Grain Size and sediment trapping efficiency of the Attakapas crevasse splay along Bayou Lafourche, Louisiana

Louisiana Sea Grant Undergraduate Research Opportunities Program Report

Jonathan Marshak

Department of Earth and Environmental Sciences, Tulane University, 6823 St. Charles Avenue,
New Orleans, Louisiana 70118-5698, USA

Abstract

Sediment trapping efficiency is an important statistic for evaluating river diversion projects for coastal restoration in the Mississippi Delta. Crevasse splays act as natural analogs of river diversions. To quantify sediment trapping efficiency of a recent crevasse splay of Bayou Lafourche formed approximately 1200 years ago (the Attakapas Splay; Bayou Lafourche is a former Mississippi River course), the grain-size distribution of the splay deposits was investigated. The sediment texture of the splay deposits was studied by a number of cross sections and qualitatively described in the field following the United States Department of Agriculture (USDA) soil texture classification. Sediment samples were taken for each of the texture class for grain-size measurements that were used to create a quantitative dataset containing percentages of clay ($< 2 \mu m$), silt ($2\text{-}62.5 \mu m$) and sand ($>62.5 \mu m$) contained within the samples. A total of 54 samples were taken and measured using two separate methods: light diffraction and image analysis. Using cross sections the volumes of sediment texture bodies within the splay was calculated, enabling an estimate of the lithology of the entire splay. Overall, we found samples in the splay to be siltier than anticipated. The swamp underlying the Attakapas Splay deposits has a conservative sediment trapping efficiency of ~49.6%, which is far greater than shallow water environments like the Wax Lake Delta which has a sediment trapping efficiency of ~30%. This indicates that swamp environments can be effective in trapping a large percentage of the Mississippi River sediment load and thus deserve to be considered as possible sites for river diversions in wetland restoration projects in the Mississippi Delta.

Introduction

The Mississippi River Delta is losing ~61 km^2 to 102 km^2 of natural wetlands every year and has lost as much as 562 km^2 in the years after hurricanes Katrina and Rita in 2005 (Allison et al 2010). These losses are generated from numerous sources including canal dredging, fault movement, gas and fluid withdrawal from underground and glacial isostatic adjustment. The main sources of wetland loss are sea level rise rate in the Gulf of Mexico of ~0.3 cm/year, compaction-driven subsidence of Holocene sediments at a rate of 0.5 to 1 cm/year (Törnqvist et al 2008) and a reduction of sediment discharge in the Lower Mississippi River due to upstream damming from ~400-500 Mt/year to ~205 Mt/year, 15-30% of which is now diverted to the Atchafalaya Basin, the Wax Lake Delta and the Atchafalaya Delta via the Old River Control Complex (Mossa 1996, Blum and Roberts 2009). I am evaluating an important aspect of river diversions by estimating the potential sediment trapping efficiency of diverting sediments into vegetated swamp environments. This will be done by quantitatively measuring the grain size distribution of facies in a crevasse splay developed in a cypress swamp and using cross sections to estimate the lithologic content of the splay. By comparing the sediment texture of splay deposits with the sediment load of the Mississippi River it is possible to estimate the sediment trapping efficiency of the splay.

A crevasse splay is natural feature that is formed when a river breaches its natural levees and deposits its sediment load into adjacent flood plains. Our investigation focuses on a crevasse splay called the Attakapas Splay in the Mississippi River Delta located west of New Orleans (Figure 1). The Attakapas Splay began to form ~1200 years ago (Nijuis 2010), and was an effective method of building sustainable land near the Mississippi River channel. However, with the settlement of people in the area came extraction of fluids like natural gas, petroleum and water leading to local subsidence as well as a depleted sediment supply due to intensive damming of the river upstream and artificial levee construction that severely limited the introduction of sediments to floodplains.

Researchers and engineers have begun to investigate the possibility of diverting water and sediment to rebuild land in specified locations. One of the few areas in the Mississippi River Delta that is creating wetlands is in the Wax Lake Delta. This delta is 3-3.5 meters thick and is sand dominated at ~70% with a calculated sediment trapping efficiency of ~30% (Roberts et al., 2003, Törnqvist et al., 2007, Kim et al., 2009). This means a very large, particularly fine grained portion of the suspended sediment load of the Atchafalaya River is not being captured in the delta, but discharged to the ocean.

Inland swamps have been considered as another possible location for river diversions. Holocene sediments in swampy environments have been shown to contain large percentages of silt and clay particles, resembling more closely the sediment load of the Mississippi River (Törnqvist et al.,1996) which has been estimated as being ~80% silt and clay (Nittrouer et al., 2008). Based on these observations, it can be inferred that inland swamps might be more efficient at trapping Mississippi River sediments than shallow water coastal environments like the Wax Lake Delta and thus deserve some attention from engineers and researchers involved in restoration of wetlands in the delta. The purpose of my report is to provide evidence that shallow marsh environments have high potential sediment-trapping efficiency. This will be done by investigating the lithologic content of a feature called the Attakapas Splay using grain size analysis. The Attakapas Splay is a crevasse splay which was formed 1200 years ago by Bayou Lafourche (a former major Mississippi River distributary channel) in a cypress swamp when Bayou Lafourche sediment discharge probably mimicked modern day conditions and it can thus be treated as a natural analog for modern river diversion studies in swamp environments.

Field Area

Fieldwork took place near Napoleonville, Louisiana (Figure 1) from April 2010 to early June 2010 as well as March of 2011. Hand-drilled cores were used to generate cross sections of the subsurface architecture based on sediment description according to the United States Department of Agriculture (USDA) soil classification system. Samples from three boreholes in the field area (Figure 1) were taken for grain size measurement: 1094.010, 1094.032 and 1094.059.

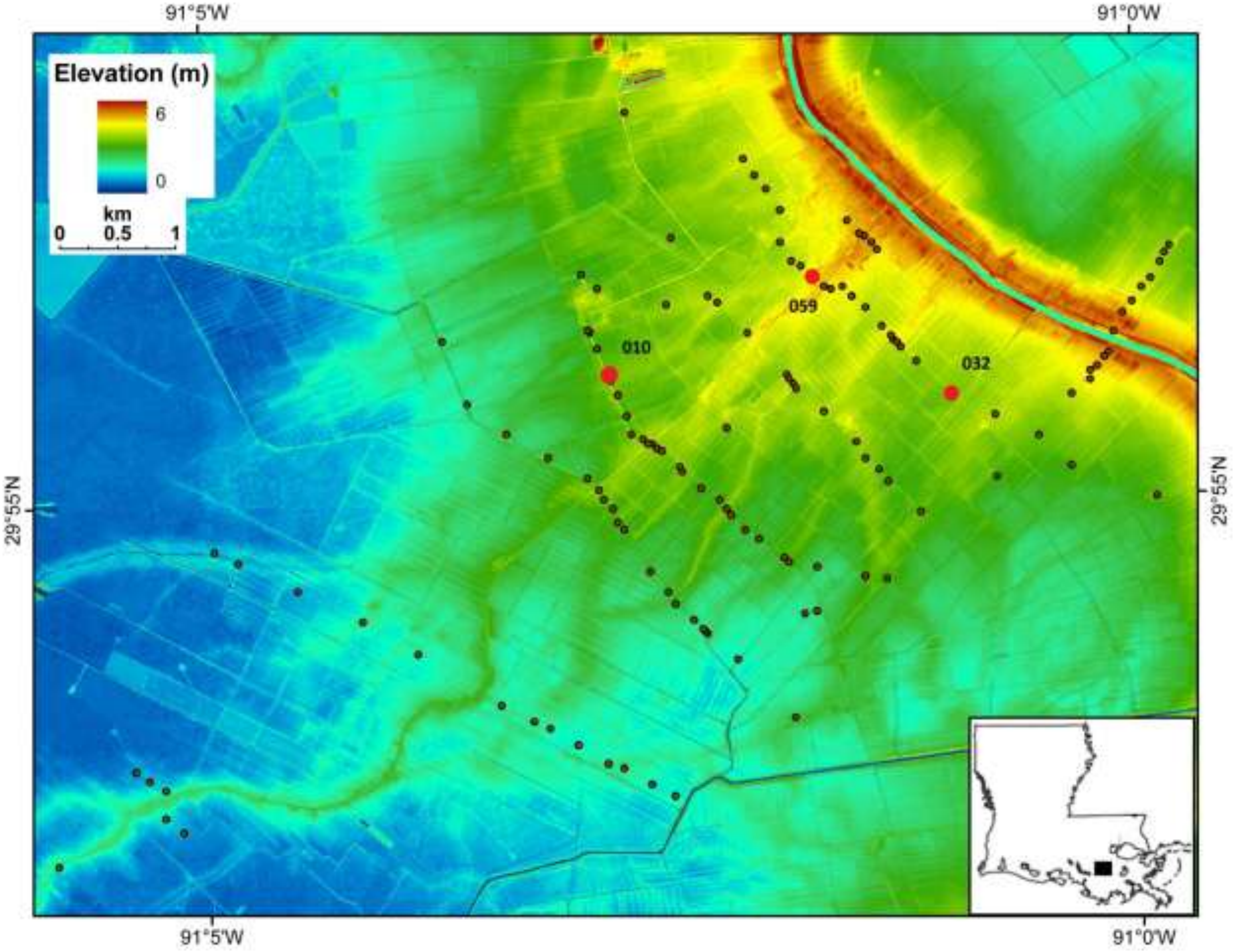


Figure 1. LIDAR map of the Attakapas Splay field area with core locations indicated by brown dots. The red dots indicate cores analyzed for grain size measurements (1094.010, 1094.059 and 1094.032). The inset map specifies the location (black square) of the field site.

Methods

Field Methods

In the splay we encountered six sediment textures (from coarsest to finest): very fine sand (vfs), sandy loam (SL), silt loam (SiL), silty clay loam (SiCL), silty clay (SiC) and clay (C). These texture classes correspond to proportions of sand (>63 µm), silt (2-63 µm) and clay (< 2 µm) particles contained within a sample and are represented by regions on a USDA textural ternary diagram (Figure 2). It is not feasible to use quantitative methods such as grain-size analysis in the field to determine the texture of a sediment sample, which is why qualitative descriptions of texture are employed.

