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BEACH SAND TEXTURES FROM THE ATLANTIC COAST OF DELAWARE

The south side of Indian River Inlet during Hurricane Dennis, Sept. 1, 1999.

By

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INTRODUCTION

Sand is a precisely defined term in geologic practice: rock fragments or particles with diameters between 2 millimeters (mm) and 1/16 mm (Folk, 1974; Lewis, 1984). The sizes of particles that accumulate to form geologic deposits are sensitive to the currents that carry the fragments and tend to be in equilibrium with their depositional environments. Sampling, laboratory, and statistical techniques have been devised to measure sand grain sizes and their distribution (texture). Even without these complex measures, it has long been observed that there are differences between sands in rivers, dunes, and beaches. *Beach sand* is identifiable because its texture is developed by the agitation and sorting of waves, currents, and winds. It is adjusted to its environment; fine particles are washed offshore or blown into dunes, and larger particles accumulate in the area of highest energy in the surf zone. The remaining sand on the beach is adjusted to the energy and currents between low and high tides.

The purpose of this report is to characterize Delaware Atlantic Coast beach sand on the basis of sand texture data in order to identify geologic material suitable for beach nourishment. The textural properties that are important for characterization include mean sand grain size and sorting (deviation of grain size about the mean). Material placed on the beach as nourishment sand should be similar in texture to that on the natural beach in order to ensure stability (U.S Army Corps of Engineers, 1984a). The textures of these sands represent the size and sorting that are stable under average wave and current activity. This is important because material considerably finer than that of the natural beach could be rapidly removed by wind or waves. Material considerably coarser may make the beach profile (the shape of the slope of the beach from the dunes to offshore) steeper and reduce beach width (U.S Army Corps of Engineers, 1984a).

According to the U.S. Army Corps of Engineers (1984a) Shore Protection Manual, this process of characterizing the beach sands leads to the recognition of an average native texture called a "native composite." This native composite is used to evaluate the suitability of potential borrow sand because the native textural patterns are assumed to be the direct response of sand sorting by natural processes. This study establishes a native composite for the Delaware Atlantic Coast.

Acknowledgments

This publication revises and updates a contract report written in 1989 for the Delaware Department of Natural Resources and Environmental Control Beach Preservation Section as a part of the South-East Area Sand Inventory Project (SEASIP) conducted by the Delaware Geological Survey to identify onshore sand resources for beach nourishment. Marijke J. Reilly helped with the word processing and graphs in this report. Lillian T. Wang produced Figure 1. William S. Schenck prepared the document for presentation on the DGS Web Site. Stefanie J. Baxter, Kimberly K. McKenna, and Peter P. McLaughlin reviewed the manuscript.

Database

Data were compiled from ten previous studies of beach sand from Delaware's Atlantic Coast (Table 1). The period of sampling covered 55 years (1929 to 1984). The number of sample sites ranges from a minimum of 1 to a maximum of 24 for the individual studies. Most of the data are from U. S. Army Corps of Engineers unpublished project reports. Additional data were obtained from M. S. theses from the Department of Geology at the University of Delaware. The data were collected prior to any major beach nourishment projects along the Atlantic Coast of Delaware, thus are assumed to be representative of the natural beach sands.

Table 1
Sources of data of beach sediment texture.

YEAR	SOURCE AND YEAR PUBLISHED	# LOCALITIES SAMPLED	BEACH SITE	TIME OF YEAR SAMPLED
1929	U.S.A.C.E. (1966)	2	MHW	November
1936	U.S.A.C.E. (1966)	24	MT	Unknown
1950	U.S.A.C.E. (1966)	5	MHW	November
1953	U.S.A.C.E. (1966)	2	MT	June
1954	U.S.A.C.E. (1966)	24	PFL	August-October
1964	U.S.A.C.E. (1966)	12	PFL	June-August
1974	U.S.A.C.E. (1975)	2	PFL	Spring
1980	McDonald (1981)	4	PFL	Unknown
1983	U.S.A.C.E. (1984b)	1	PFL?	May
1984	Toscano (1986)	2	PFL	Summer

A.C.E. – U.S. Army Corps of Engineers
MHW – mean high water
MT – mid-tide
PFL – across profile

