

**ORIGIN OF ATLANTIC COASTAL PLAIN PONDS
IN NEW YORK AND NEW JERSEY**

A Final Report Presented

by

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Abstract of the Report
The Origin of Fox Pond

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This study places constraints on the origin of the Coastal Plain ponds in New Jersey and Long Island, which are a subset of the elliptical, small, shallow, groundwater-fed ponds found on the siliciclastic sands of the Atlantic Coastal Plain from Florida to Long Island. French and Demitroff (2001) considered a variety of hypotheses for the origin of the Coastal Plain ponds of New Jersey, known as spungs, and concluded that the most viable model is that the depressions are blowouts formed by eolian processes during the periglacial period between 20,000 and 13,000 years ago. More recently Howard et al, 2007 have suggested that the origin of the Coastal Plain ponds in North and South Carolina, know as Carolina Bays, may be due to a comet that broke up and then the pieces may have exploded over or on the Laurentian Ice Sheet near the Great Lakes and

the Hudson Bay some 12,900 years ago. This impact would have made airborne large masses of ice from the comet and the glacier. When these ice masses landed, they created the shallow depressions forming the Carolina Bays. The approach used to test these models was grain-size analysis of the conspicuous rims of the Coastal Plain pond depressions. If the depressions were blowouts, the rim sediments should have eolian characteristics. If they were formed by impacts, the material thrown out of the depressions would not be sorted and the rim sediments should have characteristics of the sediments underlying the depressions. The depressions in New Jersey and on Long Island were deposited on alluvial sediments. Cumulative curves and plots indicate that the rim sediments from these ponds have alluvial not eolian characteristics. Extensions of the long axes of the Coastal Plain ponds including those of the Carolina Bays, New Jersey and Long Island converge on the Great Lakes and Hudson Bay in Canada where the proposed comet pieces burst or impacted. Thus, the data are consistent with an impact model while in conflict with a blowout model. Only two hypotheses were tested. Therefore, it does not mean that an extra-terrestrial impact was the actual cause for the formation of the ponds. More information is needed to test this hypothesis and if necessary to develop new hypotheses.

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Table of Contents

Abstract.....	ii
Acknowledgements	iv
List of Figures.....	vi
List of Tables	vii
Chapter 1: Introduction	1
Chapter 2 Method for Grain Size Analysis	12
Chapter 3 Results.....	16
Histogram plots and Cumulative curves	19
Trask’s parameters	28
Graphical Parameters	29
Moment Parameters	32
Chapter 4 Hypotheses for the origin of Coastal Plain ponds.....	38
Carolina Bays.....	39
Chapter 5 Conclusion and Future Work.....	57
Bibliography	58

List of Figures

Figure 1.1 Loess Core in Wildwood Park, Long Island with ages.	3
Figure 1. 2 Locations of New Jersey Spungs in this study.	5
Figure 1. 3 Locations of Long Island Ponds in this study.	6
Figure 1. 4 Fox Pond shown on a DEM map.	8
Figure 1. 5 Bathymetry of Fox Pond in meters.	9
Figure 1. 6 Profiles across Fox Pond. All data are in meters.	10
Figure 2.1 Dry the samples	13
Figure 2.2 Weigh and record sieves to 0.01 gram	14
Figure 2.3 Clean the sieves with soft paper	14
Figure 2.4 Shake the Sieve Set with Sample in the sieve shaker.	15
Figure 3.1a Histogram Plots of sediments from the rims of Long Island Ponds and Dunes	21
Figure 3.1b Histogram Plots of the sediments from the rims of New Jersey Spungs	22
Figure 3.1c Histogram Plots of the rims from Carolina Bays.	23
Figure 3.2a Cumulative Curves of sediments from the rims of New Jersey Spungs.	24
Figure 3.2b Cumulative Curves of sediments from the rims of Long Island Ponds and Dunes	25
Figure 3.2c Cumulative Curves of sediments from the rims of Carolina Bays	26
Figure 3.3 Comparison of the Cumulative Curves of sediments from the rims of New Jersey Spungs, Long Island Ponds, Carolina Bays and Long Island Dunes.	27
Figure 3.4 Plots of moment parameters: Skewness against Standard Deviation	36
Figure 3.5 Plots of moment parameters: Mean against Skewness.	37
Figure 3.6 Plots of moment parameters: Mean against Standard Deviation	37

Figure 4.1 Coastal Plain Ponds in New York bight.....	38
Figure 4.2 The orientation of the long axes of Carolina bays converge.	39
Figure 4.3 The Wind blowout model of New Jersey Spungs.	44
Figure 4.4 Calverton Ponds (Image from Google Earth).....	45
Figure 4.5 The orientation of the long axes of the Spungs and Ponds in this study.	55
Figure 4.6 Comparison of orientation of Carolina Bays and ponds studied in this study	56

List of Tables

Table 1.1 Locations of Ponds Selected in This Study	7
Table3.1a The Grain Size Distribution Data for sediment on the rims of Long Island Ponds and Dunes.....	17
Table3.1b The Grain Size Distribution Data of rims of New Jersey Spungs	18
Table3.1c The Grain Size Distribution Data of rims of Carolina Bays	19
Table 3.2 Grain-size parameters	29
Table 3.3a Graphical Parameters calculated for Long Island Ponds	31
Table 3.3b Graphical Parameters calculated for New Jersey Spungs.....	31
Table 3.3c Graphical Parameters calculated for Carolina Bays	31
Table 3.3d Graphical Parameters calculated for Lond Island Dunes.....	32
Table 3.4a Moment Paramters calculated for Long Island Ponds	35
Table3.4b Moment Paramters calculated for New Jersey Spungs.....	35
Table3.4c Moment Paramters calculated for Carolina Bays	35
Table3.4d Moment Paramters calculated for Carolina Bays	36
Table 4.1 Orientation of ponds selected in this study.....	47

Chapter 1: Introduction

The Calverton Ponds on Long Island are examples of Coastal Plain Ponds, which are small, groundwater-fed ponds that occur on the siliciclastic sands of the Atlantic Coastal Plain. These ponds are small, shallow (only a few feet deep), groundwater-fed ponds.

Several studies have focused on the origin of Coastal Plain Ponds located in New Jersey (The ponds in New Jersey are called spungs.) and South and North Carolina (Carolina Bays). Wolfe (1952, 1953) attributed the enclosed shallow depressions located on the New Jersey coastal plain as a result of freezing and thawing in a periglacial climate during the Late Wisconsinan. Wind action, mass wastage, and erosion further modified them after their formation. Wolfe (1956, 1977) later reinterpreted them as thermokarst lakes or thermokarst basins. Bonfiglio and Cresson (1982) chose a “pingo-scar” hypothesis to explain their formation. French and Demitroff (2001) argued that the enclosed wetlands of southern New Jersey are not the result of pingo degradation. They asserted that the enclosed wetlands could best be explained by the periglacial wind-action hypothesis.

The Carolina Bays are a group of about 500,000 elliptical depressions on the Atlantic Coastal Plain mostly in the states of South and North Carolina. Some of the Carolina Bays are ponds, but many are dry because the bottoms of the depressions are above the water table. The origin of the Carolina Bays has been discussed for more than half a century, including meteor impact (Melton, 1933; Prouty, 1952), whale wallows (Grant 1945), artesian springs (LeGrand, 1953), dissolution of underlying material (May

and Warne, 1999; Siple, 1960), earthquakes (LeGrand 1983), and ice push (Bliley and Burney, 1988), wind blow out (Kaczorowski, 1977; Thom, 1970; Odum, 1952). Based on the discovery of charcoal, vitreous carbon, magnetic spherules and excess iridium in the sediments in the rims of the depressions and the northwest elongation of the elliptical depressions, Howard et al (2007) suggested that they were excavated by an extraterrestrial air burst over Canada near the end of the Wisconsinan some 12,900 years ago (Firestone et al, 2007). Firestone et al (2006) suggested that the impactor was most likely a large dustball or icy comet that broke up before impacting some 13,000 years ago. Some of the pieces of comet impacted on or burst over the Laurentian Ice Sheet, throwing large chunks of ice and comet outward. When these chunks landed, they formed shallow elliptical depressions elongated in the path of the chunks. During this process, sediments within the depression would be thrown out rapidly without sorting and the sediments in the rims should have the same grain size distribution as the sediments in the depressions.

Kundic (2005) dated a loess core on Long Island using optically stimulated luminescence (OSL) and radiocarbon on charcoal (Figure 1.1). If the OSL ages are correct, the lower two ages of this core show that the loess deposit date was during the Younger Dryas 12,900 to 11,500 years ago and the upper age is consistent with this loess being deposited during the 8.2 ka event. This suggests that during the Younger Dryas intense wind existed. While the upper radiocarbon age is consistent with the uppermost OSL age of $7,730 \pm 690$ years even if the possible 20% age reduction due to the anomalous fading is taken into account (Kundic, 2005), the lower radiocarbon ages are too young. Firestone et al (2006) suggest that radiocarbon can increase during impacts by comets and asteroids leading to younger ages. In addition, charcoal in the loess core is evidence of fire.

These two characters are consistent with the extraterrestrial impact event about 12,900 years ago, which is thought to be the trigger of Younger Dryas. The comet exploded above the ground, creating high a temperature shock wave that caused intense fires in North America. The charcoal was blown about with the loess by intense winds and deposited with loess during the Younger Dryas. If this analysis is correct, the charcoal in the loess and its young ^{14}C ages might be evidence supporting an extraterrestrial impact.

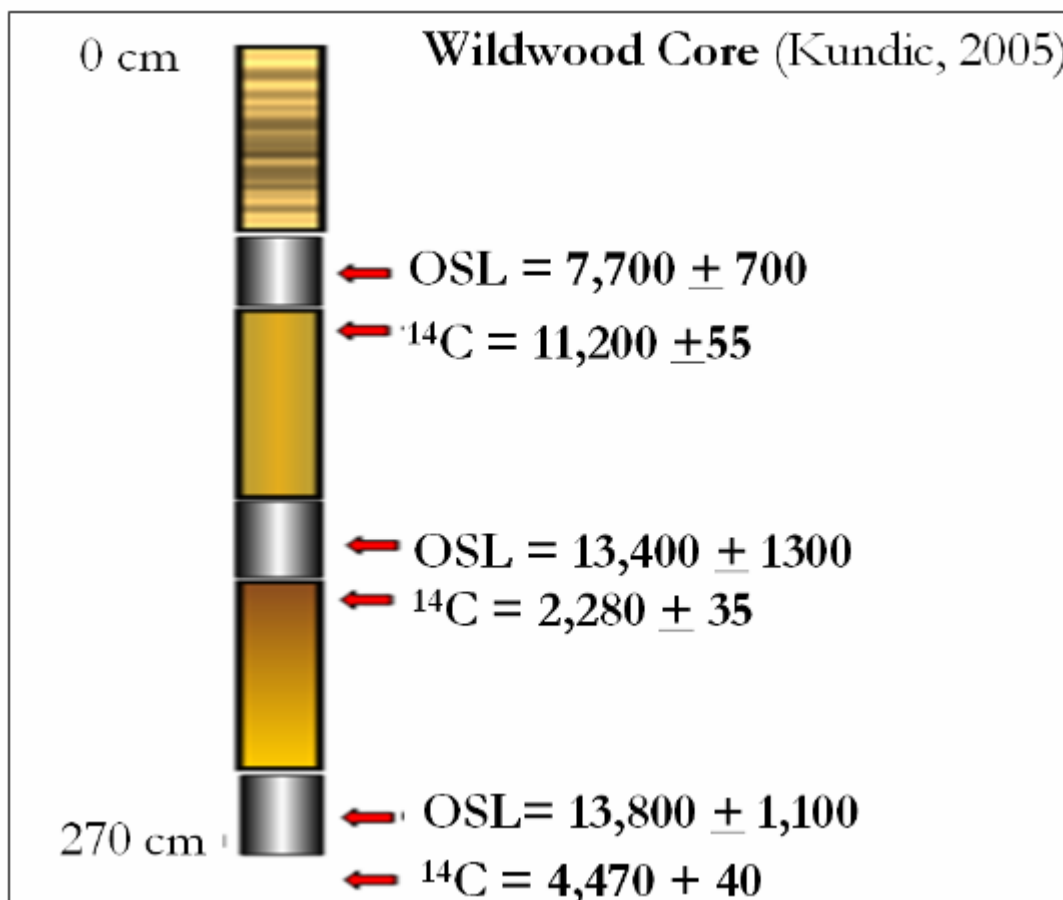


Figure 1.1 Loess Core in Wildwood Park, Long Island with ages.

(Modified from Kundic, 2005)

I will be testing two viable models for the origins of the Coastal Plain pond depressions in New Jersey and Long Island: (1) the depressions are blow outs formed by eolian processes during the post-glacial periglacial period between 20,000 and 13,000 years ago, and (2) the depressions were formed by an extra-terrestrial impactor that may have exploded over or on the Laurentian Ice Sheet some 12,900 years ago. If the depressions are blowouts the sediments in the rims should be well sorted sands similar to those in dunes. If the depressions are a result of an extra-terrestrial impact the sediments in the rims and depressions should have the same characteristics.

The ponds in New Jersey and Long Island selected for sampling are located on the Atlantic Coastal Plain. The ponds in New Jersey are located in the New Jersey Pine Barrens area, the surface sediments of which are alluvial deposits (Figures 1.2). The ponds selected for study on Long Island are on outwash plains, the surface sediments of which are also alluvial deposits (Figure 1.3). The locations of the ponds are given in Table 1.1.

