY AREA AND SAMPLING STATIONS

Atchafalaya Bay, receiving a relatively high volume of river discharge and sediment load from the Mississippi River, has built a slowly expanding delta at its mouth on the south-central Lou-

isiana coast (ROBERTS *et al.*, 1980). The surrounding area is flanked by low lying and healthy marshes (Figure 1a). The Atchafalaya Basin was described as a sediment-rich and riverine-dominated basin with a large amount of freshwater inflow (WANG *et al.*, 1993).

Oyster Bayou, a tidal inlet, connects directly to the Gulf of Mexico at the terminus of Fourleague Bay. The upper portion of Fourleague Bay connects with Atchafalaya Bay via a 2.5 km wide passage, and the lower portion of the bay communicates with the Gulf of Mexico at its south end through a 250 m wide tidal inlet, the Oyster Bayou (Figure 1a).

This tidal bayou, about 3.5 km long, runs in a north-south orientation (Figure 1b). Two sampling stations, about 3.0 km apart along the bayou, were chosen for field measurements. Station 14, at the Bay entrance, is located at the northern end of the bayou. Station 16, at the Gulf entrance, is located at the southern end of the bayou.

The water depth of the tidal bayou varied from 5.0 to 6.5 m at Station 14 (Bay Station); and from 7.0 to 8.5 m at Station 16 (Gulf Station). The bayou widths, at the highest water stage, were 268 and 182 m at Station 14 and Station 16, respectively. Depending on the range over a tidal cycle, the bayou depth and width at each station vary. Consequently, the cross-sectional area at each station is a time-varying function. However, the bed of the bayou is relatively stable. The study area is adjacent to a series of discontinuous oyster shell reefs. These reef chains died out in the late 1960's, due to the increasing influx of fresh water and sediment into Atchafalaya Bay (SHLEMON, 1972).

MATERIALS AND METHODS

Data Collection

Prior to field sampling trips, tidal heights were predicted for Eugene Island (24 km west of our sampling stations, see Figure 1a), according to the methods described by the National Oceanic and Atmospheric Administration (NOAA, 1992). Temporary staff gauges were set near the bayou bank at both stations and the relative water levels were recorded hourly.

A research vessel, the *Acadiana*, was anchored at Station 16 (29°13.36'N and 91°07.90'W) while a small boat, the *Coli*, was manned at Station 14. At both stations, hourly current velocities were simultaneously measured with current meters (Montedoro Whitney PVM-2A), and water salinity and temperature readings were taken concur-

rently with SCT meters (Yellow Springs Model 33). The vertical profiles of each physical parameter were taken at 0.5-m intervals, at the top 1-m layer and the bottom 1-m layer and at 1-m intervals in between.

Water samples were collected hourly at 1-m and 4-m depths with water samplers (Lamotte Model JT-1). The water samples were kept in clean 250 ml plastic bottles which were stored in an ice cooler for sediment concentration analysis in the laboratory. At Station 14, hourly wind speeds and directions were measured with a hand-held anemometer (Bedford Model 446A). At Station 16, the wind speeds and directions were recorded at 15-minute time intervals with a portable anemometer (Davis Instrument Weather Wizard II).

During spring tides in the low river flow season, 25-hour (1600 Oct 23–1700 Oct 24, 1992) continuous measurements were made. During spring tides in the high river flow season, a 50-hour (1200 March 22–1400 March 24, 1993) sampling study was conducted. The long-term mean river discharges at Simmesport (240 km north of the study area) for the month of October and March were 50,000 and 100,000 m³/sec, respectively (WANG *et al.*, 1993).

Laboratory Analysis

Water samples were analyzed in the laboratory for total suspended sediment concentrations by a modification of the Environmental Protection Agency Method 160 (EPA, 1979) for residue analysis. Whatman glass microfiber filters (GF/C, diameter = 4.7 cm, pore size = 1.2 μm) were used to filter water samples. Filters were ignited first at 550 ± 50 °C for 15 minutes. The clean, ignited filters were weighted immediately before use. Then, a 200-ml well-mixed water sample was filtered through the clean filter and the residue retained on the filter was dried for 24 hours at 103–105 °C to a constant weight and reweighed. The dry filters were again ignited at 550 ± 50 °C for 15 minutes to burn off the organic matter. The burned filters were reweighed. The total suspended, inorganic and organic sediment concentrations were calculated as:

Total Sediment Concentration (ppm):

$$C_{\text{total}} = (W_2 - W_1) \times 10^6 / V_s \quad (1)$$

Organic Sediment Concentration (ppm):

$$C_{\text{org}} = (W_2 - W_3) \times 10^6 / V_s \quad (2)$$

Inorganic Sediment Concentration (ppm):

$$C_{\text{inorg}} = C_{\text{total}} - C_{\text{org}} \quad (3)$$

where W_1 = weight of clean and ignited filter (g), W_2 = total weight of filter and residue (g), W_3 = total weight of filter and ignited residue (g), and V_s = volume of water samples (ml).

Data Computation

Channel Cross-Sections

Channel cross-sections at both stations were scanned by a Raytheon Fathometer (Model DE-719) from a small boat during each sampling trip. The cross-sectional areas are computed for both stations as functions of water depth and channel width (WANG *et al.*, 1993). The channel area is treated as a time-varying function. It is further divided horizontally into a number of areal elements for the computation of instantaneous water and sediment fluxes.

Water Flux Computation

The flow velocity (m/sec) in an areal element i and at time t , $v_{ai}(t)$, is taken as the average of the flow velocities measured at the two adjacent depth-increments i and $i + 1$, $v_i(t)$ and $v_{i+1}(t)$

$$v_{ai}(t) = [v_i(t) + v_{i+1}(t)]/2 \quad (4)$$

where i is the depth index ($i = 1, 2, \dots, n$).

The instantaneous water flux is computed as the sum of all the water discharges in each areal element

$$Q(t) = \sum v_{ai}(t) \Delta A_i(t) \quad (5)$$

where $Q(t)$ is the water discharge (m³/sec) and $\Delta A_i(t)$ is the area of i th areal element (m²) at time t .

Sediment Flux Computation

The instantaneous sediment flux is then computed from

$$F(t) = 10^{-3} Q(t) C(t) \quad (6)$$

where $F(t)$ is the sediment flux (kg/sec), and $C(t)$ is the average of sediment concentrations (g/m³) at 1 and 4 meters below the water surface at time t .

RESULTS AND DISCUSSION

To study the hydrodynamics of flow in the Oyster Bayou, the only tidal inlet connecting Fourleague Bay/Atchafalaya Bay to the Gulf of Mexico, field measurements of hourly water level, flow velocity, suspended sediment, and water salinity

have been analyzed. The results of time series are presented in the sequence of the measured relative water level H , the computed cross-sectionally and vertically averaged flow velocity V , and the depth-averaged suspended sediment concentration SSC , followed by the computed instantaneous water flux Q and sediment flux F .

Subsequently, the relationships of the above physical parameters are compared in a pairwise fashion (H and V , H and SSC , V and SSC). Finally, the results are discussed in the context of shear velocity taken as the difference of velocity at the top (at 1-m depth) and bottom (at 4-m depth) layers; and stratification strength defined as the difference of salinity at the top and bottom layers of a water column. For simplicity, the following symbols are used: "t" for time series, "v" for vertically averaged, "c" for cross-sectional averaged, " Δ " for the difference between the two layers, "₁₄" for Station 14 and "₁₆" for Station 16.

Field Observation During Low River Flow Season (Fall 1992)

More than 25 hours (from 1300 October 23 to 1800 October 24, 1992) of continuous hourly measurements were carried out simultaneously at both stations. The sampling periods were scheduled during a semi-diurnal spring tide, with the predicted tidal range of 60 cm at Eugene Island; and within a low river flow season with the long-term mean river discharge of 50,000 m³/sec at Simmesport. During the sampling period, the weather was relatively calm. Wind speeds rarely exceeded 2.5 m/sec and were predominantly from east-south-easterly.

Water Level H , Flow Velocity V , Suspended Sediment Concentration SSC (Fall 1992)

Rise and fall in water levels at Station 16 were about 2 hours ahead of Station 14 (Figure 2a), because Station 16 is closer to the Gulf of Mexico (Figure 1b). The pattern of water levels at both stations followed closely the predicted tidal heights at Eugene Island. The range of water stages was 55 cm at both stations and was about 5 cm lower than the predicted tidal range (60 cm).