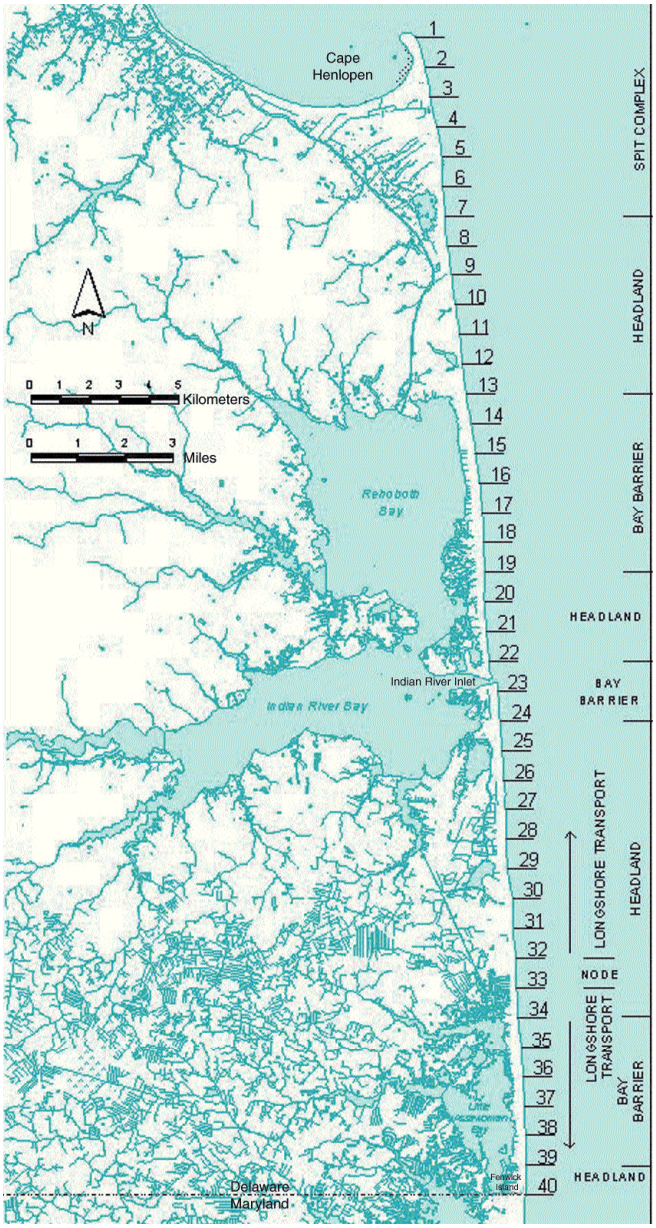

Figure 1. Map of Atlantic Coast of Delaware showing major geomorphic features and 1-km segments (numbered 1 to 40) used in this study.

Treatment of Data

In order to detect trends in sand textures along the Delaware Atlantic Coast, the shoreline was divided into 40 segments, each 1 km in length (Figure 1). Segment boundaries correspond with the Universal Transverse Mercator 1000-meter northing lines as published on the USGS. 1:24,000-scale topographic maps that cover the Delaware Atlantic Coast. Grain size and sorting data for each segment are given in Tables 2 and 3. Of the 40 segments, 9 were not sampled in any study and 8 others were only sampled once. The other 23 segments were sampled anywhere from two to five times.

Size and sorting data are presented in terms of phi size, a log scale of grain size in mm (Appendix A). Data originally reported in mm were converted to phi. The phi scale values decrease as grain sizes become coarser or sediments become better sorted. Tables 2 and 3 present the average of the mean grain size and sorting data, respectively, from a series of samples across a beach profile (from the dune to the low tide line). Single samples were collected from the mean high water (MHW) or from the mid-tide (MT— halfway between high and low tide) region on the beach (Table 1).

These textural data reflect the textural characteristics of the beach sand at the sample locality. They, however, can only be used as an approximation for the beach textures. Variability in sampling methodology, location of samples on the beach, textural analysis methodology (sieving or rapid settling analysis), formulas used in calculating the textural data, and the time of year of sampling all affect the results. Nevertheless, the data provide a general characterization of the north-south distribution of average beach textures over the last 55 years. Further, the historical data are significant because later nourishment projects have altered the natural, stable sand texture.

