Board of County Commissioners • Escambia County, Florida

Bayou Chico Contaminated Sediment Remediation Project – Planning Phase

Distribution and Quantification of Unconsolidated Fine-Grain Sediments

Summary Report for Data Collected

February – September 2017

Prepared by: Escambia County

Natural Resources Management Department

Water Quality & Land Management Division

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3363 West Park Place • Pensacola, Florida 32505

850.595.3445 Office • 850.595-3634 Fax

myescambia

bw, mk

Project Purpose

The overall purpose of the project is to improve benthic habitat and surface water quality within Bayou Chico through the remediation of contaminants found within the fine-grain unconsolidated bayou sediments. The project also seeks to enhance economic and recreational opportunities along the working waterfront. Open discussions of remediation of Bayou Chico contaminated sediments have occurred for years, but until recently adequate funding was not available to begin planning for implementation.

The purpose of this portion of the planning phase of the project was to map the current distribution of unconsolidated fine-grain sediments throughout the bayou, and to provide an up to date estimate of total volume. Heavy metals and hydrophobic organic compounds, such as PAHs and PCBs, bind strongly to sediments. If present, these contaminants are more likely to be associated with fine-grain sediments or organic rich sediments compared to coarser sand. Therefore, mapping fine-grain sediments can be a helpful preliminary step in delineating potential areas of contamination. The overall remediation plan will be developed in part with the data collected for this study.

Funding

The Gulf Coast Ecosystem Restoration Council (Council) was established by the RESTORE Act in 2012 to administer a portion of the Clean Water Act administrative and civil penalties related to the Deepwater Horizon Oil Spill (aka Pot 2 Federal funds). The Bayou Chico Contaminated Sediment Remediation Project was identified as a tier one project by the Council in the 2016 approved Funded Priorities List (FPL). Subsequently, the Council awarded a planning grant to the Florida Department of Environmental Protection (FDEP) to oversee the project. In 2017, Escambia County received a $335,000 subaward from FDEP for planning, design, and permitting. Furthermore, the Escambia County Board of County Commissioners has selected the implementation of the eventual Bayou Chico remediation plan as the county's sole submittal through the Florida Gulf Consortium for inclusion in the Florida State Expenditure Plan (aka Pot 3 State funds).

History

Bayou Chico is located within the Pensacola Bay watershed in south central Escambia County. The bayou has a surface water area of approximately 235 acres with a surrounding drainage basin of more than 6,600 acres. The eastern half of the bayou and associated contributing basin is located generally within the City of Pensacola with the remaining western bayou and associated contributing basin located outside city limits in unincorporated Escambia County. A federally maintained navigational channel extends north through the mouth of the bayou along the east shoreline to a point opposite of the western arm of the bayou. The federal channel terminates into a turning basin maintained for large vessels. Average water depth in the bayou is approximately eight feet (2.5 m). Deeper areas are located within the navigational channel. Maximum water depth exceeds 20 feet (6.0 m).

The Bayou Chico watershed is found within the urban core of Escambia County. Existing land uses within the basin include industrial, commercial, military, transportation, and single/multifamily residential. Existing waterfront uses range from parks and single family residential to heavy industry. Historic land uses included a booming timber and wood preservative industry that existed until the early to mid-20th century. Waste products from the timber industry, including chemicals used as wood preservatives, were either directly discharged into the bayou or were leached into the bayou from unlined holding ponds. As recent as 1971, a conservative estimate of eight major industrial and wastewater facilities discharged directly into the bayou. Permitted domestic wastewater discharges alone exceed 2.5 million gallons per day. Many anecdotal accounts exist of severely limited biologic activity within the bayou. Summer fish kills were common.

All major industrial and wastewater discharges to Bayou Chico have since been diverted. Tens of millions of dollars of water quality improvement, stormwater retrofit, and sewer expansion projects have been completed by Escambia County, City of Pensacola, Emerald Coast Utilities Authority, and other project partners. Marina facilities have also improved practices. Both stationary and mobile septage pump out facilities are now readily available.

Despite recent efforts to improve surface water quality, significant concentrations of legacy contaminates remain confined in the sediments of the bayou. Numerous studies have documented elevated levels of heavy metals (cadmium, chromium, copper, lead, mercury), polycyclic aromatic hydrocarbons (PAHs) (benzo(a)-pyrene, anthracene, acenaphthene), pesticides (chlordane, DDD, DDT, endrin, dieldrin, Mirex), and polychlorinated biphenyls (PCBs) (Mohrherr et al., 2006; Debusk et al., 2002; Wood and Bartel, 1994; Stone and Morgan, 1991).

Historic Estimates of Fine-Grain Sediment Quantity & Distribution

In 1977, The Florida Resources and Environmental Analysis Center at Florida State University prepared an assessment of the bayou for the Florida Department of Environmental Regulation. The assessment included an estimate of the unconsolidated fine-grain sediments within the bayou. At that time, the bayou was estimated to contain approximately 2 million m^3 (almost 2.5 million yd^3) of unconsolidated fine-grain sediments (Glassen, 1977). Numerous locations were shown to have >10 feet of “sludge” with the bulk of the material located south and east of the island toward the former Barrancas Avenue bridge and west of the turning basin. Historic sediment thickness distribution map is included below in Figure 1. The estimated volume and distribution were based on data collected from a total of 45 separate stations and an overall open water area of 208.4 acres (8,843,342.1 m^2). Most stations were located along the navigational channel or otherwise away from shore near the centerline of the bayou. The technology utilized for the 1977 study limited accuracy of mapping of sample locations and acreage calculations.

Escambia County Sediment Mapping Efforts using Remote Sensing

An initial effort was made in February 2017 to map the unconsolidated fine-grain sediments in the bayou using acoustic remote sensing. Three test lines were run under the supervision of the County Surveyor using a dual frequency echo sounder operating at 230 KHz and 12 KHz. Test line locations are depicted below in Figure 2. High frequency returns were expected to represent the sediment surface. Since lower frequencies are capable of greater penetration, low frequency returns were expected to represent the hard sand surface below the fine-grain sediment. The difference between the two returns was thought to represent the thickness or depth of fine-grain sediments. The initial results using dual frequency sonar appeared promising. Data appeared to indicate depth of fine-grain sediments along the test lines ranged from 0.0 - 3.9 feet (0.0 to 1.2 m). Test lines were then verified by physically measuring the thickness of the fine-grain sediments at five points using the method described below. The acoustic remote sensing data was not consistent with the physical measurements. The thickness of the fine-grain sediments was measured to be greater than 10 feet (3 m) at three of the five stations. Therefore, dual frequency sonar using the applied methodology was determined to be ineffective at measuring the overall thickness of the Bayou Chico fine-grain sediments based on the inconsistency between the remote sensing data and direct physical measurements.

Escambia County Sediment Mapping Efforts using Direct Physical Measurement

Station Selection

Sampling stations were selected by creating a grid with coverage of the entire bayou using the fishnet tool in ArcGIS 10.3 software suite. The origin of the fishnet grid was set at the surveyed northern most corner of Section 52 located in Township 2S and Range 30W (1092419.3560, 520538.5088 feet, NAD 1983 HARN Florida North FIPS 0903). The grid was orientated approximately parallel to the eastern shore of the bayou. This parallel alignment was developed by converting the shoreline from the entrance to Pensacola Bay northwest to the former location of the railroad trestle into a series of points. A “best fit” approach was taken to create a straight line representing the east shore using these points. The resulting angle of the y-axis used for the grid was approximately 121 degrees relative to true north. The cell size selected for the grid was 50 x 50 feet. Potential sampling stations were created at the centroid of each grid cell.

Stations were selected for this study 100 feet apart along shore parallel transects located 200 feet on center. The spacing of the stations and transects was based on guidance received from the consulting firm, Environmental Science Associates (ESA), tasked with assisting the Florida Gulf Consortium with developing projects. Stations were identified by indicating the xy location relative to the grid (e.g. 27 – 33, 55 – 49, etc.). A total of 507 sample stations were initially identified for this study. Un-sampled fishnet grid cells could be included in the future studies if determined additional resolution is required for the project. Sampling grid and stations are depicted below in Figure 3.

Sampling Methods

A 24-foot pontoon boat with davit arm and winch was utilized as the sampling platform for the study. The vessel was piloted to the approximate center of grid cells using a standard consumer grade GPS. The goal, given the limitations of piloting the pontoon boat, was to collect samples at known locations near the center of the appropriate grid cell. A small anchor with float was deployed when the boat was on location. The pontoon boat would then be re-positioned to account for wind and current prior to anchoring relative to the marker. Aluminum spuds were used to hold position for shallow water stations (<=12 feet), while three 18 lb. river anchors were required to hold position at deeper stations (>12 feet). Anchored positions were collected using a Differential Corrected GPS for sub-decimeter accuracy.

Shoreline constraints and other obstacles (i.e. docks, moored vessels, construction work associated with the construction of the new 3-Mile bridge, etc.) limited access to a number of the original sampling locations. Alternate sites were selected in the field for most inaccessible locations. Stations were sampled from June through September 2017.

Physical measurements were made from the bow of the pontoon boat by probing the fine-grain sediment with a 1 $^{3}/_{8}$" diameter,17-gauge galvanized steel pipe with convex cap covering the terminal end. Up to four ten-foot sections of interlocking galvanized steel pipe were required to provide the necessary length to reach the bottom of the thickest sediments in the deepest portions of the bayou. Each section of galvanized pipe was graduated in 0.1 foot increments. Once on location, the depth of water over sediment was carefully measured to the nearest 0.1 foot using the probe. The probe was then forced downward through the sediment until refusal. A second measurement was taken at depth. The difference between the two measurements was then calculated to determine the thickness of unconsolidated fine-grain sediment. The davit arm and winch was used to recover the probe as necessary. Photographs showing the equipment used are provided below as Figures 5 through 10.