Figure 2b displays the cross-sectionally and vertically averaged current velocity at both stations. Both the flood current (positive sign indicating bayward/northward) and ebb current (negative sign indicating gulfward/southward) at Station 16 were faster than those at Station 14. During the sampling period, at Station 14 the

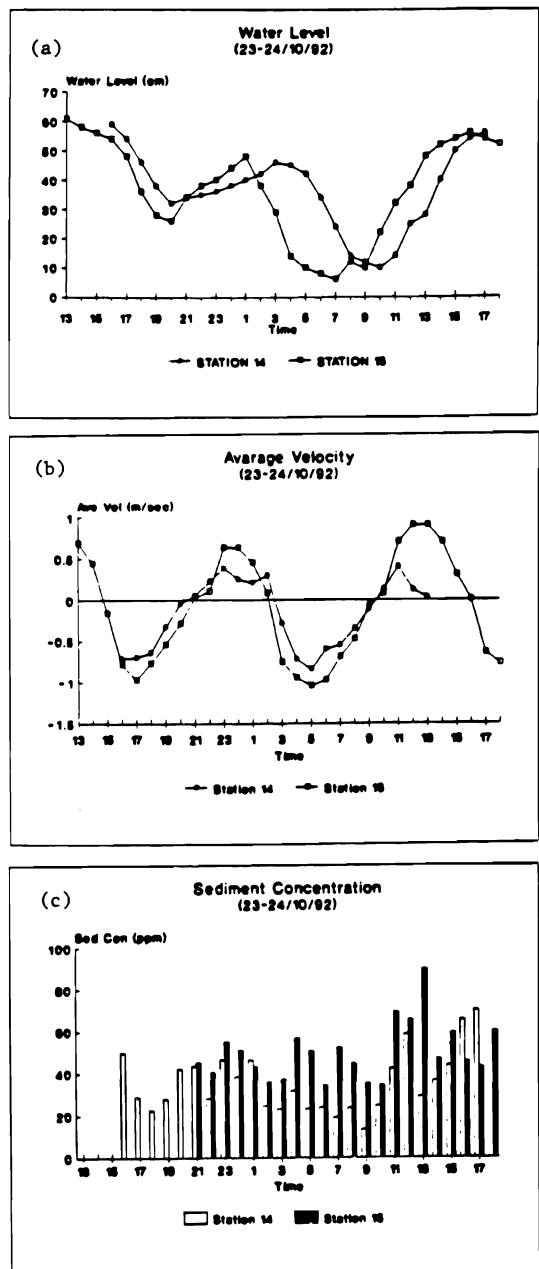


Figure 2. Field measurements of (a) relative water level, (b) cross-sectional averaged current velocity, and (c) total suspended sediment concentration at Station 14 and Station 16 conducted during low river flow season (1300 October 23–1800 October 24, 1992).

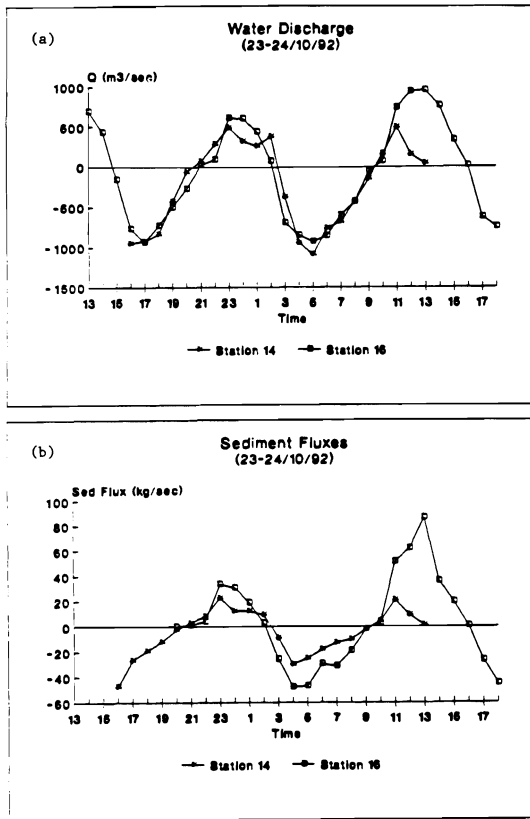


Figure 3. Computed instantaneous (a) water discharge, and (b) sediment flux at Station 14 and Station 16 during low river flow season (1300 October 23–1800 October 24, 1992).