Grain size parameters for all of the Army Corps of Engineers reports were reported as a median grain size (the phi size at the 50th percentile). Sorting was calculated as the square root of the grain size of the 25th percentile divided by the 75th percentile. McDonald's (1981) data are reported in terms of a graphic mean value (Folk, 1974). A mean value uses a formula that takes into account the median as well as the distribution about the median. Examination of the distribution curves of McDonald (1981) show that none of the samples has a bimodal distribution, thus the means and medians are comparable and are treated as such. The sorting data are treated likewise. Toscano (1986) used the graphic mean value as well. The sorting values about the mean indicate that other than for a very few samples, the samples are well to very well sorted and do not have bimodal distribution. Mean values are considered to be comparable to median values and are treated as such. Sorting values are treated likewise.

The data for each 1-km segment were averaged to provide averages of grain sizes and sorting. In order to determine if variations along the coast correspond to "natural" elements (position of inlet or node) or to sand sources (headlands) and sinks (spit, barriers) along the coast, the coastline was divided using several groupings: north or south of Indian River Inlet; north or south of the longshore transport node (approximately at South Bethany); and geomorphic position (spit, headland, bay barrier) (Figure 1). Averages of the sand texture data for each of these groupings is presented in Tables 2 and 3.

Discussion

The yearly averages do not show any significant trends through time. Samples taken during 1936 were from the mid-tide level, a zone that normally contains sand coarser than the average over the entire beach profile. Size data from the entire profile for 1954, however, are not significantly different from those of the mid-tide zone of 1936 (1.11 phi versus 1.04 phi). Samples from 1964 (1.68 phi) showed finer sand than that of previous years. The finer size may reflect the condition of beaches following the major northeaster of 1962. Data from other years are too sparse to make any meaningful comparisons.

Figure 2 shows the distribution of mean size and Figure 3 shows distribution of sorting along the Delaware coast. The sands fall within the coarse to medium sand-size range and are well to moderately well sorted. An average

Table 2

Grain size data and averages (in phi units) for “natural elements” along Delaware’s Atlantic Coast.

KM SEGMENT	1929	1936	1950	1953	1954	1964	1974	1981	1983	1984	AVERAGE	N INLET	N NODE	SPIT COMPLEX
1						1.75				1.69	1.72			
2				1.5							1.5			
3	1.45		1.9	0.98	0.98	1.58					1.38			
4					1.19						1.19			
5					0.95						0.95			1.31
6														-0.25
7		1.28			0.65	1.5					1.14			
8		1.3			1.03						1.17			HEADLAND
9														
10		1.35	1.5		0.74		1.34				1.23			
11		0.88			0.79	1.5					1.06			1.16
12												1.21		-0.06
13		0.91	1.7		0.92						1.18	-0.21		
14														BAY BARRIER
15		0.56			1.14	1.51					1.07			
		0.85									0.85			
16		1.07			0.93						1			1.11
17														-0.24
18		1.5									1.5			
19		0.72			0.91	1.89				1.53	1.26		1.22	HEADLAND
20													-0.23	
21		1.05			0.71				1.53		1.1			1.24
22		0.97			1.39	1.7					1.35			-0.11
23		0.76			0.85						0.81	S INLET		BAY BARRIER
24		0.84			1.41	1.85					1.37			1.09 (0.28)
25														HEADLAND
26		1.25									1.25			
27		0.65			1.1						0.88			
28								1.36			1.36			
29		1.35			0.9	1.71		1.16			1.28			1.27
30			2.2		1.19						1.7			-0.32
		1.3			1.3						1.3			
31					1.9			0.88			1.39		S NODE	
32		1						1.15			1.08	1.3		
33					1.85	1.79	1.78				1.81	-0.32		
34		0.71									0.71			
35		1.45			1.52						1.49			BAY BARRIER
36													1.37	
37		1.14									1.14		-0.35	1.38
38		1.35			1.47	1.73					1.52			-0.17
39														
40	1.75	1.5	2.32		1.3	2.24					1.82			HEADLAND
														1.82 (0.40)

1.26	AVG	
1.82	MAX	
0.27	STD	(standard deviation)
0.71	MIN	
33	Number of stations sampled	

Table 3

Sorting data and averages (in phi units) for “natural elements” along Delaware’s Atlantic Coast.