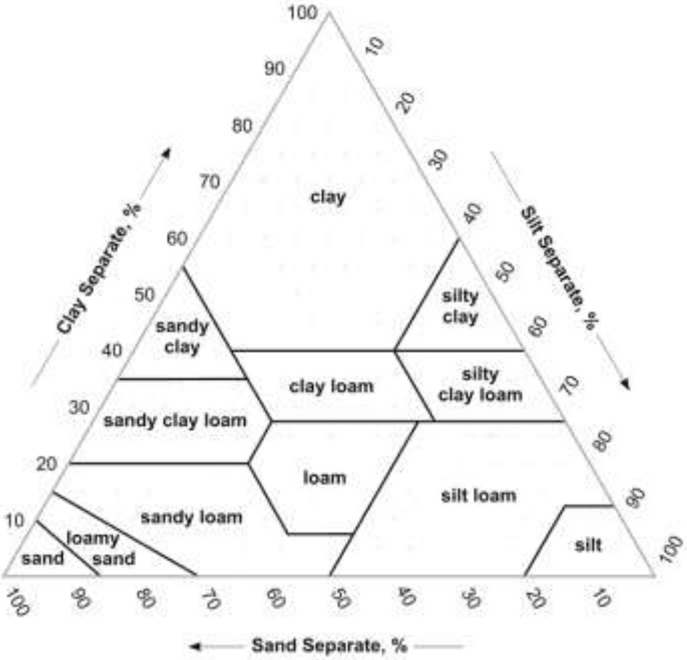


Figure 2. A USDA Textural Ternary Diagram. Source: U.S. Department of Agriculture.

A very important component of this report is to determine whether our qualitative soil texture descriptions correspond with quantitative grain size measurements. This goal can be reached using particle size analysis of numerous samples from each of the six sediment texture classes we encountered in the splay. These data can be used to develop a reliable dataset detailing quantitative percentages of sand, silt and clay particles contained within each texture class, and thus, the overall lithologic content of the splay can be estimated.

Hand-drilling equipment was used to describe the soil texture of the splay at 10 cm depth increments until a peat or humic clay layer (indicating pre-splay deposits) was reached. Organic and herbaceous material, siderite, wood and iron as well soil color were documented in addition to soil texture. A total of 54 samples were taken in 5-10 cm increments from boreholes 1094.010, 1094.032 and 1094.059 (Figure 3) and used for grain size measurement. A total of 36 samples were taken from the .010 borehole, 2 samples from the .059 borehole and 16 samples from the .032 borehole.

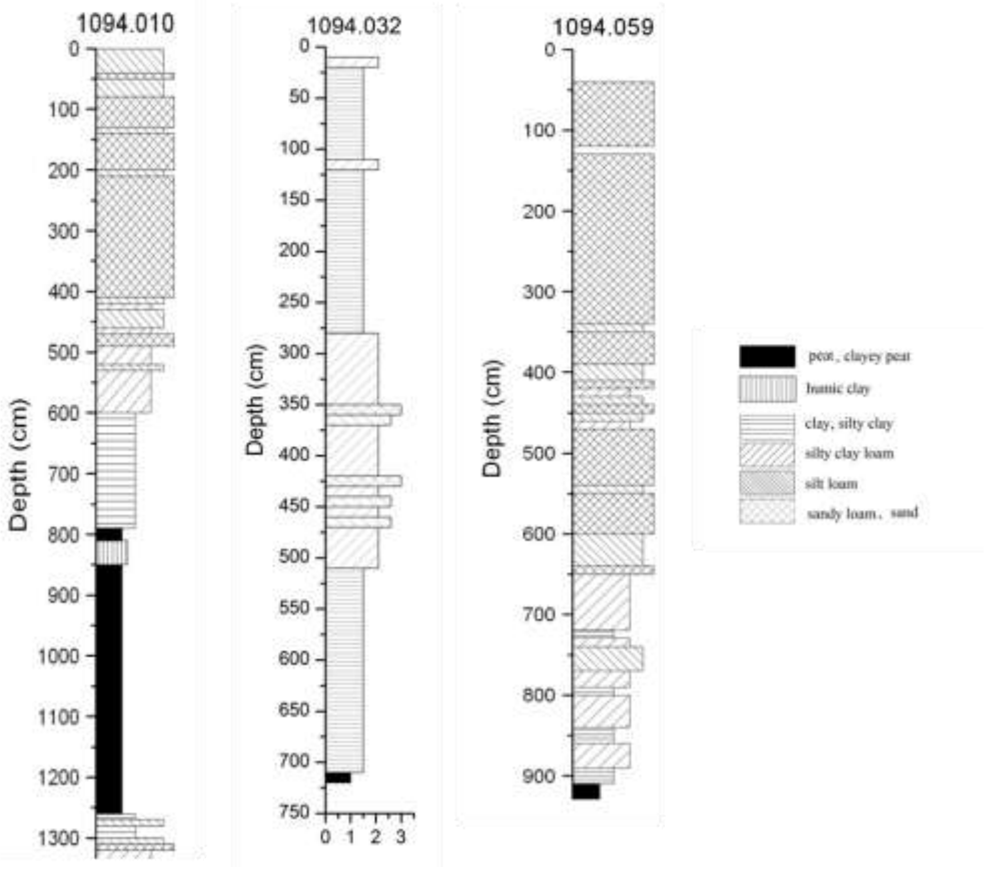


Figure 3. USDA soil texture descriptions from 3 boreholes of the Attakapas Splay: 1094.010, 1094.032 and 1094.059.

Laboratory Methods

Part1: Sample Preparation

The samples were prepared in the Quaternary Research Laboratory at Tulane University from June of 2010 to December of 2011. Approximately 20 mL of each sample and 25 mL of particularly sandy samples was taken and placed in a 500 mL beaker. The next step was to chemically treat samples in order to remove organic matter and carbonates from the mineral matrix.

A solution of 10% Hydrochloric acid (HCl) was prepared to dissolve carbonates within the samples, and a solution of 10% NaOH was prepared to neutralize the acidic sample after the carbonates were dissolved. A pH meter was used to monitor the pH of the sample as the diluted NaOH was slowly added and when the pH registered in the 6-8 range, no more NaOH was added. Finally, a solution of 10% H_2O_2 was added to remove organic matter. Samples were heated on a stove to speed up the process of organic consumption and were removed when there was no more reaction. Often, large pieces of wood (>5mm) were difficult to be consumed by chemicals and heat alone, in which case the samples were passed through a 250 µm sieve to remove these pieces.

The samples were then passed through a 106 µm sieve to separate the samples into grains > and < 106 µm. Grains < 106 µm were measured using the Horiba LA300 and grains > 106 µm were measured using the Retsch Technology CAMSIZER. The samples were then dried in a laboratory oven and subsequently weighed.

Part 2: Grain Size Analysis

Grain size analysis was performed in the Sediment Dynamics Laboratory at Tulane University from June 2010 to December 2011. The LA300 accurately measures particles from 1-200 µm by laser diffraction methods (Lyons 2004). Laser diffraction works in the LA300 by broadcasting light of a known wavelength into a column with suspended particles and records the angle of light scatter caused by light hitting the edges of particles and being reflected back to the sensor. Relatively larger particles scatter light at smaller angles whereas smaller particles scatter light at larger angles and the sensor can determine the grain diameter based on the constant wavelength of light and the angle of light scatter. The CAMSIZER was used to measure grains greater than 106 µm using digital imaging processing which accurately measures grains between 30 µm and 30000 µm by taking pictures of each grain. The machine utilizes two cameras: a "zoom camera" which analyzes smaller grains and a "basic camera" which analyzes the larger grains. Each sample was run three times on the LA300 and the CAMSIZER to improve the precision of the data.

A grain size of 106 µm was chosen as the separation point because it is far enough away from the silt-sand split at 63 µm. Also, 106 µm is comfortably within the range of performance ability of the LA300 and CAMSIZER (Lyons 2004). Each machine recorded data and produced a histogram with grain size classes in microns on the x-axis and frequency percentages of each of these classes on the y-axis. Data from each of the three trials were combined in a Microsoft Excel spreadsheet to produce averaged data from each of the machines. The grain size classes produced from the LA300 measurements had to be converted so that they would match the CAMSIZER grain size classes and the data could be combined. Finally, individual weights of the CAMSIZER and LA300 sample were entered into an Excel spreadsheet which was specifically designed to standardize data from the two machines, determine the relative contribution of each fraction based on their mass and combine the results into one dataset. From this data, a frequency distribution of grain sizes within a sample were produced and percentages of sand, silt and clay could then be calculated.

When this process was complete, the machines produced a frequency distribution of grain sizes ranging from 0 to 6092 µm. To determine the percentage for clay particles contained within the sample, frequency percentages for the grain size classes from 0 to 2 µm were summed, for silt particles 2 to 62.5 µm and for sand particles anything greater than 62.5 µm was summed. Thus, percentages of sand, silt and clay totaling 100% were produced and could be plotted in the textural ternary diagram.

.	Additional results can be extracted from the data produced by the LA300 and the CAMSIZER. Average frequency distribution curves and average cumulative frequency distribution curves for each of the texture classes were produced to help visualizing the precision of our methods.

Part 3: Calculating the Areas of Sediment Bodies

The final step of this investigation involves the calculation of the areas of sediment bodies contained within the Attakapas Splay. In order to solve this problem, we have to estimate the lithologic content of the entire splay and compare it to the sediment load of the lower Mississippi River. When generating cross sections of the splay, we consolidated the 6 texture classes into 3 texture classes: “vfs, SL” (represented by red), “SiL, SiCL” (represented by yellow) and “SiC, C” (represented by green) (Figure 4).   I used a PDF editing program called Bluebeam PDF Revu to calculate the areas of each of these sediment bodies contained within the splay for each of the 7 cross sections. Averages of sand, silt and clay percentages of the 3 texture classes and the total area of the sediment bodies for the seven cross sections was used to estimate the lithologic content for the entire splay; an overall sediment texture classification for the splay was estimated by calculating the relative weight of each of the 3 revised texture classes to the splay and thus weight percentage of sand, silt and clay particles within each of these classes.