maximum gulfward velocity (-0.84 m/sec) was twice the maximum bayward velocity (0.40 m/sec). This revealed the asymmetry of ebb-dominance with a short falling duration and relatively strong ebb currents. However, at Station 16, both the maximum gulfward velocity (-0.97 m/sec) and bayward velocity (0.90 m/sec) were nearly equal.

The total suspended sediment concentrations at both stations were relatively low (Figure 2c). They varied from 15 ppm to 70 ppm at Station 14; and 35 ppm to 90 ppm at Station 16 during the sampling period. The overall-averaged suspended sediment concentrations during the sampling period were 35 ppm and 50 ppm at Station 14 and Station 16, respectively. In general, the suspended sediment concentrations at Station 16 were greater than those at Station 14. This implies

that during the low river flow season, the tidal-dominated flow regime contributes to sediment sources derived largely from marine processes.

Water Discharge Q , Sediment Flux F (Fall 1992)

At Station 14, the cross-sectional areas (varied from 1,220 to 1,330 m²) were larger than the cross-sectional areas at Station 16 (ranged from 890 to 1,000 m²) during the sampling periods. Consequently, the larger areas compensated the slower tidal currents at Station 14, resulting in an equivalent water discharge at both stations (Figure 3a).

The results of sediment fluxes (Figure 3b) indicated that, during a full tidal period the sediment fluxes in and out of the Oyster Bayou at both stations were nearly balanced. Apparently, under a normal tidal-flow regime when calm periods prevail, the net non-tidal flow discharge and sediment flux from the Oyster Bayou to the Gulf are negligible.

Relationships of V and H , SSC and H , SSC and V (Fall 1992)

At Station 14, V_{ct14} led (relative) H_{t14} by 4 hours while at Station 16 V_{ct16} led (relative) H_{t16} by 2 hours (Figure 2a and b). It is noted that gulfward (negative) and bayward (positive) velocity maxima at each station remained the same magnitude, whereas the two (relative) water level minima drastically changed (a 20-cm difference from one low water level to the next). This indicates that current velocity depends primarily on the phase of semi-diurnal tide.

At both stations, the suspended sediment concentrations, SSC_{vt14} and SSC_{vt16} , increased as the water level rose and decreased before the highest water level and increased again during the low water level (Figure 2a and c). At Station 14, SSC_{vt14} increased and decreased as the bayward velocity increased and decreased. At Station 16, SSC_{vt16} remained relatively higher during the period of bayward flow than during the period of the gulfward flow (Figure 2b and c). This suggests that suspended sediments are being transported from the Gulf to the Bay over this limited period of field observations.

Mean Shear ΔV , Stratification Strength ΔS , Flow Velocity V (Fall 1992)

In general, the top layer (at 1-m depth) travelled faster than the lower layer (at 4-m depth), that is, $V_1 > V_4$. However, the bottom layer was

more saline than the top layer. Mean shear in the water column at both stations, ΔV_{t14} and ΔV_{t16} , were computed as the difference of velocity at the top and bottom layers ($\Delta V = V1 - V4$). Stratification strengths, ΔS_{t14} and ΔS_{t16} , were defined as the difference of salinity at the bottom and top layers ($\Delta S = S4 - S1$). Figure 4a and b display the mean shear and stratification strength in the water column, together with the cross-sectionally and vertically averaged velocity for Station 14 and Station 16, respectively.

At Station 14, in Figure 4a, relatively high shear, weak stratification, and nearly maximum gulfward velocity occurred during the same time period (CST 1800 23/10/92; 0500 24/10/92). The strong shears induced turbulent dispersion as one of the mixing mechanisms. Conversely, relatively low shear, strong stratification, and nearly maximum bayward velocity occurred during the same time period (CST 0200 24/10/92). The maximum bayward velocity, which was about half the maximum gulfward velocity, generated a relatively weaker shear. This resulted in a lack of turbulent dispersion that permitted a more stratified water column.