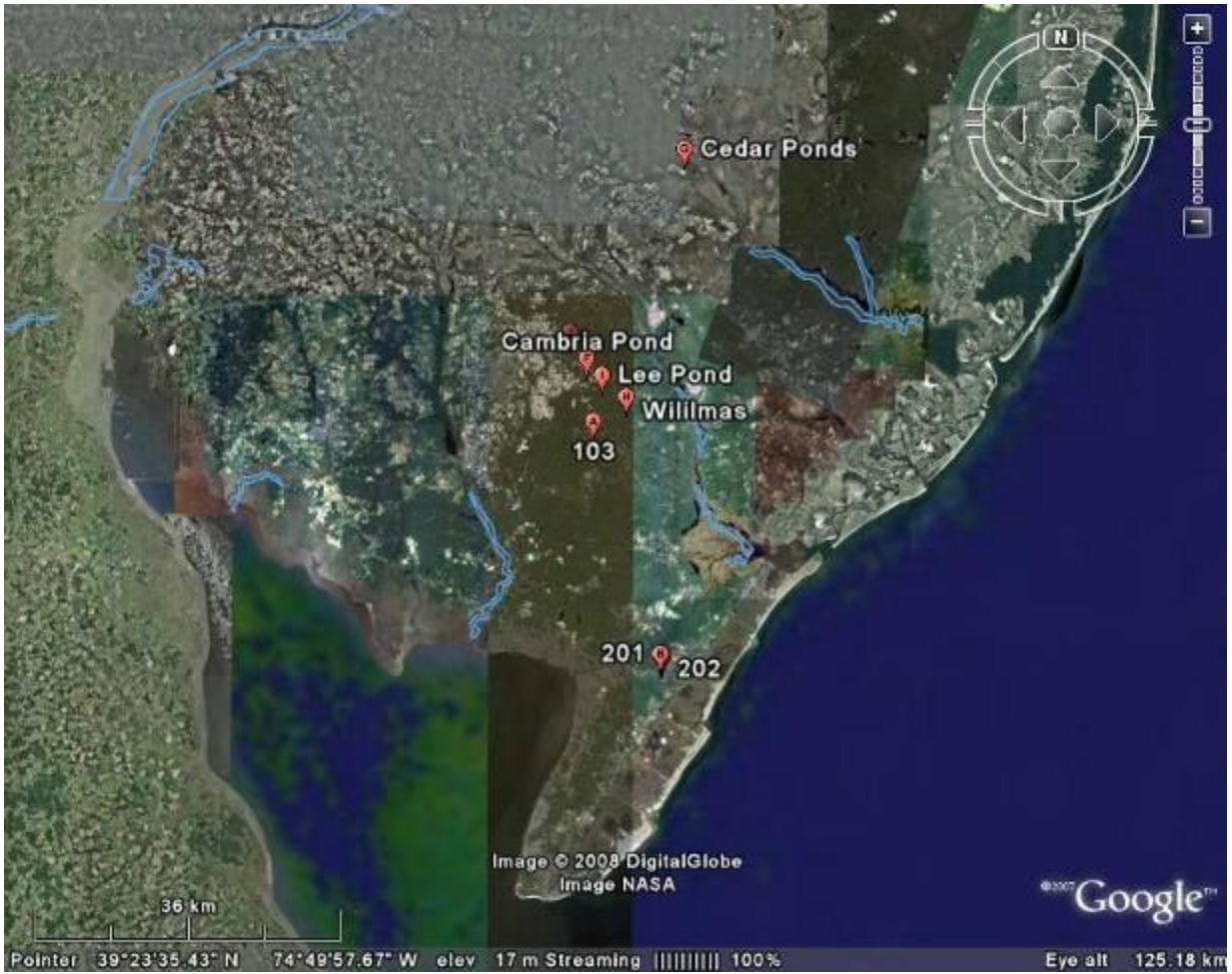


Figure 1. 2 Locations of New Jersey Spungs in this study.
(A: 103, B: 201, C: 202, D: 204, E: 205, F: Cambria, G: Cedar, H: Williams, I: Lee, J: Horse Break)



Figure 1. 3 Locations of Long Island Ponds in this study.
(1: Fox Pond, 2: Sandy Pond, 3: NF-3, 4: NF-2, 5: P-4, 6: P-5, 7: Slate Pond, 8: Jones Pond, 9: C-3)

Table 1.1 Locations of ponds selected in this study

Pond	Location		
	Latitude	Longitude	
New Jersey	103	39°24'54.16"N	74°51'54.78"W
	201	39°10'6.37"N	74°46'24.11"W
	202	39°10'4.25"N	74°46'17.70"W
	204	39°10'0.15"N	74°46'13.29"W
	205	39° 9'54.75"N	74°46'18.91"W
	Cambria	39°28'54.92"N	74°52'26.63"W
	Cedar	39°42'13.41"N	74°44'22.52"W
	Williams	39°26'28.35"N	74°49'11.53"W
	Lee	39°27'50.87"N	74°51'12.02"W
	Horse Break	39°30'35.30"N	74°53'53.30"W
Long Island	Fox	40°53'24.99"N	72°48'35.88"W
	Sandy	40°53'33.32"N	72°48'23.35"W
	NF-2	41° 6'41.27"N	72°22'2.40"W
	NF-3	41° 3'18.69"N	72°27'31.47"W
	P-4	40°54'21.28"N	72°38'32.57"W
	P-5	40°53'46.06"N	72°38'25.52"W
	Slate	40°56'55.80"N	72°17'57.78"W
	Jones	40°52'19.60"N	72°49'15.15"W
	C-3	40°52'30.48"N	72°46'48.26"W

Fox Pond

Fox Pond is a Calverton Pond, with classical Calverton Ponds features, small, shallow, groundwater-fed with low gradient walls. An elevation, a sand rim, can be observed to the east and southeast sides of the Fox Pond on the DEM map (Figure 1.4).

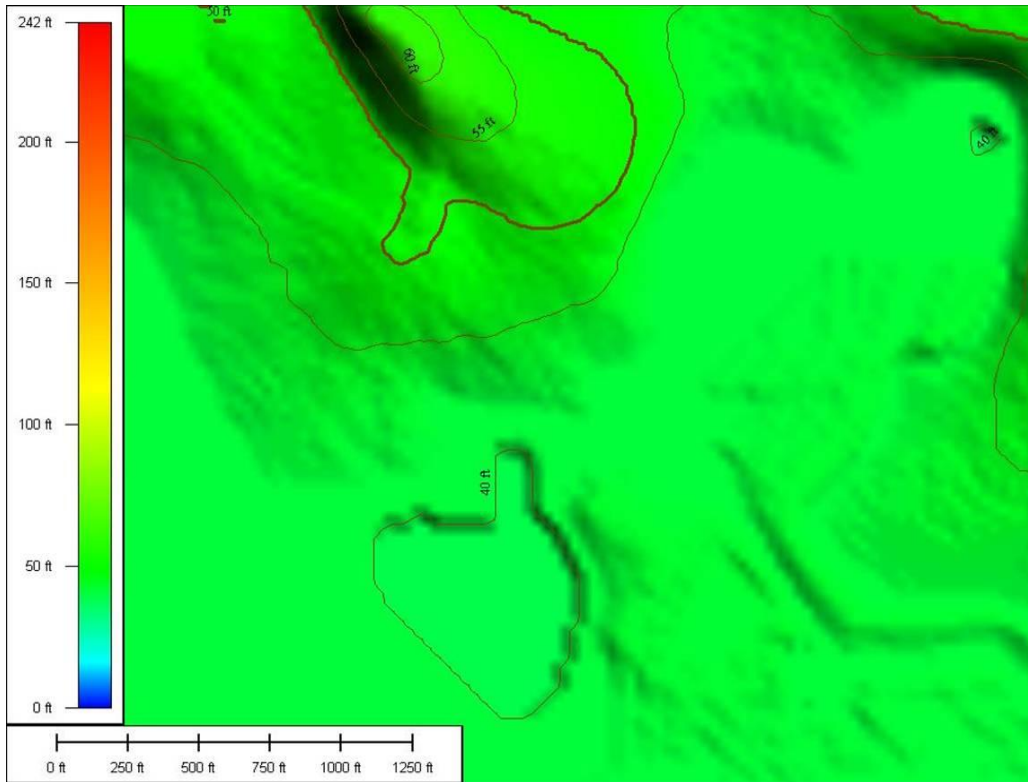


Figure 1. 4 Fox Pond shown on a DEM map. (The intervals of contours in the map are 5')

Bathymetry contours for Fox Pond from Marilyn Jordan (The Nature Conservancy in New York) are shown in Figure 1.5. The contours shown in Figure 1.6 are the distance from the water surface to the top of the mud layer in meters. The mud layer overlies sand. The top of the sand should represent the depth when the depression formed. Two profiles, AA' and BB' pass through the widest part of Fox Pond from west to east. The deepest point, measured from water surface to the top of the sand layer, was found in the middle of the line BB', which is 1.8m or about 6 feet. The slope of the of walls of the pond is extremely low as seen in these profiles.

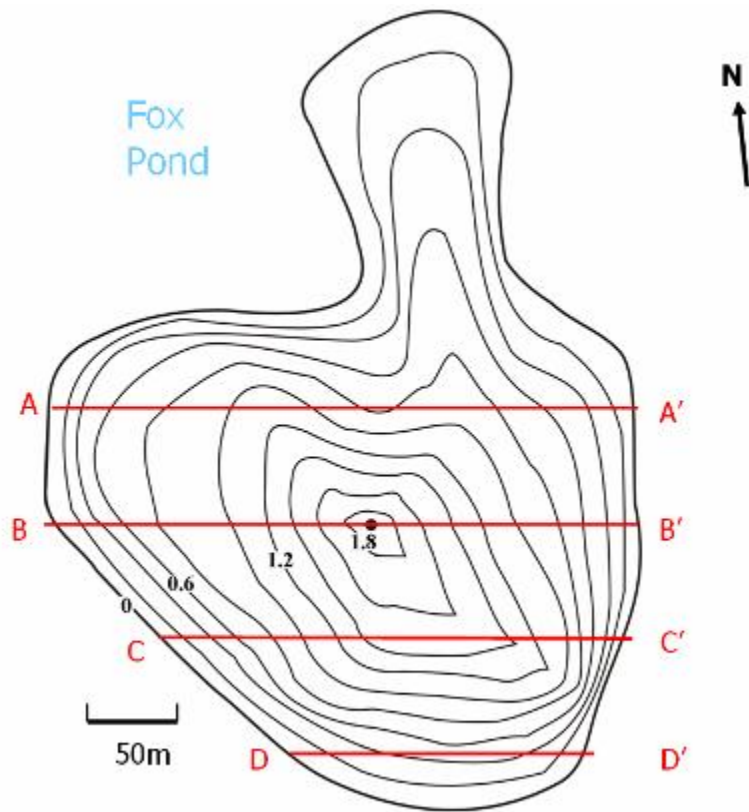


Figure 1. 5 Bathymetry of Fox Pond in meters. The locations of the four profiles shown in Fig. 1.6 are given by the red lines.

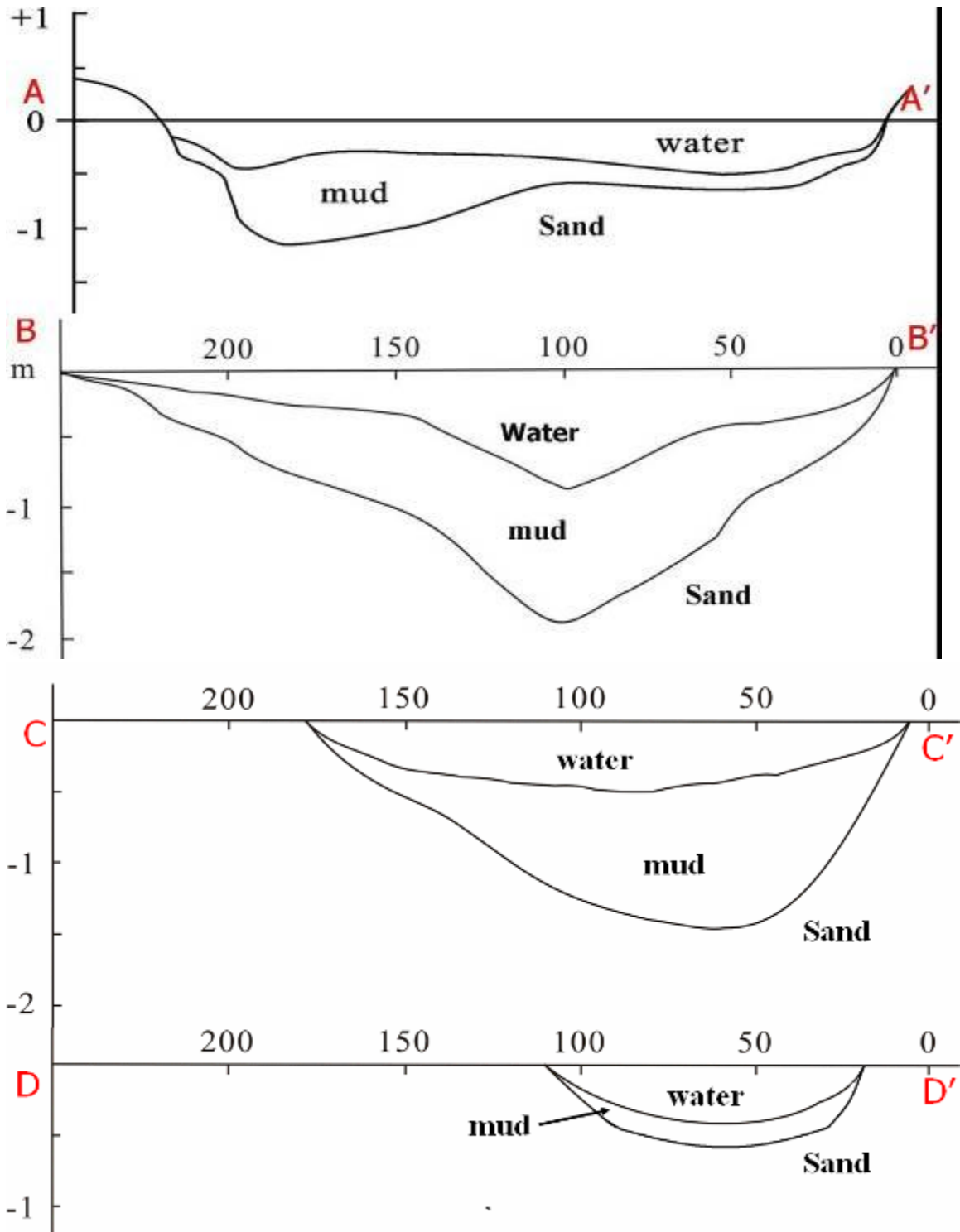


Figure 1. 6 Profiles across Fox Pond. All data are in meters. (Data from Marilyn Jordan, The Nature Conservancy in New York)

Fox Pond was used to grow cranberries. So human activity may have impacted the bathymetry of Fox Pond and the types of sediment in its rim. Samples from the rims of other Calverton Ponds, which were not used to grow cranberries, were analyzed to determine the grain size distribution of sediments to test these hypotheses.

Grain size is the most fundamental property of sediment particles, affecting their entrainment, transport and deposition. The grain size and grain-size distribution of a clastic sediment are measures of the energy of the depositing medium (Reineck, 1979). Grain size analysis can provide important clues to the sediment provenance, transport history and depositional conditions (Blott, 2001). Thus, the depositional environment can be classified and the hypotheses for the origin of ponds can be tested.

In this study, a total of twenty-two samples from New Jersey Spungs, Long Island ponds and Long Island dunes were analyzed. For comparison grain size analysis of the rims of some of the Carolina Bays were sent by Howard, G.A. and Kimbel, D.R. (written communication, 2007).