KM SEGMENT	1929	1936	1950	1953	1954	1964	1974	1981	1983	1984	AVERAGE	N INLET	N NODE	SPIT COMPLEX
1						0.42				0.64	0.53			
2				0.61							0.61			
3	0.55			0.82	0.65	0.42					0.63			
4					0.57						0.57			
5					0.51						0.51			0.55
6														-0.06
7		0.37			0.54	0.4					0.44			
8		0.45			0.55						0.5			HEADLAND
9														
10		0.32			0.49						0.41			
11		0.57			0.48	0.47	0.84				0.59			0.49
12												0.5		-0.07
13		0.46			0.46						0.46	-0.08		
14														BAY BARRIER
15		0.32			0.34	0.47					0.38			
		0.55									0.55			
16		0.43			0.4						0.42			0.44
17														-0.07
18		0.4									0.4			
19		0.55			0.54	0.56				0.5	0.54		0.47	HEADLAND
20													0.09	
21		0.41			0.63						0.52			0.48
22		0.35			0.39	0.44					0.39			-0.06
23		0.37			0.79				0.53		0.56	S INLET		BAY BARRIER
24		0.36			0.58	0.44					0.46			0.51 (0.05)
25														HEADLAND
26		0.3									0.3			
27		0.45			0.48						0.47			
28								0.42			0.42			
29		0.31			0.41	0.39		0.43			0.39			0.42
30					0.36						0.36			-0.07
		0.35			0.39						0.37			
31					0.34			0.54			0.44		S NODE	
32		0.41						0.51			0.46	0.42		
33					0.41	0.36	0.96				0.58	-0.07		
34		0.46									0.46			
35		0.36			0.28	0.45					0.36			BAY BARRIER
36													0.43	
37		0.44									0.44		-0.07	0.38
38		0.37			0.32						0.35			-0.04
39														
40	0.38	0.36			0.38	0.38					0.37			HEADLAND
														0.38 (0.00)

0.46	AVG	
0.63	MAX	
0.08	STD	(standard deviation)
0.30	MIN	
33	Number of stations sampled	

size for the entire coast is 1.26 phi (± 0.27 phi) (medium sand) with an average sorting of 0.46 phi (well sorted).

The distribution of grain size and sorting along the coast shows a slight fining trend from north to south with a correlative increase in sorting (Figures 2 and 3). The effect of Indian River Inlet appears to be local. Sand on the immediate south side of the Inlet is coarser than the overall Atlantic beach average and much coarser than that on the adjacent north side of the Inlet (Figure 2). The position of the longshore transport node and geomorphic features appear to have little to no effect on grain size and sorting. An exception is that the sands on Cape Henlopen spit are finer grained and slightly less well sorted than those to the south (Figures 2 and 3).

Conclusions

Recommendations based on the data presented are (1) sand placed on Delaware's Atlantic Coast beaches should be in the coarse sand or the coarse half of the medium sand range of the standard Wentworth grade scale, and (2) it