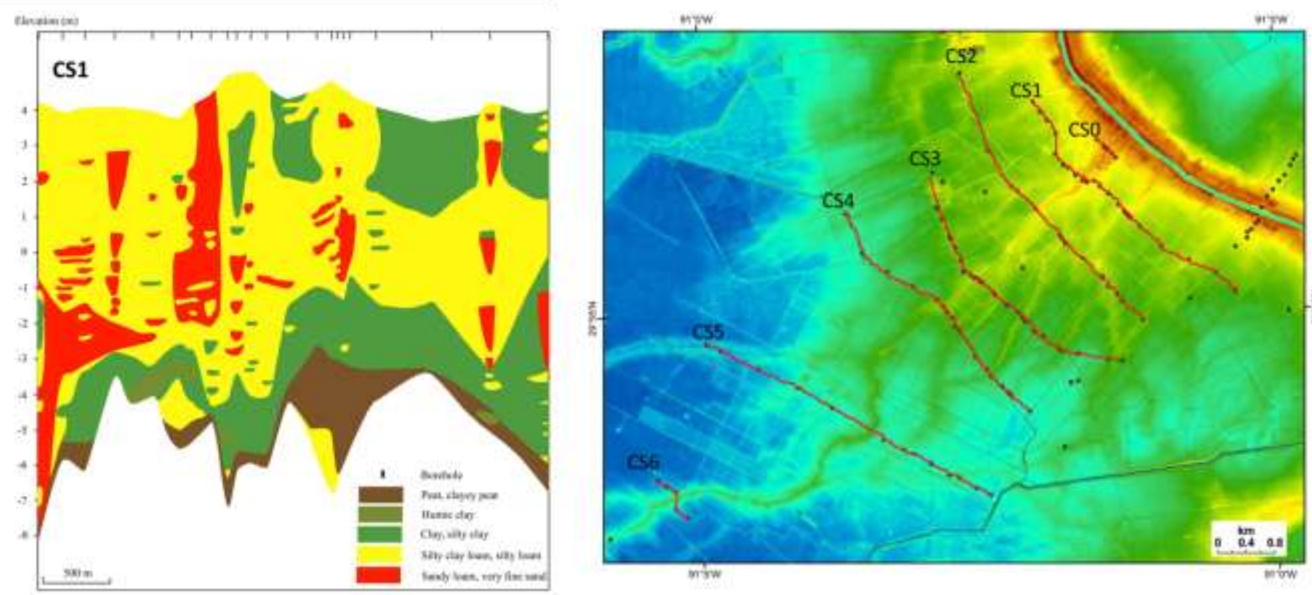


Figure 4. Map of the Attakapas Splay with locations of 7 cross sections abbreviated CS (CS0, CS1, CS2, CS3, CS4, CS5 and CS6, see appendix Figure S2 for other cross sections) that are marked by red lines. To the left of the map is a vertical cross section of CS1. The x axis is the horizontal component of the splay and core locations are indicated by black tick marks and the y axis is the vertical depth component which measures thickness of deposits (in meters) relative to sea level. Sediment texture bodies are indicated by red (sandy loam, very fine sand), yellow (silty clay loam, silty loam) and green (clay, silty clay) whereas brown-green (humic clay) and brown (peat, clayey peat) indicate the lower margin of the splay deposits.

Results

There were a total of 6 vfS samples (Table S1, see appendix) with a median grain size of ~26 µm (Figure 5). Based on the USDA descriptions, the very fine sands range from 90-100% sand sized particles, 0-15% silt sized particles and 0-10% clay sized particles. While our data was self-consistent for each of the samples, it did not match USDA descriptions for vfS. The very fine sands contain 23.2% sand, 65.8% silt and 10.9% clay (Figure 5). While the data for clay particles nearly fits within the USDA range, sand particles and silt particles seemed to be reversed. The sample contains a much greater percentage of silt and less sand than anticipated. This is probably caused by the fact that very fine sands are the finest of all sands and we were unable to differentiate silty material from very fine sandy material in our field observations.

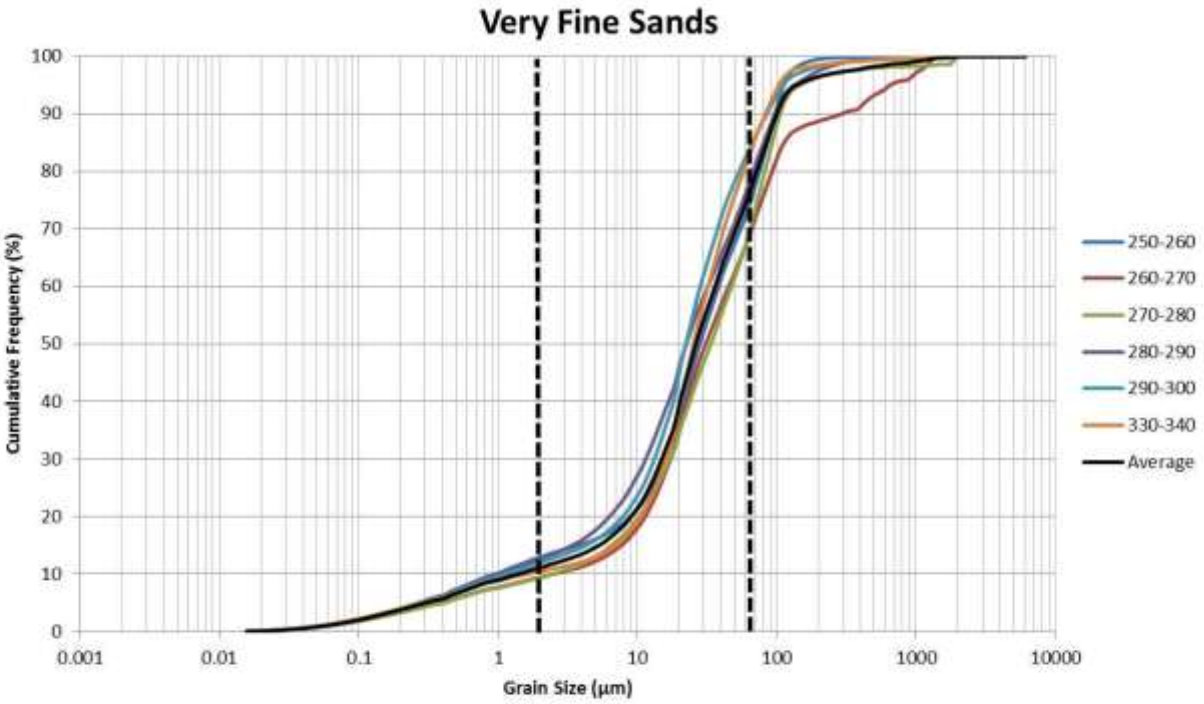


Figure 5. A cumulative frequency grain size distribution curve of clay samples. Individual samples and an average line is plotted together. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

There were a total of 14 SL samples (Table S2, see appendix) with a median grain size of ~24 µm (Figure 6). Based on USDA descriptions the sandy loams contain 43-85% sand, 0-50% silt and 0-20% clay. Once again, the field descriptions are self-consistent, however they do not match USDA ranges. The samples contain an average of 10.1% clay which fits in the USDA range. However, the average percentage of sand (17%) falls below the USDA ranges and the average percentage for silt particles (72.9%) is much greater than the USDA ranges (Figure 6).

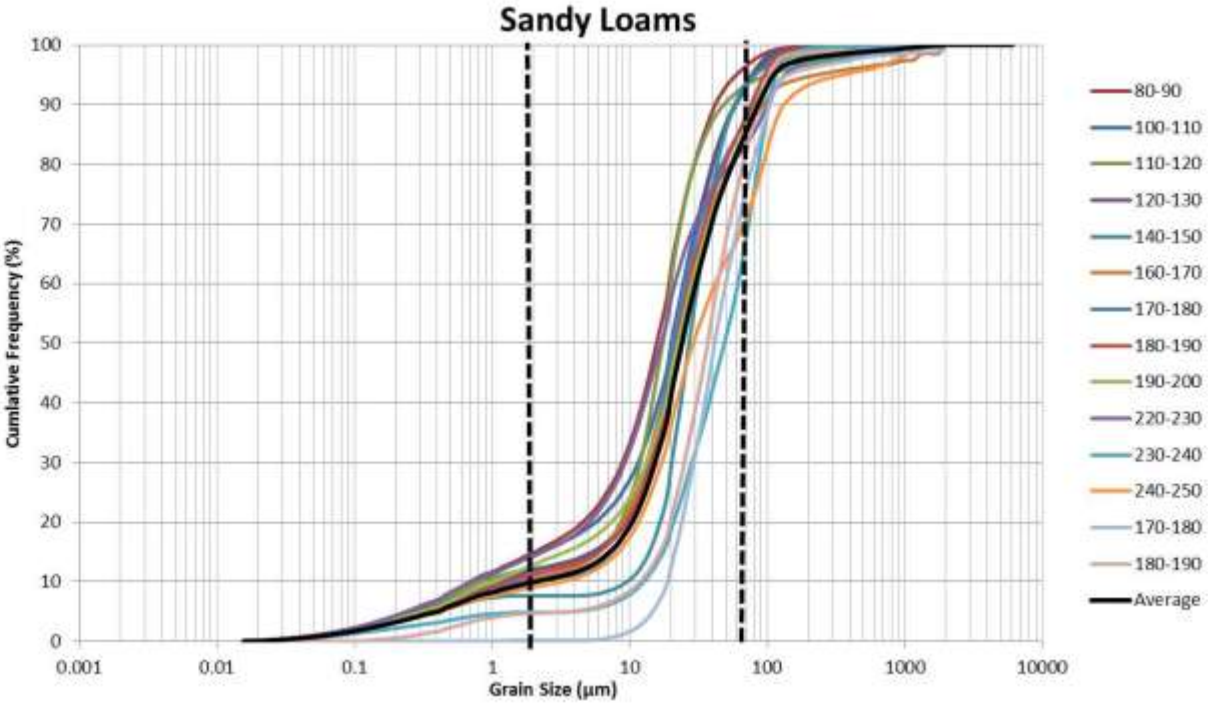


Figure 6. A cumulative frequency grain size distribution curve of sandy loam samples. Individual samples and an average line is plotted together. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

There are 9 silt loam samples (Table S3, see appendix) with a median grain size of ~15 µm (Figure 7). According to USDA descriptions silt loams contain 0-50% sand, 50-88% silt and 0-27% clay. Our field data for silt loams is not only the most self-consistent but also accurately fit into USDA ranges of grain sizes containing sand (4.9%), silt (79.4%) and clay (15.6%) (Figure 7). The sand percentages are on the low end of the USDA range while silt is on the higher end of the USDA range and this was probably because there were many grains on the fine line between sand and silt that we were unable to identify using our field methods.