Chapter 2 Method for Grain Size Analysis

In the laboratory, grain size analysis was made by the conventional sieving methods for each sample. The basic principle of this technique is as follows. A sand sample of known weight is passed through a set of sieves of known mesh sizes. The sieves are arranged in downward decreasing mesh diameters. The sieves are mechanically vibrated for a fixed period of time. The weight of sediment retained on each sieve is measured and converted into a percentage of the total sediment sample. This method is quick and sufficiently accurate for most purposes. (Anderson, website access)

The procedures are as follows.

Procedures:

1. Air dry each sample before analysis. (Figure 2.1)
2. Take a dried sample of sand that weighs about 250 g and weigh and record the mass of sample to 0.01 grams.
3. Prepare a stack of sieves. Sieves having larger opening sizes (i.e. lower numbers) are placed above the ones having smaller opening sizes (i.e. higher numbers). A pan is placed under the last sieve to collect the portion of sample passing the last sieve. In my analysis, I used the half Phi as an interval values from -2 to 3.5 or (4 mm to 0.088 mm)
4. Make sure sieves are clean. Weigh all sieves and the pan separately. Record them in a table. And then assemble them in the ascending order of sieve numbers and a pan on the bottom. (Figures 2.2 and 2.3)

5. Carefully pour the sample into the top sieve and place a cover on it.
7. Put the sieve stack in the sieve shaker (Ro-tap) and fix the clamps and shake for 20 minutes. (Figure 2.4)
8. Remove the sieve stack from the shaker and measure and record the mass of each sieve with its retained sample. Also the pan and sample retained should be weighed and recorded.
9. Obtain the mass of sample retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve with its retained sample, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals to the initial mass of the sample.
10. Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.



Figure 2.1 Dry the samples



Figure 2.2 Weigh and record sieves to 0.01 gram



Figure 2.3 Clean the sieves with soft paper



Figure 2.4 Shake the Sieve Set with Sample in the sieve shaker.

Chapter 3 Results

Grain Size Distribution Analysis

The grain size of a clastic sediment is a measure of the energy of the depositing medium and the energy of the basin of deposition (Reineck, 1979). Previous researchers have tried to distinguish the different sedimentary environments using various factors related to grain size distribution (Inman, 1952; Mason and Folk, 1958; Folk and Ward, 1957; Friedman, 1961, 1962, 1967, 1979; Folk, 1966; Moiola and Weiser, 1968; Shepard and Young, 1961; Sahu, 1964; Solohub, 1970; Mabesoone, 1964; Duane, 1964; McLaren, 1980; Doeglas, 1968; Tanner, 1991; Martins, 1965, 2003). These factors include the shape of cumulative curves, histograms and various statistical parameters calculated from grain-size distributions. In this study, graphic parameter sand moment parameters were used to interpret the deposit environment of the Fox pond.

A total of twenty-two samples were collected and analyzed to determine the grain size distribution using the sieve technique. Ten samples were from New Jersey spunges, nine samples were from Long Island ponds and three were dune samples collected from the South Shore and North Shore of Long Island. The raw data are given in Table 3.1 (Table 3.1a for New Jersey spunges, Table 3.1b for Long Island ponds and dunes). For comparison, the grain size distribution of the rims of some of the Carolina Bays from Howard, G.A. and Kimbel, D.R.(written communication, 2007) are shown in Table 3.1c.

Table 3.1a The Grain Size Distribution Data for sediment on the rims of Long Island Ponds and Dunes. (Data shown in the table are the percentage retained)

Sieve Number	Grain Size (ϕ)	Long Island Ponds									Long Island Dunes		
		Fox1	Fox2	Sandy1	Jones	Slate	P-4	P-5	NF-3	C-3	Walking Dunes	Grandifolia Dunes	Fire Island Dune
5	-2	0.12	0.00	0.00	0.00	3.18	1.80	0.00	2.00	0.00	0.00	0.00	0.00
7	-1.5	0.08	0.18	0.00	0.17	1.16	0.56	0.08	1.26	0.17	0.00	0.00	0.00
10	-1	0.56	0.31	0.17	0.56	1.83	0.21	0.21	2.61	0.22	0.00	0.04	0.31
14	-0.5	0.48	0.55	0.42	1.91	2.55	2.06	0.84	4.31	0.52	0.08	0.16	0.87
18	0	1.33	1.29	1.69	4.43	3.80	3.73	2.57	5.53	1.71	0.42	0.63	2.97
25	0.5	3.58	3.43	4.94	10.51	7.34	6.82	8.35	8.88	4.55	3.62	4.66	6.90
35	1	13.75	14.28	17.10	24.41	16.91	18.05	22.18	17.41	15.26	19.92	27.66	19.12
45	1.5	28.30	28.43	33.43	26.63	20.67	25.29	25.31	16.02	26.54	36.88	36.29	31.86
60	2	24.52	25.92	28.70	17.81	16.51	19.89	16.70	14.71	20.94	27.33	22.53	25.14
80	2.5	13.02	13.24	10.30	7.86	10.51	10.89	9.45	9.06	12.51	9.39	7.13	11.22
120	3	5.39	5.15	2.28	2.95	5.46	5.02	5.74	5.14	7.13	2.40	1.33	2.53
170	3.5	1.93	1.53	0.17	0.78	2.06	2.06	2.61	2.18	3.37	0.17	0.04	0.13
Pan	6	7.07	6.18	0.68	2.56	8.05	4.07	5.44	10.11	7.43	0.17	0.08	0.22

Table 3.1b The Grain Size Distribution Data of rims of New Jersey Spungs (Data shown in the table are the percentage retained)

Sieve Number	Grain Size (φ)	New Jersey Ponds									
		Cambria	Willimas	Cedar	Horse	Lee	103	201	202	204	205
5	-2	2.51	0.00	0.00	0.00	0.34	0.00	0.56	0.00	0.14	0.35
7	-1.5	1.57	0.21	0.00	0.17	0.13	0.23	0.70	0.12	0.24	0.26
10	-1	2.91	0.55	0.22	0.25	0.30	0.28	1.27	0.16	0.39	0.39
14	-0.5	5.02	0.80	0.49	0.59	0.60	0.65	2.91	0.88	1.06	1.08
18	0	7.71	2.24	0.98	2.51	1.75	1.39	4.70	1.52	1.88	1.94
25	0.5	10.63	7.75	3.09	10.10	4.43	5.79	6.20	3.29	3.13	3.41
35	1	15.20	20.63	10.25	23.39	13.35	16.16	9.59	10.63	9.35	8.28
45	1.5	13.86	23.97	18.26	21.08	20.85	22.08	14.61	22.29	17.40	16.44
60	2	10.31	17.49	21.97	17.39	26.65	19.68	14.80	24.18	19.42	20.84
80	2.5	9.06	12.20	21.30	10.69	13.18	14.95	19.08	19.17	18.17	23.34
120	3	6.68	7.24	15.12	6.96	7.55	9.81	15.27	9.10	12.24	12.38
170	3.5	3.68	2.29	4.97	2.98	3.80	3.47	3.57	2.09	4.34	2.50
Pan	6	10.90	5.51	3.85	6.58	6.95	6.34	7.00	6.90	12.05	9.32

Table 3.1c The Grain Size Distribution Data of rims of Carolina Bays (Data from Howard and Kimbel by personal contact through Email, 2007; Data shown in the table are the percentage retained)

Grain Size (ϕ)	Cumulative Percent					
	Sewell yellow 40"	Sewell yellow 50"	Sewell yellow 60"	Sewell berm peak	Salter's Lake berm	Harrison
-1.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.38	1.59	4.32	4.72	2.95	3.21
0.75	6.21	7.42	12.64	18.06	15.43	9.28
1.00	27.58	35.36	27.16	26.47	25.56	18.57
1.25	50.63	42.08	42.07	26.20	33.82	41.85
2.00	14.53	13.30	12.87	22.68	21.65	23.53
2.75	0.67	0.25	0.94	1.75	0.57	3.26
3.25	0.00	0.00	0.00	0.12	0.00	0.30
3.75	0.00	0.00	0.00	0.00	0.00	0.00

Histogram plots and Cumulative curves

Both histogram plots and cumulative curves tell the main range of grain size distribution. Histogram plots are shown in Figures 3.1a, 3.1b, and 3.1c. The cumulative curves are plotted in Figures 3.2a, 3.2b and 3.2c. The cumulative curves of the sediments from these three different locations show that the sediments are reasonably well sorted. Most of the sediment grain sizes are in the range of 0.5ϕ to 2.5ϕ values. Sediments from Carolina Bays are better sorted, than those from Long Island and New Jersey. Sediments from New Jersey spungs and Long Island ponds have more fine sediments than those from Carolina Bays. The shapes of the cumulative curves for Long Island and New Jersey sediments are similar suggesting the possibility of a similar origin. The New Jersey sediments are slightly finer than those for Long Island which may reflect a slightly different source material. The sediments on which the Calverton Ponds rest are outwash

plain sediments deposited close to the glacier front. Whereas the New Jersey sediments would have been deposited more distally.

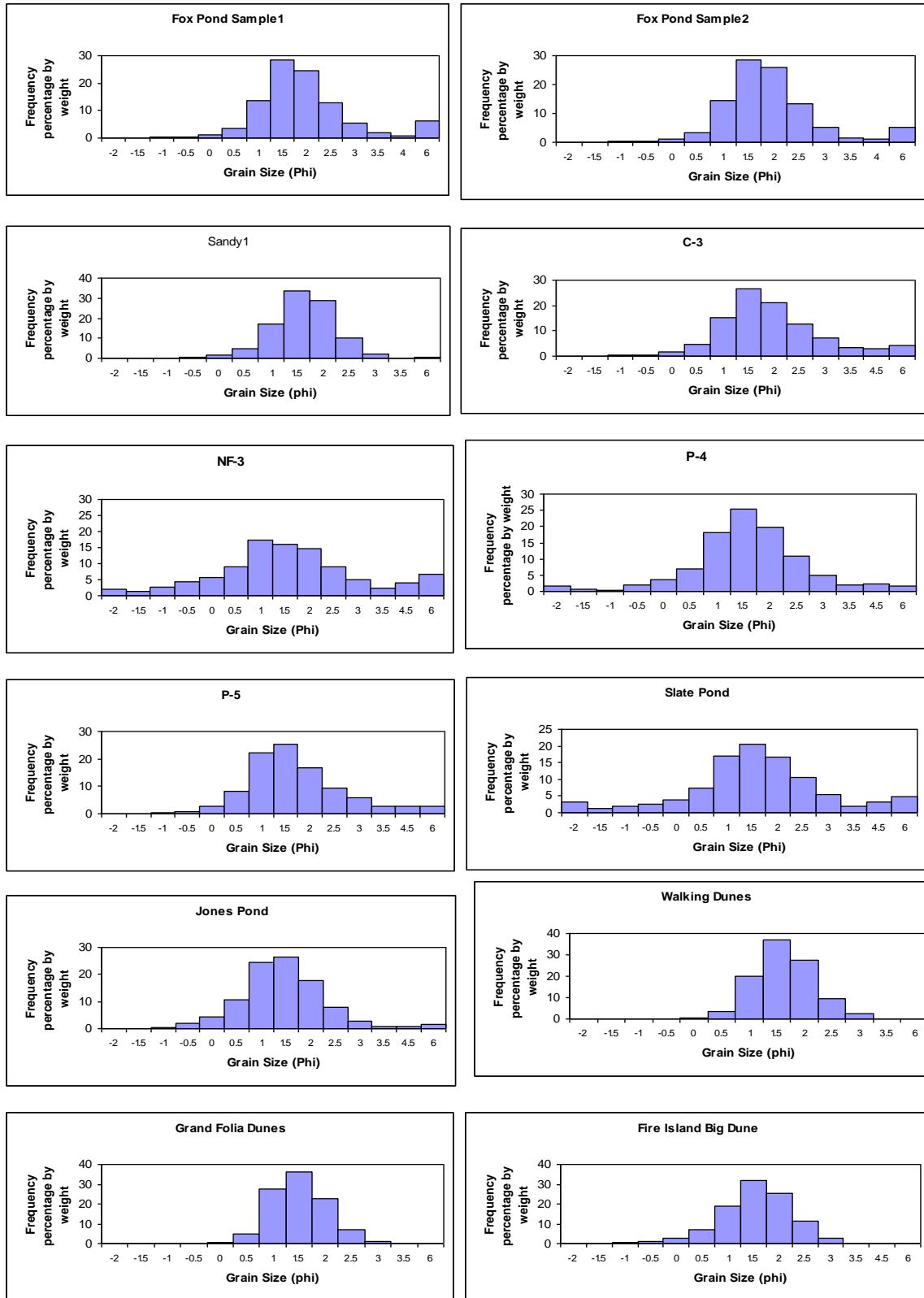


Figure 3.1a Histogram Plots of sediments from the rims of Long Island Ponds and Dunes