Data was reviewed and cross checked. Location data was differentially corrected during post processing. The processed location data was used to establish the exact grid cell sampled if different from the original sampling plan.

Data Evaluation & Results

Thickness of unconsolidated fine-grain sediments was measured throughout Bayou Chico at 485 of the original 507 stations. Sample locations are shown below in Figure 4. Observed values ranged from <0.1 to 21.4 feet (0.0 – 6.5 m) with a mean thickness of 5.4 feet (1.7 m). As expected, the raw dataset is moderately skewed to the right (skewness = 0.872). A histogram of the raw dataset is provided below in Figure 11. Data are sufficient to conclude with 95% confidence that the data are not normally distributed based on a calculated Lilliefors Test

Statistic of 0.182 with a 5% critical value of 0.040. A Box and Whisker Plot and QQ Plot of the raw dataset are provided below as Figures 12 and 13, respectively.

A data transformation was attempted by calculating the natural log of the raw data according to the following equation $x = Ln(x+1)$. The transformation reduced the amount of skew in the dataset (skewness = -0.021). A histogram of the transformed dataset is provided below as Figure 14. The mean thickness of the transformed dataset was 3.3 feet (1.0 m). While the transformed dataset did more closely resemble the normal distribution, data are still sufficient to conclude with 95% confidence that the data are not normally distributed based on a calculated Lilliefors Test Statistic of 0.083 with a 5% critical value of 0.040. A Box and Whisker Plot and QQ Plot of the transformed dataset are provided below as Figures 15 and 16, respectively. An inspection of the transformed data histogram suggests the possibility the dataset for this study is comprised of two separate overlapping normal distributions each subset possibly governed by separate processes (e.g. natural depositional forces such as tides or currents vs. anthropogenic factors such as dredging).

Statistics for the raw and transformed datasets were calculated using Visual Sampling Plan 7.10 (VPS). Raw and transformed datasets are provided by station in Table 1.

The mean of both the raw and transformed datasets are not necessarily reliable measures of central tendency since the normal distribution cannot be assumed in either case. Geospatial interpolation can be a powerful tool to evaluate spatial relationships among data, creating continuous surfaces from point data, calculating quantities, and mapping distributions. Geospatial interpolation through kriging is an especially helpful tool in this case since it is not dependent on any distribution assumptions.

Project boundary for geospatial interpolation was created as a shapefile in ArcGIS 10.3 by digitizing the visible shoreline using 2013 Escambia County aerial photography with 1-foot spatial resolution. The open water extent of the bayou was estimated using this method at 234.0 acres not including a 1.5-acre island located along the western edge of the navigational channel west of the Barrancas Avenue bridge. Project boundary and sample stations were imported into VPS for kriging. The experimental variogram was calculated using the software to serve as a model of the spatial relationship between sampling locations. The generalized weighted linear regression algorithm was then used by the software to estimate continuous fine-grain sediment thickness data from the initial point data for the entire bayou. Variogram and kriging input variables are provided in Table 2 and Figure 17.

The resulting raster was exported as a Geo TIFF from VPS for use in ArcGIS. The continuous surface created by geospatial interpolation through kriging provided a reasonable approximation of the overall distribution of fine-grain sediments in the bayou. Contours were created from the imported raster using the focal statistics and contouring with barrier tools. Distribution of fine-grain sediments are depicted below in Figures 18, 19, and 20. The raster was also used to calculate volumes using the raster calculator tool. The volume of Bayou Chico unconsolidated fine-grain sediment was calculated at 2,034,994 or 2.0 million yd^3 (1.5 million m^3) from the TIN with a mean thickness of 5.5 feet (1.7 m).

Discussion & Conclusions

Most of Bayou Chico is covered by a layer of fine-grain sediments. The thickness of the layer differs greatly depending on location. This study found the majority (measured by volume) of the fine-grain sediments within the bayou are associated with two depositional areas. The first is located west of the navigational channel from the location of the old Barrancas Avenue bridge extending northwest past the new bridge toward the island, and the second area is located south of the island extending northwest into the center of the bayou.

Previous efforts to quantify the unconsolidated fine-grain sediments in Bayou Chico found the bayou to contain 1,854,477 or 2 million m^3 (2,425,564 yd^3). The current study estimated the quantity of fine-grain sediments to be 2,034,994 or 2.0 million yd^3 (1,555,865 m^3). The current study reflects an overall estimated reduction in fine-grain sediments of 390,570 yd^3 or 16.1%.

The kriged distribution of fine-grain sediment developed by this study generally agree with the previous Glassen study. However, there are discrepancies between the two studies. Some of the main discrepancies are listed below. Direct comparison of the distribution of sediments between the two studies is not possible because historic figures presented limited sediment thickness categories, and a significant number of the sample locations used in the Glassen study were not preserved.

- Glassen identified a significant area of fine-grain sediment within the navigational channel greater than 10 feet thick. The current study did not find any significant deposition of fine-grain sediment within the channel northwest of the Barracas Avenue bridge.

- Glassen identified fine-grain sediment deposits greater than 5 feet extending into the upper reaches of the north arm of the bayou. The current study found less extensive areas of fine-grain sediment in the north arm of the bayou.

- Glassen identified an area of only 1-5 feet of fine-grain sediments northwest of the island extending west to the shoreline. The current study found fine-grain sediments in the area northwest of the island exceeding 15 feet thick.

- Glassen indicated areas of thick (≥ 10 feet) fine-grain sediment continued from areas of deposition up to the adjacent shoreline. The current study found a gradient of decreasing fine-grain sediment thickness from areas of significant deposition located away from shore trending toward mostly sandy sediments along adjacent shorelines.

These discrepancies between the output of the two studies can be accounted for by a number of different factors. The previous study had limited coverage and relatively small sample size. The limited sample distribution (especially in transition areas in the nearshore areas) resulted in an over estimation of the size and distribution of fine-grain sediment depositional areas. Technological limitations led to an under estimation of the of the open water area associated with the bayou by over 26 acres or 10%. Previous fine-grain sediments observed in the north arm of the bayou may still exist under a sandy depositional layer from more recent heavy extreme rain events (i.e. July 2012, April 2014). Dredging of the navigational channel by the U.S. Army Corps of Engineers in 2008 removed approximately 185,000 yd^3 of material from the bayou (NWFWMD). A portion of this material may have been of a fine enough consistency to be measured using the methods described in this study resulting in a decreased volume estimate.

This study should provide a reasonable estimate of the current volume and distribution of unconsolidated fine-grain sediments in the bayou. The following caveats should be considered when using data presented in this study.

- The volume and distribution of fine-grain sediments in Bayou Chico have been estimated by Escambia County using the described methods. Data is subject to reasonable error based on factors such as sample size, coverage, variability, and assumptions made by using the described methods.

- Measurements of fine-grain sediments should be considered the minimum thickness. Subsurface obstructions or sand/shell inclusions may have prevented a complete measurement of the maximum depth of fine-grain sediments using the methods described. Additionally, previous dredging activities could have resulted in sediment mixing, making the interface between fine-grain sediment and sand difficult to determine.

- Volume of fine-grain sediments was measured in place. The volume of material disturbed as the result of the implementation of a future remediation project will likely exceed estimates because of bulk added by structural disruption and water entrainment. The amount of additional bulk will depend on the consistency of the sediment and the selected remediation methods.

- Mapping unconsolidated fine-grain sediments is a necessary initial step to identify, delineate, and quantify contamination. Volume or distribution of fine-grain sediments does not equate to the volume or distribution of contaminated sediments. An analysis of contaminant types, concentrations, vertical / horizontal distribution, and cost-benefit will be necessary to calculate the actual volume and distribution of sediment to be remediated.

References

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August 1994. 48 p.