At Station 16, in Figure 4b, relatively steady and small shear throughout the study period indicated the lack of turbulence. However, ΔS_{t16} showed temporal variation of stratification. Maximum and minimum stratification occurred during periods of maximum bayward velocity and maximum gulfward velocity, respectively. During this low river flow season, our results showed that stratification of the water column occurred during flood flow and destratification occurred during ebb flow.

Field Observation During High River Flow Season (Spring 1993)

A total of 50 hours (from 1200 March 22 to 1400 March 24, 1993) continuous hourly measurements were conducted simultaneously at both stations. This March 1993 trip was scheduled during a high river flow season with the long-term river discharge of 100,000 m³/sec at Simmesport. During the sampling period, semi-diurnal tides combined with the diurnal tide resulted in mixed-type tides with unequal high tides and low tides. The tidal inequality was largely exhibited in the low tides.

During our 50 hours sampling period, two frontal passages were encountered. Based upon synoptic weather type classification (MULLER, 1977), stormy weather periods occurred between March

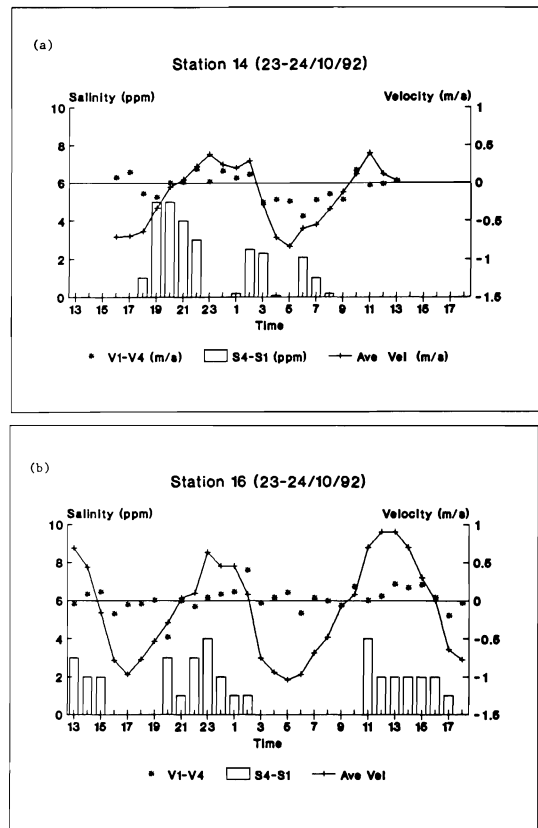


Figure 4. Time series of mean shear (Δ Velocity), stratification strength (Δ Salinity), and cross-sectional averaged velocity (V) at (a) Station 14 and (b) Station 16 during low river flow season (1300 October 23–1800 October 24, 1992).

19–23, 1993 (MULLER *et al.*, 1993). Frontal Overrunning (FOR) weather was followed by Frontal Gulf Return (FGR) weather. The first front occurred in the beginning of the sampling period (CDT 1200–2300 March 22), the second one happened near the end of our sampling period (CDT 000–1200 March 24).

During the frontal passage, winds were strong (5–10 m/sec) and shifted directions from predominantly south–southeasterly to north–northwesterly during pre- and post-frontal periods. Between these two frontal passages, steady and strong northerly winds (5–10 m/sec) also prevailed in the second day during the time period of 0800–1800 on March 23, and then gradually tapered off until the second frontal passage on March 24th. Be-