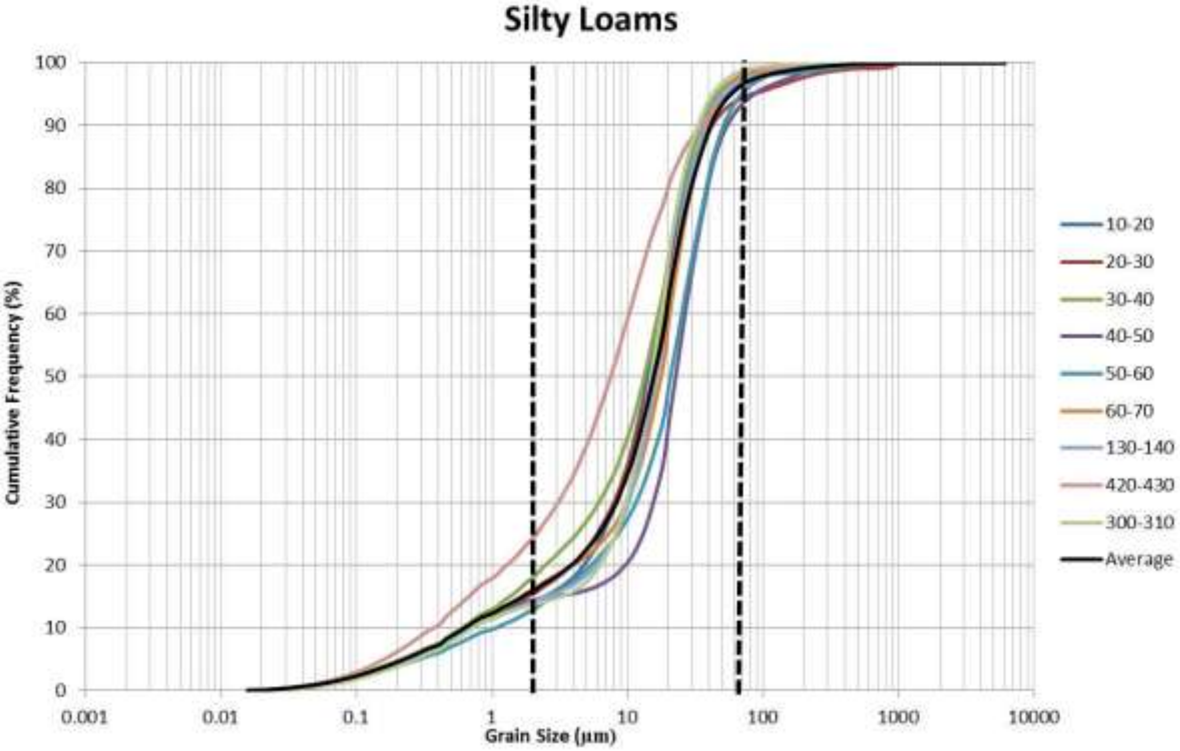


Figure 7. A cumulative frequency grain size distribution curve of silt loam samples. Individual samples and an average line is plotted together. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

There are 10 silty clay loam samples (Table S4, see appendix) with a median grain size of ~5 µm (Figure 8). Based on USDA descriptions, silty clay loams contain 0-20% sand, 40-73% silt and 27-40% clay and our data is quite variable. Our percentages of sand (3.7%), silt (68.5%) and clay (27.9%) (Figure 8) fit within the USDA ranges. However, there are several samples that deviate from the rest. Samples 430-440 and 470-480 have much higher percentages of sand (19.8% and 12.5% respectively) and significantly lower percentages of clay than the rest of the data.

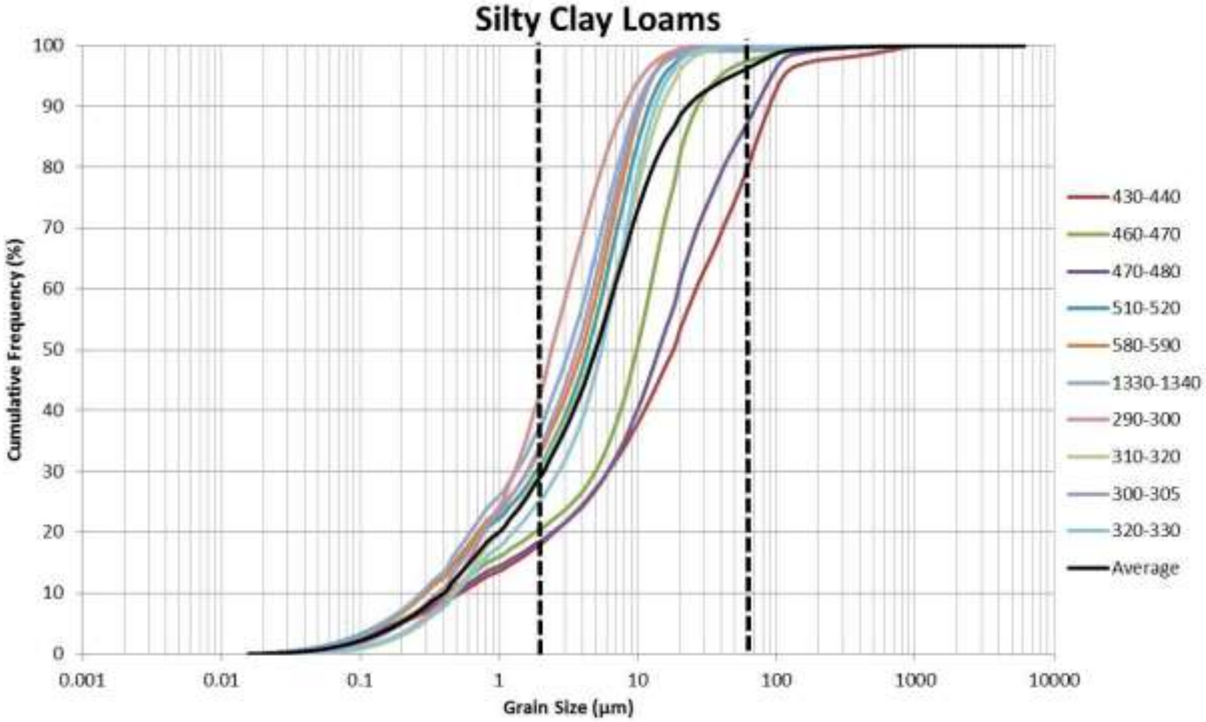


Figure 8. A cumulative frequency grain size distribution curve of silty clay samples. Individual samples and an average line is plotted together. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

There are 7 silty clay samples (Table S5, see appendix) with a median grain size of ~3.8 µm (Figure 9). Silty clays contain 0-20% sand, 40-60% silt and 40-60% clay. Our data is self-consistent with field descriptions except for two outliers at depths 680-690 and 770-780 that have higher percentages of clay and lower percentages of silt than the other samples. Nonetheless, our data for silty clays is fairly consistent with the USDA ranges with sand (0.6%) falling with the USDA ranges, silt (68.8%) falling above USDA ranges, and clay (30.6%) falling below the USDA ranges (Figure 9).

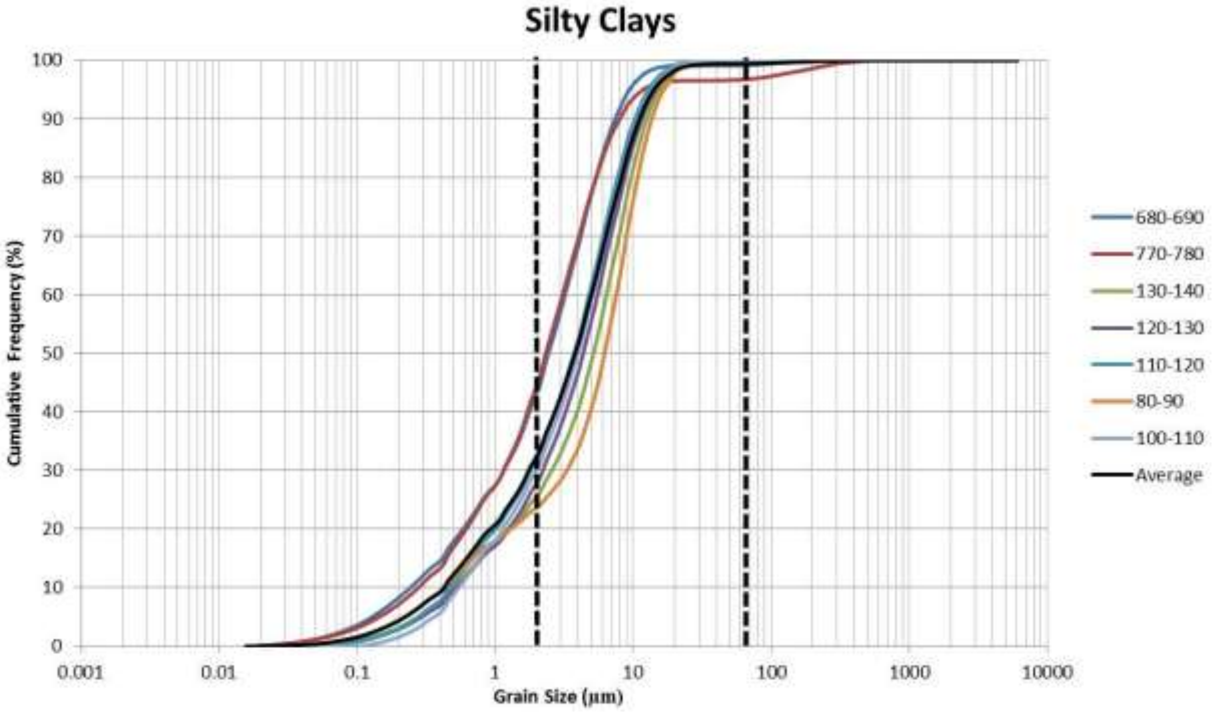


Figure 9. A cumulative frequency grain size distribution curve of silty clay samples. Individual samples and an average line is plotted together to show precision within samples of the same texture class. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

There are 8 total clay samples (Table S6, see appendix) with a median grain size of ~2.8 µm (Figure 10). According to USDA descriptions, clays contain 0-45% sand, 0-40% silt and 40-100% clay particles. Our field descriptions are self-consistent and sand percentages (0.524%) fall in the USDA ranges whereas silt percentages (59.5 %) fall way above USDA ranges and clay percentages (39.97%) just below the USDA ranges (Figure 10).