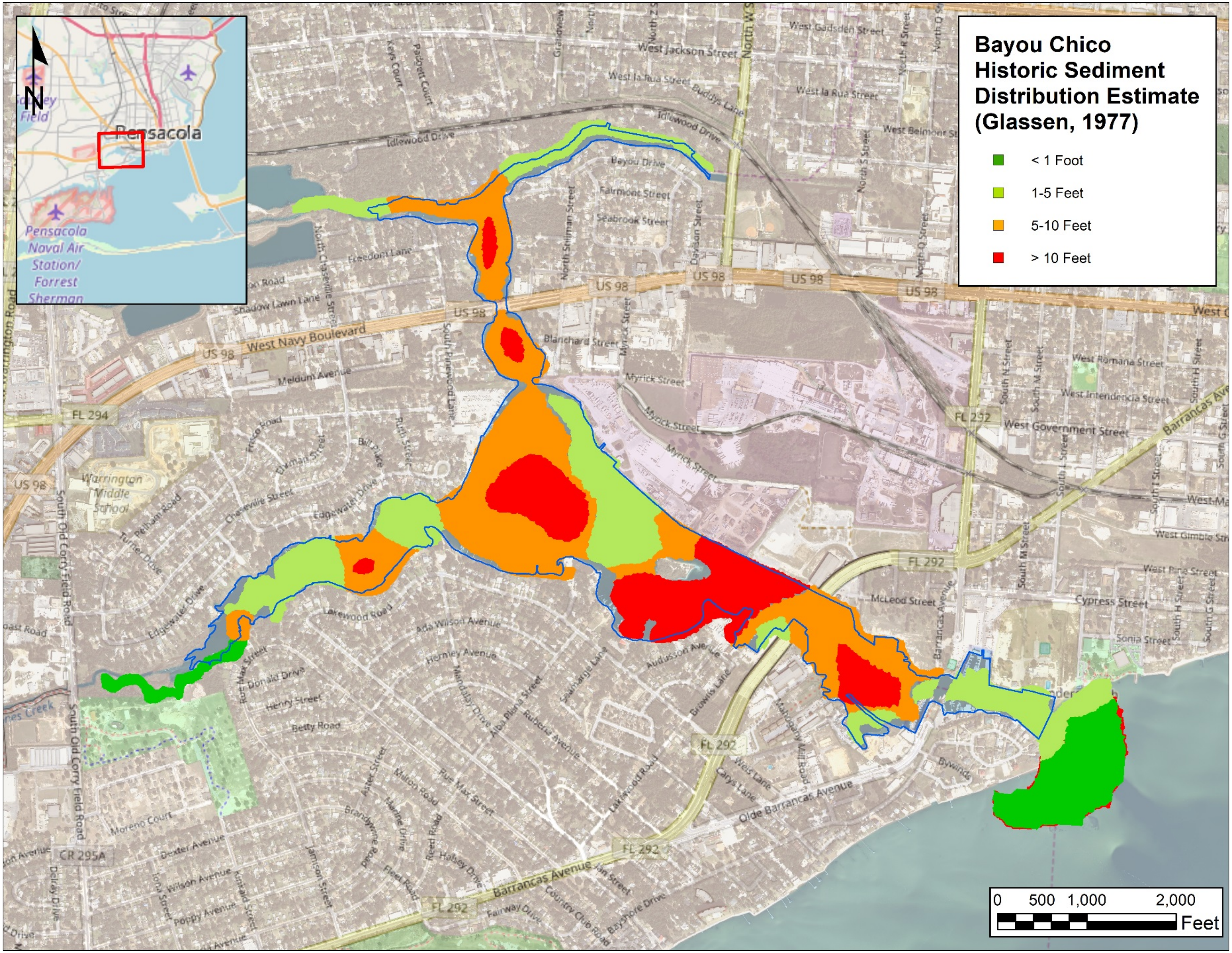


Figure 1: Digitized Map of Historic Distribution of Bayou Chico Unconsolidated Fine-Grain Sediment (Glassen, 1977)

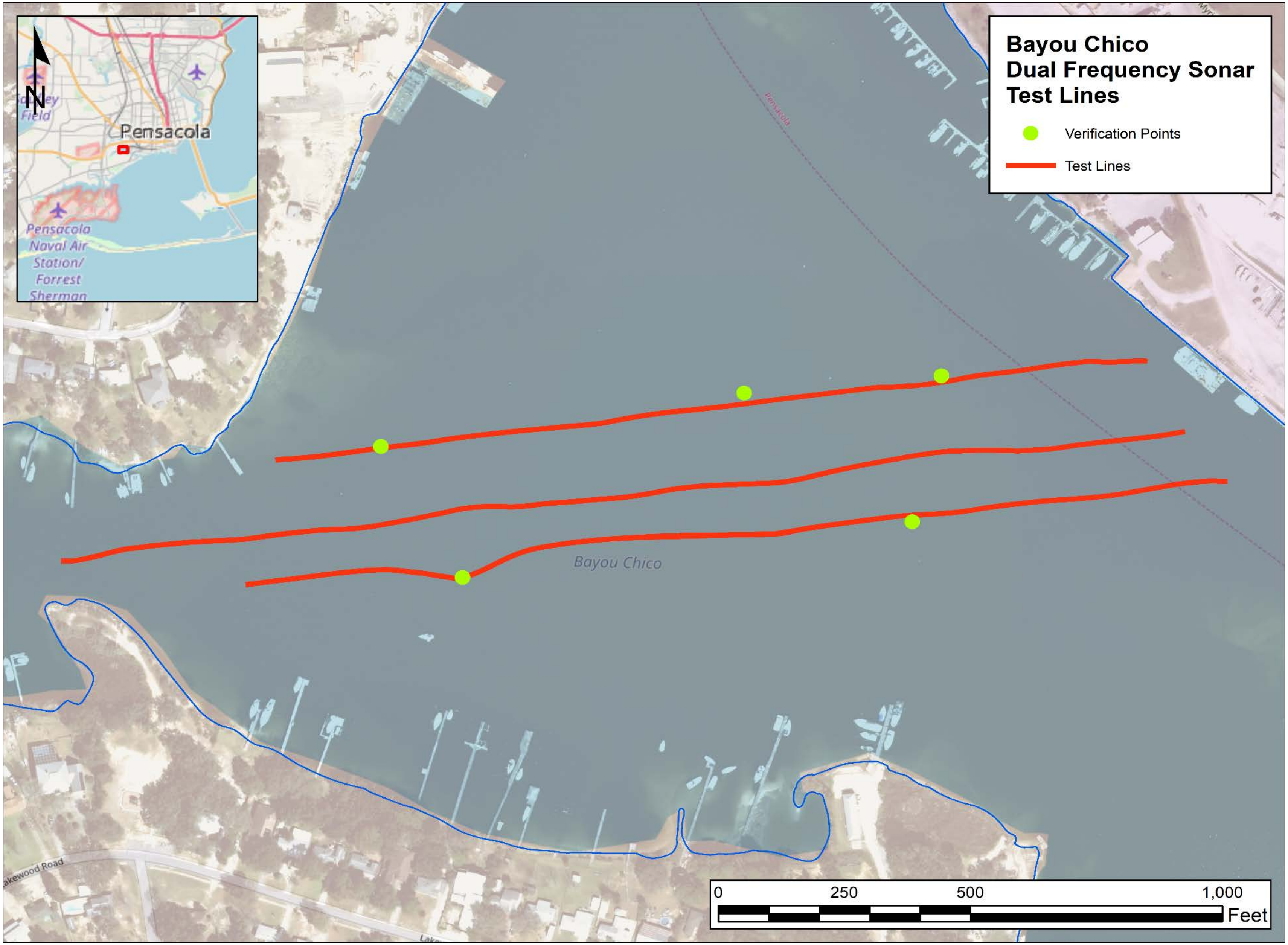


Figure 2: Test Lines Analyzed using Duel Frequency Parametric Echo Sounder

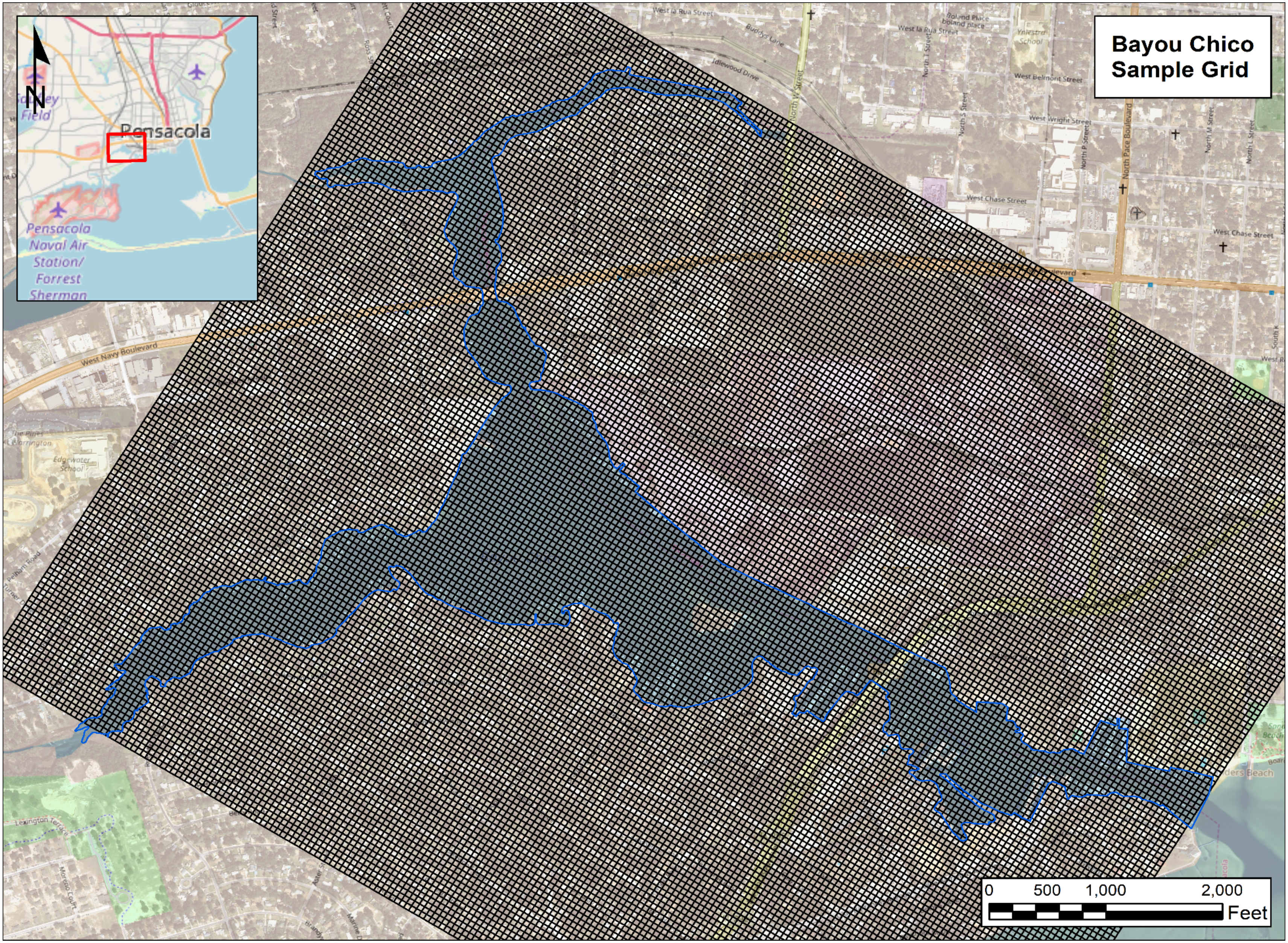


Figure 3: Bayou Chico Sampling Grid Created for Direct Physical Measurement of Unconsolidated Fine-Grain Sediments