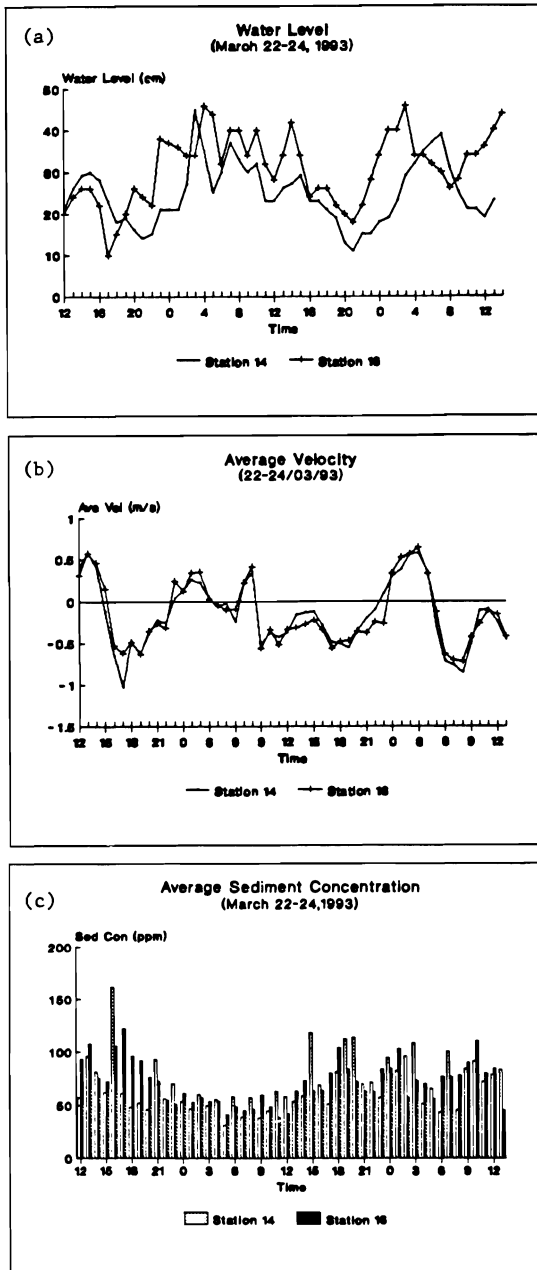


Figure 5. Field measurements of (a) relative water level, (b) cross-sectional averaged current velocity, and (c) total suspended sediment concentration at Station 14 and Station 16 conducted during high river flow season (1200 March 22–1400 March 24, 1993).

cause of this high river flow season confounded with the passage of fronts during our sampling periods, it is rather difficult to separate precisely the influence of high river discharge from the effect of wind on hourly measurements of physical processes.

Water Level H , Flow Velocity V , Suspended Sediment Concentration SSC (Spring 1993)

The effects of winds on water levels were observed. Pre-frontal phase southerly winds raised water levels and the post-frontal phase northerly winds drove water levels down. The steady and strong northerly winds after the first frontal passage resulted in a continuous water level decline during the time period from 0800 to 2000 on March 23 (Figure 5a). The patterns of water levels at both stations were distorted and dissimilar to the predicted tides at Eugene Island. These observations show that the meteorological tides (wind setup or setdown) dominate the astronomical tides on the coastal water levels in our study area.

At Station 14, in Figure 5b, the maximum gulfward velocity (-1.03 m/sec) was faster than that at Station 16 (-0.63 m/sec). The maximum bayward velocities at both stations were nearly equal (0.59 m/sec and 0.57 m/sec, respectively). At Station 14, the maximum gulfward velocity (-1.03 m/sec) was much larger than the maximum bayward velocity (0.59 m/sec), indicating the asymmetry of ebb-dominance with a relatively short falling and moderately strong ebb currents. At Station 16, the maximum gulfward velocity (-0.63 m/sec) and bayward velocity (0.57 m/sec) were nearly equal.

During the high river flow season, the suspended sediment concentrations at both stations were much higher than the concentrations during the low river flow season. At Station 14, SSC_{vt14} ranged from 30 ppm to 160 ppm while at Station 16, SSC_{vt14} varied from 40 ppm to 120 ppm (Figure 5c). The overall-averaged sediment concentrations at both stations during the sampling period were nearly equal, 70 ppm. The results indicate that during high flow season confronted with frontal passages, the flow regime contributes to the sediment sources derived from both riverine and marine processes.

Water Discharge Q , Sediment Flux F (Spring 1993)

During the high river flow season, the bayou cross-sectional areas at both stations were much

larger than the flow areas during the low river flow season. At Station 14, flow areas varied from 1,400 to 1,500 m² while at Station 16, flow areas changed from 1,080 to 1,170 m². Larger area and faster flow contributed to high water discharge at Station 14 (Figure 6a). This imbalance of water fluxes inundated the local marshes adjacent to the Oyster Bayou, a phenomenon that was observed during the trip.