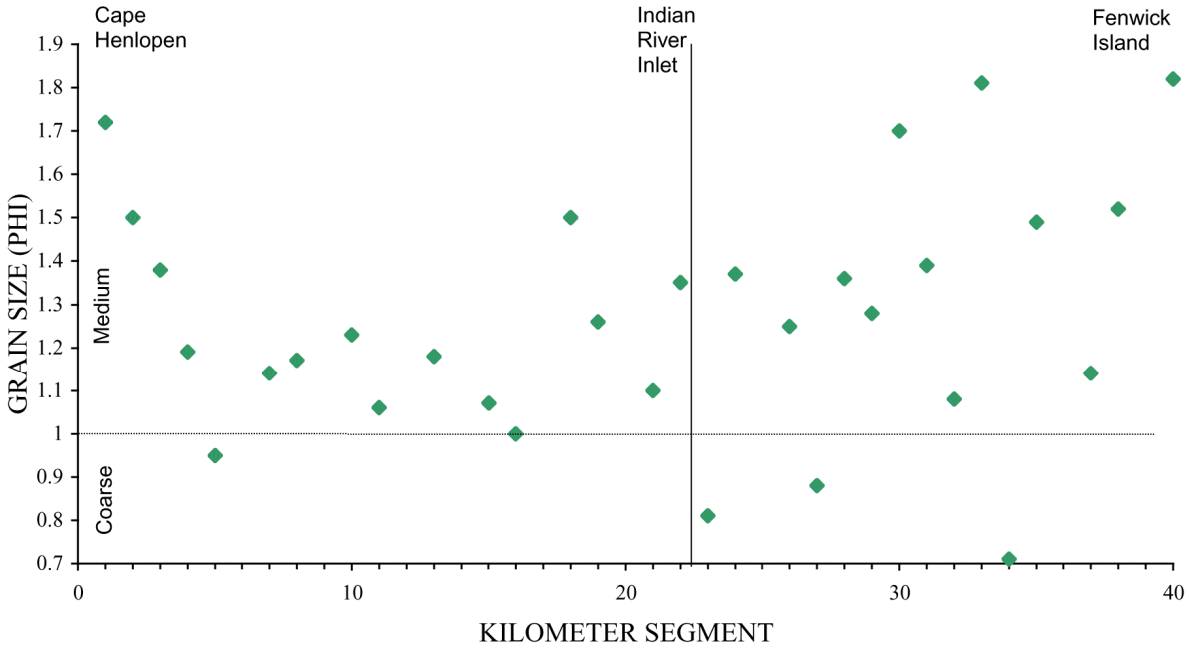

Figure 2. Plot of grain size along the Atlantic Coast of Delaware.

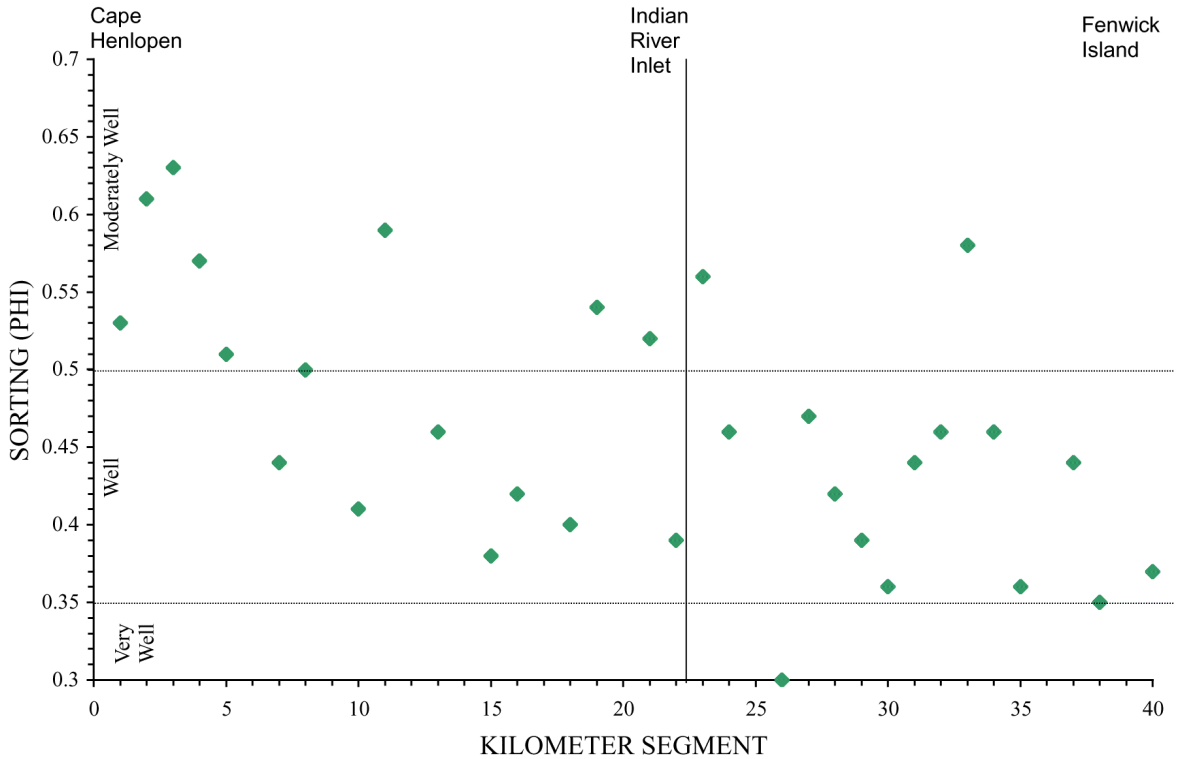

Figure 3. Plot of sorting along the Atlantic Coast of Delaware.