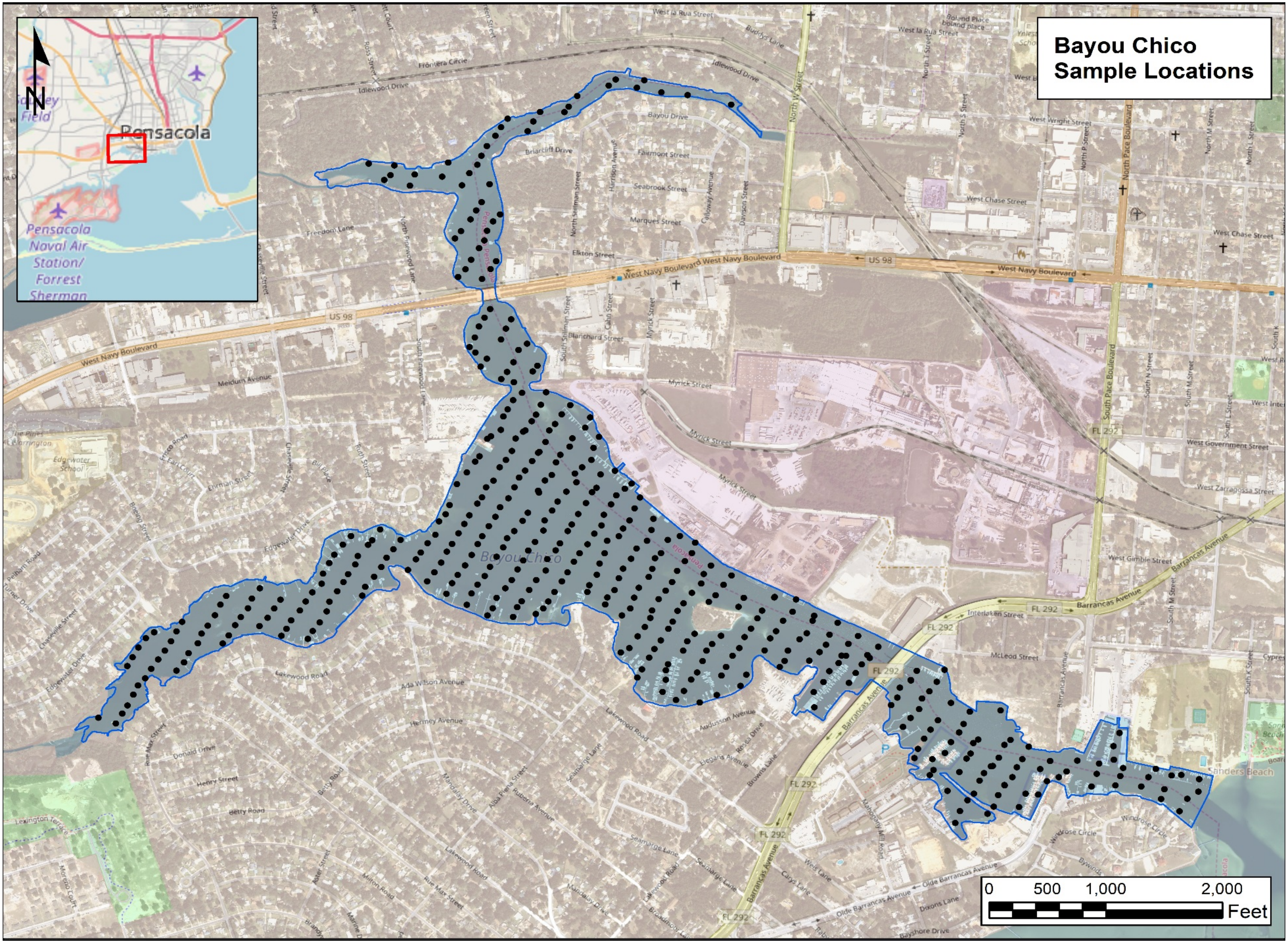


Figure 4: Bayou Chico Sample Sites Measured by Direct Physical Measurement

Figure 5: Escambia County Sampling Vessel Approaching Sampling Station

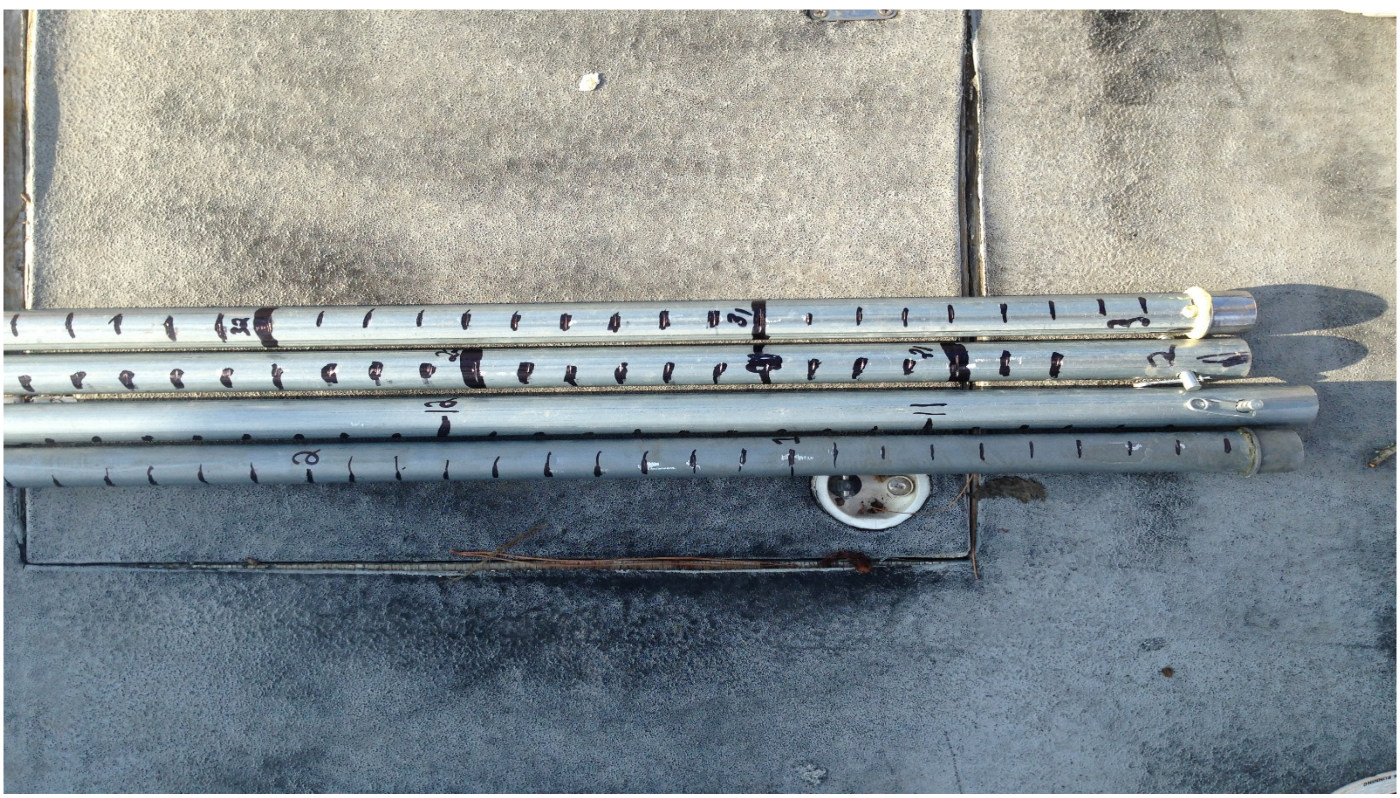


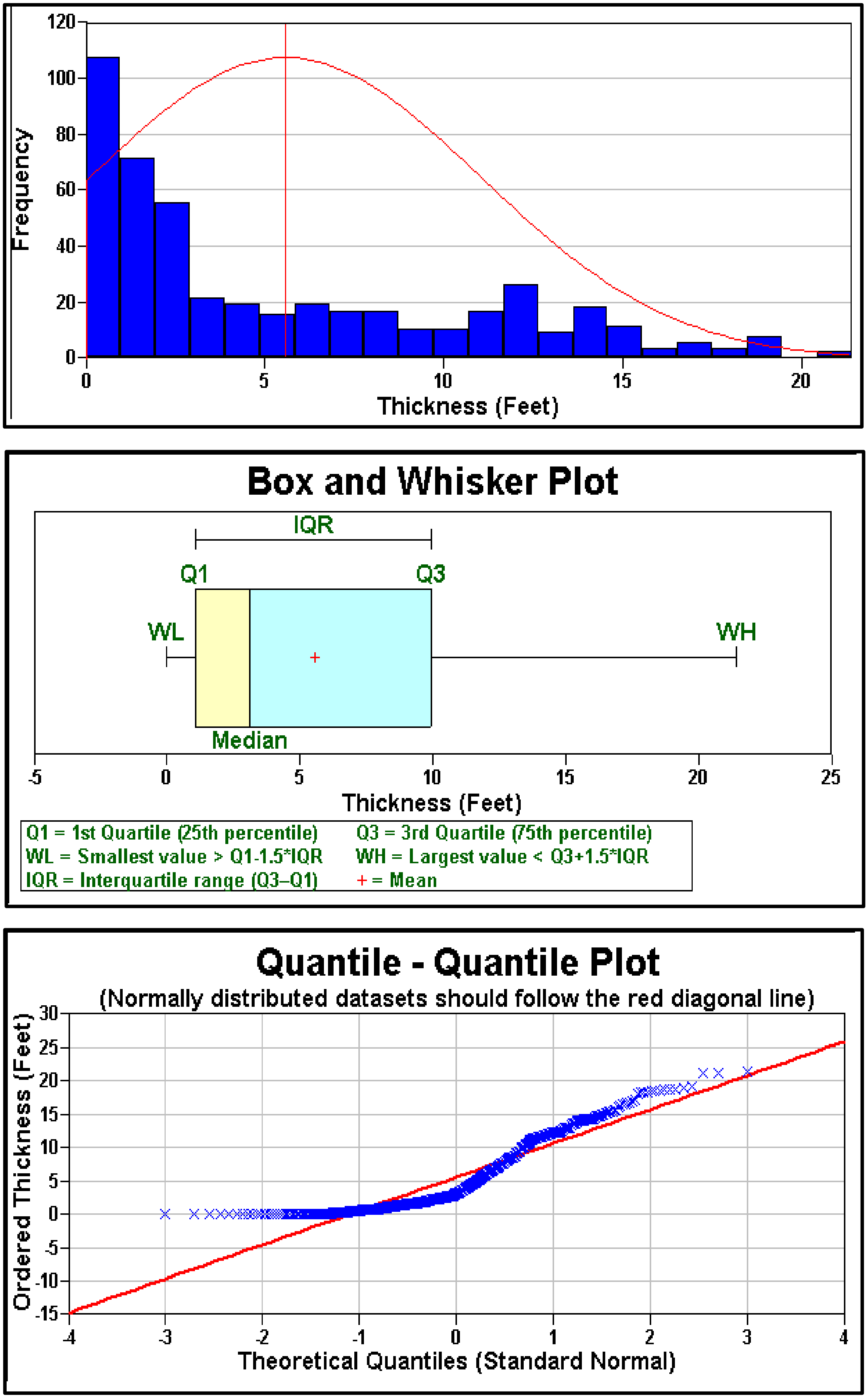
Figure 6: Graduated Sampling Probe Constructed from Galvanized Pipe