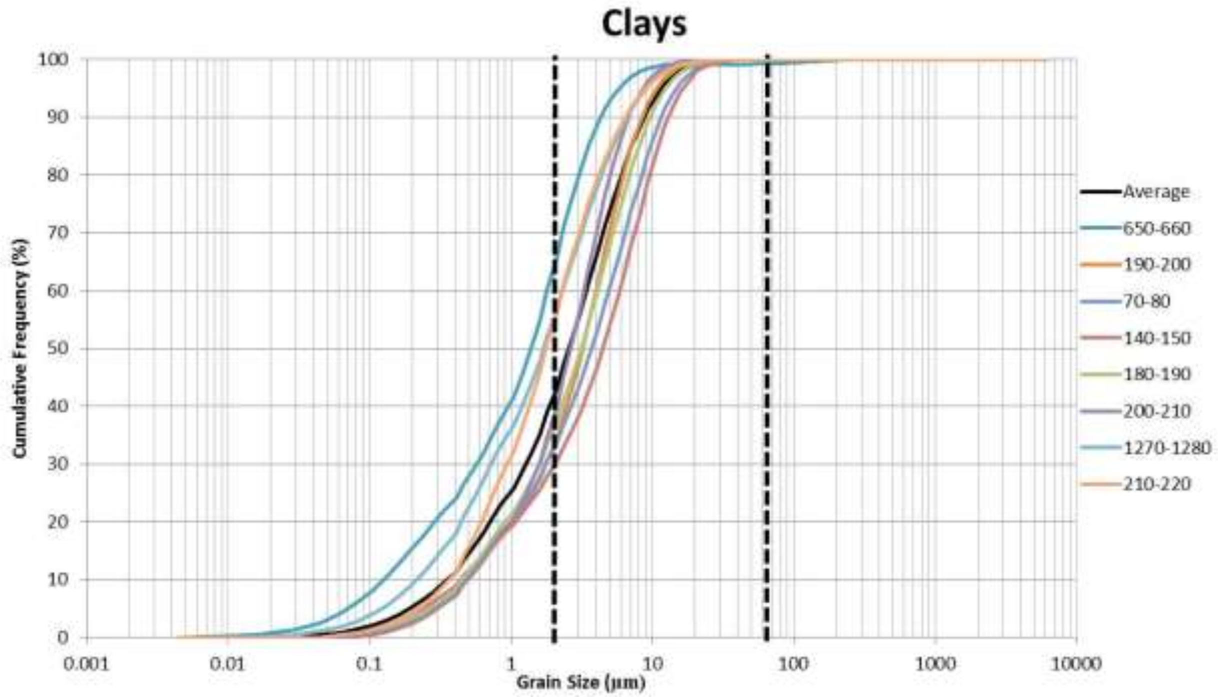


Figure 10. A cumulative frequency grain size distribution curve of clay samples. Individual samples and an average line is plotted together to show precision within samples of the same texture class. Dotted lines signify clay-silt and silt-sand separation zones (from left to right respectively).

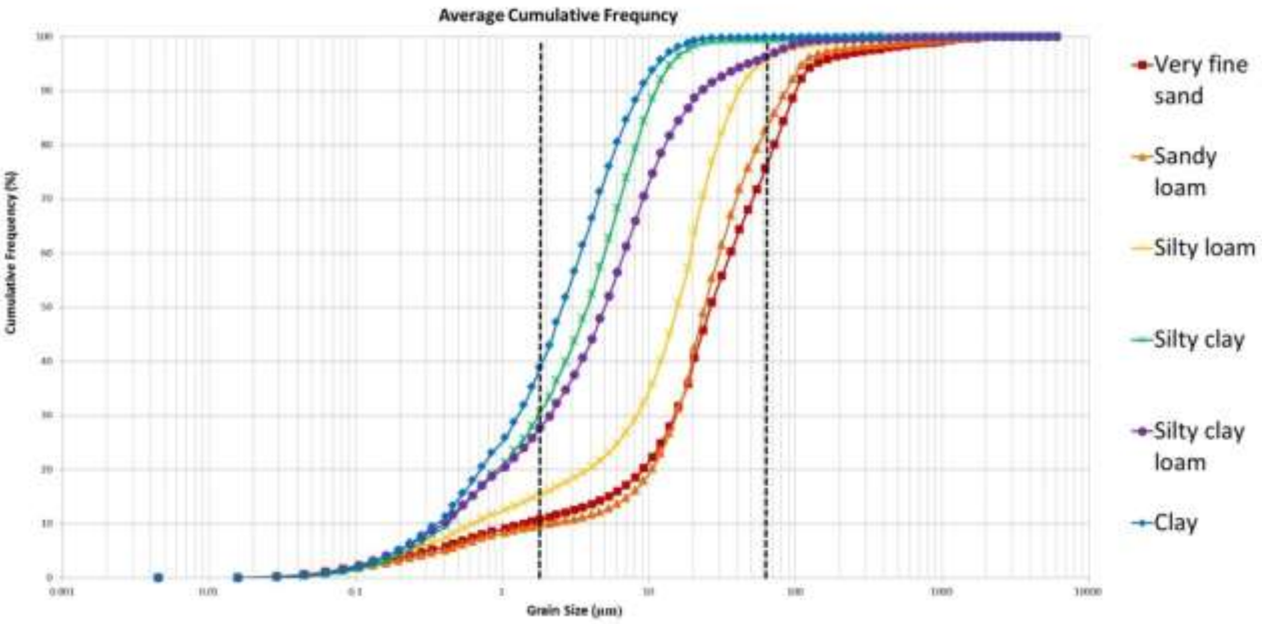


Figure 11. An average cumulative frequency plot of 6 textural classes in the Attakapas Splay. Dashed lines represent the clay-silt and silt-sand separation zones from left to right respectively.

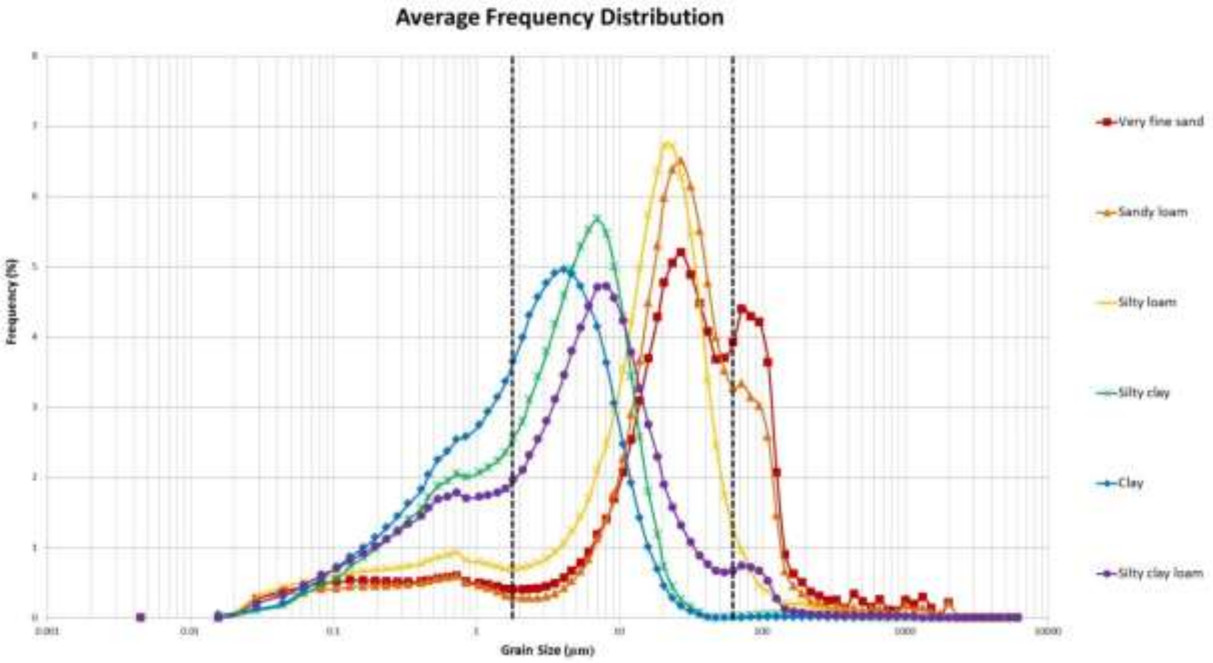


Figure 12. An average frequency distribution plot of 6 textural classes in the Attakapas Splay. Dashed lines represent the clay-silt and silt-sand separation zones from left to right respectively.

Figures 11 and 12 were generated to visually represent the average grain size distribution for each texture class. Figure 11 is an average cumulative distribution of grain size in which the median grain size of each texture class can be calculated by reading the grain size at a cumulative frequency of 50%. This plot is also intended to determine the contributions of sand, silt and clay for each of the texture classes. Figure 12 is an average frequency distribution of grain size plot which indicates the percentage that each grain size contributes to the entire sample and can be used to find the mode grain size.

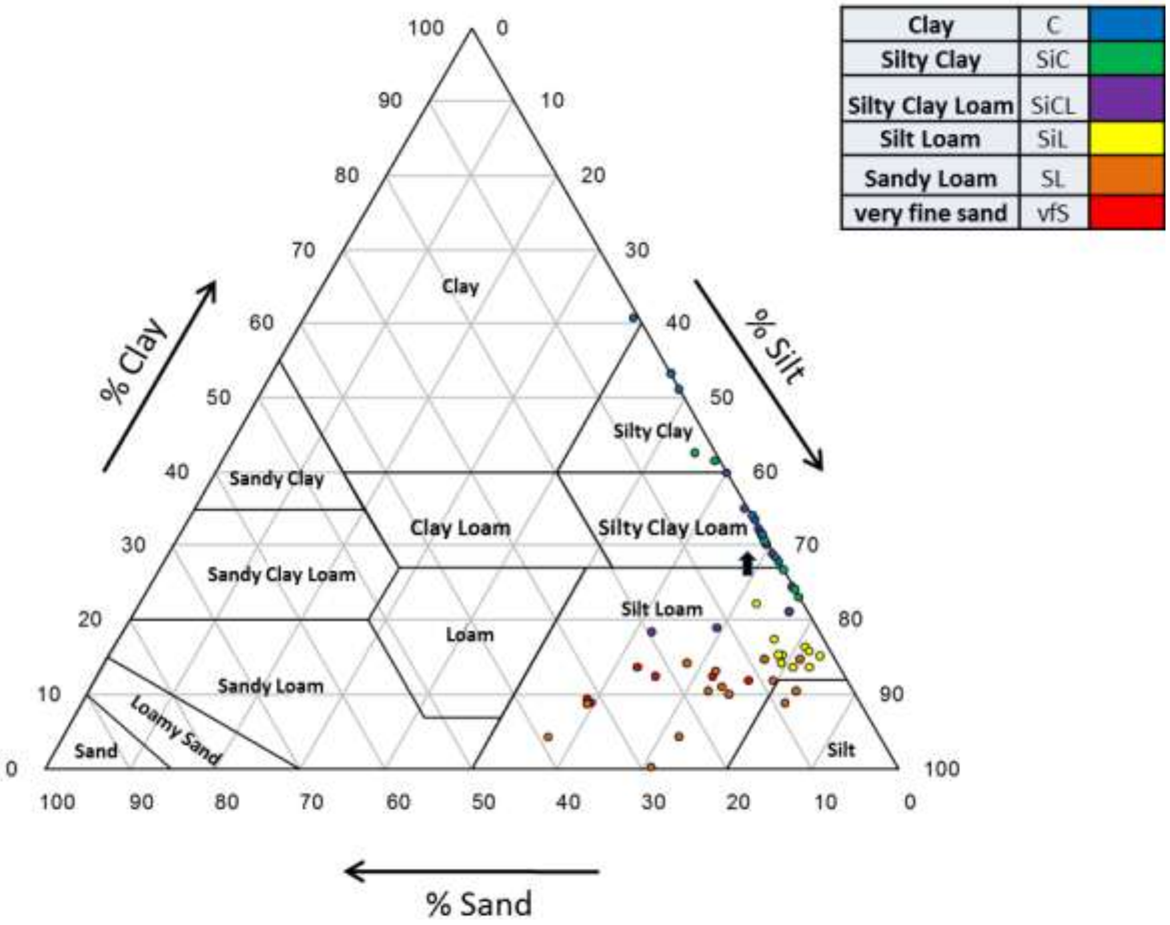


Figure 13. A U.S.D.A. textural ternary triangle with 54 samples plotted. This diagram was generated by Textural Auto Lookup program for windows and was used to compare our quantitative data to theoretical sediment texture classifications. The black arrow represents the sediment classification for the entire Attakapas Splay.