should be well sorted or very well sorted. In precise statistical terms, the sand should meet these specifications:

Mean grain size 1.5 to 0.5 phi (coarse to medium sand)
Sorting 0.5 or less phi (well to very well sorted)

These specifications are considered to be the native composite sand for the Delaware Atlantic Coast in accord with the U.S. Army Corps of Engineers (1984a) Shore Protection Manual.

REFERENCES CITED

Folk, R. L., 1974, Petrology of Sedimentary Rocks: Austin, Tex., Hemphill Publishing Co., 182 p.

Lewis, D. W., 1984, Practical Sedimentology: Stroudsburg, Pa., Hutchinson Ross Publishing Company, 229 p.

McDonald, K. A., 1981, Three-dimensional analysis of Pleistocene and Holocene coastal sedimentary units at Bethany Beach, Delaware: unpublished M. S. Thesis, Department of Geology, University of Delaware, 205 p.

Toscano, M. A., 1986, Vertical sedimentary sequences of Delaware's Holocene prograding spit and transgressive barrier based on sedimentary discriminant analysis: unpublished M. S. Thesis, Department of Geology, University of Delaware.

U. S. Army Corps of Engineers, 1966, Beach erosion control and hurricane protection along the Delaware Coast: U. S. Army Corps of Engineers, Philadelphia District.

____1975, Beach erosion control and hurricane protection, general design memorandum Phase 2: U. S. Army Corps of Engineers, Philadelphia District.

____1984a, Shore protection manual, 4th Edition: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Volume 1, p. 5-9 to 5-12.

____1984b, General design memorandum and environmental assessment: U. S. Army Corps of Engineers, Philadelphia District.

Appendix A

Grain size scale for sediments (from Folk, 1974)

US Standard Sieve Mesh #		Millimeters	Microns	Phi (ϕ)	Wentworth Size Class
		4096		-12	
		1024		-10	Boulder (-8 to -12 ϕ)
		256		-8	
		128		-7	Cobble (-6 to -8 ϕ)
		64		-6	
		16		-4	Pebble (-2 to -6 ϕ)
5.00		4.00		-2	
6.00		3.36		-1.75	
7.00		2.83		-1.5	Granule
8.00		2.38		-1.25	
10.00		2.00		-1.0	
12.00		1.68		-0.75	
14.00		1.41		-0.5	Very Coarse Sand
16.00		1.19		-0.25	
18.00		1.00		0.0	
20.00		0.84		0.25	
25.00		0.71		0.5	Coarse Sand
30.00		0.59		0.75	
35.00	1/2	0.50	500	1.0	
40.00		0.42	420	1.25	
45.00		0.35	350	1.5	Medium Sand
50.00		0.30	300	1.75	
60.00	1/4	0.25	250	2.0	
70.00		0.210	210	2.25	
80.00		0.177	177	2.5	Fine Sand
100.00		0.149	149	2.75	
120.00	1/8	0.125	125	3.0	
140.00		0.105	105	3.25	
170.00		0.088	88	3.5	Very Fine Sand
200.00		0.074	74	3.75	
230.00	1/16	0.0625	62.5	4.0	
270.00		0.053	53	4.25	
325.00		0.044	44	4.5	Coarse Silt
		0.037	37	4.75	
	1/32	0.031	31	5.0	
	1/64	0.0156	15.6	6.0	Medium Silt
	1/128	0.0078	7.8	7.0	Fine to Very Fine Silt
	1/256	0.0039	3.9	8.0	
		0.0020	2.0	9.0	
		0.00098	0.98	10.0	
		0.00049	0.49	11.0	Clay
		0.00024	0.24	12.0	
		0.00012	0.12	13.0	
		0.00006	0.06	14.0	