Figure 7: Sampling Crew Measuring Top of Sediment Surface (same location as below)

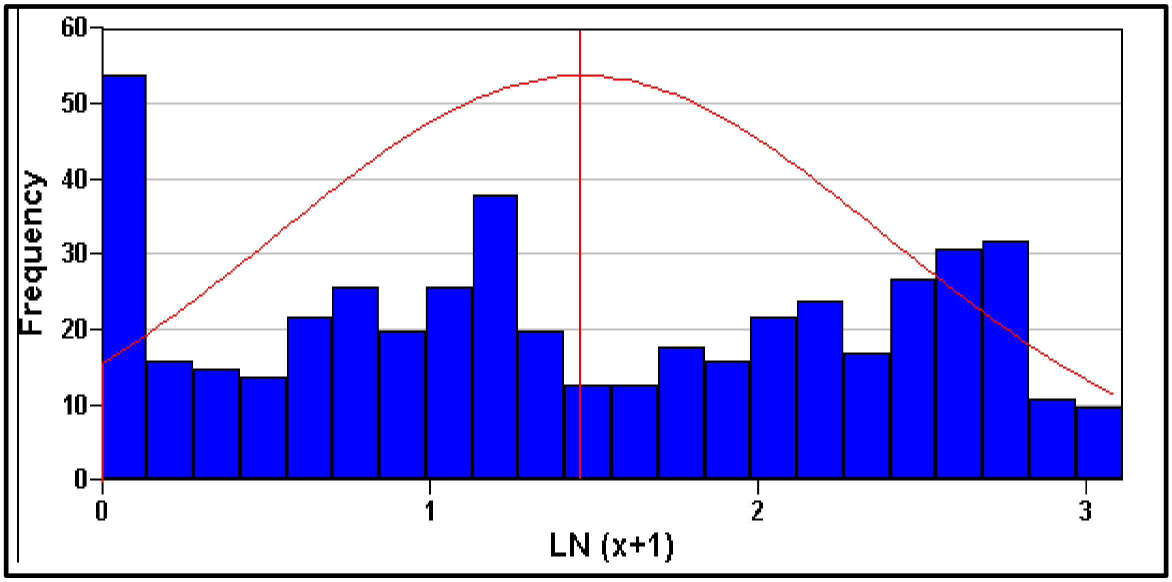
Figure 8: Sampling Crew Measuring Extent of Fine Sediment (same location as above)

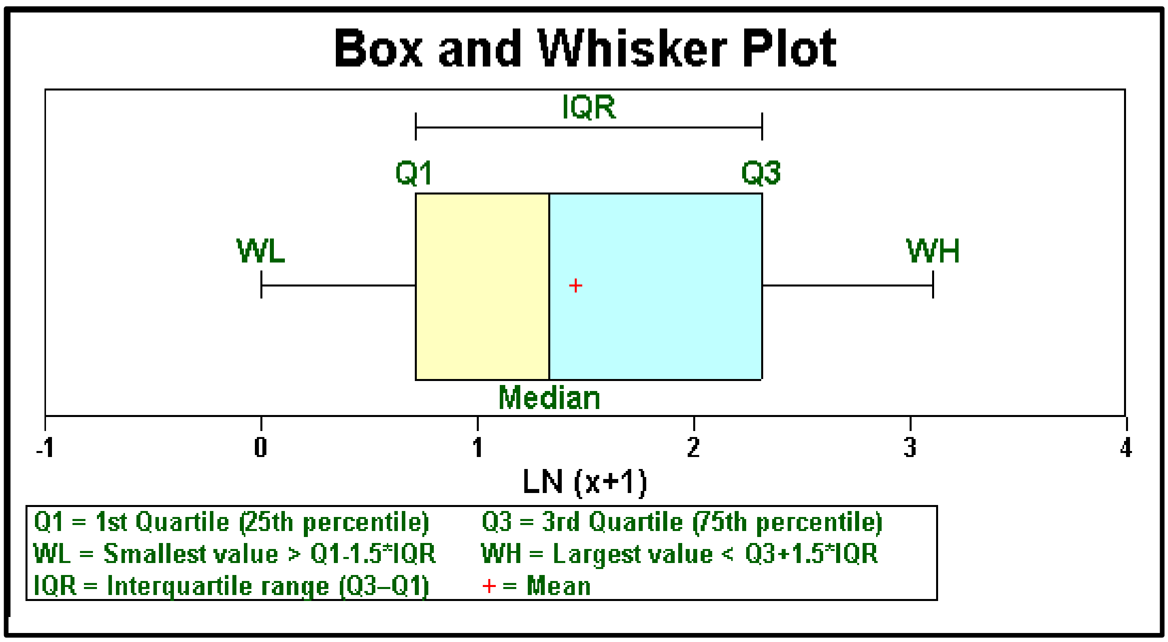
Figure 9: Data Collection

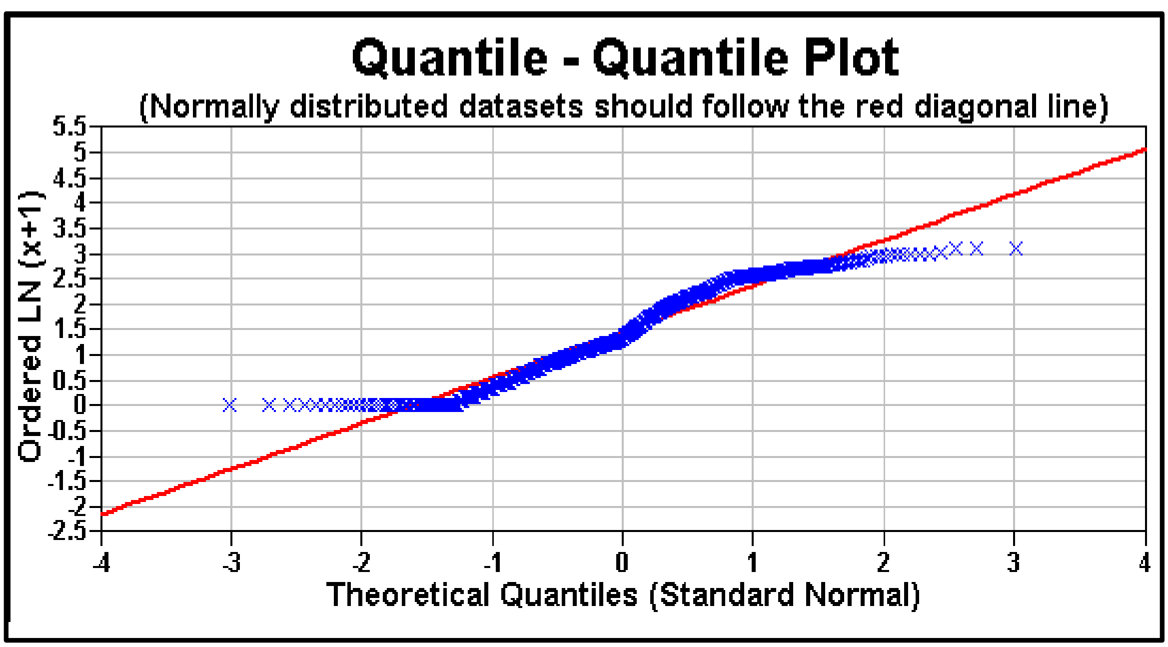
Figure 10: Shallow Water Site Collected by Kayak