Consequently, both the bayward and gulfward sediment fluxes at Station 14 were larger than those at Station 16 (Figure 6b). The net sediment flux at Station 14 was larger than that at Station 16. The resulting net sediment flux in the gulfward direction indicated that sediments were transported gulfward. The excess of sediment flux contributed directly to the increased sedimentation rates in the adjacent marshes.

Relationships of V and H , SSC and H , SSC and V (Spring 1993)

At Station 14, V_{ct14} led (relative) H_{t14} by 2 hours while at Station 16 V_{ct16} led (relative) H_{t16} by 1 hour (Figure 5a and b). At both stations, the magnitudes of gulfward and bayward velocity were relatively steady as compared to water-level peaks and troughs. This suggests that flow velocity depends on the phases of diurnal and semi-diurnal tides.

Suspended sediment concentrations at both stations, SSC_{v14} and SSC_{v16} , were high during low water level and low during high water level (Figure 5a and c). Note that at Station 14, H_{t14} was relatively lower than at Station 16, H_{t16} , and that the suspended sediment concentrations at Station 14, SSC_{v14} , were nearly the same as SSC_{v16} at Station 16. Both riverine and marine sediments contribute directly to each station.

At Station 14, SSC_{v14} remained relatively higher during the period of gulfward flow than during the period of the bayward flow (Figure 5b and c). A similar trend was observed at Station 16. In addition, SSC_{v16} increased and decreased as the gulfward velocity, V_{ct16} , increased and decreased. This indicates that suspended sediments are being transported from bayward to gulfward which is expected during the high river flow season.

Mean Shear ΔV , Stratification Strength ΔS , Flow Velocity V (Spring 1993)

In Figure 7a and b, at both stations, relatively high shear (ΔV_{t14} , ΔV_{t16}), weak stratification (ΔS_{t14} , ΔS_{t16}), and fast gulfward flow occurred during the

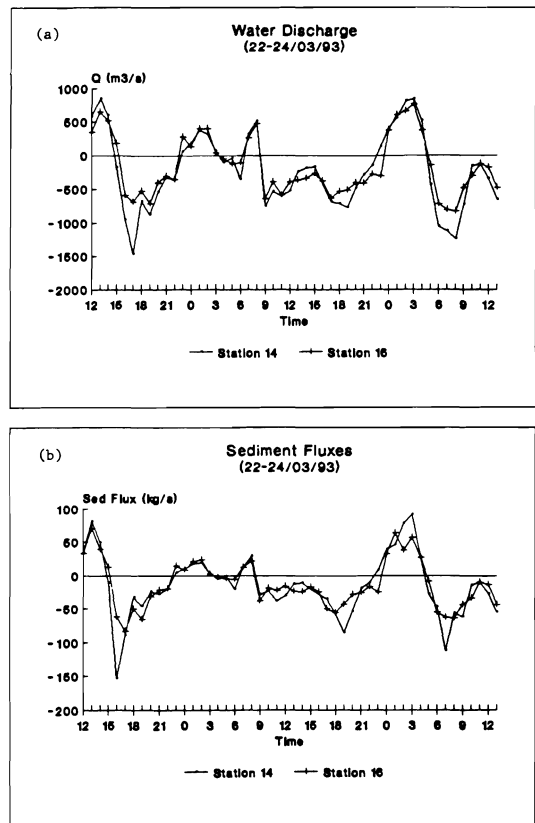


Figure 6. Computed instantaneous (a) water discharge, and (b) sediment flux at Station 14 and Station 16 during high river flow season (1200 March 22–1400 March 24, 1993).

same time period (CST 1800 March 22, 1800 March 23). This indicates that the mixing mechanism is largely due to turbulent dispersion induced by strong shears. However, ΔS_{t14} and ΔS_{t16} at both stations exhibited periodic stratification variations. At Station 14, in general, moderate stratification ($\Delta S = 10$ ppt) occurred during the period of bayward flow, and moderately weak stratification ($\Delta S = 5$ ppt) occurred during the period of gulfward flow. Apparently, moderate shears weaken the stratification tendency. However, at Station 16, strong stratification ($\Delta S = 15$ ppt) and moderate stratification ($\Delta S = 10$ ppt) occurred throughout the study period.