Our data show that sediments trapped in the splay contain very high percentages (>40%) of silt. In addition, there appears to be more clay on average than sand in the samples. Coarse grained samples never contain more than 40% sand whereas some of the finest grained samples contain as much as 60% clay (Figure 13). Overall, we did not successfully predict the exact percentages of sand, silt and clay for the texture classes as according to USDA standards. However, our field descriptions are still useful because samples belonging to different texture classes plot in logical sectors of the textural diagram (Figure 13) relative to one another. A prominent trend exhibited in the data shows that from vfs-SiL the sand percentage decreases and the silt percentage increases with clay percentages staying fairly even around ~10%. From SiL to C, silt percentages decrease while clay percentages increase with sand percentages staying even at ~ 2%. These results show that while samples were interpreted as being very coarse-grained or very fine-grained, in reality, they were actually silty. These data are in agreement with the drainage basin of the Mississippi River being dominated by loess.

Sediment Area Calculations

In order to ascribe the grain size measurements to the cross sections, I first consolidated the percentages of sand, silt and clay from the data set from six textural groups to three (“SL,vfs”, “SiCL, SiL” and “C, SiC”). This was done by averaging the percentages of sand, silt and clay for the two textural classes within the consolidated classes (Table 1).

Table 1. Lithology and area of sediment bodies in Attakapas Splay cross sections

	Sand %	Silt %	Clay %	Area (10^6 m^2)
🟩 C, SiC	20.1	70.9	10	15.4
🟨 SiCL, SiL	4.3	74	21.7	13.3
🟥 SL, vfs	0.5	64.2	35.3	1.44

To estimate the overall sediment composition, the 2-dimensional vertical area of sediment bodies was calculated and added together for all 7 of the cross sections (Table 1). From these numbers and the new, consolidated sediment texture classifications, I was able to calculate the areas of sand, silt and clay within each of the texture bodies and then add them up and estimate the contribution of sand, silt and clay to the entire splay. By using this method, I found that the splay contains about 3.4% sand, 69.5% silt and 27.2% clay.

Sediment Trapping Efficiency Calculation

The quantitative data allow us to estimate the sediment trapping efficiency of the Attakapas Splay. We assume that all of the sand brought to the splay was trapped. Therefore, the total weight of sand contained within the splay is found by multiplying the percentage of sand (***A***) of flooding sediments introduced to the splay during a crevassing event by the total weight of sediment brought to the splay during the crevassing event (***W***). Taking the sediment trapping efficiency as ***C***, the total weight of the splay deposits is found by multiplying ***W*** and ***C***. Therefore, the percentage of sand of the splay deposits (***B***) is found by:

$$\boldsymbol{B = \frac{A * W}{C * W} \ (1)}$$

$$\boldsymbol{C = \frac{A}{B} \ (2)}$$

The equation was rearranged to calculate sediment trapping efficiency ***C*** by dividing ***A*** by ***B*** (Equation 2). The value of ***B*** was generated from the grain size measurements and cross section analysis as being 3.4%. The value of ***A*** is calculated below (Equation 6).

The percentage of sand of flooding sediments supplied to the splay by the trunk river channel (***A***) was calculated by combining data from two sources. First, it is estimated that the flooding sediments had to come from the upper 10 m of the trunk river channel flow given that the crevasse channel is probably ~10 m deep based on a cross section (CS0 in Figure 4) cutting through the crevasse channel near Bayou Lafourche. In order to describe how the sediment load of sand changes with trunk river channel depth (***x***) (***x*** is expressed as percentage of depth relative to the full channel depth) during major flooding events, a function ***f(x)*** was developed. Function ***f(x)*** is composed of 2 components: ***h(x)*** and ***g(x)***.

Function ***h(x)*** expresses how the concentration of sand in the suspended sediment load varies with depth and was developed from a plot of sand concentration in suspended load (SSC) in mg/L with increasing water depth taken during a high discharge period in April, 2008 near Empire, LA (Allison et al., 2010). To get ***h(x)*** I fitted a linear function to these data (Figure S1, see appendix) and found:

$$\boldsymbol{h(x) = 23.2x + 0.33 \ (3)}$$

Function ***g(x)*** expresses how river width changes with channel depth. Given average channel geometries of Bayou Lafourche; the channel is ~40 m deep (Fisk 1952), 430 m wide and banks have an angle of 30° (Wallinga 1997). This function is important because it describes how the Bayou Lafourche river channel changes spatially with depth which is important in understanding the percentage of sand carried in flooding sediments ($\boldsymbol{A}$). I found ***g(x)*** as:

$$\boldsymbol{g(x) = -160x + 430 \ (4)}$$

$$\boldsymbol{df(x) = g(x) * h(x) * d(x) = (-3712\mathrm{x}^2 + 9923.2x + 142) * dx \ \ (5)}$$

Finally, ***dx*** represents incremental changes in depth over which the function ***f(x)*** is integrated. We are interested in calculating the percentage of sand introduced by the trunk river channel in the upper 10 m (25%, 0.25) of the flow, which is $\boldsymbol{A}$. This was calculated by integrating ***f(x)*** for the upper 25% of the river channel and dividing it by the integration of ***f(x)*** for the entire river channel (100%, 1) and multiplied by the percentage of suspended sand carried by the Mississippi River during peak discharge events that is approximated by the suspended sand load of the modern Mississippi River which is ~20% (Nittrouer et al., 2008).

$$\boldsymbol{A} = \frac{\int_{0}^{0.25} \boldsymbol{df}(\boldsymbol{x})}{\int_{0}^{1} \boldsymbol{df}(\boldsymbol{x})} * \mathbf{0.20} \cong \mathbf{0.017}\ (\mathbf{6})$$

$$\boldsymbol{x} = \frac{\boldsymbol{A}}{\boldsymbol{B}} = \frac{\mathbf{0.019}}{\mathbf{0.034}} * \mathbf{100} = \mathbf{49.6}\%\ \ (\mathbf{7})$$

A depth of 10 m was estimated from CS0 (Figure 4) which was the closest cross section we took to the river channel, however, deposits directly next to the trunk river channel may indicate thicker deposits. Second, the 40 m depth is probably the maximum depth of Bayou Lafourche. A shallower channel should have higher percentage of sand supplied by the trunk river channel in the upper 10 m of the flow and thus a higher sediment trapping efficiency according to my methods. Third, the sediment load of Bayou Lafourche probably contained >20% of sand in suspension (which is a modern-day estimate) when the Attakapas Splay was formed because after dam construction, sand should have been preferentially trapped by dams. Therefore, the sediment trapping efficiency of ~49.6% is probably a conservative estimate for the sediment trapping efficiency of the Attakapas Splay and was used to illustrate a scenario for sediment trapping efficiency of a vegetated swamp and to show that it is still much greater than deep water environments like the Wax Lake Delta.

Discussion

The Lafourche subdelta became active ~1500 years ago (Törnqvist et al., 1996) and has an average thickness of 10 m, area of 10,000 km^2 and a specific density of 1.5 gcm^{-3} (Törnqvist et al., 2007). The Attakapas Splay itself has been the subject of several recent studies examining the effectiveness of shallow swamps as a location of river diversions. Austin Nijhuis' report in 2011 with the aid of a UROP grant from Louisiana State University's Sea Grant used OSL dating techniques to estimate that the splay was formed from ~700-1200 years ago and ~9 m of sediment accumulated at a rate of 0.7-2.5 cm/year (Nijhuis 2011). The Attakapas Splay is an ideal study area because it was formed at a time when the Bayou Lafourche sediment load was probably similar to modern-day Mississippi.

The Attakapas Splay contains 69.5% silt and 27.2% clay particles amounting to almost 97% of all the material in the splay whereas only 3.4% of the splay is within the sand fraction. Based on an estimation of sediment trapping efficiency of ~49.6% for the Attakapas Splay, vegetated swamps can be favorable locations for future river diversions and deserve consideration for wetland restoration projects. Another location that has been extensively studied an example for river diversion is the Wax Lake Delta. Deposits in the Wax Lake Delta contain ~70% sand (Roberts 2003) and have a sediment trapping efficiency of ~30% (Kim et al., 2009) indicating that 90% of the sediment load represented by mud is not trapped and is carried away by alongshore currents.

A recent study has indicated that sites with a trapping efficiency of 40% given current sea level, compaction and sedimentation conditions have the ability to build 700-900 km^2 of new land in the next 100 years (Blum and Roberts 2009). A vegetated swamp like that which underlies the Attakapas Splay has a higher sediment trapping efficiency in this model. Therefore, one could optimistically say that if all of the Mississippi River sediment load were introduced to vegetated swamps like in the Attakapas Splay, more than the estimated 700-900 km^2 of new land would be built in the next 100 years.

Conclusions

The Attakapas Splay was far better at trapping the Mississippi River sediment load than the Wax Lake Delta with a trapping efficiency of ~49.6% and the sediment within the splay is dominantly silt (69.5%) and clay (27.2%) with minimal amounts of trapped sand (3.4%). This study shows that shallow swamp environments adjacent to the Mississippi River channel can be effective sites for river diversions and are much better than open-water environments like the Wax Lake Delta.

In future research, I plan to use GIS software to more accurately calculate volumes of sediment bodies to refine the accuracy of the overall sediment texture of the splay. Our grain size measurement dataset can be further improved by increasing the number of samples as well as the locations where these samples are taken.