Figures 11-13: Histogram, Box and Whisker Plot, & QQ Plot of Raw Dataset







Figures 14 - 16: Histogram, Box and Whisker Plot, & QQ Plot of Transformed Dataset.

statID (x,y)	Thickness (ft)	x = Ln(x+1)
1 - 21	0.1	0.095310
3 - 21	3.8	1.568616
3 - 25	3.8	1.568616
5 - 25	2.5	1.252763
7 - 21	0	0.000000
7 - 25	3.1	1.410987
9 - 21	0	0.000000
9 - 25	3.3	1.458615
11 - 25	3.1	1.410987
13 - 21	3.8	1.568616
13 - 25	4.1	1.629241
15 - 21	1.5	0.916291
15 - 25	8.1	2.208274
17 - 21	2.1	1.131402
17 - 25	6.8	2.054124
17 - 29	2.7	1.308333
19 - 21	1.4	0.875469
19 - 25	6.9	2.066863
19 - 29	1.7	0.993252
21 - 21	1	0.693147
21 - 25	5.6	1.887070
21 - 29	1.9	1.064711
23 - 25	3.2	1.435085
23 - 29	2.8	1.335001
25 - 25	4.2	1.648659
25 - 29	1.2	0.788457
25 - 33	1	0.693147
27 - 29	2.4	1.223775
27 - 33	6	1.945910
29 - 29	2.6	1.280934
29 - 33	4	1.609438
31 - 29	1.1	0.741937
31 - 33	2.1	1.131402
31 - 37	0.9	0.641854
31 - 41	1.2	0.788457
33 - 29	1.1	0.741937
33 - 33	2.5	1.252763
33 - 37	2.2	1.163151
33 - 41	0.4	0.336472
33 - 45	1.4	0.875469
35 - 33	1.3	0.832909
35 - 37	1.3	0.832909
35 - 41	0.5	0.405465
35 - 45	8.1	2.208274
37 - 33	1.4	0.875469
37 - 37	2.4	1.223775
37 - 41	5.5	1.871802
37 - 45	8.8	2.282382
39 - 41	4.2	1.648659
39 - 45	8	2.197225
41 - 41	6.8	2.054124
41 - 45	4.8	1.757858
41 - 49	0	0.000000
43 - 41	9.4	2.341806
43 - 45	11.1	2.493205
43 - 49	0	0.000000
45 - 41	1.3	0.832909

statID (x,y)	Thickness (ft)	x = Ln(x+1)
45 - 45	11.6	2.533697
45 - 49	0.1	0.095310
47 - 41	2.6	1.280934
47 - 45	12	2.564949
47 - 49	1.3	0.832909
49 - 41	2.3	1.193922
49 - 45	11.2	2.501436
49 - 49	1	0.693147
49 - 53	0.5	0.405465
51 - 41	1.6	0.955511
51 - 45	9.1	2.312535
51 - 49	13	2.639057
53 - 41	4.5	1.704748
53 - 45	6.6	2.028148
53 - 49	10.1	2.406945
53 - 53	0	0.000000
53 - 57	0	0.000000
53 - 61	0	0.000000
53 - 65	0	0.000000
53 - 69	0.3	0.262364
55 - 45	2	1.098612
55 - 49	1.7	0.993252
55 - 53	12.5	2.602690
55 - 57	1.2	0.788457
55 - 61	0.6	0.470004
55 - 65	1.6	0.955511
55 - 69	1.7	0.993252
55 - 73	1.6	0.955511
57 - 101	2.3	1.193922
57 - 105	0.7	0.530628
57 - 45	1	0.693147
57 - 49	0.3	0.262364
57 - 53	6.1	1.960095
57 - 57	12.1	2.572612
57 - 61	12.4	2.595255
57 - 65	10	2.397895
57 - 69	5.1	1.808289
57 - 73	4.6	1.722767
57 - 77	0.8	0.587787
57 - 97	0.2	0.182322
59 - 101	8.4	2.240710
59 - 105	0.5	0.405465
59 - 109	0	0.000000
59 - 53	4.8	1.757858
59 - 57	11.8	2.549445
59 - 61	13.8	2.694627
59 - 65	12	2.564949
59 - 69	12.2	2.580217
59 - 73	5.1	1.808289
59 - 77	2.7	1.308333
59 - 93	2.1	1.131402
59 - 97	0.8	0.587787
61 - 101	18.5	2.970414
61 - 105	9.5	2.351375
61 - 109	1.8	1.029619
61 - 53	0.2	0.182322
61 - 57	8.5	2.251292

statID (x,y)	Thickness (ft)	x = Ln(x+1)
61 - 61	8.4	2.240710
61 - 65	12.2	2.580217
61 - 69	12.9	2.631889
61 - 73	12.1	2.572612
61 - 77	1.1	0.741937
61 - 93	2.6	1.280934
61 - 97	18.2	2.954910
63 - 101	19.2	3.005683
63 - 105	14	2.708050
63 - 109	1.5	0.916291
63 - 157	0.9	0.641854
63 - 53	0	0.000000
63 - 57	1.3	0.832909
63 - 61	7.8	2.174752
63 - 65	12.4	2.595255
63 - 69	14.7	2.753661
63 - 73	13	2.639057
63 - 77	0.5	0.405465
63 - 93	14.8	2.760010
63 - 97	15.7	2.815409
65 - 101	15.2	2.785011
65 - 105	13.7	2.687847
65 - 109	5	1.791759
65 - 113	0.4	0.336472
65 - 157	0	0.000000
65 - 53	0	0.000000
65 - 57	1.6	0.955511
65 - 61	6.2	1.974081
65 - 65	10.5	2.442347
65 - 69	12.8	2.624669
65 - 73	14.7	2.753661
65 - 77	11.1	2.493205
65 - 81	3.2	1.435085
65 - 85	3.1	1.410987
65 - 89	2.5	1.252763
65 - 93	14.4	2.734368
65 - 97	12.9	2.631889
67 - 101	14.3	2.727853
67 - 105	14.2	2.721295
67 - 109	10	2.397895
67 - 113	0.3	0.262364
67 - 149	2.2	1.163151
67 - 153	0.8	0.587787
67 - 157	3.2	1.435085
67 - 161	0.1	0.095310
67 - 53	0	0.000000
67 - 57	2	1.098612
67 - 61	5.7	1.902108
67 - 65	9.8	2.379546
67 - 69	12.9	2.631889
67 - 73	11.9	2.557227
67 - 77	11.3	2.509599
67 - 81	0.9	0.641854
67 - 85	14.2	2.721295
67 - 89	7.3	2.116256
67 - 93	18.4	2.965273
67 - 97	11.3	2.509599

statID (x,y)	Thickness (ft)	x = Ln(x+1)
69 - 101	0	0.000000
69 - 105	9.2	2.322388
69 - 109	21.4	3.109061
69 - 125	4.4	1.686399
69 - 145	1.5	0.916291
69 - 149	0	0.000000
69 - 157	0	0.000000
69 - 161	0	0.000000
69 - 57	1.6	0.955511
69 - 61	6.4	2.001480
69 - 65	7.4	2.128232
69 - 69	14.3	2.727853
69 - 73	12	2.564949
69 - 77	12.5	2.602690
69 - 81	14.1	2.714695
69 - 85	17.2	2.901422
69 - 89	11.7	2.541602
69 - 93	18.7	2.980619
69 - 97	16.7	2.873565
71 - 105	8.7	2.272126
71 - 109	21.1	3.095578
71 - 117	0.5	0.405465
71 - 125	5.1	1.808289
71 - 145	2.4	1.223775
71 - 149	2.1	1.131402
71 - 153	0	0.000000
71 - 157	19	2.995732
71 - 161	2.6	1.280934
71 - 165	2.9	1.360977
71 - 53	1.2	0.788457
71 - 57	0.6	0.470004
71 - 61	7.2	2.104134
71 - 65	14.6	2.747271
71 - 69	14.2	2.721295
71 - 73	14.1	2.714695
71 - 77	13	2.639057
71 - 81	11.9	2.557227
71 - 85	13.7	2.687847
71 - 89	16.8	2.879198
71 - 93	18.1	2.949688
71 - 97	2.3	1.193922
73 - 109	21.1	3.095578
73 - 113	0.6	0.470004
73 - 117	0.6	0.470004
73 - 125	1.9	1.064711
73 - 141	2.5	1.252763
73 - 145	13.7	2.687847
73 - 149	5.8	1.916923
73 - 153	18.8	2.985682
73 - 157	16.2	2.844909
73 - 161	18.6	2.975530
73 - 165	0.8	0.587787
73 - 53	8.2	2.219203
73 - 57	1.8	1.029619
73 - 61	7	2.079442
73 - 65	10.3	2.424803
73 - 69	14	2.708050