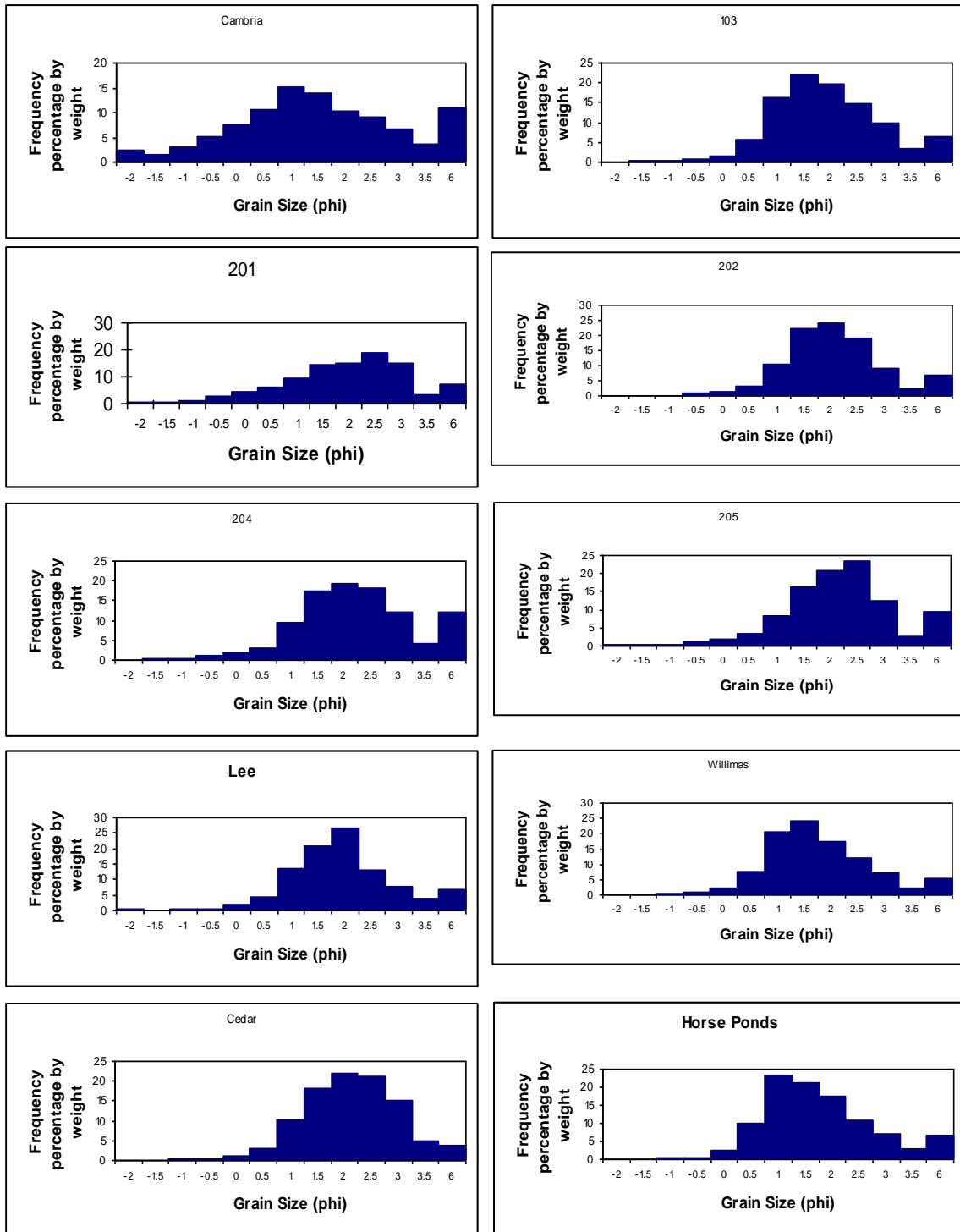


Figure 3.1b Histogram Plots of the sediments from the rims of New Jersey Spungs

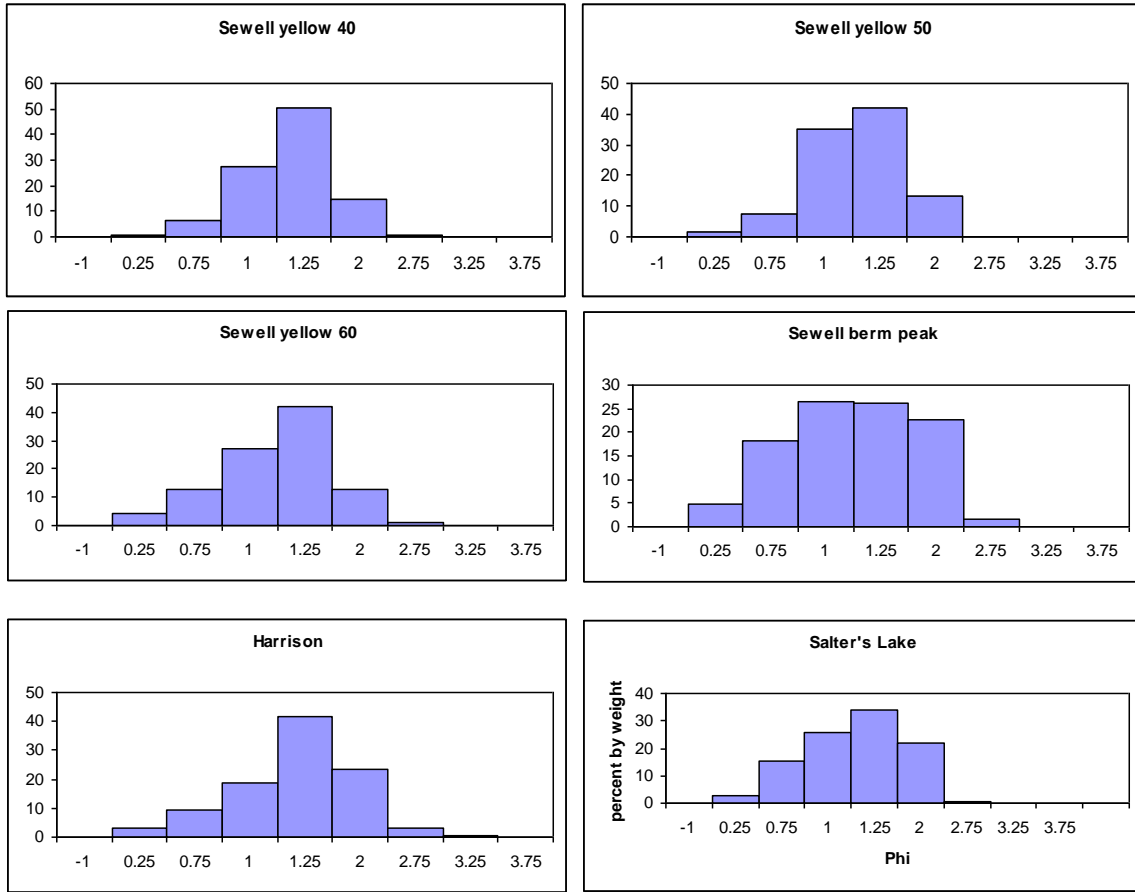


Figure 3.1c Histogram Plots of the rims from Carolina Bays

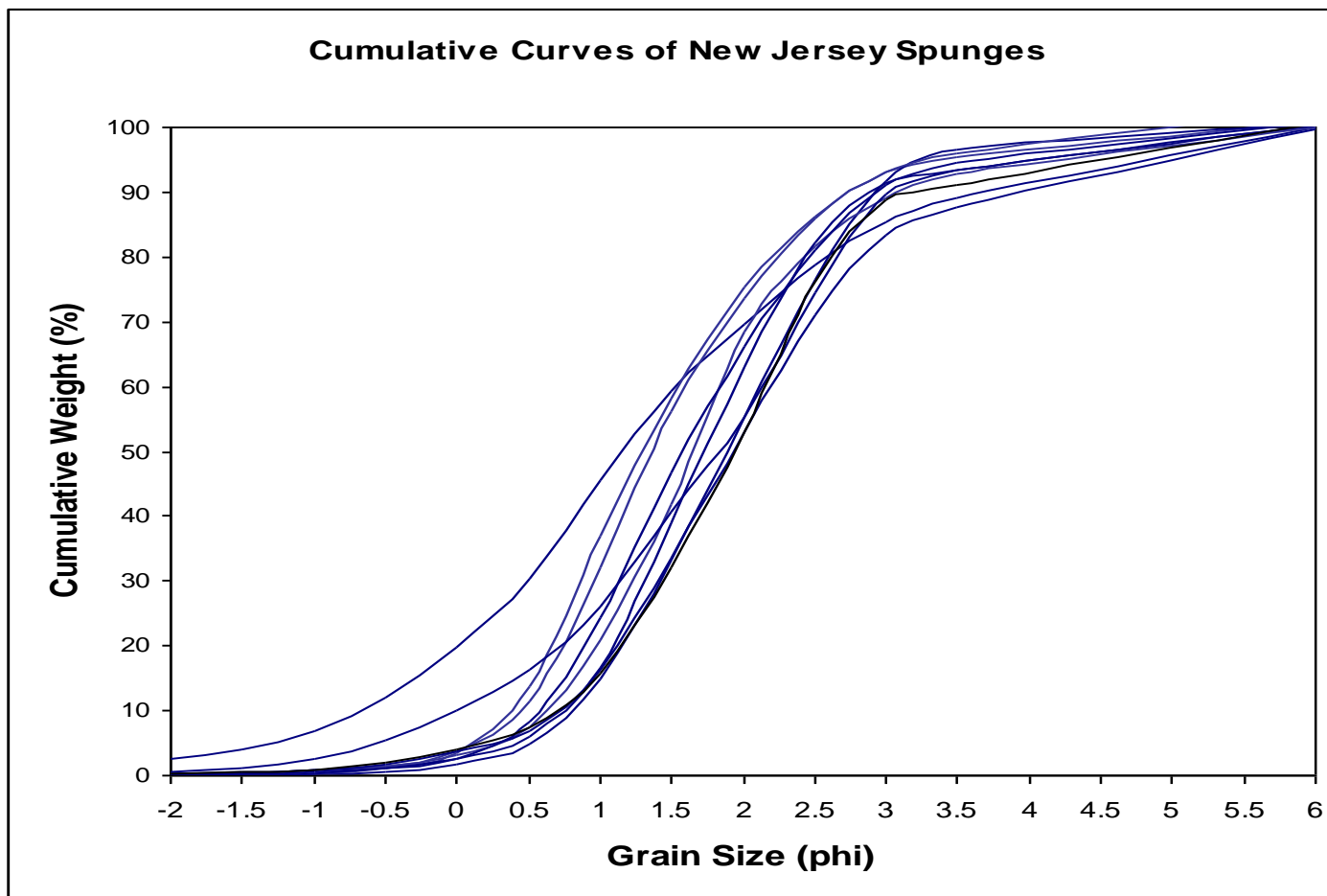


Figure 3.2a Cumulative Curves of sediments from the rims of New Jersey Sponges

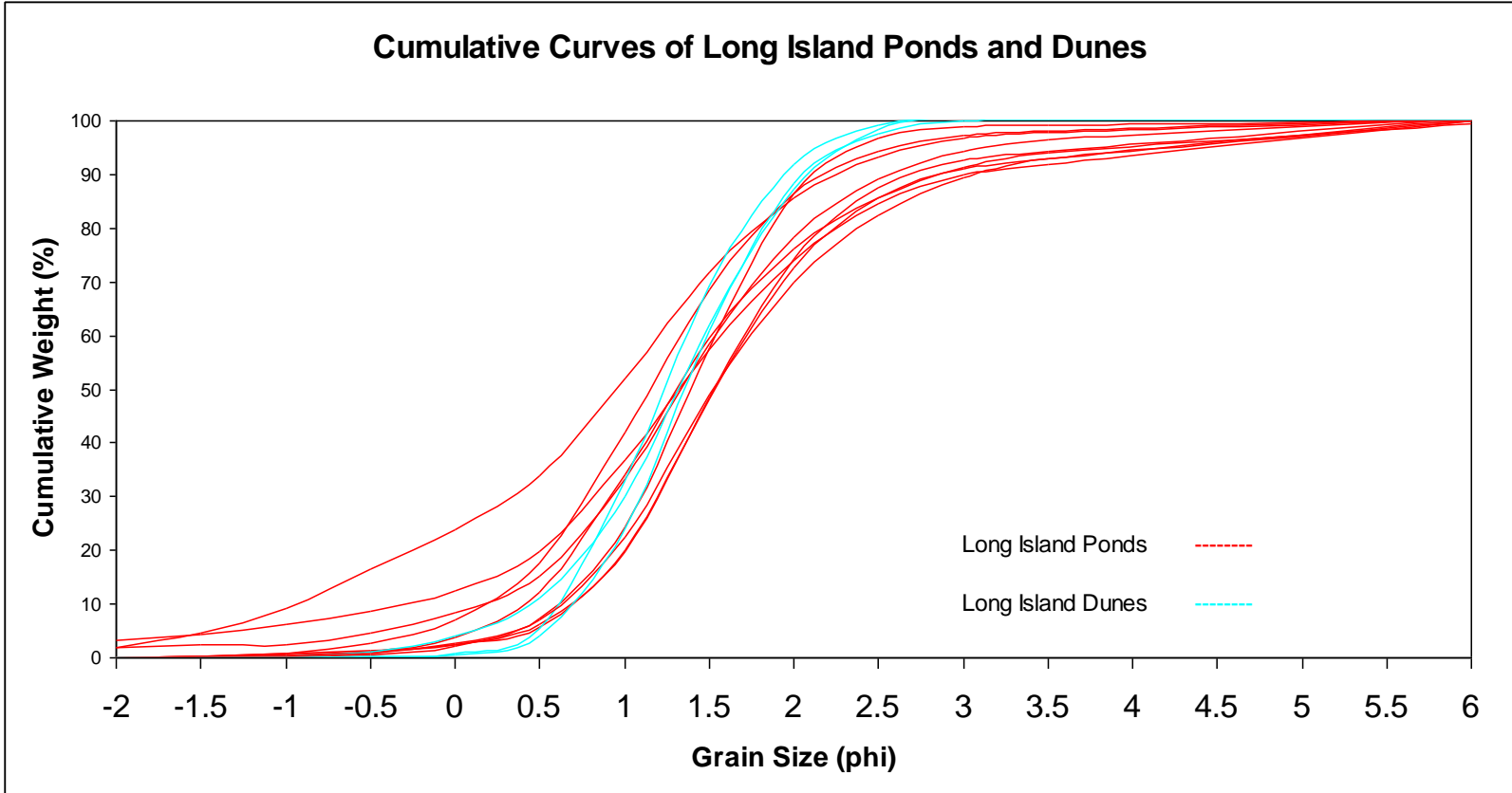


Figure 3.2b Cumulative Curves of sediments from the rims of Long Island Ponds and Dunes