Acknowledgements

I would first like to thank Louisiana State University's Sea Grant Program for giving me the Undergraduate Research Opportunities Grant and allowing me to perform research for the last year. I would also like to thank my advisors, Torbjörn Törnqvist and Zhixiong Shen for guidance in field work, laboratory work, data preparation and analysis as well as in preparing this report. I would also like to thank lab technician Jenny Kuykendall for her enormous help in my understanding of laboratory and field techniques and Dr. Kyle Straub for allowing me to use his lab for grain size measurements.

References

Allison, M.A. & Meselhe, E.A. (2010). The use of large water and sediment diversions in the lower Mississippi River (Louisiana) for coastal restoration. *Journal of Hydrology, 287, 346-360.*

Blum, M.D. & Roberts, H.H. (2009). Drowning of the Mississippi Delta due to insufficienct sediment supply and global sea-level rise. *Nature Geoscience. 2, 288-491*.

Brown, R. B. (1998). Soil Texture. [Gainesville, Fla.]: University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.

Fisk, H.N. (1952) Geological Investigation of the Atchafalaya Basin and Problems of Mississippi River Diversion, Vol. I and II, US Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS.

Horowitz, A.J. (2009). A Quarter Century of Declining Suspended Sediment Fluxes in the Mississippi River and the Effect of the 1993 Flood. *Hydrological Processes*.

Kim, W., D. Mohrig, R. Twilley, C. Paola, and G. Parker (2009), Is it feasible to build new land in the Mississippi River delta?, Eos Trans. AGU, 90(42), 373–374.

Lyons, William J. Doctoral Dissertation. (2004). Quantifying Channelized Submarine Depositional Systems from Bed to Basin Scale. Joint Program in Oceanography/Applied Ocean Science and Engineering.

Mossa, J. (1996). Sediment Dynamics in the Lowermost Mississippi River. *Engineering Geology*. 45.1-4 457-79.

Nijuis, A. (2010). Quantifying Wetland Accretion Rates in the Mississippi River Delta Using Recent Crevasse Splay Deposits as Natural Analogs for River Diversions. Louisiana Sea Grant Undergraduate Research Opportunities Program Report.

Nittrouer, J. A., M. A. Allison, and R. Campanella (2008), Bedform transport rates for the lowermost Mississippi River. *Journal of Geophysics Research*, 113.

Roberts, H.H.& Sneider, J. (2003). Atchafalaya-Wax Lake Deltas: The New Regressive Phase of the Mississippi River Delta Complex. Guidebook Series No. 6. Louisiana Geological Survey.

Törnqvist, T.E., Kidder, T.R., Autin, W.J., van der Borg, K., de Jong, A.F.M., Klerks, C.J.W., Snijders, E.M.A., Storms, J.E.A., van Dam, R.L., Wiemann, M.C.(1996). A revised chronology for Mississipi river subdeltas. *Science 273, 1693-1696.*

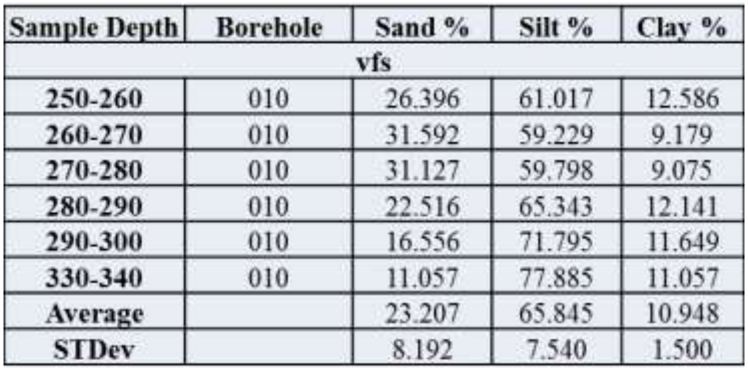
Törnqvist, T.E., Paola, C., Parker, G., Liu, K. Mohrig, D., Holbrook, J.M., Twilley, R.R. (2007). Comment on "Wetland Sedimentation from Hurricane Katrina and Rita". *Science 316, 201.*

Törnqvist, T.E., Wallace, D.J., Storms, J.E.A., Wallinga, J., van Dam, R.L., Blaauw, M., Derksen, M.S., Klerks, C.J.W., Meijneken, C., Snijders, E.M.A. (2008). Mississippi Delta subsidence primarily caused by compaction of Holocene strata. *Nature Geoscience. 1, 173-176.*

Wallinga, J. (1997). Bayou Lafourche: a study focusing on channel deposits and proximal overbank deposits of Bayou Lafourche, Louisiana, USA. Utrecht University, Netherlands.

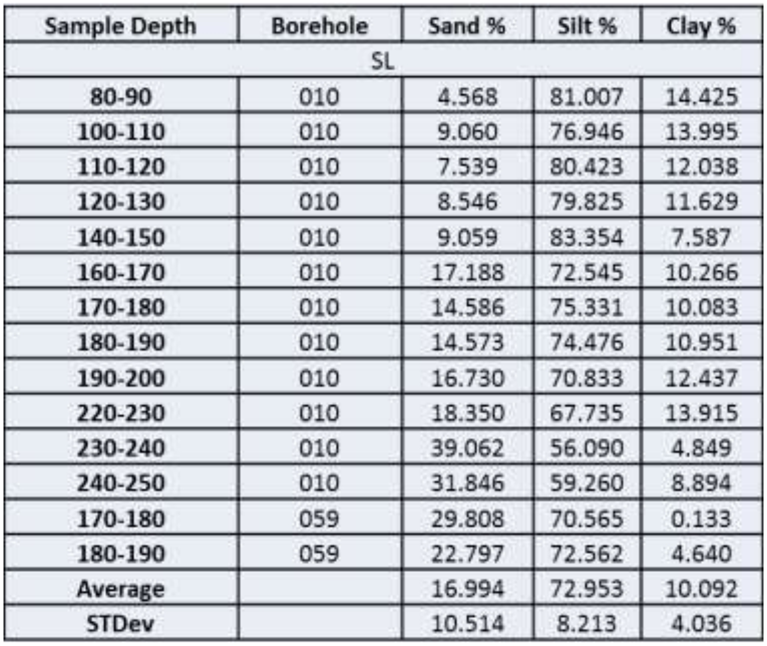
Appendix

Table S1. vfS samples and sand, silt and clay %



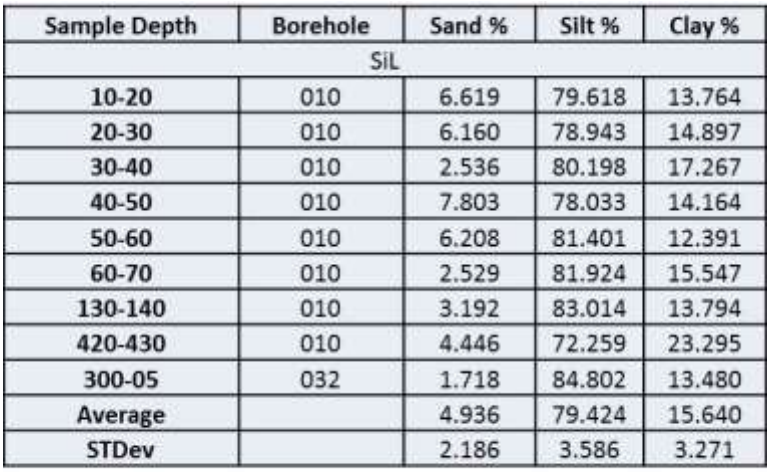
Sample Depth	Borehole	Sand %	Silt %	Clay %
vfs				
250-260	010	26.396	61.017	12.586
260-270	010	31.592	59.229	9.179
270-280	010	31.127	59.798	9.075
280-290	010	22.516	65.343	12.141
290-300	010	16.556	71.795	11.649
330-340	010	11.057	77.885	11.057
Average		23.207	65.845	10.948
STDev		8.192	7.540	1.500

Table S2. SL samples with sand, silt and clay %



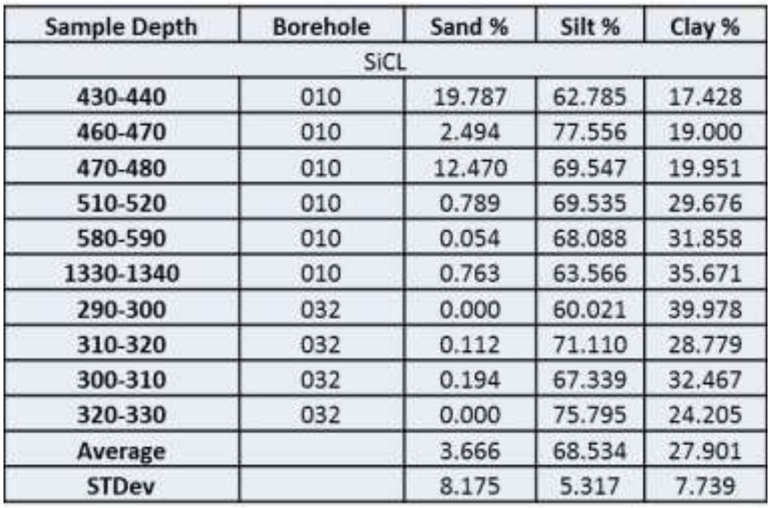
Sample Depth	Borehole	Sand %	Silt %	Clay %
		SL		
80-90	010	4.568	81.007	14.425
100-110	010	9.060	76.946	13.995
110-120	010	7.539	80.423	12.038
120-130	010	8.546	79.825	11.629
140-150	010	9.059	83.354	7.587
160-170	010	17.188	72.545	10.266
170-180	010	14.586	75.331	10.083
180-190	010	14.573	74.476	10.951
190-200	010	16.730	70.833	12.437
220-230	010	18.350	67.735	13.915
230-240	010	39.062	56.090	4.849
240-250	010	31.846	59.260	8.894
170-180	059	29.808	70.565	0.133
180-190	059	22.797	72.562	4.640
Average		16.994	72.953	10.092
STDev		10.514	8.213	4.036