statID (x,y)	Thickness (ft)	x = Ln(x+1)
73 - 73	9.3	2.332144
73 - 77	12.8	2.624669
73 - 81	12.1	2.572612
73 - 85	14.9	2.766319
73 - 89	15.4	2.797281
73 - 93	2.2	1.163151
73 - 97	0	0.000000
75 - 101	0	0.000000
75 - 109	10.9	2.476538
75 - 113	10.1	2.406945
75 - 117	11.6	2.533697
75 - 121	0.7	0.530628
75 - 125	14.1	2.714695
75 - 129	6.1	1.960095
75 - 137	6.9	2.066863
75 - 141	11.5	2.525729
75 - 145	12.2	2.580217
91 - 173	1.9	1.064711
91 - 185	0.2	0.182322
91 - 189	2.9	1.360977
91 - 45	0	0.000000
91 - 49	2.5	1.252763
91 - 53	1.7	0.993252
91 - 57	0	0.000000
91 - 61	1	0.693147
91 - 65	1.3	0.832909
91 - 69	0	0.000000
93 - 41	0.4	0.336472
93 - 45	2.5	1.252763
93 - 49	13.7	2.687847
93 - 53	0	0.000000
93 - 57	0	0.000000
93 - 61	0.9	0.641854
93 - 65	0.4	0.336472
95 - 41	2.3	1.193922
95 - 45	14	2.708050
95 - 49	16.1	2.839078
95 - 53	3.4	1.481605
97 - 41	2.2	1.163151
97 - 45	8.4	2.240710
97 - 49	5.4	1.856298
97 - 53	2.6	1.280934
99 - 41	2.7	1.308333
99 - 45	2.8	1.335001
99 - 49	1.1	0.741937
101 - 41	7	2.079442
101 - 45	0.2	0.182322
103 - 33	2.5	1.252763
105 - 33	1.3	0.832909
105 - 37	1.6	0.955511
107 - 33	3.5	1.504077
107 - 37	1.6	0.955511
109 - 29	0.7	0.530628
109 - 33	10	2.397895
109 - 37	0.8	0.587787
111 - 13	2.3	1.193922
111 - 29	6	1.945910

statID (x,y)	Thickness (ft)	x = Ln(x+1)
111 - 33	5.8	1.916923
113 - 13	7.6	2.151762
113 - 17	0.1	0.095310
113 - 29	10.4	2.433613
113 - 33	6.6	2.028148
113 - 9	1.8	1.029619
115 - 13	0.6	0.470004
115 - 17	1.8	1.029619
115 - 21	2	1.098612
115 - 29	11.6	2.533697
115 - 33	0.9	0.641854
117 - 21	8.6	2.261763
117 - 25	1.5	0.916291
117 - 29	11.1	2.493205
117 - 33	0.8	0.587787
120 - 21	0.6	0.470004
120 - 25	10.6	2.451005
120 - 29	0.3	0.262364
122 - 25	7	2.079442
124 - 25	7	2.079442
126 - 25	5.9	1.931521
128 - 25	1.5	0.916291
130 - 25	2.2	1.163151
132 - 25	0.8	0.587787
132 - 29	1.1	0.741937
134 - 29	0.2	0.182322
136 - 29	0.4	0.336472
138 - 33	2.5	1.252763
140 - 33	1.2	0.788457
142 - 33	0.8	0.587787
146 - 37	1.6	0.955511
148 - 37	1.8	1.029619
148 - 41	0.6	0.470004
150 - 41	1.7	0.993252
150 - 45	4.7	1.740466
152 - 49	3.5	1.504077
154 - 57	0	0.000000

SUMMARY OF VARIOGRAM ANALYSIS	
Variogram Type	Semivariogram
Variogram Control Parameters	
Distance Between Lags	117 feet
Lag Tolerance Length	58.5 feet
Number of Lags	30
Variogram Model	
Nugget	0
Model type 1	Exponential
Range 1	524.491 feet
Sill 1	30.6455