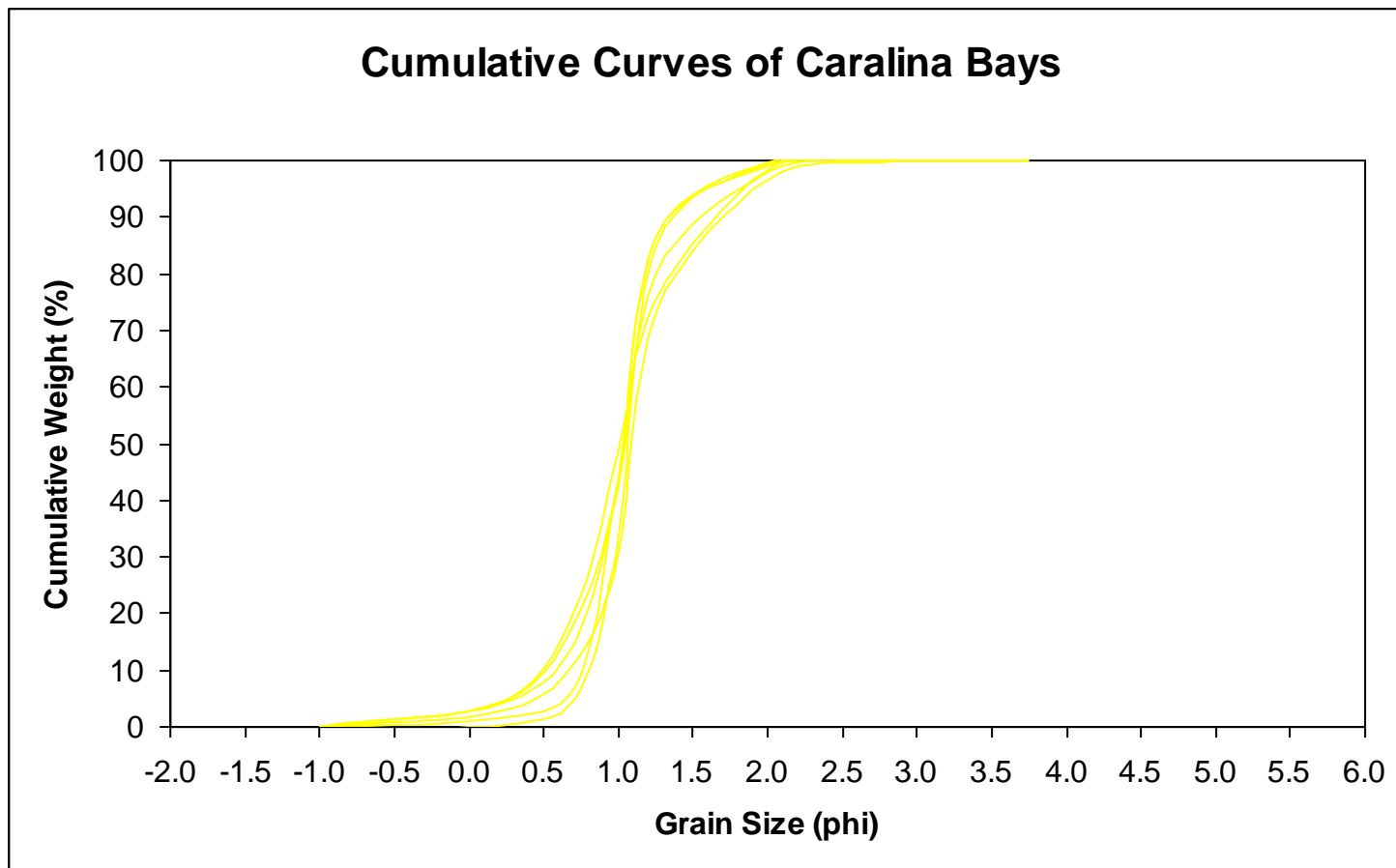


Figure 3.2c Cumulative Curves of sediments from the rims of Carolina Bays

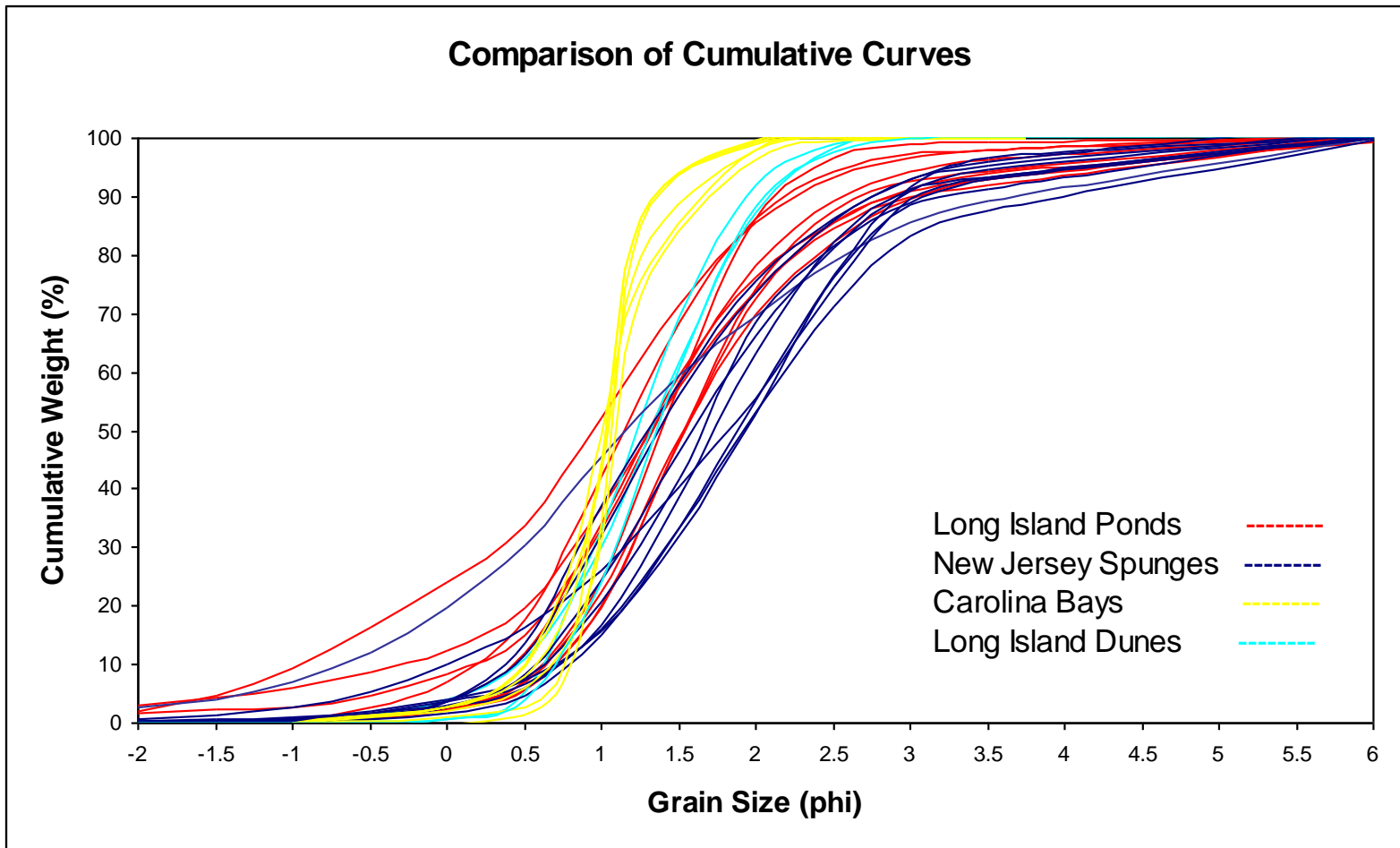


Figure 3.3 Comparison of the Cumulative Curves of sediments from the rims of New Jersey Spunges, Long Island Ponds, Carolina Bays and Long Island Dunes

There are several ways in which grain-size data can be treated statistically. The parameters used to describe a grain size distribution fall into four principal groups: those measuring (a) the average size, (b) the spread (sorting) of the sizes around the average, (c) the symmetry or preferential spread (skewness) to one side of the average, and (d) the degree of concentration of the grain relative to the average (kurtosis) (Blott, 2001). Two principal forms of analysis are normally used, graphical methods and moment methods (Mcmanus, 1988). In this report, Trask's parameters (1932) are also cited to interpret the deposit environments.

Trask's parameters

From the cumulative curves, quartiles Q1 (25%), Q2 (50%) and Q3 (75%) can be easily read. With the help of these quartiles, the Trask's parameters can be calculated with the following equations:

Median grain size (Md): Q_2

Sorting coefficient (So): $\sqrt{Q_3/Q_1}$

Skewness (Sk): $\frac{Q_1 \cdot Q_3}{Q_2^2}$

Table2 gives the results of Trask's parameters calculated for all the samples and data of some Carolina Bays. As shown in the Table 3.2, the sorting for the sediments from the rims of Carolina Bays is better than that for the Long Island's Ponds and New Jersey Spungs. It coincides with the comparison of the cumulative curves which is shown on the Figure 3.3. Sorting coefficients for samples from Long Island ponds and New

Jersey Spunges are all greater than 1.2, while skewness is less than 1. According to Fuchtbauer and Muller (1970), sediments from river bed will show such characteristics.

Table 3.2 Grain-size parameters (After Trask, 1937)

	Pond	Q1	Q2	Q3	Sk	So
New Jersey	103	1.05	1.67	2.35	0.88	1.50
	201	1	1.9	2.51	0.70	1.58
	202	1.2	1.72	2.26	0.92	1.37
	204	1.3	1.45	2.55	1.58	1.40
	205	1.32	1.45	2.55	1.60	1.39
	Cambria	0.21	1.25	2.25	0.30	3.27
	Cedar	1.3	1.85	2.4	0.91	1.36
	Willimas	0.95	1.55	2.15	0.85	1.50
	Lee	1.05	1.7	2.1	0.76	1.41
	Horse	0.7	1.25	1.95	0.87	1.67
Long Island	Fox	1.1	1.6	2.1	0.90	1.38
	Sandy1	1.05	1.45	1.7	0.85	1.27
	NF-3	0.5	1.25	2.1	0.67	2.05
	NF-2	0.1	1.6	3.4	0.13	5.83
	P-4	0.7	1.3	1.8	0.75	1.60
	P-5	0.7	1.3	1.95	0.81	1.67
	Slate	0.6	1.3	2.1	0.75	1.87
	Jones	0.6	1.1	1.6	0.79	1.63
	C-3	1.05	1.55	2.1	0.92	1.41
Dune	WD	1.05	1.15	1.8	1.43	1.31
	GFD	0.85	1.1	1.6	1.12	1.37
	FID	0.65	1.35	1.8	0.64	1.66
NC	Swell yellow 40	0.92	1.04	1.12	0.95	1.10
	Swell yellow 50	0.9	1.02	1.11	0.96	1.11
	Swell yellow 60	0.88	1.02	1.11	0.94	1.12
	Harrison	0.92	1.05	1.26	1.05	1.17
	Swell berm peak	0.78	1.01	1.24	0.95	1.26
	Salter's Lake	0.82	1.02	1.2	0.95	1.21

Graphical Parameters

Folk and Ward (1957) developed a set of graphical parameters calculated by the following equations:

(1) Mean Size (M_z)

$$M_z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

(2) Inclusive graphic standard deviation (σ_1)

$$\sigma_1 = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} + \phi_5}{6.6}$$

(3) Skewness (Sk_1)

$$Sk_1 = \frac{\phi_{84} + \phi_{16} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{95} + \phi_5 - 2\phi_{50}}{2(\phi_{95} + \phi_5)}$$

(4) Kurtosis (K_G)

$$K_G = \frac{\phi_{95} - \phi_5}{2.44 \times (\phi_{75} - \phi_{25})}$$

where ϕ_5 is the grain-size in phi unit at the 5th percentile of the grain-size distribution cumulative, and similarly for the other symbols ϕ_{16} , ϕ_{25} , ϕ_{50} , ϕ_{75} , ϕ_{84} and ϕ_{95} .

All the graphic parameters are given in Table 3.3a, 3.3b, 3.3c and 3.3d for Long Island ponds, New Jersey spungs, Carolina Bays and Long Island Dunes, separately. As shown in Table 3.3, the range of sorting is similar to that of the New Jersey Spungs and is greater than that of the sediments from Carolina Bays and Long Island dunes. This is consistent with trends for the Trask's parameters and the cumulative curves. The dune sands and Carolina Bays rims sands are better sorted than those of Long Island ponds and New Jersey spungs.

Table 3.3a Graphical Parameters calculated for Long Island Ponds

Graphical Parameters	Fox1	Fox2	Sandy	Jones	Slate	P-4	P-5	NF-2	NF-3
MEAN (M_z):	2.564	2.567	2.513	2.367	2.310	2.397	2.449	2.001	2.113
SORTING (σ_I):	0.960	0.951	0.956	1.071	1.233	1.108	1.037	1.571	1.329
SKEWNESS (Sk_I):	-0.115	-0.107	-0.074	-0.102	-0.202	-0.156	-0.122	-0.280	-0.188
KURTOSIS (K_G):	0.831	0.827	0.825	0.829	0.948	0.889	0.823	0.912	0.907

Table 3.3b Graphical Parameters calculated for New Jersey Spungs

Graphical Parameters	Cambria	Willimas	Cedar	Horse	Lee	103	201	202	204	205
MEAN	2.472	2.681	2.451	2.580	2.561	2.478	2.624	1.746	2.649	1.516
SORTING	1.033	0.910	1.047	0.976	0.989	1.137	0.937	1.647	0.968	1.726
SKEWNESS (M_z):	-0.138	-0.178	-0.135	-0.147	-0.156	-0.258	-0.146	-0.239	-0.200	-0.180
KURTOSIS (σ_I):	0.836	0.875	0.825	0.861	0.851	0.946	0.861	0.889	0.930	0.837

(Sk_I):

(K_G):

Table 3.3c Graphical Parameters calculated for Carolina Bays

Graphical Parameters	Sewell yellow 40"	Sewell yellow 50"	Sewell yellow 60"	Sewell berm peak	Salter's Lake berm	Harrison
MEAN (M_z):	1.954	1.934	1.920	1.906	1.920	1.955
SORTING (σ_I):	0.754	0.767	0.781	0.801	0.790	0.768
SKEWNESS (Sk_I):	-0.045	-0.044	-0.051	-0.075	-0.068	-0.072
KURTOSIS (K_G):	0.672	0.674	0.684	0.694	0.696	0.693

Table 3.3d Graphical Parameters calculated for Lond Island Dunes

Graphical Parameters	Walking Dunes	Grand Folia Dunes	Fire Islandd Dune
MEAN	2.521	2.459	2.462
SORTING (M_z):	0.932	0.975	1.001
SKEWNESS (σ_1):	-0.056	-0.058	-0.095
KURTOSIS (Sk_1):	0.796	0.805	0.842

(K_G):

Moment Parameters

The statistical parameters used by Friedman (1961) are the mean size, standard deviation, skewness and kurtosis. These parameters are the first to fourth moments of a grain size distribution. The formulas are described as the following:

(1) Mean (\bar{X}_ϕ) ---- First Moment

$$\bar{X}_\phi = 1/100 \sum f m_\phi$$

Where f is grade size frequency and m_ϕ is the midpoint of each grade size in phi units.

(2) Standard Deviation (σ_ϕ) ----- Second Moment

$$\sigma_\phi = \sqrt{\frac{\sum f (m_\phi - \bar{X}_\phi)^2}{100}}$$

(3) Skewness (Sk_ϕ) ---- Third Moment

$$Sk_\phi = \frac{\sum f (m_\phi - \bar{X}_\phi)^3}{100 \sigma_\phi^3}$$

(4) Kurtosis (K_ϕ) ---- Fourth Moment

$$K_\phi = \frac{\sum f (m_\phi - \bar{X}_\phi)^4}{100 \sigma_\phi^4}$$

All the moment parameters are given in the Table 3.4a, 3.4b, 3.4c and 3.4d for Long Island ponds, New Jersey spungs, Carolina Bays and Long Island Dunes, separately.

Friedman (1961) proposed that dune, beach and river sands could be identified by moment parameters, which he interpreted to reflect differences in the mode and energy of sedimentary transportation. Scatter plots of pairs of moment parameters were employed by Friedman to separate the different environments. Following Friedman's methods, three scatterplots are given from Figure 3.5 to Figure 3.7. The boundaries shown on each figure are all from Friedman original plots.

Figure 3.4---Plot of skewness against standard deviation. In this plot, all samples plot are classified as river sands. The reason that both dunes samples and Carolina Bays sediments samples fall in river part is this plot was used to distinguish between river and beach sands. But, from the other side, the plot shows that they are not beach sands.