CONCLUDING COMMENTS

The following conclusions are based upon two intensive field observations conducted during two

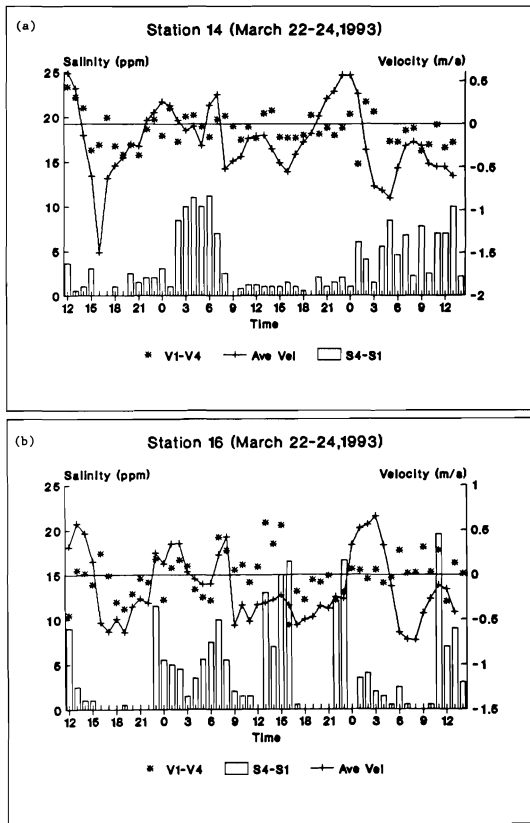


Figure 7. Time series of mean shear (Δ Velocity), stratification strength (Δ Salinity), and cross-sectional averaged velocity (V) at (a) Station 14 and (b) Station 16 during high river flow season (1200 March 22–1400 March 24, 1993).

spring tides in a low river flow season (Fall 1992) and a high river flow season (Spring 1993), respectively. Under calm weather conditions, these two-selected study periods represent a typical tidally-dominated circulation and a riverine-dominated circulation, respectively.

(1) The geometry of the Oyster Bayou strongly influences the flow dynamics and material transport in and out of the inlet.

(2) During both flow seasons, the increasing lag in maximum velocity and the slack water between the two ends of the inlet (Figures 2a and b, and 5a and b) are the result of decreasing depth and hence increasing bottom frictional effects as one moves upstream from Gulf Station (Station 16) toward Bay Station (Station 14).

(3) At Station 14 (Bay Station), the nearly two-

fold increase in overall-averaged suspended sediment concentration (70 ppm) during the high river flow season compared to the averaged sediment concentration (35 ppm) during the low river flow season (Figures 2c and 5c) indicates the influence of riverine sediments. Conversely, at Station 16 (Gulf Station), the slightly lower average sediment concentration (50 ppm) during the low river flow season compared to that (70 ppm) during the high river flow season suggests the influence of marine sediments.

(4) Under the tidally-dominated flow regime when calm periods prevail in the Fall (low river flow season), the water discharge and sediment flux at both stations are nearly balanced (Figure 3a and b). Conversely, during the high river flow season, strong ebb currents at Station 14 result in a larger quantity of water discharge and sediment flux than those at Station 16 (Figure 6a and b). Such net excess of water and sediment fluxes leads to overland flow, inundates local marshes, and contributes to sedimentation on the marsh adjacent to the bayou.

(5) During both low and high river flow seasons, relatively high shear, weak stratification, and nearly maximum gulfward velocity occur at the same time at both stations. These results indicate that the mixing mechanism is mainly due to turbulent dispersion induced by strong shears (Figures 4 and 7).

(6) Salinity difference at the top and bottom layers shows temporal variations of stratification. During the low river flow season, moderate stratification occurs during the period of bayward flow (flood flow), and weak stratification occurs during the period of gulfward flow (ebb flow). It is noted that our field results are different from the numerical results of BOWDEN and HAMILTON (1975) for an estuary in which stratification in the water column decreased with flood flow and increased with ebb flow. During the high river flow season confounded with frontal passages, our results show that stratifications occur throughout the study period.

(7) Our field observations show that Four-league Bay, a shallow estuary in south-central Louisiana, undergoes a transformation from a near-riverine estuary in the Spring to a near-marine lagoon in the Fall.

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