Table 2: Geospatial Interpolation Inputs

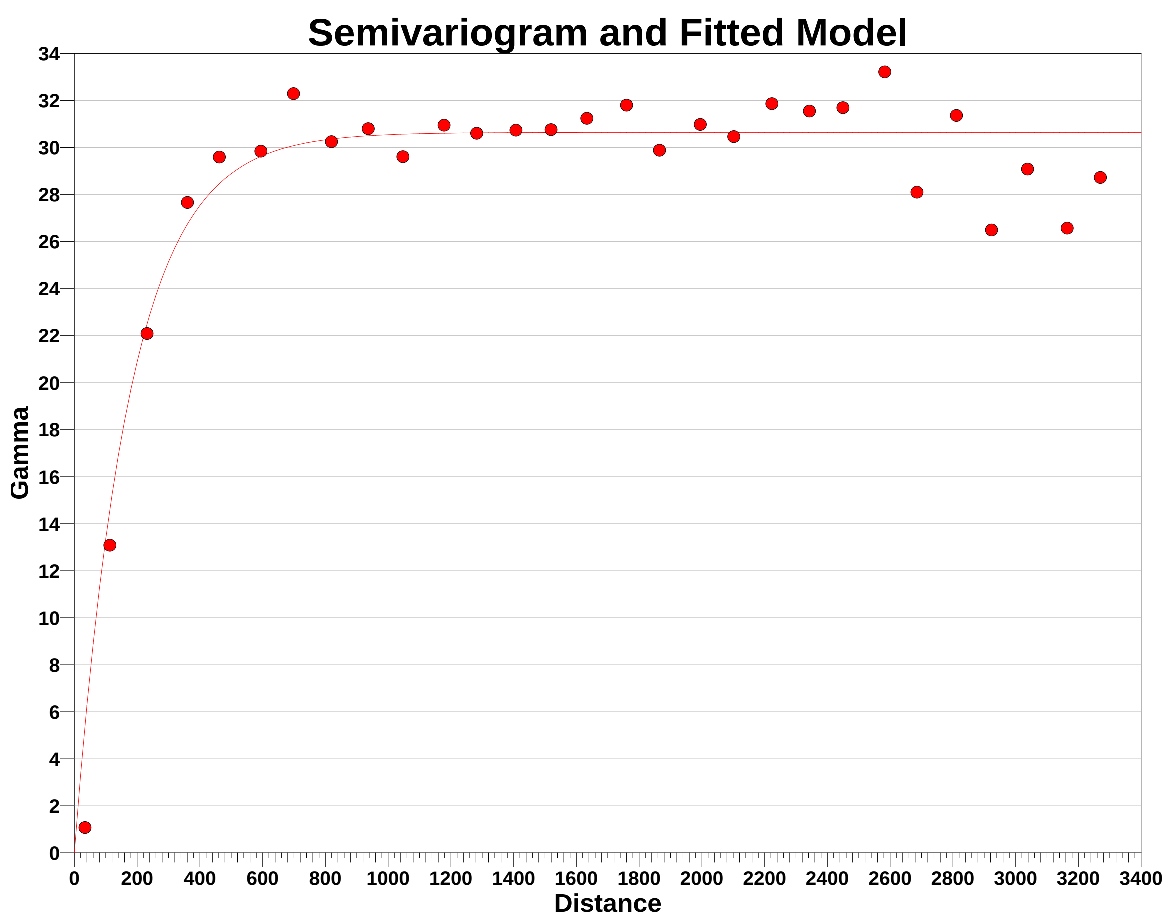


Figure 17: Semivariogram and Fitted Model

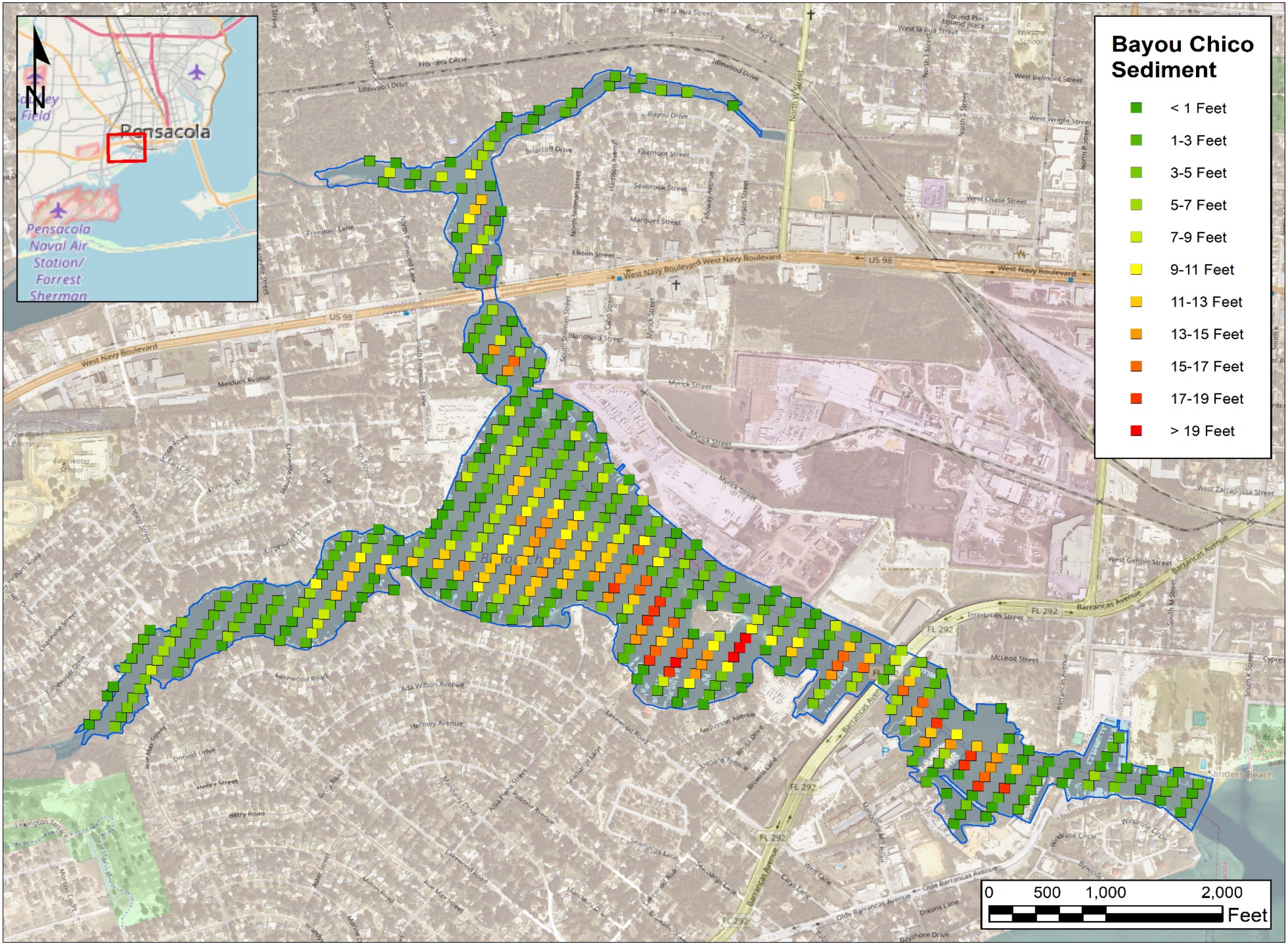


Figure 18: Distribution of Unconsolidated Fine-Grain Sediments in Bayou Chico by Sampling Station

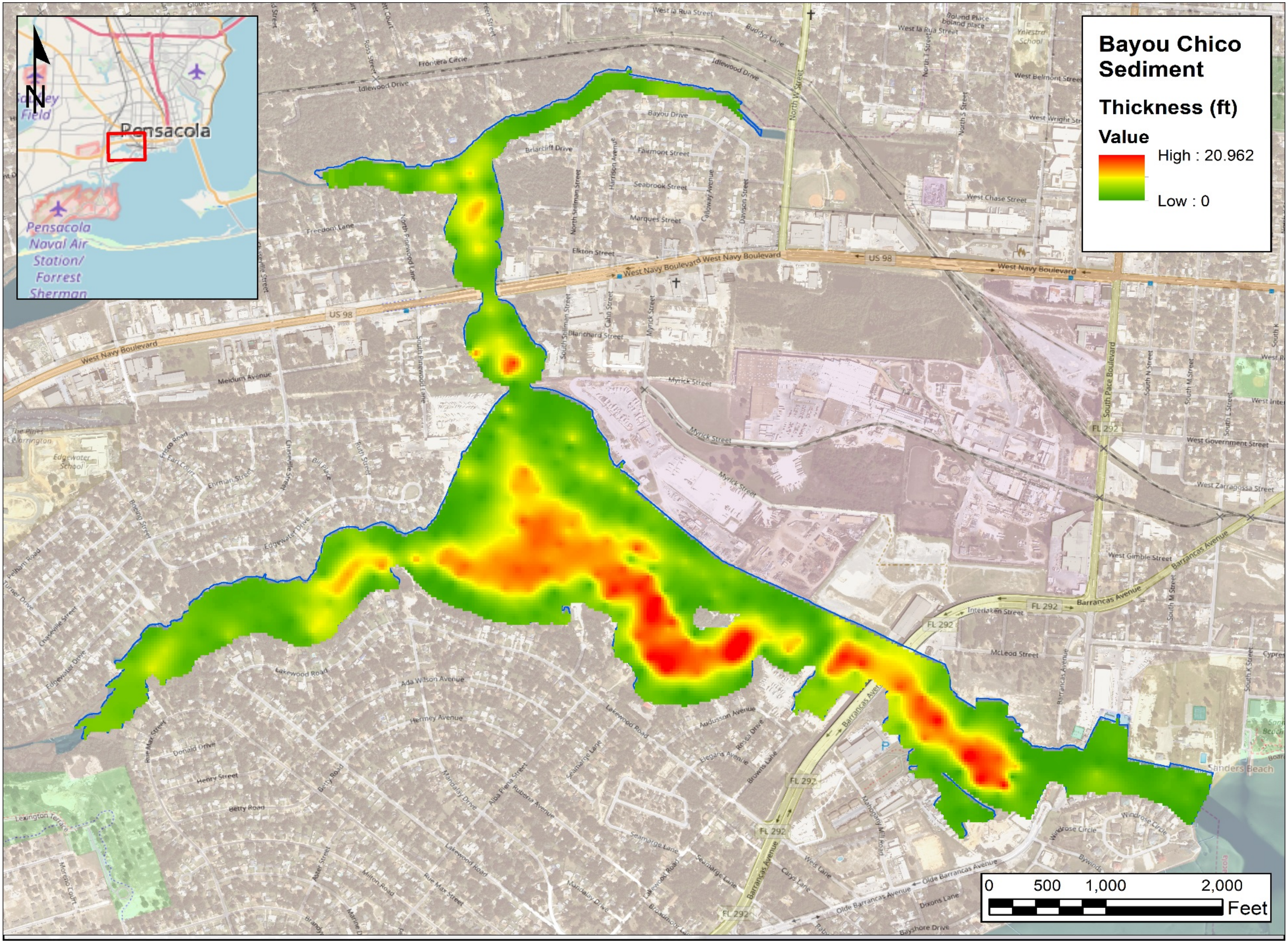


Figure 19: Spatial Distribution of Unconsolidated Fine-Grain Sediments in Bayou Chico

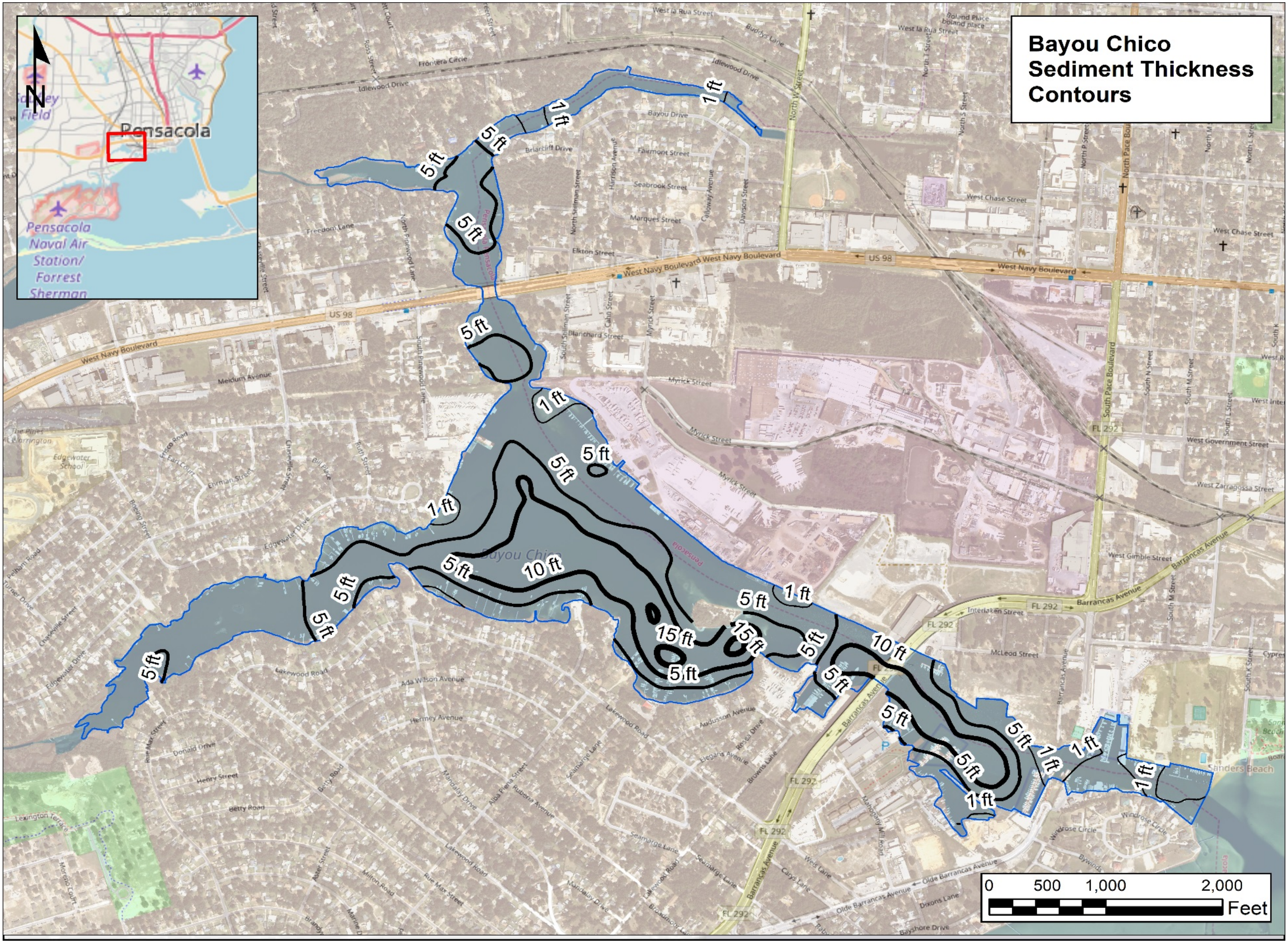


Figure 20: Contours Depicting Spatial Distribution of Unconsolidated Fine-Grain Sediments in Bayou Chico