Figure 3.5 Plot of mean against skewness. Plots of those from dunes and Carolina bays fall in the dune part of the scatterplot. Long Island ponds and New Jersey spungs sediments samples are identified as beach sands. Again, from this plot we can know that

the sediments from Long Island ponds and New Jersey spungs are different from the dunes sands and Carolina Bays sediments, which were identified as eolian deposit.

Figure 3.6 Plot of Mean against Standard Deviation. Most of the samples plot fall in the mixed parts of dune sands and river sands. Part of New Jersey Spungs sediments samples are identified as river sands. Long Island ponds and New Jersey spungs sediments samples are mostly located near the boundary between river sand part and the mixed part. Whereas, Carolina bays sediments samples plot near the boundary of the dune sands and mixed area. This indicates that Carolina Bays sediments mostly are eolian deposits.

Table 3.4a Moment Paramters calculated for Long Island Ponds

Moment Paramters	Fox1	Fox2	Sandy	Jones	Slate	P-4	P-5	NF-2	NF-3
MEAN (M_z):	2.522	2.528	2.481	2.335	2.218	2.334	2.422	1.931	2.049
SORTING (σ_I):	0.951	0.936	0.928	1.044	1.259	1.129	1.000	1.537	1.309
SKEWNESS (Sk_I):	-0.613	-0.552	-0.405	-0.466	-0.931	-0.877	-0.457	-0.768	-0.684
KURTOSIS (K_G):	3.116	2.887	2.485	2.568	3.718	3.877	2.477	2.803	2.919

Table 3.4b Moment Paramters calculated for New Jersey Spungs

Moment Paramters	Cambria	Willimas	Cedar	Horse	Lee	103	201	202	204	205
MEAN (M_z):	2.439	2.643	2.423	2.528	2.520	2.415	2.582	1.686	2.589	1.469
SORTING (σ_I):	1.005	0.897	1.010	0.976	0.969	1.141	0.928	1.589	0.985	1.648
SKEWNESS (Sk_I):	-0.545	-0.687	-0.479	-0.743	-0.610	-0.938	-0.661	-0.610	-0.977	-0.435
KURTOSIS (K_G):	2.725	3.027	2.498	3.506	2.879	3.591	3.073	2.508	4.147	2.217

Table 3.4c Moment Paramters calculated for Carolina Bays

Moment Paramters	Sewell yellow 40"	Sewell yellow 50"	Sewell yellow 60"	Sewell berm peak	Salter's Lake berm	Harrison
MEAN (M_z):	1.967	1.926	1.893	1.882	1.895	1.968
SORTING (σ_I):	0.708	0.729	0.754	0.768	0.761	0.729
SKEWNESS (Sk_I):	-0.245	-0.212	-0.230	-0.247	-0.263	-0.365
KURTOSIS (K_G):	1.767	1.752	1.807	1.797	1.831	1.964

Table 3.4d Moment Paramters calculated for Carolina Bays

Moment Paramters	Walking Dunes	Grand Folia Dunes	Fire Islanddd Dune
MEAN (M_z):	2.499	2.443	2.432
SORTING (σ_s):	0.898	0.927	0.969
SKEWNESS (Sk_f):	-0.287	-0.265	-0.454
KURTOSIS (K_G):	2.168	2.145	2.571

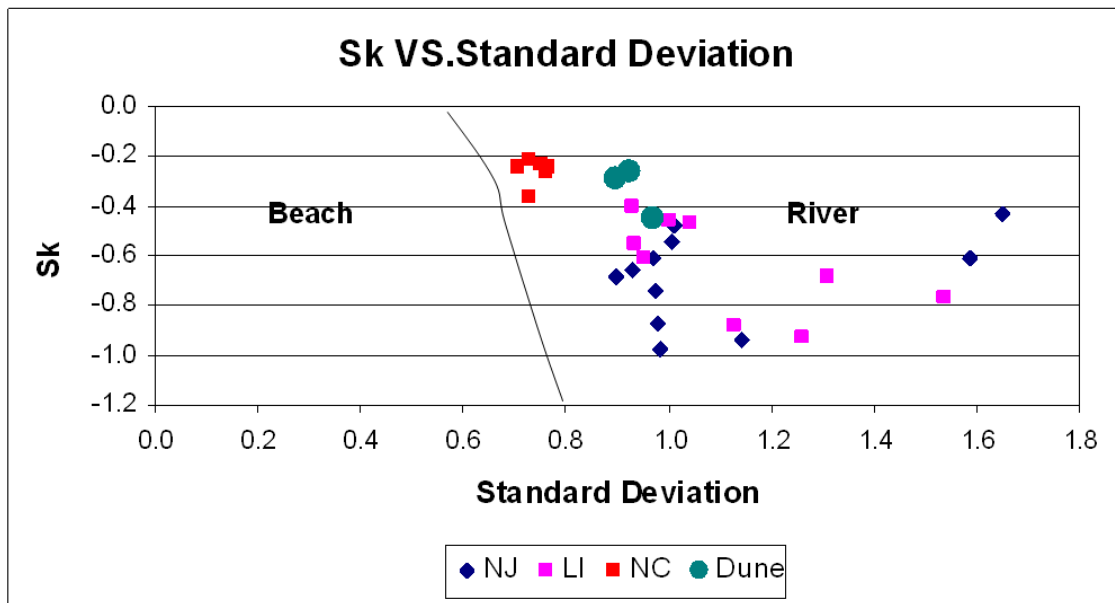


Figure 3.4 Plots of moment parameters: Skewness against Standard Deviation

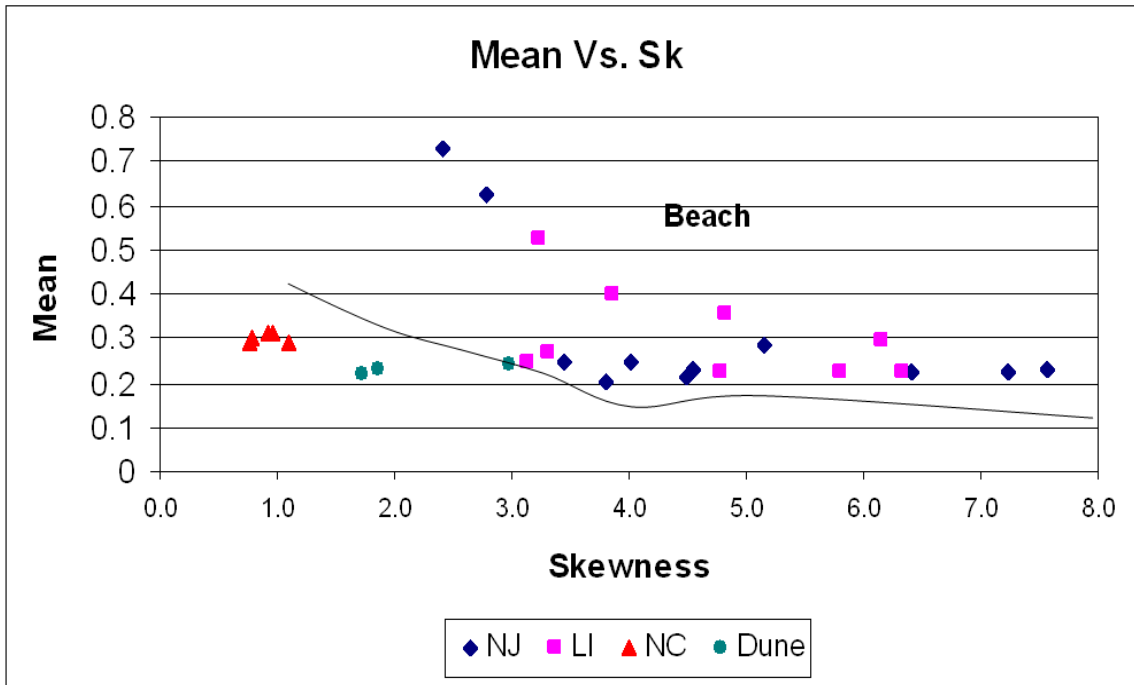


Figure 3.5 Plots of moment parameters: Mean against Skewness

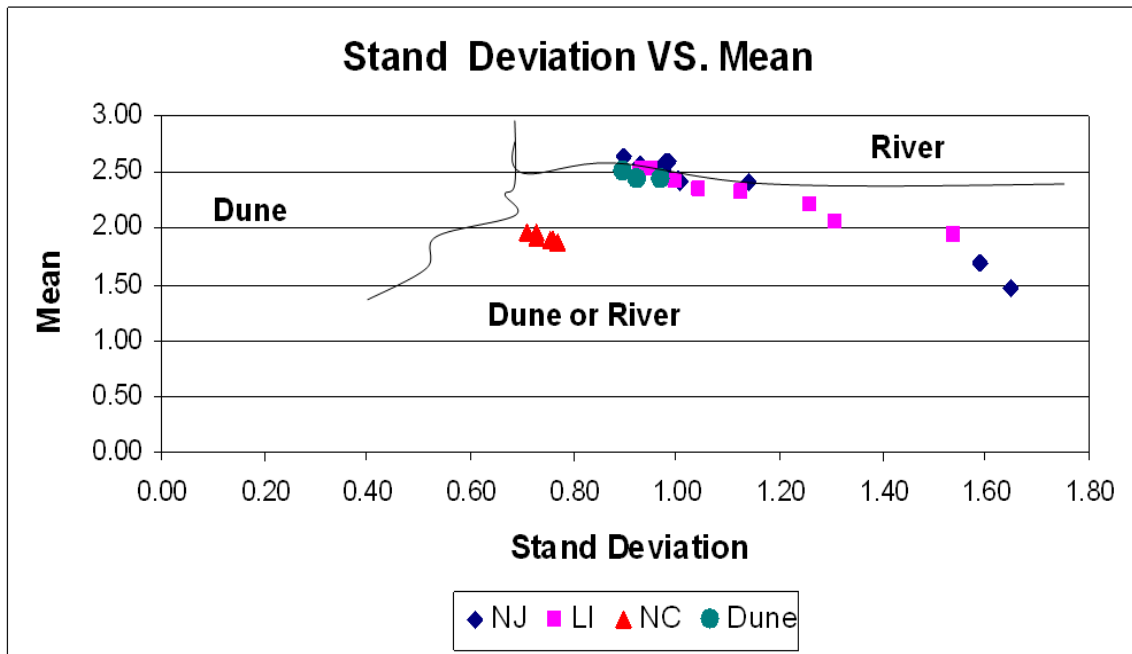


Figure 3.6 Plots of moment parameters: Mean against Standard Deviation

Chapter 4 Hypotheses for the origin of Coastal Plain ponds

Coastal plain ponds are small, groundwater-fed ponds with gently sloping shorelines that occur on the Atlantic Coastal Plain. In the New York Bight, these ponds occur in both the glaciated Coastal Plain lowlands on Long Island, where they occupy shallow depressions on the moraines and outwash plains, and in the relatively flat landscape of the non-glaciated Coastal Plain in southern New Jersey. Concentrations of these ponds occur in Cape May, the southern New Jersey Pinelands, the Peconic River headwaters in the Long Island Pine Barrens, and the Long Pond Greenbelt on Long Island (Figure 4.1) (U.S. Fish and Wildlife Service, 1997). The highest concentrations of Coastal Plain ponds are in North and South Carolina, where they are elliptical shaped shallow depressions. The Coastal Plain ponds on Long Island are known as Calverton Ponds. In New Jersey they are called spunges and in North and South Carolina they are known as Carolina Bays. The Carolina Bays, are not bays, rather they are noted for the bay trees that tend to grow in these depressions.



Figure 4.1 Coastal Plain Ponds in New York bight. (U.S.FWS, 1997)

There are a number of hypotheses for the origin of the Carolina Bays and the spung New Jersey.

Carolina Bays

Within the Atlantic Coastal Plain, the orientation of the long axes of the Carolina Bays and the direction of movement of adjacent sand dunes, where present, are generally perpendicular to each other. They are characterized by an elevated rim of fine sand surrounding the perimeter and are oriented along their long axis from the northwest to the southeast (Figure 4.2).

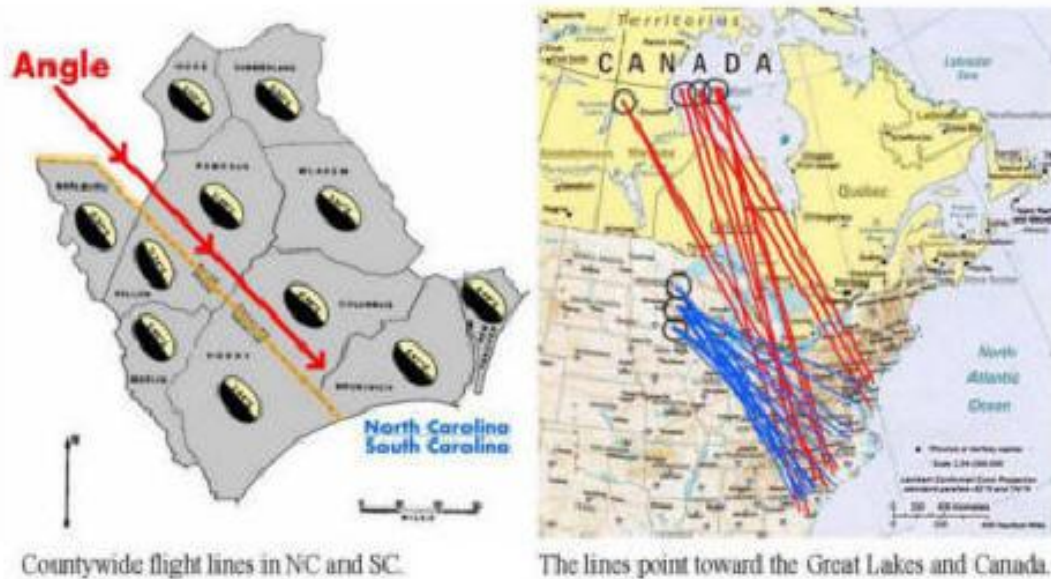


Figure 4.2 The orientation of the long axes of Carolina bays converge. (<http://www.georgehoward.net/cbays.htm>, assessed at Feb. 17, 2008)

Surface sediments of most of the Atlantic Coastal Plain in North and South Carolina are sandy, and are often extensively blown about by the wind (Johnson, 1942). The Carolina Bays occur only in unconsolidated sediments. In South Carolina they are found on relict marine barrier beaches associated with Pleistocene sea level fluctuations,

in dune fields, on stream terraces and sandy portions of back barrier flats (Thom, 1970). Ivester (2004) also found that the Carolina Bay rims are composed of both shore face and eolian deposits.