Table S3. SiL samples with sand, silt and clay %



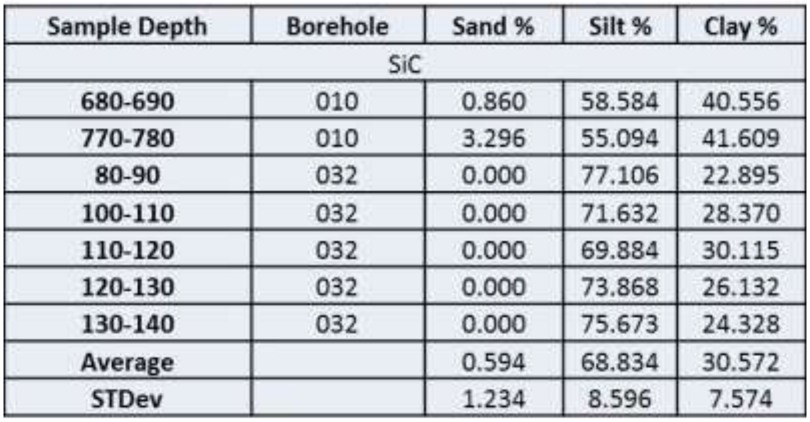
Sample Depth	Borehole	Sand %	Silt %	Clay %
		SiL		
10-20	010	6.619	79.618	13.764
20-30	010	6.160	78.943	14.897
30-40	010	2.536	80.198	17.267
40-50	010	7.803	78.033	14.164
50-60	010	6.208	81.401	12.391
60-70	010	2.529	81.924	15.547
130-140	010	3.192	83.014	13.794
420-430	010	4.446	72.259	23.295
300-05	032	1.718	84.802	13.480
Average		4.936	79.424	15.640
STDev		2.186	3.586	3.271

Table S4. SiCL samples with sand, silt and clay %



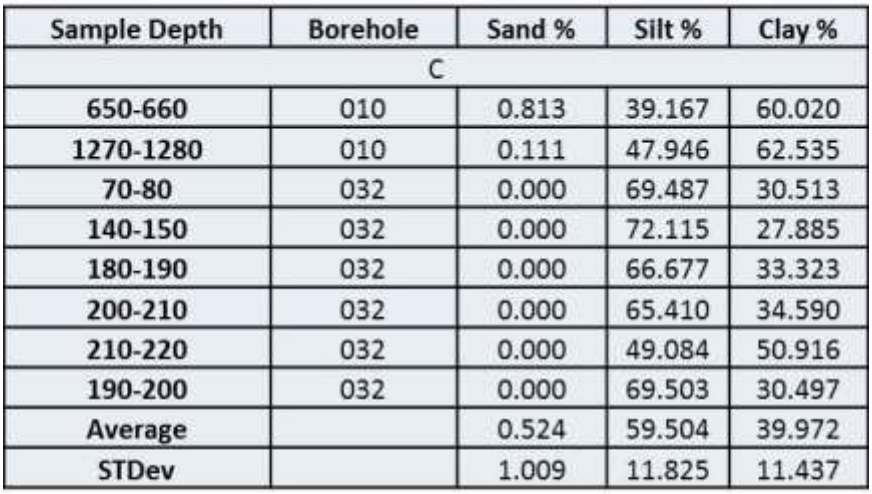
Sample Depth	Borehole	Sand %	Silt %	Clay %
SiCL				
430-440	010	19.787	62.785	17.428
460-470	010	2.494	77.556	19.000
470-480	010	12.470	69.547	19.951
510-520	010	0.789	69.535	29.676
580-590	010	0.054	68.088	31.858
1330-1340	010	0.763	63.566	35.671
290-300	032	0.000	60.021	39.978
310-320	032	0.112	71.110	28.779
300-310	032	0.194	67.339	32.467
320-330	032	0.000	75.795	24.205
Average		3.666	68.534	27.901
STDev		8.175	5.317	7.739

Table S5. SiC samples with sand, silt and clay %



Sample Depth	Borehole	Sand %	Silt %	Clay %
SiC				
680-690	010	0.860	58.584	40.556
770-780	010	3.296	55.094	41.609
80-90	032	0.000	77.106	22.895
100-110	032	0.000	71.632	28.370
110-120	032	0.000	69.884	30.115
120-130	032	0.000	73.868	26.132
130-140	032	0.000	75.673	24.328
Average		0.594	68.834	30.572
STDev		1.234	8.596	7.574

Table S6. C samples with sand, silt and clay %



Sample Depth	Borehole	Sand %	Silt %	Clay %
C				
650-660	010	0.813	39.167	60.020
1270-1280	010	0.111	47.946	62.535
70-80	032	0.000	69.487	30.513
140-150	032	0.000	72.115	27.885
180-190	032	0.000	66.677	33.323
200-210	032	0.000	65.410	34.590
210-220	032	0.000	49.084	50.916
190-200	032	0.000	69.503	30.497
Average		0.524	59.504	39.972
STDev		1.009	11.825	11.437

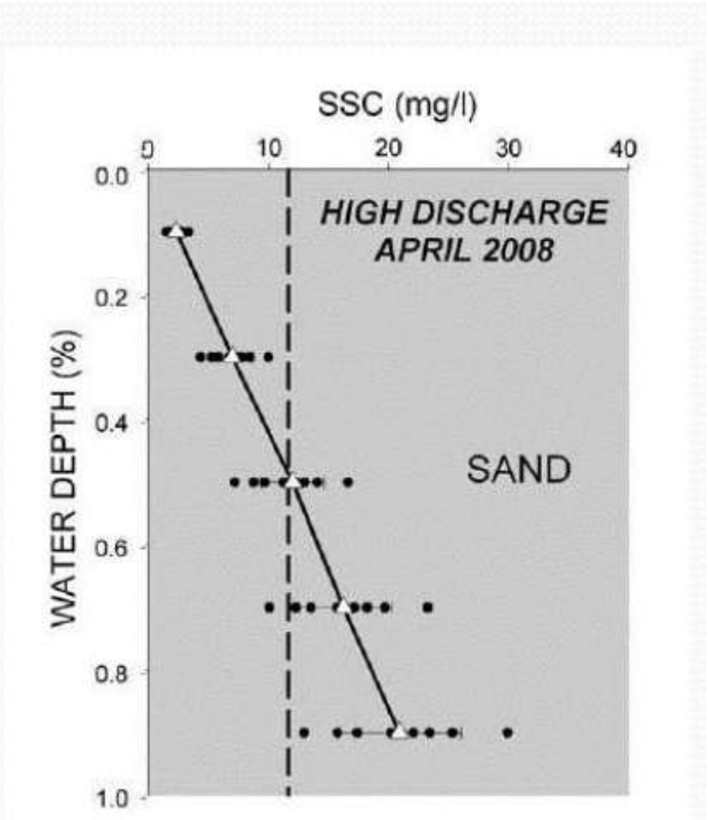


Figure S1. A plot of suspended sediment concentration (SSC) vs. percentage of river channel depth from Allison et al., 2010 (see references). The data was collected during high discharge period of the Mississippi River in April, 2008 near Empire, LA

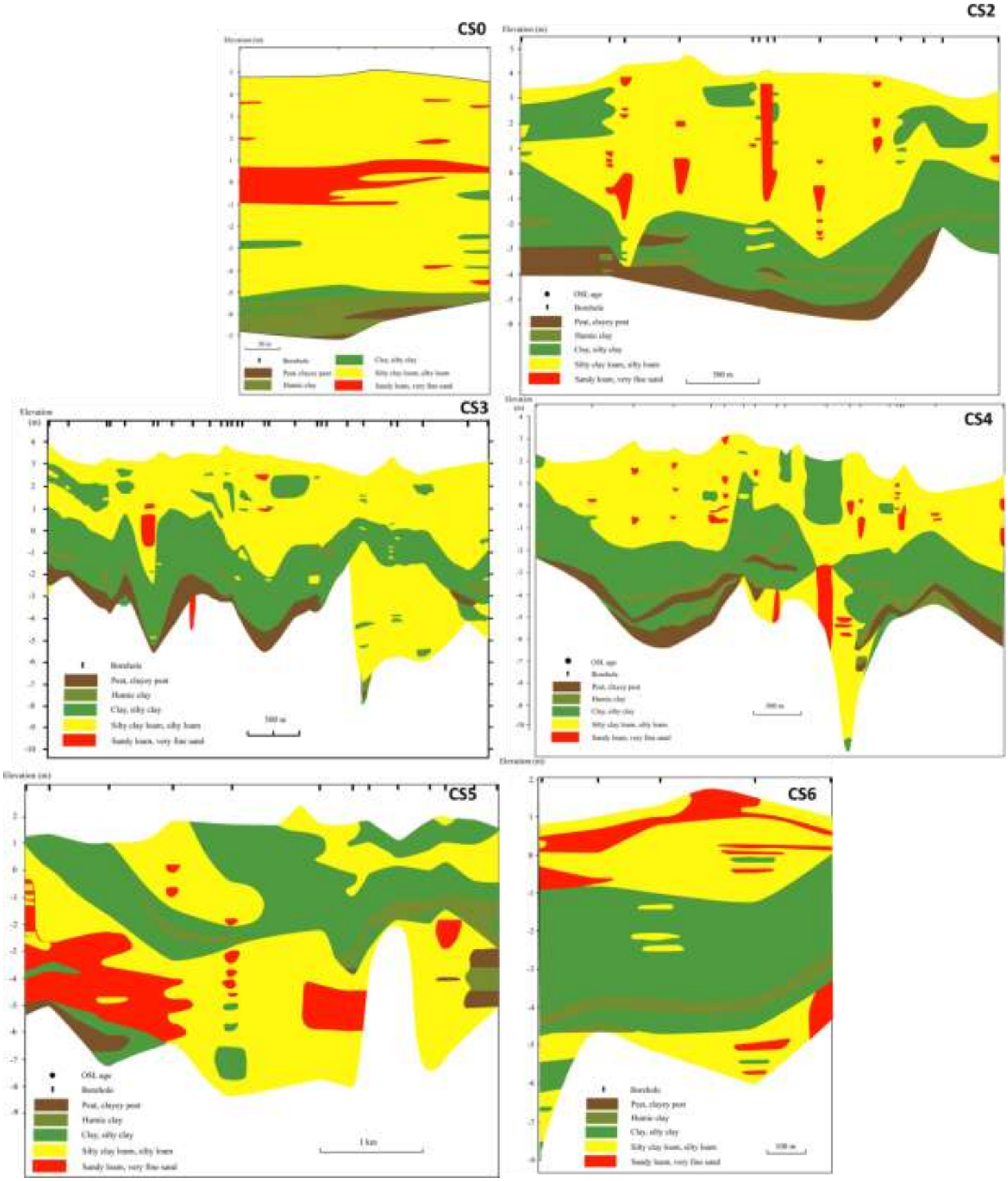


Figure S2. CS0, CS2, CS3, CS4, CS5 and CS6 vertical cross sections (refer to Figure 4 for corresponding map), The x axis is the horizontal component of the splay and core locations are indicated by black tick marks and the y axis is the vertical depth component which measures thickness of deposits (in meters) relative to sea level. Sediment texture bodies are indicated by red (sandy loam, very fine sand), yellow (silty clay loam, silty loam) and green (clay, silty clay) whereas brown-green (humic clay) and brown (peat, clayey peat) indicate the lower margin of the splay deposits.