The origin of the Carolina Bays has been discussed for more than half a century. Suggested origins include meteorite impact (Melton, 1933; Prouty, 1952; MacCarthy, 1935), whale wallows (Grant 1945), artesian springs (LeGrand, 1953), dissolution of underlying material (May and Warne, 1999; Siple, 1960), earthquakes (LeGrand 1983), ice push (Bliley and Burney, 1988), and wind blow out (Kaczorowski, 1977; Thom, 1970; Odum, 1952). In general, the controversies regarding the origin of the Carolina Bays can be divided into two different groups: terrestrial versus extraterrestrial hypotheses. Based on the discovery of charcoal, vitreous carbon, magnetic spherules and excess iridium in the sediments of the rims of the Carolina Bays and the northwest elongation of the elliptical depressions, Howard et al (2007) suggested that these elliptical depressions were excavated by multiple extraterrestrial air burst over the Laurentian Ice Sheet near the end of the Wisconsinan some 12,900 years ago. Eyton (1975) described a similar hypothesis as follows:

Examination of impact mechanics and Carolina Bay morphometry eliminates traditional impact phenomena resulting from meteoroid swarms or asteroids. However, the unique orbital and physical characteristics of a comet favor a model in which a high velocity retrograde comet or a low velocity prograde comet collided with the Earth. The incoming nucleus approached from the northwest and fragmented. The fragments, diverging from the main trajectory, volatiled and subsequently exploded in the

atmosphere near the surface. The resultant shock waves created shallow elliptical depressions which are best displayed in the sandy sediments of the Coastal Plain.

However, the Optically Stimulated Luminescence (OSL) dates obtained by Ivester et al. (2007) from samples of the sand rims of numerous Carolina Bays give ages as old as 80,000 to 100,000 BP. Based on 45 OSL dates, Iveter et al (2007) argue that these results indicate that present-day bays are not the result of a single event, but are a result of multiple processes active episodically over a long period of time. Ivester et al (2007) further showed that these ages are similar to the ages of eolian landforms in the Atlantic Coastal Plain. The wide range of ages seems to conflict with a single extraterrestrial impact event.

Daniels and Gamble (1972) described the Pinehurst Formation which is the uppermost layer of the upper North Carolina Coastal Plain as an eolian unit with coarse to medium sand. They suggested that the relative age of the Pinehurst Formation could be as old as late Miocene to as young as early Pleistocene. All the Carolina Bays for which I obtained grain size analysis data are located on the upper North Carolina Coastal Plain, to the east of the Sandhills Ecoregion, which is considered as a boundary of the Atlantic Coastal Plain. The top layer of the sandhills is Pliocene and Pleistocene sands deposited up to ten million years ago by strong southwest prevailing winds (Murray 1995). These sand deposits are the source of sediments for the Carolina Bay rims.

The wide range of ages and the similarity of the cumulative curve shapes and sorting coefficients for the sediments in the depressions and rims for the Carolina Bays

may be compatible with an impact hypothesis, When the air burst or ice impacted these loose source sediments, the sediments would not have been sorted and the event(s) could have occurred too fast or there was not adequate light to reset the optically stimulated ages of the sediments in the rims.

Thus, the hypothesis proposed by Howard (2007) maybe a reasonable interpretation for the origin of Carolina Bays. He suggested that at least some modern Carolina Bays may have evolved from depressions which were excavated by primary ejecta, secondary ejecta, and/or the shock wave from the Younger Dryas impact event.

New Jersey Spungs

The term ‘Spungs’ was locally used for the depressions and basins located in the New Jersey Pine Barrens, which is a wilderness tract of over 1.4 million acres of low-lying terrain occurring mainly on the outer coastal plain of southern New Jersey (French, 2001).

Wolfe (1952, 1953) attributed the enclosed shallow depressions located in the New Jersey coastal plain as a result of freezing and thawing in a periglacial climate during the Late Wisconsinan. Wind action, mass wastage, and erosion further modified them after their formation. Wolfe (1956, 1977) later reinterpreted them as thermokarst lakes or thermokarst basins. Bonfiglio and Cresson (1982) chose a “pingo-scar” hypothesis to explain their formation.

French and Demitroff (2001) summarized the hypotheses that might explain the origin of these spungs as (1) solution subsidence; (2) water-upwelling and subsidence; (3) Pingo-scar hypothesis; (4) thermokarst-lake-basin and (5) erosion by periglacial wind action. And then they tested these hypotheses and rejected all of them but a wind blow out process. Because of the lack of carbonate rocks and soft sediment deformations, solution subsidence and water-up welling and subsidence are unlikely. A pingo-scar hypothesis was rejected because the topographic and hydrological conditions are lacking and water depths were insufficient to form pingo-scars. So, they suggested that periglacial wind action formed the spungs by strong, cold katabatic winds blowing directly off the ice sheets. They were especially effective in eroding and transporting sediment because the vegetation cover was sparse and often xeric (French, 2003). Eolian activity on exposed surfaces initiated deflation blowouts, sand rims formed in the downwind side (Figure 4.3).

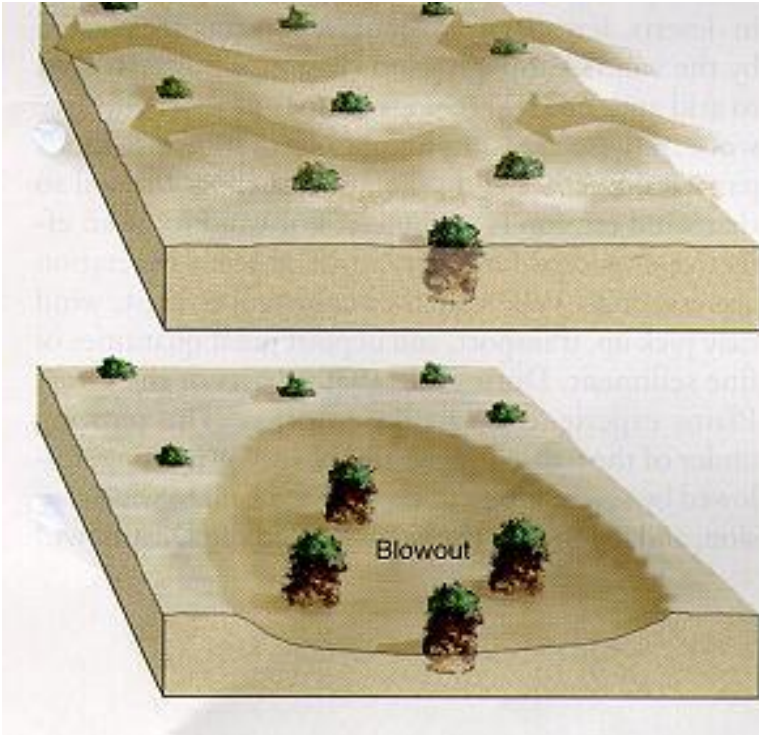


Figure 4.3 The Wind blowout model of New Jersey Spunges (Hanson, 2007).

Although the wind blowout model proposed by French and Demitroff is a reasonable hypothesis for the origin of the spunges, the grain size analysis does not support the hypothesis. According to this model, the grain size distribution of the sand in the rims should be consistent with an eolian origin. However, the cumulative curve shapes and other parameters suggest that they formed in an alluvial environment, not an eolian environment.

Calverton Ponds

The Calverton Ponds are generally elongated with an orientation from northwest to southeast (Figure 4.4).



Figure 4.4 Calverton Ponds (Image from Google Earth)

Could they be a result of an extraterrestrial impact? Or, were they excavated by wind? Or, were they formed by other processes?

Two requirements can be summarized from the French and Demitroff's (2003) wind blow out model, one is strong wind blowing and the other is perennially frozen ground (permafrost). The Laurentide Ice Sheet retreated from Long Island about 18000-20000 years before present, leaving behind a periglacial environment and permafrost. The permafrost on Long Island may have lasted until 13,000 years ago (Hanson, 2006). The evidence for permafrost is found in the forms of ice wedges (Nieter, 1975) and thermokarst involution (Kundic and Hanson, 2006). Ice-wedge casts indicative of former permafrost conditions have been reported from southern New England (Stone and Ashley,

1992) and Southern New Jersey (French et al., 2007). This implies that permafrost was present in almost all parts of Northeastern USA and it extended far south of Long Island.

While Fox Pond was used for growing cranberries and the results for it may be suspect the grain size distribution of samples from the rims of other Coastal Plain Ponds located on Long Island, which were not used to grow cranberries, are similar with alluvial characteristics. Grain-size distribution, cumulative curves, parameters and the plots drawn with the parameters, of the samples from Calverton Ponds are similar to those for samples from the spungs in New Jersey, that is, they are characteristically alluvial. Reineck and Singh (1975) stated that grain size of wind-deposited sands commonly ranges from silt (60μ) to coarse sand (2mm). Grains over 5mm are rarely found in wind deposited sediments. The sediments from both New Jersey Spungs and the Calverton Ponds contain about 1 percent of sands coarser than -2 phi, or 4mm. All these factors suggest that the wind blow out model is not consistent for the origin of the Calverton Ponds.

The grain-size distributions of samples from the rims of the New Jersey spungs and those of from Long Island ponds are significantly different from the sediments in the Carolina Bays. The source sediment of Carolina Bays is eolian-deposited sands, whereas the sediments on which the Calverton Ponds rest are outwash plain sediments deposited in streams close to the glacier front. Thus, these data are consistent with an extra-terrestrial impact origin.

Firestone, et al (2006) concluded that Carolina Bay axes point toward the Great Lakes and Hudson Bay in Canada which are the possible impact sites. So, if the origin of spungns and ponds in this study were related to the impact, the long axes should point to the same positions as the Carolina Bay axes point. The orientation of the axes of the spungns in New Jersey and the Long Island ponds (Table 4.1) in this study are consistent with those of the Carolina bay axes which point toward Hudson Bay (Figure 4.5 and 4.6). So this evidence is consistent with the origin of Calverton Ponds being related to the extraterrestrial impact.

Table 4.1 Orientation of ponds selected in this study

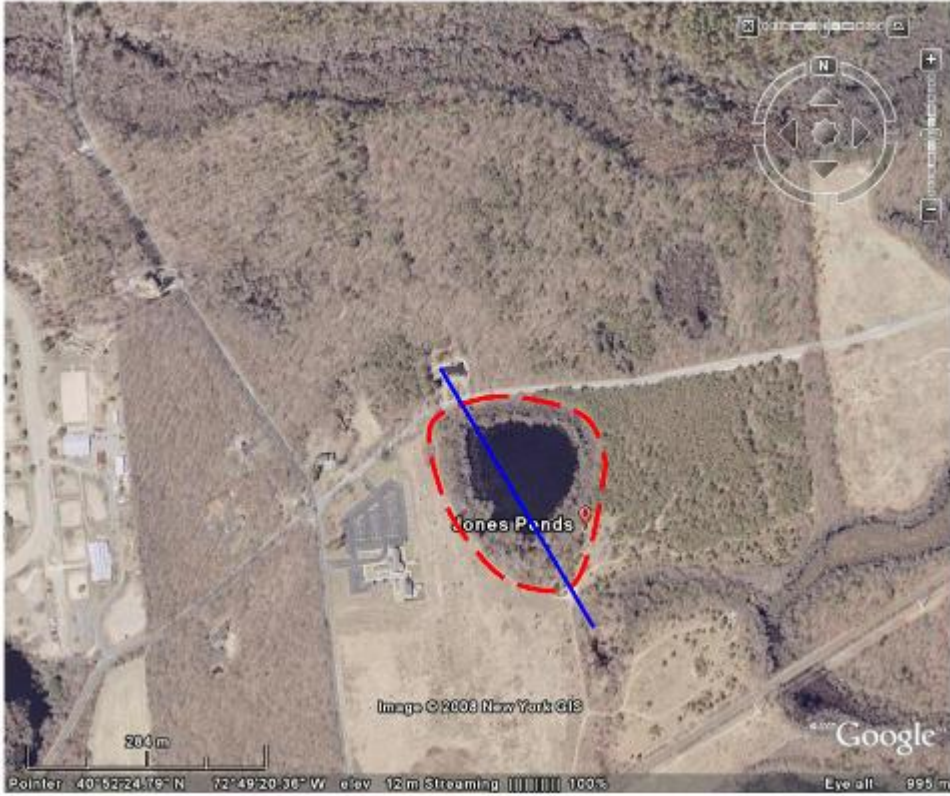
Pond		Orientation
		Angle
New Jersey	103	326°
	201*	276°
	202*	323°
	204*	327°
	205*	277.5°
	Cambria	296.5°
	Cedar	320°
	Willimas	338°
	Lee	323°
	Horse Break	323°
Long Island	Fox**	330°
	Sandy**	330°
	NF-2	329°
	NF-3	327°
	P-4	335.5°
	P-5	323°
	Slate	328°
	Jones	330.5°
	C-3	327.5°

* The group of these ponds shows an orientation as 320°

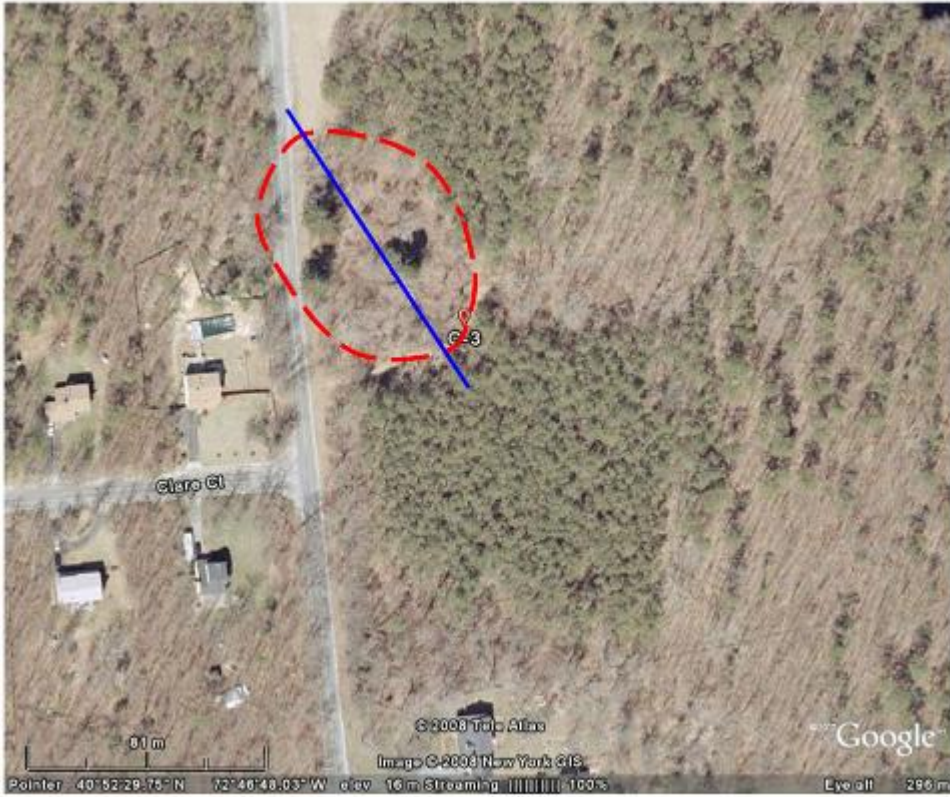
** The angle is the representative of the Calverton Ponds



Calverton Ponds ($\alpha = 330^\circ$)



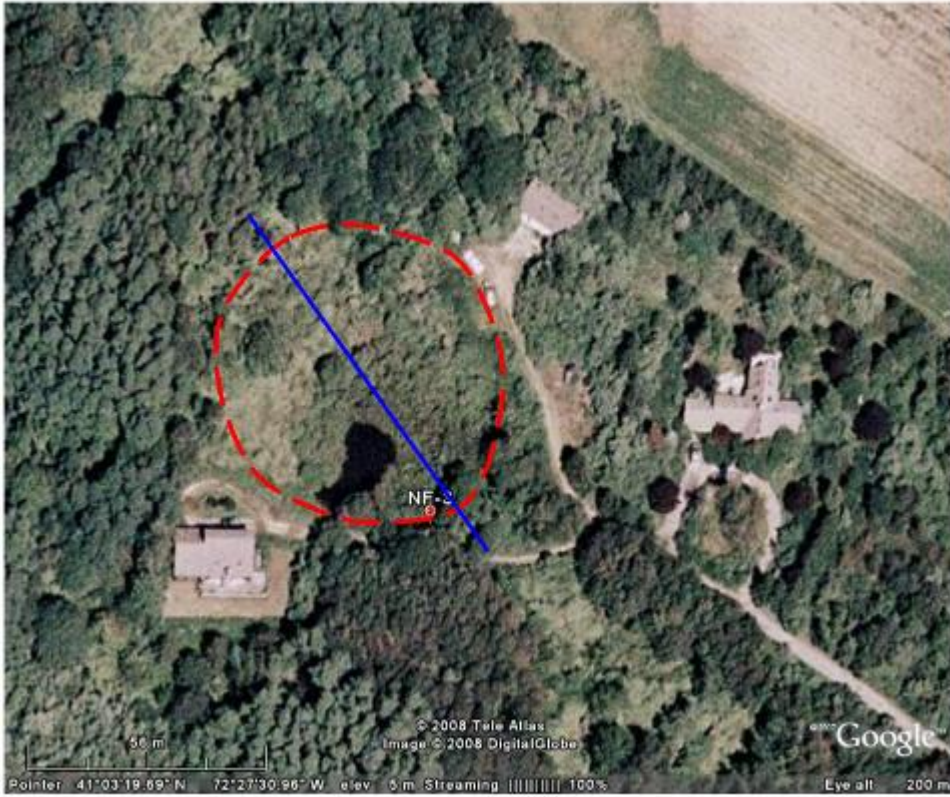
Jones Pond ($\alpha = 330.5^\circ$)



C-3 Pond ($\alpha = 327.5^\circ$)



NF-2 Pond ($\alpha = 329^\circ$)



NF-3 Pond ($\alpha = 327^\circ$)



P-4 Pond ($\alpha = 323^\circ$)



103 Pond ($\alpha = 326^\circ$)



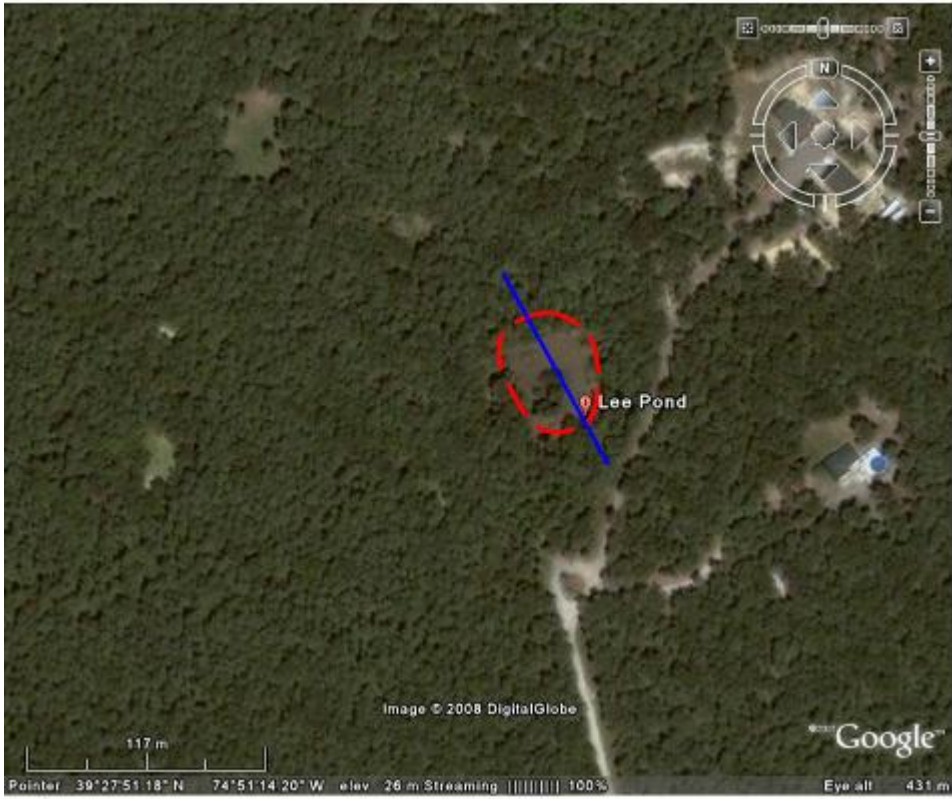
Cedar Pond ($\alpha = 338^\circ$)



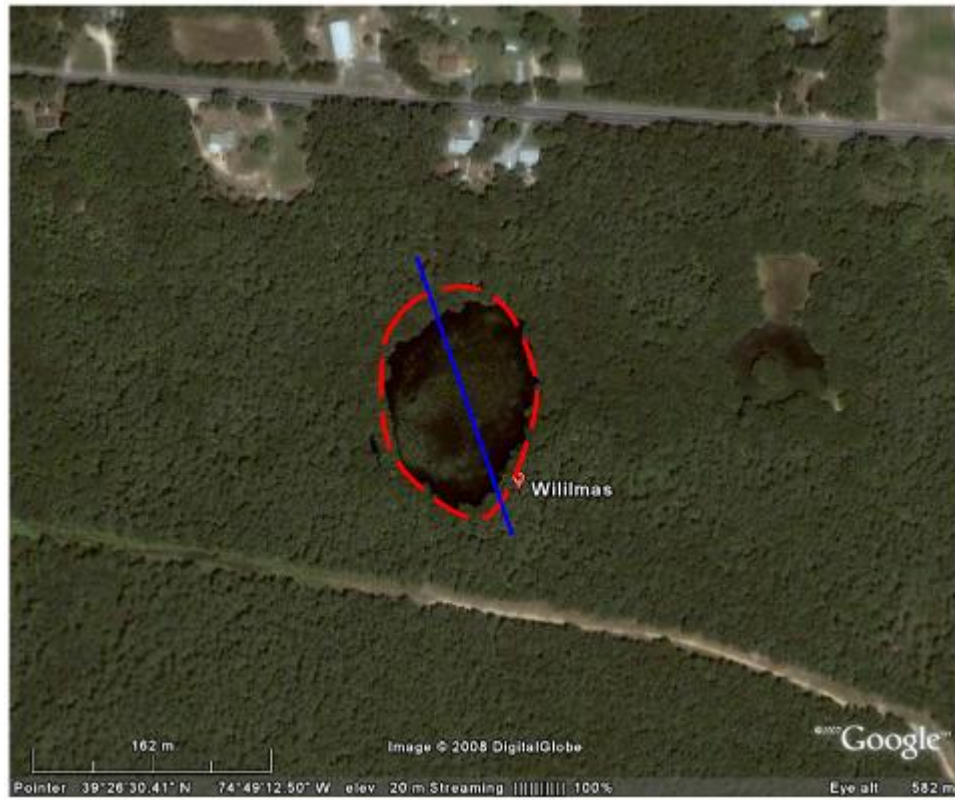
Cambria Pond ($\alpha = 296.5^\circ$)



Horse Break Pond ($\alpha = 323^\circ$)



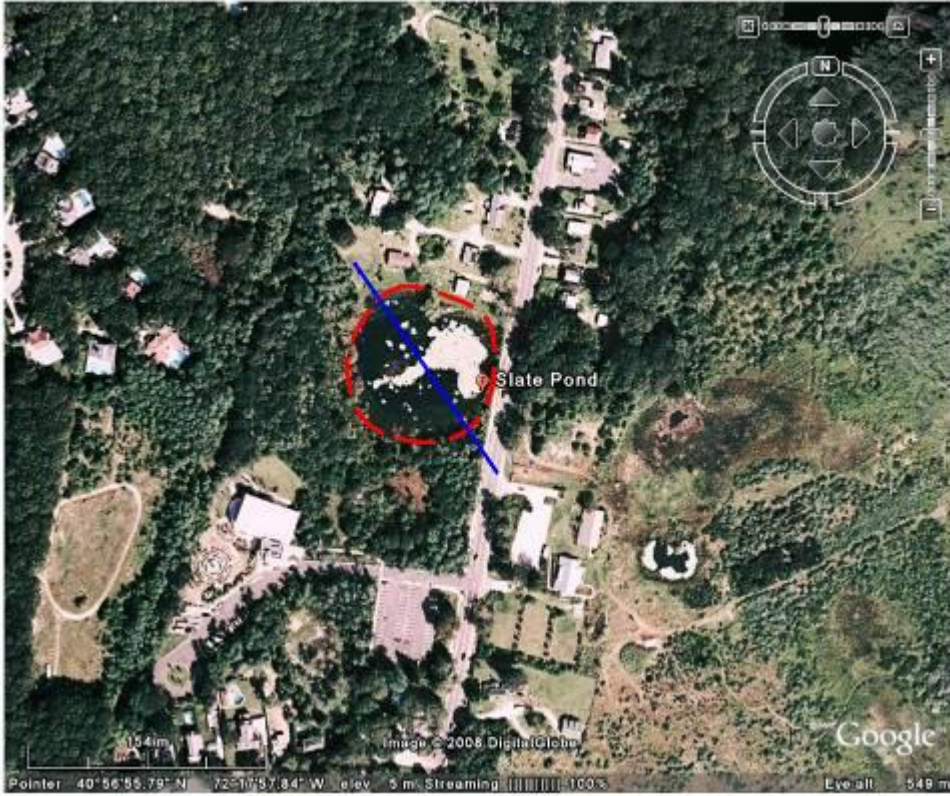
Lee Pond ($\alpha = 323^\circ$)



Willimas Pond ($\alpha = 338^\circ$)



P-5 Pond ($\alpha = 323^\circ$)

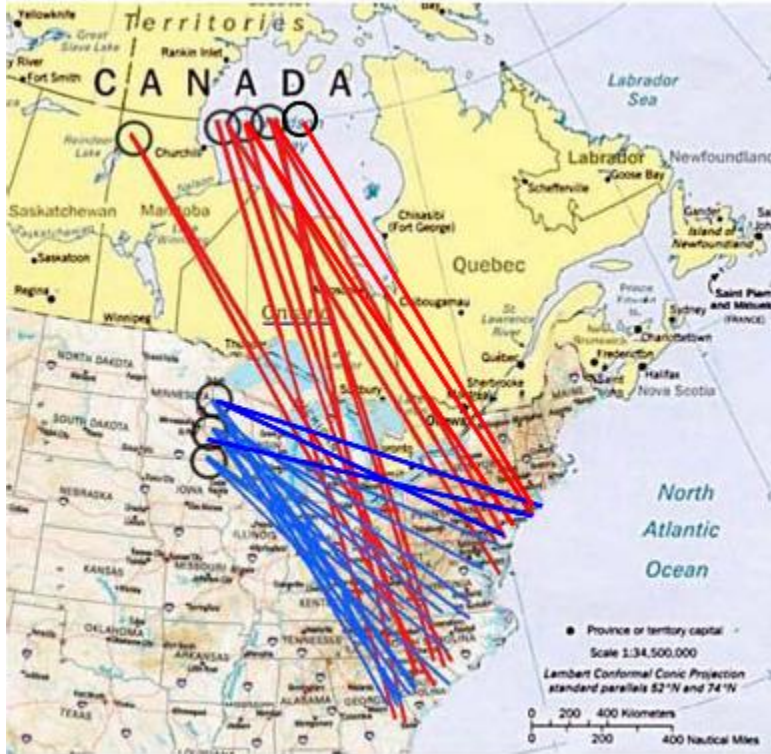


Slate Pond ($\alpha = 328^\circ$)



201 Pond ($\alpha = 276^\circ$); 202 Pond ($\alpha = 323^\circ$); 204 Pond ($\alpha = 327^\circ$); 205 Pond ($\alpha = 277.5^\circ$);
 (Orientation of this group of ponds; $\alpha = 320^\circ$)

Figure 4.5 The orientation of the long axes of the Spungs and Ponds in this study.



The lines point toward the Great Lakes and Canada.
 Figure 4.6 Comparison of orientation of Carolina Bays and ponds studied in this study
 (Modified from Figure 4.2)

Chapter 5 Conclusion and Future Work

Twenty two sediment samples were collected from ponds and dunes located on Long Island, New York and New Jersey coastal plain. Grain size distribution was analyzed by the conventional sieving methods. Cumulative curves and plots indicate that sediments from these ponds have alluvial not eolian characteristics. Extensions of the long axes of the Coastal Plain ponds including those of the Carolina Bays, New Jersey and Long Island converge on the Great Lakes and Hudson Bay in Canada where the proposed comet pieces burst or impacted. Thus, the data are consistent with an impact model while in conflict with a blowout model.

While the data presented here are consistent with an impact model for the origin of the ponds in New Jersey and Long Island, at this stage that does not mean that an extra-terrestrial impact was the actual cause for the formation of the ponds. More information is needed to test this hypothesis.

➤ Use of DEM's based on LiDAR data. LiDAR for Suffolk County has been collected and should be available to the public soon. It was very useful in studying the Carolina Bays because it provides much more precise elevation data showing more details regarding the depressions than are visible with maps based on 10 foot contour intervals.

➤ Search for excessive charcoal, vitreous carbon, magnetic spherules and excess iridium in the rims of the depressions. These are indicators of an extra-terrestrial origin.

➤ Dating of the age of deposition of the rims. If it has an impact origin the age should be about 12,900 years. It is not clear what technique could be used for this dating. Radiocarbon dating of the charcoal may have excess radiocarbon, yielding ages that are too young.

If such future studies show that the impact model is not viable, other models consistent with the new results will need to be developed.

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